Out of date

This report has been withdrawn because it is out of date.

For a copy of the updated River Severn drought order environmental report please contact the Environment Agency.

Habitats Regulations Assessment (River Severn Drought Order)

Version 3 - December 2013

UNCLASSIFIED

We are the Environment Agency. We protect and improve the environment and make it a better place for people and wildlife in England.

We operate at the place where environmental change has its greatest impact on people's lives. We reduce the risks to people and properties from flooding; make sure there is enough water for people and wildlife; protect and improve air, land and water quality and apply the environmental standards within which industry can operate.

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We cannot do this alone. We work closely with a wide range of partners including government, business, local authorities, other agencies, civil society groups and the communities we serve.

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Foreword

This Habitats Regulations Assessment (HRA) report has been produced by the Environment Agency, in consultation with Natural Resources Wales and two of its predecessors (Countryside Council for Wales and Environment Agency Wales). From 1 April 2013 Natural Resources Wales, which was formed by the Welsh Government, took over the functions previously carried out by Environment Agency Wales, Countryside Council for Wales and the Forestry Commission Wales. The relationship between Natural Resources Wales and the Environment Agency was set out in a Memorandum of Understanding, with the Environment Agency remaining the lead organisation for water resources planning activities in the River Severn catchment. However, the River Severn flows through England and Wales and the geographical area covered includes Powys, which is now the overall responsibility of Natural Resources Wales

While site-based work is only generally undertaken by Environment Agency staff in England and by Natural Resources Wales staff in Wales, we plan together in relation to shared water bodies, water catchments, estuaries, and groundwater resources. The Environment Agency leads on water resources planning activities in the Severn catchment, which includes River Severn regulation and drought planning, while Natural Resources Wales lead in the Dee and Wye catchments which also flow through England and Wales.

Natural Resources Wales has a dual role in relation to the RSDO and the assessment of impacts on Habitat Directive sites. In its regulatory capacity it has a duty to manage the water resources of Wales (similar to the Environment Agency's role in England). It is also a statutory consultee under the Habitats Regulations (similar to Natural England).

To produce this report the Environment Agency has also closely consulted with Natural England to ensure protected areas of land, designated sites and the wildlife habitats within these areas are considered appropriately and the report satisfied the HRA requirements. We also consulted the water companies, Severn Trent Water Ltd and South Staffordshire Water Ltd, to ensure we assessed the potential combined impacts of the water companies operating their RSDOs on the River Severn whilst we operated the RSDO.

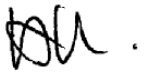
Version Control

Version 1: 2010-2013	First draft report and investigation work. Initial consultation run November 2012-March 2013 with EA, Natural England, Countryside Council for Wales, EA Wales, Severn Trent Water ltd and South Staffordshire Water Ltd.
Version 2: 2009-2011	Draft amended to address initial consultation feedback and organisational changes. Structure and content amended with support from Natural England and comments from the Countryside Council for Wales (now part of Natural Resources Wales).
Version 3: December 2013	*Draft updated to address external consultation comments.*

Update project sign off

River Severn Drought Order (RSDO) Environmental Report

Approved by:

(1) **Project Manager**		**(2)** **Project Executive and Environment Agency West Area Drought Manager**	
Name: Signature: Date:	Kate Evans  12 December 2013	Name: Signature: Date:	Mark Bowers  12 December 2013

(3) **Natural Resources Wales**	
Name: Signature: Date:	Rhian Jardine  22 January 2014
Comments:	*Please refer to the Further Work section and consultation responses.*

Activities Audit

	Item	Comments
Project management		
	Project timescale	2010-2013
	Project initiated, staffed and documentation set up.	Complete
	Communication with internal stakeholders	Specialists in hydrology, water quality, ecology, biodiversity, fisheries, water resource licensing and environment planning formed the internal project group and wider network. This included staff from West area, Midlands region, South West region and Environment Agency Wales (South East and North region). Advisory support was received from National and legal teams. Organisational change on 1 April 2013, Welsh Government formed Natural Resources Wales.
	Communication with other external stakeholders	Natural England, Countryside Council for Wales (now part of Natural Resources Wales), Severn Trent Water Ltd, South Staffordshire Water Ltd and the Canal and River Trust (formerly British Waterways).
	External consultation	Draft report published for external consultation July 2013-August 2013. Consultation was open to the public and key organisations contacted directly to encourage involvement. Responses included National Farmers Unions, United Utilities, Dŵr Cymru Welsh Water, the Institute for Civil Engineers and the above external stakeholders.
File location		
	Environment Agency project files at update project sign off	*N:\Midlands\FP\Environment Management\Monitoring\Water\Rivers\Hydrologists\West Area\Drought work\3 Drought Orders for West\Sev DO*
	Final report sharing with Natural Resources Wales at update project sign off	*O:\EADP\EADP2011\C - Midlands\Severn Drought Order*
	Final (working draft) report published on external website	Publication January 2014, to be located next to the Midlands Drought Plan or adjacent page via a clear link.

Future update time table

The River Severn Drought Order Environmental report will remain a live document, allowing for minor updates to be made as appropriate. However a set timetable for comprehensive reviews will also be set as the following;

- RSDO Environmental Report and supporting documents (e.g. HRA and SGS ER) to undergo a full review/update every 3-3.5 years or following a drought event. **Next programmed update: 2016/17**
- RSDO environmental monitoring programme to be reviewed annually (spring time recommended). This will include a summary of the data collected and a review of the sites and methods being used.

Executive summary

Droughts are infrequent events in the UK but when they do occur their impact can be significant. The Environment Agency has responsibility for alleviating the effects of drought on people, businesses and the environment through sensible management of water resources in England.

The Severn Estuary is over five miles wide and has the second largest tidal range in the world. It is designated as a Site of Special Scientific Interest (SSSI), a Special Protection Area (SPA), a Special Area of Conservation (SAC) and is included on the list of wetlands of international importance under the Ramsar Convention (Ramsar Site).

The River Severn is one of four large rivers which feed into the Severn Estuary. Around six million people rely on the River Severn catchment for drinking water as well as a huge number of businesses, leisure clubs and wildlife. The Environment Agency and Natural Resources Wales Natural Resources Wales ensure that the River Severn is able to support all of these uses without compromising the environment. We must decide how much water needs to be released to the river from both surface water and groundwater storage sources to balance the needs of the river against the demands of abstraction. This is called River Severn regulation, and involves legal responsibility under the Joint Clywedog Reservoir Act (1963).

A set of operating rules has been developed for the day-to-day management of the Severn regulation, which maintains available water resources through most dry and drought years. However, if a drought lasts for a long time water levels in Llyn Clywedog reservoir can become seriously low and a River Severn Drought Order (RSDO) may be applied for. The RSDO would allow us to reduce the quantity of water released from the reservoir and restrict abstractions from the River Severn. This would preserve the remaining water resources and allow support to continue for longer to protect people and the environment against extended droughts.

A RSDO application would be accompanied by an Environmental Report, which assesses the potential environmental effects of implementing the RSDO. Under the Conservation of Habitats and Species Regulations 2010, we must undertake a Habitats Regulations Assessment (HRA) for the RSDO. This document presents the HRA screening for the RSDO; identifies the potential impacts of the drought options on classified sites; and determines whether they are likely to be significant. The HRA screening process also identifies sites where an Appropriate Assessment is required; this document includes the RSDO Appropriate Assessment.

Nine sites were screened on the basis that they were either in direct hydrological connectivity with the River Severn; were linked to the Severn Estuary; or where designated fish species migrate through the Estuary.

If a drought persists, flows get lower and the environment will already be impacted by drought conditions. **This report is focused on assessing the effects of the RSDO, not the natural consequences of drought.** The modelling does take account of background environmental conditions caused by the drought. This data is taken from the 1975/6, 1984 and 1989 droughts, as well as anecdotal evidence. It concludes that the lowest flows are experienced in the Lower tidal Severn, particularly around Gloucester.

Implementation of the RSDO alone is unlikely to cause significant effects on inflow to the estuary. The tidal processes of the estuary and the Lower tidal Severn; and the water quality of the estuary are not expected to be adversely affected. Implementation of the RSDO alone is also unlikely to have a significant effect on the surrounding habitats or wildlife.

The Lower tidal Severn is particularly vulnerable to the impact of drought due to saline intrusion associated with Spring and Neap tides. The combination of low flows and increased salinity has led to low levels of dissolved oxygen which have resulted in fish deaths in the past. Water quality has significantly improved since these historic droughts, however migratory fish are particularly vulnerable to reductions of flow. This can potentially leave them stranded in pools, trapped behind

weirs and isolated at the periphery of the river. They are at even greater risk if the drought is accompanied by high temperatures as these ponded areas or fringes of the river tend to dry out quickly and temperatures rise more rapidly. Besides the risk of fish kills, low flows can also impact on their migration up or down the river. Due to these potential impacts on fish, an Appropriate Assessment was carried out for individual fish species and the migratory fish feature of the Severn Estuary SAC and Ramsar site. The results are included in this document.

One of the largest potential abstractions between Deerhurst and the Severn Estuary is the Canal & River Trust's (*the Trust*, formerly British Waterways) abstraction to the Gloucester & Sharpness Canal. This is taken from the East channel where the River Severn splits. *The abstraction supports the water demands for the canal, including the statutory duty to maintain navigation, the Open Port Duty at Sharpness Docks* and Bristol Water also abstract directly from the canal for public water supply, for which the Trust hold the abstraction licence.

The Trust's abstraction from the River Severn and tributaries remains exempt from abstraction licensing under the Water Resources Act 1991. The Trust operates this abstraction in accordance with an Operating Agreement (1998) with the Environment Agency which acts to safeguard the Severn Estuary inflows under routine operation. However, severe droughts represent exceptional circumstances covered by clause 7 of the agreement, which entitles the Trust to override the operating rules.

The Gloucester & Sharpness Canal abstraction *was assessed to determine whether it had a significant effect on freshwater flows from the Severn into the Estuary, which was the emphasis of the Stage 3 Appropriate Assessment. Both influenced and natural flow are well above what is considered 'Good ecological status' therefore there are sufficient flows into the estuary. The work on migratory fish also concluded that none of the abstractions (including this one) had an impact on the integrity on shad and lamprey alone or in-combination.* Through modelling and the information that has become available since RoC, the effects of this abstraction *during drought conditions* are now *better understood*.

Modelling found that if the Trust abstracted up to 300 Ml/d whilst the RSDO and water company RSDOs were in operation, there was not likely to be a significant effect on the designated Severn Estuary or its features. The abstraction does have the potential to take much larger quantities, up to 691 Ml/d. When maximum abstractions have been taken *for short periods* during drought conditions they significantly reduced flows and water levels. Reports from historic droughts record flows being temporarily reduced to almost zero over the weirs in Gloucester. Under these extreme conditions the Trust's maximum abstraction, in combination with the RSDO and water company *drought permit/order* operations, has the potential to have an adverse effect on the lower tidal Severn, migratory fish and the Estuary.

It is recognised that the Trust must take enough water to *meet their statutory duties as a navigation authority*, support the public water supply abstraction for Bristol Water, and meet their legal obligations to operate Sharpness as an open port. However the ability to abstract up to the maximum amount remains a potential risk to the Severn Estuary, and could also be considered to negate the benefits provided by implementing the RSDO.

