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LINKING HYDROLOGY AND ECOLOGY

RIVER WISSEY

ANNEX C

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ANNEX C

INSTREAM FLOW REQUIREMENTS OF THE RIVER WISSEY, NORFOLK

Undertaken for the National Rivers Authority, Anglian Region

By

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SUMMARY

This document is one of a series of Annexes which accompany the report 'The River Wissey: the link between hydrology and ecology' prepared for the National Rivers Authority by the Freshwater Environments Group at Loughborough University.

This study describes the use of the Physical Habitat Simulation System (PHABSIM) for prescribing instream flow requirements of the River Wissey, Norfolk. Essentially, PHABSIM is used to relate changes in discharge or channel structure to changes in physical habitat availability for a chosen species.

Seven sites were selected along the river. Water depth, velocity and substrate were recorded across seven transects and at three calibration discharges (low, medium and high) at each site. PHABSIM was then used to simulate the hydraulic characteristics of each reach over the full range of flows normally experienced. This information was then combined with habitat suitability criteria for seven species of fish (brown trout, dace, chub, roach, bream, pike and perch) and for four life stages for each (spawning, fry, juvenile and adult) and for four species of aquatic invertebrate (*Leuctra fusca*, *Rhyacophila dorsalis*, *Polycentropus flavomaculatus* and *Sphaerium corneum*). Relationships between discharge and the availability of usable habitat were then defined using PHABSIM and analysed to make recommendations concerning the instream flow requirements of the selected species.

ANNEX C INSTREAM FLOW REQUIREMENTS OF THE RIVER WISSEY, NORFOLK

C1 Introduction

The demand for habitat assessment methods that is now materialising in the U.K. has been evident in the U.S.A., particularly the western United States since the mid 1970's. A similar situation of increasing demands for irrigation, domestic, and industrial water supply led to the development of a variety of methods to assess fish habitat tradeoffs against other uses of water. The Instream Flow Incremental Methodology (IFIM) developed by the U.S. Fish and Wildlife Service Cooperative Instream Service Group (IFG) has been considered by some to be "the most scientifically and legally defensible method available for most instream flow problems" (U.S. Department of the Interior 1979). It is also one of the most widely used methods in North America for estimating the effect of changes in flow on trout habitat (Conder and Annear 1987) and is described as "the current state of the art" (Orth 1987).

The Physical Habitat Simulation (PHABSIM) System is a set of computer models that are the cornerstone of the IFIM. Essentially, PHABSIM is used to relate changes in discharge or channel structure to changes in physical habitat availability for a chosen species. The underlying principles of PHABSIM are that:

1) the chosen species exhibits preferences within a range of habitat conditions that it can tolerate,
2) these ranges can be defined for each species, and
3) the area of stream providing these conditions can be quantified as a function of discharge and channel structure (Bovee 1982).

PHABSIM considers microhabitat as defined under this methodology to consist of two basic components *i.e.* rigid structural characteristics and variable hydraulic conditions.

Structural habitat characteristics reflect the hydrogeomorphology of the channel *e.g.* bed configuration, channel width or substrate composition and are assumed to be constant over a range of flows. The hydraulic variables which affect microhabitat utility are width, depth, and velocity. All three respond differently to changing discharge in conjunction with the structural nature of the channel and so the physical microhabitat is a complex array of combinations of these parameters. This array is redefined with a different set of depth, velocity, and structure combinations each time the discharge changes.

A natural stream contains a complex mosaic of physical features. One given species may find an area of deep, slow flowing water desirable whilst another may prefer an area of deep, fast flowing water. Alternatively, a third species may find neither conditions suitable. In order to quantify physical habitat, the area associated with each combination of features and an evaluation of that combination in terms of its suitability as a habitat for a particular species must be defined. When flow changes, the hydraulic variables will alter and so under the new flow, physical habitat has to be requantified.

PHABSIM consists of four basic components representing the process of;

1) data collection,
2) hydraulic simulation,
3) suitability index curve development, and
4) habitat simulation.

The following sections outline the requirements of each of these components in turn.

C2 Information Requirements Of PHABSIM

C2.1 Data collection

Provided that the reach is suitable for hydraulic simulation (*i.e.* macrohabitat conditions such as temperature variations and water quality will be suitable) hydraulic conditions are characterised at usually three known (calibration) streamflows from measurements taken along transects within the reach. Reaches can either be representative, *i.e.* they are similar to any other reach within an area and contain most of the hydraulic variance found in the entire section, or they can be critical, *i.e.* they are particularly sensitive to changes in streamflow or contain rare habitat for a particular species or life stage. Data collection is based on field measurements at a number of transects along a chosen reach under three different flows, *i.e.* low flow, medium flow and high flow conditions. Transects are located at right angles to the flow so as to sample;

1) all the hydraulic controls, *i.e.* physical aspects of the streambed that determine the height of the water surface upstream, and
2) all habitat types that are represented along the reach.

Point measurements of flow velocity, depth, water surface level, substrate and cover need to be undertaken at exactly the same points at intervals across each transect during each visit and hence the reach has to be surveyed in detail prior to this. Essentially, these field measurements determine the amounts of different habitat conditions in the channel at particular discharges. In order to describe how these conditions change under discharges that have not been measured in the field, PHABSIM is used for hydraulic simulation purposes.

C2.2 Hydraulic simulation

Hydraulic simulation models are then used to estimate depths, velocities and substrates at unmeasured flows (Bovee & Milhous 1978). The techniques used to simulate the hydraulic condition in a stream can have a significant impact on the habitat versus streamflow relationship determined in the habitat simulation portion of PHABSIM. The approaches available for calculation of water surface elevation at unknown discharges fall into one of three categories;

1) the stage-discharge relationship (the IFG4 program),
2) the use of Manning's equation (the MANSQ program), and
3) the standard step backwater method (the WSP program).

The following sections briefly outline each of the underlying concepts behind each application. A complete and detailed description of the theories underpinning each program has been discussed by Bovee and Milhous (1978).

IFG4

The most accurate method of obtaining a relationship between stage and discharge is to measure the discharge at various stages and to develop an empirical equation relating discharge to stage. This relationship is influenced by a number of factors, *e.g.* cross-sectional area, shape, slope and roughness and it is the interaction of these factors which control the relationship. Essentially, the IFG4 program uses an empirical equation between stage (*i.e.* water surface elevation) and discharge of the following form:

$$WSL = a\,Q^{b} \qquad \text{(Equation 1)}$$

where:
WSL = stage or water surface elevation
Q = discharge

a, b = regression coefficients from measures values of discharge and stage.

Using a log transformation for this equation, results in a linear function of the form:

$$\text{Log (WSL - SZF)} = \text{Log (a)} + b * \text{Log (Q)} \qquad \text{(Equation 2)}$$

where the water surface elevation has been adjusted by the stage of zero flow (SZF). Given two or more measurements of the stage - discharge relationship at a cross section, the above equation is then solved for the coefficients a and b which then serves as the basis upon which predicted stage is computed for any specified discharge. This is highlighted in figure C.1 below.

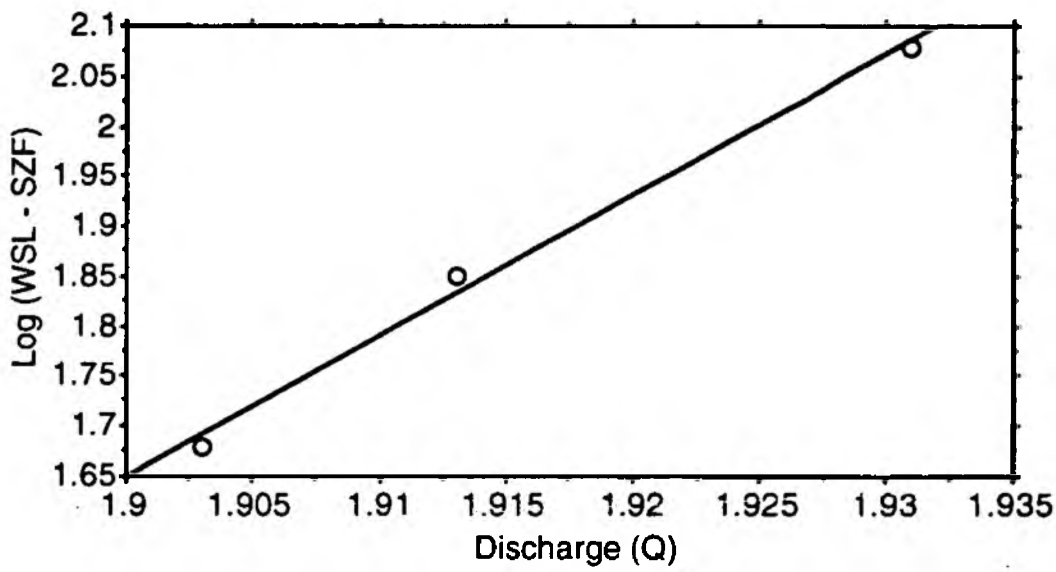

Figure C.1 - Example of a stage discharge relationship generated by IFG4

It is also important to note that the IFG4 treats each cross section independently of all others in the data set.

After satisfactory development of this relationship, velocities are predicted by solving Mannings equation. Velocity data is used from one of the measured flows to derive Mannings n from the following equation.

$$n_i = [\ 1.49 * S_e^{1/2} * d_i^{2/3}\ ] / v_i \quad \text{(Equation 3)}$$

where:
n_i = Estimated Mannings n value at vertical i
S_e = Energy slope for transect
d_i = Depth at vertical i
v_i = Velocity at vertical i

The apparent discharge for the transect is then determined from the predicted velocity values. This discharge may not necessarily be the same as the discharge requested in the simulation and so a Velocity Adjustment Factor (VAF) is obtained through the use of a mass balance to rectify this.

MANSQ

Similar to the IFG4 program, MANSQ treats each transect independently but will only simulate water surface elevations and not velocities. The Mannings equation can be written in the form:

$$Q = [\ (1.49 / n) * S^{1/2}\ ] * A * R^{2/3} \quad \text{(Equation 4)}$$

where:
Q = Discharge
n = Mannings n
S = Slope
A = Area of cross-section
R = Hydraulic radius

which can be simplified to :

$$Q = K\ A\ R^{2/3} \quad \text{(Equation 5)}$$

and the value of K is determined from one set of discharge-water surface elevation pairs. The MANSQ program calculates the average velocity in the channel and is not used to simulate individual cell velocities. Mannings equation is solved for n at one discharge for which the measurements of the water surface elevation and the discharge at the measured flow, the hydraulic slope and the dimensions of the cross section have been made. Mannings n is solved in accordance with the equations above and assumed constant in subsequent calculations where new stages are calculated for different discharges.

WSP

The Water Surface Profile (WSP) program differs from the previous two programs in that it treats cross-sections as dependent on the adjacent one downstream. The calculation of water surface elevations start from a known water surface elevation at the most downstream transect and uses the 'standard step backwater' method to calculate the water surface elevation at the next upstream cross section. This next cross section then becomes the downstream cross section and the water surface elevation for the next upstream is determined. The program provides very detailed depth and transverse velocity information. In this case, the model allows the computation of the change in roughness as a function of discharge by using roughness multipliers.

In many situations it may be necessary to use a mixture of models to simulate the hydraulic characteristics of the reach over the full range of flows. For instance, under low flows the IFG4 program may simulate water surface elevations and velocities most accurately whereas WSP may be more suitable over the higher flows. The correct choice of hydraulic model(s) as well as the proper calibration can be time consuming but may represent the most difficult step in the process of analysing streamflows.

C2.3 Suitability index curve development

The third step utilises the information developed in suitability index curves. Different species of fish,macroinvertebrates and aquatic macrophytes occupy different habitat types in streams. Knowledge about the conditions that provide favourable habitat for a species, and those that do not, is defined as habitat suitability criteria: characteristic behavioural traits of a species which cause it to select specific habitat types in terms of preferred water velocities, depths and substrates. For example, the habitat suitability curves for adult brown trout are shown below. A separate graph is constructed for the depths, velocities and substrate types. These are based on the fact that a functional relationship exists between a response variable (*e.g.* depth, velocity or substrate) and the degree to which the variable is "usable" over a scale of 0.0 (no use) to 1.0 (maximum use).

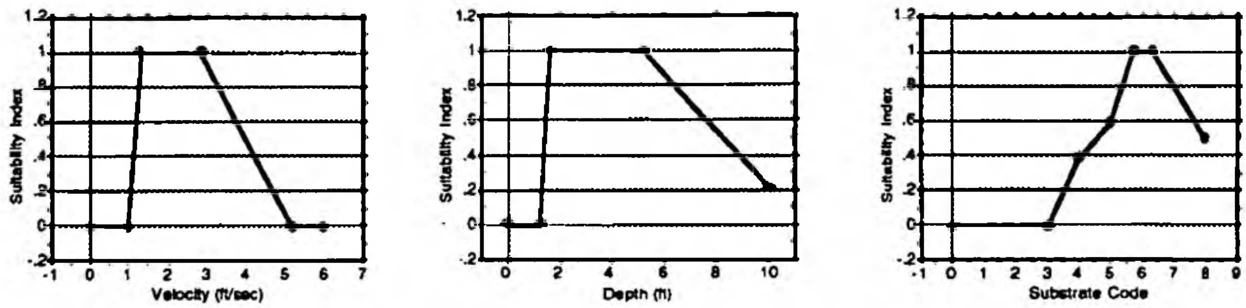

Figure C.2 - Examples of habitat suitability curves for adult brown trout.

Further information concerning the development and evaluation of habitat suitability criteria for use in the IFIM has been described by Bovee (1986).

C2.4 Habitat simulation

The final step is that of habitat simulation. Hydraulic simulation has already been applied to determine the characteristics of the stream in terms of depth, velocity and substrate as a function of discharge. Physical habitat or weighted usable area (WUA) in the reach is then quantified based on the suitability of the variables simulated by the hydraulic models for a target organism. Similar to the hydraulic simulation, PHABSIM contains a number of different programs that can be used for this purpose, each of which has specific conditions in which it can be most suitably applied.

Individual suitabilities are extracted from the habitat preference curves and these are combined to give a single cell suitability in one of three ways. Multiplicative aggregation is given by:

$$C_i = V_i * D_i * S_i \qquad \text{(Equation 6)}$$

where:

C_i = Composite suitability of cell i
V_i = Suitability associated with velocity in cell i
D_i = Suitability associated with depth in cell i
S_i = Suitability associated with substrate in cell i

Alternatively, the geometric mean can be used which implies a compensation effect. For example, if two of the three individual composite suitabilities are within the optimum range and the third is very low, the third individual composite suitability has a reduced effect on the computation of the composite suitability. It is calculated by:

$$C_i = (V_i * D_i * S_i)^{1/3} \quad \text{(Equation 7)}$$

Finally, the aggregate of the individual suitability factors using the concept of the limiting factor can be calculated by:

$$C_i = \text{Min} (V_i, D_i, S_i) \quad \text{(Equation 8)}$$

Once the composite suitability has been determined, the amount of Weighted Usable Area (WUA) is computed according to the equation:

$$WUA = \sum A_i * C_i \quad \text{(Equation 9)}$$

where:
WUA = Total weighted usable area in stream at specified discharge
C_i = Composite suitability for cell i
A_i = Surface area of cell i

With the final step completed, the effects of changes in streamflow on the physical habitat of the target organism can be evaluated by changes in the amount of WUA. This enables PHABSIM to present biological information in a format suitable for entry into the water resource planning process.

At this juncture it must also be emphasised that predictions of PHABSIM are explicitly made in terms of changes to the **physical properties of the aquatic habitat (*i.e.* velocity, depth and substrate)** and do not predict changes in the biomass of organisms. Failure to recognise this fact has led to much criticism in the literature when PHABSIM results were applied and interpreted without consideration for other factors such as water quality, temperature, food availability and fishing mortality.

C3 Use Of PHABSIM Within The Wissey Catchment

C3.1 Site Selection

Sites used for PHABSIM evaluation were selected to coincide with those used for invertebrate sampling. The criteria on which these sites were selected is outlined in Annex E. For PHABSIM simulation, each site consisted of a riffle - pool - riffle - pool - riffle sequence. Figure C.3 shows the location of these sites.

