National Rivers Authority

NRA

Research & Development Programme
Topic B2 : Flow Regimes

Project B2.2 :
Assessment of Low Flow Conditions

Phase 1 - Proposed Methodology

FINAL REPORT

Scott Wilson Kirkpatrick
CONSULTING ENGINEERS

March 1991

National Rivers Authority
R&D PROGRAMME
TOPIC B2 : FLOW REGIMES
PROJECT B 2.2 : ASSESSMENT OF LOW FLOW CONDITIONS
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PROJECT TEAM

This study has been directed on behalf of the NRA by Thames Region. The staff involved were:

Dr Mike Owen	Topic Leader
Mr Tony Jones	Project Leader
Mr Gareth Llewellyn	NRA R&D Manager
Mr John Gardner	(from Jan. 1991) NRA R&D Manager

The Consultants core project team consisted of:

Mr Mike Le Gouais	Project Director
Mr Shammy Puri	Project Manager
Dr Phil Kerrison	Aquatic Ecology Specialist
Ms Anne Knape	Landscape Specialist

EXECUTIVE SUMMARY

This report presents the results of phase I of a research contract carried out between August 1990 and March 1991 by Scott Wilson Kirkpatrick & Partners under NRA R&D Project B2.2, "Assessment of Low Flow Conditions".

The overall project objective is "to review low flows due to abstraction and to standardise the assessment of the condition". Phase I is concerned with proposing a methodology for the assessment.

The standard assessment method proposed, addresses the conflict between the need for minimum input of staff resources by the NRA and the need to separate low flow impacts from water quality impacts on the ecology by means of a two stage procedure comprising Preliminary Screening and Full Assessment.

The method is based on five Indicators, viz,

Hydrological
Ecological
Landscape/Amenity
Public Perception
Cost of Alleviation

The Cost Indicator is only used for the Full Assessment stage whereas the other four can be used at either stage.

For the *Full Assessment*, a 'score' is calculated for each Indicator by combining scores assigned to a number of weighted parameters within the Indicator (see Sections 7 to 10).

The Indicators can be combined in a number of ways (see Section 12) to determine for any site,

*** the severity of the condition**
*** the reliability of the assessment**
*** whether the problem is 'real' or 'perceived'**
*** the priority which the site should receive, Nationally or Regionally, for alleviation.**

For the *Preliminary Screening* scores are assigned directly to a chosen parameter within each Indicator (see Section 13). This stage can be used to establish approximately the severity of the condition and a rough order of priority.

It is expected that affected sites will proceed from Preliminary Screening to Full Assessment before significant capital resources are applied to alleviation.

In both cases, it is expected that only those parameters and indicators for which data is available or can be collected at minimum cost will be used.

The 'scores' and 'weights' proposed are based upon experience and on information and reports provided by NRA Regions during the study.

The method needs to be tested and developed to confirm or amend such 'scores' and 'weights' based upon application experience. To this end, the phase I report proposes that testing should be carried out by the Regions between June and September 1991 and that there should be a small supplementary research project to co-ordinate the testing, receive feedback and modify the proposed method accordingly.

1. INTRODUCTION

The National Rivers Authority (NRA) Research & Development (R&D) programme was published in May 1990 (NRA 1990). In that program, the problem of low flows was identified as one area requiring specific attention. Following NRA Thames Region's invitation to submit a proposal, Scott Wilson Kirkpatrick were appointed Consultants on 15th August 1990, to undertake the Project B2.2, Assessment of Low Flow Conditions, which is part of Topic B2, Flow Regimes.

An Interim Report containing the outline of proposals was submitted in November 1990 which were the subject of consultations and comments received from NRA Regions in January 1991.

The present document constitutes the Final Report of phase I required by the Terms of Reference. The proposed methodology has yet to be been tested by the NRA Regions. This has not been done within the duration of this project due, primarily to the difficulties of programming consultations with heavily committed staff in the NRA Regions.

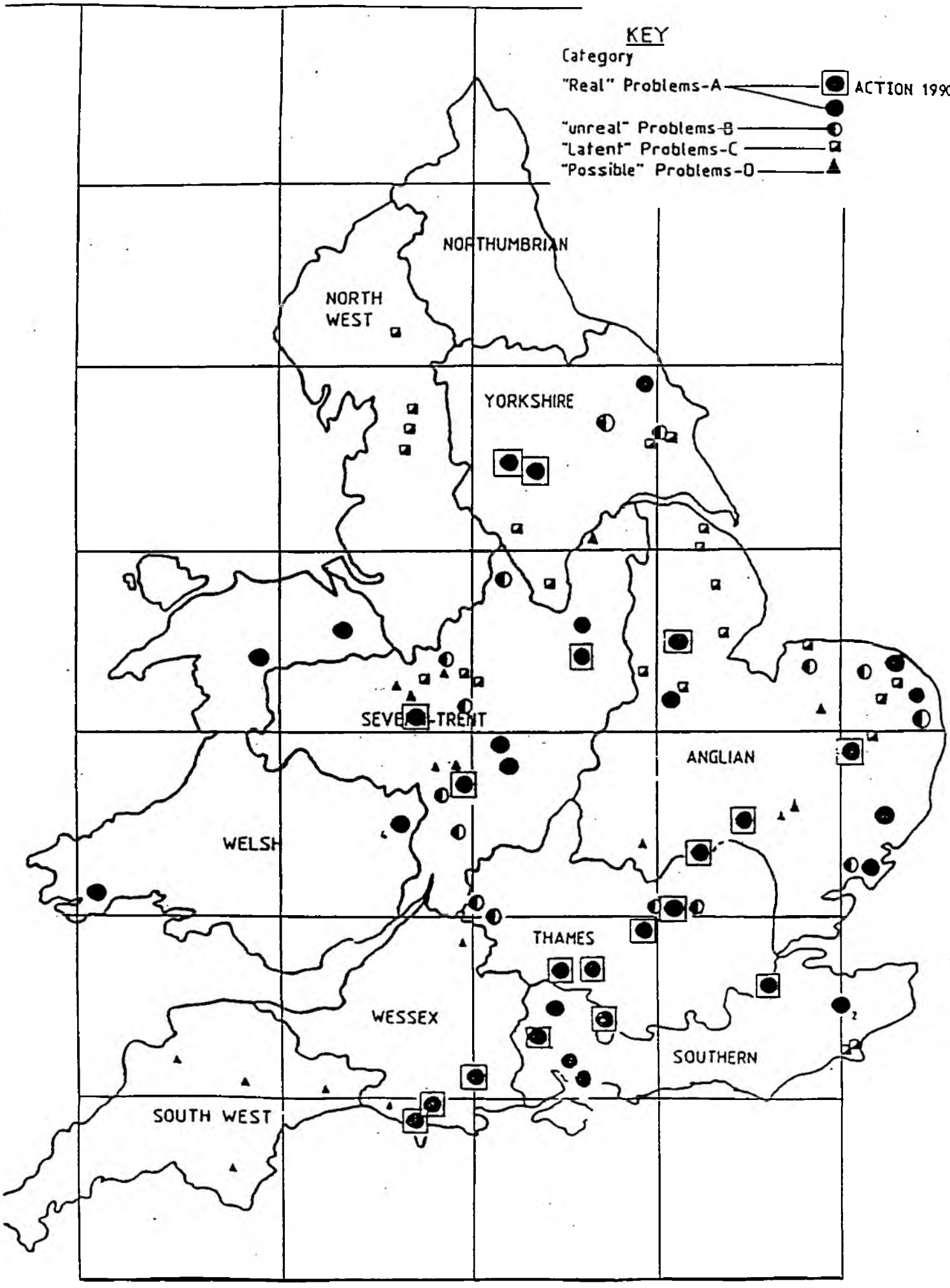
The objective of this project was to provide the NRA with the means to objectively assess the severity of , and define priority in resolving low flows problems across the whole of England and Wales, which is under their jurisdiction. To meet these objectives, following consultations with the Regions, the Consultants have devised a relatively straightforward numerical system of assessment. Occurrences of known low flows are shown on Figure 1.

This report sets out the proposed Assessment Method, which is based upon five Indicators, namely:

Hydrological	The indicator which accounts for the hydrology of the stream system
Ecological	The indicator which accounts for the aquatic ecology system
Landscape/Amenity	The indicator which addresses Landscape Value and Amenity Use (or loss of Amenity ?)
Public Perception	The indicator which accounts for public complaints to the NRA both actual and potential
Cost of Alleviation	The indicator which addresses cost benefit

The proposed method includes provision for an optional Preliminary Screening before the Full Assessment is carried out and provides a means of assessing both the severity of artificially induced low flow problems at any site and the reliability of that assessment.

For a rapid summary of the method, the reader is directed to Chapters 5, 6 and 12 of this report.



Known Instances of Low Flows in England & Wales

Figure 1

Scott Wilson Kirkpatrick 1991

2. INTERRELATIONSHIP WITH OTHER R&D PROJECTS

At the time of the preparation of the Interim Report on flow assessment it was noted by the Consultants that the relevant part of the NRA R&D programme was slow to start. The status at the time was reported fully. Since then no major changes affecting this project have occurred though the programme is now beginning to pick up pace.

The following paragraphs summarise the position stated in the Interim Report and add to it the latest situation.

The newly recast project "**B2.1, Ecologically Acceptable Flows**" is clearly one situation where the data requirements could be shared. The details of the project's aim are of such interest to this project that they are reproduced in Annex 2, to enable the staff in the Regions to refer to these while conducting the low flow assessment as recommended in this report (Section 7.5).

Figure 2 shows the interrelationship of the "Assessment of Low Flow Conditions" project with other relevant R&D projects. The inner ring signifies closer association with the 'Low Flow' project, and the outer ring a more distant, but relevant association.

These other R&D projects have two potential impacts on the 'Low Flows' project, namely:

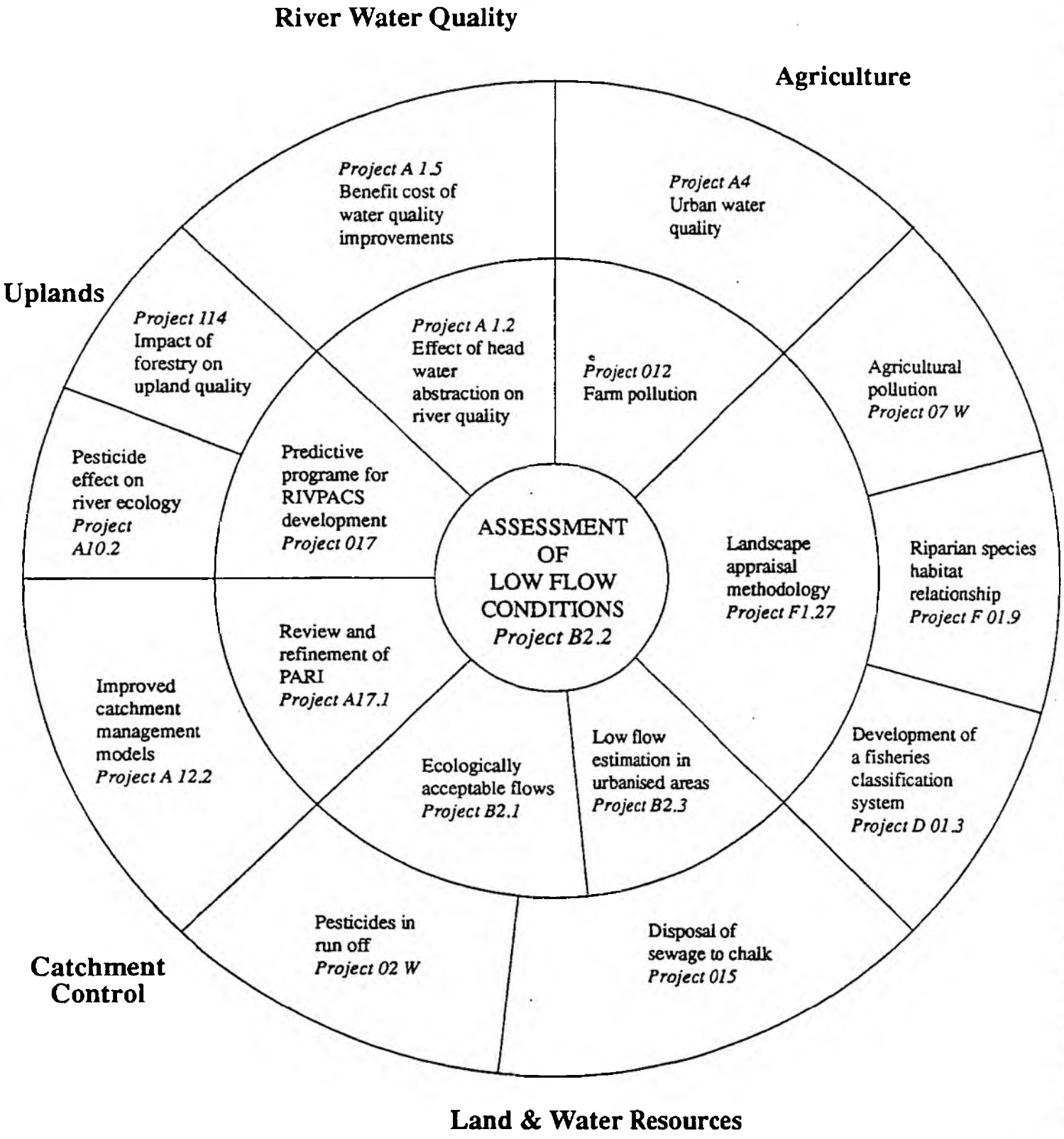
i) to provide a means of assessing specific target values for assessment parameters or alleviation objectives (e.g. Minimum Acceptable Flow, Ecologically Acceptable Flows), and

ii) to stimulate data collection or manipulation exercises, which would provide data for the assessment of low flows.

The Consultants are conscious of the fact that overall data collection within the NRA should be coordinated to serve as many purposes as possible for the minimum cost of collection. Thus in assessing which parameters to use for the low flow assessment, preference should be given to those parameters for which data is already collected or for which the data has a number of other uses within the R&D programme. It may be anticipated that the quantity and quality of data to be collected by the NRA may progressively change in the future, particularly with the objective of ensuring that the same level of data collection is achieved in all Regions.

A summary of findings to date on other R&D projects is given in Annex 4.

Many of the projects which would have a bearing on the 'Low Flow' project, are at the early stage of their initiation. Their conclusions could be important to this study but are unavailable at the time of completion of the project. In view of this fact, assumptions are made which have permitted the Consultants to proceed with concluding phase I of this project within the agreed time frame.



NRA R&D Projects Interelationship
Figure 2

3. REVIEW OF PREVIOUS NRA WORK

Some NRA Regions in their previous guise of the Regional Water Authorities had initiated some work on Low Flows within their respective areas but without much coordination with each other. On vesting day, the NRA took over the coordinating role, for the whole of England and Wales.

'Low Flows' as a problem was recognised in a number of Regional Water Authorities. However, the definitions, and therefore the regional perception of the problem were viewed in a variety of differing ways in each Authority.

Following vesting day, a survey was undertaken by the NRA Anglian Region, to determine the perceptions of each region with a view to establishing the extent of the problem at a national level.

The following paragraphs review these findings which are based on Roger Cook's (Anglian Region Water Resources Manager) reports and other internal NRA reports (Annex 5). The definition of 'Categories of Problem' and summary tables from Roger Cook's Report are produced below.

Category A - "real problems"	locations where there is a clear case for action.
Category B -"unreal problems"	locations when despite public outcry there is not a clear case for action.
Category C -"latent problems"	locations which are likely to be recognised as problems if action is seen to be taken on Category A.

During the survey by Anglian Region a fourth category was identified which was described as "possible problems" i.e. those where there is perceived to be a problem which has not yet been publicly recognised but the cause and the solution have yet to be evaluated. These have been denoted "Category D".

Table 1 shows the number of streams by Category in each Region which are considered to have been affected.

The largest number of problem locations were identified in the Severn Trent Region, while Northumbria reported none. A total of 40 Category A problems were identified, with the largest number occurring in the Anglian Region.

Table 2, which was also compiled in the same survey, shows by Region and by Category the estimated costs of alleviation. Work currently underway in the Regions is aimed at better establishing these cost estimates shown in the Table 2.

Table 1 NUMBER OF PROBLEM LOCATIONS IDENTIFIED

REGIONS	Number of Locations & Category				Totals
	A	B	C	D	
	Real	Unreal	Latent	Possible	
Anglian	9	4	10	4	27
Northumbria	-	-	-	-	-
North West	-	-	4	-	4
Severn Trent	6	5	3	6	20
Southern	7	-	1	-	8
South West	-	-	-	3+	3
Thames	5	4	-	-	9
Welsh	7	-	-	-	7
Wessex	3	-	-	2	5
Yorkshire	3	2	4	-	9
Total	40	15	22	15	92

The above information was provided in the Interim Report. Since that time a number of ongoing regional low flow studies have progressed. It is beyond the scope of the present report to describe all of these detail. The Consultants are aware of two specific regions, Severn Trent and South West, where region wide studies devoted to low flow alleviation have been initiated. Investigations related to specific streams eg the Darent (Southern) and the Slea (Anglian), are also underway.

TABLE 2 - COSTS (£000)

Category	A			B			C		
Region	Capital	Operating	Compen-sation	Capital	Operating	Compen-sation	Capital	Operating	Compen-sation
Anglian	2775	16	-	195	6	-	710	28	5500
Northumbrian	-	-	-	-	-	-	-	-	-
North West	-	-	-	-	-	-	-	-	6100
Severn Trent	295	30	500	530	50	300	----	Not Costed	-----
Southern	20000	200	6000	-	-	-	-	-	5000
South West	-	-	-	-	-	-	28	-	-
Thames	9500	230	-	2300	60	1200	-	-	-
Welsh	500	100	1100	-	-	-	-	-	-
Wessex	4250	175	-	-	-	-	-	-	-
Yorkshire	200	-	60	500	10	50	750	10	560
Total	37520	751	7660	3525	126	1550	1488	38	17160

4. SUMMARY OF THE EXISTING SITUATION

As a first step in this study the existing situation as regards investigation and study of low flows in each NRA Region was fully reviewed by the Consultants. In order to completely appreciate the concern of the Regions, all of them were visited prior to the preparation of the Interim Report (except Northumbria). Table 3 summarises the dates of visits. Discussions with the Regions were aimed at establishing their concerns, their current practices and anticipated approaches to dealing with the low flow problem in their own areas. Due to the nature of the present project, detailed evaluation of every occurrence of low flows in each region could not be made. It was therefore decided to select two contrasting occurrences of low flows and to discuss them.

In selecting two occurrences, the aim was to obtain a good, albeit, subjective appreciation of the problem faced by each region. These were summarised, from the Consultant's view point, in the Interim Report. The Regions were then asked to comment on the Consultant's understanding of the situation. The revised summary of the situation within each region is given in Appendix 3.

As part of Stages 1 and 2 of this phase of the Study (Figure 3), the following information was obtained :

* confirmed list of low flow sites previously reported.
* the basis on which the above list of sites were drawn up by each Region.
* a preliminary list of appropriate assessment parameters relevant to the sites affected by low flows.
* reports for rivers/sites which have been studied previously.

Northumbria Region was not visited since no Category A or B sites were identified. Telephone discussions with Mr David Archer of Northumbria Region have been held however.

4.1 Approach to Stage 1 and 2 Survey and Consultation

Before the programme of consultation, a standard letter was issued to each Region, setting out the objectives of the study and giving a preliminary list of parameters for the assessment procedure.

At each visit the following procedure was adopted:

i) The Consultant explained the scope and objectives of the study and requested location maps of each affected site.

ii) The Consultants requested the Region to confirm that the sites listed in the returns to Roger Cook were correct or to identify any variations or additional sites.

iii) The Consultants tabled a list of possible assessment parameters (which was revised in the course of consultations) and invited the Region to nominate for discussions two of the sites identified in their Region. One for which a considerable amount of data exists and the occurrence of low flows is not in question, and another for which data is lacking and the evidence is not clear. This was to take account of the fact that the assessment procedure will be required to compare such differing sites on an equitable basis.

iv) The applicability of the list of assessment parameters was then discussed,

a) to identify which of those or which other parameters have been used by the Region to identify the two nominated sites, and

b) to seek the Regions's views on the relevance and relative importance of each parameter in their Region and Nationally.

v) Finally the Regional staff were asked for any other comments or suggestions for the study.

4.2 Staffing of Consultation

Since one of the questions addressed in later stages of the study is the balance between water resources and conservation / environmental factors, the views obtained from the consultation were influenced by the officers consulted and, to a lesser extent, by the specialists fielded by the Consultants.