The Gloucester & Sharpness Canal abstraction could have an adverse effect on the migratory fish if it is operated alone or in combination with the RSDO and water company drought permits. Where adverse effects are identified which cannot be avoided or mitigated against, alternative options or solutions must be considered. *We cannot regulate this abstraction therefore since the Habitats Directive embodies the precautionary principle, to reduce the risk to the Severn Estuary and migratory fish, (for the present) during RSDO operation an abstraction cap of 300 Ml/d (figure subject to change) will be imposed on this abstraction when flows drop below 1200 Ml/d at Deerhurst.*

The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operation of the Gloucester & Sharpness Canal and the Bristol Water abstraction it supports, work is ongoing to

assess the full impact this restriction could have. If sufficient evidence can be provided to show a higher abstraction is justified then the abstraction limit will be reviewed.

Please note: during the period when this document was being written British Waterways became the Canal & River Trust and throughout the document will be referred to as the Trust. Similarly the Countryside Council for Wales has amalgamated with Environment Agency Wales and Forestry Commission Wales to become Natural Resources Wales.

Natural Resources Wales has a dual role in relation to the RSDO. In its regulatory capacity it has a duty to manage the water resources of Wales (similar to the Environment Agency's role in England). It is also a statutory consultee under the Habitats Regulations (similar to Natural England). Functional separation between these sections of Natural Resources Wales will ensure transparent and rigorous scrutiny of the proposals.

Crynodeb gweithredol

Digwyddiad prin yw sychder yn y Deyrnas Unedig ond pan fydd yn digwydd gall ei effaith fod yn sylweddol. Mae gan Asiantaeth yr Amgylchedd gyfrifoldeb am liniaru effeithiau sychder ar bobl, busnesau a'r amgylchedd trwy reolaeth synhwyrol ar adnoddau dŵr yn Lloegr.

Mae'r Aber Hafren yn fwy na phum milltir o led ac mae ganddo yr ail amrediad llanw mwyaf yn y byd. Mae wedi'i ddynodi'n Safle o Ddiddordeb Gwyddonol Arbennig (SoDdGA), Ardal Gwarchodaeth Arbennig (AGA) ac Ardal Cadwraeth Arbennig (ACA), ac mae wedi'i gynnwys ar y rhestr o wlyptiroedd o bwys rhyngwladol o dan Gonfensiwn Ramsar (Safle Ramsar).

Mae'r Afon Hafren yn un o bedair afon fawr sy'n llifo i mewn i Aber yr Hafren. Mae tua chwe miliwn o bobl yn dibynnu ar ddalgylch yr Afon Hafren am ddŵr yfed yn ogystal â nifer anferth o fusnesau, clybiau hamdden a bywyd gwyllt. Mae Asiantaeth yr Amgylchedd ac NRW yn sicrhau bod yr Afon Hafren yn gallu cefnogi'r holl ddefnyddiau hyn heb beryglu'r amgylchedd. Mae'n rhaid inni benderfynu faint o ddŵr sydd angen ei ryddhau i'r afon o ffynonellau storio dŵr wyneb a dŵr daear er mwyn cydbwyso anghenion yr afon yn ôl gofynion tynnu dŵr. Gelwir hyn yn rheoleiddio Afon Hafren, ac mae'n cynnwys cyfrifoldeb cyfreithiol dan Gyd-ddeddf Cronfa Ddŵr Clywedog (1963).

Datblygwyd set o reolau gweithredu ar gyfer rheoli rheoleiddiad yr Hafren o ddydd i ddydd, sy'n cynnal adnoddau dŵr sydd ar gael trwy'r rhan fwyaf o flynyddoedd sych a blynyddoedd o sychder. Fodd bynnag, os yw sychder yn parhau am amser hir gall lefelau dŵr yng nghronfa ddŵr Llyn Clywedog fynd yn ddifrifol o isel a gellir ymgeisio am Orchymyn Sychder Afon Hafren (RSDO). Byddai'r RSDO yn caniatáu inni leihau'r maint o ddŵr a ryddheir o'r gronfa ddŵr a chyfyngu ar dynnu dŵr o'r Afon Hafren. Byddai hyn yn cadw'r adnoddau dŵr sy'n weddill a chaniatáu i gymorth barhau'n hwy er mwyn amddiffyn pobl a'r amgylchedd yn erbyn sychderau estynedig.

Byddai cais am RSDO yn cyd-fynd ag Adroddiad Amgylcheddol, sy'n asesu'r effeithiau amgylcheddol posibl o weithredu'r gorchymyn sychder. Dan y Rheoliadau Cadwraeth Cynefinoedd a Rhywogaethau 2010, mae'n rhaid inni wneud Asesiad Rheoliadau Cynefinoedd (HRA) am yr RSDO. Mae'r ddogfen hon yn cyflwyno'r broses sgrinio HRA ar gyfer yr RSDO; mae'n adnabod effeithiau posibl yr opsiynau sychder ar safleoedd dosbarthedig; ac mae'n penderfynu a ydynt yn debygol o fod yn sylweddol. Hefyd mae'r broses sgrinio HRA yn adnabod safleoedd lle mae angen Asesiad Priodol; mae'r ddogfen hon yn cynnwys yr Asesiad Priodol RSDO.

Cafodd naw safle eu sgrinio ar y sail naill ai eu bod mewn cysylltedd hydrolegol uniongyrchol â'r Afon Hafren; eu bod wedi'u cysylltu â'r Aber Hafren; neu lle mae rhywogaethau pysgod dynodedig yn mudo trwy'r Aber.

Os yw sychder yn parhau, mae llifau'n mynd yn is a bydd yr amgylchedd wedi'i effeithio eisoes gan amodau sychder. **Mae'r adroddiad hwn yn canolbwyntio ar asesu effeithiau'r RSDO, nid canlyniadau naturiol sychder. Nid yw'r modelu'n ystyried amodau amgylcheddol cefndirol a achosir gan y sychder.** Cymerir y data o sychderau 1975/6, 1984 a 1989 yn ogystal â thystiolaeth anecdotaidd. Mae'n casglu bod y llifau isaf yn cael eu profi yn ardal Llanwol Isaf yr Hafren, yn arbennig o gwmpas Caerloyw.

Mae'n annhebygol y bydd gweithredu'r RSDO ei hunan yn achosi effeithiau sylweddol ar lif i mewn i'r aber. Ni ddisgwylir y bydd prosesau llanwol yr aber a'r Hafren Llanwol Isaf ac ansawdd dŵr yr aber yn cael eu heffeithio'n niweidiol. Hefyd mae'n annhebygol y bydd gweithredu'r RSDO ei hunan yn cael effaith sylweddol ar y cynefinoedd amgylchynol neu fywyd gwyllt.

Mae'r Hafren Lanwol Isaf yn arbennig o agored i niwed ynghylch effaith sychder oherwydd amhariad hallt sy'n gysylltiedig â llanwau Gwanwyn a llanwau Isel. Mae'r cyfuniad o lifau isel a halltedd cynyddol wedi arwain at lefelau isel o ocsigen toddedig sydd wedi achosi marwolaethau pysgod yn y gorffennol. Mae ansawdd dŵr wedi gwella'n sylweddol ers y sychderau hanesyddol hyn, fodd bynnag mae pysgod ymfudol yn arbennig o agored i niwed ynghylch gostyngiadau mewn

llif. Mae'n bosibl y gallai hyn eu gadael yn sownd mewn pyllau, wedi'u maglu y tu ôl i goredau ac wedi'u hynysu ar ymylon yr afon. Maent mewn perygl hyd yn oed yn fwy os yw'r sychder yn digwydd ar yr un pryd â thymereddau uchel gan fod yr ardaloedd pyllog neu ymylon yr afon yn tueddu i sychu'n gyflym ac mae tymereddau'n codi'n gynt. Heblaw am y risg o farwolaethau pysgod, gall llifau isel hefyd effeithio ar eu hymfudo i fyny neu i lawr yr afon. Oherwydd yr effeithiau posibl hyn ar bysgod, gwnaed Asesiad Priodol ar gyfer rhywogaethau unigol o bysgod a nodwedd bysgod ymfudol SAC yr Aber Hafren a safle Ramsar. Cynhwysir y canlyniadau yn y ddogfen hon.

Un o'r tyniadau dŵr posibl mwyaf rhwng Deerhurst a'r Aber Hafren yw tyniad yr Ymddiriedolaeth Camlesi ac Afonydd (yr Ymddiriedolaeth, Dyfrffyrdd Prydain gynt) i'r Gloucester & Sharpness Canal. Cymerir hyn o'r sianel ddwyreiniol lle mae'r Afon Hafren yn rhannu. Mae'r tyniad yn cefnogi'r galwadau dŵr ar gyfer y gamlas, yn cynnwys dyletswydd statudol i gynnal llywio, y Dyletswydd Porth Agored yn Nociau Sharpness ac mae Bristol Water yn tynnu'n uniongyrchol o'r gamlas ar gyfer y cyflenwad dŵr cyhoeddus, y mae'r Ymddiriedolaeth yn dal y drwydded tynnu ar ei gyfer.

Mae tyniad dŵr yr Ymddiriedolaeth o'r Afon Hafren a'i hisafonydd yn dal wedi'i eithrio rhag trwyddedu tynnu dŵr dan Ddeddf Adnoddau Dŵr 1991. Mae'r Ymddiriedolaeth yn gweithredu yn unol â Chytundeb Gweithredu (1998) gydag Asiantaeth yr Amgylchedd, mae'r cytundeb yn gweithredu i ddiogelu llifau i mewn i Aber Hafren o dan weithredu arferol. Fodd bynnag, mae sychderau llym yn cyflwyno amgylchiadau eithriadol a drafodir gan gymal 7 y cytundeb, sy'n rhoi'r hawl i'r Ymddiriedolaeth wrthwneud y rheolau gweithredu

Aseswyd tyniad dŵr Gloucester & Sharpness Canal i bennu a oedd wedi cael effaith arwyddocaol ar lifoedd dŵr croyw o'r Hafren i'r Aber, sef pwyslais yr Asesiad Priodol Cam 3. Mae llif a ddylanwadwyd a naturiol ymhell uwchlaw'r hyn a ystyrir i fod yn 'Statws ecolegol da', felly mae yna lifoedd digonol i'r aber. Casglodd y gwaith ar bysgod mudol hefyd nad oedd yr un o'r tyniadau (yn cynnwys hwn) yn cael effaith ar gyfanrwydd gwangod a lampreiod yn unigol neu mewn cyfuniad. Trwy fodelu a'r wybodaeth sydd wedi dod ar gael ers yr RoC mae gennym well dealltwriaeth o effeithiau'r tyniad dŵr hwn yn ystod amodau sychder erbyn hyn.

Canfu modelu, pe byddai'r Ymddiriedolaeth yn tynnu hyd at 300 Ml/d tra bod yr RSDO a gorchmynion sychder y cwmni dŵr yn weithredol, roedd yn debygol na fyddai effaith sylweddol ar yr aber dynodedig na'i nodweddion. Ond mae'r tyniad dŵr â'r potensial i gymryd meintiau llawer mwy, hyd at 691 Ml/d. Pan yw'r tyniadau dŵr mwyaf hyn wedi'u cymryd am gyfnodau byr yn ystod amodau sychder maent yn lleihau llifau a lefelau dŵr yn sylweddol. Mae adroddiadau o sychderau hanesyddol yn cofnodi llifau'n cael eu lleihau dros dro i sero bron dros y coredau yng Nghaerloyw. Dan yr amodau eithafol hyn mae gan dyniad dŵr mwyaf yr Ymddiriedolaeth, ar y cyd â'r RSDO a gweithrediadau gorchmynion/trwyddedau sychder y cwmni dŵr, y potensial i effeithio'n niweidiol ar yr Hafren Lanwol Isaf, pysgod ymfudol a'r Aber.