C3.2 Hydraulic Data

The guidelines established by Bovee and Milhous (1978) were followed to collect data for the hydraulic simulation models. Seven transects were established along each reach in order to sample the microhabitat variability present at each site. In each case, the most downstream transect was placed at right angles to the flow across a hydraulic control, *i.e.* the crest of a riffle. Moving upstream, cross-section two was placed across the centre of a pool, transects three, four and five across the middle riffle, cross-section six across the upstream pool and transect seven across the upstream riffle. Numbers three, four and five were also used for the invertebrate sampling outlined in Annex E. Survey markers were placed on either side of the stream at these transects and their exact position surveyed relative to each other. This enabled the accurate mapping of the reach for hydraulic simulation. Stream widths were recorded at each cross-section and the transect profiles were also surveyed. Water depths and velocities were measured using a standard Ott current meter type C2"10.150" across each transect at approximately equidistant points. The number of measuring points across each transect is shown in table C.1 below. Each transect is represented by between 15 and 38 points.

Table C.1 - Number of observation points per transect

	Transect No.							Max. Water
Site	1	2	3	4	5	6	7	Width (m)
Bodney Bridge	19	18	19	20	18	16	17	8.5
Chalk Hall Farm	18	21	19	20	16	16	19	8.0
Didlington Gravel	23	24	38	33	22	18	23	12.5
Didlington Sand	25	25	19	22	23	20	20	10.0
Langford Gravel	23	19	32	31	24	19	20	13.0
Langford Sand	20	18	19	20	21	15	28	12.0
Northwold	25	25	30	28	24	22	28	11.5

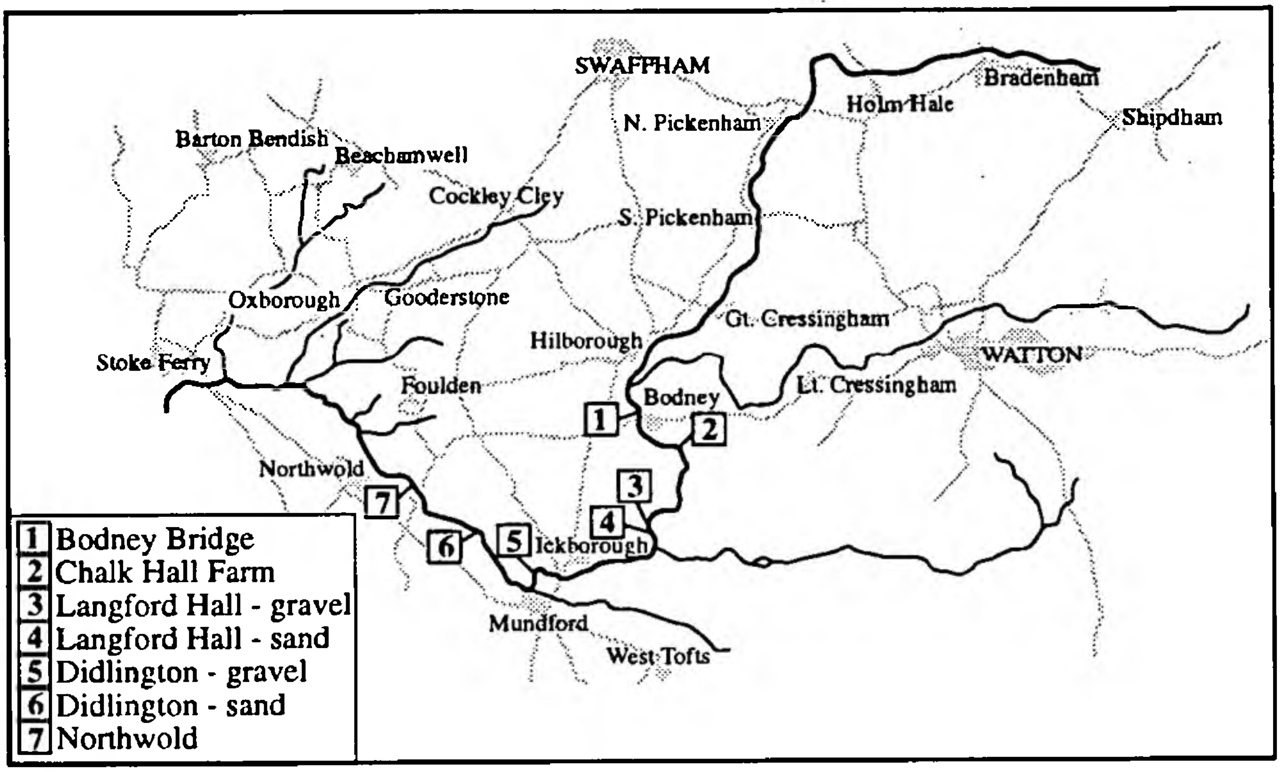

Figure C.3 - PHABSIM study site location.

Table C.2 - Discharges at Northwold gauging station during the field surveys at each site.

SITE NAME	LOW FLOW (cumecs)	MEDIUM FLOW (cumecs)	HIGH FLOW (cumecs)
Bodney Bridge	.225	.749	1.756
Chalk Hall Farm	.225	.749	2.326
Langford Hall - gravel	.225	.711	1.756
Langford Hall - sand	.225	.711	2.326
Didlington - gravel	.231	.705	1.756
Didlington - sand	.234	.701	2.326
Northwold	.234	.705	1.756

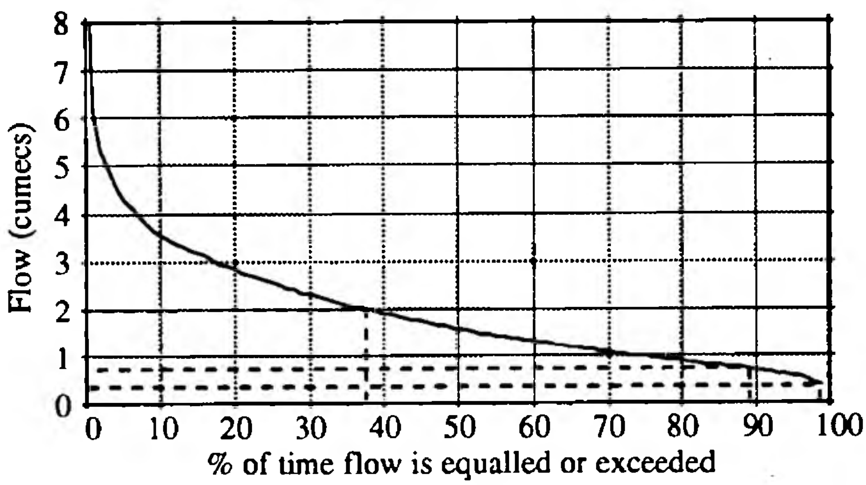

Figure C.4 - Flow duration curve for Northwold gauging station (1961-1987) and the associated percentiles at which calibration flows were measured.

Mean velocities were measured at 0.6 times the depth. Substrate type was also recorded for each point based on the presence of Wentworth (1922) grain size categories using the scheme proposed by Trihey and Wegner (1981) shown in table C.3 below. A mixture of two adjacent substrate types can also be described with this code. For example, a code of 5.5 indicates a substrate mixture of 50% gravel and 50% rubble. Similarly, a code of 4.2 indicates a mixture of 80% sand and 20% gravel.

Table C.3 - Substrate classification scheme after Trihey and Wegner (1981).

Code No.	Substrate Type
1.	Plant Detritus
2.	Mud
3.	Silt (< 0.062 mm)
4.	Sand (0.062 - 2 mm)
5.	Gravel (2 - 64 mm)
6.	Rubble (64 - 250 mm)
7.	Boulder (250 - 4000 mm)
8.	Bedrock (solid rock)

Each site was visited under three different flows i.e. low, medium and high calibration flows. On each occasion, water surface elevations and velocities were recorded whereas substrate is assumed to be constant and was therefore only recorded on one of the visits. For each stage that was surveyed, the discharge estimates at all cross-sections were averaged to obtain the overall stream discharge. The discharges at each site during the surveys are shown with the associated %ile flow from the nearest gauging station in table C.2 and figure C.4. The three flows for which the sites were sampled, successfully covered the majority of the normal flows experienced.

C3.3 Ecological data

Microhabitat suitability curves utilised in this study were originally developed by Armitage and Ladle (1989) and Mountford and Gomes (1989). The curves themselves were developed based on experience and local knowledge of UK conditions. Curves have been used for:-

- seven species of fish (Brown trout, Dace, Chub, Roach, Bream, Pike and Perch),

- four life stages for each fish species (i.e. spawning, fry, juvenile and adult),
- four species of aquatic invertebrates (i.e. one stonefly (*Leuctra fusca*), two caseless caddis (*Rhyacophila dorsalis* and *Polycentropus flavomaculatus*) and one pea mussel (*Sphaerium corneum*)).

Habitat preferences are expressed in each case as suitability functions of depth, velocity and substrate.

C4 PHABSIM Simulation And Results

For each site, data was processed through the standard paths described in sections C2.1 to C2.4 and shown diagramatically in figure C.5. The flows that are simulated at each site are constrained by certain guidelines laid down by the PHABSIM system based on realistic extrapolations from observed data. For instance, it is not possible to simulate hydraulic conditions under extreme high flows based on the measured data set during extreme low flows. Consequently, simulated flows never fall below 0.4 times the lowest calibration flow or 2.5 times the highest calibration flow. Hydraulic conditions were simulated with a combination of the IFG4 and WSP hydraulic simulation programs. For all habitat simulations, the most widely used multiplicative composite suitability index function was adopted as described in section C2.4 and Equation 6.

C4.1 Habitat versus discharge relationships

Output from the PHABSIM simulations were used to illustrate the habitat versus discharge relationships for the selected life stages and species. A full list of these results are shown in Appendix A. An example of this relationship is shown in figure C.6 which highlights the results for Brown trout at Northwold. Habitat is expressed as a percentage of the reach that is usable habitat for the chosen species/life stage and discharge is expressed in m^3s^{-1}. From this diagram it is possible to recognise three main features;

- critical flows below which the habitat availability rapidly declines,
- critical flows below which no habitat is available,
- the species and life stages for which the reach is most suitable.

From this example it is evident that the Northwold reach is more suitable for the juvenile life stage of brown trout but habitat availability rapidly declines below flows of 0.45 m^3s^{-1}. Also,

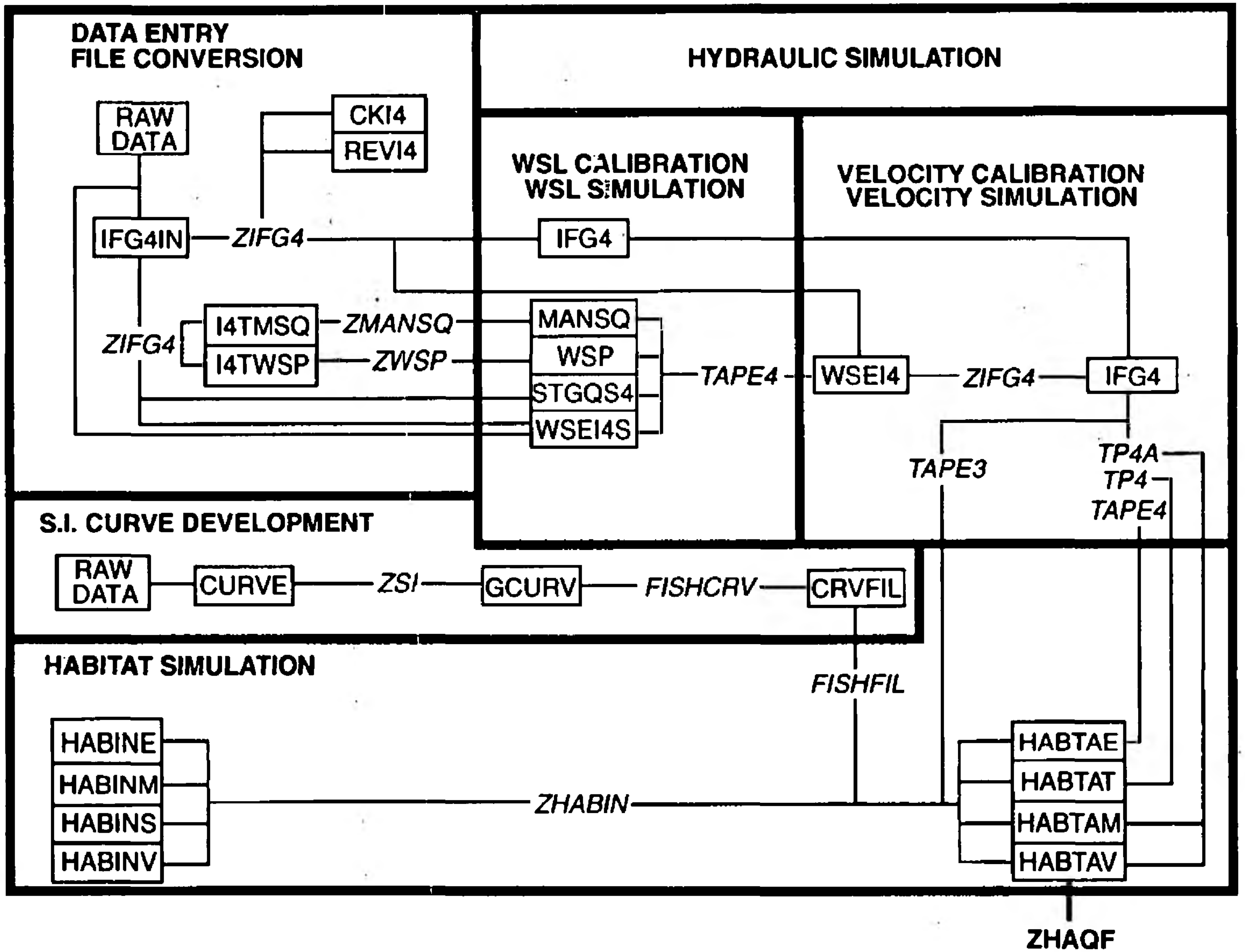

Figure C.5 - PHABSIM information flow. Programs are contained within boxes and default file names are italicized (Hardy 1991).

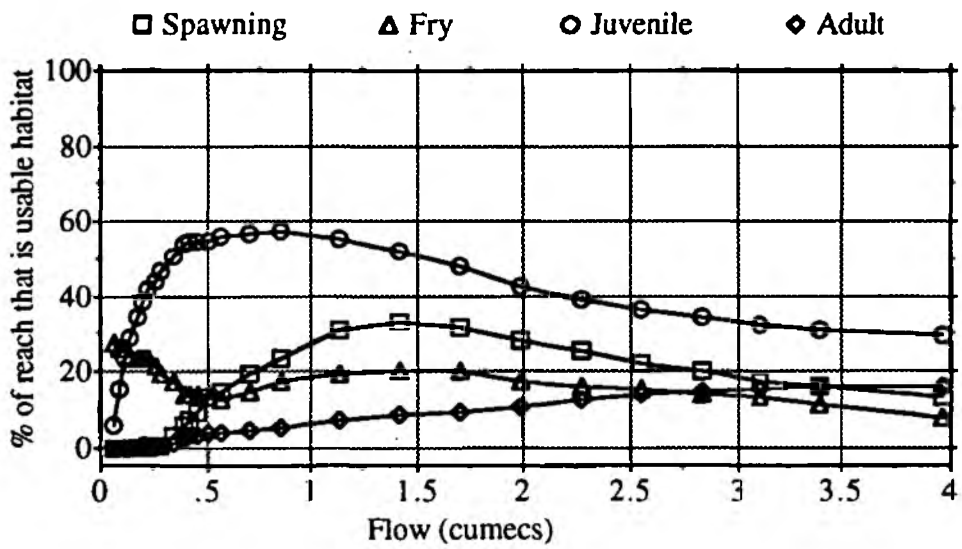

Figure C.6 - Habitat-discharge relationships for Brown trout at Northwold

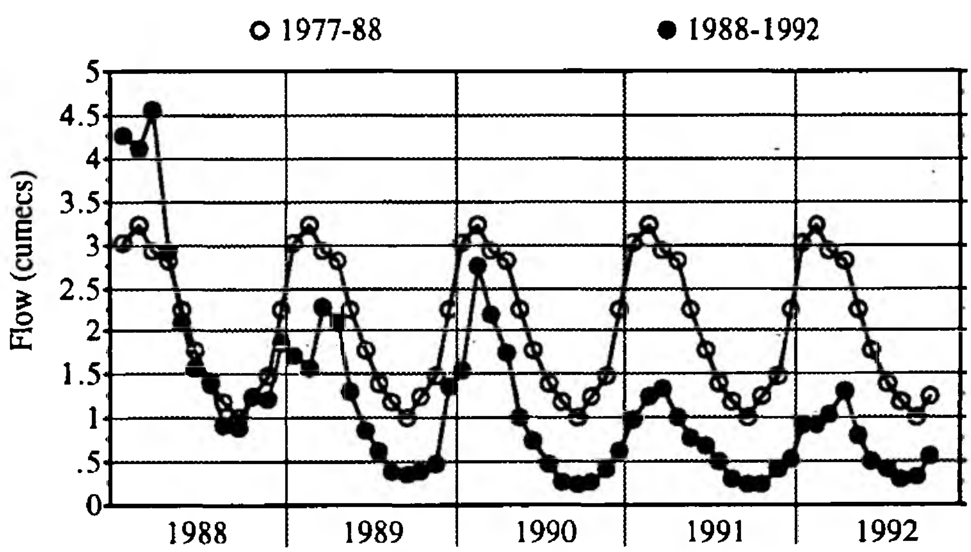

Figure C.7 - Discharge-time series based on average monthly flows at Northwold the reach is characterised by no suitable habitat for the adult life stage when flows are below 0.20 m^3s^{-1}.

