Flood Defence Levels of Service - Stage 2

Final Report

Robert Gould Consultants

R&D Note 127

National Rivers Authority

Contents

Addendum

The recommended system was presented at a meeting in London on 29th November 1990. Those present were:

I. Whittle	NRA HQ (Chairman)
M. Bramley	NRA HQ
A. Rogers	NRA HQ
A. Hunter-Blair	NRA Anglian
C. Flanders	NRA Anglian
C. Candish	NRA Thames
D. Wilkes	NRA Yorkshire
J. Fitzsimons	NRA Severn Trent
D. Major	NRA North West
A. Abrams	NRA Welsh
T. Clarke	NRA Northumbria
T. Kermode	NRA Southern
J. Cole	Water Research Centre
K. Taylor	Robertson Gould Consultants
P. Reaston	Robertson Gould Consultants
I. Townend	Sir William Halcrow and Partners

Following the presentation, a discussion was held during which a number of points were raised. It was agreed that these points should be recorded and bound into the draft report as an addendum to create the Final Report. The following pages record these key points.

These are, in many cases, a consolidation of responses from several individuals.

Land Use Assessment

Table 3.1 in this report details the customer interests assessed within the recommended LOS system. These are considered the minimum acceptable for undertaking a floodplain land use assessment. Increasing sophistication may be achieved with further refinement of the categories for example HE values could be defined for the following:

Houses categorised into
- Bungalows
- Terraced/semi detached
- Detached

Each road grade categorised into
- urban (implying heavy usage)
- rural (implying light usage)

Each Non Residential Property grouping categorised on a unit area basis, and possibly grouped into large, medium and small.

It was recognised that such refinements would add to the system's credibility, but it is essential, when making such additional categorisations, that objective criteria for inclusion of a particular interest in a category are provided to ensure consistency.

For Non Residential Properties, this is likely to be on the basis of the area of the site. For roads the presence or distance to alternatives, or frequency of use may provide suitably objective alternative methods.

It is understood that MPFHRC data may be available on these aspects. Early definition of these additional categorisations and HE values is necessary to ensure that any data collection identifies all the information necessary.

Effects of Waterlogging

This research project has been restricted to flood defence levels of service. It is recognised that in some areas a significant factor in determining the river operations undertaken is the provision of effective land drainage. Further study is therefore essential to address this aspect.

The Consultants believe that it is feasible to integrate a land drainage levels of service system with that recommended for flood defence.

Asset Assessment

Annex E accompanying this report describes two techniques for assessing the adequacy of service of flood defence assets. A probability approach is described in Appendix 1 of Annex E and is suggested as a possible means to incorporate asset assessment observations into the assessment of adequacy of service provision. The values quoted in the appendix are relative values to allow ranking of assets on the basis of reported conditions rather than being true probabilities. Further research is needed to validate these 'utility' values and this approach, though perceived as a valuable interim method, requires additional testing before it can be fully recommended. In the interim a subjective approach is recommended as outlined at 3.6 in the Final Report and in the main text of Annex E.

Saline Flooding

Salt water flooding causes increased damage compared with fresh water flooding. In view of this several NRA regions have adopted a higher target standard of flood defence provision in areas liable to salt water flooding, commonly double that for fluvial events. Therefore, to account for this additional damage potential and in keeping with the implied convention, it is proposed that customer interests that have been or may be affected by salt water flooding are given double the HE value in the reactive and predictive scoring methods. It may be desirable to verify this by referring to any research done on the subject.

Erosion, Siltation

In some areas it is reported that river works are undertaken to reduce the effect of silt deposition following flood events and that silt deposited on agricultural land may cause greater losses than assumed at present within the system. Consideration may need to be given to inclusion of this aspect where it is thought to be significant.

Definition of flood risk areas

The report recommends that the area considered is the extent of maximum known flooding, a definition that is clear, concise and expedient for most situations. Indeed it is understood that several NRA regions used this basis for definition of schedule 24/5 maps.

In some instances it is reported that because of capital works there are no known flood events. In such situations the area for consideration should be the defended area.

In other situations, often in more remote areas, floods may have occurred but have not been recorded, these are currently classified as band X. Various techniques are available to define a flood area in such situations, though for the short term the most expedient measure may be for local operations staff to provide an indication of likely flood extent. Future research work may identify a more appropriate technique for defining flood risk areas in these situations.

A number of other observations were made which are recorded below:

1. There are a number of other related R & D projects underway which need to be integrated with LOS.

2. Although band E reaches are given the lowest priority, they will form by far the largest proportion of reaches overall.

3. Data gathering costs should not be seen as a limitation.

4. Training of users is an essential pre-requisite of successful implementation.

5. The predictive monitoring system is a significant improvement on earlier versions of the system.

6. When interpreting the assessment of service adequacy, it is important to recognise that in some cases, a marginal difference in operations activity could have a major impact on service.

7. A more streamlined (ie less costly) approach may be more appropriate for assessing flood plain land use in Bands C, D, and E.

8. It may be possible to undertake crude benefit: costs analyses at regional or national level on the basis of data obtained in implementing the system.

Acknowledgements

Laurence Gould Consultants Limited wishes to acknowledge the assistance and hospitality given by staff in the National Rivers Authority Welsh, Yorkshire and Anglian regions during the second stage of the Levels of Service Study.

1. INTRODUCTION

In January 1990, the National Rivers Authority (NRA) Anglian region, commissioned Laurence Gould Consultants Limited (LGC) working in association with Sir William Halcrow and Partners to undertake an assignment to develop a system, which could be applied nationally, for the definition and monitoring of flood defence Levels of Service (LOS). Two stages of work were anticipated with the first, reported in March 1990, reviewing the current regional situation and data availability. The second stage, to develop a system which could be applied nationally, is the subject of this report.

This document sets out the consultants' recommendations of the most appropriate techniques to define and monitor LOS and is intended as a draft report for circulation to members of the Steering group set up to monitor the progress and outcome of the project.

The consultants have written this report so that it may act as a basic blueprint for the system. The report is structured so that the main report contains summary points of principle. Detail relating to components of the overall framework are covered in separate annexes. Cross-references are made as necessary. A summary report detailing the application of the proposed technique in broad detail also accompanies this report and annexes. However time and budget constraints make it impossible to address every single situation that will be encountered when completing the assessment. The most common have whenever possible been included in the examples illustrating the recommended approach.

The terminology used throughout is consistent with both the common usage that has developed in parallel with the systems development and that used in the stage 1 report. However this activity now falls under the remit of the Department of the Environment (DoE). The DoE has existing frameworks in place which make use of a different set of terms, although the concepts are largely similar. Caution should, therefore, be exercised when interpreting statements relating to LOS.