Cydnabyddir bod yn rhaid i'r Ymddiriedolaeth gymryd digon o ddŵr i fodloni eu dyletswyddau statudol fel awdurdod llywio, cefnogi tyniad dŵr y cyflenwad dŵr cyhoeddus i Bristol Water, a chwrdd â'u hymrwymiadau cyfreithiol i weithredu Sharpness fel porthladd agored. Fodd bynnag, mae'r gallu i dynnu hyd at y maint mwyaf yn aros fel risg bosibl i'r Aber Hafren, a hefyd gellid ystyried ei fod yn negyddu'r manteision a ddarperir trwy weithredu'r RSDO.

Gallai tyniad dŵr camlas Gloucester and Sharpness gael effaith niweidiol ar y pysgod ymfudol os y'i gweithredir ar ei ben ei hunan neu ar y cyd gyda'r RSDO a thrwyddedau sychder y cwmni dŵr. Lle adnabyddir effeithiau niweidiol na ellir eu hosgoi na liniaru yn eu herbyn, mae'n rhaid ystyried opsiynau neu ddatrysiadau eraill. Ni allwn reoleiddio'r tyniad dŵr hwn felly, gan fod y Gyfarwyddeb Cynefinoedd yn ymgorffori yr egwyddor rhagofalus, i leihau'r risg i Aber yr Hafren a physgod mudol, (ar hyn o bryd) yn ystod gweithrediad RSDO a chap tyniad o 300 MI/d (ffigwr yn amodol i newid) a fydd yn cael ei osod ar y tyniad hwn pan fydd llif yn gostwng islaw 1200 MI/d yn Deerhurst.

Mae'r Ymddiriedolaeth Camlesi ac Afonydd wedi nodi pryderon y gallai 300MI/d gyflwyno risg i'w gwaith o weithredu Camlas Gloucester and Sharpness a'r tyniad Bristol Water mae'n ei gefnogi,

mae gwaith yn mynd rhagddo i asesu effaith lawn y cyfyngiad posibl hwn. Os gellir darparu tystiolaeth ddigonol i gyfiawnhau tyniad uwch, yna byddwn yn adolygu'r terfyn tynnu.

Noder: Yn ystod y cyfnod pan oedd y ddogfen hon yn cael ei hysgrifennu, cafodd Dyfrffyrdd Prydain ei ddisodli gan yr Ymddiriedolaeth Camlesi ac Afonydd, ac fe gyfeirir at y sefydliad ym mhob rhan o'r ddogfen hon fel yr Ymddiriedolaeth. Yn yr un modd, mae Cyngor Cefn Gwlad Cymru wedi uno ag Asiantaeth yr Amgylchedd Cymru a Chomisiwn Coedwigaeth Cymru i greu Cyfoeth Naturiol Cymru.

Mae gan Cyfoeth Naturiol Cymru ddwy rôl i'w chwarae mewn perthynas â Gorchymyn Sychder Afon Hafren. O safbwynt rheoleiddio, mae ganddo ddyletswydd i reoli adnoddau dŵr Cymru (rôl debyg i rôl Asiantaeth yr Amgylchedd yn Lloegr). Mae hefyd yn ymgynghorai statudol dan y Rheoliadau Cynefinoedd (rôl debyg i rôl Natural England). Bydd gwahanu swyddogaethau rhwng yr adrannau hyn yn Cyfoeth Naturiol Cymru yn sicrhau y creffir yn dryloyw ac yn ofalus ar y cynigion.

Contents

1. Introduction

1.1. Background and Purpose of Report

Drought Permit applications in England are made directly to the Environment Agency, however since the Environment Agency cannot grant itself a Drought Permit, an application to implement a River Severn Drought Order (RSDO) would have to be made directly to the Secretary of State and the Welsh Assembly Government, on behalf of the Environment Agency and Natural Resources wales.

However when determining a RSDO the Secretary of State or Welsh Ministers must be satisfied that:-

- a serious deficiency of supplies of water in any area, exists or is threatened

or

- such a deficiency in the flow or level of water in any inland waterway to pose a serious threat to any flora or fauna which are dependent on those waters, exists or is threatened

and that

the reason for the deficiency is an exceptional shortage of rain.

As stated previously, drought permit and RSDO applications must be accompanied by an Environmental Report and this Habitats Directive Assessment has been produced as part of this process. It should aim to include all the information necessary to allow the Secretary of State or National Assembly for Wales to undertake an Appropriate Assessment and ascertain whether or not the proposal will adversely affect the integrity of the European site. The scope and content of this assessment will depend on the circumstance of the case but must relate specifically to the site in question, designated features and to the sites Conservation Objectives.

The process is typically iterative and the screening and assessment has been and will be further revised on the basis of consultation with the Statutory Consultees and comments received during the public consultation.

1.2. HRA Process and Stages

The Habitats Directive (Directive 92/43/EEC on the Conservation of Natural Habitats and Wild Flora and Fauna) protects habitats and species of European nature conservation importance. Together with the *Birds Directive (Directive 2009/147/EC on the protection of wild birds)*, the Habitats Directive established a network of internationally important sites designated for their ecological status. Special Areas of Conservation (Sacs) are designated to promote the protection of flora, fauna and habitats. Special Protection Areas (SPAs) are designated under the Birds Directive in order to protect rare, vulnerable and migratory birds. Internationally important wetlands are designated under the Ramsar Convention 1971. UK Government policy states that the Ramsar sites are afforded the same protection as SPAs and SACs for the purpose of considering development proposals that may affect them. These sites combine to create a Europe-wide 'Natura 2000' network of European Sites, which are hereafter referred to as 'European Sites'. Ramsar sites are included with the European sites for the purposes of this report and for consistency and simplicity the term designated Severn Estuary site is used throughout this report and refers to the SAC, SPA and Ramsar sites. This includes the designated features, sub features and supporting habitats as set out in Table 4.

The Environment Agency and Natural Resources Wales are both a 'competent authority' under Regulation 7(1) of the Conservation of Habitats and Species Regulations 2010 (SI No. 2010/490) commonly referred to as the Habitats Regulations. Natural Resources Wales also has the dual role of being a statutory consultee under the Habitats Regulations (similar to Natural England).

Under Regulation 9(5) it states that "a competent authority must have regard to the requirements of the Habitats Directive when exercising any of its functions", which includes activities authorised by a RSDO. It is therefore necessary for the Environment Agency to undertake a Habitats Regulations Assessment (HRA) for this RSDO. The HRA tests whether the impacts identified as arising from a permit, project or plan are likely to have a significant effect on European sites.

In accordance with Environment Agency guidance (2010) there are four defined stages that are collectively known as the Habitats Regulations Assessment (HRA):-

Stage 1: Screening

Determining whether the permission, plan or project (in this case each drought option) 'either alone or in combination with other plans or projects' is likely to have a significant effect on a European site(s). This is the stage at which relevant sites are identified.

Stage 2: Assessment of Likely Significant Effect (LSE)

Assessing the LSE of a permission, plan or project (PPP). Fig 1 below provides a summary of the procedure to be followed (Environment Agency. Aug 2010). Those that are considered likely to have a significant effect then require an Appropriate Assessment.

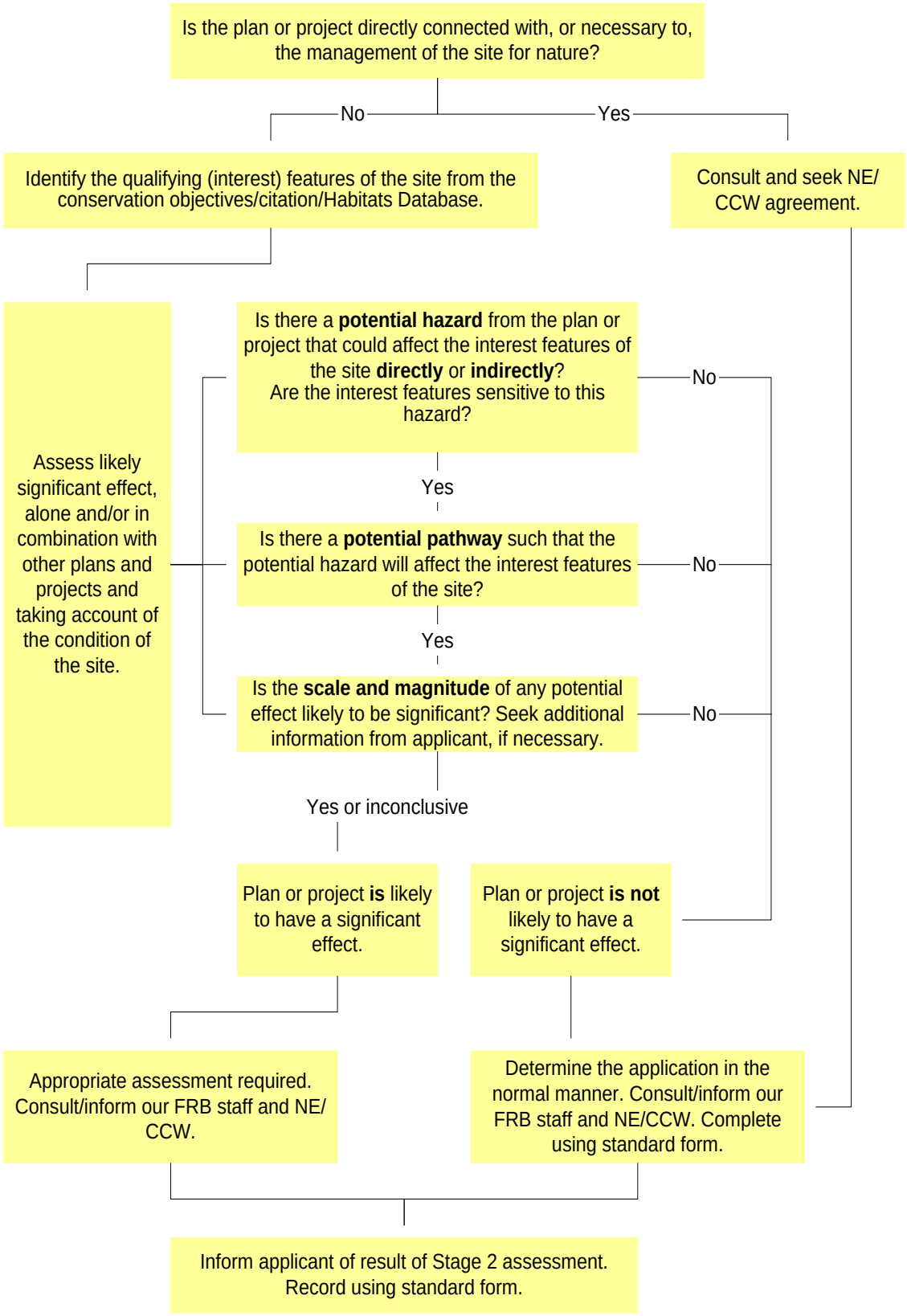
Stage 3: Appropriate Assessment

The Appropriate Assessment determines whether, in view of the European site's conservation objectives, the permission, plan or project (in this case drought options) 'either alone or in combination with other plans or projects' would have an adverse effect on the integrity of the site. Where adverse effects (which cannot be avoided or mitigated) are identified through the Appropriate Assessment, alternative options or solutions must be considered.

Stage Four: Assessment where no Alternative Solutions Exist

If it is not possible to identify mitigation or alternatives, consideration should be given to whether the sites host priority habitats/species, and if there are important human health/safety considerations 'imperative reasons of overriding public interest' (IROPI). If Imperative Reasons of Overriding Public Interest (IROPI) are determined, then compensatory measures must be designed, assessed and put in place, prior to the commencement of the plan. This is not considered a standard part of the process and will only be carried out in exceptional circumstances.

Figure 1. A summary of the procedure for assessing whether a permission, plan or project is likely to have a significant effect on a European site



*Please note that where CCW is referred to in the above diagram consultation should now take place with Natural Resources Wales.