These relationships highlight critical flows which are essential for the maintenance of habitat for each life stage. Further conclusions can be made when these results are assessed in conjunction with the actual flows that are experienced at the site. Long term average monthly flows, based on the period 1977-88 can be compared to those experienced during subsequent years (1988-92) as shown in figure C.7. During the 1977-88 period taken as a whole, average monthly flow varied from 3.227 m^3s^{-1} in February to 1.015 m^3s^{-1} in September. In the subsequent years, average monthly flow was consistently below the long term average from October 1988 with a minimum value of 0.228 m^3s^{-1} in September 1991. The following section models the effect of these reduced flows on habitat availability for the selected species.

C4.2 Habitat area-time series

The results of the discharge versus percent usable area relationships have been combined with the actual discharges experienced during the drought to show the effect these reduced flows have had on habitat area available for each life stage of brown trout at the Northwold site. Consequently, for this reach figure C.8 indicates the habitat area-time series for the 1977-88 'average' conditions and for 1988-92 for each life stage of brown trout.

For spawning:-

- the amount of suitable spawning areas normally ranges from 21% to 49% of the reach,
- spawning areas were available but in reduced amounts during November/December 1990 and 1991,
- flows during January 1991 and 1992 increased to levels which maintained habitat for spawning at long term average conditions.

For fry:-

- a relatively constant proportion of the reach is usable over the majority of the simulated flows (i.e.15-20%),
- percent usable area actually increases under the lower flows.

Thus, the habitat area-time series for the fry life stage shows that the area of habitat available increased during the drought.

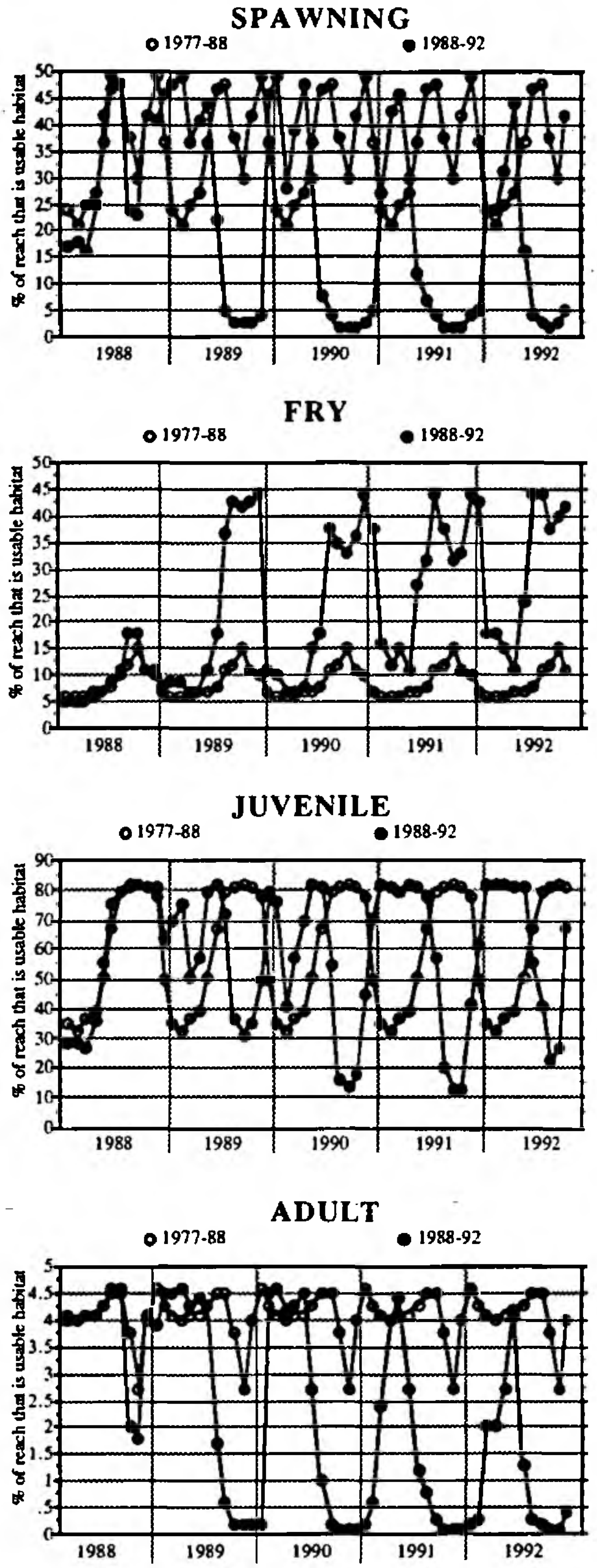

Figure C.8. - Habitat time-series for Brown trout at Northwold

For juveniles:-

- under average conditions, % usable habitat varies between 31-81%,
- under the drought conditions usable habitat varied around average conditions except during summer 1990 and 1991 but nevertheless did not fall below 11% of the total reach.

For adult brown trout:-

- under average conditions, % usable habitat varies between 2.7-4.5%.
- maximum habitat is available during late winter/spring,
- suitable habitat was virtually eliminated during the late summer periods of 1989-1992.

Clearly these diagrams provide information on how the reduced flows have affected habitat availability during the drought period in relation to the long term average. However, they only provide evidence at one of the seven sites and for one of the seven fish species. The following section provides further analysis in order to evaluate the impact of reduced flows on all the other species/life stages and at the other sites.

C4.3 Habitat availability under reduced flows

Many existing methods (e.g. Tennant 1976, Orth and Maughan 1981) for prescribing minimum flows are based on the premise that the resident biota are adapted to exist during the average low flow conditions experienced in the recent past. Therefore, long term average flows may be used as a benchmark and reductions below this level will exert stress on the natural system. Below this discharge, the shape of the habitat versus discharge relationship is critical in defining whether the selected species/life stage will be adversely affected by reduced flows. This is illustrated by the different curves in figure C.9. The top four diagrams highlight four different responses to reducing flow below the minimum average monthly flow and these are outlined below. Within each typology it is possible to distinguish responses at a more detailed level, illustrated in the four diagrams in the lower half. The response of habitat availability below 'average' low flow conditions can be characterised as follows;

- **Type A** - reduced habitat
  - A1 slow reduction but maintained above 50% of the initial level,
  - A2 steady reduction with habitat always present but falling below 50% of initial level,
  - A3 rapid reduction with a critical flow below which no habitat is available.

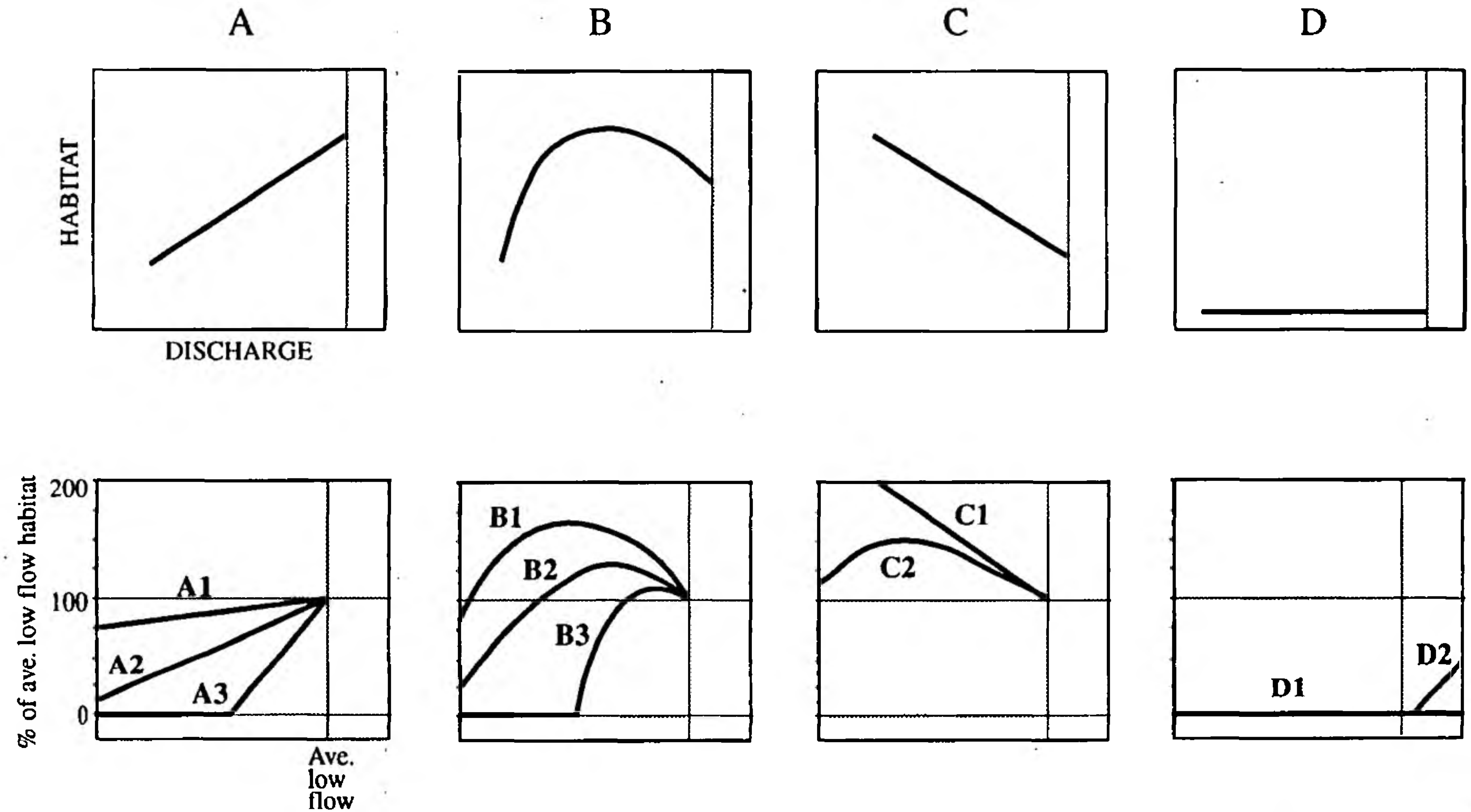

Figure C.9 - Response of habitat availability under low flows

- **Type B** - rise in habitat but falls below initial level at lower flow
  - B1 habitat increases as flow reduces until extreme low flows,
  - B2 initial rise but falls below 50% of initial levels under extreme low flows,
  - B3 initial rise but falls at rapid rate to a critical flow below which no habitat is available.
- **Type C** - habitat remains above initial levels
  - C1 constant rise with reduced flows,
  - C2 habitat falls under lower flows but still remains above initial levels.
- **Type D** - no habitat available below minimum average monthly flow
  - D1 no habitat available even under higher discharges,
  - D2 some habitat becomes available under higher discharges.

Based on this typology, it is evident that certain categories will be more susceptible to reductions in flow below average levels than others. For instance, species with type A responses suffer decreasing habitat availability and are likely to be the most susceptible to these conditions with sub-type A3 being more prone than A1. Within the B category, B3 will be affected in a similar manner as flows fall below a critical threshold. Category C species will not be affected beyond normal low flow level habitat and category D species experiences no habitat at this level.

In order to examine the effect of a reduction in flow below the minimum average monthly flow (i.e. 1.015 m^3s^{-1} at Northwold), each habitat versus discharge relationship was examined and the % usable habitat available at that discharge noted. This value is shown in table C.4 below. In order to standardise flows at the upstream sites to discharges at Northwold, the current meter gauging data collected during the invertebrate surveys were utilised. This related flows at Bodney Bridge and Chalk Hall Farm at 0.5 of those at Northwold ($r^2 = 0.89$ and 0.88), flows at the Langford sites at 0.6 times the Northwold values ($r^2 = 0.89$) and 0.9 times the levels at Northwold for the Didlington sites ($r^2 = 0.92$). The maximum depth in metres during the medium flow calibration set (whilst flow at Northwold was approximately 0.72 m^3s^{-1}) is also shown to give an indication of the river bed configuration. Didlington Sand has the greatest value at this discharge of 0.6 m and was characterised by a general absence of shallows along the majority of the reach. For each species listed below, the site which provides the greatest proportion of habitat is shown in bold type. Over half (10 of the 19) of the species have the largest proportion of habitat available at Didlington Sand. This is due to these species preferring deep water habitats and the associated nature of this site as described above.

Table C.4 - Maximum depth and % usable habitat available under minimum average monthly flow.

		Bodney Bridge	Chalk Hall Farm	Lang-ford Gravel	Lang-ford Sand	Did-lington Gravel	Did-lington Sand	North-wold
Max. depth (m)		0.48	0.47	0.50	0.49	0.56	**0.60**	0.53
Brown trout	fry	16	13.5	35	**40**	27	22.5	15
	juvenile	80	55	58	66	66	68	**81**
	adult	2.8	3.2	1.6	2	**4.8**	0	2.8
Dace	fry	**2.4**	0.05	0.8	0.7	1.6	1.5	0.7
	juvenile	22	12.6	29.2	33	31.6	**72**	23.5
	adult	36	18	27	28	37	**69**	32
Chub	fry	0.9	0	0.4	0.03	1.28	**2.1**	0
	adult & juvenile	9	5.5	5.6	5.5	9.5	**35**	6.4
Roach	fry	4	6	**12**	9	10	8	3.5
	adult & juvenile	0.48	0	0.06	0	0.4	**0.82**	0
Bream	fry	0.57	0	**1.85**	0.3	0.2	0.7	0.08
	juvenile	0	0	0	0	0	0	0
	adult	0	0	0	0	0	0	0
Pike	fry	0	0	0	0	0	**1.28**	0
	juvenile	15.6	7.2	17	13.4	14.6	**18.5**	9.6
	adult	2.5	1.0	2.62	2.4	3.3	**8.75**	1.68
Perch	fry	4.2	3.4	**12**	3.2	2.5	7.75	0.95
	juvenile	21.8	6.5	25.6	37.5	19.8	**71**	8.2
	adult	17	5.8	21.6	34	16.4	**70**	9.5

From these benchmark values of habitat availability under 'average' low flow conditions, the habitat versus discharge relationships were examined in order to evaluate each species susceptibility to reduced flows. The results of this is illustrated in figure C.10 with a key at the top of each page. In each column chart, discharge at Northwold gauging station is indicated on the vertical axis and site along the horizontal axis. Columns shaded in black indicate that at that particular flow, habitat availability is actually higher than under the 1.015 m^3s^{-1} benchmark. Lighter shading indicates reduced habitat with clear sections highlighting flows at which no habitat is available at that particular site for the chosen species and life stage. Each diagram can therefore be used to gauge the response of habitat availability as flow decreases for all species and life stages at each site. The following section outlines the response of each species to a