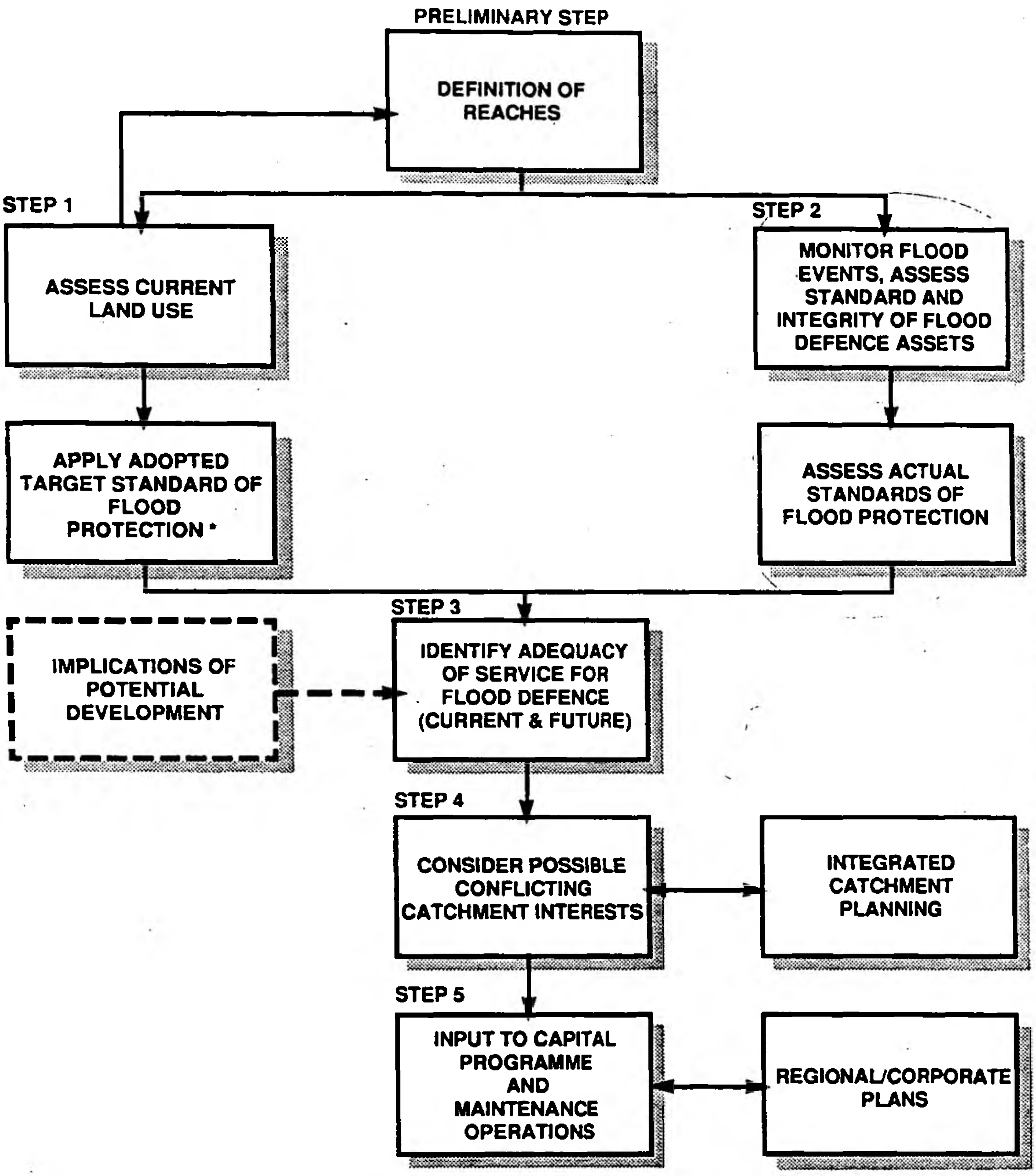
When defining the recommended system, the consultants have been aware of the results of stage 1 of this study which assessed information availability. Whilst ensuring that their consideration has not been constrained by fitting it to the lowest common level of available information, the consultants have been aware that there are inevitably constraints on resources available. The consultants believe that the system proposed offers an acceptable balance between the need for a comprehensive and accurate method of assessing LOS and the constraints of available resources.

The work has been directed at flood defence only, and no consideration has been given towards the effects of waterlogging resulting from high river levels. Similarly, the LOS for flood warning/forecasting have not been taken into account.

The data gathered in the asset assessment was used to devise and test an appropriate method for considering the level of service provided by particular flood defence assets. Details of this are given in Annex E.

In addition the basic flood extent data was used to identify the local authorities to be contacted for data to develop a growth index reflecting the potential future pressures for a change in level of service provision, as detailed in Annex D.

FIGURE 2.1 LEVELS OF SERVICE FRAMEWORK



** Targets will be set by the NRA for each land use band, based on recommendations from the consultants.*

2. BACKGROUND AND APPROACH

2.1 BACKGROUND

The flood defence Levels of Service (LOS) is defined as the standard to which the NRA provide flood defence for its customers. This is normally achieved through the provision of capital works, routine maintenance and the operation of control structures.

The NRA has a responsibility to allocate its limited resources to achieve the optimum LOS, although it is able to exercise judgement in this allocation through the permissive nature of its powers. Current practice involves a significant degree of subjectivity in the decision making process and substantial variation in approach exists between the ten regions. Such an approach also makes it difficult to justify the need for a particular level of resourcing on a well reasoned basis, as there is no link between it, and the levels of service provided. These problems have been widely recognised, and several NRA regions have researched more systematic methods of directing their activities.

The basis for a LOS system can be summarised, see Figure 2.1 opposite. This reflects the generally accepted view that targets should be set by the NRA in relation to land use and be defined in a way that allows comparison with actual or anticipated events.

2.2 APPROACH

The approach adopted by the consultants has been to use pilot catchment areas from three NRA regions to test the various proposed methods. The lengths of river and coastline were chosen to provide a sample which gave a broad range of scenarios as well as complementing the situations already encountered by the consultants in their earlier work on LOS. Table 2.1 identifies the main sections chosen for the study. In addition a number of minor tributaries of these rivers were included.

In each pilot area, the following procedure was followed:

- maps obtained of the areas under consideration;
- local flood defence staff visited and briefed;
- maximum known extent of flooding defined on 1:25,000 maps;
- field surveys undertaken to assess current land use;
- asset assessment undertaken by engineer;
- flood defence staff revisited to ascertain flooding histories and flood characteristics of the river.

The data gathered on current land use and incidence of flooding was then analysed using the two methods as proposed by Anglian and Thames region. Annexes B and C detail the two methods and the advantages and disadvantages of each leading to the recommendation of the method considered most appropriate.

Table 2.1 Rivers and Coastal Units Forming Pilot Study sample

NRA Region	Watercourse Name/ Coastal Unit	Area Considered
Anglian	River Waveney	Confluence with Oulton Dyke to source
	Oulton Broad/Oulton Dyke	A146 Lowestoft to R. Waveney confluence
	Little Ouse River	Brandon Creek to source
	Steeping/Lymn	Whole length
	Unit 28	Benacre
	Unit 12,13	Skegness
Yorkshire	River Wharfe	Nr Bolton Abbey to Hubberholme
	River Spen	Whole length
Welsh	Low Level leftdrain or Maltreath Marsh	Whole length
	Afon Erch	From sea to Llanwyda
	Afon Elwy/Gallen/Cledwen	Llanfair Talhaiarn to source
	Afon Dysynni	Whole length

3. PROPOSED NATIONAL FLOOD DEFENCE LOS SYSTEM

3.1 INTRODUCTION

In this main report, only the key points of the proposed national system are related. This allows the reader to obtain an overall appreciation of what is being proposed without being inundated by points of detail. However, where a deeper understanding may be required, a series of Annexes have been prepared which provide detailed discussion of these key aspects.

3.2 DEFINITION AND REFERENCING OF REACHES AND AREAS BENEFITING FROM PROTECTION

3.2.1 Introduction

It is now generally accepted that the standard of flood alleviation provided to an area should vary in relation to the nature and extent of land use in that area. To be able to assess this, it is necessary firstly to define the boundary of the area to be assessed. The area thus defined will need to be divided into smaller units for a variety of reasons. In addition a referencing system will need to be created which enables information about these units to be conveyed between system users with the minimum of difficulty. The detailed discussion of relevant points is provided in Annex A, but the main issues are considered below.

3.2.2 Definition of areas to be Considered

There are various criteria by which the boundary of the area could be determined. It is proposed that the "extent of maximum known flooding" be used. It is acknowledged that the extent of coverage, quality and form of data currently available to define this area varies between NRA regions. Nevertheless, this definition is clear, concise and logical for most situations. This principle should also be applied to areas which have subsequently benefited from the protection afforded by a capital scheme.
Annex A, 2.1.

3.2.3 Definition of Reaches

Some sub-division of the area within the extent of maximum known flooding is necessary because:

- variations in hydraulic and hydrological characteristics exist;

- major variations in land use exist;

- it is necessary to create a link between flood defence work completed and the area benefiting;

- of the difficulty of managing data relating to a large, non-homogeneous area of land.

It is therefore proposed that river reaches be divided into lengths of between four and seven km as closely as possible and that the areas thus defined are then separated into left and right bank. The end points for left and right bank reaches should be the same, however it is recognised that on a limited number of occasions the region may need to consider the use of staggered reach limits, though this should be avoided whenever possible. Coastal units should also be defined to be between four km and seven km in length however the nature of coastal defences may make it more appropriate to define reaches in relation to specific flood defence structures/assets. A number of difficulties arise when dividing the area at risk into areas to be associated with a particular reach. Wherever possible this reach limit should follow a clear feature (such as a road or railway), or, be perpendicular to the main direction of flow or coastline. One particularly significant point of detail arises when considering land which is vulnerable to flooding from more than one source, such as:

- confluences;
- estuaries;
- low-lying land between two or more highland carriers.

It is proposed that these areas are linked to each potential source of flooding, in effect double, or even treble counted. Note should be made on the land use assessment form of those interests which are double counted so that the interests can be separately identified in a database.
Annex A 2.2 to 2.5.

3.2.4. Referencing

Applying the above recommendations will generate a large number of river reaches and coastal units, each potentially with an associated area of land. Some system will be needed for naming and/or numbering all such units.

It is recommended that coastal reaches are referred to separately from all other Estuary, Tidal and Fluvial reaches. For coastal reaches the recommended method is as follows.