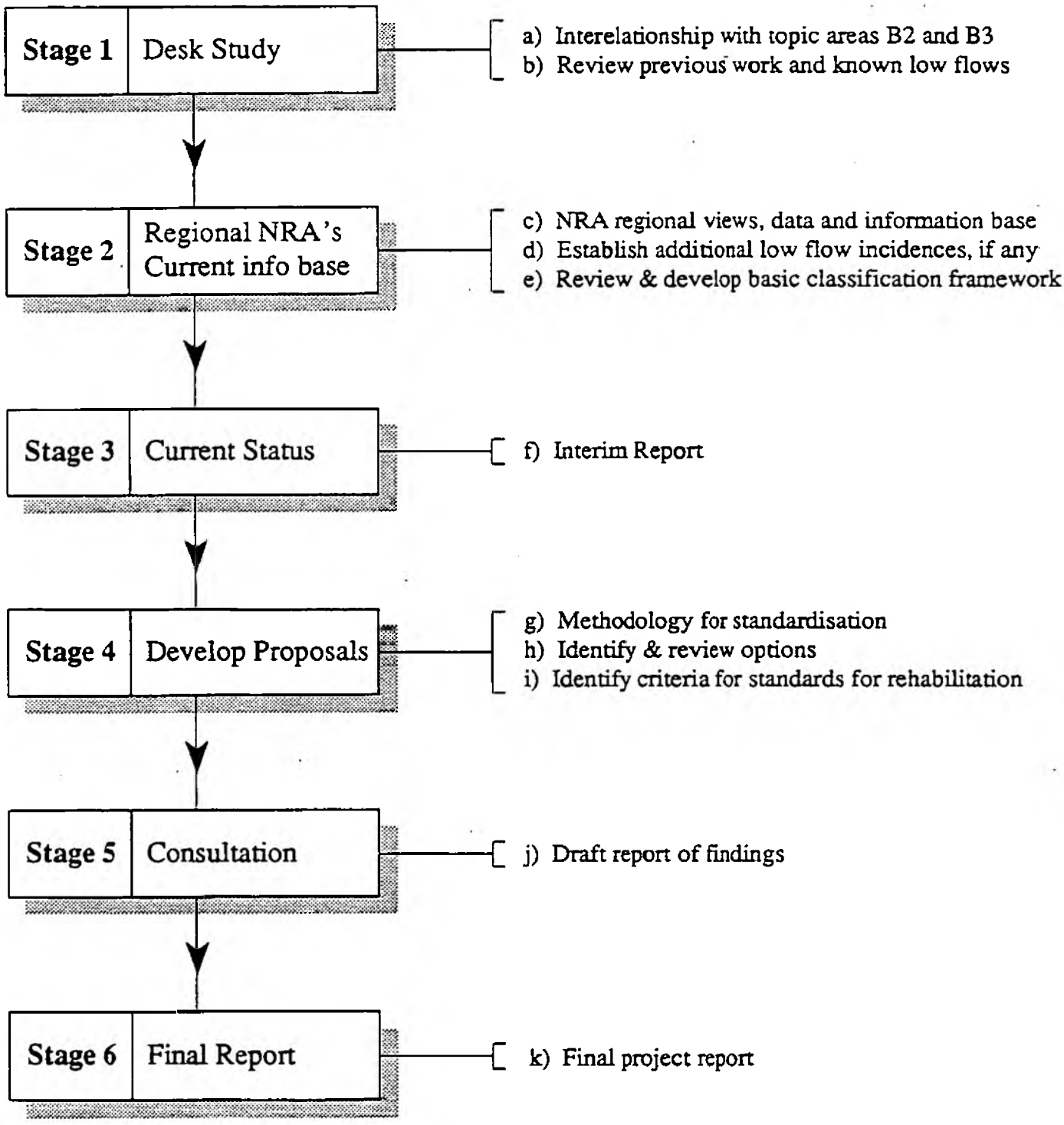
In setting up the Stage 1 and 2 meetings, this was pointed out to each Region but there was considerable variation in the range of disciplines fielded by each Region. In all cases a Water Resources officer attended the meeting but the representation of the Conservation/Environmental aspects varied. From the Consultants side, the Water Resources aspect was dealt with by Mike Le Gouais (for predominantly surface water areas) or Shammy Puri (for predominantly groundwater areas), with both together attending meetings easily accessible to Basingstoke in order to ensure a consistent approach.

For budgetary purposes the inputs from the Consultants on environmental aspects have been limited to 3 visits each from Anne Knape and Dr Phil Kerrison, ie visits to two 'groundwater' areas and one 'surface water' area with one joint visit (to Anglian Region) to ensure co-ordination.

TABLE 3

List of Liaison Meetings with NRA Regions

NRA Region	NRA Staff Met	Consultants Staff	Date of Meeting
Anglian	Mr Roger Cook Mr David Evans	S Puri Anne Knape P Kerrison	31/8/90
South West	Mr Peter Nicholson Mr Nigel Reader Dr Janet Cochrane Dr Rosanne Proome	M Le Gouais S Puri	14/9/90
Thames	Mr Nigel Hawkes Ms Maggie Pratt Mr Alastair Driver	M Le Gouais S Puri	19/9/90
Southern	Mr Steven Oakes	S Puri	24/9/90
Welsh	Ms Jean Frost Mr Richard Howell	M Le Gouais P Kerrison	24/9/90
Wessex	Dr Terry Newman Mr Richard Symonds	M Le Gouais S Puri	26/9/90
Severn Trent	Mr Elfyn Parry Mr Bob Harris Mr Roger Goodhew	S Puri P Kerrison	4/10/90
Yorkshire	Mr P Towlson Mr D Franklin Mr I Barker Mr J Pygott	S Puri Anne Knape	15/10/90
North West	Mr M Aprahamlan Mr R Ward Mr B Repton Mr R Chambers Dr M Owens	S Puri Anne Knape	18/10/90
Northumbria	Mr David Archer	M Le Gouais	(te lephone discussion)



Study Workplan
Figure 3

The NRA staff also varied considerably in seniority, from those only concerned with some aspects of a few sites in one area to those at senior level who had been addressing all aspects for the whole of their Region at strategic levels.

This perceived imbalance was corrected when the Interim Report was circulated to the Regions in Stage 5 consultation in January 1991. A number of important contributions were made which have assisted in the final development of the assessment methodology.

4.3 Summary of Findings

A broad summary of the problems and perceptions of each Region is given in Annex 3.

There is considerable variation in Regional perceptions on the problem of low flows and the objectives that any alleviation proposals should have. Basically these can be classified as follows:-

> Reduction in flow (real), in some cases to zero, arising (usually) from groundwater abstraction and leading to environmental degradation and public protest.
>
> Reduction in flow due to surface water abstraction, leading to the same problems as above.
>
> Potential low flow problems arising from abstraction licences which cumulatively exceed the river's catchment base flow and which may have not yet been taken up to the full licensed quantity.

Other problems such as lack of 'freshets' allowing fish migration have been mentioned in one or two regions.

Public pressure (both justified and unjustified) is a major driving force in the implementation of studies in many regions but real and potential problems have also been identified by NRA regions without, or in advance of, public pressure.

The approach adopted in resolving the problem appears to the Consultants to have been biased by discipline of the NRA staff consulted. The Water Resources Staff have generally viewed the problems within the terms of essentially providing additional flow in the stream. Generally, the approach of the biological-ecological staff appears to have been governed by Water Resources aspects and as a consequence their activities have been concerned with documenting and monitoring the invertebrate data of the affected streams.

Broadly, the problem causes can be defined on water resources - hydrogeology basis as follows:

Over abstracted and/or over licensed Chalk (or other) aquifer

Over abstracted and/or over licensed surface water resources

Inadequate reservoir releases

Other reasons : e.g. impact of land use, drainage, urbanisation.

5. APPROACH TO THE ASSESSMENT

In the Interim Report it was stated that:-

> "The requirements for the method of assessment are that it should produce an equitable and reproducible assessment of the relative degree of severity of artificially-induced low flows in a wide range of watercourses, taking into account wide differences in:-
>
> i) causes and impacts
> ii) water resources and environmental aspects
> iii) quantity and quality of data available
> iv) public awareness/perception
> v) cost of alleviation measures.
>
> It was also concluded that, in addition to indicating the degree of severity, the method of assessment should indicate the level of confidence that can be placed in the assessment (ie. the quantity, quality and relevance of the data used in the assessment). In addition (and perhaps most important) the method of assessment should require the minimum appropriate commitment of resources by the hard-pressed Regions. Thus it should be based as far as possible on data which is already collected for other purposes, or on new data which can be collected at minimum cost.
>
> A further dimension to the Classification Framework is that, in addition to assessing the relative degree of severity of the problem (on which prioritising or ranking of sites would be based) it should also describe the type or quality of problem, to enable alleviation strategies to link with overall policies for environmental improvements."

In developing the framework the Consultants have addressed the conflict between the need for minimum input of staff resources from the Regions, and the need to solve the complex problem of separating quality impacts from low flow impacts on the ecology.

The Consultants have tried not to use the need for minimum demands on staff resources as an excuse for producing a simplistic method. As a result, the proposed full assessment appears to be rather more complex than might have been hoped.

However, it is believed that it can be approached in a simple and straightforward way as follows,

i) by understanding the principles set out in Section 5.2 below.

ii) by conducting a two-stage assessment procedure - ie a Preliminary Screening (Chapter 13) and a Full Assessment (Chapter 6 to 12).

iii) and, by using only those parts of the assessment appropriate to the stage of the procedure used, and to the available data.

5.1 Preliminary Screening

It is not proposed that the full assessment should be applied to every stretch of river in the country to determine if there is a low flow problem.

Nor is it proposed that all problems in rivers should be presumed to have a low flow dimension until proven otherwise. It is proposed that the assessment should be applied only to those rivers or sites for which there is some reason to believe that low flow problems are occurring. The Consultants have learned from their discussions that the NRA Regions have a good idea of streams affected by low flows.

5.2 Principles of Full Assessment

The assessment proposal is based on three principles:

i) The assessment should indicate the degree of artificial interference with low flows (Severity Index) as well as the reliability of that assessment (Reliability Index).

ii) The evidence of low flow problems is derived from four primary Indicators, namely Hydrological, Ecological, Landscape/Amenity and Public Perception. A fifth indicator, Cost of Alleviation is relevant to the setting of priorities for alleviation but not to the assessment of the severity of the problem.

iii) Because the evidence of indicators may take different forms between regions there will be a degree of redundancy in the assessment, ie. not all of the assessment need be used on any of looking at this is as a 'menu' selection of parameters.

In the Full Assessment each Indicator is 'built-up' from a number of contributing parameters to which scores are assigned by the assessor. These scores are then combined using pre-set weights for each parameter, ie. they are pre-set in the method, and are not modified by the assessor.

However, for the Preliminary Screening (Section 5.1) a single parameter for each Indicator could be used, as indeed, one Indicator from above could be used to confirm the occurrence of low flow prior to proceeding to its Full Assessment.

6. INTRODUCTION TO ASSESSMENT METHOD

The Assessment Method is based on obtaining adequate evidence from five Indicators, namely:-

Hydrological Indicator
Ecological Indicator
Landscape/Amenity Indicator
Public Perception Indicator
Cost of Alleviation Indicator

The steps involved in the assessment are shown on Table 4.

Scores are assigned to each Indicator and they can be combined in a number of ways (as set out in Section 12) to determine for any site:-

* the severity of artificially-induced low flows (*The Severity Index*)

* the reliability of the assessment (*The Reliability Index*)

* the degree to which the problem is *real or perceived* only

* the *priority* which the site should receive, Regionally or Nationally for alleviation

The Indicators can be used at two levels:-

* **Preliminary Screening**, which requires minimum data and staff resource

* **Full Assessment**, which requires a large data base and input from staff working in a number of disciplines.

For the Preliminary Screening, scores may be assigned directly to the Indicators by the assessor (see Section 13). However, this level of assessment will result in a low Reliability Index, as it relies on very limited data.

For the Full Assessment the score for each Indicator is calculated by combining scores assigned to a number of weighted parameters related to each Indicator (see Sections 7 to 10). The Full Assessment is comprehensive and time consuming and it is expected that it will only be applied to those sites for which the Preliminary Screening suggested that the stream is suffering the effects of low flows.

In either case, it is not necessary to use every one of the Parameters or Indicators, but only those for which data is available, or those for which data can be collected at minimum cost.

Having assessed the Severity Index and the Reliability Index the action arising from this assessment might be categorised as shown in Table 5. Detailed action by the NRA following the assessment is beyond the scope of this project and therefore it has not been considered further.

Table 4 : THE SEQUENCE OF THE ASSESSMENT

STEPS	Assessment required at each step
1	Define whether *Preliminary Screening or Full Assessment* required
2	Select Indicators of low flows (at least one for Preliminary, all for Full) Hydrological Indicator Ecological Indicator Landscape/Amenity Indicator Cost Indicator
3	Assign scores for each parameter of every Indicator used
4	Calculate *Severity Index* and *Reliability Index* for each of the indicators selected
5	Combine the Indicator Indices to obtain Overall Severity Index, and Overall Reliability Index
6	Decide on the further action for the stream system, according to the guide given on Table 5
7	Repeat steps 2 to 6 if more data is available

Table 5 : SUGGESTED ACTION RESULTING FROM ASSESSMENT OF LOW FLOWS

Severity Index	Reliability Index	Action Required
High	High	Put in NRA Capital Works programme for alleviation
High	Low	Further study and data collection required
Low	High	No action unless strong public pressure in which case mount a public relations campaign to explain that there is no problem.
Low	Low	No action unless strong public pressure in which case initiate minimum cost studies and mount public relations campaign

7. THE HYDROLOGICAL INDICATOR

The Consultants propose that the Hydrological Indicator should be assessed on the basis of six parameters. Each of these parameters and the system of their scoring is discussed in the following sections. Table 6 shows a summary of all the parameters proposed.

7.1 Groundwater Balance Parameter (H1)

This parameter, applicable to streams mainly supported by groundwater flow would be calculated for the groundwater catchment considered to be suffering low flows . It is the sum of all annual groundwater abstraction licences (ALA) divided by the calculated annual recharge (AR), for the catchment upstream of an assessment point.

$$H1 - \frac{ALA}{AR}$$

Licensed surface water abstractions (SWALA in table 7) and effluent returns (ER in table 7) would be included only if

a) parameter H2 is **not** used, **and**

b) abstraction is primarily supported by spring flow. Otherwise they would be ignored.

Scoring would be as follows:

$\frac{ALA}{AR}$ 10yrDrought*	Score	$\frac{ALA}{AR}$ AnnualAverage*
>1	4	>0.8
0.7 - 1.0	3	0.5 - 0.8
0.4 - 0.7	2	0.3 - 0.5
0.2 - 0.4	1	0.1 - 0.3
<0.2	0	<0.1

* see (ii) below.

The weighting assigned is 30%.

SUMMARY OF HYDROLOGICAL INDICATOR	
Parameters are:	
Groundwater Balance parameter H1 =	Annual Licensed Abstraction (ALA/AR) Annual Recharge Groundwater catchment. May need to add surface water abstractions and effluent returns. *Weighting = 30%.*
River Flow Balance parameter H2 =	Daily Maximum Licensed Abstraction (DMLA/Q95nat.) • Q95 "Natural" Surface water catchment. May need to add licensed groundwater abstractions, effluent returns and compensation releases. *Weighting = 30%.*
Aquifer Gradient parameter H3 =	Groundwater Levels : Current v Historic (di/dt) Calculated as annual rate of change of piezometric gradient (di/dt), where di = 1 - (New Gradient/Old Gradient) x 100%. *Weighting = 20%.*
Stream Morphology parameter H4 = .	Channel Size (% of Channel) Percentage of 'normal low flow channel' occupied by low flows at end of August. Ratio of XSA(current) : XSA(normal). *Weighting = 20%.*
Flow and Ecology relationship parameter H5 =	Residual Flow Minimum Ecologically Acceptable Flow (Q95 - DMLA) / MEAF Residual flow = Q95 "Natural" - DMLA. *Weighting = 60%.*
Receding Springhead parameter H6 =	Change in Stream Type Length of stream reaches with changed classification (perennial - intermittent, intermittent - ephemeral). *Weighting = 20%.*

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Table 6 : Summary of parameters related to the Hydrological Indicator

Two points should be made concerning the application of this parameter

i) As many affected sites are in the headwaters, it is likely in some (or many) cases that abstraction in adjacent catchments may affect low flows. Some judgement will be required to decide what is the appropriate catchment to be considered, or whether groups of catchments should be considered together.

ii) It has initially been assumed that this parameter would be calculated on the basis of the *average annual recharge* on the grounds that the marking system can be adjusted to allow for drought years. However, there is a strong argument for using the calculated annual recharge in the *1 in 10 year drought* in order to more directly take into account drought conditions in setting abstraction licences

7.2 Riverflow Balance Parameter (H2)

This parameter, applicable to streams supported mainly by surface runoff would be calculated for the surface water catchment and consists of the sum of the daily maximum licensed abstraction (DMLA) divided by the 95 percentile flow (Q_{95}) assessed by the Institute of Hydrology (IoH) Low Flow Study methods

Effluent returns and compensation releases would be added algebraically to the DMLA. In the event that parameter H1 is not used, licensed groundwater abstractions deemed to have a direct impact on low flows (eg within 250m of river) would be similarly added.

$$H2 - \frac{DMLA}{Q_{95}} natural$$

Scoring would be as follows:

$H2-\frac{DMLA}{Q_{95}}$	Score
>1	4
0.7 - 1.0	3
0.4 - 0.7	2
0.2 - 0.4	1
<0.2	0

The weighting assigned is 30%.

In collecting the data to assign a score to this parameter the following points should be noted:

i) There has been some discussion on the relative merits of Q_{95}, the 95 percentile flow based on the flow duration curve and MAM the Mean Annual Minimum flow based on the flow frequency curves. Both of these measures are derived from the same basic data set and may not be truly representative of the 'natural' or 'historic' conditions since this data may include some flow data affected by long term abstraction.

It is understood that neither measure is 'better' than the other but consultation with the Regions indicated that Q_{95} is more commonly used in this context.

ii) The Consultants have also considered whether the 1-day, 7-day or 10-day Q_{95} should be used. Provided that the same measure is consistently used, we do not believe it is critical which is used and we would propose the 7-day Q_{95}.

iii) The same arguments concerning 'drought' conditions as for parameter H1 above apply for long-term licences but not for annual irrigation licences.

7.3 Aquifer Gradient Parameter (H3)

During consultation with Regions it was consistently stated that a measure based on ground water levels should be included, as level decline, if demonstrated, would be a clearer indication of lowering of aquifer levels.

The value of this parameter may be reduced because appropriate groundwater level data are not likely to be available. Nevertheless the parameter is worth including in the assessment methodology. However, rather than direct use of levels, it may be more appropriate to use *the change in mean piezometric gradient* than absolute levels and the rate of change with (long term) time is also considered more significant. If long term data are available the parameter should be calculated from the annual minimum level.

The gradient (i) is calculated along an appropriate groundwater flow path from the catchment boundary to the stream. A series of gradient profiles for annual minimum conditions should be plotted to ascertain whether such data would apply to the stream under consideration.

The % *change* in gradient (di) is expressed as

$$di = 1 - \frac{NewGradient}{OldGradient} \times 100$$

$$\frac{di}{dt} = \frac{di}{NO.ofYrs}$$

$$H3 = \frac{di}{dt}$$

This method is applicable for positive or negative gradients (flow towards river positive) provided that under 'natural' or unaffected conditions the gradient was positive.

Scoring would be:

$\frac{di}{dt}$	Score
>8%	4
5 - 8%	3
2 - 5%	2
0.5 - 2%	1
<0.5%	0

Some judgement in the use of the parameter is required. The ranges of gradients and level declines in various aquifer systems in the UK will not be consistent. For a long

period of record (say > 10 years) the maximum annual rate of change over a 5 year period should be used. As the assessment method is yet to be tested in the Regions it is anticipated that modifications to the di/dt ratio will be necessary.

The weighting assigned to the parameter is 20%.

7.4 Stream Morphology Parameter (H4)

This parameter reflects the proportion of the "normal low flow channel" occupied by low flows at the end of August. It would be calculated as the mean of the ratios of current cross-sectional area of flow (XSA current) to 'normal' cross-sectional area of flow (XSA normal) at not less than 5 representative cross sections.

A suggested definition of 'normal low flow channel' is the channel occupied by the base flow at the end of the month in which a Soil Moisture Deficit first occurs.

This is based on the premise that the impact of abstraction on low flows is far greater at the end of the dry season (when storage is drawn down) than at the beginning of the dry season, when storage should be more or less full. The Consultants have considered using wetted perimeter or hydraulic radius but have concluded that cross-sectional area is most appropriate. Since this parameter is based on relative rather than absolute areas, we believe it is acceptable to calculate area as surface width x maximum depth. However, this parameter must be used with caution,

a) because following a dry winter in which full recharge does not occur, the 'normal low flow' may be abnormally low and

b) it is also a measure of the 'flashiness' of the river which is dependent on other factors such as geology and land use.

$$H4 = \frac{XSA(Current)}{XSA(Normal)}$$

Scoring would be:

% of Channel	Score
<10%	4
10 - 30%	3
30 - 50%	2
50 -70%	1
>70%	0

The weighting assigned is 20%.

7.5 Flow and Ecology Relationship Parameter (H5)

The development of techniques to establish minimum ecologically acceptable flows (MEAF) is the subject of another NRA research project, reference B2.1 discussed in Chapter 2 of this report.

In using the MEAF it should be have noted that the ecologically acceptable flow will not be a single value for a given river but will vary with season. As the methodology has not yet been defined its application in low flow assessment, is to an extent premature. However, when such techniques are available, the relationship between low flow occurring and MEAF will be the most important single parameter in describing the severity of the problem and in monitoring and managing low flows. The following parameter is therefore proposed.

As a measure of low flow problems in surface water areas, the proposed parameter would be:

$$H5 = \frac{Q_{95} - DMLA}{MEAF}$$

where Q_{95} = 95 percentile flow for 'natural' catchment calculated from IoH Low Flows Study. (In this case MAM, may be a better measure than Q_{95} since it is based on a consecutive run of low flows).

DMLA = is as defined in H2 above

MEAF = minimum ecologically acceptable flow in the critical month (September)

A possible problem is that the ecologically acceptable flow may be achieved in the month which is critical in terms of minimum flow but the (higher) ecologically acceptable flow required at some other time of year may not be achieved, ie the critical time in terms of low flows may not coincide with the critical time in terms of ecologically acceptable flows.

This parameter is more difficult to quantify where the abstraction is primarily from groundwater and in such a case the measured residual flow may have to be used.

The scoring would be as follows:

Parameter Value $\frac{Q_{95}-DMLA}{MEAF}$	Score
<60%	4
60 - 80%	3
80 - 100%	2
100 - 120%	1
>120%	0

The weighting assigned is 60%

7.6 Movement of Springhead (H6)

Stream reaches can be classified into 3 main types: perennial, intermittent and ephemeral. These are defined, for this project, as follows:

> Perennial reaches flow throughout the year.
>
> Intermittent reaches flow for most of the year but are dry for at least 2 weeks (in the summer).
>
> Ephemeral reaches only flow during and immediately after rainfall or snow melt.