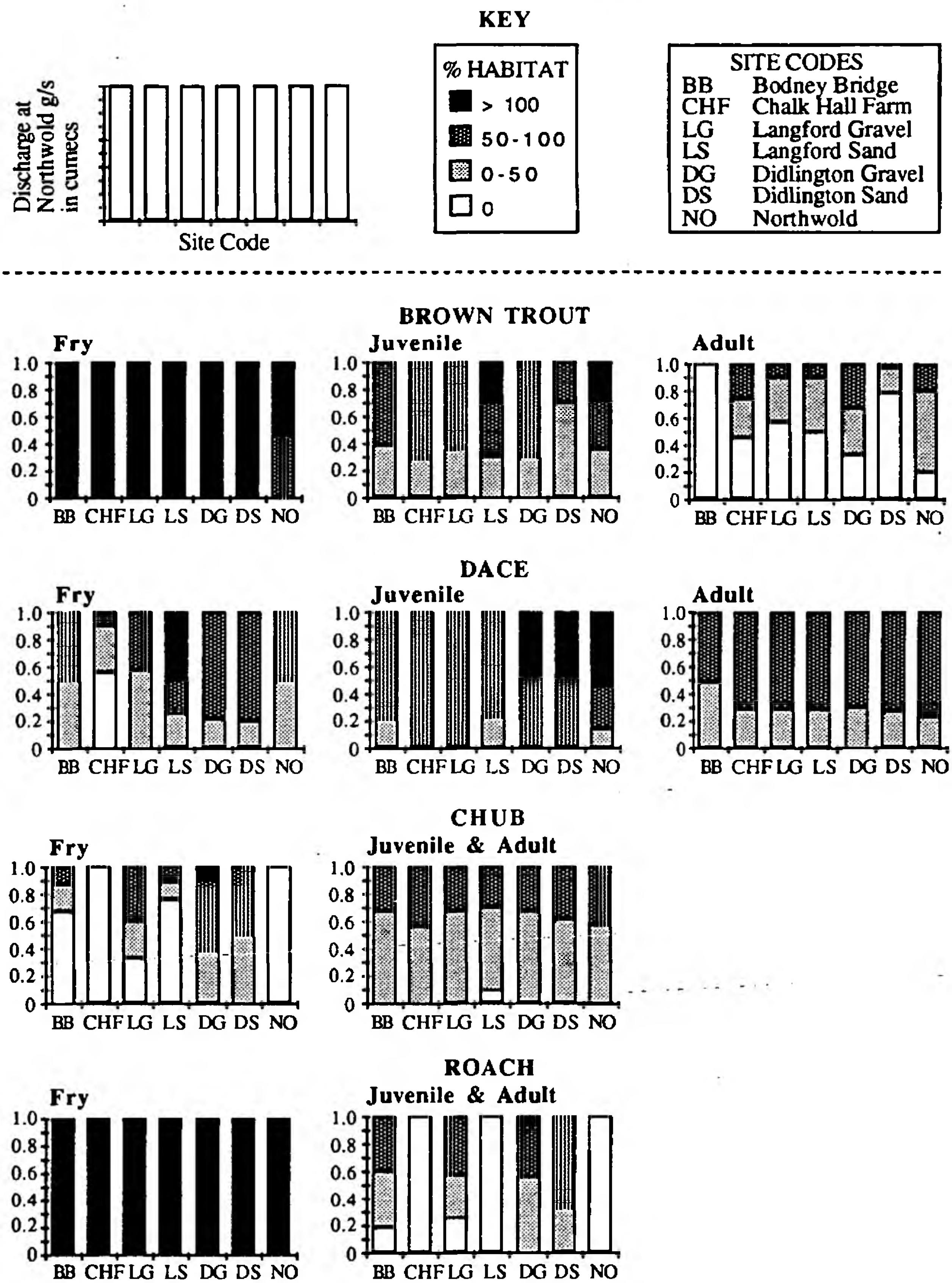

Figure C.10 - Effect of reduced flows on habitat availability for chosen species/life stages

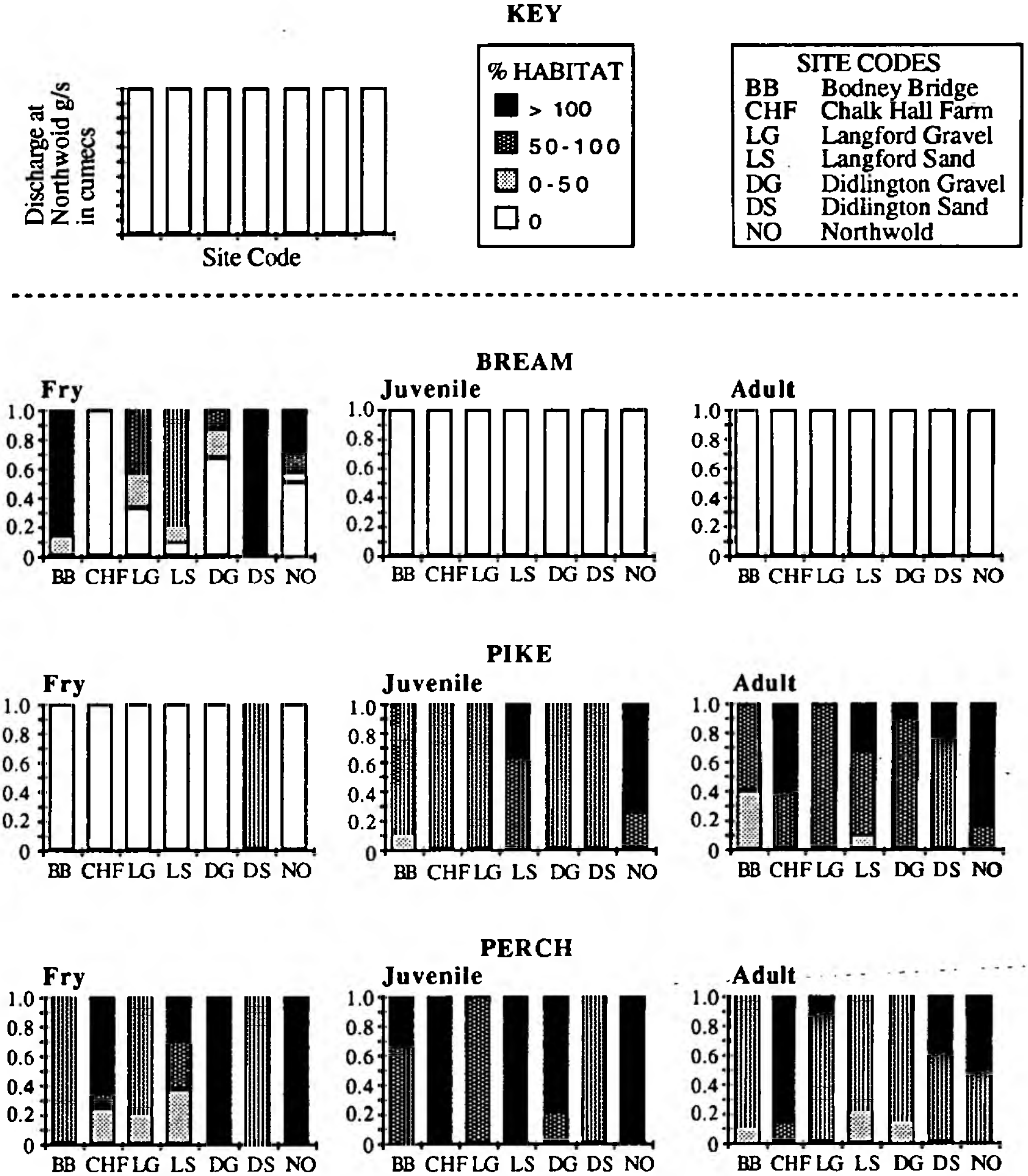

Figure C.10 contd. - Effect of reduced flows on habitat availability for chosen species/life stages reduction in discharge. The letter in brackets after the species/life stage is given where a curve type can be applied at the majority of sites.

Brown trout fry (C)

Percent usable area actually increases under the lower flows and therefore apart from at Northwold (below discharges of 0.45 m^3s^{-1}) habitat is at increased levels at all sites than at the benchmark flow.

Brown trout juvenile (A2 & B2)

All sites experience reduced habitat below 0.70 m^3s^{-1} and all have less than 50% of the low flow level below 0.28 m^3s^{-1}.

Brown trout adult (A3)

Bodney Bridge has no habitat at the selected flows and all others experience rapidly reducing habitat availability. Habitat is maintained in some proportion at all sites at flows above 0.78 m^3s^{-1}. All adult habitat is lost at all sites when flows fall below 0.20 m^3s^{-1}.

Dace fry (A)

All sites have reduced habitat at flows less than 0.50 m^3s^{-1} and all have less than 50% normal low flow levels below 0.20 m^3s^{-1}.

Dace juvenile

All sites experience reduced habitat below 0.45 m^3s^{-1} with three sites having less than 50% original levels below discharges of 0.14 m^3s^{-1}.

Dace adult (A2)

Reductions in dace adult habitat are largely uniform at all sites with less than 50% available under 0.27 m^3s^{-1}.

Chub fry

The first site to lose all habitat is Langford Sand at a critical discharge of 0.75 m^3s^{-1}. Below flows of 0.33 m^3s^{-1}, only two sites maintain some habitat and these occur at less than 50% of the normal low flow levels.

Chub juvenile and adult (A2)

Similar to dace adult, all experience reductions in habitat with little inter-site differences. A flow above 0.10 m^3s^{-1} is necessary to maintain some habitat at all sites.

Roach fry (C)

Due to their preference for lower velocities and depths, all sites experience greater habitat availability under lower flows and roach fry are not susceptible to flow reduction.

Roach adult and juvenile (A)

Three sites have no habitat availability under the selected discharges. Of the remaining four, a minimum discharge of 0.25 m^3s^{-1} is necessary to ensure some habitat remains available.

Bream fry

This species/life stage experiences very different responses at each site. For instance, at Didlington Sand, habitat remains above low flow levels, no habitat is available at Chalk Hall Farm and rapid reductions to zero habitat are present at Langford Gravel, Langford Sand, Didlington Gravel and Northwold.

Bream juvenile (D)

no habitat available at any site below average low flow values.

Bream adult (D)

no habitat available at any site below average low flow values.

Pike fry (D)

no habitat available at six of the seven sites below average low flow values.

Pike juvenile (A)

All sites experience reduced habitat below 0.25 m^3s^{-1} and a discharge of 0.12 m^3s^{-1} is necessary to maintain habitat above 50% levels at Bodney Bridge.

Pike adult (B)

A discharge of 0.17 m^3s^{-1} is necessary to before all sites experience reduced habitat.

Perch fry

Two sites experience increased habitat over the full range of flows examined whereas three fall below their 50% levels at a discharge of 0.22 m^3s^{-1}.

Perch juvenile

Three sites experience increased habitat over the full range of flows examined whereas four fall below their original levels at a discharge of 0.22 m^3s^{-1}.

Perch adult

Four sites initially exhibit an increase in habitat availability as flow reduce but a discharge above 0.14 m^3s^{-1} is essential below which all sites have some reduction.

C4.4 Spawning habitat

Habitat versus discharge relationships were also simulated for the spawning requirements of each fish species and the results are shown in Appendix A. From these results, table C.5 below was constructed to illustrate the discharge necessary to maintain some spawning habitat for each species at each site. As with section C4.3, discharges have been standardised and refer to the flows in m^3s^{-1} necessary at Northwold gauging station.

Table C.5 - Discharge requirements (in m^3s^{-1}) at Northwold gauging station to maintain some spawning habitat.

Species	Bodney Bridge	Chalk Hall Farm	Lang-ford Gravel	Lang-ford Sand	Did-lington Gravel	Did-lington Sand	North-wold
Brown trout	0.66	0.40	0.37	0.57	0.38	1.58	**0.14**
Dace	0.66	0.40	0.42	none	0.83	1.89	**0.14**
Chub	0.44	0.22	0.23	0.18	0.15	0.16	**0.14**
Roach	1.00	0.80	none	none	**0.44**	1.58	0.71
Bream	none	none	none	3.80	none	**0.38**	none
Pike	0.84	4.40	2.40	0.94	0.15	**0.12**	none
Perch	**0.06**	**0.06**	0.09	**0.06**	0.14	0.11	0.14

The minimum discharge necessary to maintain some spawning habitat for each species has been highlighted in bold type. Clearly a discharge of 0.44 m^3s^{-1} is required to maintain some spawning habitat for all species. None of the species normally spawn between July and September and therefore the value of 0.44 m^3s^{-1} is required during the subsequent months.

C4.5 Habitat versus discharge relationships for invertebrates

Results of the PHABSIM simulations are listed in Appendix A. Figure C.11 highlights the discharge versus habitat relationships for the four species of invertebrates for each site. In each case, it is possible to define a broad threshold below which the amount of usable habitat rapidly declines. A general threshold below which habitat reaches less than half the optimum values can also be arbitrarily defined. From figure C.11 it is evident that;

- habitat for *Leuctra fusca* begins to rapidly decline at flows below 0.51 m^3s^{-1} and is reduced to less than half optimum values 0.34 m^3s^{-1}.
- habitat for *Rhyacophila dorsalis* begins to rapidly decline below 0.51 m^3s^{-1} and is reduced to less than half optimum values below 0.34 m^3s^{-1}.
- habitat for *Polycentropus flavomaculatus* rapidly declines at discharges at Northwold gauging station of 0.57 m^3s^{-1} and is reduced below half optimum values at discharges less than 0.28 m^3s^{-1}.
- habitat for *Sphaerium corneum* begins to rapidly decline at flows below 0.51 m^3s^{-1} and is reduced to less than half optimum values below 0.31 m^3s^{-1}.

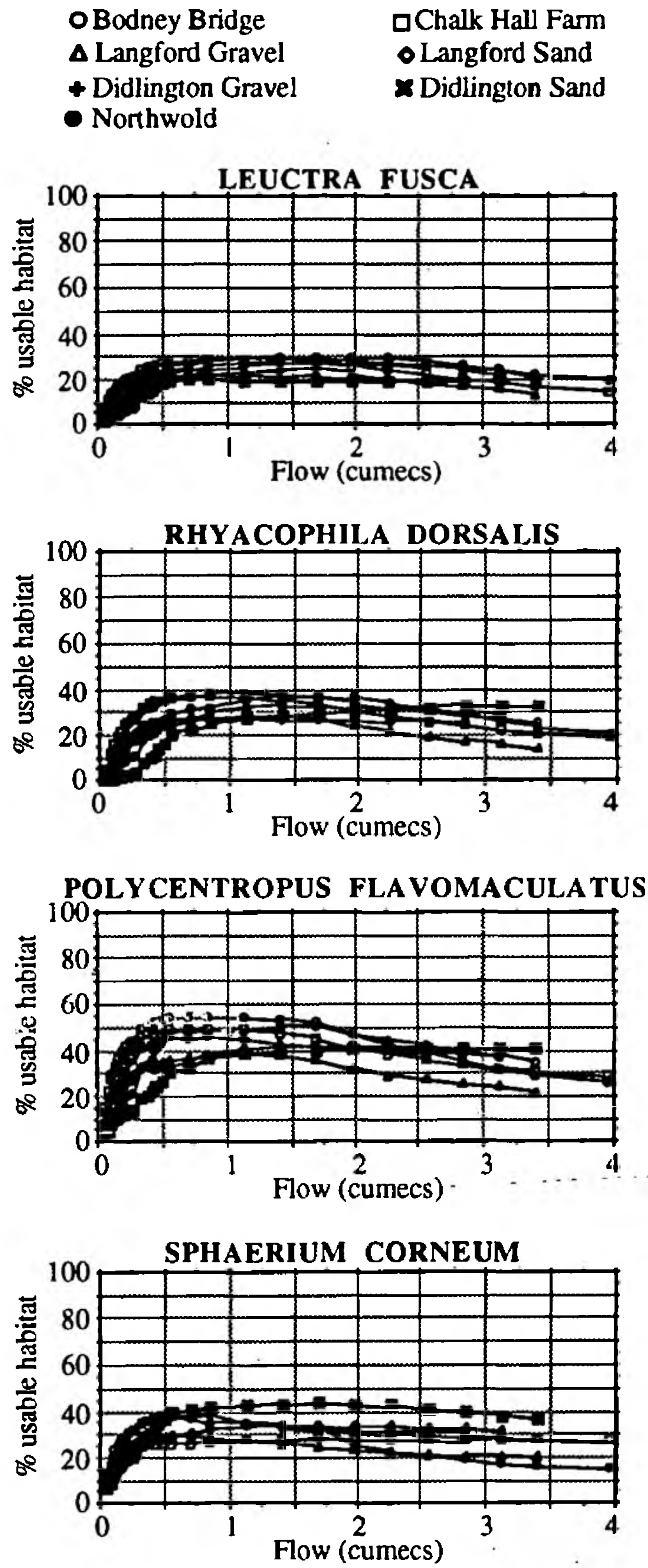

Figure C.11 - Habitat-discharge relationships for four invertebrate species

Taken as a whole for the seven chosen sites, the invertebrates selected begin to experience a reduction in the availability of suitable habitat below discharges of 0.51-0.57 m^3s^{-1}. Only half optimum values of percent usable habitat are available as flows decline 0.28-0.34 m^3s^{-1}.

C5 Conclusions And Recommendations

Analysis of the availability of suitable physical habitat at seven sites on the River Wissey and for seven species of fish and four species of aquatic invertebrate using PHABSIM suggest that:-

- Brown trout adults will be the most susceptible to reduced flows in the Wissey catchment because they have;
  1) a relatively constant proportion of habitat available under the normal flow regime,
  2) exhibit a rapid decline in suitable habitat at discharges below those normally experienced,
  3) experience total loss of habitat under extreme low flow conditions.

- from those species/life stages that have suitable habitat available under average low flow conditions (1.015 m^3s^{-1}), the first total loss of habitat occurs below a discharge of 0.78 m^3s^{-1} at Northwold gauging station (i.e. for Brown trout adults at Didlington Sand).