Regional Identifier	Coastal Unit Number	LOS reach Number
____/	____/	____

Coastal LOS reaches should be numbered clockwise round the coast.

For Estuary, Tidal and Fluvial reaches a more detailed referencing system is needed.

Regional Identifier	District	River Number	Tributary Number	LOS reach Number	Estuary, Tidal, Fluvial	Left or Right bank
____/	____/	____/	____/	____/	____/	____

Table 3.1: House Equivalents for Customer Interests

Land Use Factor	Unit	House Equivalent HE/Unit
House	Total Number	1.0
Garden/Allotments	Total Number	0.2
NRP - Distribution	Total Number	40.2
NRP - Manufacturing	Total Number	64.6
NRP - Other	Total Number	5.3
C Roads	Total Number	2.4
B Roads	Total Number	5.7
A Roads (Non Trunk)	Total Number	14.3
A Roads (Trunk)	Total Number	28.6
Motorway	Total Number	57.3
Railway	Total Number	57.3
Forestry and Scrub	100 Ha	0
Extensive Pasture	100 Ha	1.3
Intensive Pasture	100 Ha	3.0
Extensive Arable	100 Ha	6.9
Intensive Arable	100 Ha	40.2
Formal Parks	Total Number	0.6
Golf/Race Courses	Total Number	0.6
Playing Fields	Total Number	0.1
Special Parks	Total Number	8.5

The numbering of these reaches is completed independently for each river or tributary with reach 1 as the most downstream for each. For some rivers the most downstream reach will begin at the demarcation specified in the 1949 Coast Protection Act Schedule 4 with a number of estuary and tidal reaches before the numbering continues with fluvial reaches.
Annex A 3.1 and 3.2.

3.3 LAND USE ASSESSMENT

3.3.1 Introduction

Having defined, sub-divided and named the areas at risk from flooding it is necessary to consider how to assess the use of this unit of land if the agreed concepts are to be applied. As a basic premise, it is advocated that actual land use is considered and not potential (subject to the application of the Growth Index - see Section 3.8). It is also assumed that LOS for flood defence cannot be finely adjusted to fit each individual unit of land at risk. It is also taken as a basic principle that individual features of land use, such as single houses, should not be given a specific level of service, but that the generality of land use should be taken into account.

It is therefore proposed that each unit is allocated to one of five land use bands, and that these bands represent the continuum from heavily urbanised (band A) through to rural (band E). For units where no floodplain is identified a sixth category X is defined. the method for allocating each unit to a land use band is detailed below.

3.3.2 Allocation of Land to Appropriate Land Use Bands

In applying this technique, a number of alternatives have been examined. (See Annex B). Whilst advantages are perceived in the technique of further sub-dividing reaches into parcels of homogeneous land use, where this use exceeds one hectare, and then applying target standards for each block, there are significant disadvantages. These include:

- the inability to take into account widely spread but significant features, such as farm houses and buildings;

- the inability to match these sub-divisions to lengths of watercourse;

- the difficulty of assessing actual LOS provided to individual parcels with any degree of accuracy.

It is therefore proposed that to allocate land to a particular band, in as consistent and objective a manner as practical, the technique employing the assessment of House Equivalents (HE's) is used; a HE being defined as the average cost of damage to the average house when flooded. This is then used as a common unit with which to assess the intensity of land use within an area at risk. A house within the area being assessed would register, by definition, one HE, whereas a major manufacturing plant would register 64.6. Values have been derived for twenty land use features, and are indicated in table 3.1 opposite.

The detailed recommendations of how this should be completed are provided in Annex B.

Table 3.2 : HE's/km Recommended as Appropriate for Each Land Use Band

Land Use Band	HE's/Km
A	50 or more
B	25 to 49.99
C	5 to 24.99
D	1.25 to 4.99
E	0.01 to 1.24
Category X	0

Note: The same HE's/km ranges are used for both fluvial and tidal reaches. The increased potential damage from tidal flooding is reflected in the method for assessing each actual or possible flood occurrence.

The number of HE's within the area at risk from flooding can then be used as an accurate guide to the allocation of that land to the appropriate band. After careful consideration, it is proposed that HE/Km of river or coastline be used to determine the allocation. Firstly, to allow comparison of lengths of river and their associated interests on an equal basis it is necessary to remove the element of viability brought about by reaches being of differing lengths. This is achieved by dividing total HE's by reach length. Secondly, it has been suggested that the allocation to land use band could be made on the basis of HE/Km ^{2}. However this is considered inappropriate, because the density of distribution of the interests is irrelevant being principally determined by the area of agricultural land present which has already been accounted for in the assessment of agricultural HE's. It should be noted that this choice of technique is inextricably linked with the ability and method used to monitor actual levels of service (see section 3.5).

Allocation to an appropriate land use band can then be based on the recommended parameters shown in Table 3.2 opposite.

This recommendation is derived from work done in four NRA regional units modified to take account of the division of right and left banks by dividing the original parameters by two. This is then also consistent with the coastal situation.

The five principal land use bands represent the continuum from heavily urbanised reaches through to the more rural reaches. Each LOS reach can be ascribed to one of the land use bands following the land use assessment. Table 3.3 below and overleaf gives an indication of the typical nature of land use in each of the five bands. It is important to recognise that it is not possible to consistently and accurately define land use bands for reaches on the basis of these descriptions alone. They merely serve as an indication of typical land uses for reaches classified in that band.

Table 3.3 Typical Nature of Land Use by Band

BAND A

A reach containing the urban elements of housing and non-residential property distributed over a significant proportion of its length, or densely populated or developed areas over some of its length. Any agricultural influence is likely to be over-ridden by the urban interests. Amenity use such as parks and sports fields may be prominent in view of the floodplain's proximity to areas of population density.

BAND B

Band B category reaches will contain either housing or non-residential property distributed over or concentrated in part on its length but not of the same density as band A. Agricultural use could be more intensive in the less populated areas of band B reaches.

Table 3.3 continued

BAND C

Isolated rural communities at risk from flooding, with both residential and commercial interests, will be found in band C reaches but in limited numbers. Consequently, farming interests will be more apparent than band A and B reaches.

BAND D

Isolated properties at risk from flooding, both residential and commercial, will be found in band D reaches but in limited numbers. Agricultural use will probably be the main customer interest with arable farming being a feature. Where band D reaches are found in undeveloped pockets of largely urban use, amenity interest may be prominent.

BAND E

There are likely to be very few properties and roads at risk from flooding in these reaches. Agricultural use will be the main customer interest with extensive grassland the most common land use in the floodplain. Amenity interests are likely to be limited to public footpaths along or across the river.

A category X has also been identified for those reaches where there is no area at risk from flooding. The absence of any area at risk may be due to both local topography and hydraulic conditions or may be due to the lack of information on the flooding that occurs on such reaches. It is important to identify band X reaches so that effort can be directed at identifying areas at risk and thus the interests that need to be protected, or where no risk area exists effort can be made to ensure that scarce resources are not used without firm justification in these areas.

As suggested in the earlier report, caveats may need to accompany these descriptions as a wide range of combinations of interest can be arrived at - the very reason for adopting the matrix approach.

Experience in other regions suggests that band X reaches can make up a significant percentage of the total reaches.
Annex B section 3 and 4.

3.4 RECOMMENDED METHOD FOR EXPRESSING TARGET LEVELS OF SERVICE

It is necessary to define target LOS for each of the land use bands, in terms of an acceptable degree of flooding occurrence or a required standard of protection from flooding. This is the fundamental raison d'etre of the LOS system. Those recommended by the consultants are shown in Table 3.4 overleaf.

Table 3.4 Recommended target LOS by land use band.

Land Use Band	Target range of average HE's affected /Km per year	
	Max	Min
A	1	0.5
B	1	0.5
C	1	0.5
D	1	0.5
E	1	0.5

Note: Category X has no target as there should be no flooding occurrences. If flooding is identified the reach should be allocated to one of the other land use bands.

Such targets are not in themselves absolutely correct or incorrect but should reflect policy criteria, public and professional perceptions and available resources at a given point in time.

Annex C and the next section of this report give the details of the recommended system. In summary this is a modified version of the Thames approach which incorporates the flood return period envelopes of the Anglian scoring approach. The scoring system assesses the number of House Equivalents which may be affected by flooding over a given period of time. Various points should be noted.

3.4.1 Source of Targets

The targets used have two basic sources:

- empirical experience in other areas, modified to allow for the expression of targets on a per Km of bank basis;

- the generally accepted target standards, quoted in flood return periods for areas of urban through to rural land. (See stage 1 report).

The targets do not take into account benefit: cost analyses and should be regarded as a preliminary set of parameters which it may be necessary to modify in the light of further experience.