The change in classification of a stream reach from either perennial to intermittent or intermittent to ephemeral is assumed to indicate a low flow problem. Such a change during 1 in 10 year drought, however, is an exception to this and is not included. The "change" in stream parameter is defined as:

> The total length of reaches of a stream, upstream of the assessment point, that have changed their classification from either perennial to intermittent, or intermittent to ephemeral.
>
> **H6** = *Total Length of River with Changed Classification*

Scoring would be as follows:

Length of river (Km)	Score
>8	4
4 - 8	3
2 - 4	2
0 - 2	1
0	0

Equal importance is assumed for a change from perennial to intermittent, as a change from intermittent to ephemeral. Changes from perennial to ephemeral are unlikely but can be scored in exactly the same way.

The weighting assigned is 20%.

7.7 Accretion/Depletion Profiles (H7)

If available, such profiles are very descriptive of the problem but not easy to convert to a simple parameter. They measure the quality of the problem rather than its quantity. For the present it is not therefore proposed to include this in the list of assessment parameters.

7.8 Sample Calculation of Hydrological Indicator

Once all the parameters related to the Hydrological Indicator have been decided, based on data availability and suitability of the parameters for the catchment area, scores are calculated by the assessor. The score of four is the maximum that any parameter may be given. The degree of significance of each parameter is determined by a parameter weight, which is multiplied by the given score to arrive at a weighted score. The weighted scores are added together and divided by the sum of weights of parameters actually used, four times, which will give the value of the *Hydrology Severity Index (HSI)*.

Hydrology Reliability Index (HRI) is the sum of Weight of Parameter used. Not all parameters need to be used since there is a certain degree of overlap between parameters.

Example Calculation of the Hydrological Indicator

Parameter	Parameter weight *(a)*	Weight of parameters used	Score (out of 4) *(b)*	Weighted score *(a) * (b)*
H1	0.3	0.3	4	1.2
H2	0.3	-	-	-
H3	0.2	0.2	3	0.6
H4	0.2	0.2	3	0.6
H5	0.6	-	-	-
H6	0.2	-	-	-
Totals		0.7 *(Y)*		2.4 *(Z)*

From the above example the following calculations may be made:

Hydrology Severity Index (HSI)

$$HSI = \frac{TotWeightedScore}{TotWeightofParms * 4}$$

$$= \frac{Z}{Y * 4}$$

$$= \frac{2.4}{0.7 * 4}$$

$$= 0.86$$

Hydrology Reliability Index (HRI)

$$HRI = TotWeightofParmsUsed$$

$$= 0.7$$

The HRI may not exceed 1, if it does it is set to equal 1.

A complete sample calculation for a sample stream is shown on Table 7. Blank sheets for use of assessors are given in Annex 6 when the assessment is undertaken by the Regional NRA's. The calculation has been set up on a LOTUS spreadsheet for ease of calculation and a copy of the disk may be obtained from the Consultants on request.

TABLE 7 : SAMPLE CALCULATION

HYDROLOGICAL INDICATOR

NRA REGION: A region NAME OF STREAM: River Example DATE: 12/8/92

(see Report Chapters 7.1 to 7.6 for full explanation of the methodology)

H1 ANNUAL LICENSED ABSTRACTION parameter
ANNUAL RECHARGE

Total Groundwater ALA =	1400	m3/a	(GWALA)	
Calculated AR (long-term average) =	1800	m3/a	(AR1)	
Calculated AR (1 in 10 yr drought) =	1500	m3/a	(AR2)	
Total Surface Water ALA =	400	m3/a	(SWALA	} ONLY enter if H2 not used and
Effluent Returns (annual) =	300	m3/a	(ER)	} ALA is supported by spring flow

For average: ALA/AR (1) = (GWALA+SWALA-ER)/AR1 = 0.83
For drought: ALA/AR (2) = (GWALA+SWALA-ER)/AR2 = 1.00

ALA/AR (1)	Score	ALA/AR (2)
>1.0	4	>0.8
0.7-1.0	3	0.5-0.8
0.4-0.7	2	0.3-0.5
0.2-0.4	1	0.1-0.3
<0.2	0	<0.1

Assign score: H1 = 3 (average)
4 (drought)

H2 DAILY MAXIMUM LICENSED ABSTRACTION parameter
Q95 "NATURAL"

Total Surface Water DMLA =	200	m3/d	(SWDMLA)	
Q95(7) =	300	m3/d	(QNF)	
Total Groundwater DMLA (<250m from river) =	30	m3/d	(GWDMLA)	}
Effluent Returns (mean daily) =	20	m3/d	(ERTWO)	} ONLY enter if H1 not used
Compensation Releases (mean daily) =	10	m3/d	(CR)	}

DMLA/Q95 = (SWDMLA+GWDMLA-ERTWO-CR)/QNF = 0.67

DMLA/Q95	Score
>1.0	4
0.7-1.0	3
0.4-0.7	2
0.2-0.4	1
<0.2	0

Assign score: H2 = 2

H3 GROUNDWATER GRADIENTS : CURRENT V HISTORIC parameter

Old Piezometric Gradient =		m/km	(OPG)
New Piezometric Gradient =		m/km	(NPG)
Number of years =		yrs	(YRS)

% Change in Gradient = 1 - (NPG/OPG) x 100 = 0.0 (i)
Annual Rate of Change = I/YRS = 0.0 (di/dt)

di/dt	Score
>8%	4
5-8%	3
2-5%	2
0.5-2%	1
<0.5%	0

Assign score: H3 =

TABLE 7 : SAMPLE CALCULATION (con't.)

HYDROLOGICAL INDICATOR

NRA REGION: A region NAME OF STREAM: River Example DATE: 12/8/92

(see Report Chapters 7.1 to 7.6 for full explanation of the methodology)

H4 CHANNEL SIZE parameter

Cross Section	Current XSA of flow (m2)	Normal XSA of flow (m2)	Current Normal
1	18	25	72%
2	19	34	56%
3	25	39	64%
4	32	53	60%
5	24	56	43%
		Mean =	59%

% of Channel	Score
<10%	4
10-30%	3
30-50%	2
50-70%	1
>70%	0

Assign score: H4 = 1

H5 RESIDUAL FLOW parameter

MINIMUM ECOLOGICALLY ACCEPTABLE FLOW

(Note: MEAF is under development as part of NRA R&D Project B2.1 and is as yet undefined)

Q95(7) 'natural' = m3/d
Total Surface Water DMLA (see H2) = m3/d
MEAF (critical month) = m3/d (Q95-DMLA)/MEAF = 0%

(Q95-DMLA)/MEAF	Score
<60%	4
60-80%	3
80-100%	2
100-120%	1
>120%	0

Assign score: H5 =

H6 MOVEMENT OF SPRINGHEAD parameter

Total length of reaches changed from perennial to intermittent = 2.5 km
Total length of reaches changed from intermittent to ephemeral = 1.0 km
Sum = 3.5 km

Sum of reaches (km)	Score
>8	4
4-8	3
2-4	2
0-2	1
0	0

Assign score: H6 = 2

CALCULATION OF HYDROLOGICAL INDICATOR

Parameter	Param. weight	Weight of params. used	Score	Weight x Score
H1	0.3	0.3	3	0.9
H2	0.3	0.3	2	0.6
H3	0.2			0
H4	0.2	0.2	1	0.2
H5	0.6			0
H6	0.2	0.2	2	0.4
		SUM1 = 1	SUM2 =	2.1

Hydrology Severity Index = SUM2/(SUM1x4) = 0.53

Hydrology Reliability Index = SUM1 = 1.00 *(If SUM1>1, set SUM1=1)*

8. THE ECOLOGICAL INDICATOR

Five ecological parameters are proposed (Table 8), of which the first four will measure the impact of existing low flow conditions and the fifth, conservation, will be used only if there is other evidence (hydrological or ecological) that low flows are occurring. Data on invertebrates and fisheries will be used as measures of low flow conditions because they respond to sustained periods of low flows. These invertebrates and fish parameters may appear to be complicated, but this is essential so that the effects of low flows can be differentiated from effects of water quality and engineering. Bankside plants may contribute some limited information about the lowering of the water table.

The importance of habitat requirements of fish and invertebrates and the need for their inclusion in low flow management calculations of rivers is increasingly being accepted. A river which is achieving its full ecological potential supports a diverse and well balanced community which is not subject to water or habitat constraints. (Unsympathetic channel 'management' can cause habitat constraints). To fulfil these conditions, values of the major variables characterising or constraining the reach (that is flow depth and velocity, temperature and water quality) would lie within a relatively narrow range. The mid point of this range would define the channel's 'natural' character. Species associated with this range would make up the channel's 'natural' community and this would be adversely affected by any significant alterations in the constraining variables. Total numbers of fish and invertebrates and also the number of species are adversely affected by low flows.

The ultimate aim of low flows research should be to link hydrological data bases and low flows models with habitat-based models. This would enable low flows to be managed on the basis of comprehensive hydrological data to maintain river habitat features (and the communities they support) appropriate to a particular river reach and to satisfy water quality demands. Such a system would incorporate ecological aspects into low flow calculations, which are traditionally based on only hydrological and water quality criteria.

8.1 Invertebrate Community Parameter (E1)

Flow regime, habitat availability, water quality and temperature are the variables which exert most influence on river macro invertebrates. Flows which are artificially maintained at values above those occurring naturally, can cause macro-invertebrate production to increase and if spates are also removed then species with lower flow preferences may preside. This is because under natural conditions, species compete for the habitat. In contrast, when flow is constantly low, macro-invertebrate productivity declines allowing only species adapted to damp conditions under rocks or in isolated pools to survive. Low flows accompanied by intermittent spates are particularly damaging, as this combination wets otherwise uncovered areas of channel causing populations to become stranded, banks to be eroded and the pool/riffle sequence to be disrupted.

SUMMARY OF ECOLOGICAL INDICATOR		
Parameters are:		
E1	Invertebrate Community (potential : measured ASPT)	Based on Average Score Per Taxon (ASPT). Ratio of measured ASPT : potential ASPT. *Weighting = 40%.*
E2	Fishery (Game/Coarse/Estuarine fish)	Decline in fish community from game to coarse or estuarine fishing, primarily due to low flows. Also loss of fishing in short-term. *Weighting = 20%.*
E3	Fish Stocks (present/potential fish stock x 100%)	Ratio of present fish stock : 'potential' fish stock. *Weighting = 30%.*
E4	Plants	Seasonal change in terrestial plants in channel and long-term change in bankside flora. *Weighting = 10%.*
E5	Conservation	Assessed on basis of NCC designated sites and conservation value of non-designated sites. *Weighting = 30%.*

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Table 8 : Summary of parameters related to the Ecological Indicator

Although invertebrate data are available in the NRA regions,they have been collected primarily for water quality monitoring purposes. The biotic indices generated by this data, such as the widely used Biological Monitoring Working Party score (BMWP), are unable to distinguish the effects of water quality from the effects of low flow conditions.

Since 1989 macro invertebrates data have been collected nationally in a standardised way. Also identification has been made - as far as possible - to species level. These data have been collected for use in the River Invertebrates Prediction and Classification System (RIVPACS) software (Cox et al, 1991). This methodology has been available to the NRA only since January 1991.

RIVPACS provides classification and prediction facilities for running-water macro-invertebrate assemblages in British rivers. It is used to compare the macro-invertebrate fauna of a newly sampled site with an existing national site classification.

RIVPACS suggests the species assemblage most likely to occur at a site under the conditions prevailing at the time of sampling (employing eleven physico-chemical characteristics). These conditions may have been produced by extended periods of low flow, or by channel engineering, and under such circumstances RIVPACS would predict the most diverse species assemblage *likely* to occur. In other words, the species to be expected under those conditions, provided that water quality were not limiting. This is not necessarily the *'natural'* invertebrate community for the river reach.

RIVPACS will be useful for low flow purposes when it has been sufficiently developed to include historic data from the catchment. This will enable the package to determine the species assemblage which would have occurred before channel engineering and low flow constraints were a problem. This truly would be an estimate of the *'natural'* community.

A parameter defined as Average Score Per Taxon (ASPT) is already calculated for water quality purposes by the NRA. First, the BMWP score is determined and is then divided by the number of taxa. BMWP may not entirely reflect quality, since the score improves as sample size increases and may be biased by factors other than pollution, such as geographical location and season. ASPT is largely independent of those factors (Armitage et al., 1983).

The maximum achievable ASPT might therefore be a useful starting point from which to adapt water quality data for low flow application. The Consultants proposal is to successively down rate the index to take account of constraints due to water quality, channel engineering, and location (ie whether the source is in an upland or lowland, and whether the site is in a headstream, mid-stream or lower reach). The product would be a coarse estimate of the ASPT potential of a stretch of river. If the ASPT measured for the stretch failed to reach this value then it would indicate derogation, for which flow is likely to be the cause. The procedure would start with the question:-

1) Are macro-invertebrate data available?

If the answer is 'No' then the algorithm ends, but if the answer is 'Yes' then proceed to 2.

2) Generate potential ASPT, as shown on the flow chart in Figure 4.

This would score the invertebrate communities in fast-flowing eroding headwaters with various proportions of sewage effluent differently from those in slower flowing more depositing reaches with similar sewage effluent components. In the same way, depositing or 'heavily-managed' lower river reaches could be scored. The system would need to be fine-tuned in the Regions, which would be achieved by adjusting the factors.

3) Generate (measured ASPT: potential ASPT) ratio.

Scores for parameter E1, consistent with the other parameters can be allocated using the table below:

Measured ASPT	Potential ASPT					
	<4.5	4.5-5.0	5.1-5.5	5.6-6.0	6.1-6.5	>6.5
<4.5	0	1	2	3	4	4
4.5-5.0		0	1	2	3	4
5.1-5.5			0	1	2	3
5.6-6.0				0	1	2
6.1-6.5					0	1
>6.5						0

Thus the maximum score of 4 would be allocated for the lowest ratio of measured to potential ASPT.

The weighting for this invertebrate community parameter, (E1) is 40%.

Angling and Fishery Parameters

Data on species composition, population density and biomass are generally available in the NRA regions. Fish, particularly trout and salmon, are extremely useful indicators of environmental conditions in rivers because:

i) they respond to changes in habitat and fluctuations in flow, dissolved oxygen concentration, water quality and temperature, and

ii) records of catches of game fish such as trout and salmon are often available. In addition, anglers often report changes in river habitat, flow conditions and water quality although not always accurately.

Two parameters *E2, Fishery* and *E3 Fish Stocks*, have been selected to assess the impact of low flow conditions on fish population. These parameters incorporate information on 'fishing interest' as well as the condition of the fishery and can highlight both long-term and short-term effects. However the impact of low flows needs to be distinguished from water quality and channel engineering effects.

8.2 Fishery Parameter (E2)

The aim of the Fishery parameter (E2) is to assess any short-term or long-term decline in fisheries as a result of low flows. A certain amount of subjective judgement by experienced fishery personnel, for example, may be required to distinguish whether the major cause of any identified decline is due to low flows. Long term declines may be assessed by comparison of historic or long term records with current conditions. If there is evidence that a decline in the fish community from game to coarse or estuarine fishing is primarily due to low flows, then scores will be assigned from the table below :

	Fisheries under normal flow conditions	Decline in fisheries under low flow conditions to:				
		(b)	(c)	(d)	(e)	< (e)
Game	(a)Trout, salmon	1	2	3	4	
	(b)mixture of (a) and (c)		1	2	3	
Coarse	(c)Barbel, chub, dace, perch, pike, roach, etc			1	2	
	(d)Bream, perch, roach, tench				1	
Estuarine	(e)Eels, flounders					1

Alternatively, short term impact of low flows on fisheries can be assessed by awarding a score of four where there is a loss of fishing appropriate to a river reach, as a result of low flows :

Score	Description
0	No evidence of short term impact of low flows on fisheries.
+4	No fishing was possible during a fishing season as a result of low flows.

It is suggested that the maximum score from either of the above sources is carried forward to be used in calculating the ecology indicator.

The weighting of the fishery parameter (E2) is 20%.

8.3 Fish Stock Parameter (E3)

This parameter (E3) may be calculated where data on fish stocks are available. This system is flexible in that data in various forms could be used. This might include population density and biomass or whichever system is adopted in individual Regions. Total biomass or population density would be the quickest variable to calculate as changes in species composition are accounted for in E2.

The assessment of the fish stocks parameter is based upon a comparison of the present fish stock and the 'potential' fish stock. Potential stock would take account of past fish stocks and subsequent adverse impacts of sewage effluent and channel modifications. An algorithm similar to that used for invertebrates, shown below, is suggested to separate out the effects of low flow conditions from those caused by channel modifications or water quality.

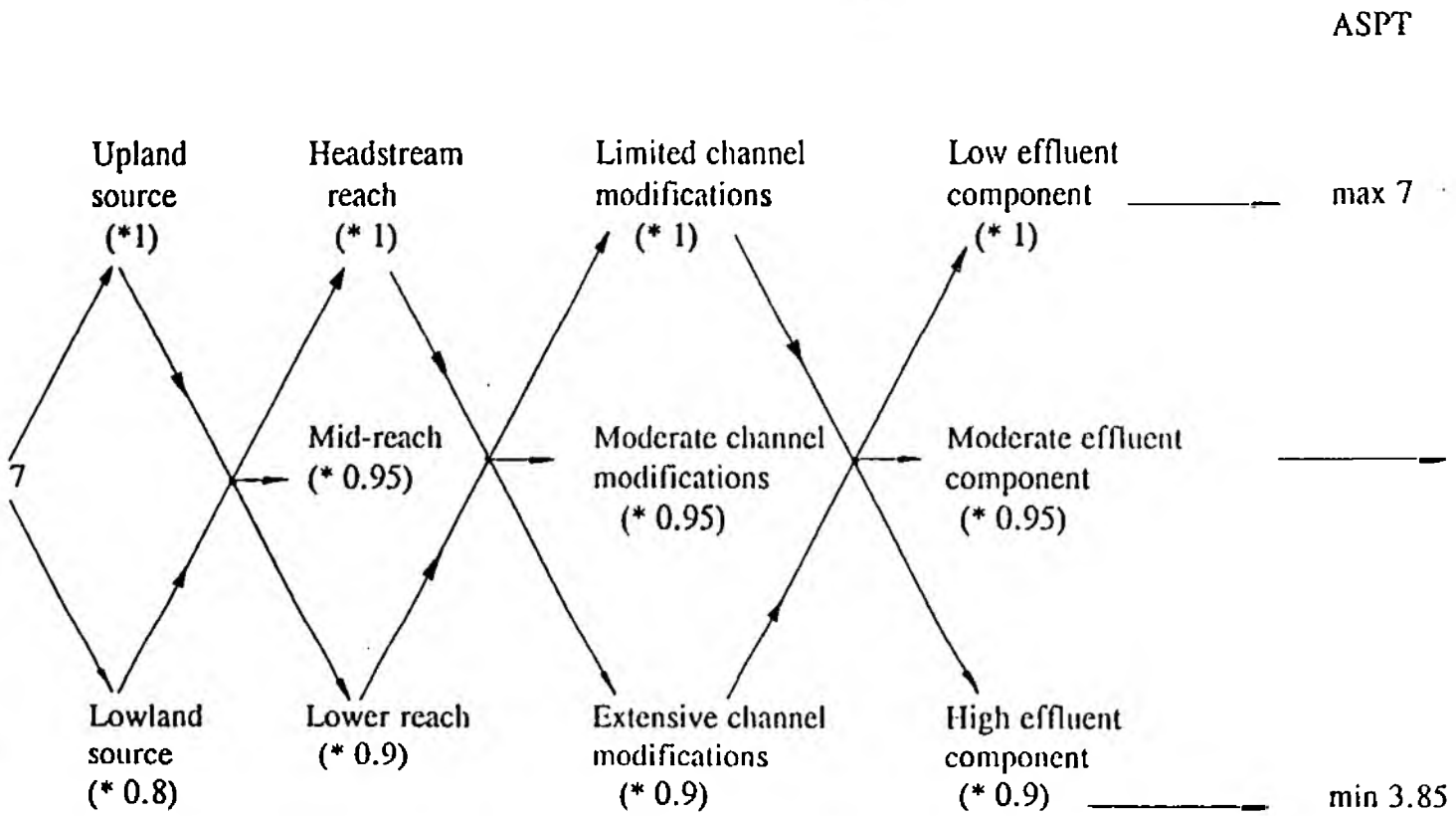

FIGURE 4. Flow Chart to Generate Potential ASPT

The procedure on the flow chart below would start with the question :

1) Are data on fish stock available for the period *before* low flows were perceived as a problem.

If the answer is 'No' then the algorithm ends, but if the answer is 'Yes' then proceed to 2.

2) Use flow chart below to generate *'potential'* fish stock:

	Channel modifications	Effluent component	'Potential' fish stock value = NP
Past fish stock = N →	Low (*1)	Decrease (*1)	
	Moderate (*.9)	No change (*1)	
	High (*.8)	Increase (*.8)	

3) Compare the measured present fish stocks (NM) with the potential fish (NP) stock generated by the algorithm:

$$FSR\% = \frac{PresentFishStock}{PotentialFishStock} * 100$$

$$= \frac{NM}{NP}$$

A value of less than 100% indicates that a decline in fish stocks may possibly result from low flows. A value of greater than 100% indicates that there is probably no decline in fish stocks due to low flows.

Parameter scores may be determined on the basis of:

the greater the stock depletion, the more serious the effects of low flow.

A scoring system for this parameter is suggested below. The sensitivity of the system and the numerical ranges or factors employed will need to be verified in each Region.

Score	Ratio of present to 'potential' fish stock (FSR)	Decline in fish stock related to low flows
4	<40%	Serious decline
3	40 - 59%	Large decline
2	60 - 79%	Moderate decline
1	80 - 99%	Small decline
0	>100%	None

The weighting of this Fish Stock (E3) parameter is 30%.