- total loss of habitat at all sites for any species occurs at discharges below 0.20 m^3s^{-1} (i.e for Brown trout adults).

Therefore, PHABSIM results suggest that under ideal conditions, flows should not fall below 0.78 m^3s^{-1} at Northwold gauging station. This would maintain some suitable habitat for all species and life stages that experience available habitat under the normal flow regime. A discharge of 0.20 m^3s^{-1} at Northwold may be considered as an absolute minimum flow, below which a total loss of habitat may be experienced by selected species.

C6 References

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APPENDIX A - RIVER WISSEY PHABSIM RESULTS

Appendix A. River Wissey PHABSIM results-BODNEY BRIDGE

flow cfs	flow cumecs	Bo Bri Brn Trt spawn	Bo Bri Brn Trt fry	Bo Bri Brn Trt juv	Bo Bri Brn Trt adult	Bo Bri Dace spawn	Bo Bri Dace fry	Bo Bri Dace juv	Bo Bri Dace adult	Bo Bri Chub spawn	Bo Bri Chub fry	Bo Bri Chub juv+ad	Bo Bri Roach spawn	Bo Bri Roach fry	Bo Bri Roach juv+ad	Bo Bri Bream spawn	Bo Bri Bream fry	Bo Bri Bream juv
2.0	0.0566	0.00	38.31	5.56	0.00	0.00	0.10	6.12	4.00	0.00	0.00	0.01	0.00	38.10	0.00	0.00	0.07	0.00
3.0	0.0849	0.00	44.79	10.62	0.00	0.00	0.15	7.78	4.89	0.00	0.00	0.08	0.00	44.37	0.00	0.00	0.39	0.00
4.0	0.1132	0.00	47.38	18.07	0.00	0.00	0.21	9.33	5.99	0.00	0.00	0.16	0.00	41.66	0.01	0.00	0.49	0.00
5.0	0.1415	0.00	48.63	24.79	0.00	0.00	0.27	11.11	7.38	0.00	0.00	0.29	0.00	38.05	0.02	0.00	0.54	0.00
6.0	0.1698	0.00	48.66	31.80	0.00	0.00	0.34	12.72	8.73	0.00	0.00	0.44	0.00	31.63	0.03	0.00	0.58	0.00
7.0	0.1981	0.00	48.15	37.36	0.00	0.00	0.40	14.22	10.24	0.00	0.00	0.62	0.00	23.85	0.04	0.00	0.61	0.00
8.0	0.2264	0.00	47.60	41.93	0.00	0.00	0.46	15.33	11.55	0.26	0.00	0.80	0.00	16.93	0.05	0.00	0.59	0.00
9.0	0.2547	0.00	46.32	46.60	0.00	0.00	0.51	16.17	13.14	0.57	0.00	1.08	0.00	14.10	0.07	0.00	0.58	0.00
10.0	0.2830	0.00	45.30	50.88	0.00	0.00	0.55	16.45	14.72	1.05	0.00	1.34	0.00	11.56	0.08	0.00	0.55	0.00
12.0	0.3396	0.05	40.06	57.89	0.00	0.46	0.65	17.11	17.49	2.88	0.00	1.96	0.00	7.34	0.11	0.00	0.50	0.00
14.0	0.3962	0.48	32.21	64.65	0.00	1.48	0.73	17.35	20.02	5.44	0.07	2.55	0.00	6.53	0.13	0.00	0.43	0.00
15.0	0.4245	1.15	29.19	67.37	0.00	2.30	0.78	17.47	21.40	6.71	0.13	2.92	0.00	6.18	0.15	0.00	0.39	0.00
16.0	0.4528	2.56	26.59	69.58	0.00	2.97	0.84	17.60	22.60	7.90	0.20	3.33	0.00	5.84	0.17	0.00	0.36	0.00
18.0	0.5094	6.51	24.94	73.48	0.00	4.91	0.94	17.97	24.97	10.29	0.28	4.09	0.02	5.64	0.20	0.00	0.29	0.00
20.0	0.5660	11.82	24.08	76.40	0.00	8.00	1.07	18.17	27.22	11.83	0.39	4.96	0.09	5.83	0.25	0.00	0.21	0.00
25.0	0.7075	20.49	20.91	80.54	0.57	19.13	1.36	20.98	31.16	20.58	0.58	6.86	1.54	5.76	0.35	0.00	0.09	0.00
30.0	0.8490	28.03	18.94	81.84	2.31	24.47	1.78	23.11	34.64	33.82	0.78	8.34	4.56	4.84	0.46	0.00	0.50	0.00
40.0	1.1320	41.96	13.97	78.91	3.26	28.73	2.79	21.16	37.24	56.31	1.06	9.63	10.00	3.41	0.50	0.00	0.63	0.00
50.0	1.4150	42.87	11.49	73.71	3.29	28.85	3.94	20.85	37.05	61.86	1.09	10.73	9.89	2.29	0.46	0.00	0.68	0.00
60.0	1.6980	40.28	9.35	68.11	4.44	28.70	4.95	17.79	35.54	62.06	0.21	12.27	11.34	2.48	0.56	0.00	0.58	0.00
70.0	1.9810	36.13	8.72	62.33	7.63	26.45	5.91	17.46	33.18	59.47	0.00	14.47	8.45	2.78	0.67	0.00	0.52	0.00
80.0	2.2640	31.92	8.27	57.41	11.05	22.60	6.23	17.90	30.48	52.71	0.00	15.23	8.17	3.01	0.80	0.00	0.44	0.00
90.0	2.5470	28.65	7.80	53.12	13.99	21.50	6.73	17.36	27.78	39.94	0.00	14.89	7.06	2.92	0.92	0.00	0.35	0.00
100.0	2.8300	25.37	7.60	49.53	16.24	20.67	7.30	16.65	26.00	33.27	0.00	14.04	6.64	2.89	0.99	0.00	0.25	0.00
110.0	3.1130																	
120.0	3.3960																	
140.0	3.9620																	

Appendix A. River Wissey PHABSIM results-BODNEY BRIDGE

flow	flow	Bo Bri	Bo Bri	Bo Bri	Bo Bri	Bo Bri	Bo Bri	Bo Bri	Bo Bri	Bo Bri	Bo Bri	Bo Bri	Bo Bri	Bo Bri
cfs	cumecs	Bream	Pike	Pike	Pike	Pike	Perch	Perch	Perch	Perch	Leuct.	Rhyac.	Polyc.	Sphae.
		adult	spawn	fry	juv	adult	spawn	fry	juv	adult	fusca	dorsal.	flavom.	corn.
2.0	0.0566	0.00	0.00	0.00	7.62	1.07	13.05	2.98	19.68	8.70	5.63	4.85	12.84	11.57
3.0	0.0849	0.00	0.00	0.00	8.81	1.25	14.54	3.15	21.01	9.95	8.57	9.05	18.87	16.13
4.0	0.1132	0.00	0.00	0.00	9.40	1.38	15.38	3.18	21.45	10.78	11.33	13.20	24.43	19.85
5.0	0.1415	0.00	0.00	0.00	10.06	1.49	16.16	3.26	22.16	11.98	13.45	16.16	29.00	22.78
6.0	0.1698	0.00	0.00	0.00	10.63	1.58	16.85	3.15	22.76	12.96	15.30	18.85	33.26	25.27
7.0	0.1981	0.00	0.00	0.00	11.12	1.66	17.53	3.04	23.08	13.95	16.94	21.01	36.44	27.17
8.0	0.2264	0.00	0.00	0.00	11.59	1.73	18.09	3.04	23.48	14.68	18.38	22.95	39.42	28.74
9.0	0.2547	0.00	0.00	0.00	12.09	1.80	18.73	3.04	24.11	15.33	19.74	24.61	41.72	30.17
10.0	0.2830	0.00	0.00	0.00	12.59	1.86	19.53	3.06	24.81	15.62	21.06	26.18	43.89	31.58
12.0	0.3396	0.00	0.00	0.00	13.44	2.06	21.58	3.26	26.32	16.47	22.74	28.62	46.96	33.44
14.0	0.3962	0.00	0.00	0.00	14.03	2.17	21.43	3.26	26.63	16.81	24.04	30.51	48.99	34.83
15.0	0.4245	0.00	0.02	0.00	14.33	2.23	21.14	3.39	26.74	17.01	24.56	31.27	49.82	35.41
16.0	0.4528	0.00	0.08	0.00	14.42	2.27	20.65	3.53	26.66	17.23	25.06	32.06	50.62	35.92
18.0	0.5094	0.00	0.16	0.00	14.71	2.34	20.92	3.64	26.30	17.59	25.82	33.26	51.76	36.71
20.0	0.5660	0.00	0.27	0.00	15.06	2.41	21.62	3.87	26.31	17.81	26.47	34.19	52.66	37.27
25.0	0.7075	0.00	0.49	0.00	15.66	2.47	19.49	3.75	25.87	18.04	27.58	35.92	53.83	37.02
30.0	0.8490	0.00	0.74	0.00	15.82	2.55	15.28	4.00	24.01	17.94	28.09	36.92	54.32	36.35
40.0	1.1320	0.00	0.60	0.00	15.61	2.49	13.11	4.25	20.20	16.38	28.83	37.70	54.29	34.59
50.0	1.4150	0.00	0.30	0.00	15.42	2.54	14.06	4.93	19.96	13.55	29.29	37.28	53.13	33.36
60.0	1.6980	0.00	0.04	0.00	15.94	2.60	12.83	5.83	19.02	13.75	29.31	36.26	51.28	32.31
70.0	1.9810	0.00	0.32	0.00	16.62	2.73	11.55	6.33	17.86	15.13	28.90	34.93	49.00	31.41
80.0	2.2640	0.00	0.62	0.00	17.61	2.83	11.41	6.69	18.12	17.01	27.89	33.41	46.45	30.56
90.0	2.5470	0.00	0.94	0.00	17.82	2.96	11.84	6.91	18.83	17.09	26.96	31.62	43.88	29.73
100.0	2.8300	0.00	1.14	0.00	17.77	3.09	12.34	7.13	19.06	16.05	25.94	29.81	41.51	28.91
110.0	3.1130													
120.0	3.3960													
140.0	3.9620													

Appendix A. River Wissey PHABSIM results-CHALK HALL FARM

flow cfs	flow cumecs	C H F Brn Trt spawn	C H F Brn Trt fry	C H F Brn Trt juv	C H F Brn Trt adult	C H F Dace spawn	C H F Dace fry	C H F Dace juv	C H F Dace adult	C H F Chub spawn	C H F Chub fry	C H F Chub juv+ad	C H F Roach spawn	C H F Roach fry	C H F Roach juv+ad	C H F Bream spawn	C H F Bream fry	C H F Bream juv
2.0	0.0566	0.00	27.80	5.63	0.00	0.00	0.28	6.91	8.25	0.00	0.00	0.56	0.00	44.56	0.00	0.00	0.56	0.00
3.0	0.0849	0.00	26.04	15.59	0.00	0.00	0.00	11.25	7.08	0.00	0.00	0.29	0.00	24.06	0.00	0.00	0.00	0.00
4.0	0.1132	0.00	26.13	23.20	0.00	0.00	0.00	11.76	8.16	1.92	0.00	0.49	0.00	20.84	0.00	0.00	0.00	0.00
5.0	0.1415	0.00	24.34	28.75	0.00	0.00	0.00	11.71	9.03	4.90	0.00	0.76	0.00	17.54	0.00	0.00	0.00	0.00
6.0	0.1698	0.00	23.62	34.01	0.00	0.00	0.00	12.13	10.20	7.90	0.00	1.06	0.00	15.67	0.00	0.00	0.00	0.00
7.0	0.1981	0.03	23.71	38.61	0.00	0.17	0.00	12.59	11.33	10.24	0.00	1.39	0.00	14.90	0.00	0.00	0.00	0.00
8.0	0.2264	0.21	23.17	41.54	0.00	0.85	0.00	12.49	11.94	11.79	0.00	1.74	0.00	11.71	0.00	0.00	0.00	0.00
9.0	0.2547	0.29	21.12	43.76	0.04	1.88	0.00	12.70	12.61	12.64	0.00	2.16	0.00	9.62	0.00	0.00	0.00	0.00
10.0	0.2830	0.30	19.52	46.16	0.27	2.83	0.00	12.71	13.29	13.05	0.00	2.62	0.00	8.97	0.00	0.00	0.00	0.00
12.0	0.3396	3.18	17.13	50.55	1.00	5.20	0.01	12.54	14.65	14.31	0.00	3.49	0.00	8.15	0.00	0.00	0.00	0.00
14.0	0.3962	5.60	14.01	53.67	2.40	7.13	0.02	12.81	16.34	15.87	0.00	4.39	0.60	6.12	0.00	0.00	0.00	0.00
15.0	0.4245	7.22	13.93	54.30	2.95	7.87	0.03	12.75	16.85	16.67	0.00	4.70	1.21	5.38	0.00	0.00	0.00	0.00
16.0	0.4528	9.10	14.02	54.33	3.05	8.77	0.04	12.59	17.18	17.29	0.00	4.98	1.84	5.61	0.00	0.00	0.00	0.00
18.0	0.5094	12.97	13.39	54.82	3.49	11.22	0.06	12.65	18.02	18.64	0.00	5.59	2.87	6.20	0.00	0.00	0.00	0.00
20.0	0.5660	14.88	12.73	56.21	4.06	13.33	0.11	12.85	19.15	19.85	0.00	6.32	3.06	6.87	0.00	0.00	0.00	0.00
25.0	0.7075	19.23	14.77	56.73	4.73	19.29	0.66	12.45	21.18	21.91	0.03	7.86	3.02	5.16	0.00	0.00	0.00	0.00
30.0	0.8490	23.50	17.61	57.44	5.39	25.51	1.92	10.87	23.09	25.00	0.31	9.44	4.15	7.76	0.00	0.00	0.00	0.00
40.0	1.1320	31.16	19.48	55.61	6.99	26.97	3.54	9.86	24.80	34.69	0.81	11.78	7.50	8.57	0.03	0.00	0.24	0.00
50.0	1.4150	33.23	20.01	51.57	8.22	25.19	4.22	10.37	24.77	38.52	1.27	12.44	10.00	6.78	0.08	0.00	1.55	0.00
60.0	1.6980	31.56	19.90	47.72	9.40	24.87	5.45	11.24	24.48	35.32	1.84	12.27	10.34	5.90	0.14	0.00	1.98	0.00
70.0	1.9810	28.18	17.31	42.54	10.81	23.51	6.27	12.32	23.77	31.20	2.57	12.13	8.92	4.43	0.20	0.00	2.03	0.00
80.0	2.2640	25.56	15.77	38.91	12.41	21.03	6.92	16.73	23.47	30.15	3.25	12.52	8.66	1.93	0.27	0.00	1.38	0.00
90.0	2.5470	22.38	15.03	36.43	14.04	19.05	7.31	18.81	23.26	25.13	4.17	13.08	8.10	1.29	0.36	0.00	2.98	0.00
100.0	2.8300	19.82	14.21	34.12	14.89	17.51	7.99	18.93	23.40	20.25	5.39	13.09	8.35	1.14	0.44	0.00	3.09	0.00
110.0	3.1130	17.31	13.25	32.29	15.50	15.48	8.14	18.81	23.82	18.40	6.47	13.39	9.47	1.11	0.58	0.00	3.20	0.00
120.0	3.3960	15.77	11.45	30.96	15.78	13.95	8.64	18.48	24.51	18.23	7.47	14.56	10.20	1.11	0.79	0.00	3.09	0.00
140.0	3.9620	13.52	8.09	29.43	15.97	12.05	7.50	17.53	25.46	17.51	9.49	16.63	9.70	1.09	1.28	0.07	2.76	0.00