3.4.2 There is a range of target scores shown in Table 3.4 for each land use band

The objective of providing a range of scores is two fold. Firstly to take account of the land use variations within reaches of the same land use band and secondly to allow some latitude for the variation that inevitably occurs with a relatively imprecise service such as flood defence In practice it is impossible for any regime of maintenance to produce a precise degree of flood protection year after year. Annual variation in flooding means that scores will fluctuate around an average level, it is this average level that is important when determining the LOS provided, not exceptional results from a single year.

3.4.3 There is both a maximum and minimum target score shown in Table 3.4 for each land use band

The maximum target score reflects the maximum degree of flooding considered acceptable for a particular land use band. The maximum score is readily understood as there is obviously a point beyond which the degree of flooding becomes unacceptably high. The inclusion of a minimum score reflects the concept that not all flooding is unacceptable. This is an extension of the washlands principle where agricultural land is allowed to flood to reduce the incidence of more damaging urban flooding. Applying to all reaches even urban ones will highlight those areas where scarce resources are being directed to protect areas of relatively little value or to protect areas to an inappropriately high standard. Such resources can be redirected elsewhere.

Table 3.5

Actual HE's/km/year	Adequacy of Service Provision	Interpretation
> 1.0	Inadequate	HE's affected is greater than the target and is considered unacceptable. More resources may need to be directed at this reach to correct inadequate LOS
0.5-1.0	Adequate Category A	HE's affected falls within the acceptable range. Continue current management strategy
< 0.5	Adequate Category B	HE's affected is less than the target range. Consider scope to reduce resource input

Comparison of the score of actual HE's by flooding in a reach with the targets can produce one of the three results of adequacy of service as illustrated in Table 3.5 opposite. This aspect is more fully considered in Section 3.7 of this report.

3.4.4 Applying the same target scores to each land use band.

The House Equivalent has been used as a common unit for both the land use assessment and the scoring system. It is therefore appropriate that the same range of acceptable scores should apply to each land use band so that similar interests receive the same standard of protection. If different target scores are used for different land use bands it becomes possible for identical groups of interests affected by identical flood events to be assessed differently. In one case the interests may be assessed as receiving an unacceptably high degree of flooding but in another reach the degree of flooding of the same interests would be acceptable.

Adoption of the same target score for each reach means the assessment of acceptability of the flooding is based on the overall damage that on average occurs in the reach. In the more rural reaches a number of events covering a large proportion of the floodplain are usually required to achieve the same score as a much less extensive event in a more urban reach.

3.4.5 Standards for Tidal Flooding

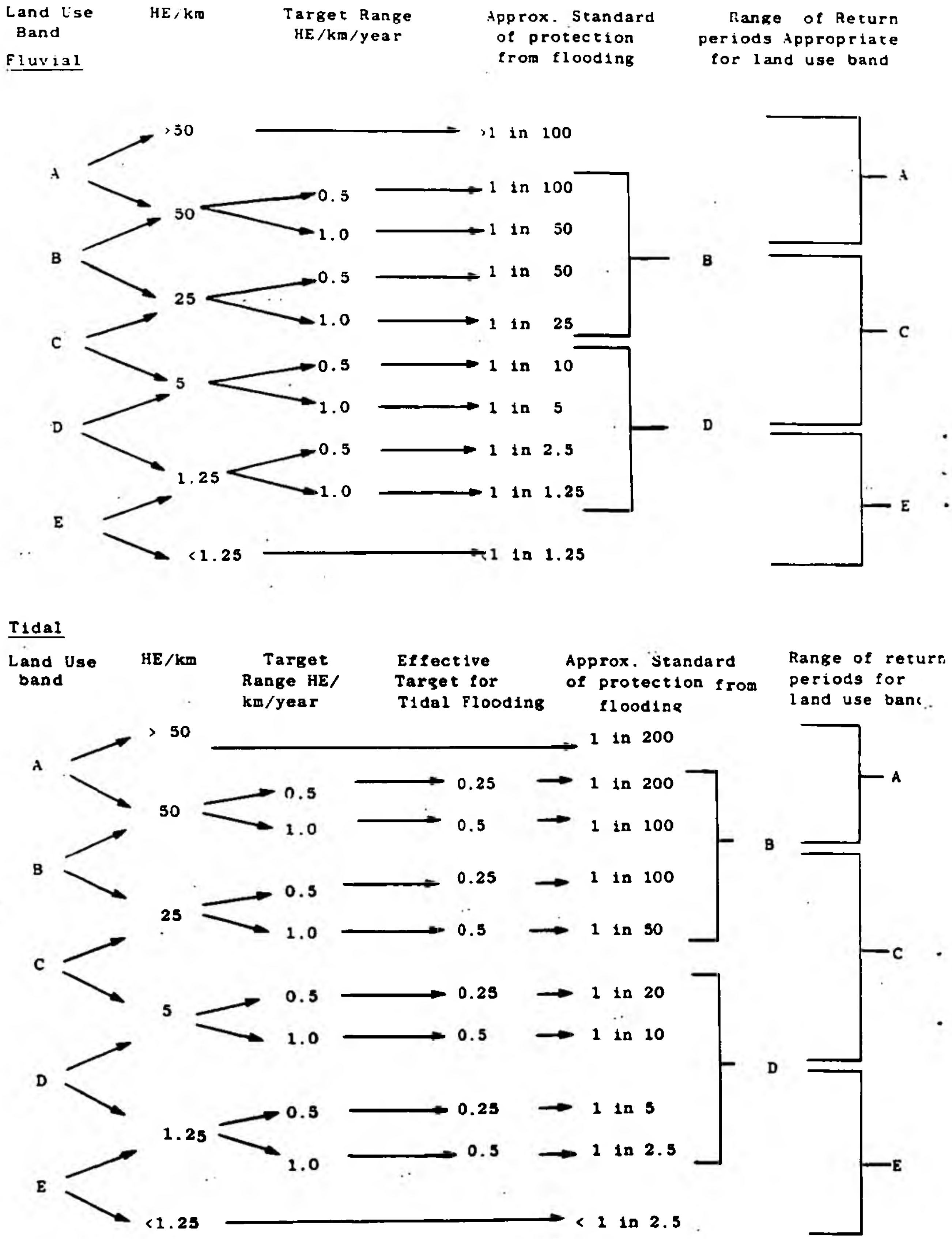
To maintain the simplicity of any scoring system the same target scores are recommended for Tidal Flooding as for Fluvial Flooding. However it is proposed that each House Equivalent affected by tidal flooding is doubled to reflect the extra damage of saline flooding. The standard of protection that these targets give is then double that provided from fluvial flooding.

3.4.6 Linking HE's to Flood Return Periods

The figures detailed in Table 3.4 indicate targets of acceptable flooding occurrence as recommended by the consultants for each of the land use bands in terms of the HE's affected per km per year within a reach. Standards of protection from flooding are more usually defined in terms of flood return periods or the probability of flooding in any one year. For the HE targets shown it is possible to identify the appropriate flood return periods by considering the extremes of land use in each band as well as the range of target scores. Figure 3.1 overleaf illustrates this and shows how the target return periods for different land use bands can overlap. Return periods for all land use bands are shown in Table 3.6 below. For example, for fluvial flooding land use band C will include areas with between 5 and 25 HE's/km. If up to 1 He/km/year can be affected, the maximum acceptable is a flood affecting the whole of an area containing 5 HEs/km once in five years. In contrast, an area with 25 HE's/km, with as little as 0.5 HE/km affected/1 year may only experience a flood once in fifty years, and be an acceptable provision of service.

Figure 3.1

Relationship between HE/km and acceptable range of return periods by land use band for Fluvial and Tidal flooding.



* The effects of salt water flooding are accounted for by doubling the HE's affected by such floods. i.e. 1 house flooded by saline floods =2 HE's. The targets specified are then in effect halved for the same magnitude of event.