8.4 Plant Parameter (E4)

Aquatic plants respond to many environmental factors of which low flow is but only one. It is very difficult to isolate the effects of low flows on aquatic plants. However the short-term seasonal effect of terrestrial plants invading the normal river channel during the summer months, and the longer-term changes in herbs, shrubs and trees growing on the river banks resulting from a lower groundwater table will provide a useful parameter.

Score	Description
0	No change, other than normal seasonal variation in channel or bankside flora.
2	Marginal terrestrial plants regularly invade the river channel in the summer.
4	The bankside flora has changed or is changing due to a lower water table.

The plant parameter (E4) weighting is 10%.

8.5 Conservation Parameter (E5)

This parameter (E5) assesses the value of the river corridors in conserving natural habitats and wildlife. The assessment is based on two sources of information. First, it takes account of the formal designation of conservation areas which rely on groundwater or surface water to maintain their character. Second, this parameter incorporates the duty of the NRA to conserve the whole river system, including groundwater levels and springs. This parameter does not assess the impact of low flows. However, if other parameters suggest that low flows are threatening the river system, the conservation parameter will assist in prioritising sites for support.

The scores apply to ponds and open water as well as flood plain meadows, marshlands, swamps, fens, carrs, mires, flushes and river banks and islands. Assessments for this parameter should be based on the Nature Conservancy Council's list of designated sites, and also the conservation values of sites not formally designated, as referred to in the NCC Review, 1977. Assessments will also be based on river corridor survey work within the NRA regions and the conclusions of the Regional Conservation Officer. Formally designated sites would be awarded scores as outlined in the table below :

Score	Description
3	Nationally or internationally designated sites (eg Ramsar, SSSI, National Nature Reserve) as well as protected species under the Countryside Act.
2	Conservation sites of regional or county importance (eg Naturalist Trust Reserve, RSPB reserve).
1	Local nature reserve
0	No formal designation

Sites within the river system would be awarded scores as suggested in the table below:

Score	Description
2	High conservation value, eg a diverse, natural and typical habitat of a viable size and containing species sensitive to disturbance.
1	Moderate conservation value, eg a smaller or less diverse site; or a site with natural or typical habitat but no sensitive species.
0	Site of no or low conservation value.

Scores would be added to a maximum of 4. Ramsar or SSSI sites will automatically score 5 but a score of only 4 would be used to calculate the ecological indicator. The conservation parameter (E5) weighting would be 30%.

If there is no other evidence that low flows are threatening the river system, this parameter should not be used.

8.6 Sample Calculation of Ecological Indicator

A full sample calculation for the Ecological Indicator is shown in Table 9. Blank calculation sheets to use in NRA Regions are attached in Annex 6.

TABLE 9 : SAMPLE CALCULATION

ECOLOGICAL INDICATOR

NRA REGION: A region **NAME OF STREAM:** River Example **DATE:** 12/8/92

(see Report Chapters 8.1 to 8.5 for full explanation of methodology)

E1 INVERTEBRATE COMMUNITY parameter

Generate potential ASPT:

Select multipliers:

SOURCE =	1.00	SOURCE: Upland = 1; Lowland = 0.8
REACH =	0.95	REACH: Headstream = 1; Mid = 0.95; Lower = 0.9
CHAN.MODS. =	0.95	CHANNEL MODIFICATIONS.: Limited = 1; Moderate = 0.95; Extensive = 0.9
EFF.COMP. =	1.00	EFFLUENT COMPONENT: Low = 1; Moderate = 0.95; High = 0.9

Potential ASPT = 6.32

Measured ASPT = 4.80

Score		Potential ASPT					
		<4.6	4.6-5.0	5.1-5.5	5.6-6.0	6.1-6.5	>6.5
	<4.5	0	1	2	3	4	4
	4.6-5.0		0	1	2	3	4
Measured	5.1-5.5			0	1	2	3
ASPT	5.6-6.0				0	1	2
	6.1-6.5					0	1
	>6.6						0

Assign score: E1 = 3

E2 FISHERY parameter

Score		Fisheries under normal flow conditions	Decline in fisheries under low flow conditions to: b)	c)	d)	e)	<e)
Game	a)	Trout, Salmon	1	2	3	4	
	b)	mixture of a) & c)		1	2	3	
Coarse	c)	Barbel, Chub, Dace, Perch, Pike, Roach, etc.			1	2	
	d)	Bream, Perch, Roach Tench				1	
Estuarine	e)	Eels, Flounders					1

OR:

Short-term impact parameter	Score
No fishing was possible during a fishing season as a result of low flows	4
No evidence of short-term impact of low flows on fisheries	0

Assign score: E2 = 2

E3 FISH STOCKS parameter

Generate potential fish stock:

Past fish stock (N) =

Select multipliers:

CHAN.MODS.=		CHANNEL MODIFICATIONS: Low = 1; Moderate = 0.9; High = 0.8
EFF.COMP. =		EFFLUENT COMPONENT: Decrease = 1; No Change = 1; Increase = 0.8

Potential fisk stock (NP) = 0

Measured present fish stock (NM) =

Present/Potential Fish Stock (FSR%) = 0%

Present/Potential	Decline related to low flows	Score
<40%	Serious decline	4
40-59%	Large decline	3
60-79%	Moderate decline	2
80-99%	Small decline	1
>100%	None	0

Assign score: E3 =

TABLE 9 : SAMPLE CALCULATION (cont'd)

ECOLOGICAL INDICATOR

NRA REGION: A region NAME OF STREAM: River Example DATE: 12/8/92

(see Report Chapters 8.1 to 8.5 for full explanation of methodology)

E4 PLANTS parameter

Description of changes	Score
The bankside flora has changed or is changing due to a lower water table	4
Marginal terrestial plants regularly invade the river channel in the summer	2
No change, other than normal seasonal variation in channel or bankside flora	0

Assign score: E4 =

E5 CONSERVATION parameter

Only use this parameter if other Ecological parameters are also used

Formally designated sites:

Description	Score
Nationally or Internationally designated sites (eg Ramsar, SSSI, National Nature Reserve) as well as protected species under the Countryside Act	3
Conservation sites of regional or county importance (eg Naturalist Trust Reserve, RSPB Reserve)	2
Local nature reserves	1
No formal designation	0

Sites within the river system:

Description	Score
High conservation value, eg a diverse, natural and typical habitat of a viable size and containing species sensitive to disturbance	3
Moderate conservation value, eg a smaller or less diverse site; or a site with natural or typical habitat but no sensitive species	2
Site of no or low conservation value	1

Add scores to a maximum of 4.

Assign score: E5 = 4

CALCULATION OF ECOLOGICAL INDICATOR

Parameter	Param.weight	Weight of params. used	Score	Weight x Score
E1	0.4	0.4	3	1.2
E2	0.2	0.2	2	0.4
E3	0.3			0.0
E4	0.1			0.0
E5	0.3	0.3	4	1.2
		SUM1 = 0.9	SUM2 =	2.8

Ecology Severity Index = SUM2/(SUM1x4) = 0.78

Ecology Reliability Index = SUM1 = 0.90 *(If SUM1>1, set SUM1=1)*

9. THE LANDSCAPE AND AMENITY INDICATOR

This indicator incorporates parameters describing the overall importance of the river in the landscape and also the impact of low flows on the visual outlook and on the recreational and amenity use of the river. A summary of the parameters included in this Indicator is given in Table 10. This indicator provides an assessment of the value of the river and river corridor, as perceived by people. The wider implications of the landscape must be established first, in order that the seriousness of any problems associated with low flows can be assessed. Secondly, this indicator assesses the extent to which the amenity of the river/river corridor is affected by low flows during the summer months.

Data collected in a consistent manner and recorded in a standard form, will produce consistent and comparable results. The component parts of the landscape, such as trees, landforms and artifacts, will be recorded and their importance to the landscape as a whole will be assessed. All landscape assessments should take place at a specified time of year. This could possibly correspond with the timing of the first sampling of river invertebrates in spring/early summer. This assessment could be carried out by the same ecological / conservation survey team, after an introduction to the specialist techniques required. Alternatively, personnel trained in landscape assessment techniques could be employed.

9.1 Landscape Designation and Rarity Parameter (L1)

This parameter L1, assesses the *importance* of the landscape through which the river flows. It will be important in prioritising competing projects for low flow alleviation, but since it is not a measure of low flows as such, it should be only used if there is other evidence that low flows occur. The parameter L1 is derived from two components, the landscape designation and landscape rarity.

Landscape Designation

The value of the landscape to people has already been established by the designation of tracts of landscape into categories such as National or Country Parks. These categories indicate the importance of a piece of landscape in the national and local context and have been allocated scores accordingly:

Score	Description
2	Important in a national context, ie National Parks and Areas of Outstanding Natural Beauty.
0	Important in a local context ie Country Parks,
1	Landscape has no official designation.

SUMMARY OF LANDSCAPE AND AMENITY INDICATOR		
Parameters are:		
L1	Landscape Designation and Rarity (Designation + Rarity Score)	Designation: Nat.Parks & Areas of Outstanding Natural Beauty/Country Parks/no desig. Rarity: 'National' and 'Local' Rarity. *Weighting = 30%.*
L2	Importance of the river as a landscape feature and its impact on adjacent land	Importance: Visual importance of river. Impact: Beneficial or degraded adjacent land use. *Weighting = 40%.* (Importance + Impact)
L3	Recreation	Number of water-contact activities unable to take place in certain time periods. (Not Fishing or Angling - see E2). *Weighting = 40%.*
L4	Amenity	Based on Odour at channel, Visual problems in channel, and Visual problems on river bank/adjacent land. *Weighting = 20%.*
L5	Historical and Cultural Associations	Importance of historical and archaeological interest sites. *Weighting = 10%.*

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Table 10 : Summary of parameters related to Landscape and Amenity Indicator

An additional score may be awarded as follows:

+1 Areas which are undergoing environmental improvements (either national or local) and where finance exists to support such improvements ie landscapes within Development Corporation Areas, Local Initiative Areas.

Landscape Rarity

The importance of a river or river corridor within its wider landscape is assessed by this score for rarity. A higher score is awarded to a river or river corridor which is rare in a *national* context - as opposed to a *local* context - as this reflects the greater sensitivity with which these landscapes have to be treated.

Score	Description
2	Where river/river corridor landscape is "the only" or "one of the best examples of ...." in the national context.
1	Where river/river corridor landscape is "the only" "one of the best examples of ...." in the local context.
0	The river has no rarity value.

The score for Parameter L1 is the sum of the scores assigned under Landscape Designation and Landscape Rarity, with a range of 0 to 4 ie a score of 5, which is possible , would be counted as 4.

Landscape designation and rarity parameter (L1) weighting is 30%.

9.2 The Importance of the River as a Landscape Feature and its Impact on Adjacent Land (L2)

This parameter (L2) is also derived from two components:

The Importance of the river as a landscape feature

This component establishes how visually important the river is within the landscape, regardless of any planning designation. The assessment should be made from places which are accessible to the public, such as footpaths, roads and local vantage points within the river corridor. Where several access points exist, the dominant overall impression should be recorded.

Score	Description
3	High importance - dominant landscape feature, due associated artifacts such as weirs, bridges etc.
2	Medium importance - only stretches of the river are visible, or the course is only noticeable because of bankside vegetation being visible.
1	Low importance - the river is barely noticeable.

Impact of River on Adjacent Land

In many areas the river has had a considerable impact on the adjacent landscape. Many towns grew because the adjacent river was navigable or was used as an energy source for mills etc. In addition the 'management' of the river either allowed the adjacent land to be drained or to flood so changing its agricultural use. It is important within this parameter that only the present day use is recorded, as the historical element is allowed for in L5.

The scoring is based on the principle that the greater the score assigned to each parameter, the greater the 'problem'. However within this parameter there are both positive and negative impacts in relation to the river and its effect on adjacent land. Consequently the score for 'importance' above is reduced by a negative mark where the overall impact is beneficial, in order to reduce the overall score and vice versa. For example, a score of 3 for 'importance' would be followed by -1 for impact if the drainage of the adjacent land had resulted in better agricultural land or reduced flooding.

Score	Description
-1	Where a beneficial adjacent land-use (within 500m) is primarily as a result of man's impact on or management of the river
+1	Where a degraded or unsightly adjacent land use is primarily as a result of the man's impact on or management of river which could be remedied if remedial action were taken to the river

The two scores are added to produce a score with a range of 0 to 4. The weighting of this parameter (L2) is 40%.

9.3 Recreation Parameter (L3)

The parameter L3, assesses the impact of low flows on water-based recreational activities. As the impact of low flows on fishing is assessed in parameter E2, fishing and angling are excluded from the following assessment of water-contact recreational activities.

Recreational use may be passive or active. In general active use is associated with sports which require direct contact with water, such as: canoeing; sailing; rowing; boating; swimming; diving; water-skiing and wind surfing. These sports should have a higher score than passive recreational use, as any reduction in water quantity or quality as a result of low flows, can seriously affect participation in the sport. The scores should be awarded if the activity has been affected by a reduced volume or flow of water or a change in water quality due to low flows has occurred within the specified time period.

Score	Description
4	Three or more water-contact recreational activities were unable to take place during consecutive periods over a five year period.
3	Three or more water-contact recreational activities were unable to take place at any time in any one twelve month period.
2	One or two water-contact recreational activities were unable to take place at any time in any twelve month period.
1	Any water-contact recreational activity was affected by low flows within the last five years. This is also includes a reduction in enjoyment of a sport, resulting from low river flows.
0	No change has been noted.

Fishing and angling are not included in the score of recreational activities in the above table.

The above score takes into account the present (and potential) use of the river for recreation. However if historical evidence exists, which can be authenticated, that an active water-contact activity was possible on the river in the past (say 25 yrs) and there is a demand for that sport nationally or locally an additional score of +1 may be awarded as follows, up to a maximum total of 4 for this parameter.

Score **Description**

+1 The river was able to support a water-contact recreational activity within the past 25 years, but this activity is no longer possible due to lower river flows.

The weighting of the recreation parameter (L3) is 40%.

9.4 Amenity Parameter (L4)

This parameter L4 assesses the impact of low flows on the general amenity of the river by reference to bank-side recreational pursuits and access to the river. Although low flows do not prevent walking, birdwatching, sightseeing and picnicking from taking place, the enjoyment of these recreational pursuits may be affected. Odour and visual

impact are based on pollution and nuisance, as measured in some NRA regions. These will need to be recorded during the summer months at specified times, which it is suggested should be in the first week of August.

The parameter score is derived from the sum of scores, up to a total of 4, based on the following three components of the parameter.

Odour

Score	Description
2	Strong odour at channel edge eg sludge, sewage, chemical or farmyard wastes and noticeable at a distance of more than 10 metres from the channel.
1	Noticeable odour at the channel edge.
0	No noticeable odour.

Visual River Channel

This includes unnatural water colour, farm wastes, foam, sewage, fungus, crude sewage, visible solids, rotting vegetation.

Score	Description
3	Two or more of the above elements which persist over a period of several months, as a result of low flows or three or more of the above elements which occur intermittently.
2	One or two of the above elements which persist over a period of several months, as a result of low flows.
1	One of the above elements which occur intermittently, as a result of low flows.
0	No visual problem.

Visual - River Bank and Adjacent Land

An additional score of 1 can be awarded where the general public are encouraged to have access to the river as part of a wider planning designation such as: a public open space; or the provision of a long distance footpath or nature trail.

Score	Description
+1	Where planning designation encourage public use.

The weighting of the amenity parameter (L4) is 20%

9.5 Historical and Cultural Associations (L5)

This parameter allows the evaluation of impact on the river within a wider context, eg does the name of a building or a town derive from the name of the river or is the landscape character particularly influenced by water mills, designed parkland or particular bankside vegetation. If so, such associations reinforce the requirement to maintain appropriate water levels.

Score	Description
4	Sites of national historical/archaeological interest ie.National Monuments, National Trust sites.
3	Sites of regional historical/archaeological interest.
2	Sites which have national cultural associations such as paintings and literature, or local archaeological sites.
1	Sites of local historical archaeological, cultural or literary interest, such as place names.....
0	No historical or cultural associations.

The weighting of this historical and cultural parameter (L5) is 10%.

9.6 Sample Calculation of Landscape and Amenity Indicator

A full sample calculation for the Landscape/Amenity Indicator is shown on Table 11. Blank calculation sheets for use by NRA Regions are attached in Annex 6 to this report.

TABLE 11 : SAMPLE CALCULATION

LANDSCAPE AND AMENITY INDICATOR

NRA REGION: A region **NAME OF STREAM:** River Example **DATE:** 12/8/92

(see Report Chapters 9.1 to 9.5 for full explanation of methodology)

L1 LANDSCAPE DESIGNATION AND RARITY parameter

For Landscape Designation:

Description	Score
Important in a national context, ie National Parks and Areas of Outstanding Natural Beauty	2
Important in a local context, ie Country Parks	1
Landscape has no official designation	0
An additional score may be awarded to :	
Areas which are undergoing environmental improvements (either national or local) and where finance exists to suport such improvements, ie areas with Development Corporation Areas, Local Initiative Areas	+1

For Landscape Rarity:

Description	Score
Where river/river corridor landscape is "the only" or "one of the best examples of..." in the national context	2
Where river/river corridor landscape is "the only" or "one of the best examples of..." in the local context	1
The river has no rarity value	0

Add scores to a maximum of 4. **Assign score: L1 = 3**

L2 IMPORTANCE OF THE RIVER AS A LANDSCAPE FEATURE AND ITS IMPACT ON ADJACENT LAND parameter

For Importance:

Description	Score
High importance - dominant landscape feature, due to associated artifacts such as weirs, bridges etc.	3
Medium importance - only stretches of the river are visible, or the course is only noticeable because of bankside vegetation being visible	2
Low importance - the river is barely noticeable	1

For Impact:

Description	Score
Where a beneficial adjacent land use (within 500m) is primarily as a result of man's impact on, or management of, the river	-1
Where a degraded or unsightly adjacent land use is primarily as a result of man's impact on, or management of, the river, which could be remedied if remedial action were taken to the river	+1

Add scores to a maximum of 4. **Assign score: L2 = 3**

L3 RECREATION parameter

Description (do not include fishing/angling)	Score
3 or more water-contact recreational activities were unable to take place during consecutive periods over a 5 year period	4
3 or more water-contact recreational activities were unable to take place at any time in any one 12 month period	3
1 or 2 water-contact recreational activities were unable to take place at any time in any 12 month period	2
Any water-contact recreational activity was affected by low flows within the last 5 years. This also includes a reduction in enjoyment of a sport, resulting from low river flows	1
Where no change has been noted	0
An additional score may be awarded where: The river was able to support a water-contact recreational activity within the past 25 years, but this activity is no longer possible due to lower river flows	+1

Maximum of 4. **Assign score: L3 = 2**

TABLE 11 : SAMPLE CALCULATION (cont'd)

LANDSCAPE AND AMENITY INDICATOR

NRA REGION: A region NAME OF STREAM: River Example DATE: 12/8/92

(see Report Chapters 9.1 to 9.5 for full explanation of methodology)

L4 AMENITY parameter

For Odour:

Description	Score
Strong odour at channel edge, eg sludge, sewage,chemical or farmyard wastes and noticeable at a distance of > 10m from the channel	2
Noticeable odour at the channel edge	1
No noticeable odour	0

For Visual Impairment at the river channel:

(Elements include unnatural water colour, farm wastes, foam, sewage, fungus, crude sewage, visible solids, rotting vegetation)

Description	Score
2 or more of the elements which persist over a period of several months, as result of low flows, or 3 or more of the above elements which occur intermittently	3
1 or 2 of the elements which persist over a period of several months, as result of low flows	2
1 of the elements which occurs intermittently, as a result of low flows	1
No visual problem	0

For Visual Impairment on the river bank and adjacent land:

Description	Score
Where planning designation encourages public use	+1

Add scores to a maximum of 4. Assign score: L4 = 3

L5 HISTORICAL AND CULTURAL ASSOCIATIONS parameter

Description	Score
Sites of national historical/archaeological interest, ie National Monuments, National Trust	4
Sites of regional historical/archaeological interest	3
Sites which have national cultural associations such as paintings and literature, or local archaeological sites	2
Sites of local historical/archaeological, cultural or literary interest, such as place names	1
No historical or cultural associations	0

Assign score: L5 = 3

CALCULATION OF LANDSCAPE AND AMENITY INDICATOR

Parameter	Param.weight	Weight of params.used	Score	Weight x Score
L1	0.3	0.3	3	0.9
L2	0.4	0.4	3	1.2
L3	0.4	0.4	2	0.8
L4	0.2	0.2	3	0.6
L5	0.1	0.1	3	0.3
		SUM1 = 1.4		SUM2 = 3.8

Landscape and Amenity Severity Index = SUM2/(SUM1x4) = 0.68

Landscape and Amenity Severity Index = SUM1 = 1.40 *(if SUM1>1, set SUM1=1)*

10. THE PUBLIC PERCEPTION INDICATOR

The Public Perception Indicator is based on two parameters, the *proximity* of the river to urban areas and the extent of *complaints* received by the NRA. The parameters are summarised in Table 12.

10.1 Proximity of River to Centres of Population Parameter (P1)

This parameter assesses the number of people within reasonable proximity of the river who might be affected by low flows in the river and who might be disadvantaged if alleviation work is not undertaken. Recreation and amenity are assessed by parameters L3 and L4 and parameter P2 assesses complaints from the public.

Score	Description
4	River flows through a large centre of population ie. a town.
3	River flows through a small centre of population ie. a village.
2	River flows within 1km of a town.
1	River flows within 1km of a village.

The distinction between a town and a village is usually evident in a given Region but where this is not the case a suitable guideline might be to classify a town as any conurbation with more than 10,000 population.

The weighting of the proximity of river to centres of population parameter (P1) is 30%.