flow	flow	C H F	C H F	C H F	C H F	C H F	C H F	C H F	C H F	C H F	C H F	C H F	C H F	C H F
cfs	cumecs	Bream	Pike	Pike	Pike	Pike	Perch	Perch	Perch	Perch	Leuct.	Rhyac.	Polyc.	Sphae.
		adult	spawn	fry	juv	adult	spawn	fry	juv	adult	fusca	dorsal.	flavom.	corn.
2.0	0.0566	0.00	0.00	0.00	7.58	0.81	21.82	1.30	10.33	5.35	6.67	5.11	14.70	13.23
3.0	0.0849	0.00	0.00	0.00	5.84	0.87	18.83	0.78	8.92	7.14	10.81	11.83	21.72	16.06
4.0	0.1132	0.00	0.00	0.00	6.38	0.91	18.89	1.52	9.40	7.15	13.24	15.89	26.60	18.48
5.0	0.1415	0.00	0.00	0.00	6.37	0.91	18.24	2.46	9.49	6.61	14.58	18.58	29.59	19.57
6.0	0.1698	0.00	0.00	0.00	6.41	0.95	18.80	3.25	9.77	6.43	16.10	21.29	33.12	21.28
7.0	0.1981	0.00	0.00	0.00	6.51	0.99	19.43	3.35	9.65	6.31	17.22	23.41	35.49	22.29
8.0	0.2264	0.00	0.00	0.00	6.40	0.96	19.30	3.21	9.26	6.05	18.10	25.10	37.42	22.87
9.0	0.2547	0.00	0.00	0.00	6.41	0.94	16.75	3.19	9.20	6.01	19.15	26.96	39.23	23.22
10.0	0.2830	0.00	0.00	0.00	6.41	0.95	13.76	3.16	9.12	5.96	20.14	28.73	41.05	23.57
12.0	0.3396	0.00	0.00	0.00	6.51	0.96	11.30	3.15	8.70	5.86	21.91	31.47	44.04	24.23
14.0	0.3962	0.00	0.00	0.00	6.78	1.02	8.55	3.28	7.86	5.74	23.44	33.61	46.59	25.28
15.0	0.4245	0.00	0.00	0.00	6.95	1.02	8.52	3.34	7.34	5.66	23.92	34.19	47.27	25.41
16.0	0.4528	0.00	0.00	0.00	7.14	1.01	8.70	3.32	6.82	5.49	24.08	34.41	47.40	25.31
18.0	0.5094	0.00	0.00	0.00	7.54	1.00	8.60	3.39	6.38	5.79	24.46	34.65	47.44	25.21
20.0	0.5660	0.00	0.00	0.00	8.09	1.01	8.65	4.11	7.17	6.07	25.22	35.32	48.14	25.48
25.0	0.7075	0.00	0.00	0.00	8.68	1.06	8.22	5.42	8.85	4.93	26.19	35.93	48.16	25.59
30.0	0.8490	0.00	0.00	0.00	10.61	1.10	7.81	5.94	9.64	4.97	27.70	36.90	49.16	26.24
40.0	1.1320	0.00	0.00	0.00	15.17	1.21	9.52	11.78	16.58	5.65	28.83	36.49	48.66	27.03
50.0	1.4150	0.00	0.00	0.00	16.63	1.29	11.62	13.18	21.03	6.98	28.84	35.09	47.17	27.50
60.0	1.6980	0.00	0.00	0.00	17.44	1.64	15.66	13.28	22.31	8.48	27.85	33.07	44.58	27.70
70.0	1.9810	0.00	0.00	0.00	18.39	2.30	18.57	13.56	22.75	10.24	25.60	29.91	40.91	27.06
80.0	2.2640	0.00	0.76	0.00	19.30	2.89	20.50	14.06	23.71	15.44	23.41	27.66	38.19	27.04
90.0	2.5470	0.00	1.67	0.00	19.99	3.37	21.60	12.75	23.58	18.86	21.46	25.47	35.68	27.07
100.0	2.8300	0.00	1.83	0.00	21.13	4.11	21.86	12.02	23.38	20.05	19.72	23.41	33.43	27.01
110.0	3.1130	0.00	1.99	1.36	21.84	4.73	21.40	12.60	23.26	20.19	18.34	21.72	31.89	27.06
120.0	3.3960	0.00	2.78	1.88	22.19	5.26	21.03	13.26	23.96	20.80	17.03	20.51	30.62	27.09
140.0	3.9620	0.00	3.75	1.35	23.21	6.20	21.45	12.87	23.74	21.83	14.47	18.44	28.35	27.00

Appendix A. River Wissey PHABSIM results-DIDLINGTON GRAVEL

flow	flow	D Grv	D Grv	D Grv	D Grv	D Grv	D Grv	D Grv	D Grv	D Grv	D Grv	D Grv	D Grv	D Grv	D Grv	D Grv	D Grv	D Grv
cfs	cumecs	Brn Trt	Brn Trt	Brn Trt	Brn Trt	Dace	Dace	Dace	Dace	Chub	Chub	Chub	Roach	Roach	Roach	Bream	Bream	Bream
		spawn	fry	juv	adult	spawn	fry	juv	adult	spawn	fry	juv+ad	spawn	fry	juv+ad	spawn	fry	juv
2.0	0.0566																	
3.0	0.0849																	
4.0	0.1132																	
5.0	0.1415	0.00	35.57	15.30	0.00	0.00	0.65	15.96	12.50	1.08	0.05	0.06	0.00	33.14	0.03	0.00	1.22	0.00
6.0	0.1698	0.00	38.98	19.04	0.00	0.00	0.73	18.43	13.99	3.22	0.25	0.15	0.00	32.04	0.05	0.00	1.25	0.00
7.0	0.1981	0.00	40.95	23.80	0.00	0.00	0.81	20.31	15.44	5.61	0.49	0.24	0.00	30.40	0.06	0.00	1.27	0.00
8.0	0.2264	0.00	41.53	27.33	0.00	0.00	0.89	22.25	16.99	7.79	0.54	0.45	0.00	29.31	0.08	0.00	1.30	0.00
9.0	0.2547	0.00	42.08	31.26	0.00	0.00	0.97	23.85	18.24	10.28	0.56	0.60	0.00	27.69	0.09	0.00	1.14	0.00
10.0	0.2830	0.00	42.53	34.80	0.00	0.00	1.06	25.98	19.56	12.01	0.60	0.89	0.00	25.92	0.11	0.00	0.97	0.00
12.0	0.3396	0.50	42.37	43.72	0.00	0.00	1.23	28.40	21.94	16.48	0.65	1.38	0.00	23.71	0.13	0.00	0.57	0.00
14.0	0.3962	1.31	40.70	51.45	0.20	0.00	1.38	30.26	24.16	21.52	0.69	1.93	0.14	18.99	0.16	0.00	0.15	0.00
15.0	0.4245	1.69	39.94	54.20	0.44	0.00	1.39	30.86	25.18	24.39	0.70	2.26	0.29	16.95	0.17	0.00	0.00	0.00
16.0	0.4528	2.14	38.67	56.79	0.71	0.00	1.40	31.23	26.02	26.31	0.72	2.62	0.55	15.05	0.18	0.00	0.00	0.00
18.0	0.5094	3.43	37.14	60.90	1.23	0.38	1.41	32.36	27.67	30.50	0.75	3.28	1.18	12.31	0.20	0.00	0.00	0.00
20.0	0.5660	5.64	35.30	63.18	1.67	1.97	1.44	33.08	29.33	33.55	0.79	4.10	1.96	11.15	0.22	0.00	0.00	0.00
25.0	0.7075	13.60	30.45	66.44	3.21	7.91	1.51	32.44	32.37	36.25	0.92	6.08	3.15	10.56	0.27	0.00	0.02	0.00
30.0	0.8490	19.12	27.54	67.13	4.38	13.74	1.59	32.56	36.75	39.09	1.45	9.26	5.00	9.99	0.40	0.00	0.12	0.00
40.0	1.1320	27.72	22.87	63.91	6.40	26.55	1.76	27.45	35.81	40.40	0.42	11.13	9.47	9.02	0.40	0.00	0.11	0.00
50.0	1.4150	29.94	21.21	58.94	7.76	29.91	1.12	24.31	33.53	37.71	0.46	11.39	9.89	8.85	0.27	0.00	0.40	0.00
60.0	1.6980	29.91	21.29	56.00	8.25	27.48	1.28	21.40	33.43	40.08	0.56	13.14	9.22	8.97	0.14	0.00	0.69	0.00
70.0	1.9810	31.90	22.89	54.75	8.79	28.28	2.24	19.90	33.61	42.16	0.71	15.05	8.32	9.82	0.16	0.00	4.26	0.00
80.0	2.2640	32.51	22.78	53.63	9.51	27.84	3.36	18.73	33.41	43.36	0.87	15.88	7.83	10.82	0.18	0.00	4.66	0.00
90.0	2.5470	31.95	21.53	52.70	10.26	28.97	3.97	18.05	32.79	39.77	1.05	16.21	8.26	10.46	0.20	0.00	4.76	0.00
100.0	2.8300	30.54	20.94	51.73	10.94	29.38	4.59	18.27	32.73	36.88	1.23	16.73	8.63	9.57	0.24	0.00	5.05	0.00
110.0	3.1130																	
120.0	3.3960																	
140.0	3.9620																	

Appendix A. River Wissey PHABSIM results-DIDLINGTON GRAVEL

flow cfs	flow cumecs	D Grv Bream adult	D Grv Pike spawn	D Grv Pike fry	D Grv Pike juv	D Grv Pike adult	D Grv Perch spawn	D Grv Perch fry	D Grv Perch juv	D Grv Perch adult	D Grv Leuct. fusca	D Grv Rhyac. dorsal.	D Grv Polyc. flavom.	D Grv Sphae. corn.
2.0	0.0566													
3.0	0.0849													
4.0	0.1132													
5.0	0.1415	0.00	0.58	0.00	13.94	2.05	31.72	9.62	19.11	8.08	9.20	8.90	20.56	20.45
6.0	0.1698	0.00	0.70	0.00	14.25	2.18	33.68	10.04	19.48	8.65	10.54	10.52	23.43	22.94
7.0	0.1981	0.00	0.79	0.00	14.33	2.28	34.88	10.32	19.94	9.21	11.96	12.53	26.48	25.47
8.0	0.2264	0.00	0.92	0.00	14.50	2.40	36.35	10.29	20.47	9.84	13.33	14.32	29.08	27.72
9.0	0.2547	0.00	0.98	0.00	14.62	2.46	37.24	10.12	20.84	10.43	14.55	15.99	31.64	29.61
10.0	0.2830	0.00	1.08	0.00	14.70	2.54	38.53	9.91	21.29	11.23	15.62	17.59	33.86	31.23
12.0	0.3396	0.00	1.16	0.00	14.79	2.66	39.78	8.70	21.50	12.36	17.41	20.50	37.70	33.76
14.0	0.3962	0.00	1.18	0.00	14.78	2.78	39.20	7.47	21.41	13.31	18.76	22.58	40.52	35.55
15.0	0.4245	0.00	1.19	0.00	14.76	2.83	38.31	6.86	21.38	13.55	19.23	23.13	41.39	35.97
16.0	0.4528	0.00	1.06	0.00	14.70	2.88	36.96	6.16	21.25	13.82	19.62	23.80	42.42	36.35
18.0	0.5094	0.00	0.56	0.00	14.57	2.93	36.20	4.72	21.12	14.29	20.40	24.95	44.06	37.08
20.0	0.5660	0.00	0.09	0.00	14.53	3.01	34.17	3.81	21.04	14.72	21.00	25.65	44.81	37.51
25.0	0.7075	0.00	0.00	0.00	14.47	3.11	26.59	2.34	20.78	15.14	22.13	26.98	46.01	38.10
30.0	0.8490	0.00	0.00	0.00	14.84	3.39	27.25	2.48	20.87	16.47	22.06	27.29	46.00	38.41
40.0	1.1320	0.00	0.00	0.00	13.76	2.93	15.25	2.43	14.42	15.75	21.63	27.47	44.45	34.80
50.0	1.4150	0.00	0.00	0.00	12.90	2.67	11.15	2.92	10.61	13.76	20.79	26.36	42.05	32.11
60.0	1.6980	0.00	0.00	0.00	12.82	2.51	9.56	3.56	9.77	11.07	20.49	25.93	41.41	31.05
70.0	1.9810	0.00	0.00	0.00	13.91	2.44	10.52	4.36	10.12	10.07	20.30	25.79	41.56	31.04
80.0	2.2640	0.00	0.02	0.00	16.46	2.40	11.20	5.42	11.47	9.62	20.09	25.50	41.55	31.16
90.0	2.5470	0.00	0.06	0.00	18.55	2.33	11.88	7.64	14.37	9.23	20.17	25.30	41.34	31.18
100.0	2.8300	0.00	0.45	0.00	19.25	2.32	12.83	9.74	17.04	9.84	19.98	24.85	40.74	31.16
110.0	3.1130													
120.0	3.3960													
140.0	3.9620													

Appendix A. River Wissey PHABSIM results-DIDLINGTON SAND

flow	flow	D Snd	D Snd	D Snd	D Snd	D Snd	D Snd	D Snd	D Snd	D Snd	D Snd	D Snd	D Snd	D Snd	D Snd	D Snd	D Snd	D Snd
cfs	cumecs	Brn Trt	Brn Trt	Brn Trt	Brn Trt	Dace	Dace	Dace	Dace	Chub	Chub	Chub	Roach	Roach	Roach	Bream	Bream	Bream
		spawn	fry	juv	adult	spawn	fry	juv	adult	spawn	fry	juv+ad	spawn	fry	juv+ad	spawn	fry	juv
2.0	0.0566																	
3.0	0.0849																	
4.0	0.1132	0.00	47.35	0.37	0.00	0.00	0.63	39.65	24.65	0.00	0.31	1.55	0.00	21.68	0.21	0.00	1.11	0.00
5.0	0.1415	0.00	51.73	0.64	0.00	0.00	0.68	44.56	27.46	0.01	0.45	2.05	0.00	18.75	0.25	0.00	1.15	0.00
6.0	0.1698	0.00	55.09	1.08	0.00	0.00	0.73	49.05	29.98	0.15	0.52	2.69	0.00	16.53	0.28	0.00	1.18	0.00
7.0	0.1981	0.00	56.35	1.64	0.00	0.00	0.77	52.63	32.30	0.41	0.56	3.51	0.00	14.91	0.32	0.00	1.20	0.00
8.0	0.2264	0.00	55.93	2.27	0.00	0.00	0.81	55.73	34.45	0.72	0.60	4.46	0.00	13.77	0.35	0.00	1.21	0.00
9.0	0.2547	0.00	54.31	3.03	0.00	0.00	0.85	58.22	36.53	0.96	0.64	5.47	0.00	13.34	0.38	0.00	1.23	0.00
10.0	0.2830	0.00	52.55	4.03	0.00	0.00	0.89	60.79	38.39	1.23	0.67	6.45	0.00	12.92	0.40	0.00	1.20	0.00
12.0	0.3396	0.00	47.97	6.31	0.00	0.00	0.96	65.46	42.10	2.28	0.76	8.66	0.00	12.11	0.44	0.06	1.18	0.00
14.0	0.3962	0.00	42.86	8.90	0.00	0.00	1.03	69.05	45.73	3.61	0.89	11.13	0.00	11.40	0.49	0.14	1.16	0.00
15.0	0.4245	0.00	41.00	10.77	0.00	0.00	1.06	70.29	47.34	4.33	0.94	12.31	0.00	11.07	0.50	0.16	1.13	0.00
16.0	0.4528	0.00	38.82	12.94	0.00	0.00	1.10	71.25	49.04	5.19	1.00	13.65	0.00	10.78	0.52	0.20	1.10	0.00
18.0	0.5094	0.00	35.03	19.03	0.00	0.00	1.16	72.27	52.23	7.21	1.12	16.28	0.00	10.30	0.57	0.26	1.04	0.00
20.0	0.5660	0.00	31.65	26.64	0.00	0.00	1.22	72.55	55.28	9.91	1.23	19.03	0.00	10.16	0.61	0.31	0.98	0.00
25.0	0.7075	0.00	26.25	46.77	0.00	0.00	1.38	72.58	62.01	25.42	1.59	26.23	0.00	8.73	0.71	0.45	0.88	0.00
30.0	0.8490	0.00	23.21	65.52	0.02	0.00	1.49	72.06	67.97	47.64	1.97	33.71	0.00	8.32	0.80	0.58	0.74	0.00
40.0	1.1320	0.00	19.15	79.68	0.61	0.00	1.47	71.24	74.13	73.56	2.62	48.45	0.00	7.80	1.01	0.79	0.52	0.00
50.0	1.4150	0.53	16.42	81.45	5.89	0.00	1.44	71.36	75.61	76.87	3.11	59.85	0.02	6.45	1.18	0.98	0.42	0.00
60.0	1.6980	11.17	14.28	82.27	17.77	0.01	1.50	70.10	76.06	77.25	3.49	64.97	0.25	5.26	1.34	1.06	1.66	0.00
70.0	1.9810	37.01	13.36	82.87	23.98	0.24	1.60	64.59	76.05	77.68	3.76	67.51	0.36	4.42	1.46	1.11	1.92	0.00
80.0	2.2640	50.49	12.64	83.19	26.90	0.89	1.81	57.62	75.97	78.04	3.98	69.18	0.35	3.54	1.57	1.13	2.00	0.00
90.0	2.5470	57.02	12.08	83.35	28.18	2.94	1.84	50.37	75.69	78.08	4.25	70.57	0.35	2.96	1.68	1.15	1.85	0.00
100.0	2.8300	61.64	11.89	83.05	28.92	5.42	2.01	42.98	74.66	78.05	4.50	71.49	0.35	2.32	1.77	1.12	1.63	0.07
110.0	3.1130	64.74	11.64	81.53	29.18	6.86	2.17	36.77	71.80	78.03	4.82	72.19	0.35	2.00	1.85	1.05	1.47	0.21
120.0	3.3960	65.85	11.39	79.20	29.44	6.84	2.37	32.82	67.83	77.97	5.14	72.09	0.34	1.55	1.92	0.99	1.30	0.34
140.0	3.9620	66.65	10.65	73.11	29.65	7.12	2.73	28.38	58.35	76.19	5.36	65.23	0.10	0.91	2.01	0.86	1.81	0.53