Table 3.6

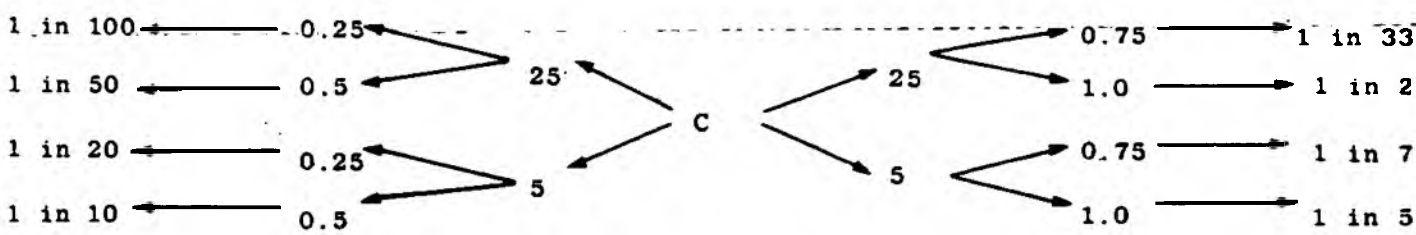
Land Use Band	Target range of average * HE's affected /Km per year		Approximate standard of protection from flooding (Fluvial Floods) *	Approximate standard of protection from flooding (Tidal Floods)
	Max	Min		
A	1	0.5	1 in 50 - 1 in 100	1 in 100 - 1 in 200
B	1	0.5	1 in 25 - 1 in 100	1 in 50 - 1 in 200
C	1	0.5	1 in 5 - 1 in 50	1 in 10 - 1 in 100
D	1	0.5	1 in 1.25 - 1 in 10	1 in 2.5 - 1 in 20
E	1	0.5	< 1 in 2.5	< 1 in 5

Note: These are for reaches which comprise one bank only.

3.4.7 Setting Target Standards

The target ranges of HE's affected per km per year and the corresponding return period of flooding are those recommended by the consultants. These targets can be altered if other standards are deemed more appropriate. For example compare the following ranges of return periods for fluvial flooding in a band C reach with those shown for fluvial flooding in figure 3.1.

Both the range and absolute level of the values can be altered to give a higher standard of service or lower target standard of service. A similar approach can of course be taken for every land use band.



3.5 ASSESSMENT OF FLOOD EVENTS

The actual LOS being provided are a combination of both the flooding occurrence either actual or probable and the condition and integrity of any flood defence assets providing a standard of flood defence. This section will outline the recommended technique for assessing the actual and probable flooding occurrence as considered in Annex C. The integrity of flood defence assets is considered in Annex E. The integration of the asset assessment with the monitoring data is considered in section 3.7 of this main report.

A dual technique of assessing flooding events is recommended as this provides an assessment of short term flooding as manifest in actual events and an assessment of the longer term effects of a level of service by considering the probability in any year of particular interests being affected by flooding. The two aspects to the scoring are termed reactive and predictive.

Annex C.

Table 3.7 Reactive Method: Severity Weighting Matrix

Flood Event Component	Category for Severity of Event				Weighting
	0	1	2	3	
Timing Duration	Nov-Feb $\leq$ 1 day	Mar or Oct >1 <5 days	Apr or Sep 5-7 days	May-Aug >7 days	0.25 0.25

For each component of the flood event, timing or duration, the category of severity is identified as 0, 1, 2 or 3. This category score is then multiplied by the weighting for the particular component. Summing these scores for timing and duration of event gives the overall severity weighting for the event. This approach is illustrated in the following examples

Example (1)

Flood event in March for 4 days

Timing March (1) x weighting (0.25) = 0.25
Duration 4 days (1) x weighting (0.25) = 0.25

Severity weighting = 0.5

Example (2)

Flood event in June for 6 days

Timing June (3) x weighting (0.25) = 0.75
Duration 6 days (2) x weighting (0.25) = 0.5

Severity weighting = 1.25

3.5.1 Reactive Method

The reactive scoring method is essentially that developed by the consultants in association with Thames region and involves assessing what interest have been affected by flooding over a given period of time. In detail the method is as follows.

Those interests affected by flooding are identified and the total number of House Equivalents that have been affected by each event is calculated using the following formula:

Urban HE's affected plus (Agricultural HE's affected * x Severity Weighting).**

* Agricultural HE's affected is calculated from the HE score per unit area of the assessed predominant agricultural land use multiplied by the area of agricultural land affected in the reach by the particular event.

** The severity weighting is the means by which the effects of timing and duration of events on agricultural land are accounted for. The severity weighting is calculated using Table 3.7 opposite.

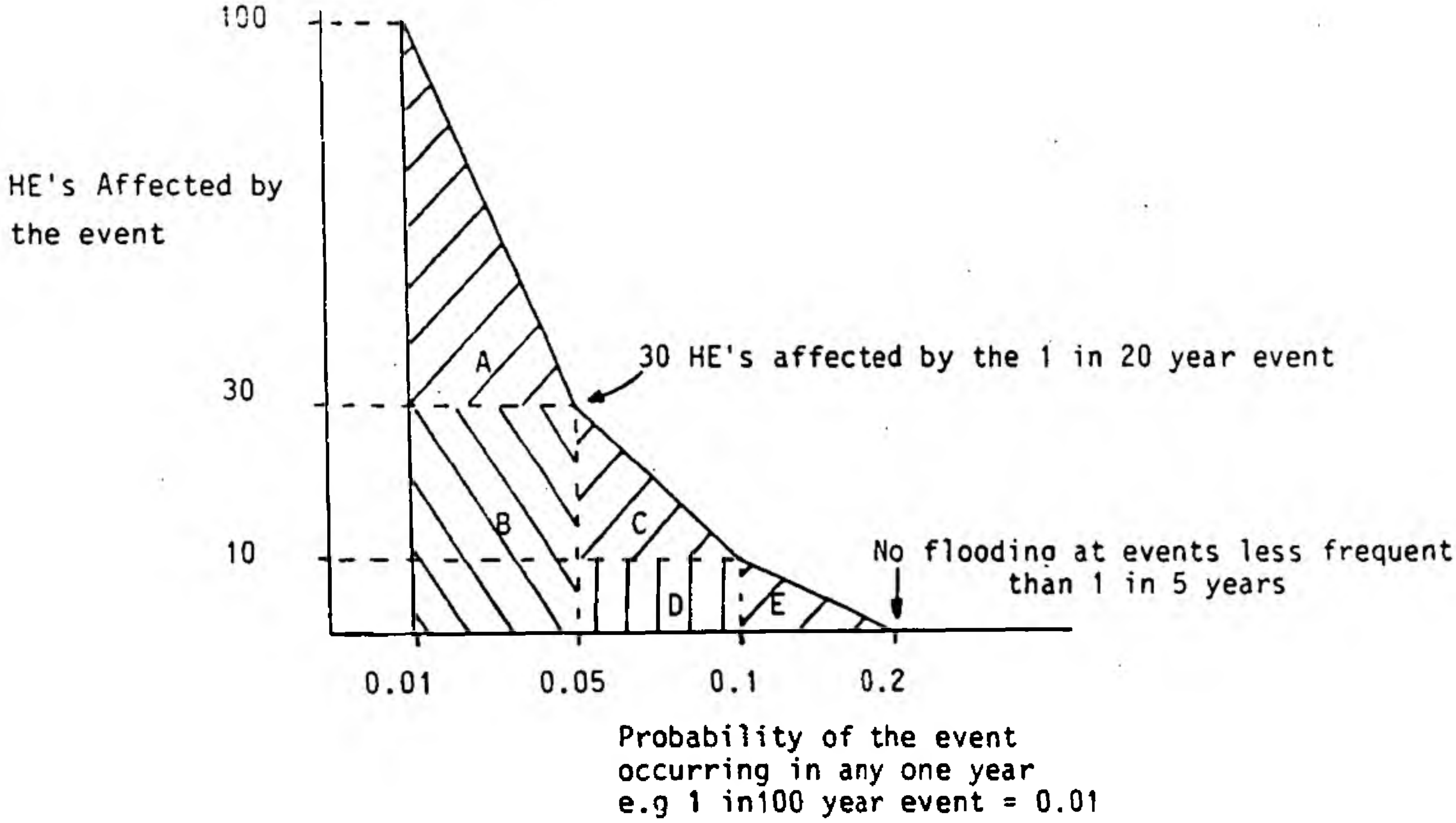
The scores for each event in each reach can be calculated and averaged over a <u>five</u> year rolling monitoring period to reduce seasonal variation, giving an average annual monitoring score for each reach. This is then converted to a per Km basis using the specific reach length. The figure is then compared to the target range.

The main deficiencies of this system are:

- the monitoring period of 5 years means that on it's own the reactive method is only appropriate for bands D and E which have target return periods of acceptable flooding approximating to 1 in 5 years. For bands A, B and C, the acceptable return period is generally in excess of 1 in 5 years;
- the failure to provide an adequate LOS will only be discovered after a major event.

For all reaches, no matter the land use band classification, both the reactive and predictive flood assessments should be completed. Even though the reactive method covers too short a timescale to be used on it's own as an indicator of the level of service for land use band A, B and C reaches, it can provide a valuable indication of any remedial works that may be needed.
Annex C 4.1.