10.2 Complaints Received from the Public Parameter (P2)

Public pressure is an important factor in highlighting perceived 'problems' of low river flows, whether the problems are real or not. It is therefore important to allow for this factor within the framework, although it is recognised that not all complaints are factually correct. Scores will be awarded where complaints about low river flows have been received over a number of years, and not in relation to a single incident of a particularly severe drought.

SUMMARY OF PUBLIC PERCEPTION INDICATOR			
Parameters are:			
P1	Proximity of River to Centres of Population	Based on size of pop. and proximity.	*Weighting = 30%.*
P2	Complaints received from the Public	Number and source of complaints.	*Weighting = 70%.*

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Table 12 : Summary of parameters related to Public Perception Indicator

Score	Description
4	Written complaints received from national organisations in support of local pressure groups formed specifically to deal with problems affecting the river and its environment.
3	Written complaints received from national organisations or local clubs or pressure groups.
2	A moderate number (over 5 per annum on average) of written complaints received from individuals about problems related to low river flows over a period of years.
1	Up to 5 written complaints received on average per annum from individuals about problems related to low river flows over a period of years.
0	No complaints received about problems related to low river flows.

The weighting of the Complaints Received from the Public parameter (P2) is 70%.

10.3 Sample Calculation of Public Perception Indicator

A full sample calculation of the public perception indicators is shown in Table 13. Blank calculation sheets are included in Annex 6 for use by the NRA Regions.

TABLE 13 : SAMPLE CALCULATION

PUBLIC PERCEPTION INDICATOR

NRA REGION: A region NAME OF STREAM: River Example DATE: 12/8/92

(see Report Chapters 10.1 to 10.2 for full explanation of methodology)

P1 PROXIMITY OF RIVER TO CENTRES OF POPULATION parameter

Description	Score
River flows through a large centre of population, ie a town	4
River flows through a small centre of population, ie a village	3
River flows within 1km of a town	2
River flows within 1km of a village	1

(If unsure, use: Town = > 10,000 pop.)

Assign score: P1 = 4

P2 COMPLAINTS RECEIVED FROM THE PUBLIC parameter

Description	Score
Written complaints received from national organisations in support of local pressure groups formed specifically to deal with problems affecting the river and it's environment	4
Written complaints received from national organisations or local clubs or pressure groups	3
A moderate number (> 5/annum average) of written complaints received from individuals about problems related to low river flows over a period of years	2
Up to 5/annum average written complaints received from individuals about problems related to low river flows over a period of years	1
No complaints received about problems related to low river flows	0

Assign score: P2 = 1

CALCULATION OF PUBLIC PERCEPTION INDICATOR

Parameter	Param.weight	Weight of params.used	Score	Weight x Score
P1	0.3	0.3	4	1.2
P2	0.7			0
		SUM1 = 0.3		SUM2 = 1.2

Public Perception Severity Index = SUM2/(SUM1x4) = 1.00

Public Perception Reliability Index = SUM1 = 0.30 *(if SUM1>1, set SUM1=1)*

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11. THE COST INDICATOR

The Cost Indicator is based on the following:-

i) The cost of 'buying out' an existing licence has been quoted in a number of Regions as approximately #1 million per Ml/day.

ii) Any alleviation scheme will have an effect equivalent to a reduction in licensed abstraction. For example, if a re-circulation scheme or groundwater support scheme produces an increase in low flow of 0.5 Ml/day without affecting the available abstraction, this can be considered as having the same value as buying out abstraction licences of this magnitude, ie. a Value or Benefit of #500,000.

iii) The cost of the alleviation scheme can be expressed as a commuted sum (Net Present Value of Costs). It is suggested that should this be calculated at a discount rate of 5% over 30 years.

Thus the Cost Indicator, summarised in Table 14 could be expressed as the Benefit/Cost ratio with the Benefit calculated as in ii) above and the Cost calculated as in iii) above.

This is only an approximate indicator as the Consultants have not investigated the accuracy of the quoted cost of buying out licences, and the relationship between the increase in low flow achieved by alleviation measures and the corresponding availability of licensed abstraction is, in some cases complex. However it does give some guide to the viability of alleviation options.

In principle, no alleviation scheme should proceed if its Benefit/ Cost Ratio is less than 1 since this means that it would be more cost-effective to 'buy-out' licences.

In practice, however, alternative sources may not be available or may only be available at higher cost. Since the cost of buying out licences should be based on the cost of alternative sources, this would signal that the quoted cost of buying out is inaccurate.

In reality, the cost of alternative sources and hence of buying out licences will vary but the figure quoted above may be taken as a starting point.

A full sample calculation of the cost indicator is shown in Table 15. Blank calculation sheets are included in Annex 6 for use by the NRA Regions.

SUMMARY OF COST INDICATOR		
Benefit/Cost ratio		
Benefit = increase in low flow resulting from alleviation scheme in Ml/day	x	£1 million
Cost = Net Present Value of costs of alleviation scheme		

Table 14 : Summary of Cost Indicator

Table 15 : Sample calculation

COST INDICATOR				
NRA REGION:	A region	NAME OF STREAM:	River Example	DATE: 12/8/92
(see Report Chapter 11 for full explanation of methodology)				
Cost Indicator is expressed as BENEFIT/COST ratio				
BENEFIT:				
Increase in low flow resulting from alleviation scheme =	0.5	Ml/day		
Benefit (or Value) = (approx.)	£0.50	million		
COST:				
Net Present Value of costs of alleviation scheme = *(discount rate = 5% over 30 years)*	£0.45	million		
BENEFIT/COST ratio =	1.11			

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12. COMBINING THE INDICATORS

Having established 'scores' in the form of *Severity Index* and *Reliability Index* for each Indicator, they can be combined in a number of ways. Table 16 shows this for the sample calculations used in previous chapters.

12.1 Overall Severity Index

The Severity Index (SI) calculated as the sum of the (weighted) SI's for each of the Indicators as follows:-

	Indicator SI (a)	Weight % (b)	Weighted SI (a) * (b)
Hydrology HSI		40%	
Ecology ESI		30%	
Landscape/Amenity LSI		10%	
Public Perception PSI		20%	

$$TotalSI = \sum (a * b)$$

It should be noted that the weights are fixed but all other spaces are filled in by the assessor. A further discussion of weights is given in Chapter 14 of this report.

12.2 Overall Reliability Index

The Overall Reliability Index is calculated in exactly the same way as the Overall Severity Index.

12.3 Real or Perceived Problem

The assessment of whether there is a real problem or a problem only in the public's perception is based upon a *qualitative comparison* of the Hydrological and Ecological Indicators with the Public Perception Indicator.

In the case where the Public Perception Indicator is high but the other Indicators show a low Severity Index with a medium to high Reliability Index then the problem can be categorised as a perceived problem only.

In all other cases, the Public Perception Indicator is most unlikely to change the conclusion drawn from the other indicators but may influence the likely order of priority.

12.4 Influence of Cost on Priorities

The cost, or more correctly, the Benefit/Cost Ratio of an alleviation scheme does not affect the severity of the problem but should have some influence on the order of priority assigned to schemes. If in order to mitigate the effects of 1Ml/d abstraction, an alleviation scheme in one area costs 10 times as much as an equivalent scheme in another area, the latter should be moved up the list of priorities. That is not to say that the schemes should be ranked solely on the basis of benefit/cost ratio. Following the rules:-

i) increasing Benefit/Cost ratio should increase priority and

ii) increasing Severity Index should increase priority.

One obvious way of taking account of the Benefit/Cost (B/C) ratio is to multiply the Severity Index as calculated under 12.1 above by the B/C ratio.

Intuitively, however this is likely to give too much significance to the B/C ratio and a suggested multiplier would be

$$(1+0.5(\frac{B}{C}-1))$$

It may be that in testing this method, the 'reduction factor' of 0.5 in the above expression will be shown to be still too high and will be reduced.

TABLE 16 : SAMPLE CALCULATION OF THE OVERALL INDICES

CALCULATION OF OVERALL INDICATORS

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NRA REGION: A region NAME OF STREAM: River Example DATE: 12/8/92

OVERALL SEVERITY INDEX (SI)

SI type	SI	Weight	Weighted SI
Hydrological SI	0.53	40.0%	0.21
Ecological SI	0.78	30.0%	0.23
Landscape and Amenity SI	0.68	10.0%	0.07
Public Perception SI	1.00	20.0%	0.20
		Total SI =	0.71

OVERALL RELIABILITY INDEX (RI)

RI type	RI (orig.)	RI (</= 1)	Weight	Weighted SI
Hydrological RI	1.00	1.00	40.0%	0.40
Ecological RI	0.90	0.90	30.0%	0.27
Landscape and Amenity RI	1.40	1.00	10.0%	0.14
Public Perception RI	0.30	0.30	20.0%	0.06
			Total RI =	0.87

POSSIBLE ACTION

SI	RI	Action
High	High	Put in Capital Programme for Alleviation
High	Low	Further studies required
Low	High	No action unless strong public pressure, in which case mount public relations campaign
Low	Low	No action unless strong public pressure, in which case initiate minimum cost further studies and mount public relations campaign

INFLUENCE OF COST ON PRIORITIES

Total Severity Index (TSI) =	0.71
Benefit/Cost ratio =	1.11
TSI, taking account of Benefit/Cost ratio =	1.06

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13. PRELIMINARY SCREENING

In order to 'focus' the assessment effort on those sites which have a low flow problem it is proposed that there should be a preliminary screening of sites using the Primary Indicators.

As a first stage, clearly, only those rivers or sites for which there is *some* reason to believe that there may be a problem would be considered. This reason could be minimal at this stage, e.g. one complaint or known problems in an adjacent catchment.

For such rivers or sites it is proposed that one parameter should be selected from each Indicator as representing that Indicator. Any parameter can be selected but it is most likely that the parameters chosen will be those which are the easiest to evaluate, and which will give the highest (most severe) mark in that particular area.

For each Indicator, the *Severity Index* is taken as

$$\frac{MarkforChosenParm}{MaximumMarkforParm}$$

The overall preliminary Severity Index is then the sum of the SI's calculated for the Indicators used.

It is proposed that if the Preliminary SI exceeds 1 (ie at least two Indicators with a Severity Index of 0.5 or more) then the site would be considered to be suffering a low flow problem of sufficient magnitude to warrant the full assessment procedure.

14. WEIGHTING - NATIONAL OR REGIONAL

14.1 Introduction

A key issue is the weight to be assigned to each Indicator.
The discussions with the Regions have focused this issue into two questions :

i) how much weight should be given to Public Perception or 'pressure' compared to other, more objective Indicators?

ii) should the same weights be used in every Region or should the Regions set their own weighting?

Although these are quite separate questions, the suggestion that Regions should set their own weighting usually arises in Regions which are experiencing considerable public pressure over low flow sites and are concerned that a national weighting system would not give as much weight as they would to public pressure.

Taking the two questions in turn :

14.2 Public Perception

In the Interim Report the question was set out as follows :

> "A dichotomy within the Regions, which this study must address and resolve, is the relative importance of Public Pressure, and other "subjective" or "judgemental" indicators in comparison with the Hydrological and Ecological Indicators.
>
> On the one hand there is an argument that since the investigation of low flows has been largely driven by public pressure and since this pressure is based upon the public's subjective and judgemental assessment of landscape and amenity, these indicators should be given a high priority as part of NRA policy to be responsive to public concern.
>
> On the other hand there is an argument that it would be wrong simply to seek the public's perception of a problem and alleviate the problem, thus perceived. This would amount to tackling the symptom rather than the cause, and would be unlikely to prevent further problems. In addition, public perception, and recreation-amenity- landscape aspects often reflect the proximity of a site to centres of population or the activities of pressure groups. These factors may negatively bias the assessment of isolated habitats and it is argued that such a bias would be wrong. "

In further consultation, some Regions have pointed out that public pressure is not necessarily subjective and can be based on 'hard' objective data. It may also be

concluded that there is a degree of linkage between the Landscape Indicator and Public Perception. Indeed the classification of sites such as SSSI and AONB could be considered as *"Official"* public perception.

Therefore, although separately assessed, it is also worth looking at these two indicators together.

It has been suggested that the weight should be roughly one third each for :

Hydrology, Ecology, and
[Landscape/Amenity + Public Perception].

The latter two Indicators could also be considered as the 'Subjective' Indicators as they measure the impact on man rather than on the natural environment.

14.3 National v. Regional Weights

The question of whether weights should be set Nationally or Regionally is linked to whether funding for alleviation measures is to be Nationally or Regionally allocated.

It is understood that the objective of this research project is to develop a National assessment procedure, implying that weights should be set Nationally. If weights were set Regionally it is unlikely that there would be a consistency of assessment between Regions.

It is therefore proposed that Indicator weights should be set Nationally but that a limited proportion (say 10% of the overall weight) should be at the discretion of the Region. Parameter weights would be set Nationally i.e. they would be the same in every Region.

14.4 Proposed Weights

The following Indicator Weights are proposed

Indicator	More 'Subjective'	*Proposed*	More 'Objective'
Hydrology	35%	40%	40%
Ecology	25%	30%	35%
Landscape/Amenity	15%	15%	15%
Public Perception	25%	15%	10%

In all cases, the greatest weight is given to the hydrological indicator which is the most direct measurement of the problem and is an independent indicator, whereas all the others are dependent, ie they measure consequences of low flow. Ecology is

probably the next most important indicator since it suffers the most direct consequences.

Landscape/Amenity has the lowest weight, because it 'overlaps' with ecology and public perception and in particular, because public perception is likely to be based upon landscape/amenity aspects.

Public perception is given a relatively high weight because in the real world, it is an important driving force of the need to identify and alleviate low flows.

To provide the Regional discretion in weighting it is proposed that in carrying out the assessment, the Region may add the 10% 'discretionary weight' to any Indicator weight and then divide the resulting overall SI and RI by 1.1 to correct it to a total weight of 100%.

15. ALLEVIATION OPTIONS

The TOR for this project require an overview of the options that are available for alleviation of the low flows. It would be beyond the scope of this report to review them in terms of a full benefit assessment, as these would require considerable local data in each case, as well as the results of field investigations. The review, therefore is qualitative in approach and provides a series of options which, either in combination, or singly, could be applied to specific low flow instances.

Most NRA Regions have already given some degree of consideration to the alleviation options available to them to mitigate the impact of low flows. For historical reasons, the options can be broadly grouped into two categories :

* fire fighting, interim alleviation option
* long term resource management option

Previous administrative constraints necessitated the above categorisation and to some extent the solutions proposed to the water authorities by their Consultants were to resolve local problems with localised solutions. In the present circumstances with the NRA taking a far wider view of water resource conservation in terms of environmental enhancement, more long term and permanent options can be seriously considered. This does not imply that immediate solutions that are urgently required should be abandoned but that rather they should be seen as temporary solutions.

Table 17 shows a list of options that are available, as well as an indication of whether the options falls into the category of "local and short term" or "regional and long term". The table also indicates the applicability of the option in terms of possible difficulties in its implementation.

Many of the options listed in the table have either already been investigated in the UK or have been tested at pilot scheme scale. Some of the previous augmentation schemes promoted by the Anglian, Southern, Thames and Severn Trent Water Authorities should be re-reviewed in the light of the new objectives that have been assigned to the NRA by the Water Act of 1989. Although those schemes do not directly apply to the present list of cases affected by low flows, the experience gained can be put to good use in evaluating how the alleviation options could be applied.

The alleviation options available in the context of the above categorisation are considered next.

15.1 Localised, fire fighting options

i) Flow augmentation :
this is the most common and obvious option. Ground water from boreholes located close to the affected streams can be used to provide stream support in localised conditions.

Options 1 to 3 listed on Table 17 are a variation of this principle. These options can only be used where aquifers provide the stream base flow. The stream bed permeability is a critical factor in utilising such options. Options 8 and 9 are similar to these but there is the added water quality constraint.

ii) Localised bed lining :

this option, usually combined with augmentation, would be effective in many Chalk aquifer type situations. The earliest tests of this approach were used in Gussage Brook in 1970/71 by the then Avon and Dorset River Authority.

Options 4 and 5 would be used for this type of alleviation. Because of cost constraints, and to an extent ecological factors these options have been used on relatively short stretches of streams. There are certain technical difficulties associated with the bed lining approach, concerned with the possible build up of hydraulic pressure below the lining causing rupture - solutions to reduce this are available but would require testing in any given solution.

iii) Localised artificial recharge :

given appropriate conditions recharge through wells could support springs or limited stream sections. Trials of this type were carried out by the Anglian Water Authority at Ashwell springs in 1978/79.

Options 6 to 8 on Table 17 indicate the variations of artificial recharge, as enhanced recharge - sewage spreading has been tested in Hampshire on the chalk aquifer and other localised examples are known. However, these need to be reevaluated in the content of their providing support to the river, affected by low flows.

iv) Engineered landscape :

an option with some promise where conditions have so altered from the 'natural' that the only solutions would be to fully 'engineer' the stream and its immediate environment.

Options under this heading are listed under 4, 20 and 21 in Table 17. Generally the capital costs of these schemes would make them prohibitive, as also the running costs subsequently including the need to allocate NRA staff resources. However, where appropriate, local volunteer and special interest groups may well wish to run these type of schemes. A similar situation has occurred on the Blackwater Canal where an embankment and the associated works have been reconstructed and are maintained by a committed local volunteer organisation.

15.2 Long term resource management option

i) Relocation of major abstractions :

boreholes which are known to closely impact spring flows and river flows could be relocated to other more remote sites.

Option 2 and 11 are sub sets of this approach. A number of investigations related to this approach have been studied in the UK principally in the Chalk aquifer and some pilot scale testing was carried out. During extreme droughts some such schemes have been implemented though mainly to provide public supply rather than to provide low flow alleviation. Experience gained from operating these schemes and further evaluation of them would provide adequate information to undertake preliminary pre-feasibility study of potential for low flow alleviation.

ii) Revocation of Licences :
an option similar to that above, would require shut downs of boreholes.

Options 12, 13 and 14 on Table 17 are variations of this approach. Some negotiations are already underway between the NRA and Water Plc's to consider how best this could be achieved within the context of Environmental Statements being prepared by the Water Plc's.

iii) integrated catchment resource management:
an option based on a combination of the two above, involving relocation of some sources combined with revocation of others.

iv) Conjunctive use :
conjunctive use option of considering multiple sources, if available, would be an attractive option.

The two categories in iii) and iv) are listed as options 15, 16 and 17 on Table 17. To implement any one of these, or a combination will require negotiation with major licence holders ie mainly the Water Plc's and Water Co's. Some other users eg the electricity industry also have large licences which should be included for possible negotiation.

v) Remote and new river sources :
seasonal abstraction depending on river flows and ground water levels.

Options 1, 2 and 11 would apply under this category. This category has been listed separately in spite of the possible duplication above to stress how adding or removing options to proposed alleviation can subtly change the emphasis and would require a completely new level of field trials and pre-feasibility investigation. Previously option 11 was mentioned under category 15.2.(i), in the context of relocation, here however it is mentioned in the context of manipulation of the aquifer storage.

vi) Artificial recharge :
an option (within catchment management) which has in the past been considered uneconomic. With the current suggestions of environmental impact costs, it may be appropriate to reconsider artificial recharge in appropriate aquifers.

This category includes options 6 to 8 and 10, with emphasis on 10. The option may be unacceptable from quality viewpoint in situations where contaminants could be introduced eg road surface run off, run off from urbanised areas, etc.

vii) Ecological engineering:

an alternate approach to alleviating the impact of low flow by restoring them could be to accept the reduced flows but to 'engineer' the ecological habitat into an acceptable but artificial balance. This would include options 21 and 22 but they would only be applicable in exceptional situations.

TABLE 17 : SUMMARY OF ALLEVIATION OPTIONS

Alleviation Option	Option	Applicability
AQUIFER FED STREAMS		
1. Flow augmentation from near stream boreholes	Localised, short term	Streams with low bed permeability
2. River support from distant boreholes	Localised, short term	Stream with bed permeability similar to aquifer
3. River support from aquifer not in contact with stream	Localised, short term	Stream not underlain by the aquifer providing the support
4. Stream bed lining with 'engineered' flora, fauna, landscape and amenity	Localised, short term	Lining material compatible with underlying aquifer system eg puddled chalk on chalk aquifer
5. Stream bed lining coupled with 2 or 3 above	Localised, long term	As above, 4, and where bed material is permeable
6. Artificial recharge to maintain spring head or environmentally sensitive ponds	Localised, medium term	Aquifer of medium tranmissivity and storage
7. Aquifer recharge by partly treated sewage effluent	Localised, medium term	Medium transmissivity aquifer of good buffer capacity to improve quality as it travels towards stream
8. Discharge of treated sewage effluent to streams	Regional, long term	Sewage treatment works located close to, or at headwater of streams
9. Recirculation of stream flow by pumping back to headwaters	Localised, long term	Treatment by aeration to minimise quality deterioration
10. Regional aquifer recharge enhancement from storm run off storage ponds	Regional, long term	Appropriate storage ponds, appropriately sited, aquifer of moderate transmissivity

TABLE 17. Continued.