flow cfs	flow cumecs	D Snd Bream adult	D Snd Pike spawn	D Snd Pike fry	D Snd Pike juv	D Snd Pike adult	D Snd Perch spawn	D Snd Perch fry	D Snd Perch juv	D Snd Perch adult	D Snd Leuct. fusca	D Snd Rhyac. dorsal.	D Snd Polyc. flavom.	D Snd Sphae. corn.
2.0	0.0566													
3.0	0.0849													
4.0	0.1132	0.00	0.94	1.01	15.92	6.24	72.53	7.31	70.67	55.62	3.33	0.56	6.56	11.04
5.0	0.1415	0.00	0.96	1.03	15.99	6.71	75.37	7.53	71.07	59.21	4.17	0.87	7.92	13.28
6.0	0.1698	0.00	0.98	1.05	16.05	7.06	77.69	7.37	71.25	62.09	5.02	1.27	9.22	15.37
7.0	0.1981	0.00	0.99	1.06	16.01	7.30	79.32	6.99	70.62	63.92	5.86	1.71	10.39	17.23
8.0	0.2264	0.00	1.00	1.08	16.02	7.47	80.41	6.62	69.95	65.08	6.76	2.19	11.59	19.01
9.0	0.2547	0.00	1.01	1.09	16.11	7.64	81.33	6.38	69.56	65.83	7.76	2.68	12.79	20.75
10.0	0.2830	0.00	1.03	1.10	16.20	7.78	82.09	6.39	69.33	66.56	8.94	3.37	14.09	22.52
12.0	0.3396	0.00	1.05	1.12	16.42	8.04	83.35	6.41	69.43	67.65	11.19	5.14	16.76	25.81
14.0	0.3962	0.00	1.07	1.15	16.69	8.25	84.43	6.43	69.74	68.48	13.15	7.59	19.37	28.77
15.0	0.4245	0.00	1.08	1.16	16.78	8.32	84.73	6.46	69.86	68.73	14.18	9.21	20.72	30.25
16.0	0.4528	0.00	1.09	1.17	16.86	8.40	85.09	6.51	70.00	69.13	15.00	10.67	21.88	31.55
18.0	0.5094	0.00	1.11	1.18	17.00	8.50	85.52	6.62	70.27	69.71	16.65	13.78	24.26	34.11
20.0	0.5660	0.00	1.13	1.20	17.13	8.59	85.92	6.81	70.22	69.96	17.97	16.44	26.33	36.23
25.0	0.7075	0.00	1.18	1.23	17.82	8.78	86.55	7.12	70.16	70.34	19.44	20.26	29.80	39.12
30.0	0.8490	0.00	1.23	1.27	18.35	8.81	87.36	7.65	70.95	70.02	19.69	22.08	32.16	40.26
40.0	1.1320	0.00	1.35	1.32	19.16	8.48	86.02	8.30	71.15	69.85	19.61	24.56	36.00	41.46
50.0	1.4150	0.00	1.45	1.37	19.65	8.12	70.98	9.04	65.59	70.41	19.50	26.49	38.70	42.32
60.0	1.6980	0.00	1.44	1.30	19.37	7.82	41.79	9.31	49.00	70.64	19.43	27.87	39.70	43.02
70.0	1.9810	0.00	1.29	1.12	19.20	7.50	29.44	8.82	35.42	64.13	19.37	28.98	39.98	43.48
80.0	2.2640	0.00	1.15	0.95	19.16	7.22	23.44	8.40	28.21	48.42	19.39	30.03	40.13	43.08
90.0	2.5470	0.00	0.98	0.78	19.19	6.98	22.05	8.83	24.52	40.86	19.40	30.96	40.22	41.94
100.0	2.8300	0.00	1.00	0.73	18.92	6.71	21.75	9.10	22.68	35.76	19.45	31.77	40.27	40.42
110.0	3.1130	0.00	1.15	0.68	18.43	6.45	21.42	9.21	21.77	31.62	19.54	32.27	40.31	38.92
120.0	3.3960	0.00	1.33	0.46	17.99	6.22	21.04	8.91	21.13	28.17	19.61	32.42	40.31	37.77
140.0	3.9620	0.00	1.54	0.22	17.02	5.87	20.55	8.02	20.11	25.07	20.12	32.46	40.15	35.83

Appendix A. River Wissey PHABSIM results-LANGFORD HALL GRAVEL

flow cfs	flow cumecs	L Grv Brn Trt spawn	L Grv Brn Trt fry	L Grv Brn Trt juv	L Grv Brn Trt adult	L Grv Dace spawn	L Grv Dace fry	L Grv Dace juv	L Grv Dace adult	L Grv Chub spawn	L Grv Chub fry	L Grv Chub juv+ad	L Grv Roach spawn	L Grv Roach fry	L Grv Roach juv+ad	L Grv Bream spawn	L Grv Bream fry	L Grv Bream juv
2.0	0.0566																	
3.0	0.0849	0.00	49.15	8.47	0.00	0.00	0.04	16.17	8.86	0.00	0.00	0.07	0.00	36.70	0.00	0.00	0.00	0.00
4.0	0.1132	0.00	53.13	11.52	0.00	0.00	0.06	19.25	10.26	0.00	0.00	0.12	0.00	33.45	0.00	0.00	0.00	0.00
5.0	0.1415	0.00	53.35	15.36	0.00	0.00	0.11	21.88	11.89	0.16	0.00	0.22	0.00	32.65	0.00	0.00	0.00	0.00
6.0	0.1698	0.00	52.85	21.10	0.00	0.00	0.16	23.89	13.39	1.12	0.00	0.33	0.00	32.22	0.01	0.00	0.00	0.00
7.0	0.1981	0.00	52.00	27.18	0.00	0.00	0.19	24.76	14.54	2.99	0.00	0.42	0.00	30.15	0.01	0.00	0.00	0.00
8.0	0.2264	0.07	51.70	33.15	0.00	0.00	0.24	25.71	16.02	4.99	0.05	0.60	0.00	26.76	0.02	0.00	0.04	0.00
9.0	0.2547	0.24	51.35	37.57	0.00	0.14	0.28	26.32	17.28	7.70	0.09	0.84	0.00	21.59	0.02	0.00	0.13	0.00
10.0	0.2830	0.49	51.52	41.33	0.00	0.74	0.32	26.72	18.53	10.17	0.12	1.14	0.00	17.92	0.02	0.00	0.38	0.00
12.0	0.3396	0.98	50.60	47.20	0.00	2.68	0.41	26.91	20.54	14.30	0.18	1.87	0.00	15.59	0.03	0.00	0.95	0.00
14.0	0.3962	1.56	45.48	51.31	0.07	5.21	0.51	27.77	22.52	18.53	0.24	2.76	0.00	14.49	0.04	0.00	1.47	0.00
15.0	0.4245	1.75	42.88	53.09	0.17	6.45	0.54	28.01	23.14	19.98	0.26	3.09	0.00	14.14	0.04	0.00	1.50	0.00
16.0	0.4528	1.94	40.95	54.47	0.33	7.12	0.60	28.45	24.06	21.00	0.29	3.59	0.00	13.98	0.04	0.00	1.56	0.00
18.0	0.5094	4.01	37.79	56.37	0.63	7.38	0.70	28.96	25.32	22.36	0.34	4.50	0.00	13.18	0.05	0.00	1.65	0.00
20.0	0.5660	7.80	35.75	57.58	1.22	8.04	0.80	29.29	26.46	23.46	0.38	5.31	0.02	12.18	0.06	0.00	1.81	0.00
25.0	0.7075	16.07	30.50	58.88	3.21	14.71	1.05	28.88	28.43	25.95	0.47	6.98	0.00	9.81	0.08	0.00	2.14	0.00
30.0	0.8490	26.13	28.91	58.77	4.42	16.76	1.28	25.95	30.13	28.41	0.68	8.49	0.00	9.15	0.10	0.00	2.36	0.00
40.0	1.1320	32.07	26.82	56.53	5.67	19.34	1.59	21.93	31.28	33.36	1.18	11.07	0.00	7.87	0.12	0.00	2.39	0.00
50.0	1.4150	32.32	26.03	52.91	6.66	19.85	1.87	20.81	28.98	36.27	1.60	12.97	0.00	6.89	0.08	0.00	2.12	0.00
60.0	1.6980	29.32	24.53	48.23	7.69	16.15	2.14	21.34	25.92	36.32	2.10	11.86	0.00	6.14	0.12	0.00	1.86	0.00
70.0	1.9810	24.71	23.07	42.84	7.73	6.76	2.38	21.17	22.56	28.93	2.13	8.86	0.00	5.00	0.16	0.00	1.68	0.00
80.0	2.2640	20.35	21.40	38.39	7.48	6.26	2.62	22.18	21.04	24.32	2.31	7.10	0.00	3.68	0.20	0.00	1.68	0.00
90.0	2.5470	17.17	20.14	34.94	7.37	4.85	2.80	23.30	20.51	23.81	2.82	6.45	0.00	2.76	0.25	0.00	1.93	0.00
100.0	2.8300	15.25	19.45	33.01	7.19	5.43	2.96	24.08	20.23	20.16	3.35	6.06	0.00	2.20	0.34	0.00	2.19	0.00
110.0	3.1130	14.23	18.60	31.19	6.86	5.40	3.12	23.99	20.12	17.77	3.91	5.71	0.00	2.10	0.41	0.00	2.34	0.00
120.0	3.3960	13.57	17.14	29.86	6.41	4.46	3.27	23.52	20.57	15.67	4.56	6.14	0.00	2.15	0.48	0.00	2.48	0.00
140.0	3.9620	11.85	13.74	28.07	5.83	3.53	3.57	22.57	21.50	14.02	5.63	7.45	0.00	2.11	0.60	0.13	2.73	0.00

Appendix A. River Wissey PHABSIM results-LANGFORD HALL GRAVEL

flow cfs	flow cumecs	L Grv Bream adult	L Grv Pike spawn	L Grv Pike fry	L Grv Pike juv	L Grv Pike adult	L Grv Perch spawn	L Grv Perch fry	L Grv Perch juv	L Grv Perch adult	L Grv Leuct. fusca	L Grv Rhyac. dorsal.	L Grv Polyc. flavom.	L Grv Sphae. corn.
2.0	0.0566													
3.0	0.0849	0.00	0.00	0.00	11.43	1.76	26.14	5.16	17.65	14.27	6.19	5.00	12.56	13.52
4.0	0.1132	0.00	0.00	0.00	12.29	1.90	27.26	5.54	18.10	15.40	8.28	7.19	16.19	16.51
5.0	0.1415	0.00	0.00	0.00	13.31	2.09	28.75	6.62	19.42	16.64	10.36	10.01	19.51	19.39
6.0	0.1698	0.00	0.00	0.00	14.18	2.23	29.86	7.53	20.60	17.55	12.27	12.63	22.53	21.96
7.0	0.1981	0.00	0.00	0.00	14.25	2.30	30.26	8.04	21.14	17.82	13.29	14.19	24.25	23.16
8.0	0.2264	0.00	0.00	0.00	14.37	2.41	31.14	8.72	22.07	18.17	14.37	15.70	26.04	24.55
9.0	0.2547	0.00	0.00	0.00	14.56	2.46	31.86	9.18	22.86	18.45	15.23	16.98	27.53	25.52
10.0	0.2830	0.00	0.00	0.00	14.79	2.51	32.50	9.71	23.70	18.72	16.01	18.15	28.94	26.39
12.0	0.3396	0.00	0.00	0.00	15.27	2.52	33.11	10.03	24.07	18.95	17.00	19.78	31.02	27.30
14.0	0.3962	0.00	0.00	0.00	15.90	2.57	32.48	10.14	24.37	19.89	17.87	21.23	32.70	28.00
15.0	0.4245	0.00	0.00	0.00	16.02	2.55	30.52	10.26	24.43	20.10	18.28	21.92	33.37	28.14
16.0	0.4528	0.00	0.00	0.00	16.36	2.58	29.45	10.67	24.77	20.58	18.65	22.45	33.86	28.32
18.0	0.5094	0.00	0.00	0.00	16.70	2.59	27.90	11.17	25.08	21.30	19.29	23.52	34.86	28.52
20.0	0.5660	0.00	0.00	0.00	16.98	2.62	26.13	11.86	25.60	21.95	19.73	24.17	35.52	28.72
25.0	0.7075	0.00	0.00	0.00	17.13	2.62	19.62	13.00	25.67	20.69	20.90	25.86	36.83	28.45
30.0	0.8490	0.00	0.00	0.00	16.84	2.59	18.31	13.67	24.99	18.67	21.82	26.93	37.55	28.04
40.0	1.1320	0.00	0.00	0.00	16.85	2.52	18.76	13.44	22.88	15.72	23.17	28.17	38.05	26.74
50.0	1.4150	0.00	0.51	0.00	16.99	2.46	20.47	12.91	22.13	15.81	24.36	27.96	36.98	25.38
60.0	1.6980	0.00	1.09	0.00	17.29	2.50	20.86	13.30	22.98	17.70	25.04	27.06	35.67	24.50
70.0	1.9810	0.00	1.39	0.00	17.32	2.66	20.51	14.06	23.72	18.60	23.95	25.45	33.58	23.59
80.0	2.2640	0.00	1.55	0.11	17.33	2.90	20.58	14.96	24.64	19.41	22.49	23.58	31.55	22.87
90.0	2.5470	0.00	1.71	0.91	17.27	3.12	19.75	14.80	24.13	20.39	19.85	21.16	28.55	21.83
100.0	2.8300	0.00	1.93	1.13	17.19	3.30	20.01	14.64	23.62	22.14	18.10	19.31	26.70	21.25
110.0	3.1130	0.00	1.99	1.05	17.17	3.47	20.56	14.43	23.06	23.21	16.55	17.66	24.99	20.70
120.0	3.3960	0.00	1.93	0.86	17.23	3.64	20.93	14.31	22.56	23.34	15.25	16.07	23.53	20.26
140.0	3.9620	0.00	1.68	0.52	17.50	4.00	19.86	14.17	21.68	22.86	12.91	13.87	21.42	19.61