1.3. Conservation Objectives

Any plan or project which during this 'screening process' is considered likely to have a significant effect on an interest feature of a European site (either alone or in combination with other plans or projects) and is not directly connected with or necessary for the management of the site, must be subject to an Appropriate Assessment to determine the implications for the site in view of the site's conservation objectives.

The relevant Conservation objectives for each site have been considered. For the Severn Estuary SAC, SPA and Ramsar site the objectives and advice given under the Regulation 33(2)(a) of the Conservation (Natural Habitats, &c.) Regulations 1994, amended June 2009, written by Natural England and the Countryside Council for Wales (now Natural Resources Wales) was used.

1.4. In combination Assessment

Regulation 61 of the Habitats Regulations 2010 requires the competent authority to consider within the Appropriate Assessment, any permission, plans or projects (including EA permissions) which are likely to have a significant effect on a European site, either alone or in combination with other permissions, plans or projects. All the EA permissions outlined in this scoping assessment will be assessed in combination with each other and with other relevant plans and projects, which will be discussed further in Section 2.7 and 3.15.

1.5. Consultation on the HRA

Under Regulation 61 (3) of the Habitats Regulations 2010, the competent authority must for the purposes of the (HRA) assessment consult the appropriate nature conservation body and have regard to any representations made by that body within such reasonable time as the authority specify. In this case both Natural England (NE) and the Countryside Council for Wales (Natural Resources Wales) have been consulted throughout the process due to the European sites in question being within both England and Wales. As the HRA process is an iterative process advice and comments have been taken into account and the assessment amended accordingly.

2. HRA Screening of the River Severn Drought Order

The study area for the environmental report (which includes this HRA) covers a corridor of land to either side of the River Severn from the source to the estuary, together with the reservoirs/lakes, canals and wetland sites which are in hydrological connectivity with the River Severn and the estuary. Tributaries have not been included, other than the River Teme and River Clun which are used by migratory fish which are necessary to the life cycle of the Freshwater Water Pearl Mussel.

The screening process forms the first stage of any HRA and is focused on determining relevant sites and then **'likely significant effect'** (LSE) test. The aim of the LSE test is to determine whether the RSDO options either alone, or in-combination with other plans and projects are likely to result in a significant effect at European Site[s].

This is essentially a risk assessment process that seeks to understand whether there are any mechanisms for identified impacts arising from the plan to adversely affect the European Sites (i.e. a cause-effect pathway). The key questions asked are:

- would the effect undermine the conservation objectives for the European Site?
- can significant effects be excluded on the basis of objective information?

To assess the likely significant effect, a risk assessment consisting of three elements should be completed. The elements are based on answering the following questions:

i. Is there a potential hazard by which the proposal could affect the interest features of the site either directly or indirectly? Are the interest features sensitive to this hazard?
ii. Is there a pathway such that the potential hazard could affect the interest features of the site alone and/or in combination. What is the exposure of the feature to this hazard?
iii. For each hazard is the potential scale or magnitude of any effect likely to be significant?

A likely significant effect is one that is reasonably predicted and may affect the interest features for which the site is designated. If implementation of the RSDO is likely to have a significant effect, an appropriate assessment is required*. It is recognised that it can be difficult to attribute the impact of plans, groups of plans, unconsented activities and natural processes in which the precautionary principle should be applied and an appropriate assessment undertaken.*

In this case there is a need to consider what effects the implementation of the options (which relate very specifically to the management of limited water resources) would be likely to have on the interest features and conservation objectives of the relevant European sites through effects such as hydrological change or disturbance. The environmental effect of the RSDO options will be considered within the context of the current licence operating conditions.

During a drought, river flows and therefore freshwater input into the Severn estuary will naturally be reduced, the Environment Agency RSDO determines how the limited remaining water will be managed to sustain artificially elevated flows for as long as possible. It is noted that some drought options may have different environmental effects depending on the season of implementation (eg. summer versus winter drought). As drought measures can theoretically be required and implemented at any time of year, overall impacts will be assessed on a worst case basis.

2.1. European Site Identification, Characterisation and Features

This HRA refers to the assessment of the potential effects of implementation of the RSDO on Natura 2000 sites i.e. SACs and SPAs as well as Ramsar sites.

SACs are designated under the Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna) and target particular habitats (Annex I) and or species (Annex II) identified as being of European importance.

SPAs are classified under the European Council Directive 'on the conservation of wild birds' (Directive 2009/147/EC) for the protection of wild birds and their habitats (including particularly rare and vulnerable species listed in Annex 1 of the Birds Directive, and migratory species)

Ramsar sites support internationally important wetland habitats and are listed under the convention on Wetlands of International Importance (Ramsar Convention 1971) and are expected to be treated in the same manner as SACs and SPAs for new permissions, plans or projects.

Using the guidance recommendations made in the Environment Agency's Screening and Assessing new water resources permissions for impacts on conservation, heritage and landscape (Operational instruction 226_10, 2012) the following criteria were used to identify European sites that were at potential risk from implementation of the RSDO:

- European sites that fall within the boundary of the River Severn
- Any European site that is in hydrological continuity with the River Severn

The relevant sites are listed below in Table 1. Although the River Usk SAC, River Wye SAC and Afon Tywi SAC lie outside the River Severn they are intrinsically linked to the Severn Estuary SAC in relation to migratory fish. It was agreed by both Natural England (NE) and the Countryside Council for Wales (now Natural Resources Wales) pers comm. that potential effects to the Rivers Usk, Wye and Afon Twyi SACs will not be directly considered as part of the assessment. However they will be considered in relation to the Severn Estuary migratory fish feature, specifically in relation to Atlantic Salmon, shad and sea lamprey.

Table 1. European sites within or in hydraulic continuity with the River Severn

Site	Designation	Relationship to River Severn
Berwyn and South Clwyd Mountains	SAC	Headwaters of the River Vyrnwy which provides a component of the River Severn Regulation
Montgomery Canal	SAC	In direct hydraulic connectivity with the River Severn as it is fed by water taken from River Severn and River Tanat. This is allowed under an Act of Parliament not an abstraction.
River Clun	SAC	In direct connectivity with the River Teme which is a major tributary of the River Severn. Salmon which are a feature of the Severn Estuary are a feature of the Freshwater Pearl Mussel life cycle.
Downton Gorge	SAC	River Teme which is a major tributary of the River Severn flows through this site. Salmon migrate up the River Teme to get to the River Clun where they are a feature of the Freshwater Pearl Mussel life cycle
Walmore Common	SAC & Ramsar	In direct hydraulic connectivity with the River Severn via ditches
Severn Estuary	SAC, SPA & Ramsar	In direct hydraulic connectivity with the River Severn. The estuary is covered by several designations and designated for a range of features, many of which overlap or support other features. This is set out in Table 5
River Wye	SAC	Although not linked to the River Severn is linked to the Severn Estuary
River Usk	SAC	Although not linked to the River Severn is linked to the Severn Estuary

River Tywi	SAC	Although not linked to the River Severn is linked to the Severn Estuary

2.2. River Severn Regulation

To understand the effects of implementation of the RSDO and its potential effects on the European sites and designated features, it is necessary to understand the existing regulation of the River Severn which balances the needs of water users with the protection of the environment. This balance is managed by the Environment Agency in liaison with water users and the Operating Rules have been up-dated to reflect what has happened during actual droughts and implementation of Shropshire Groundwater Scheme. The regulation system consists of the surface water reservoirs Llyn Clywedog and Lake Vyrnwy in the Welsh mountains, and the Shropshire Groundwater Scheme (SGS).

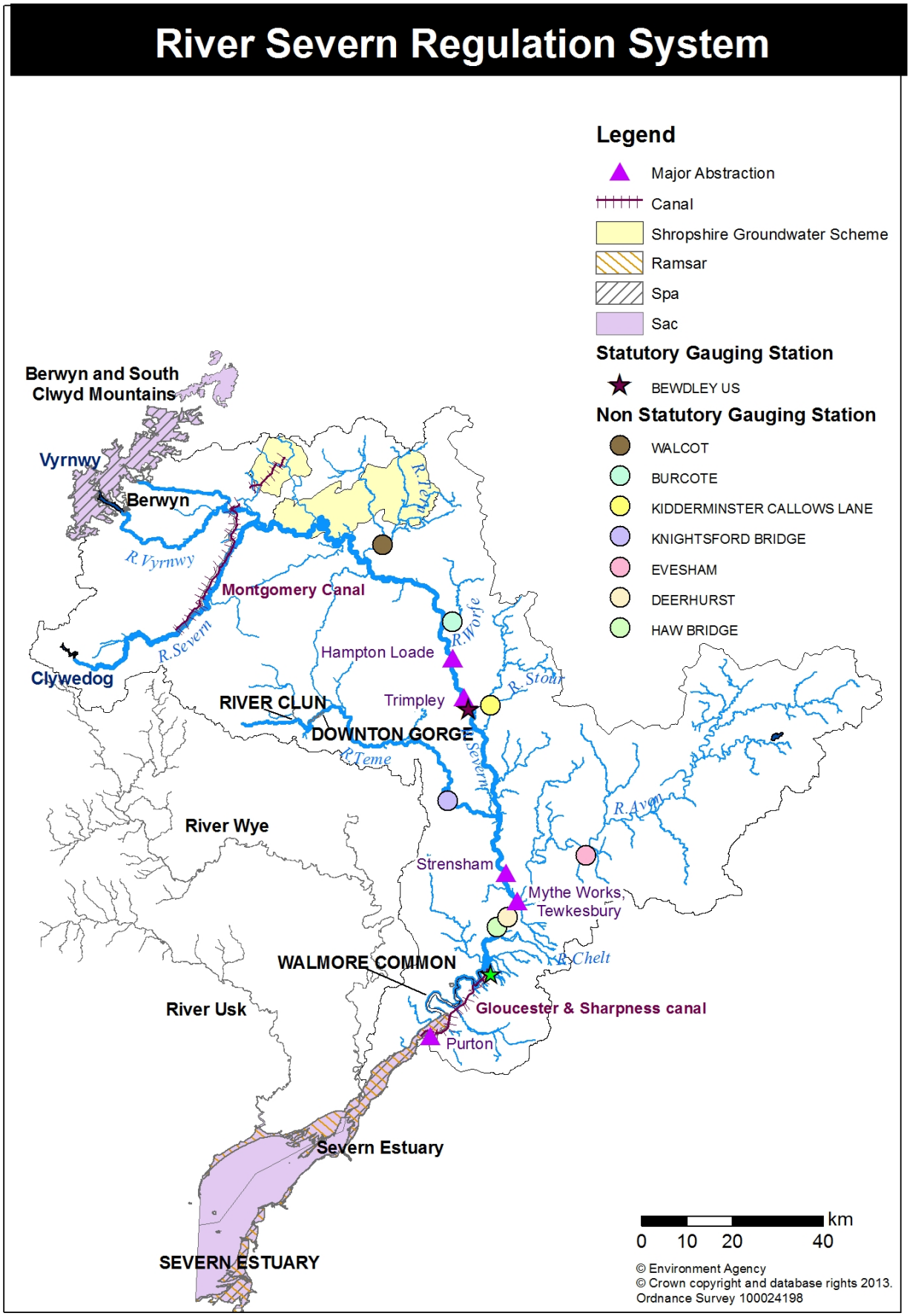
Llyn Clywedog with a storage capacity of 50,000 million litres is the major source of supply for River Severn Regulation. Lake Vyrnwy has a capacity of 59,666 million litres and was constructed with the principal objective of providing a water supply to Liverpool. If able to operate at a reduced daily compensation discharge, the stored compensation water is accumulated as Lake Vyrnwy Bank, a theoretical bank of water which can be used to supplement regulation of the River Severn. The Shropshire Groundwater Scheme (SGS) provides a means of abstracting groundwater from underlying Sandstone aquifers which can be used for augmentation of the River Severn. Its primary role is to provide a phased level of support during dry years when surface water resources are limited, which helps prolong Llyn Clywedog storage. It draws resources from groundwater which has a more delayed response to drought impacts and depleted recharge.

