Environmental Protection Report

EXE FRESHWATER MODEL – QUASAR MODEL DESIGN

24 August 1992
RP–NRA–1981AA–1001(01)
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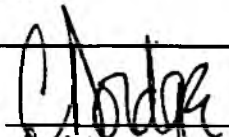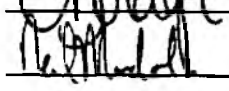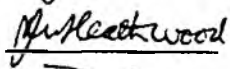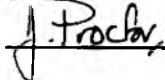
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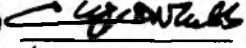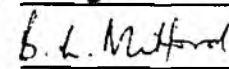
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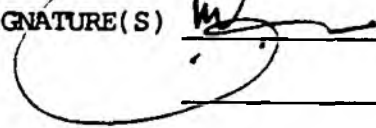
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EXE FRESHWATER MODEL

FOREWORD

The Water Quality function has to assess their response to the determination of abstraction licence applications on the basis that the proposed water resources development does not cause deterioration in water quality (if at all) of more than 10%   This effect is defined using key appropriate determinands for the affected inland water or ground water.   Large developments affecting almost the whole of a major river system are assessed using a water quality simulation model - QUASAR.

A licence application for a Wimbleball Pumped Storage Scheme was received in January 1993.

The generic QUASAR model requires ...

o   a design, setting out the physical representation of the river

o   calibrating, using a quality controlled data set; and

o   a proposed scenario(s) for modelling.

Three associated reports describe these three processes for the assessment of the Wimbleball Pumped Storage Scheme proposal.

These three reports are...

RP-NRA 1981AA_1001 (01)   Quasar model design

RP-NRA 1981AA_1002 (01)   Quasar validation/calibration

RP-NRA 1981AA_1004 (01)   Wimbleball pumped storage scheme scenario modelling

This foreword is at the front of each of these separate reports to place them in context with one another.

Alan Weston
Water resources planning officer

Project Title   :   Exe Freshwater Model

Document Title   :   QUASAR Model Design

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NRA - South West

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Contents

1. Introduction

The plan for setting up a model was described in the document, 'QUASAR Set Up Manual', N. Murdoch & B. Mann, Dec. 1990, (NRA ref. DI/04/02/0001/D3), in which three tasks were identified. These tasks were :

Task 1	–	river specification
" 2	–	data collection and entry
" 3	–	model checking

This document deals with Tasks 1 and 2.

2. River Specification

2.1.1 NRA Project Team
The project team was as follows :

Project Manager	Malcolm Newton	Responsible for overseeing the project.
Project Leader	Neil Murdoch	Responsible for planning the project and resolving technical issues
Project Sponsor	Rosanne Broome	The ultimate user. Responsible for ensuring the delivered goods will meet requirements. Also responsible for chemical water quality modelling issues.
EP Planner	Judy Proctor	Responsible for accepting the model from the modeller; running the model and providing output to the project sponsor.
Modeller	Cathy Doidge	Responsible for constructing the model and validating it.

2.1.2 SWW Project Team

Hugh Sambrook**	Responsible for overseeing the planning and resolution of the technical issues in the project.
Dave Croome**	Responsible for ensuring WH have all necessary help and liaison within SWWSL in resolving computer related aspects (hardware and software).
Ashley Gray*	Responsible for ensuring all water quality aspects of the project are planned, resourced and executed within agreed timescales, as well as identifying and resolving technical issues, and overall interpretation.
Allan Philp*	Responsible for co-ordination of data analysis and data auditing in the WH Bridgwater office; also acting as backup modeller.
Tom McVey*	Responsible for QUASAR river water quality modelling, data analysis and auditing.
Derek Rodman*	Responsible for interpretation of reservoir water quality aspects, particulary related to algae.