flow cfs	flow cumecs	L Snd Brn Trt spawn	L Snd Brn Trt fry	L Snd Brn Trt juv	L Snd Brn Trt adult	L Snd Dace spawn	L Snd Dace fry	L Snd Dace juv	L Snd Dace adult	L Snd Chub spawn	L Snd Chub fry	L Snd Chub juv+ad	L Snd Roach spawn	L Snd Roach fry	L Snd Roach juv+ad	L Snd Bream spawn	L Snd Bream fry	L Snd Bream juv
2.0	0.0566	0.00	67.75	2.03	0.00	0.00	0.10	8.93	7.10	0.00	0.00	0.00	0.00	39.62	0.00	0.00	0.00	0.00
3.0	0.0849	0.00	76.26	4.66	0.00	0.00	0.18	12.55	9.03	0.00	0.00	0.12	0.00	40.56	0.00	0.00	0.13	0.00
4.0	0.1132	0.00	78.64	12.91	0.00	0.00	0.22	14.46	10.12	0.25	0.00	0.17	0.00	38.54	0.00	0.00	0.13	0.00
5.0	0.1415	0.00	81.44	20.45	0.00	0.00	0.30	16.42	11.60	0.75	0.00	0.28	0.00	36.44	0.00	0.00	0.18	0.00
6.0	0.1698	0.00	83.35	28.49	0.00	0.00	0.39	18.06	13.09	1.69	0.00	0.40	0.00	34.64	0.00	0.00	0.21	0.00
7.0	0.1981	0.00	84.41	36.16	0.00	0.00	0.47	19.22	14.58	3.35	0.00	0.61	0.00	31.69	0.00	0.00	0.23	0.00
8.0	0.2264	0.00	84.81	42.50	0.00	0.00	0.54	19.99	16.12	5.72	0.00	0.91	0.00	28.21	0.00	0.00	0.23	0.00
9.0	0.2547	0.00	84.61	48.20	0.00	0.00	0.60	20.84	17.47	9.58	0.00	1.18	0.00	23.37	0.00	0.00	0.22	0.00
10.0	0.2830	0.00	82.47	53.34	0.00	0.00	0.67	22.15	18.89	13.91	0.00	1.53	0.00	20.72	0.00	0.00	0.22	0.00
12.0	0.3396	0.05	74.84	60.54	0.03	0.00	0.78	25.10	21.39	22.09	0.00	2.23	0.00	18.10	0.00	0.00	0.22	0.00
14.0	0.3962	0.86	59.84	65.35	0.09	0.00	0.88	29.77	24.39	28.23	0.00	3.42	0.00	11.38	0.00	0.00	0.21	0.00
15.0	0.4245	2.06	56.71	66.15	0.15	0.00	0.86	31.09	25.24	29.58	0.00	3.86	0.00	10.09	0.00	0.00	0.20	0.00
16.0	0.4528	4.74	47.33	63.32	0.57	0.00	0.74	31.64	25.36	30.72	0.00	4.46	0.00	8.47	0.00	0.00	0.18	0.00
18.0	0.5094	7.94	41.26	64.99	1.47	0.00	0.70	33.60	27.13	33.82	0.01	5.23	0.00	9.17	0.00	0.00	0.27	0.00
20.0	0.5660	21.79	35.15	68.75	3.39	0.00	0.90	33.93	31.25	38.08	0.08	7.12	0.00	9.89	0.00	0.00	0.44	0.00
25.0	0.7075	32.90	35.35	71.87	4.53	0.00	1.11	32.12	34.99	41.32	0.14	9.15	0.00	9.47	0.00	0.00	0.52	0.00
30.0	0.8490	45.02	35.58	76.43	6.69	0.00	1.51	30.31	41.46	50.12	0.37	14.29	0.00	11.48	0.02	0.00	0.76	0.00
40.0	1.1320	49.35	34.24	80.70	8.97	0.00	1.87	31.23	45.63	61.63	0.71	19.88	0.00	9.49	0.04	0.00	0.63	0.00
50.0	1.4150	50.03	28.98	81.72	11.17	0.00	2.23	29.77	47.39	66.35	1.10	23.10	0.00	4.99	0.07	0.00	0.60	0.00
60.0	1.6980	48.98	24.64	81.37	13.15	0.00	2.55	29.59	47.97	64.41	0.92	24.89	0.00	2.70	0.11	0.00	0.80	0.00
70.0	1.9810	47.34	19.10	79.26	15.23	0.00	3.04	28.88	48.90	63.16	1.14	27.88	0.00	2.28	0.16	0.00	1.57	0.00
80.0	2.2640	45.00	14.62	76.24	16.53	0.00	3.54	31.18	48.73	62.77	1.49	30.00	0.00	1.85	0.21	0.03	1.65	0.00
90.0	2.5470	42.94	10.77	73.61	17.37	0.00	4.11	34.23	48.72	64.69	1.86	32.03	0.00	1.16	0.25	0.05	1.68	0.00
100.0	2.8300	40.72	8.22	71.20	17.82	0.00	4.50	32.86	48.53	61.42	2.28	33.09	0.00	0.94	0.28	0.08	1.85	0.00
110.0	3.1130	38.66	6.95	68.99	18.07	0.00	4.92	30.51	48.52	58.06	2.87	33.83	0.08	0.86	0.31	0.09	1.87	0.00
120.0	3.3960	34.41	5.60	65.02	18.30	0.00	5.32	26.89	47.69	55.26	3.93	36.26	0.26	0.58	0.45	0.05	1.74	0.00
140.0	3.9620																	

Appendix A. River Wissey PHABSIM results-LANGFORD HALL SAND

flow cfs	flow cumecs	L Snd Bream adult	L Snd Pike spawn	L Snd Pike fry	L Snd Pike juv	L Snd Pike adult	L Snd Perch spawn	L Snd Perch fry	L Snd Perch juv	L Snd Perch adult	L Snd Leuct. fusca	L Snd Rhyac. dorsal.	L Snd Polyc. flavom.	L Snd Sphae. corn.
2.0	0.0566	0.00	0.00	0.00	7.97	1.28	17.91	0.08	43.24	12.84	5.46	2.65	8.36	10.22
3.0	0.0849	0.00	0.00	0.00	8.60	1.47	20.49	0.38	44.71	15.45	8.19	4.75	11.35	13.50
4.0	0.1132	0.00	0.00	0.00	8.72	1.50	20.89	0.63	44.84	15.81	11.43	8.58	15.10	16.55
5.0	0.1415	0.00	0.00	0.00	9.32	1.64	22.81	0.76	45.76	17.01	13.85	11.73	18.06	19.03
6.0	0.1698	0.00	0.00	0.00	9.92	1.78	24.77	1.02	46.69	18.37	15.73	14.39	20.59	21.01
7.0	0.1981	0.00	0.00	0.00	10.64	1.91	26.71	1.43	48.30	19.48	17.20	16.58	22.73	22.63
8.0	0.2264	0.00	0.00	0.00	11.34	2.05	28.85	1.77	50.12	20.32	18.34	18.34	24.61	23.98
9.0	0.2547	0.00	0.00	0.00	11.73	2.14	30.35	2.09	51.55	21.17	19.23	19.80	26.34	24.95
10.0	0.2830	0.00	0.00	0.00	12.27	2.23	31.37	2.40	53.04	22.46	19.93	20.91	27.79	25.79
12.0	0.3396	0.00	0.00	0.00	13.08	2.31	31.10	2.63	54.11	25.30	21.08	22.69	30.15	27.08
14.0	0.3962	0.00	0.00	0.00	13.67	2.40	29.01	3.12	53.22	29.83	22.25	24.57	32.50	28.36
15.0	0.4245	0.00	0.00	0.00	13.80	2.43	28.21	3.21	51.68	31.23	22.60	25.13	33.11	28.74
16.0	0.4528	0.00	0.00	0.00	13.05	2.31	22.84	3.13	44.90	31.87	21.67	24.15	31.73	27.51
18.0	0.5094	0.00	0.00	0.00	13.26	2.37	16.95	3.20	40.30	33.61	22.21	24.69	32.32	28.13
20.0	0.5660	0.00	0.04	0.00	13.88	2.51	10.90	3.21	29.09	34.07	23.21	25.89	33.40	29.50
25.0	0.7075	0.00	0.09	0.00	14.46	2.63	10.32	3.73	25.51	26.01	24.15	27.27	34.81	30.60
30.0	0.8490	0.00	0.44	0.00	16.09	2.77	11.89	4.42	25.76	19.94	25.72	29.93	37.77	32.13
40.0	1.1320	0.00	0.91	0.00	17.58	2.97	15.04	5.83	33.85	19.53	26.56	31.45	40.33	33.22
50.0	1.4150	0.00	1.28	0.16	17.09	3.05	15.03	5.83	32.99	21.06	27.24	32.31	41.59	33.41
60.0	1.6980	0.00	1.32	0.31	16.76	3.37	17.02	5.08	28.87	24.20	27.56	32.54	41.67	33.39
70.0	1.9810	0.00	1.07	0.37	16.27	3.78	17.68	4.52	25.39	24.29	27.43	32.29	41.28	33.34
80.0	2.2640	0.00	0.88	0.48	16.03	4.07	17.52	3.84	21.97	26.68	26.95	31.90	40.61	33.02
90.0	2.5470	0.00	0.88	0.83	16.13	4.40	17.27	3.34	19.74	29.96	26.15	31.33	39.81	32.81
100.0	2.8300	0.00	0.96	0.90	16.29	4.60	18.01	3.34	18.51	28.06	25.28	30.65	38.99	32.42
110.0	3.1130	0.00	1.08	0.94	16.70	4.81	18.60	3.55	18.19	26.02	24.22	29.90	38.14	31.99
120.0	3.3960	0.00	1.76	1.02	16.96	4.97	18.95	3.88	19.06	23.59	22.19	28.39	36.43	30.96
140.0	3.9620													

Appendix A. River Wissey PHABSIM results-NORTHWOLD

flow cfs	flow cumecs	North Brn Trt spawn	North Brn Trt fry	North Brn Trt juv	North Brn Trt adult	North Dace spawn	North Dace fry	North Dace juv	North Dace adult	North Chub spawn	North Chub fry	North Chub juv+ad	North Roach spawn	North Roach fry	North Roach juv+ad	North Bream spawn	North Bream fry	North Bream juv
2.0	0.0566																	
3.0	0.0849																	
4.0	0.1132																	
5.0	0.1415	1.17	26.19	7.11	0.00	0.07	0.05	12.71	11.61	2.22	0.00	0.48	0.00	47.73	0.00	0.00	0.00	0.00
6.0	0.1698	1.61	28.20	8.81	0.00	0.33	0.07	13.59	12.54	2.18	0.00	0.54	0.00	46.56	0.00	0.00	0.00	0.00
7.0	0.1981	1.64	30.69	11.56	0.01	0.45	0.08	14.20	13.26	2.82	0.00	0.63	0.00	45.66	0.00	0.00	0.00	0.00
8.0	0.2264	1.82	33.54	13.71	0.04	0.92	0.12	15.76	14.72	3.57	0.00	0.86	0.00	44.95	0.00	0.00	0.00	0.00
9.0	0.2547	1.94	35.88	15.84	0.07	0.92	0.17	17.20	16.12	3.97	0.00	1.11	0.00	44.47	0.00	0.00	0.00	0.00
10.0	0.2830	2.11	37.83	19.34	0.07	0.95	0.18	17.89	16.87	4.99	0.00	1.18	0.00	42.09	0.00	0.00	0.00	0.00
12.0	0.3396	2.26	41.32	29.61	0.13	0.99	0.18	18.86	18.08	8.90	0.00	1.26	0.00	37.45	0.00	0.00	0.00	0.00
14.0	0.3962	2.84	44.32	39.34	0.18	1.01	0.24	21.72	20.44	11.81	0.00	1.51	0.00	33.48	0.00	0.00	0.00	0.00
15.0	0.4245	3.09	44.62	44.60	0.19	1.01	0.25	23.01	21.56	14.20	0.00	1.69	0.00	29.93	0.00	0.00	0.00	0.00
16.0	0.4528	3.26	44.68	49.41	0.19	1.05	0.27	24.00	22.55	16.12	0.00	1.86	0.00	26.61	0.00	0.00	0.00	0.00
18.0	0.5094	3.32	43.99	59.05	0.26	0.76	0.34	26.73	25.01	20.11	0.00	2.52	0.00	20.21	0.00	0.00	0.00	0.00
20.0	0.5660	3.61	41.58	67.44	0.43	0.22	0.40	28.39	27.03	24.18	0.00	3.24	0.00	15.30	0.00	0.00	0.03	0.00
25.0	0.7075	6.94	30.93	80.22	0.92	0.40	0.56	30.73	30.35	34.44	0.01	4.90	0.26	5.75	0.00	0.00	0.09	0.00
30.0	0.8490	20.14	19.43	81.79	1.58	3.66	0.60	28.72	30.91	36.84	0.01	5.72	1.18	3.73	0.00	0.00	0.09	0.00
40.0	1.1320	38.36	12.00	80.72	3.62	26.50	0.83	20.06	31.92	37.10	0.00	6.91	2.70	3.95	0.00	0.00	0.06	0.00
50.0	1.4150	48.90	10.32	80.46	4.70	36.03	1.67	15.82	35.42	45.54	0.00	9.03	5.13	3.35	0.00	0.00	0.58	0.00
60.0	1.6980	48.95	8.90	70.47	4.56	38.43	1.63	7.89	27.36	43.10	0.00	7.36	3.93	3.13	0.00	0.00	0.58	0.00
70.0	1.9810	44.82	7.47	60.04	4.47	38.05	1.75	5.92	20.26	36.12	0.00	5.83	2.27	2.83	0.00	0.00	0.70	0.00
80.0	2.2640	37.27	6.77	51.31	4.29	34.76	1.97	5.09	15.92	27.66	0.00	4.83	0.85	2.46	0.00	0.00	0.93	0.00
90.0	2.5470	30.53	6.45	44.20	4.19	27.37	2.20	4.67	13.60	22.28	0.00	4.39	0.94	2.45	0.00	0.00	1.16	0.00
100.0	2.8300	26.14	6.16	38.91	4.12	24.72	2.33	4.51	12.19	20.38	0.00	4.16	0.93	2.42	0.00	0.00	1.38	0.00
110.0	3.1130	22.44	5.94	34.71	4.02	22.43	2.43	4.43	11.05	15.96	0.00	4.05	0.15	2.33	0.00	0.00	1.37	0.00
120.0	3.3960	19.28	5.35	31.14	3.92	18.04	2.49	4.38	10.10	10.86	0.00	3.90	0.06	2.43	0.00	0.00	1.34	0.00
140.0	3.9620																	

flow cfs	flow cumecs	North Bream adult	North Pike spawn	North Pike fry	North Pike juv	North Pike adult	North Perch spawn	North Perch fry	North Perch juv	North Perch adult	North Leuct. fusca	North Rhyac. dorsal.	North Polyc. flavom.	North Sphae. corn.
2.0	0.0566													
3.0	0.0849													
4.0	0.1132													
5.0	0.1415	0.00	0.00	0.00	8.97	1.64	28.78	1.87	11.29	6.45	5.90	4.81	10.69	10.92
6.0	0.1698	0.00	0.00	0.00	9.14	1.71	29.63	2.04	11.30	6.23	6.94	5.88	12.47	12.78
7.0	0.1981	0.00	0.00	0.00	9.18	1.74	30.02	2.13	11.21	6.19	8.17	7.12	14.49	14.71
8.0	0.2264	0.00	0.00	0.00	9.54	1.87	32.60	2.48	11.38	7.17	9.31	8.02	16.41	16.78
9.0	0.2547	0.00	0.00	0.00	9.83	1.97	34.69	2.82	11.64	8.05	10.50	9.09	18.53	18.96
10.0	0.2830	0.00	0.00	0.00	9.86	1.97	35.05	2.86	11.55	8.15	11.85	10.79	21.04	21.06
12.0	0.3396	0.00	0.00	0.00	9.76	1.90	33.38	2.72	11.47	7.80	14.40	14.57	26.24	25.09
14.0	0.3962	0.00	0.00	0.00	9.96	1.96	34.96	2.87	11.50	8.51	16.58	17.57	30.88	29.08
15.0	0.4245	0.00	0.00	0.00	10.02	1.97	35.23	2.88	11.55	8.74	17.65	19.05	33.20	30.72
16.0	0.4528	0.00	0.00	0.00	10.09	1.97	35.34	2.89	11.58	8.84	18.74	20.60	35.50	32.29
18.0	0.5094	0.00	0.00	0.00	10.33	2.05	36.30	2.63	11.80	9.68	20.64	23.57	39.55	35.15
20.0	0.5660	0.00	0.00	0.00	10.56	2.10	34.63	2.23	12.00	10.60	21.91	26.00	42.64	37.01
25.0	0.7075	0.00	0.00	0.00	10.79	2.08	25.70	1.35	12.79	12.95	23.52	29.34	47.14	38.71
30.0	0.8490	0.00	0.00	0.00	10.16	1.86	13.74	0.96	9.53	12.76	24.45	31.70	48.59	38.47
40.0	1.1320	0.00	0.00	0.00	9.30	1.53	5.22	0.95	7.20	7.10	25.73	35.02	49.30	34.80
50.0	1.4150	0.00	0.00	0.00	9.64	1.49	5.13	1.31	7.32	6.21	26.61	36.58	50.15	33.79
60.0	1.6980	0.00	0.00	0.00	8.16	0.99	4.56	1.23	6.43	4.92	28.04	37.15	49.11	28.22
70.0	1.9810	0.00	0.00	0.00	7.09	0.77	4.53	1.15	6.29	3.90	28.97	36.06	46.49	24.99
80.0	2.2640	0.00	0.00	0.00	6.46	0.66	4.46	1.06	6.32	3.86	29.05	33.79	42.63	22.46
90.0	2.5470	0.00	0.00	0.00	6.14	0.62	4.49	0.95	6.43	3.89	27.96	31.20	38.85	20.42
100.0	2.8300	0.00	0.00	0.00	6.05	0.61	4.54	0.96	6.56	3.92	25.91	28.50	35.16	18.69
110.0	3.1130	0.00	0.00	0.00	6.07	0.60	4.58	0.97	6.53	3.99	23.77	25.69	31.68	17.08
120.0	3.3960	0.00	0.00	0.00	6.08	0.60	4.64	0.98	6.24	4.02	21.50	23.16	28.63	15.68
140.0	3.9620													

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