Management of the River Severn is regulated by monitoring flows at Bewdley. As a result of the 1976 drought, in 1979 the Severn Trent Water Authority exercised powers under the Water Resources Act 1963 to increase the regulated flow at Bewdley from 727 Ml/d to 850 Ml/d over 5 days, with a minimum of 650 Ml/d in any one day. This was to provide more reliable flows in the lower reaches of the river where abstractions were increasing rapidly and the worse effects of the drought were experienced.

There are also 11 authorised abstractions for public water supply which add up to a total of 1010.6 Ml/d when flows in the River Severn are moderate or high. When river flows drop and reservoirs are at maximum regulation, these abstractions are restricted to a total of 821.6Ml/d. There are also widespread abstractions for spray irrigation from the Severn and its tributaries, particularly in Shropshire which have the potential to have a significant impact on the resource availability during drought. It should also be noted that the river receives substantial recharge from the permitted discharges of treated water.

Figure 2 below shows the location of Llyn Clywedog, Lake Vyrnwy and Shropshire Groundwater Scheme, the major abstraction and gauging points along the river and designated sites as listed in Table 1.

Figure 2. Location of main features associated with River Regulation and the designated sites

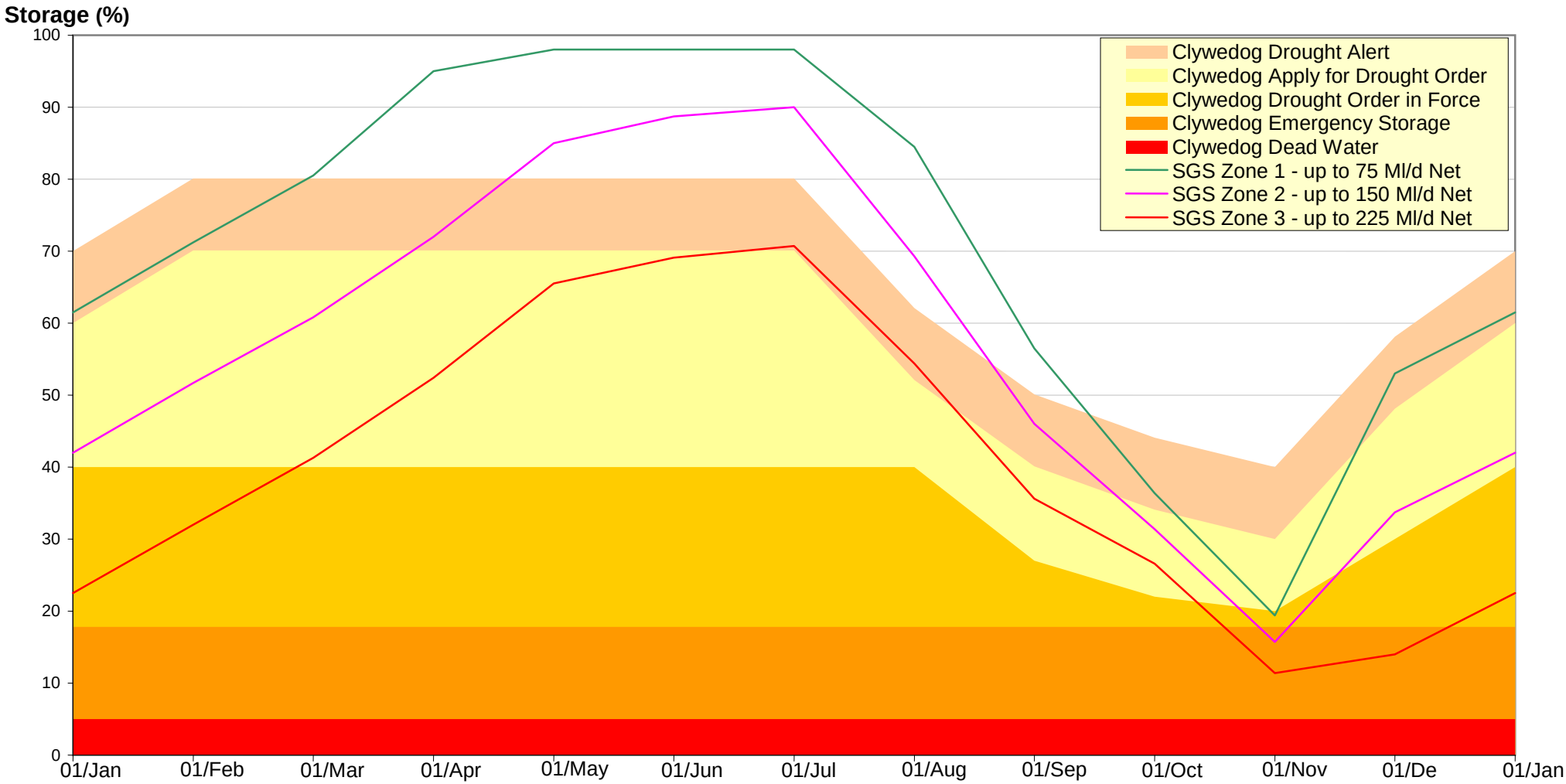


The system is operated according to a combination of statutory and discretionary criteria, with the overriding priorities being to ensure there is sufficient water in storage in the reservoirs by 1st May in readiness for regulation and to discharge sufficient water to meet statutory obligations. The need for augmentation varies from day to day depending upon rainfall and abstraction. By regulating flow at Bewdley and when necessary making releases from the reservoirs and SGS the system maintains higher flows during dry conditions than would naturally be experienced, even with abstraction accounted for. This occurred during the 1995 drought event and demonstrates how well the Severn Regulation system protects the River Severn from the majority of low flow stress experienced in non regulated catchments.

2.3. River Severn Drought Order

As the most important source of additional water, Llyn Clywedog water levels are monitored and the need for a RSDO is triggered by a series of control curves plotted against the current storage capacity of Llyn Clywedog, as shown below in Figure 3.

Figure 3. RSDO and SGS Curves (2012) - Clywedog Reservoir



The aim of applying for a RSDO is to extend the length of time that regulation support could be provided to the River Severn during an extreme drought and comprises 3 main proposals:-

1. Cap regulation releases from Clywedog Reservoir at 300 mega litres per day (Ml/d). and no more than 1.5% of the storage in Llyn Clywedog should be released once the ' RSDO in force' curve has been reached.
2. Decrease the maintained flow in the Severn at Bewdley to 730 Ml/d over a 5 day mean (120 Ml/d decrease)
3. Impose a 5% reduction in daily licence quantities on licences from the River Severn

If a drought persists and the storage capacity of Clywedog Reservoir falls below 17.8% full (Emergency Storage) then releases will be further reduced to 1.5% of remaining active storage.

There are many years in which river flows will be capable of sustaining the river abstractions without support from Llyn Clywedog. In these years storage in Llyn Clywedog may not fall below the Shropshire curve.

Antecedent conditions are crucial in determining whether the RSDO triggers are crossed. Below average groundwater levels significantly reduce base flow to the River Severn and therefore result in high regulation releases being required to maintain the prescribed Bewdley flow. Consistent high regulation increases the risk of the Environment Agency having to apply for a RSDO.

As part of the screening process it was necessary to determine “whether the permission, plan or project is directly connected with or necessary to the management of the site for nature conservation”. If the RSDO was considered as necessary for management of the Severn Estuary an assessment of likely significant effect and Appropriate Assessment are not required. In view of the fact that the RSDO determines how limited available water will be managed, it could be argued that it is necessary to the management of the designated sites i.e. the Severn Estuary. The tightening up of the regulations to provide better protection to the natural environment in light of the 1976 and 1989 drought conditions would certainly support this view. However the aim of the RSDO is given as follows:-

“We consider it to be more beneficial to abstractors of water and the aquatic environment to be able to regulate the Severn for a longer period of time but to a lower flow than to keep regulating to a higher flow and risk running out of water.”

As reference is made specifically to the aquatic environment rather than the actual Severn Estuary designated sites, Natural England and Natural Resources Wales took the view that the RSDO was not necessary for management of the site therefore an assessment of likely significant effect was required.

2.4. Screening Assessment and Identification of Likely Impacts

The Appropriate Assessment carried out for RoC concluded that the current regulation operation is sufficient to support water resources in the Severn Estuary however it acknowledged exclusion of **rare** magnitude droughts. This HRA is concerned specifically with the RSDO (alone and in combination), which is a means of managing the limited water resources during a rare magnitude drought.

Reduced flow into the estuary is the natural consequence of drought, which is a natural process. The river is regulated and regardless of the fact that restricted abstractions will be taking place, the RSDO will allow the river to continue being regulated so that rather than maintaining higher flows and risk running out of water, there will be lower flows which can be maintained for a longer period. Please note that these lower flows will still be higher than the natural base flow expected during a drought.

The management of the available water resource is the activity that is being assessed not the effects of drought. Reduced available water caused by drought will directly impact on

watercourses and can lead to a reduction in flow, both in the river and of freshwater flow into the estuary. Whilst low flows are an obvious hazard there are also other potential hazards as shown in Table 2 below.

Table 2. Generic sensitivity matrix for features in relation to water resources

Hazard	Habitat Group		Species Group	Bird Species Group		Plant Group
	Estuarine and inter-tidal habitats	Submerged marine habitats	Migratory fish	Birds of estuarine habitats	Birds of lowland freshwaters and their margins	Vascular plants of aquatic habitats
Change in water level or table (groundwater only)	●	●	●	●	●	●
Change in flow or velocity regime	●	●	●	●	●	●
Change in surface flooding	●	●	●	●	●	●
Changes in water chemistry	●	●	●	●	●	●
Change in freshwater flow to estuary	●	●	●	●	●	●
Change in salinity regime	●	●	●	●	●	●
Reduced dilution capacity	●	●	●	●	●	●
Habitat loss	●	●	●	●	●	●
Entrapment	●	●	●	●	●	●

● Indicates that at least one of the features in the group is potentially sensitive to the hazard.

From a water quality perspective reduced freshwater flow into the estuary can lead to changes in water chemistry, salinity and a reduced capacity for dilution which can lead to toxic contamination and eutrophication. This can then affect the availability of oxygen which can impact on designated species such as fish. Increased nutrient loadings can result in eutrophication which in turn can impact directly on vegetation of aquatic habitats if sensitive, and indirectly by changing the component communities. Eutrophication can also lead to algal blooms which can then impact on oxygen availability.

Table 3. Generic sensitivity matrix for features in relation to water quality.

Hazard	Habitat Group		Species Group	Bird Species Group		Plant Group
	Estuarine and inter-tidal habitats	Submerged marine habitats	Migratory fish	Birds of estuarine habitats	Birds of lowland freshwaters and their margins	Vascular plants of aquatic habitats
Toxic contamination	●	●	●	●	●	●
Nutrient enrichment	●	●	●	●	●	●
pH	●	●	●	●	●	●
Salinity	●	●	●	●	●	●
Changes in water temperature	●	●	●	●	●	●
Turbidity	●	●	●	●	●	●
Siltation	●	●	●	●	●	●
Physical damage	●			●	●	●

● Indicates that at least one of the features in the group is potentially sensitive to the hazard.

A judgement on likely significant effect will be based on potential hazards (given in tables 2 & 3 above), pathway (via hydraulic connectivity), scale and magnitude, duration and resilience of feature.