Paul Battersby*   Responsible for data analysis

Spencer Searle*   Responsible for data analysis (Bridgwater office)

**   indicates South West Water Services Limited personnel
*   indicates Watson Hawksley personnel

2.2 Modelled Branch
The modelled branch is from Wimbleball Reservoir to Trews Weir, Exeter.

2.3 Tributaries and Runoff
The tributaries modelled as inputs to the modelled branch are :

Upper R. Exe
R. Pulham
R. Barle
R. Brockey
Ironmill Stream
R. Batherm
Calverleigh Stream
R. Lowman
R. Dart
R. Burn
R. Culm
R. Creedy

Runoff is not directly modelled but is included in Micro Low Flow
Statistics (Regional Version) from which the natural input flows are
obtained.
Water quality determinands, if not available on the tributary, are
provisionally set at the same values as those at the nearest downstream
sampling points. This procedure will be re-appraised later.

2.4 Discharges
The following discharges will be modelled :

Tiverton Sewage Treatment Works
Thorverton Sewage Treatment Works
Brampford Speke Sewage Treatment Works

Heathcotes Dye Works

Hartford Fish Farm
Exe Valley Fish Farm
Highleigh Fish Farm
Oakfordbridge Fish Farm

The decision to include these in the model was based on informed judgement
by NRA SW water quality staff.

2.5 Abstractions

The following abstractions will be modelled :

Exebridge (to River Taw)
Bolham Treatment Works
Northbridge (to Pynes Treatment Works)

Heathcotes off-take

Hartford Fish Farm
Highleigh Fish Farm
Oakfordbridge Fish Farm

The decision to include these in the model was based on informed judgement by NRA SW water quality and hydrology staff.

(NB   Exe Valley Fish Farm abstracts from R Barle)

2.6 Reaches

The modelled branch of the Exe is segmented into the following reaches :

1	Wimbleball	–	Hartford
2	Hartford	–	Pixton
3	Pixton	–	Exebridge
4	Exebridge	–	Oakford
5	Oakford	–	Halfpenny Bridge
6	Halfpenny Bridge	–	Lythcourt
7	Lythcourt	–	Bolham Leat
8	Bolham Leat	–	Tiverton New Bridge
9	Tiverton New Bridge	–	Collipriest
10	Collipriest	–	Ashley
11	Ashley	–	Bickleigh
12	Bickleigh	–	Thorverton
13	Thorverton	–	North Bridge
14	North Bridge	–	Stafford Bridge
15	Stafford Bridge	–	Exwick
16	Exwick	–	Trews Weir

2.7 Diagram

Figure 2.1 is a schematic representation of the modelled branch, tributaries, discharges, abstractions and reaches.

Reach

```
                        WIMBLEBALL
                            |
        PULHAM_____|
                            |_____  Hartford FF Abstraction
                            |
   1        HARTFORD        |
                            |_____  Hartford FF Discharge
        UPPER EXE_____      |
                            |
   2         PIXTON         |
                            |
        BARLE_____|
                            |_____  EXE abstraction to R Taw
                            |_____  EXE Valley FF Discharge
   3        EXEBRIDGE       |
                            |
        BROCKEY_____|
                            |_____  Highleigh FF Abstraction
                            |_____  Highleigh FF Discharge
   4         OAKFORD        |
                            |_____  Oakfordbridge FF Abstraction
                            |_____  Oakfordbridge FF Discharge
        IRONMILL_____      |
                            |
   5        HALFPENNY       |
                            |
        BATHERM_____       |
                            |
   6        LYTHCOURT       |
                            |
                            |_____  BOLHAM abstraction
                            |
   7        BOLHAM LEAT     |
                            |
        CALVERLEIGH____     |
                            |_____  HEATHCOATS abstraction
                            |
   8         TIVERTON       |
                            |
        LOWMAN_____       |
                            |_____  HEATHCOATS discharge
                            |
   9        COLLIPRIEST     |
                            |
                            |_____  TIVERTON STW
                            |
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10              ASHLEY
                       |
 DART_____|
11              BICKLEIGH
                       |
 BURN_____|
                       |_____  THORVERTON STW
                       |
12              THORVERTON
                       |
                       |_____  NORTHBRIDGE abstraction
                       |
13              NORTH BRIDGE
                       |
 CULM_____|
                       |
14              STAFFORD
                       |              BRAMPFORD
                       |_____  BRAMPTON SPEKE STW
 CREEDY_____|
                       |
15              EXWICK
                       |
                       |
16              TREWS WEIR
```

3. Data

3.1 Spatial Data
The following spatial data were obtained as indicated :

Lengths	—	measured from 1:25000 OS maps
Depths	—	no measurements so assumed to be 1m
Widths	—	as for Depths, assumed to be 15m

The depths are used to scale the water quality decay rates; they are not used in computing the hydraulics. The widths are not used and are included for reference only.