Alleviation Option	Option	Applicability
11. Seasonal abstraction from near river and more distant boreholes, including induced recharge from river beds.	Regional, long term	Appropriate aquifer conditions and stream bed conditions
12. Revocation of unused licences in affected area	Local, long term	Appropriate legal powers
13. Renegotiation of licences to reduce licence to a lower (probably the actual) limit	Local, long term	Cordial conditions for negotiation and legal powers
14. Renegotiation of licence conditions requiring, eg, river support discharge	Local, regional, long term	Appropriate negotiations and aquifer-stream interaction
AQUIFER PLUS SURFACE FED STREAMS		
15. Integrated catchment resource management	Regional, long term	Coordinates in water resources, ecology and conservation, including amenity and landscape
16. Conjunctive use: combining surface and aquifer abstraction	Regional, long term	Needs full evaluation of all catchment abstraction, discharge and stream flow
17. Increase storage of surface reservoirs to provide additional 'resource' for stream support	Localised, long term	Appropriate conditions to increase storage and provide releases

TABLE 17. Continued

Alleviation Option	Option	Applicability
SURFACE FED STREAMS		
18. Modify reservoir releases to provide additional discharge during low flows	Localised, long term	Appropriate conditions to modify existing weirs
19. Install checks in stream to provide water depth in low flow periods	Localised, long term	Acceptable conditions on ecological and quality grounds
20. Revoke licences not in use of those that are over licenced	Localised, long term	Appropriate legal power
ECOLOGICAL AND LANDSCAPE ENGINEERING		
21. Introduction of new ecological balance in streams irrevocably degraded	Localised, long term	Acceptance by ecological and conservation interests
22. Managed landscape and habitat, water garden	Very localised, long term	Economics may be prohibitive, solution could be unacceptable to public

16. CRITERIA FOR REHABILITATION STANDARDS

16.1 Introduction

In setting the criteria for rehabilitation standards the objective is to answer the following questions:

i) Which parameters should be used to define the level of rehabilitation to be achieved?

ii) to what extent should rehabilitation seek to restore the 'historic' or 'natural' conditions, or better? (ie quantitative criteria).

iii) Should rehabilitation be the same standards in all cases and, if not, on what grounds should different standards be applied?

iv) To what extent should cost influence the rehabilitation standards?

The most obvious solution is to use the Standard Assessment Method and to assign target reductions in the Severity Index to be achieved by rehabilitation.

The Standard Assessment Method encompasses the most comprehensive criteria, based on the assessment parameters. However, some of the parameters are much more relevant to rehabilitation standards than others and in any given case, rehabilitation should perhaps be focused on the particular impact or impacts which are causing most concern.

In previous work in the Regions, rehabilitation standards have been identified at two levels:-

a) flow required to achieve full species diversity - ie full restoration of habitat, although this does not necessarily mean full restoration of flows.

b) (lower) flow required to satisfy visual and amenity aspects.

Two other criteria which affect these standards and have been considered in previous work are:

c) water depth (relevant to visual/amenity aspects) and

d) water quality, which is not a parameter in the Standard Assessment Method but becomes significant in considering recirculation options for rehabilitation.

16.2 Full Restoration of Habitat

The criteria for full restoration of habitat are being developed under NRA Research Project B2.1 through the development of techniques to establish Ecologically Acceptable Flows using PHABSIM.

When these techniques are in place, they can be used to establish target flows throughout the year (or perhaps, more correctly expressed as target base flows).

These target ecologically acceptable flows can be compared with 'natural' low flows less licensed abstraction, or compared with actual flows.

They might also be used as the basis of 'conditioning' future licences to maintain an ecologically acceptable minimum flow or in negotiating the revocation of existing licences and replacement with 'conditional' licences.

It is worth repeating that full restoration of habitat does not mean full restoration of historic flow quantities. The physical parameters affecting habitat include flow velocity, depth, turbidity or sediment load and other physical and chemical characteristics.

In addition to restoring flows, it may be necessary to restore the channel, ie the restoration of flows may well not, per se, restore the habitat.

It is important therefore when considering restoration, to ensure that a flow *regime* is provided which is appropriate to the channel being restored.

Gradients associated with the riffle/pool sequence in the dry bed should be reestablished so that restoration can re-instate these habitats. Gravel should be introduced at appropriate points to assist riffle formation and thereby raise semi-fixed heads to enhance downstream pool formation.

In addition the works necessary to restore flows (eg channel lining) must be done in such a way as to preserve or provide a suitable habitat. Care should be taken to preserve plant-colonised margins through boggy areas of botanically diverse meadow land. In such stretches an underlining technique which causes minimal disturbance should be employed.

Where channels are being restored for recolonisation by plants and invertebrates rather than to preserve surviving communities, measures should be taken to ensure that the lining does not inhibit the development of plants or become damaged as they grow. In such cases, a puddled clay and/or bentonite liner would be recommended as appropriate.

Until project B2.1 reaches conclusions, it is proposed that Ecological Parameters E1 (Invertebrates) and E2 or E3 (Fisheries) be used as the basis for criteria for rehabilitation with a target mark of 0 or, exceptionally 1.

In order to establish target flows from any of these parameters it is necessary at this stage to relate the flow to that in similar watercourses or downstream reaches of the same watercourse which achieve the required target mark (ie are not suffering low flows to the extent that ecological damage is caused).

16.3 Restoration of Visual Amenity

For visual and amenity aspects we propose that parameters H4 (Channel Size) or H6 (Change in Stream Type) should be used with a target mark of 0 or, exceptionally, 1.

Parameter L4 (Amenity) may also be used but it is an indirect method of assessing target flows and therefore only be used by reference to similar watercourses to assess target flows.

16.4 Cost or Benefit/Cost

Although *target* rehabilitation standards may be independent of cost, the standards achievable are unlikely to be:

The Cost Indicator may be taken into account in setting priorities between rehabilitation schemes achieving the *same* standards in the manner set out in paragraph 12.4.

However, the Cost Indicator is a measure of the cost of restoring a given quantity of flow and on different watercourse, the same quantity of flow may rehabilitate quite different lengths of watercourse.

Another way of looking at this is that different quantities of flow may be needed to rehabilitate the same length of watercourse at different sites.

Thus an alternative cost indicator might be the cost per kilometre of watercourse restored to

a) full habitat or
b) visual/amenity requirements only.

'Cost' in this case would be the NPV of costs as set out in para 11(iii).

Thus 'typical' or 'average' costs per km could be established nationally for each of the two levels of rehabilitation and each proposed scheme compared with these 'typical' costs.

17. TESTING AND DEVELOPMENT

This report sets out a proposal for a Standard Assessment Method for Low Flow Conditions based upon the low flow conditions recorded to date in the Regions.

The scoring and weighting systems have been developed on the basis of experience, information and reports provided by the Regions.

However the method needs to be tested in the field and developed to make it as accurate as possible, given the complexity of the problems it seeks to assess.

Some testing could be carried out using existing data but it is also desirable, if not essential, that some additional field data are collected.

The testing of the Assessment Method should be to determine, inter alia :

* whether any of the proposed parameters should be 'dropped'
* whether additional parameters would be useful
* for parameters with numerical values, how appropriate are the ranges of values and corresponding 'scores'?
* are the weights assigned to parameters and/or indicators appropriate?
* should a 'discretionary' Regional weighting be allowed - for Indicators and or Parameters?
* is the assumed cost of buying out licences appropriate?
* does the method produce sensible answers?
* how difficult/costly is the method to apply?
* the staff resources required to undertake the full assessment of all the affected streams
* a consideration of how the method will stand up to public scrutiny

It is not reasonable to anticipate that the Regions could carry out the testing before the end of the 1990/91 financial year.

It is proposed that consideration be given to carrying out the testing between June and September 1991 and that provision should be made for a small supplementary research project in the 1991/92 financial year to co-ordinate the testing, receive feedback and modify the proposed method accordingly.

REFERENCES

Armitage P.D., Wright J.F. and Furse M.T. (1983). The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. Water Res., 17, 333-347.

Cox R., Furse M.T., Wright J.F. and Moss D. (1991) RIVPACS II - A User Manual. Institute of Freshwater Ecology, River Laboratory, East Stoke, Wareham, Dorset.

ANNEX 1

Project TOR and Work Programme

TERMS OF REFERENCE

FOR NRA R&D PROJECT

LOW FLOW CONDITIONS

SCHEDULE 2 : TERMS OF REFERENCE

This Schedule details the Terms of Reference for this research project and upon which the Plan of Approach specified in Schedule 5 has been based.

Objectives

Overall Project Objective

To review low flows due to abstraction and to standardise the assessment of the condition.

Specific Objectives

a) To review the preliminarily assessment of low flow conditions already made by the NRA Regions.

b) To Classify the conditions according to the magnitude of the effect and the cause (e.g. ground water abstraction, surface abstraction, impoundment).

c) To develop a methodology whereby the conditions may be assessed in an objective and standardised manner so that the NRA can make decisions on cases where action is justified.

d) To identify and review, in outline, the range of options for alleviating low flow conditions.

e) To propose the criteria to be taken into account in setting standards for rehabilitation.

Background

Following concerted public pressure over a number of years the former Thames Water Authority appointed Sir William Halcrow & Partners Ltd to undertake a study into the possible ways of alleviating low flows in six rivers which had allegedly been depleted by groundwater abstraction. The objectives of the study were to identify the areas where flow had been depleted, to determine the extent to which restoration of river flow would be desirable and practicable and to evaluate the feasibility, costs and environmental impact of the various options for improvement. The consultant's report made detailed proposals for alleviating the low flow problem in each of the six rivers concerned. A further report set out a phased programme of implementation including further investigation work.

Responsibility for the alleviation of low flows (ALF) work has now passed to the NRA. In Feb 1990 the NRA's Board approved the inclusion of the ALF scheme in the capital expenditure programme.

The creation of the NRA coupled with the Thames initiative

focused attentions on the problem of derogated river flows throughout the country generally. Shortly after vesting day a brief survey of the nature and extent of the problem was undertaken by all the Regions. This identified some 92 instances where there was perceived to be a low flow condition attributed directly or indirectly to abstraction. Possible remedial works were suggested together with a rough indication of cost. Subsequently, the NRA announced its intention to proceed with urgent studies at 40 sites of which 20 were to be given a high priority.

Although some attempt was made to categorise the cases according to the nature and severity of the problem the approach was necessarily rather simplistic in the timescale available.

This project is concerned with the development of a methodology or procedure to standardise the classification of any artificially induced low flow problem. With the high cost of remedial work it is vital that such techniques are developed so that the NRA can target resources where they will be most cost effective.

Context

The project links closely with other projects in this Topic Area B2 (Flow regimes) but particularly so with Topic element 6b which is concerned with the development of a methodology to determine minimum acceptable flows. Liaison may also be required with work being done in Topic Area B3 (Water Resources Management).

Account should be taken of previous work done in this area. In particular, reference should be made to the work undertaken for Thames Water by Sir William Halcrow & partners Ltd for the alleviation of low flows in rivers now managed by the Thames and Southern Regions of the NRA. However, it should not be assumed that the work done for that project necessarily provides a basis for this study which requires a fresh approach. Where appropriate, liaison will be established and maintained with other contractors undertaking research in this topic area.

Strategy

Method

Review of existing problems and development of method of standardisations undertaken by external Research Contractor supervised by project leader. NRA Regions will provide support in the provision of local knowledge of the derogated rivers and in the provision of specific data.

Outline of Activities :-

a) Establish inter-relationship of project with other elements of Topic Area B2 and with Topic Area B3.

b) Review previous work and acknowledged cases of low flows due to abstraction.

c) Visit each NRA region which has identified a problem to obtain relevant information and data. Seek the views and ideas of the regional water resources engineers/hydrologists.

d) Establish whether there are any other low flow sites not previously identified and obtain data.

e) Undertake review and develop basic framework of classification of the conditions.

f) Produce interim report.

g) Develop methodology for standardising assessment of the conditions.

h) Identify and review, in outline, options for alleviating conditions.

i) Identify criteria to be taken into account in setting standards for rehabilitation.

j) Complete draft report.

k) Finalise project report after review by NRA.

Monitoring

Project monitoring by Project Leader. Project contacts established in each relevant Region for reference and review.

Project Leader/Topic Leader review following item (f).

Project Leader/Topic Leader/Regional project Contacts review draft report following completion of item (j).

Targets and Timescales

These are as specified in Schedule 6 : Plan of Approach.

Outputs

These are as specified in Schedule 1.

Costs

The Authority's budget for the project is given in Schedule 8 whilst the expected annual expenditure is specified in Schedule 9.

SCHEDULE 4 : STAFF RESOURCES

The Contractor will ensure that the following key staff are employed in undertaking the project and that the duration of their input as specfied below represents the minimum time allocation for the project.

Name	:	Mr. Mike Le Gouais
Qualifications	:	B.Sc. - University of London M.Sc. - University of Southampton
Position	:	Partner
Charge rate	:	£ 17.07
Duration of Input	:	160 hours

Name	:	Mr. Shaminder Puri
Qualifications	:	M.Sc. - University of Warsaw M.Sc. - University of Birmingham
Position	:	Principal Hydrogeologist
Charge Rate	:	£ 41.76 per hour
Duration of Input	:	95 hours

Name	:	Dr. Philip Kerrison
Qualifications	:	B.Sc. - North-East London Polytechnic. M.Sc. - University of Aston University Ph.D. - University of East Anglia
Position	:	Naiad Aquatic Environmental Services
Charge Rate	:	£225 per day
Duration of Input	:	110 hours

Name	:	Dr. Anne Knape
Qualifications	:	Diploma Landscape Architecture - Leeds Poly. M.Sc. - University of Birmingham
Position	:	Partner - Cobham Resource Consultants
Charge Rate	:	£ 45.35 per hour
Duration of Input	:	60 hours

SCHEDULE 5 : PLAN OF APPROACH

This schedule details the project plan of approach as drawn up by the Contractor in response to the Terms of Reference specified in Schedule 2.

The strategy that will be adopted for the study workplan will follow the following key six elements, which would be addressed in each of the stages to provide a comprehensive coverage of the activities listed in terms of reference :

i) Definition of low flows
ii) Impacts of low flows
iii) Causes of low flows
iv) Procedures for assessment of low flows
v) Options to alleviate low flows
vi) Criteria for implementation.

The following sections explain the methodology for carrying out the study activities relating to the project activities using the same referencing as in the Terms of Reference.

Stage 1 : Desk Study

a) Interrelationships with Topic Area B2 and B3.
b) Review previous work on known low flow cases.

From the Contractors knowledge of the low flow project and its objectives the related Topic B3 : Water Resources Management will have an interrelationship with the present project. The Contractor will liaise with the Topic Leader responsible and also with project leaders.

Within the Flow Regimes Topic area two projects B2.1 Integrated Environmental Flow Monitoring and B2.3 Low flow estimation in artificially influenced catchments are also proposed. These will in all probability be carried out by the Institute of Hydrology who act as prime contractors to the NRA. The Contractor has discussed with the IoH the need for close liaison with the progress on these projects and have set up links to maintain liaison with them.

Each of the NRA Regions have identified sections of rivers where low flows have been noted. Some initial work has been done to meet the local demands and constraints. The Contractor will obtain the relevant information on these and collate them into a uniform review document. Each of the strategy elements listed above i) to vi) will be considered. As an example the approaches to the definition of low flows varies across the regions. In some areas the minimum daily flow series are used to define low flows, while in others the flow duration hydrographs are utilised. These differing methods have been developed to suit local needs but there is a requirement to justify their use.

Stage 2 : Regional NRA's Current Information Base

c) NRA regional views and ideas.
d) Additional low flow sites.

e) Review and develop framework of classification.

In this, the second phase of the study, we will visit or contact each of the Regional NRAs to obtain the views of the water resource engineers, hydrologists and ecologists. Those Regions who have already identified problems and initiated assessments or alleviation will be visited first to establish the basis of their present approach. Subsequently, regions where such work has not yet been started will be visited to discuss their perceptions of low flows and the approaches that would be appropriate.

Stream sections, additional to the 92 already identified, where low flows may have occurred which have been brought to the attention because of recent increased awareness or more recent field observations. The data on these will be collated in a methodical and systematic manner to permit easy comparison with areas where assessment has already been conducted.

As part of the visit and discussions with Regional staff we will review the information and approaches in order to formulate a framework to classify the conditions of low flow. The framework will address all the basic factors including hydrological, hydrogeological, changing land use, amenity, recreational value, urbanisation, leakage from stream channels, etc. The Contractor believes that the best approach which would address these factors in a consistent way will be to set up a database. the form of the database will be fairly simple yet it will encompass every aspect, even though in many cases, information will not yet be available to enter into it. The database will be manipulated to produce summaries in a variety of formats. These will be analysed to select the most meaningful parameters and formulate a framework which will be adopted for the subsequent project stage.

The Contractor will also review the options for alleviation which have been identified or used and the criteria which have been used in assessing them.

Stage 3 : Current Status - Report

f) Interim Report

An interim report of findings will be produced. This will contain the essential database of information provided by the Regional NRAs, their perceptions and methods of low flow assessments and experience of alleviation measures. The main value of the report will be in defining and extending the framework of classification of the low flow conditions. The interim report ill also anticipate the subsequent study stages and will particularly identify any programme variations will only arise as a result of the findings from visits to the Regions and the progress made on other parallel NRA R&D projects eg. the approach to setting Minimum Acceptable Flows.

Stage 4 : Develop Proposals

g) Develop methodology for standardising assessment of conditions.
h) Identify and review options for alleviating conditions.
i) Identify criteria in setting standards for rehabilitation.

The activities in this, the most important stage of the study, are concerned with the formulation of policies and preparation of overviews, starting from and then developing the base of information and experience within the NRA as assembled and recorded in Stages 1 to 3.

A methodology will be developed for standardising the assessments made by Regional NRA's. This could include a brief review of the statistical methods used to calculate the occurrences of low flows and indication of standard method by which more direct comparisons could be made across the regions.

As many of the incidences of low flows will be based on public perception of reduced flows, a method of classification of these will be devised eg. whether the perception is based on the use of the river bank as a visual amenity or as a recreational site, where swimming is no longer physically possible. Other factors such as reduced opportunity for licensed abstraction or impaired river use for commercial and fishing needs will be taken into account.

In many cases only one or two of the impacts or parameters are the primary controls on minimum acceptable flow (MAF), other parameters being far less significant. This suggests the possibility of a two-stage assessment procedure of which the first would be equivalent to a "scoping report" listing all potential impacts or parameters but assessing which are locally important in order to "focus" the evaluation effort.

For each of the standardised low flow conditions noted, we will identify and review in outline only, the options that would be available for alleviating these conditions. A number of direct and indirect alleviation options are available and many of these have been tested in various parts of the Regional NRA's. The practical applications of these options have also, to a large extent been considered in the past, ranging from stream bed puddling (in the Chalk) to bed lining using natural and artificial system. other options such as changed abstraction patterns, river flow augmentation will also be reviewed. The review will consider the applicability of a given option in conditions where it has not ben tested eg. stream bed puddling in other aquifer areas, based on the experience in Chalk aquifer areas.

The Contractor will identify the criteria that have to be taken into account in setting the standard of rehabilitation. It is obviously clear that flows will not be restored to the levels prior to human intervention but it would be desirable to restore them to redefine minimum acceptable flow (MAF) if this had been set too low. Although the NRA has commissioned separate studies devoted to MAF and related topics, it is clear in some instances that ecological value of streams is very important in respect of fisheries, macrophytes, benthic invertebrates etc. In order to

do this the Contractor will liaise closely with the on-going NRA R&D projects that are appropriate especially the Water Quality, Commission A.

Stage 5 : Consultation

As part of this stage we will produce a consultative report of our findings, evaluations and approach to standardisation of assessment of low flows. An important aspect of this stage will be the consultation with Topic Leaders in the NRA Regions especially these concerned with other projects in Topic Area B2, but particularly with the Topic element concerned with minimum acceptable flow.

Stage 6 : Final Report

Following consultation the final report will be produced in accordance with the requirements of the NRA.

SCHEDULE 6 : ACTIVITY SCHEDULE

This Schedule details the activities to be undertaken during the project and the timescale within which they will be accomplished.

	Activity	Date to be Completed
1.	Project Interrelationships	31/08/90
2.	Review Previous Work	07/09/90
3.	Visit NRA Regions	31/09/90
4.	Analyse Additional Low Flow Sites	31/09/90
5.	Set Framework of Classification	14/10/90
6.	Interim Report	31/10/90
7.	Standardisation of Assessment	14/11/90
8.	Analyse Options for Alleviation	07/12/90
9.	Set Criteria for Rehabilitation	07/12/90
10.	Draft Project Report	31/01/91
11.	NRA Review of Draft Project Report	28/02/91
12.	Final Project Report	31/03/91

ANNEX 2

TOR for Project "Ecologically Acceptable Flows"

PREAMBLE

Title of Project

"ECOLOGICALLY ACCEPTABLE FLOWS"

1 The Authority seeks to establish rational techniques for the determination of instream conditions appropriate to suitable habitat for a wide range of flora and fauna.

2 There are a number of concurrent research and development projects managed by the Authority concerned with identification of critical levels of river flows. The Project Manager will be advised of any circumstances where common data collection and cross fertilisation of ideas would be of benefit.

3 The principles of project management are contained within the contract documents and in particular within the Project Investment Appraisal (Schedule 2). In effect the work may be viewed as occupying two phases: the first to the 'Interim Report' which establishes the efficacy of the PHABSIM approach to a wide range of rivers and species; the second to accommodating the field data, regionalisation and software to a practical working method.

4 The overall responsibility for the conduct of the contract rests with the relevant 'Nominated Officers'. However, work sub-contracted to specialist Biologists shall have an intermediate tier of supervision: for the Contractor, by Dr P D Armitage of the Institute of Freshwater Ecology; for the Authority, by Dr A J D Ferguson of NRA Anglian Region. Major reports specified in Section 9 of Schedule 2 will be reviewed by a panel of Authority officers which will be regarded as a Project Steering Group for the purpose of advising on the direction of continued work.

PROJECT INVESTMENT APPRAISAL

1 R & D COMMISSION B - WATER RESOURCES

Topic B2	- Flow Regimes
Project Title	- Ecologically Acceptable Flows
Proposal No	- B2.1
Classification	- Applied Research with Specific Aims

2 PROJECT LEADER

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3 RESEARCH CONTRACTOR

National Environment Research Council (NERC)

Primary Agency:	Institute of Hydrology (Project Management/Hydrology/Software)
Supporting Agency:	Institute of Freshwater Ecology (Ecology/Field Data)
Probable Consultants:	Institute of Terrestrial Ecology; University of Technology, Loughborough

4 CONTRACT DETAILS

Start Date: 01/09/90 (P)
End Date: 31/03/93 (P)
Contract Type: STA

5 OBJECTIVES

Overall Project Objective:

To provide the framework for an objective method for the evaluation of prescribed minimum flows based on the recognition of ecologically acceptable flows apposite to particular seasonal requirements of aquatic life forms.