Figure 3.2 Illustration of predictive scoring method



3.5.2 Predictive Method

To overcome the inadequacies of the reactive method of assessing the current level of flood protection, a more predictive technique has been developed which reflects the probability of events of differing flood return periods occurring in any particular year. In this way the long-term average HE's affected per km per year can be identified with regard to the infrequent occurrence of the large events.

The proposed technique is described in detail in Annex C but is summarised with reference to Figure 3.2 opposite.

Various points are identified at which the HE's affected at particular return periods of event are known. These can be used to calculate the area under graph = HE's likely to be affected in the reach per year as follows:

Area under the graph = A+B+C+D+E

$$= \frac{(0.05-0.01) \times 70}{2} + (0.05-0.01) \times 30 + \frac{(0.1-0.05) \times 20}{2} + (0.1-0.05) \times 10 + \frac{(0.2-0.1) \times 10}{2}$$

= 4.1 HE's/year in this example.

This can be divided by reach length to allow comparison with target scores recommended for the particular land use bands, as defined in Table 3.4.

Obtaining information to complete this scoring method may prove difficult and resource demanding depending on the number and accuracy of definition of points on the graph shown in Figure 3.2.

Annex C identifies 3 broad options to complete this assessment:

Option 1	Assume linear relationship between HE's affected and severity of event.
Option 2	Use existing information from one or more of the existing sources of data eg flood reports or knowledge of local operations staff, to broadly define HE's affected for a number of return period events.
Option 3	Detailed analysis of flow records and possibly modelling to precisely define the return period at which each interest or group of interests are affected.

Annex C illustrates the application of these various options in a particular scenario. It is clear from this that Option 1 is an inappropriate approach providing no meaningful data on which comparison of reaches can be made either with other reaches or against target standards.

By contrast Option 3 provides the ideal situation allowing for very accurate assessment of HE's affected by particular return periods and thus accurate definition of the graph illustrated in Figure 3.2. This option is however highly resource demanding and must be viewed as a long-term aim and only fully justified in band A and B reaches. Information for it can be gathered from pre capital work studies or from specially commissioned modelling exercises.

In the short to medium-term Option 2 is the most appropriate. This would utilise information already available from a number of sources in varying degrees of detail. The technique envisaged would be to identify for particular interests or groups of interest the estimated return period at which flooding would commence. The HE's affected at different return period events can be broadly defined and applied to the graph as shown in Figure 3.2. This technique should prove easier and less resource demanding to undertake than the definition of flood return period envelopes. Where flood defence assets are present, their theoretical design standard is assumed to be provided, no account is taken at this stage of any perceived failure to provide the design standard of protection. This aspect is covered in section 3.6 Asset Assessment.
Annex C 4.2.

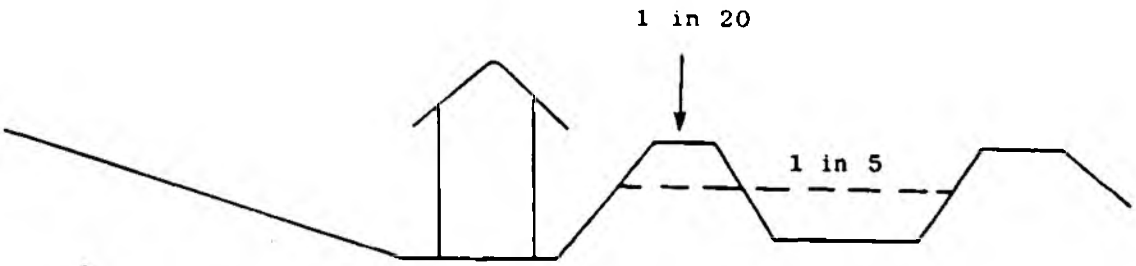
3.5.3 Agricultural Flooding in the Predictive Assessment

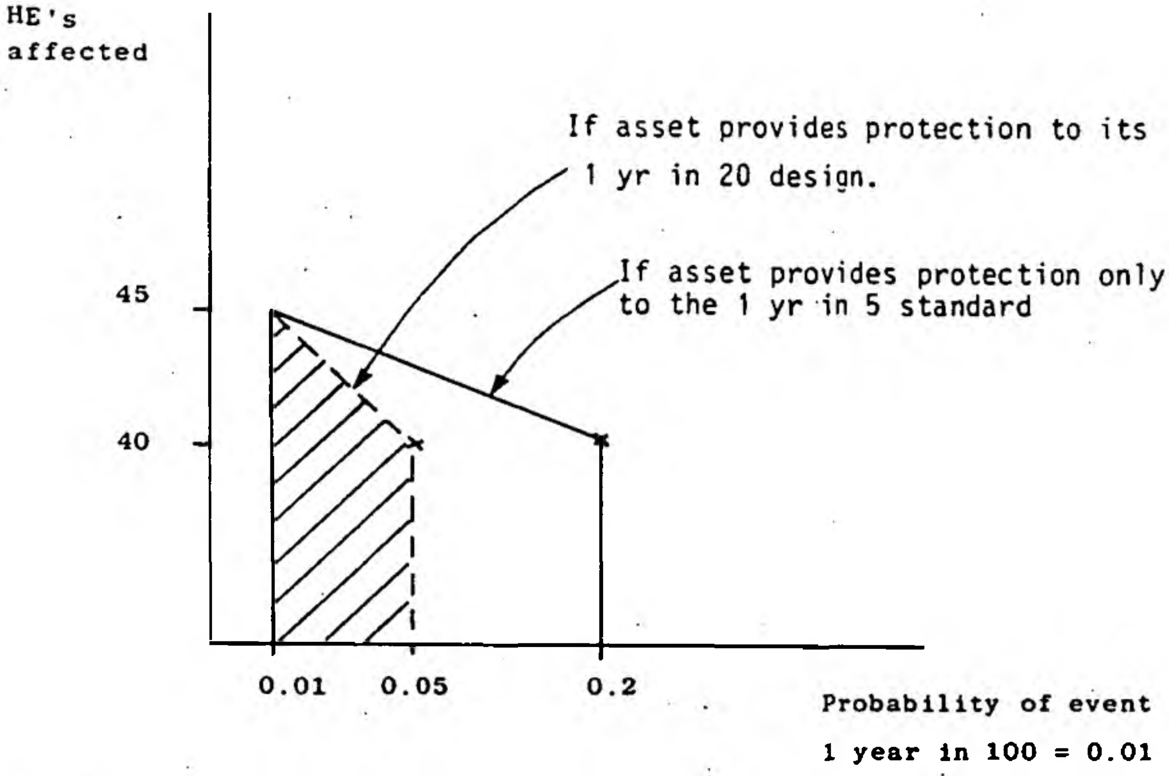
For the flooding of agricultural land it will be necessary to make allowance for the effects of different timing and duration of flood events on the damage to agricultural interests from flood events. This is achieved by considering the weighted probability of events occurring during particular months and for particular durations, Annex C appendix 1 defines the severity weighting factor for the predictive assessment of 0.5. This same factor is then applied in all predictive score calculations to the total agricultural HE's affected by a particular event. The total for the particular return period is then calculated by adding the value of urban HE's affected. The same factor is used in all cases no matter which reach or which river is being assessed.
Annex C appendix 1.

3.5.4 Saline Flooding in the reactive and predictive assessment

It is recommended that all flooding that occurs or may occur downstream of the MAFF defined limit of tidal dominance is considered to be saline in nature. For both the reactive and predictive scoring method the effects of this saline flooding is assumed to be twice as severe as fluvial flooding, ie, one house affected by fluvial flooding would contribute one HE to the score, whereas if the flooding was saline, the same house is assumed to contribute two HE's to the score

Figure 3.3





The area under the graph equals the HE's likely to be affected per year by flooding. This must be expressed on a per km basis to allow comparison. Assume reach length = 4km.

A) Assuming Asset performs to 1 in 20 year design standard.

Area under graph = 1.7 HE/YEAR

= 0.425 HE/km/YEAR

This would be the score used in the predictive assessment as described in Annex C.

B) Assuming Asset fails at events exceeding 1 year in 5 magnitude.

Area under graph = 8.075 HE/YEAR

= 2.02 HE/km/YEAR

It is recognised that there will be a degree of dilution of salinity just downstream of the MAFF limit which diminishes further downstream nearer the sea. to retain the simplicity of the system however the dilution is ignored and the salinity assumed to be constant. In this way there is no requirement for testing after flood occurrences of where a particular level of salinity is found.

3.6 ASSET ASSESSMENT

Visual assessment and instrumental survey methods will eventually be available to minimise the subjectivity of asset integrity assessment following completion of a number of independent R & D initiatives estimated to report in approximately 1994.