3.2 Velocity Flow Relations
$V = a + bQ^c$

These have been provisionally set with

	Haddeo	Exebridge	Bolham	Bickleigh	Thorverton	Pynes
a	0	0	0	0	0	0
b	0.4	0.1	0.1	0.1	0.1	0.1
c	0.5	0.7	0.7	0.7	0.95	0.3

These values were deduced from the time of travel studies 1978 by G H Murrell (see 'Assessment of Travel Time of Wimbleball Reservoir Water – River Exe', G.H Murrell , July 1978)
The values may be revised during the validation in Task 3.

3.3 Daily Mean Flows
These were provisionally derived as follows, (and may be revised) :

-   the daily mean flows from Wimbleball (plus 0.09 cumecs daily to provide for the springs).
-   the daily mean flows were available from gauging stations at Pixton, Stoodleigh and Thorverton on the River Exe; Woodmill on the River Culm and Cowley on the River Creedy.
-   Theoretical ADFs (average daily flows) for each ungauged tributary using Micro Low Flow statistics.

The daily mean flows for tributaries were found by the ratio of their ADFs to the downstream gauging station ADFs.

Daily mean flow data could not be derived by this method for the abstractions and discharges, and the following assumptions are being used (provisionally)

Exebridge Abstraction
The abstraction is in operation from May to September. Daily values were obtained from SWWSL.

Bolham Abstraction
    Daily mean values were obtained from SWWSL.

Pynes Abstraction
    As for Bolham

Heathcoats Abstraction
    The discharge consent of :
        ~0.042 cumecs is provisionally used.

Fishfarm Abstractions
    Approximate Licences of Entitlement are provisionally used:
        ~0.555 cumecs   Hartford
        ~0.750 cumecs   Highleigh
        ~1.200 cumecs   Oakfordbridge

    Highleigh and Oakfordbridge abstract between 50 and 60 percent of
    this amount during low summer flows. For June to September
    abstractions of
        ~0.375 cumecs   Highleigh
        ~0.750 cumecs   Oakfordbridge
    are provisionally used.

Discharges

Tiverton Sewage Treatment Works
        The consented Dry Weather Flow of :
            ~0.080 cumecs is provisionally used.

Thorverton Sewage Treatment Works
        The consented Dry Weather Flow of :
            ~0.002 cumecs is provisionally used.

Brampford Speke Sewage Treatment Works
        The consented Dry Weather Flow of :
            0.001 cumecs is provisionally used.

Heathcoats Discharge
        The consented discharge maximum of :
            0.042 cumecs is provisionally used.

Fish Farm Discharges
        The LOEs were used for both abstraction and discharge at Hartford,
        Highleigh and Rainbow Valley.
        Exe Valley Fish Farm abstracts from R. Barle but discharges into the
        R. Exe. LOE is 0.789 cumecs. In some cases this exceeds the flow in
        the River Barle and hence could not have been abstracted. The LOE
        implies that a significant proportion of the flow is abstracted in
        the summer months. In order to keep the water budget correct, the
        abstraction and discharge volumes are not modelled. (See 3.4 below
        for water quality aspects.)

3.4 Monthly Mean Determinands

The following determinands were obtained from the water quality archive.
These are spot sample data at routine sampling points and are used to
represent the monthly mean determinands in the model :

- DO
- BOD
- nitrate
- ammonia
- pH
- temperature.

The National Grid Reference (NGR) and User Reference Number on the Water
Quality Archive (URN) for these routine monitoring points, are listed in
Appendix A.