Secondary Objectives:

a) The assessment of 'PHABSIM' (Physical Habitat Simulation) as devised in the USA for practical evaluation of instream flow requirements for England and Wales.

b) Conduct of literature searches and fieldwork for data applicable to selected characteristic rivers for England and Wales with due attention to geographical influences; and thus to comment on the limitations of acquired data to general application.

c) Construct habitat suitability curves for PHABSIM application for the life cycle of the key elements of aquatic life forms; plants; invertebrates; fish; with regard to water flow, water depth, stream substrate and channel cover.

d) To have regard in the construction of habitat suitability curves of the influence of water quality on species distribution and populations.

e) To enhance the PHABSIM software with respect to menu structure, graphics routines, metric units, and capability to enter both cover and substrate curves; and to identify the interface between PHABSIM and appropriate hydrological software systems.

f) To make recommendations for the further advancement of this work towards a comprehensive ecological assessment for inclusion in the wider considerations in the setting of minimum acceptable flows as inferred from the Water Resources Act 1963, Section 19(5), and the Water Act 1989, Section 8(4).

6 BACKGROUND

The Water Resources Act 1963, Section 19(5), requires a variety of matters to be considered when specifying "minimum acceptable flows" in relation to an inland water. Despite the reluctance of previous Authorities to invoke the opportunities afforded for the conservation of water resources by this device it is evident that the NRA will be expected to seriously address the concept of minimum acceptable flows.

There have been good reasons in the past for averting effort from this matter into pragmatic measures for the safeguarding of the public interest in physically evident conservation at the minimum level rather than in the rational exposition of the full environmental impact. Not the least of difficulties has been the absence of the application of valid measures from biological and fisheries sources of the ecological impact of water abstraction. With the benefit of a well tried method from the USA in the form of the concept of 'Instream Flow Incremental Methodology' (IFIM), and in particular the technique of evaluation of physical habitat (PHABSIM) which is now mandatory in the USA and has stood the test of 850 applications, there is the potential for a rational examination of the ecological standards required against which to assess significant water resource developments. The suitability of this technique in British conditions requires extensive trials in relation to other methods of biological assessment.

The present high commitment of the NRA to resolving the "sins of the past" in respect of unacceptable low river flows and its continuing public credibility as "Guardians of the Environment" make it imperative that an objective method of assessing ecological effects of abstractions is developed as a matter of high priority. PHABSIM has already been explored by the Institute of Hydrology as a suitable technique using extensive data gathered for the Freshwater Biological Association's RIVPACs project. It potentially offers a readily available basis for the generation of hydrological models which incorporate the essential features of ecological protective flows in order to define the primary objectives of environmental protection as required under the legislation.

The need for the project is identified through the large capital programme for low flow remedies; in the resolution of outstanding allegations of river flow decline; and in the foundation of all water resources conservation endeavour - the determination of the hundreds of applications for new or increased abstraction licences received annually.

Context

There are very direct relationships between this research need and others in the Water Resources Commission. Some of these are parallel and some may be regarded as eventually subsequential. Notable parallel projects are Projects B2.2 and B3.2 ("Low Flow Conditions" and "Resource Assessment Methodologies") which should ideally report and receive progress information with this project.

Numerous other projects impinge on Project B2.1, in for example Topics A1, A13, C4 and Commission D, where data collection may be of reciprocal benefit. In this respect there is value in an early comparison of the various project data requirements to minimise duplication of effort.

7 STRATEGY

Method

The fitting of appropriate regional characteristics to the 'habitat preference curves' of PHABSIM software in preparation for calibration of a number of characteristic river types throughout the NRA regions. Then the enhancement of PHABSIM software with a report on techniques available to merge the outputs with dry weather predictive hydrograph techniques.

NRA regions will submit nominations for specimen river catchments for which previously collected data exists but for which field surveys of ecological, hydrologic and hydraulic, temperature, water quality characteristics may also be required. These catchments will be judged as suitable for the requirements of research and not for the resolution of existing problems.

Integration of ecologically preferred curves with hydrolgical data or predictions will have regard to the need to meet the fullest eventual requirements for a comprehensive environmental assessment including amenity; volumetric; fishing; and recreational needs.

Outline of Activities

a) Provide an 'Inception Report' at four months from study commencement to describe in detail the working method and including a justification for the initial attachment to PHABSIM as the key to an IFIM approach; a description of the proposed biological studies; and the proposed comprehensive programme of work.

b) Evaluate PHABSIM as a relevant method and compare with previous NERC research and that from specific river studies in NRA (or predecessor Authority) research on biology and particularly on matters relating to fish populations and migrations. Consider extension of the technique to include consideration of water temperature and water quality.

c) Identify through the Project Leader a sample of rivers that should be studied for application of the PHABSIM technique that will lead to witness of the national viability of the method.

d) Undertake the necessary fieldwork on sample rivers to provide data for the establishment of 'habitat suitability curves' to incorporate into the PHABSIM technique.

e) Evaluate the extrapolation of acquired data from river catchments to a more regional application and draw conclusions as to the limitations of the technique to local data availability.

f) Produce an 'Interim Report' at mid-study stage to report on progress with emphasis on changing perceptions of the direction the further study may need to take to meet the overall project objective; with particular regard to the nature of database and software requirements to reflect attitudes of the NRA deriving from contemporary research projects.

g) Develop the means by which "Ecologically Acceptable Flows" can be defined biologically and assimilated with hydrographs of statistically relevant events: either actual, simulated, or otherwise estimated time-series sequences. Flexibility to adapt to developing NRA practice of data collection, processing and presentation will be required. In particular there is a need to express results on a seasonal basis.

h) To recommend necessary areas or extended local studies for further research to accelerate the benefits of this project to general applicability within NRA objectives for the conservation of water resources and their proper use.

Monitoring

Progress will be closely monitored by the Project Leader and Specialist Advisor (where relevant) who will report at a biannual frequency to the Topic Leader and to the Research and Development Commissioner. Progress meetings will be expected to follow periodic reports at which other NRA officers with related research responsibilities will be invited to attend.

Contacts from the primary or secondary contractor with NRA regions will be established by the Project Leader and Specialist Advisor as appropriate who will expect to receive copies of relevant communications with these contacts.

Following receipt of the Interim Report all NRA regions will be consulted by the Project Leader with a view to securing their continued agreement to the direction of the studies and the consensus view on future requirements at that stage may require amendment to the ultimate shape of the detail of objectives.

8 TARGETS AND TIMESCALES

	Work Item (Ref S.7)	Date Completed	(Month)
a)	Inception Report	01.01.91	(4)
b)	Further assess PHABSIM	01.02.91	(5)
c)	Identify sample rivers	01.03.91	(6)
d)	Complete fieldwork	01.10.92	(25)
e)	Evaluate extrapolation	01.01.92	(16)
f)	Interim Report	01.01.92	(16)
g)	Presentation of results	31.12.92	(27)
h)	Recommend further work	31.03.93	(30)

9 OUTPUTS

Statements of progress at 2 month intervals	(06 copies)
Inception report at 4 months	(15 copies)
Interim report at 16 months	(15 copies)
Draft final report at 27 months	(15 copies)
Final report produced at 30 months as NRA report	(50 copies)

10 COSTS (£K)

Item	NRA External	NRA Internal	Others (Shared)
Staff	200	14	-
Travel & Subsistence	40	2	-
Capital Items	-	-	-
Consumables	30	2	-
Final Report	10	-	-
Other	-	-	-
TOTAL	280	18	-

(Note: Internal costs assumed to be 5 man days per year per region. External costs assumed negotiable to figures stated).

R & D Budget Provision (£K) (Cost Increase)

Budget	1990/91	1991/92
NRA	60(-)	120(-)
Others	-	-

NB The affinity of various data collection activities in this project with the needs of many others as identified under 'Context' suggests that there should be a co-ordinated review of all Commissions data collection programmes as these become more clearly defined. Since a large element of research expenditure concerns data collection, avenues should be open for a conjunction of such work between various topics and projects.

11 BENEFITS

For many years the licensing of water abstractions with an evident hydrological impact has been conducted in a void of reliable information about ecological impact. Streamflow protection has been afforded by a variety of algorithms for prescribing required residual flows but rarely related to parameters other than statistical or empirical standards of flow conservation. The provision of a device for assessing prescribed residual or regulated flows which truly reflect the needs of stream biota would be of profound benefit to the effective performance of the NRA. A secure foundation to the assessment of prescribed flows will provide a logic for:

i) determination of new abstraction licence applications with hard evidence for decisions;

ii) reviews of allegations of historic streamflow derogation;

iii) the economics of streamflow augmentation in remedy of historic derogation;

iv) common ground between hydrologists, biologists, conservationists, fisheries officers and engineers in the inter-relationships of their activities and aims.

12 ASSUMPTIONS AND RISKS

PHABSIM has been used extensively in the USA and is expected to be importable to the much less varied environments of England and Wales. The method, the software and its application has already been investigated in a 12 month project for the DoE by the primary contractor. Arising from that project is a framework of research initiatives which needs to be addressed not only through this new NRA project but also by continuing work by NERC (eg appropriate key target species, minimum data requirements, extension of macrophytes data) within its own 'science vote' funds. Without this contemporary research within NERC, progress towards a widely usable and credible method of prescribing minimum flows may be retarded.

In expecting the usual high level of NRA regional co-operation with the project this also implies a reliance on their patience in achieving results. Thus specimen catchments required for the development of the technique should be selected by the primary contractor for the benefit of the project and not for the immediate resolution of local problems.

When risks attach they are believed to be mainly associated with the present budget allocation which, and without evidence of a parallel funding within NERC, may be inadequate to provide the necessary impetus for data collection in the second year of the project so crucial to meeting the programme targets. Secondary risks concern the harmonization of software and databases with those concurrently developed nationally and in regions but these should be nullified by sensible communication and consultation throughout the study.

13 OVERALL APPRAISAL

This project is an essential venture for the NRA if it is to give an authoritative lead on environmental consequences of water abstractions. Not only will it provide a genuine method of relating abstractions to ecological factors but it will also demonstrate possible economies in the already identified high capital programme for low flow remedies.

Risks are largely limited to excessive expectations of the outcome; the programme for this project is aimed at establishing a method and not for providing universal answers. There will be immediate gain for the specimen catchments employed in the development but catchment specific data will still be required for many localities not initially encountered within the project. It would be expected that continued development of the project would ensue after the [illegible] year programme if the portents are good.

Dr A T Newman
30 October 1990

CPM/1889/m

ANNEX 3

Summary of Regional Problems and Perceptions

ANNEX 3

SUMMARY OF REGIONAL PROBLEMS AND PERCEPTIONS

The following summaries represent the overview of each Region's problems and perceptions which we obtained from a single visit to each Region during Stage 1 and Stage 2 of the project.

Appreciating that perhaps not all Regions have a comprehensive policy on low flows and that it is difficult to summarise such multi-facetted problems in one paragraph we have refrained from statements which might be seen as provocative.

Comments have been received from the Regions on the views given in the Interim Report. Their comments have now been incorporated as part of Stage 5 consultations. The views given here do not attempt to be comprehensive, as with continuing current work, more information and experience obtained by the Regions will permit them to refine and review their views on low flow problems found by the NRA.

ANGLIAN REGION

Anglian confirmed that the list of low flow sites is as the Roger Cook Survey.

The consultation provided an overview of the whole Regional situation.

The low flows are primarily caused by over-abstraction of groundwater from Chalk aquifers under Licences of Right. The problems are real and current with a number of rivers suffering severely reduced flows. The problems occur on headwaters mainly but with some middle courses affected.

Low flows are viewed primarily as a water resources problem with studies being driven by water resources staff with some input from conservation staff.

Some considerable data is available and some studies have been carried out but the problems have not been comprehensively studied.

There is a strong public pressure for action from high-profile public figures (e.g. David Bellamy).

Some alleviation measures have been implemented based on groundwater support to low flows but these are local, 'fire-fighting' measures rather than fully integrated schemes as part of a comprehensive strategy. Such measures are based on restoration to specified target flows and hot 'historic' flows.

NORTHUMBRIAN REGION

In a telephone discussion Northumbrian confirmed that the situation is as the Roger Cook survey, i.e. that artificially induced Low Flows are not a problem in the region.

NORTH WEST REGION

North West confirmed the list of low flow sites as the Roger Cook Survey.

The consultation provided a broad regional overview from a full range of water resources and conservation disciplines with an integrated approach.

The low flow problem is primarily a conservation problem in a surface water area and arises from the development of and management of releases from surface water reservoirs. In particular catchment transfers leave downstream tributaries depleted except during winter spill.

The problems are not well studied but are well appreciated.

No alleviation measures have been implemented and no solutions are currently being pursued but discussions are under way with NW Water Plc on the overall operation of the reservoirs. Likely solutions will involve re-negotiation of compensation releases and the introduction of facilities for release from tributory reservoirs.

There is some public perception of the problem but there is not such strong pressure as in other regions.

SEVERN TRENT REGION

Severn Trent confirmed the list of low flow sites as the Roger Cook survey with some minor reclassification of category of problem.

The consultation provided an overview of the Regional situation, from a Water Resources perspective with conservation in the background.

The low flows are caused by over-abstraction of groundwater and are real, current problems, occurring on headwaters to middle courses. Some rivers run dry but the ecological impact of this has not been assessed.

There is some public pressure arising from visual/amenity aspects but not as strong as in other regions. Low flow studies have started recently so the problems are as yet imperfectly understood.

No alleviation measures have been tried and proposals are not yet formulated but are most likely to be based on groundwater support.

The view was expressed that Alleviation of Low Flows is driven by a Public Relations need.

During stage 5 consultations, the views of the biologists were also received on the proposed methodology. Their comments were incorporated into the proposed method.

SOUTHERN REGION

Southern indicated that the list of low flow sites is thought to be as the Roger Cook survey. The consultation was with a water resources officer from one division and provided a divisional rather than regional view.

Low flows are primarily caused by over-abstraction of groundwater (mainly Chalk aquifers) under Licences of Right but there are also some reservoir release problems. The problems are real and current and affect headwaters and middle courses and in the case of Darent, the lower course. The River Darent (transferred from Thames to Southern and previously studied by Thames RWA) has well publicised problems and is the subject of strong public pressure from the Darent River Presentation Society.

Our consultation was water resource orientated but we are aware of conservation concerns in Southern Region. The problems have not been comprehensively studied apart from the River Darent. Southern Region are re-evaluating the Darent study and have initiated a study to assess a Minimum Environmentally Acceptable Flow, i.e. they are aiming for specific target flows.

Some ad-hoc alleviation measures using groundwater support have been tried but not continued or closely monitored and are 'fire-fighting' measures.

During Stage 5 consultation it was pointed out that it would be very important to refer to the recharge (to aquifers) indicated in the Content of Severity of drought. The indicator would be more meaningful if quoted as the 'recharge in a 1 in 25 year drought'.

This comment and suggestion has been incorporated into the methodology proposed in the report.

SOUTH WEST REGION

South West indicated that the sites listed in the Roger Cook survey are to be superseded by a new assessment currently under way (report received during the study).

The new assessment is based on a definition of potential low flow sites as those where the sum of the licensed abstraction quantities under Licences of Right exceed 20% of the 'theoretical' or 'natural' 95 percentile flow. The consultation provided an overview of the whole Regional situation and was fully multi-disciplinary with no one discipline in the lead.

Low flow problems are real and current with a potential further deterioration if currently under-abstracted licenses are fully taken up. Causes include surface water and groundwater abstraction, changing land use and increased land drainage and are not restricted to the upper reaches; whole catchments are affected including estuaries.

Some studies have been carried out but the Region considers them to be very limited and based on inadequate data. There is public pressure and the question of low flows is highly political but the view was expressed that the absolute needs of the rivers, objectively assessed, should overrule public pressure and that restoration should be to 'historic' or 'natural' flows.

Fish populations are considered to be a good indicator of low flow impacts because of strong fishing interests and hence it is a noticed/reported/complained about' impact.

Limited work has been done on implementation or alleviation projects but buying out or varying Licences of Right amendments to reservoir operations and substituting surface water (impounded supplies) for groundwater abstractions are being pursued.

THAMES REGION

Thames confirmed that the low flow sites are as the Roger Cook survey. The consultation provided a Regional overview.

Low flows are primarily caused by over-abstraction of groundwater from Chalk aquifers under Licences of Right leading to severely reduced low flows and long dry sections. The problems are real and current and mostly affecting headwaters.

The problems are much-studied and relatively good data exists for at least some of the sites.

Low flows are viewed as equally a Water Resources and Conservation problem with Water Resources leading, since exploitation of water resources is the cause of the problem.

There is strong public pressure for alleviation of low flows. The pressure is well-organised and influential but subjective and focussed on particular issues. The public concern tends to be in respect of landscape amenity e.g. The Chiltern Society.

Specific alleviation measures have been proposed but not yet implemented. These include groundwater support, channel lining and 'created environment' to restore habitats and re-construct landscapes.

The alleviation proposals are local 'fire-fighting' measures rather than a comprehensive strategy and are based on restoration to specified target flows and not historic flows.

Stage 5 consultation indicated that fishery interest must be given serious consideration and be included in the assessment. Low flows experienced in areas other than the Chalk aquifer are to be included in the overall programme. Additional comments relating to the method of assessment has been incorporated in the main body of the report.

WELSH WATER

Welsh Region confirmed that the low flow sites are as the Roger Cook survey. The consultation was orientated towards South-Western division in respect of Water Resources but Regional in respect of conservation.

The problems are potential in SW division but real and current in N and SE divisions and arise from over-abstraction of surface and groundwater resources and Licences of Right. There is concern that Licences of Right are not yet abstracted to their licenced quantity and the potential for further LoR abstractions has to be taken into account in assessing applications for irrigation licences.

Welsh Water RWA had a draft licencing policy which set methods of assessing a Minimum Environmental Flow (MEF) and an Acceptable Duration of MEF. This draft policy was not formally adopted but is used informally by the Region.

Welsh are concerned for the impact of low flows on Water Quality since discharge consents are related to Q_{95}. They would like Licences to be conditioned to ensure that the MEF is left in the river.

Low flows are viewed as a conservation problem as much as a water resources problem and studies are driven by both disciplines.

MEF is related to Q_{95} based on 1941 to 70 historic data with transposition of data from gauged catchments to similar ungauged catchments.

There is public pressure from the NCC and National Parks and Monmouth Rowing Club! but Welsh Region like to give precedence to objective data rather than (subjective) public pressure.

Welsh have a particular problem with exempt abstractions under the 1963 Act, now being converted to Licences of Entitlement.

The view was expressed that salmonid are the most useful/important indicator species because :

i) they are high in the food chain

ii) they are the focus of public pressure

iii) they are a sensitive indicator

iv) much data is available due to a policy of annual electrofishing at 100 sites since 1974

v) they will die before the landscape/amenity is noticeably affected.

Welsh also propose (and in some cases have implemented) that storage reservoirs should have a proportion of the stored volume under the control of the conservation officer for release when he deems necessary.

WESSEX REGION

Wessex confirmed the list of low flow sites as the Roger Cook survey but indicated that there are more sites, not subject to public pressure, which they will wish to bring forward in the future.

The consultation provided an overview of the whole Regional situation.

The low flows are caused by groundwater abstraction under Licences of Right and are real and current with severely reduced flows in headwaters and some middle courses. Low flows are viewed as both a water resources and conservation problem.

Some problems have been 'much studied' but in the Regions view the studies were not conclusive.

There is much public pressure from river protection societies, CPRE, CLA and public figures such as David Putnam. Wessex have initiated some alleviation measures with mixed results. Bed lining has not been too successful since 'leaky' beds convey water back from groundwater to surface water in the winter causing 'wash outs'.

Wessex region implied a preference for strategic solutions rather than local 'fire-fighting' and to this end have a number of catchment models in development. Revoking or modifying licences may only transfer the problem elsewhere.

Alleviation would be to specific target flows, not 'historic' flows. Targets may be based on visual/amenity or (higher flows) for good fisheries. Priorities are set by Public Pressure.

The region drew attention to the related but different problem of flow depth - reduced due to the policy of removing weirs for Land Drainage but some landowners now impounding to restore depths.

The main user of water is Public Water Supplies and the alleviation of low flows would put up the cost of water.

The need for resources to implement any low flow assessment/alleviation programme was strongly stressed.

YORKSHIRE REGION

Yorkshire confirmed the list of low flow sites as the Roger Cook survey but advised that the River Foss is upgraded to Category A.

The consultation provided an overview of the Regional situation which was balanced and well-researched.

The low flows are primarily caused by over-abstraction of groundwater under Licences of Right with some specific local problems (e.g. a 'swallow' hole in a river bed).

The problems are real and current and are seen as primarily water resources problems with a strong conservation dimension. The problems occur in headwaters to middle courses.

Fairly good data exists and the problems have been studied in reasonable depth.

There is some public pressure but there has been concern within the RWA for many years over low flows and this is reflected in the availability of data and studies. There is also pressure from Yorkshire Water Plc on water quality grounds.

Proposals for alleviation measures exist but have not been implemented. These include some local 'fire-fighting' proposals but also a well-developed strategy for positive environmental enhancement.

ANNEX 4

Status of Other Relevant R&D Project of NRA

Project 012 - Impact of farm discharges on river pollution -
Topic Leader David Palmer (Wessex Region)

This work is co-ordinated by Frank Jones (Llanelli office) and the contractor in WRc. It is a well designed study in which invertebrate community structure is assessed in detail by the use of multivariate statistics. The aim is to assess the impact of dairy farming in West Wales on small headwater streams and to develop a protocol suitable for nationwide application. Sites were selected in areas where stresses on the aquatic community from factors other than farm pollution were unlikely to occur, so the study will not provide data directly relating to low flows. However, it could be of value in revealing the invertebrate community characterising unstressed stream headwaters in West Wales. This would provide baseline or control data. The study also provides information concerning the distribution of game fish which would be relevant to the low flow appraisal system.