It should be noted that implementation of the RSDO and the different options may have different environmental effects depending on the season of implementation: a drought occurring during the summer will have different effects to a winter drought. This does have implications for the sites and designated features and in particular the estuary and fish. As drought measures can theoretically be required and implemented at any time of year, overall impacts will be assessed on a worse case basis. Due to the difficulties in determining likely significant effect on some features, where effects are uncertain those features will be taken through to an Appropriate Assessment. When the sites and features of the Natura 2000 sites are screened, although some are in hydrological continuity, they can be quickly screened out when likely nature, magnitude, duration, location and spatial extent of any changes implemented in relation to the RSDO are considered as follows.

2.4.1. Summary of Likely Significant Effects on the Berwyns

The blanket bog and transition mires and quaking bog for which much of the site is designated, give rise to the headwaters of the River Vyrnwy therefore it is in hydrological continuity with the Vynrwy Reservoir and river which form a component of the River Severn Regulation. However both Lake Vyrnwy and the River Vyrnwy are downstream of the site therefore implementation of the RSDO has no likely significant effect on this site.

2.4.2. Summary of Likely Significant Effects on Downton Gorge

This site was included as being relevant since the River Teme (a major tributary of the River Severn) flows through the site and salmon migrate up the river and through the gorge to get to the River Clun. However the designated feature of this site is woodland and is not dependent on the riverine habitat or any aquatic species therefore implementation of the RSDO has no likely significant effect on this site.

2.4.3. Summary of Likely Significant Effects on the River Clun

The River Clun is designated for Freshwater Pearl Mussel and the species has a symbiotic relationship with Atlantic salmon *Salmo salar* and brown or sea trout *Salmo trutta* during the annual reproductive phase (acting as a host for glochidae). Although the site is not designated for Atlantic salmon it has to be considered a feature of the site. Since salmon will migrate through the estuary and up the River Severn and River Teme (major tributary of the Severn) to get to the River Clun it is considered relevant in terms of hydrological continuity to the Severn Estuary and the Atlantic salmon as a designated feature.

It is interesting that glochidae from Freshwater Pearl Mussel of the River Clun use both salmon and brown trout as hosts. Should a lower number of salmon migrate up the rivers to the River Clun due to low flows, the Freshwater Pearl Mussel found in the River Clun are unlikely to be compromised since they are not solely reliant on salmon. As good population of Brown Trout are found in the River Clun and they don't move or migrate to the same extent as salmon, this further reduces any risk to the Freshwater Pearl Mussel. Although the implementation of the RSDO could potentially have an effect on salmon migration up the estuary and River Teme, it will not have a likely significant effect on Freshwater Pearl Mussel in the River Clun.

2.4.4. Summary of Likely Significant Effects on Walmore Common

This is a peaty wetland occupying a low-lying area in the Severn Vale and is used by Bewick swan for which it is designated. The site is subject to annual winter flooding and is hydrologically linked to the River Severn by open water ditches. It is largely dependent on precipitation and winter flooding: water levels can be managed and maintained on the site by means of a tilting weir and tidal flaps.

Theoretically the site is more likely to be impacted if the RSDO was evoked during the winter months when Bewick swan are found on the site. By the time a RSDO is likely to be implemented the habitat will probably be drying or dried out therefore the swan will use other sites since they are not site dependent on Walmore. Since the swans are not reliant on this site, a change in water levels in the River Severn and any accompanying management of the site will not have a likely significant effect on the swan population.

For the following sites a more detailed consideration of likely significant effect has taken place and consultation and advice sought from Natural Resources Wales and Natural England.

2.4.5. Summary of Likely Significant Effects on the Montgomery Canal

This site has a rich and diverse aquatic flora but is designated for Floating Water Plantain *Luronium natans* which is found in the Welsh section of the canal between Pant and Newtown. At the north end, water is supplied from the River Tanat to the canal at Carreghofa Locks and approximately 2km from Newtown at the south end, water is taken from the River Severn at the Byles bypass feeder above Penarth weir.

These inflows are not authorised as abstractions but are subject to an operating agreement between the Environment Agency and Canal & River Trust (the Trust), set up by the Montgomery Canal Agreement 1988. This agreement is linked to operation of the Llyn Clywedog Reservoir which is used to regulate and maintain flows in the River Severn therefore there are measures in place to deal with drought conditions. As discharges from Llyn Clywedog are restricted to manage the remaining available water, the Trust are required to reduce the amount of water taken at Penarth. Once the RSDO is activated, the Trust can only abstract a maximum of 16.43 Ml/d or 115 Ml in 7 days at Newtown. Abstraction at Carreghofa Feeder (which takes water from the River Tanat) is also limited to 49 Ml per seven days or less to maintain a residual flow of 15 Ml/d on the Tanat downstream of the feeder to the canal. During any river regulation period when storage in Llyn Clywedog is less than 25% of its full capacity the Trust must not abstract from either river. This reduced change in available water will lead to reduced water levels and flow therefore there is the potential of a likely significant effect.

Floating Water Plantain is a plant of clear, usually still or slowly flowing, fairly permanent water, ideally sufficiently shallow (less than 60cm) for its submerged rosettes to produce floating leaves and flowers. It can also persist in a non-flowering state for many years in deep water down to 2m, as well as being able to grow on the exposed damp mud of draw down zones. It seems to be able to tolerate a range of base and nutrient levels from low and fairly high. The plant has thrived in the canal in recent years because there has been minimum disturbance from boats, but sufficient maintenance to keep the waterway clear of invading reedswamp. It often reaches great abundance a few seasons after dredging operations and then gradually declines. The most relevant Conservation Objective is :- The ecological status of the water environment, including elements of water quality, depth and clarity, will be sufficient to support species-rich canal vegetation with a variety of submerged, floating and marginal species and the populations of locally rare or uncommon species in favourable condition.

It is thought that the direct impact of low flows would be limited and relate to the section of canal that was being affected. Water from the Severn only flows as far as the Wern and the biggest concentration of plants is found at Red House nearby. This stretch of the canal is fed by water from the Severn and has good shade cover therefore there is low risk of this stretch being impacted, unless it should run completely dry. When the Manchester canals were being restored, water levels were dropped during works and the Floating Water Plantain present adapted to its amphibious state. Once the water level was raised again, the plant adapted back to its aquatic mode. For the Montgomery Canal it is anticipated that if levels were reduced low enough this is what would occur and these conditions would also trigger the plant to flower Ken Perry (Natural Resources Wales pers comm.13/12/2011) and Stuart Moodie (Canal & River Trust pers comm 14/11/2011).

The indirect impact of a change in water levels and resultant change in flow also needs to be considered. The Trust recognises that maintaining water flow through the canal is an issue in the summer. Maintenance is required to reduce emergent growth in the canal to free up flow from the inlet to the outlet, and remove accumulated sediment at Penarth to allow flow through the inlet. If available water was reduced maintaining sufficient through flow is more likely to be an issue. The result of this would be stagnant water which would be less favourable for Floating Water Plantain and more favourable for more aggressive plants unless additional weed clearance and dredging was carried out.

In a ‘worse case scenario’ in which the canal dried up, if aggressive species such as marginals were removed the plant should recover. As stated the lower flows which would be experienced in the canal, particularly if abstraction ceased could trigger flowering and seed production which could benefit the plant. (Ken Perry, Natural Resources Wales & Stuart Moodie, Canal & River Trust, pers comm). Therefore due to the fact that the effect of a drought should only be short lived, the species should recover and may even benefit from drier conditions, it can be concluded that there is no likely significant effect on the Floating Water Plantain for which the site is designated.

2.5. Severn Estuary SAC, SPA and Ramsar

The Severn Estuary is designated as a SAC, SPA, Ramsar and SSSI on the basis of a range of habitats and species therefore in order to gain an understanding of the potential effects on the specific sensitivities of the designated features, it is necessary to understand the relationship between them. Table 4 below shows the wide range of nature conservation features for which the estuary is valued and the interrelationship of these features by designation. This table outlines features of European and International importance in their own right and others of national importance for which the Severn Estuary has been designated as a Site of Special Scientific Interest (SSSI). These features form an intrinsic part of the Severn ecosystem and therefore contribute to the overarching "estuary" feature of the SAC and Ramsar Site.

Table 4. Summary of Notified features of each designation

Feature	SAC	SPA	Ramsar Site	SSSI (Nationally important feature)
Estuary	Yes	Supporting habitat to designated bird interests	Yes	(Yes)
Subtidal sandbanks	Yes	No – outside boundary of SPA	No – outside boundary of Ramsar Site	No – outside boundary of SSSI
Interridal Mud and Sandbanks	Yes	Supporting habitat to designated bird interests	Component of Ramsar "estuaries" feature and supporting habitat to designated bird interests	Yes
Atlantic salt meadow/salt marshes	Yes	Supporting habitat to designated bird interests	Component of Ramsar "estuaries" feature and supporting habitat to designated bird interests	Yes
Reefs	Yes	No	Intertidal Sabellaria contiguous with subtidal reefs is a component of the hard substrates	No – outside boundary of SSSI
Migratory fish (river & sea lamprey & twaite shad)	Yes	No	Yes	(Yes)
Migratory fish (salmon, eel, sea trout and Allis Shad)	Part of notable species sub-feature of estuary feature	No	Yes	(Yes)
Assemblage of fish species (>100 species)	Notable species sub-feature of estuary feature	No	Notable species sub-feature of estuary feature)	(Yes)
Internationally important populations of migratory bird	Notable species sub-feature of estuary	Yes	Yes Internationally important populations of waterfowl	Yes

species	feature			
Internationally important populations of wintering bird species	Notable species sub-feature of estuary feature	Yes		Yes
Assemblage of nationally important populations of waterfowl	Notable species sub-feature of estuary feature	Yes	Yes	Yes
Hard substrate habitats (Rocky shores)	Notable species sub-feature of estuary feature	Supporting habitat to designated bird interests	Component of Ramsar "estuaries" feature and supporting habitat to designated bird interests	Yes
Freshwater grazing marsh / Neutral grassland	No	Supporting habitat to designated bird interests within SPA but outside European Marine Site and therefore not addressed in this Regulation 33 advice document		Yes (currently England only)

At the screening stage of RoC for the Severn Estuary it was considered that due to the huge tidal range and highly energetic environment of the Severn Estuary, there were many variables that can affect the hydrological regime of this site. The primary potential effect of drought which is a natural process, and any options put in place to manage reduced available water, is the reduction of freshwater flows to the estuary. It is difficult to relate flows to ecological and habitat impacts (what happens in the real world), especially since the estuary has the second largest tidal range in the world, is the longest river in the UK and the designated area of the estuary is large (73,715ha). Identifying the potential hazards caused by low flows that could affect the interest features of the estuary is straightforward, see Tables 2 and 3. However as with the RoC process determining the reduction of flows that has to occur to lead to changes in salinity, suspended sediments or reduction in dilution capacity is more difficult especially when other factors such as coincidence of tides with low flows, improvements to sewage treatment works are considered.

Whereas changes to the freshwater inputs may impact on the terrestrial features in their own right they also have to be considered in relation to other features such as birds that are dependent on a particular hydrological regime and habitat. A reduced surface water flow may also disrupt the migration route of important fish species. The nature of the abstraction, the seasonality, consumptiveness and quantities will all affect the extent to which the features are impacted. Therefore the effect of applying the RSDO will be assessed and discussed in relation to the overall estuary feature of the SAC and Ramsar and then also the individual habitat and species features of the designated sites, shaded in green in Table 4 above.

Due to the uncertainty and difficulties in determining likely significant effects on the estuary more detailed work has been undertaken at this earlier stage of the HRA. The process is typically iterative and as modelling has been carried out, information become available and discussions taken place with Natural England, this assessment of likely significant effect has been revised.