Until such time the consultants recommend a simple technique which is an extension of the predictive scoring methodology. This inevitably includes a degree of subjectivity but, as an interim measure with a relatively low resource requirement, is considered acceptable within the context of the study.

The information required is almost identical to that gathered for the predictive method for assessing likely flood incidence, described earlier at 3.5.2 and in more detail in Annex C. For the asset assessment however the HE's affected at different return periods of event is assessed bearing in mind any perceived reduction by operations personnel in the standard of protection afforded by flood defence assets that may be present in the reach.

A graph to illustrate the situation can be drawn and the area underneath the graph calculated. This will represent the average number of HE's likely to be affected by all flood events per year. Figure 3.3 opposite illustrates a possible scenario. The graph shown indicates the score modified to take account of a perceived reduction in the performance of the asset compared with it's theoretical design standard.

From the graph it is possible to identify for a reach.

i) The predictive score based on the theoretical design standard of protection from any assets and the effects of any river maintenance works that may be undertaken.

ii) The additional contribution to this score as a result of a perceived reduction in the standard of protection from an asset.

iii) The total score of likely flooding from the cumulative effect of all works on the reach.

For figure 3.3 the above scores are	i)	0.425 HE/km/year
	ii)	1.595 HE/km/year
	iii)	2.02 HE/km/year

This approach is detailed more fully in Annex E with some additional examples included in the summary report.

Table 3.5

Actual HE's/km/year	Adequacy of Service Provision	Interpretation
> 1.0	Inadequate	HE's affected is greater than the target and is considered unacceptable. More resources may need to be directed at this reach to correct inadequate LOS
0.5-1.0	Adequate Category A	HE's affected falls within the acceptable range. Continue current management strategy
< 0.5	Adequate Category B	HE's affected is less than the target range. Consider scope to reduce resource input

Annex E also includes details of a more complex technique for assessing the effect on adequacy of service provision of an assets integrity. However this approach would require considerable resource input to undertake asset surveys and until such time as the subjectivity involved is minimised is considered inappropriate for this stage of the study. When the various R & D objectives investigating the minimisation of subjectivity in asset assessments are completed this more complex technique may be more appropriate than the use of a simple, low resource technique.
Annex E.

3.7 ASSESSMENT OF ADEQUACY OF SERVICE PROVISION

The assessment of adequacy of service provision draws on information form:-

- the reactive method of assessing flood occurrence, based on those HE's that have been affected by flooding over a 5 year rolling period. (Annex C 4.1).

- the predictive method of assessing likely flood occurrence, based on those interests affected by different return periods of event. The long term average per year is calculated assuming flood defence assets operate to their design standards. (Annex C, 4.2).

- the asset assessment, a modified predictive score which takes account of any perceived reduction in the standard of protection afforded by flood defence assets. Annex E Section 2.

The targets recommended by the consultants are detailed in section 3.4 of this report. The scores calculated for each reach are compared with the target deemed acceptable for that reach.

For example: Figure 3.3.

A reach identified as land use band C has an acceptable range of flooding incidence of between 0.5 and 1.0 HE's per km per year.

In this example the following scores have been identified.

Reactive method	0.67 HE/km/year
Predictive method	0.425 HE/km/year
Asset Assessment*	2.02 HE/km/year

* This is the total score of the modified predictive method to account for the perceived lower than design performance of the asset, the difference between this and the predictive method is the additional contribution due to the poor asset condition.

The reactive score, though inappropriate on it's own to assess the adequacy of service on this band C reach, is compared against the target range. As indicated from table 3.5, repeated opposite, this suggests an adequate level of service is being provided.

Greater emphasis should be placed on the outcome of the predictive assessments and their comparison to target ranges.

Firstly comparing the total Asset Assessment score to the target scores indicates that for this example an unacceptably high incidence of flooding is likely. There may be a need for greater resource input in this reach to reduce the incidence of flooding.

Further analysis of the scores may indicate how an improvement can be effected.

In this particular example the score from the predictive assessment alone is below the minimum target score indicating that either the design standard of any assets present is too high or that there is too great an input of resources on river maintenance works. However the total score is taken above the upper target by the large contribution due to poor condition of the asset. It is probable that the inadequacy of service would be amended by improvements to the condition of the asset. It may be possible to offset this by reducing any river maintenance works to let the predictive score itself fall with the recommended target range.

In other examples it may be that no assets are present and in this case the asset score will equal the predictive score. In which case it can be disregarded and only the reactive and predictive scores considered. In some instances the reactive and predictive scores can give a conflicting indication of LOS provision. In most cases more weight should be placed on the predictive score with the reactive score used to provide additional information to assist identification of any necessary remedial works. Only for bands D and E is the reactive score a fair indication of LOS provision on it's own.

3.8 Assessing the required standard, in terms of flood return periods, of remedial works following identification of inadequacy of LOS provision.

The required standard of protection to be afforded by remedial works or the effect of any remedial work can be assessed by use of the graphs defined under the predictive scoring methods. These can define either the minimum standard of protection that would be necessary to provide an adequate level of service, or can assess the effect of providing protection to particular interests or groups of interests on correcting an inadequate service provision.
Annex C. Section 7.

3.9 GROWTH INDEX

A method appropriate for defining how the existing level of service may be inappropriate for new or more intensive land use and thus lead to pressure to improve the level of service - the growth index is detailed in Annex D.

Table 3.9 Growth Index

Growth Index	Pressure for Change	Description
0	Low	No development proposed.
1	↑	No change in target LOS or actual LOS provision from proposed development.
2		Local plan designated development raises the land use band classification.
3		Local plan designated development plus outstanding planning applications raises the land use band classification.
4	↓	Planning applications raises the land use band classification.
5	High	Applying land use changes from planning applications to LOS predictive scoring indicates a change of adequacy of service provision to inadequate.

In summary the method involves identifying sites which are the subject of planning applications or designated for future development, and assessing the contribution these would make to the land use assessment score, as defined in Annex B. This may, in turn, affect the land use band if they were present with no flood protection works. In addition, for sites which are the subject of planning applications the additional effect of the new development on the predictive scoring methodology is also considered.

Comparison of the post-development scores with the pre-development scores and the recommended target scores, indicates the likely pressure for change in the level of service provision. Built into this index is an appreciation of the immediacy of the likely change with planning applications being rated higher than the designated development areas. The Growth Indices for particular changes are summarised in Table 3.9 opposite.

It is believed that changes in farming practices which require improved LOS are not likely to occur in the present economic climate and so they have been excluded from the index.

The defined methodology is considered appropriate for classifying the pressures for changes in LOS provision. However the consultants believe that the benefits it gives do not justify the resources required to provide the information.

It is accepted that the growth index only provides an indication of how there may be pressure to improve LOS in the light of proposed changes in land use. However any indication that such changes are being taken into account may be taken by developers as an indication that such flood protection as necessary will eventually be provided by the NRA.

It is recommended that a more appropriate and cost: effective means of dealing with the issue of development in flood risk areas is to pursue a policy of cooperation and consultation with local authorities such that any development in flood risk areas is provided with suitable flood protection works at the expense of the developer concerned.

NRA planning and development control staff should be able to readily identify those areas where such consultation is likely to be most intensively required.
Annex D.

4. OTHER ASPECTS

4.1 DATA MANAGEMENT SYSTEMS

Computerisation of the data analysis process and management system is thought essential to allow for continuous updating of the monitoring information, and the ease of subsequent reanalysis of the level of service being provided.

The data used for this analysis includes:

- areas and interests affected by maximum known flood extent;
- areas and interests within flood envelopes of different return period events;
- the monitoring data of what has been affected by particular flood events.

With much of the data being spatially related, a Geographic Information System (GIS) would appear to be an appropriate data management system. Once installed such an approach offers several advantages over the hard copy format and conventional relational database:

- it allows for easy updating of information following identification of new data or reappraisal of existing data. Reassessment on hard copy format tends to be time consuming and cumbersome;

- it is a readily understandable format suitable for information dissemination to interested parties;

- base data can be readily manipulated by other sections within the NRA for alternative uses.

GIS is however expensive and would take considerable time to set up for all floodplain areas. They are unlikely to be justifiable for use with flood defence LOS alone. In reality much of the base data will only be altered once every few years and the total time saved by use of a GIS will be limited.

A suitable but lower investment method for data analysis is likely to be use of both hard copy format base data with a relational database for data analysis. With good management, many of the disadvantages of the hard copy format can be overcome and, with major information updates only every few years, is likely to be the cheapest way of storing the base data.

A well structured relational database is also a cost effective means for analysing the gathered data. It has the advantage that a single core programme can be written which could be used by all NRA regions with only minor modifications. Such a system was developed by Thames region in association with the consultants and would with modifications be suitable for all regions. Adoption of GIS would need a very considerable level of resourcing in each region to input the necessary base data to the system.