The data for the inputs were as follows :

For the year 1990

Wimbleball-	D/S node		R05G003
Pulham	–	WQ sampling point URN =	R05G009
Upper Exe	–	D/S node	R05G003
Barle	–	D/S node	R05E001
Brockey	–	WQ sampling point	R05E012
Ironmill	–	WQ sampling point	R05E008
Batherm	–	WQ sampling point	R05F003
Lowman	–	WQ sampling point	R05E011
Calverleigh		WQ sampling point	R05E020
Dart	–	WQ sampling point	R05D007
Burn	–	WQ sampling point	R05D008
Culm	–	WQ sampling point	R05C013
Creedy	–	WQ sampling point	R05J004

For the year 1989:-

As for 1990 except that data from three sites were not available so
the following were used:

Upper Exe	–	D/S node	R05E001
Calverleigh		D/S node	R05E004
Burn	–	D/S node	R05D001

No E. coli. concentrations for any site, either year were available.

Tiverton Sewage Treatment Works
Thorverton Sewage Treatment Works
Brampford Speke Sewage Treatment Works
Data from archive except for :

- DO   – No values were available. A DO value of 1.5
mg/l was assumed (ref R. Toft, Principal
Analyst, NRA SW).

<u>Heathcotes Dye Works</u>
Data from archive except for :
-     DO   -   No values were available. A DO value of 1.5mg/1 was assumed following analysis of Dissolved Oxygen concentrations in the effluent.

<u>Fishfarms (except for Exe Valley Fishfarms)</u>
Data for 1989 were very sparse so 1990 data from archive were used for both years. (This includes ammonia.)
Discrepancies in temperature and pH values were investigated by studying the Upstream/Downstream samples.

> Temperature: Fish farm and D/S river samples did not vary much but were normally taken early in the morning so did not include higher afternoon temperatures. Downstream node temperatures were used as fish farm input data.

> pH: There is a short-term effect possibly caused by CO_2 lasting only a few metres in the river. Downstream node pH values were used as fish farm input data.

<u>Exe Valley Fishfarm</u>
> Since the LOE is a significant proportion of the River Barle flow during the summer months, and in some cases exceeds it, the Fishfarm water quality determinands were applied to the River Barle inflow from June to September. During the winter months the downstream water quality on the River Exe was used. There is no direct sampling at the River Barle inflow.

3.5 Other Data
Water quality data are available at several reach nodes on the river. These data will be used in calibration/validation. The sampling points are:

Pixton	R05G003
Halfpenny Bridge	R05E002
Tiverton	R05E004
Collipriest	R05E005
Ashley	R05E006
Thorverton	R05D001
Stafford Bridge	R05D002
Exwick	R05D003
Trews Weir	R05D004

> Of these sites only three, Pixton, Tiverton and Thorverton, have been used for small tributaries in the model.

3.6 Choice of Year
Models for the years 1989 and 1990 are to be constructed initially.

3.7 Map File
The above data will be assembled into QUASAR Map Files called 'EXE_89.MAP' and 'EXE_90.MAP'.

Appendix A

Reach Information

	Reach Name	Length (m)
1	Hartford	1300
2	Pixton	4700
3	Exbridge	2000
4	Oakford	3100
5	Halfpenny Br	4600
6	Lythcote	7700
7	Bolham	1000
8	Tiverton	1500
9	Collipriest	1800
10	Ashley	2000
11	Bickleigh	3900
12	Thorverton	7100
13	Northbridge	6500
14	Stafford Br	2300
15	Exwick	3800
16	Trews Weir	3700

Water Quality Data Sources

River	Site Name	NGR	URN
Pulham	Pulham River	SS959295	R05G009
Exe	Warmore	SS935260	R05G003
Exe	Exbridge	SS930245	R05E001
Barle	Exbridge	SS930245	R05E001
Brockey	Brocksbridge Cott	SS924245	R05E012
Iron Mill	Iron Mill Stream	SS938209	R05E008
Batherm	Bowbierhill Wood	SS955209	R05F003
Calverleigh	Swine Bridge	SS945139	R05E020
Exe	Tiverton New Br	SS949131	R05E004
Lowman	A373 Br. Tiverton	SS956126	R05E011
Dart	Dart Bridge	SS936076	R05D007
Burn	Burn Mill Farm	SS947055	R05D008
Exe	Thorveton GS	SS936017	R05D001
Culm	Stoke Cannon	SX938976	R05C013
Creedy	Oakford Farm	SX901968	R05J004