The screening and Appropriate Assessment for RoC focused on ensuring there was enough freshwater flow from the Severn into the Estuary especially in relation to maintaining the flows in the River Severn for migratory fish. However it was recognised that drought conditions were outside the scope of the RoC process.

RoC concluded that during the screening process there were no discharge consents that were likely to have a significant likely effect on the Severn Estuary site and features. However due to the reduced water flows that would trigger implementation of the RSDO and potential this has to affect water quality this has been re-assessed under RSDO conditions.

2.5.1. Determining Likely Significant Effect

The only means of determining the likely significant effects of implementation of the RSDO options was to use the same methods, targets and modelling as employed for RoC. However models have been updated and additional data and information has become available including reports on the effects of actual droughts. This assessment again considers the effects of abstraction on the river under average flow regulation and then considers two drought conditions, Acute and Chronic. It also considers what would happen should drought continue and no further restrictions or measures are put in place i.e. a '' Do Nothing'' Baseline option.

The Severn Regulation system and measures taken leading up to a drought is explained in Section 2.2 but a limited amount of technical information has been re-iterated below for clarification. As requested by the statutory consultees detailed technical information regarding methods, targets, modelling etc is given in Apps 2, 3, 4 and 5.

2.5.2. Background

Deerhurst and Haw Bridge represent the furthest downstream flow gauges on the River Severn from which flow data can be accurately measured. Haw Bridge is impacted by tidal back water whereas Deerhurst is able to record levels without the tidal influences experienced in the lower tidal Severn. However it is 10km upstream of the boundary of the Severn Estuary Natura 2000 site and also excludes the significant abstraction for the Gloucester and Sharpness canal. Therefore for modelling purposes, U/S Sharpness provides an indication of possible flows just upstream of the abstraction point and channel split, while Lower Parting being downstream of the abstraction point is used as the main assessment point for inflows to the designated Severn Estuary.

The lower tidal Severn splits for a short distance between Upper and Lower Parting at Gloucester, with a weir in each channel. One is at Maisemore, near the up-estuary end of the West Channel, and the other is at Llanthony, near the down-estuary end of the East Channel and these two weirs influence tidal propagation in this reach of the river. Both Maisemore and Llanthony weirs can be over-topped by tidal levels reached by intermediate tides, or tides exceeding a height above chart datum (CD) of about 7.8 m at Sharpness for Llanthony weir and 8.1 m for Maisemore weir.

2.5.3. Targets

In order to assess the effect of implementing the RSDO on the designated Severn Estuary, flow targets were used to provide a guide on how significant the flow decreases would have to be to have a significant effect on the designated features. The Water Framework Directive (WFD) requires that all transitional water bodies achieve good ecological status (GES) by 2015. Stage 3 of RoC used these WFD flow targets to assess the current flow regime and gauged and modelled (Low Flows 2000) natural flows to conclude no adverse effect. The WFD Sensitivity Ranking (sensitivity to abstraction) for the Severn Estuary came out as low, reflecting the large tidal range and area involved.

Whilst WFD flow targets provide a general guide to the Estuarys' sensitivity to abstraction and freshwater inflows, site specific targets should be utilised where available. In 1992 an investigation was undertaken (Hutcherson and Wade) into the residual flow requirements for the Upper Severn Estuary. This concluded that tide height is highly influential (due to saline water movement) on how much freshwater inflow is required to restrict the amount of saline intrusion up the River Severn. A minimum Neap tide flow target of 1200Ml/d and minimum Spring tide flow target of 1800Ml/d were recommended to help support the Severn Estuary environment, and protect freshwater abstractions. Since these are the only flow targets relating to this factor they have also been included in the assessment for modelling completeness.

These targets only provide a guide on flow quantity, what this 'looks like' on the ground and how it actually impacts the designated features and habitats remains very difficult to assess. Historic drought events provide some insight and whilst working on this current RSDO old files were located which contained reports which have provided valuable information on previous events.

2.5.4. Historic Drought Events

There is no exact definition of what constitutes a drought, and classification is often dependant on meteorological, hydrological (and environment), agricultural or water supply impacts. For the Midlands region, owing to the significance of major groundwater aquifers in supporting river base flows, it is prolonged shortages of rainfall and dry winters, notably over two consecutive years that have the largest potential environmental impact. From the discovered files we are now aware that variations of the RSDO were operated in 1976, 1984 and 1989 and the information given below provides an understanding of the reality and potential impacts of operating a RSDO.

2.5.5. 1975-1976 Drought

Current analysis still shows 1976 as the most widespread and severe hydrological event for the majority of England and Wales, with subsequent droughts recording annual flows more than 30% higher than experienced in 1976 (Rodda, J.C, & Marsh, T.J. 2011 (CEH)). Estimates for the rainfall return period of England and Wales for this event vary, with estimates from a 1 in 250 year to over a 1 in 1000 year (Wright, 1976) event over a 16 month period having been quoted. Local variations and different time periods make it hard to compare results but using the Tabony technique it is thought to represent a 1 in a 200 year event.

During this event two drought order applications were made with the first being granted on 6th August which resulted in prescribed flows at Bewdley being lowered by 182 Ml/d, from the normal 727 Ml/d down to 545 Ml/d. August continued to be hot and dry with more rivers drying up and abstraction demands increasing as small reservoirs and shallow groundwater wells dried up. By mid August the Authority realised the drought event was exceeding Llyn Clywedog's original design and as projections showed only 42 days of storage remained, a second drought order was applied for. This was granted on 3rd September and would have led to prescribed flows at Bewdley being abandoned and releases limited to 2% of the remaining storage per day, subject to flows at Bewdley not exceeding 545 Ml/d. Although the second drought order was granted, it was never operated as sufficient rainfall returned.

Figure 4. Guaged and naturalised flows at Bewdley

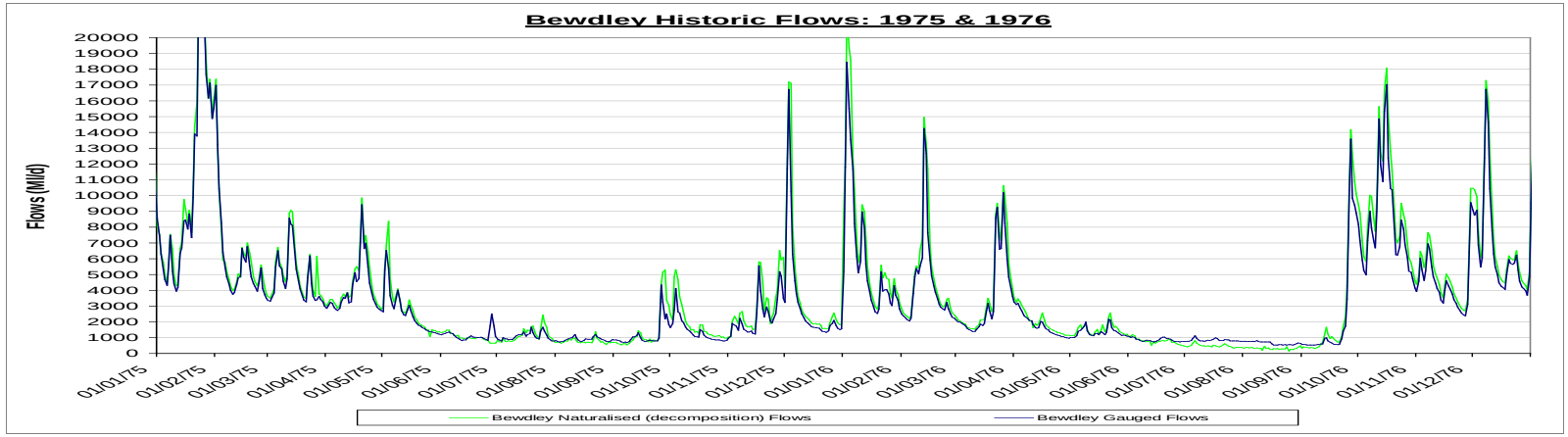
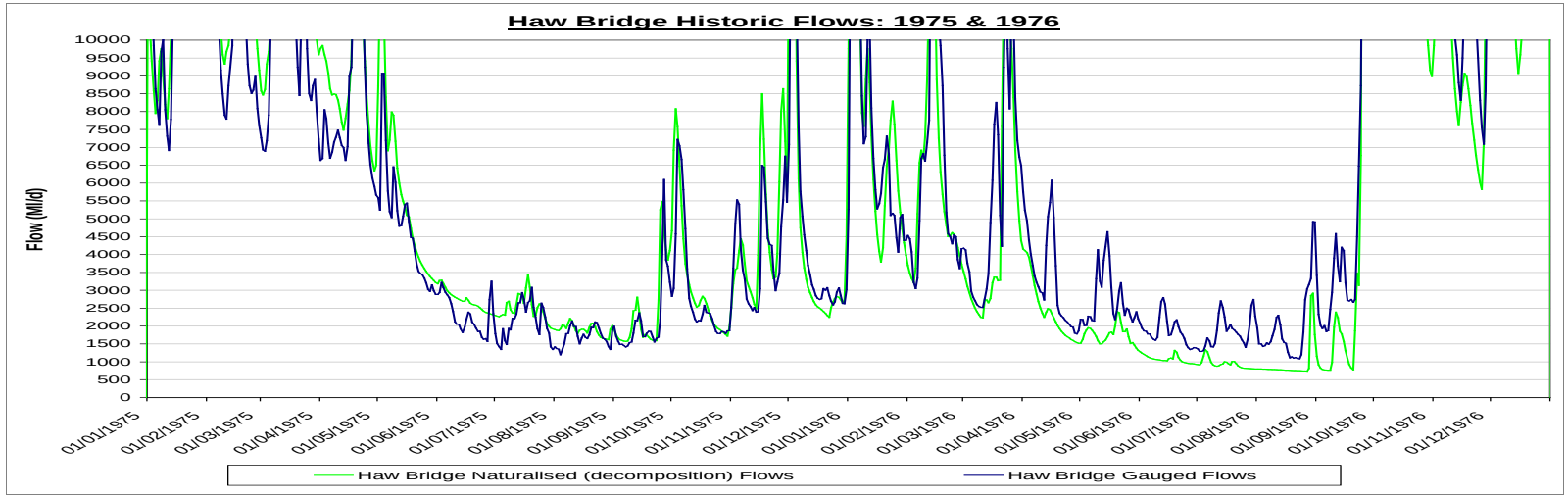


Figure 5. Guaged and naturalised flows at Haw Bridge



The graphs shown in Figures 4 and 5 for gauged and naturalised flows at Bewdley and Haw Bridge during 1975 and 1976 show that, without Severn Regulation support, flows would have been significantly lower than experienced. Even when the drought order was applied which resulted in prescribed flows being reduced, the graph illustrates that flows without the artificial support of the Severn Regulation system could have been up to a further 300 Ml/d lower.

Environmental impacts were widespread with low flows coinciding with high ambient temperatures. Water quality did not create a major issue as the temperature promoted high biological activity both in the effluent treatment plants and the river with a consequent reduction in pollution loads. Any significant reduction in biological activity could have increased concentrations of ammonia and biological oxygen demand (BOD) in the river. The River Stour was commonly documented as being a 'polluted' river during this period, and reports acknowledged a decline in water quality on the Severn downstream of the confluence with the Stour. No major problems were encountered at the major public water supply intakes and treated water standards were maintained although there were localised, small scale fish kills during late June and July. Thunderstorms and high rainfall events that ended the drought did cause a drop in water quality across the catchment but as a natural event nothing could be done to prevent this.