It is recommended that a relational database with hard copy format for base data collection and storage be adopted. The cost of this being reduced by central production of a data analysis programme. Some information will be available from the Anglian Sea Defence Management Study (ASDMS) which is held on the Integraph GIS, but it is understood that this is readily transferable to a relational database. In other NRA regions other computer databases may provide some of the necessary information and the need to extract information from these must be considered when designing the appropriate format.

GIS still remains a potential future analysis system and it is recommended that the full resource implications of its adoption are assessed. Discussions of GIS by Information Technology managers within the NRA are understood to be occurring with some pilot testing of LOS applications. That being used in the ASDMS will soon be complete and would provide an ideal way of assessing the resources needed to implement a system.

4.2 USE OF THE RECOMMENDED SYSTEM FOR PRIORITISATION AND PROGRAMMING OF RIVER WORK

In their earlier work for Thames region, the consultants explored the theory of using LOS to guide the preparation of work programmes and defined a standard method to be used to assist Thames engineers. The theory is addressed in a document produced for Thames Water in June 1989 by LGC entitled "Programming and Prioritisation of River Maintenance Work".

This aspect is currently under investigation as part of the NRA's extensive research and development programme and it is not intended to duplicate the work here. It is though worth considering the valuable role that flood defence LOS can play in providing an input to prioritisation and programming of both capital and revenue works. These are likely to include:

i. It assists in defining target standards of flood defence for each reach based on current land use.

ii. It assists in identifying the performance of current river maintenance works or flood defence assets against this target standard and thus whether this is adequate, requires improvement or could reasonably be reduced.

iii. It can provide an input into methods of prioritising capital and revenue works between reaches on the basis of greatest need, by for example the adequacy of current service provision.

The approach recommended by the consultants in this study provides information that can readily be applied to each of these uses.

4.3 OTHER CONSIDERATIONS

It is recognised that there are a variety of interfaces between flood defence and other aspects of the NRA's responsibilities such as conservation, recreation, navigation, fisheries, water quality and water resources. All of these have been specifically excluded from the determination of flood defence levels of service. In general it is believed that such interfaces should be incorporated into work programming aspects, determining how a desired LOS provision is achieved rather than what particular LOS should be provided.

For conservation and environmental aspects it is believed that their importance will be better reflected by influencing the type of river works proposed to provide a particular LOS rather than what the particular flood defence LOS should be. The integration of some of the other aspects is already apparent in some areas such as in the use of 2 stage flood channels, satisfying flood defence objectives as well as water quality and fisheries objectives by maintaining particular depth or flows of water.

5. IMPLEMENTATION OF A RECOMMENDED SYSTEM

To effect implementation of the consultants recommended LOS system in its most basic form will require a number of stages of information gathering. Once the system is operational there is both a need for ongoing maintenance of the data base and gathering of new information as well as a need to fully develop and implement the more sophisticated data analysis aspects such as flood return envelopes in the predictive scoring system.

It is recognised that different resource commitments/availability between regions may affect the completion of particular aspects in each stage. For example it is not essential to have completed development of computer systems to make an initial assessment of LOS.

5.1 STAGE 1 : PROVISION OF BASELINE INFORMATION

- Confirm definition of areas at risk from maximum known flooding extent, tidal and fluvial.
- Reference and define LOS reaches and allocate all watercourse and coastline lengths to these reaches.
- Allocate areas at risk from flooding to each LOS reach.
- Design suitable data recording format for land use, asset assessment and flooding incidence bearing in mind possible future computer applications.

5.2 STAGE 2 : ASSESSMENT AND DATA GATHERING

Land Use Assessment

- Assess current land use.

Asset Assessment

- Identify presence and design standard of protection of all flood defence assets.
- Assess actual standard of protection by assets if different from design.

Assess Flooding

i) Reactive — Record flood event occurrence in terms of timing, duration and interests affected.

ii) Predictive — Define HE's that are affected by each of a range of flood return periods for each reach. Assuming any assets provide protection from flooding to their design standard.

	iii) Asset Assessment	Define HE's that are affected by each of a range or flood return periods for each reach taking account of perceived standard of protection afforded by assets.
Data Analysis	-	Develop and test computerised data storage and analysis programmes.
Growth Index	-	Identify sites for assessment in growth index analysis if pursued.

5.3 STAGE 3 : DATA ANALYSIS

Input Data if computer system is developed.	-	Current land use.
	-	Flooding occurrence - predictive - reactive - Asset Assessment
Analysis	-	Assess adequacy of service.

5.4 FUTURE REQUIREMENTS FOR UPDATING AND SOPHISTICATION OF SYSTEM.

ONGOING - MONITORING AND UPDATING

Land Use Assessment	-	5 yearly update and validation of land use data.
	-	Periodically review HE values to account for inflation and other external factors altering relative values.
Asset Assessment	-	Regular update of perceived asset standard of protection.
Flood Monitoring	-	Ongoing monitoring of all flood events.
	-	Validation of HE's affected by different return period envelopes as necessary.
Targets	-	Review targets set in light of changes in performance. (Regional Flood Defence Committee as necessary).

FUTURE - INCREASED SOPHISTICATION

Flood Monitoring	- Complete analysis and where appropriate modelling of watercourses, coastlines to identify HE's within return period bands.
Asset Assessment	- Devise non-subjective methods to define asset condition.
Integration with other LOS systems	- The need for and integration with other LOS systems eg for waterlogging, flood warning/forecasting should be considered.

These stages of implementation do not include the need for training of staff to undertake data gathering exercises where appropriate or in the utilisation of data output. Such training must obviously link in with the need for the particular skills.

With many aspects of the system dependent on successful completion of several earlier stages, it is essential that implementation timetables are set for each activity to ensure timely completion. Appointment of an overall coordinator for each region is viewed as essential to maintain the impetus for successful implementation, and it should be recognised that the necessary resource commitment must be available.

Both the successful implementation and ongoing maintenance of the system will require commitment and contributions from the most appropriate departments. For example, asset data from both operations and new works, flood information from operations and hydrology.

6. RESOURCE IMPLICATIONS OF ADOPTING THE RECOMMENDED LOS SYSTEM

There are inherent weaknesses in making extrapolations of the likely time inputs and resource requirements to implement any system on the basis of its application in a small pilot area.

Nationally there is likely to be great variability. In most regions there will be a need for a resource input to ensure that maps showing areas of maximum known flooding extent are available and up to date for all rivers. In Welsh region this is likely to require significant resource input from staff familiar with the rivers to effect compilation of these maps which are at the core of the LOS system.

The resource requirement to assess current land use is dependent on the extent of the flood risk areas. Regions such as Anglian are likely to require significantly more resources to undertake this, than regions such as Northumbrian with fewer urban and very flat areas.

Such a distinction also applies to the completion of the various scoring methodologies. Regions with greater lengths of main river and larger flood risk areas requiring greatest resource input to complete the predictive scoring methodology.

To continue to be a valuable tool to the NRA, the LOS system will require an ongoing resource commitment. This is to allow a periodic validation of the land use predictive flooding score and asset condition data and also to maintain the recording of flood events that occur to feed into the reactive scoring system. In the short term such recording can be achieved by encouraging all operations staff to fully record the details of any events that they observe, urban and rural, large or small. Constraints in operations staff time will mean that recording of events must fit in with their other activities. For the future there may be benefit from relating flood extents and HE's affected to gauge readings. Following an initial calibration phase, it should be possible to use gauge readings as the indicator of HE's affected by the events without the need for staff to visit all areas of floodplain.

7. RECOMMENDATIONS

1. The flood defence levels of service system as described in this report and its accompanying Annexes should be adopted as recommended.

2. Rather than defining the Growth Index of land, the policy of opposing development in flood risk areas should be pursued unless the developer provides the necessary flood protection or compensatory works at 'no cost' to the NRA. The proposed development could be considered by way of a "what if" scenario.

3. Ideally there should be central development of a computerised data analysis procedure.

4. Following the completion of current R and D initiatives into non-subjective methods of asset assessment, estimated as 1994, there will be a need to further develop and test the asset assessment aspects of the levels of service system. In the interim the modified predictive method of assessing asset condition is recommended by the consultants as a low resource method of accounting for potential structural weakness of relevant assets.

5. The accurate and consistent provision of service monitoring data is a key aspect to the system. The procedures for recording the incidence of actual events for the reactive approach must be improved to cover all flood events including those occurring in the more remote areas. The predictive procedures should increasingly be developed to include the results of flood modelling studies.