The discussions with Frank Jones also revealed a study entitled 'Effects of abstraction on fisheries' carried out by Welsh Water during 1986. The study concluded that juvenile salmonid population densities declined as flow decreased due to abstraction. Various causes were suggested. Movements of adult fish and changes in the fishery resulted. Higher flows enhanced the survival of smolt. This study provides information which will be relevant to low flow appraisal.

Project 114 - Impact of Forestry on upland quality -
Topic Leader Alistair Donald (Welsh Region)

Discussions by telephone with Alistair Donald yielded the following information. The study has been carried out in the Plynlimon experimental catchments at the headwaters of the Rivers Wye and Severn. Surface water acidity is influenced by the buffering capacity and chemistry of soil in a catchment area. Direct precipitation contributes to acidification but the effect is greatly exacerbated by land use changes such as aforestation with conifers. Acidification increases the solubilities of minerals and metals such as aluminium which is extremely toxic. Aforestation lowers water yield from a catchment, which may be relevant to us but reduces the amount of acid reaching water courses. High flows which scavenge aluminium from rocks with low calcium components are a problem.

The area has been extensively studied by IOH during the past twenty years and their findings may be of value to us. The studies may yield relevant water quality data but only limited baseline ecological information, most of which will concern the distribution of trout in streams in Mid Wales.

Project A10.1 - Pesticide effect on river ecology -
Topic Leader Alistair Ferguson (Anglian Region)

Alistair Ferguson informed us that this project would be part MAFF funded but that work was not due to begin until 1990-91. Again, it may yield data on the distribution of aquatic communities in the study regions, which could be of value as baseline information against which to measure the impact of low flows.

Project B2.1 - Ecological Acceptable Flows -
Topic Leader Mike Owen (Thames Region), Now recast as Project B2.1 Ecologically Acceptable Flows - Project Leader - Dr A T Newman (Wessex Region)

This project has been recast to include the previous project "B 2.1 Integrated Environmental flow monitoring" and "P 1.11 Impact of flow regions on wildlife". This project is one of considerable significance to the low flow project as it aims to quantify aquatic biological factors with hydrological ones. The main project ToR, a copy kindly provided to us by Dr Newman, are restated here.

> "To provide the framework for an objective method for the evaluation of prescribed minimum flows based on the recognition of ecologically acceptable flows opposite to particular seasonal requirements of genetic life forms".

This project will require considerable quantities of data to construct 'habitat suitability curves' for input to PHABSIM, which is a Physical Habitat Simulation model. Much of the type of data required for this project would be used in low flow assessment methodology as described in this report which related to the NRA project B.2.2.

This project is being undertaken by IOH as the primary contractor with IFE as supporting agency with consulting input by Institute of Terrestrial Ecology (University of Technology, Loughborough). The project will be completed by March 1993, with an Interim Report by January 1992.

Project A1.2 - Effect of headwater abstraction on river quality -
Topic Leader David Stott (Thames Region)

Not yet investigated.

Project F1.11 - Impact of Flow Regimes on Wildlife -
Project Leader Alistair Ferguson (Anglian Region)

See above under project B2.4 "Ecologically Acceptable Flows".

Projects F01.10 and F01.27
Topic Leader Katharine Bryan (Severn Trent Region)

Summary of telephone conversation with K Bryan.

The 'environmental' projects most closely allied to this study are F01.10 Environmental Assessments and F01.27 Landscape Appraisal Methodology. The latter is currently out to tender, whilst the former is concentrating primarily on flood defence works and is not thought to be directly relevant to this study. Although the Low Flows study will provide an overview to the Landscape Appraisal Methodology, to date the programme for the latter has not been confirmed, so it is doubtful if there will be any overlap.

ANNEX 5

List of NRA Reports received for Low Flows Project

LIST OF NRA REPORTS RECEIVED FOR LOW FLOWS PROJECT

Anglian Region

Sir William Halcrow & Partners (April 1987) River Slea Summary Report
Sir William Halcrow & Partners (April 1987) River Slea Investigation Final Report, Volumes 1 and 2

Northumbrian Region None

North West Region

North West Waters Authority - Rivers Division (September 1976) Survey of Biological Conditions of Major Northern Area Rivers After Prolonged Drought (Part One)

North West Water - Biology South, Technical Support Group, River Division (March 1982)
The Use of Biological Data in River Quality Classification

Severn Trent Region

Scott Wilson Kirkpatrick (May 1990) Study Options for Alleviation of Low Flows (Severn Trent Region) Technical and Financial Proposal

Southern Region

Notes on public meeting regarding river Darent
NRA Southern Tonbridge District Emergency Group (January 1990)
A Report on the Drought on the River Darent

South West Region

Sir William Halcrow (September 1990)
Inception Report : Low Flows Study

Thames Region

Thames Water

Scott Wilson Kirkpatrick, Hydrotechnica & the Freshwater Biological Association (Oct 1986) Feasibility Study : Alleviation of Low River Flows Resulting from Groundwater Abstraction - Technical Proposal

Halcrow (May 1987) Study of Alleviation of Low Flow River Flows Resulting from Groundwater Abstraction - Interim Report
Main Report
Annex A - River Darent Case Study
Annex B - River Misbourne Case Study (2 copies held)

Halcrow (April 1988) Study of Alleviation of Low River Flows Resulting from Groundwater Abstraction - Final Report
Volume 1 - Main Report
Volume 2 - Drent Case Study (Jan 1988)
Volume 3 - Misbourne Case Study
Volume 8 - Annexes (A. Hydrology, B. Engineering & Costs C. Fishery Management, D. Pipeline Restoration)

NRA Thames

Scott Wilson Kirkpatrick (July 1990) Low Flow Conditions - Proposal No. B2.2 (NRA Research & Development Programme Topic B2 : Flow Regions).

Welsh Region

Welsh Water (May 1988) Guideline for Management of Water Abstraction in the Environment

Wessex Region

Wessex Water Authority, Avon & Dorset Division (Oct 1988) River Piddle Investigation - Appendix II) (N.B. App A superseded by Dec 1988 report)

Yorkshire Region

NRA, Yorkshire Region (July 1989) Proceedings of a Seminar: The Management of the River Foss

Yorkshire Water
Howard Humpheys and Partners (July 1986) Management of River Abstraction in North Yorkshire. Volume 1 - General Report

ANNEX 6

Blank Calculation Sheets for Assessment of Low Flows

HYDROLOGICAL INDICATOR

NRA REGION: NAME OF STREAM: DATE:

(see Report Chapters 7.1 to 7.6 for full explanation of the methodology)

H1 ANNUAL LICENSED ABSTRACTION / ANNUAL RECHARGE parameter

Total Groundwater ALA =		m3/a	(GWALA)
Calculated AR (long-term average) =		m3/a	(AR1)
Calculated AR (1 in 10 yr drought) =		m3/a	(AR2)
Total Surface Water ALA =		m3/a	(SWALA } *ONLY enter if H2 not used and*
Effluent Returns (annual) =		m3/a	(ER) } *ALA is supported by spring flow*

For average: ALA/AR (1) = (GWALA+SWALA-ER)/AR1 =
For drought: ALA/AR (2) = (GWALA+SWALA-ER)/AR2 =

ALA/AR (1)	Score	ALA/AR (2)
>1.0	4	>0.8
0.7-1.0	3	0.5-0.8
0.4-0.7	2	0.3-0.5
0.2-0.4	1	0.1-0.3
<0.2	0	<0.1

Assign score: H1 = (average) (drought)

H2 DAILY MAXIMUM LICENSED ABSTRACTION / Q95 "NATURAL" parameter

Total Surface Water DMLA =		m3/d	(SWDMLA)
Q95(7) =		m3/d	(QNF)
Total Groundwater DMLA (<250m from river) =		m3/d	(GWDMLA) }
Effluent Returns (mean daily) =		m3/d	(ERTWO) } *ONLY enter if H1 not used*
Compensation Releases (mean daily) =		m3/d	(CR) }

DMLA/Q95 = (SWDMLA+GWDMLA-ERTWO-CR)/QNF =

DMLA/Q95	Score
>1.0	4
0.7-1.0	3
0.4-0.7	2
0.2-0.4	1
<0.2	0

Assign score: H2 =

H3 GROUNDWATER GRADIENTS : CURRENT V HISTORIC parameter

Old Piezometric Gradient =		m/km	(OPG)
New Piezometric Gradient =		m/km	(NPG)
Number of years =		yrs	(YRS)

% Change in Gradient = 1 - (NPG/OPG) x 100 = (i)
Annual Rate of Change = i/YRS = (di/dt)

di/dt	Score
>8%	4
5-8%	3
2-5%	2
0.5-2%	1
<0.5%	0

Assign score: H3 =

HYDROLOGICAL INDICATOR

NRA REGION: NAME OF STREAM: DATE:

(see Report Chapters 7.1 to 7.6 for full explanation of the methodology)

H4 CHANNEL SIZE parameter

Cross Section	Current XSA of flow (m2)	Normal XSA of flow (m2)	Current / Normal
1			
2			
3			
4			
5			
		Mean =	

% of Channel	Score
<10%	4
10-30%	3
30-50%	2
50-70%	1
>70%	0

Assign score: H4 =

H5 RESIDUAL FLOW parameter

MINIMUM ECOLOGICALLY ACCEPTABLE FLOW

(Note: MEAF is under development as part of NRA R&D Project B2.1 and is as yet undefined)

Q95(7) 'natural' = m3/d
Total Surface Water DMLA (see H2) = m3/d
MEAF (critical month) = m3/d (Q95-DMLA)/MEAF =

(Q95-DMLA)/MEAF	Score
<60%	4
60-80%	3
80-100%	2
100-120%	1
>120%	0

Assign score: H5 =

H6 MOVEMENT OF SPRINGHEAD parameter

Total length of reaches changed from perennial to intermittent = km
Total length of reaches changed from intermittent to ephemeral = km
Sum = km

Sum of reaches (km)	Score
>8	4
4-8	3
2-4	2
0-2	1
0	0

Assign score: H6 =

CALCULATION OF HYDROLOGICAL INDICATOR

Parameter	Param. weight	Weight of params. used	Score	Weight x Score
H1	0.3			
H2	0.3			
H3	0.2			
H4	0.2			
H5	0.6			
H6	0.2			
		SUM1 =	SUM2 =	

Hydrology Severity Index = SUM2/(SUM1x4) =

Hydrology Reliability Index = SUM1 = *(If SUM1>1, set SUM1=1)*

ECOLOGICAL INDICATOR

NRA REGION: NAME OF STREAM: DATE:

(see Report Chapters 8.1 to 8.5 for full explanation of methodology)

E1 INVERTEBRATE COMMUNITY parameter

Generate potential ASPT:

Select multipliers:

SOURCE =		SOURCE: Upland = 1; Lowland = 0.8
REACH =		REACH: Headstream = 1; Mid = 0.95; Lower = 0.9
CHAN.MODS. =		CHANNEL MODIFICATIONS.: Limited = 1; Moderate = 0.95; Extensive = 0.9
EFF.COMP. =		EFFLUENT COMPONENT: Low = 1; Moderate = 0.95; High = 0.9

Potential ASPT =

Measured ASPT =

Score		Potential ASPT					
		<4.6	4.6-5.0	5.1-5.5	5.6-6.0	6.1-6.5	>6.5
	<4.5	0	1	2	3	4	4
	4.6-5.0		0	1	2	3	4
Measured	5.1-5.5			0	1	2	3
ASPT	5.6-6.0				0	1	2
	6.1-6.5					0	1
	>6.6						0

Assign score: E1 =

E2 FISHERY parameter

Score						
Fisheries under normal flow conditions		Decline in fisheries under low flow conditions to: b)	c)	d)	e)	<e)
Game	a) Trout, Salmon	1	2	3	4	
	b) mixture of a) & c)		1	2	3	
Coarse	c) Barbel, Chub, Dace, Perch, Pike, Roach, etc.			1	2	
	d) Bream, Perch, Roach Tench				1	
Estuarine	e) Eels, Flounders					1

OR:

Short-term impact parameter	Score
No fishing was possible during a fishing season as a result of low flows	4
No evidence of short-term impact of low flows on fisheries	0

Assign score: E2 =

E3 FISH STOCKS parameter

Generate potential fish stock:

Past fish stock (N) =

Select multipliers:

CHAN.MODS.=		CHANNEL MODIFICATIONS: Low = 1; Moderate = 0.9; High = 0.8
EFF.COMP. =		EFFLUENT COMPONENT: Decrease = 1; No Change = 1; Increase = 0.8

Potential fisk stock (NP) =

Measured present fish stock (NM) =

Present/Potential Fish Stock (FSR%) =

Present/Potential	Decline related to low flows	Score
<40%	Serious decline	4
40-59%	Large decline	3
60-79%	Moderate decline	2
80-99%	Small decline	1
>100%	None	0

Assign score: E3 =

ECOLOGICAL INDICATOR

NRA REGION: NAME OF STREAM: DATE:

(see Report Chapters 8.1 to 8.5 for full explanation of methodology)

E4 **PLANTS** parameter

Description of changes	Score
The bankside flora has changed or is changing due to a lower water table	4
Marginal terrestial plants regularly invade the river channel in the summer	2
No change, other than normal seasonal variation in channel or bankside flora	0

Assign score: E4 =

E5 **CONSERVATION** parameter

Only use this parameter if other Ecological parameters are also used

Formally designated sites:

Description	Score
Nationally or Internationally designated sites (eg Ramsar, SSSI, National Nature Reserve) as well as protected species under the Countryside Act	3
Conservation sites of regional or county importance (eg Naturalist Trust Reserve, RSPB Reserve)	2
Local nature reserves	1
No formal designation	0

Sites within the river system:

Description	Score
High conservation value, eg a diverse, natural and typical habitat of a viable size and containing species sensitive to disturbance	3
Moderate conservation value, eg a smaller or less diverse site; or a site with natural or typical habitat but no sensitive species	2
Site of no or low conservation value	1

Add scores to a maximum of 4.

Assign score: E5 =

CALCULATION OF ECOLOGICAL INDICATOR

Parameter	Param.weight	Weight of params. used	Score	Weight x Score
E1	0.4			
E2	0.2			
E3	0.3			
E4	0.1			
E5	0.3			
		SUM1 =	SUM2 =	

Ecology Severity Index = SUM2/(SUM1x4) =

Ecology Reliability Index = SUM1 = *(If SUM1>1, set SUM1=1)*

LANDSCAPE AND AMENITY INDICATOR

NRA REGION: NAME OF STREAM: DATE:

(see Report Chapters 9.1 to 9.5 for full explanation of methodology)

L1 LANDSCAPE DESIGNATION AND RARITY parameter

For Landscape Designation:

Description	Score
Important in a national context, ie National Parks and Areas of Outstanding Natural Beauty	2
Important in a local context, ie Country Parks	1
Landscape has no official designation	0
An additional score may be awarded to :	
Areas which are undergoing environmental improvements (either national or local) and where finance exists to suport such improvements, ie areas with Development Corporation Areas, Local Initiative Areas	+1

For Landscape Rarity:

Description	Score
Where river/river corridor landscape is "the only" or "one of the best examples of..." in the national context	2
Where river/river corridor landscape is "the only" or "one of the best examples of..." in the local context	1
The river has no rarity value	0

Add scores to a maximum of 4. Assign score: L1 =

L2 IMPORTANCE OF THE RIVER AS A LANDSCAPE FEATURE AND ITS IMPACT ON ADJACENT LAND parameter

For Importance:

Description	Score
High importance - dominant landscape feature, due to associated artifacts such as weirs, bridges etc.	3
Medium importance - only stretches of the river are visible, or the course is only noticeable because of bankside vegetation being visible	2
Low importance - the river is barely noticeable	1

For Impact:

Description	Score
Where a beneficial adjacent land use (within 500m) is primarily as a result of man's impact on, or management of, the river	-1
Where a degraded or unsightly adjacent land use is primarily as a result of man's impact on, or management of, the river, which could be remedied if remedial action were taken to the river	+1

Add scores to a maximum of 4. Assign score: L2 =

L3 RECREATION parameter

Description (do not include fishing/angling)	Score
3 or more water-contact recreational activities were unable to take place during consecutive periods over a 5 year period	4
3 or more water-contact recreational activities were unable to take place at any time in any one 12 month period	3
1 or 2 water-contact recreational activities were unable to take place at any time in any 12 month period	2
Any water-contact recreational activity was affected by low flows within the last 5 years. This also includes a reduction in enjoyment of a sport, resulting from low river flows	1
Where no change has been noted	0
An additional score may be awarded where: The river was able to support a water-contact recreational activity within the past 25 years, but this activity is no longer possible due to lower river flows	+1

Maximum of 4. Assign score: L3 =

LANDSCAPE AND AMENITY INDICATOR

NRA REGION: NAME OF STREAM: DATE:

(see Report Chapters 9.1 to 9.5 for full explanation of methodology)

L4 **AMENITY** parameter

For Odour:

Description	Score
Strong odour at channel edge, eg sludge, sewage,chemical or farmyard wastes and noticeable at a distance of > 10m from the channel	2
Noticeable odour at the channel edge	1
No noticeable odour	0

For Visual Impairment at the river channel:

(Elements include unnatural water colour, farm wastes, foam, sewage, fungus, crude sewage, visible solids, rotting vegetation)

Description	Score
2 or more of the elements which persist over a period of several months, as result of low flows, or 3 or more of the above elements which occur intermittently	3
1 or 2 of the elements which persist over a period of several months, as result of low flows	2
1 of the elements which occurs intermittently, as a result of low flows	1
No visual problem	0

For Visual Impairment on the river bank and adjacent land:

Description	Score
Where planning designation encourages public use	+1

Add scores to a maximum of 4. Assign score: L4 =

L5 **HISTORICAL AND CULTURAL ASSOCIATIONS** parameter

Description	Score
Sites of national historical/archaeological interest, ie National Monuments, National Trust	4
Sites of regional historical/archaeological interest	3
Sites which have national cultural associations such as paintings and literature, or local archaeological sites	2
Sites of local historical/archaeological, cultural or literary interest, such as place names	1
No historical or cultural associations	0

Assign score: L5 =

CALCULATION OF LANDSCAPE AND AMENITY INDICATOR

Parameter	Param.weight	Weight of params.used	Score	Weight x Score
L1	0.3			
L2	0.4			
L3	0.4			
L4	0.2			
L5	0.1			
		SUM1 =		SUM2 =

Landscape and Amenity Severity Index = SUM2/(SUM1x4) =

Landscape and Amenity Severity Index = SUM1 = *(if SUM1>1, set SUM1=1)*

PUBLIC PERCEPTION INDICATOR

NRA REGION: **NAME OF STREAM:** **DATE:**

(see Report Chapters 10.1 to 10.2 for full explanation of methodology)

P1 PROXIMITY OF RIVER TO CENTRES OF POPULATION parameter

Description	Score
River flows through a large centre of population, ie a town	4
River flows through a small centre of population, ie a village	3
River flows within 1km of a town	2
River flows within 1km of a village	1

(If unsure, use: Town = > 10,000 pop.)

Assign score: P1 =

P2 COMPLAINTS RECEIVED FROM THE PUBLIC parameter

Description	Score
Written complaints received from national organisations in support of local pressure groups formed specifically to deal with problems affecting the river and it's environment	4
Written complaints received from national organisations or local clubs or pressure groups	3
A moderate number (> 5/annum average) of written complaints received from individuals about problems related to low river flows over a period of years	2
Up to 5/annum average written complaints received from individuals about problems related to low river flows over a period of years	1
No complaints received about problems related to low river flows	0

Assign score: P2 =

CALCULATION OF PUBLIC PERCEPTION INDICATOR

Parameter	Param.weight	Weight of params.used	Score	Weight x Score
P1	0.3			
P2	0.7			
		SUM1 =		SUM2 =

Public Perception Severity Index = SUM2/(SUM1x4) =

Public Perception Reliability Index = SUM1 = *(if SUM1>1, set SUM1=1)*

COST INDICATOR

NRA REGION: NAME OF STREAM: DATE:

(see Report Chapter 11 for full explanation of methodology)

Cost Indicator is expressed as BENEFIT/COST ratio

BENEFIT:

Increase in low flow resulting from alleviation scheme = _____ Ml/day
Benefit (or Value) = (approx.) _____ million

COST:

Net Present Value of costs of alleviation scheme = _____ million
(discount rate = 5% over 30 years)

BENEFIT/COST ratio = _____

Scott Wilson Kirkpatrick Report 1991

CALCULATION OF OVERALL INDICATORS

NRA REGION: NAME OF STREAM: DATE:

OVERALL SEVERITY INDEX (SI)

SI type	SI	Weight	Weighted SI
Hydrological SI		40.0%	
Ecological SI		30.0%	
Landscape and Amenity SI		10.0%	
Public Perception SI		20.0%	
		Total SI =	

OVERALL RELIABILITY INDEX (RI)

RI type	RI (orig.)	RI (</= 1)	Weight	Weighted SI
Hydrological RI			40.0%	
Ecological RI			30.0%	
Landscape and Amenity RI			10.0%	
Public Perception RI			20.0%	
			Total RI =	

POSSIBLE ACTION

SI	RI	Action
High	High	Put in Capital Programme for Alleviation
High	Low	Further studies required
Low	High	No action unless strong public pressure, in which case mount public relations campaign
Low	Low	No action unless strong public pressure, in which case initiate minimum cost further studies and mount public relations campaign

INFLUENCE OF COST ON PRIORITIES

Total Severity Index (TSI) =	
Benefit/Cost ratio =	
TSI, taking account of Benefit/Cost ratio =	