There were concerns about saline incursion from the Severn Estuary reaching Gloucester Docks during high tides in late August as saline water entering the Sharpness canal could potentially lead to Bristol Waterworks needing to shut down the intake (public water supply abstraction) at Purton. Pumping continued during the period although the total abstracted was reduced as saline levels at Purton slightly exceeded EEC guidance targets for surface water abstraction. As the drought ended abruptly no further action was required.

Impacts on the Gloucester and Sharpness canal and Severn Estuary inflows seem to have been the most obvious and major issues, although severe problems were occurring before the RSDO was operated. High abstraction demands for the canal (lockage purposes and Bristol Waterworks Company abstraction at Purton) during low flows resulted in residual flows to the estuary being reduced to nearly zero for short periods. During peak pumping, flow in the River Severn dried up over Maisemore Weir and was reduced to only a few centimetres over Llanthony Weir (lower level). During June and prior to the RSDO being operated the western channel downstream of Upper Parting became choked with silt while little fresh water flow was reported in the east channel. These conditions combined with high temperatures resulted in some salmon and fish mortalities although numbers were limited and much lower than recorded at sites further down the designated Severn Estuary (P. Jonas pers comm.)

The 1976 report on the drought concluded that "moderate increases or decreases in the regulated flow at Bewdley would have little effect on the river or estuary" and the "circumstances [experienced] were acceptable on the basis that such "emergency" conditions were not to expected more than once or twice in a lifetime" (River Severn Basin Steering Group (STW), 1977). However as a result of this 1975-1976 drought event several steps were taken in water resource planning and drought management over subsequent years to increase the resilience of the Severn catchment. Operational drought curves for Llyn Clywedog were updated, the prescribed flow at Bewdley was raised to 850 Ml/d to buffer abstraction and improve environmental protection downstream of Bewdley, Lake Vyrnwy bank operation was formalised and further resources were developed in the Shropshire Groundwater Scheme.

The impacts observed in 1976 were largely a natural consequence of drought and would be expected to reoccur during similar events. From the evidence obtained at the time, implementation of the RSDO alone cannot have been considered to cause likely significant effects on the river or the designated site because it continued to elevate flows above what would have naturally occurred. The impacts that were seen largely related to maximum pumping into the Gloucester and Sharpness canal reducing Severn Estuary inflows to nearly zero. This exacerbated saline intrusion and silt deposition in combination with insufficient dilution of effluent from Sewage Treatment Works (STWs), particularly Netheridge which led to oxygen sags resulting in fish mortality and migration issues.

It should be noted that water quality from many of the STWs and particularly Netheridge has since been improved as the works have been upgraded therefore dissolved oxygen sags are less likely now unless triggered by saline intrusion.

For more information on this event please refer to relevant reports, listed in the reference section.

2.5.6. 1984 Drought

"As a whole 1984 was not an exceptionally dry year. Overall rainfall totals were not significantly below long term averages" (Hobbs, 1985). However the Severn catchment experienced consistently below average rainfall over the Welsh Mountains from March to July (only 9mm in April, lowest since 1938), combined with essential maintenance work leaving Llyn Clywedog at only 85% storage when regulation began on 15 June. Flows did not reach the 1976 recorded minimums.

Maximum regulation was in place by 11 July and high rainfall events provided only short term relief to the River Severn. Hosepipe bans were implemented across the Severn and Trent catchments and in some areas the National Farmers Union (NFU) organised voluntary rotas for abstractors to ration the remaining resources and reduce the likelihood of further restrictions being applied. During August drought order applications were made for Elan Valley reservoir compensation flow reductions and for Bristol Waterworks Company to increase abstraction at Purton.

A RSDO application was made on 1 August and operated from 18 August, for 2 months between 4 October and 4 December. This capped releases from Llyn Clywedog to 2% of storage but there was no reference to prescribed flow reduction at Bewdley and recorded flows did not fall below 850 Ml/d consistently enough to suspect they were altered significantly.

Regulation supported flows significantly higher than would have naturally occurred during a drought. Over 300 Ml/d of additional flow (above natural) was provided to the River Severn at both Bewdley and Haw Bridge. The minimum daily mean flows recorded were 707 Ml/d at Bewdley on 1 September and 1253 Ml/d at Haw Bridge on 27 July (flows in August were all above 1400 Ml/d).

2.5.7. 1989 Drought

Rainfall shortages began during August 1988 and extended over the winter, resulting in virtually no groundwater recharge by the end of January 1989. February to mid April saw rainfall return, but only modest recharge was recorded with the majority of groundwater sites only experiencing a slackening in the overall decline. From mid April persistently dry weather returned and river recessions began.

The regulation alert was issued on 22 May 1989 and the first day considered as regulation was 30 May, however hydroelectric power releases were made from 26 May to aid with local equipment replacement. Rainfall was periodic and heavy from June into September, causing releases to be constantly changed. River flows rapidly receded once rainfall events ended, with releases primarily from Llyn Clywedog and Lake Vyrnwy. The Shropshire Groundwater Scheme alert was issued on 22 June and activated on 17 July.

Baseflows at Bewdley dropped down to 500 Ml/d (flows to be expected without Severn regulation support), requiring high regulation support to achieve the prescribed flow. By 31 August Llyn Clywedog storage was down to 40% and a meeting was held to agree the RSDO application. The RSDO came into force on 30 September 1989, lowering prescribed flows at Bewdley to 730 Ml/d. Storage in Llyn Clywedog reached a minimum 30% on 10 October, but widespread heavy rainfall between 19-20 October brought an end to the drought and River Severn regulation for 1989.

Fish kills in the Severn Estuary were recorded on 25 June (114 adult Salmon), 13 July (92 adult Salmon) and 22 July (61 Salmon). The cause was attributed to sudden oxygen depletion, with

large numbers of Salmon spending long periods in the Estuary awaiting higher flows to begin migration. All significant fish kills occured prior to the RSDO application or operation.

2.5.8. Post 1984 Drought

In over 20 years and most notably during the 1995-96 event, the fact that the RSDO has not been required reflects the effectiveness of the measures put in place to increase resilience of the system and the ongoing development of further resources in the Shropshire Groundwater Scheme.

2.5.9. Average Flow Regulation

Before considering the effects of drought and implementing the RSDO it is worth being reminded that under the current flow regime (abstractions and discharges as they normally exist), regulation of the Severn supports flows above the Severn Estuary's Good Ecological Status (GES) at all times and all flow conditions are above what would naturally occur. This supports the RoC findings and confirms that Severn Regulation is supporting the achievement of WFD targets and raises the lowest and most drought related flows above what would naturally occur at the Deerhurst location.

However when tested against the residual flow targets (Hutcherson and Wade) even under natural conditions the Spring Tide inflow target would be failed by up to 576 Ml for 5% (Q95) of the time (approximately 37 days over the 2 year period). The current flow regime slightly increases this period to 8% (Q92) of the time (average 58 days), but reduces the magnitude of failure to 483 Ml, an improvement of 93 Ml. Both natural and current flows consistently support the Neap Tide inflow target at Deerhurst. This is a natural consequence of the fact that the estuary is tidal.

2.5.10. Estuary Inflows

To determine the likely significant effect of low flows and implementation of the RSDO options it was necessary to carry out the following flow modelling which incorporates all normal abstractions and discharges and the following scenarios:

- what could happen if no RSDOs or permits were operated,
- what could happen if the RSDO but no water company drought permits were operated,
- what could happen if the RSDO and all known Drought Permits were operated in-combination. (This scenario will be considered in the In-combination assessment).

As stated previously modelled data for Lower Parting was used due to its location downstream of the Gloucester and Sharpness Canal abstraction. Water framework Directive (WFD) 'transitional waterbody' flow targets (in line with RoC) and the 1992 Spring and Neap tide flow recommendations were used to assess the likely flow impacts of the RSDO on the Severn Estuary.

The Aquator model is the best water resources tool available at this time and can predict worse case scenarios however it can never truly represent the real situation and results need to be considered with this in mind. In order to trigger the need for a RSDO the modelling system had to be pushed into drought of a magnitude which has yet to be experienced.

The risks and failures modelled under the '' Do Nothing'' Baseline scenarios (of Acute and Chronic drought conditions) represent the natural drought effects, which are considered a direct result of an exceptional natural drought event and come under article 4.6 of the WFD. These results have therefore been used as the benchmark for what impacts could occur during Acute or Chronic droughts conditions and then used to assess what additional impacts implementation of the RSDO in-combination with water company drought permits could have.

2.5.11. Results

Detailed technical information with regard to the model used (Aquator), data used, limitation of the model and results obtained including graphs and detailed discussion can all be found in App 2. For the purposes of this assessment of likely significant effect they have been summarised and tabulated in Table 5 below:

Table 5. Summary of modelling results of RSDO options on estuary inflows based at flows at Lower Parting

Acute Condition - triggers the need for a single summer RSDO		**Chronic Condition - triggers the need for two consecutive summer RSDOs**	
' Do Nothing'	**RSDO (EA)**	**' Do Nothing'**	**RSDO (EA)**
Represents predicted flows if no RSDO is implemented to manage the developing drought, and no other water company drought permits are active. Modelling shows that initial flow conditions would be better but if the drought continued, flows would crash to minimal levels and there would be little resilience if the drought continued. Modelling indicates that at Deerhurst low flows could fall by up to 43% (670Ml/d) and if the drought continued long enough to cause regulation failure, low flows could drop a total 74% (980Ml/d) - therefore flow reduction in the lower tidal Severn is potentially significant. Temporary failure of WFD 'Good Ecological Status'	Modelling shows that if the RSDO was implemented initially predicted flow conditions would be worse but if the drought continued beyond maintainable prescribed flows at Bewdley i.e. regulation failure then higher minimum flows would be maintained than under the ' Do Nothing' option. No additional WFD GES or MES deterioration	Represents predicted flows if no RSDO is implemented to manage the developing drought, and no water company drought permits are active. As with Acute condition initial flow conditions are better until regulation resources are exhausted and flows crash to severe minimums. Main difference to the Acute onditionis little resilience to cope with a consecutive year of drought, as reservoir storage cannot recover quickly enough. Modelling suggests Deerhurst Q95 flow reductions are less in comparison to the Acute condition, demonstrating how the extended drought duration spreads the impacts. Potential flow reduction in lower tidal Severn is likely to have a significant effect. Temporary failure of WFD GES & MES flow targets as a	Modelling predicts that operation of the EA RSDO during the first year saves water which is then available for regulation during the second or subsequent years. This delays the need for a RSDO during the second year and greatly reduces the risk of regulation failure compared to the ' Do Nothing' scenario. This significantly improves the ability to protect flows in both the river and estuary The predicted benefits of operating the EA RSDO under the Chronic condition are much clearer, demonstrating its operation is a long term drought management option. No additional WFD

(GES) and Moderate Ecological Status (MES) flow targets. Failures significant but temporary and direct result of natural event therefore covered by WFD Article 4.6. Could be increased failure of the Spring and Neap Tide flow targets but dependent on low flows coinciding with these tides.	compared to the ' Do Nothing' scenario at Lower Parting. No additional Spring or Neap Tide inflow target failures at Lower Parting	consequence of natural drought, again failures are significant but temporary. Potentially more failures of the Spring and Neap Tide flow targets than under the Acute condition, due to the prolonged period of drought. Again impacts would depend on coincidence of low flows and tides.	deteriorations although flow reductions occur for longer. Modelling indicates the RSDO could protect GES at Deerhurst., Increased risk of failing Neap Tide target at Deerhurst No additional Spring or Neap Tide failures at Lower Parting, suggesting the impacts at Deerhurst are more likely the natural consequence of drought.

The '' Do Nothing'' Baseline models represent what would naturally occur during droughts of a magnitude to trigger a RSDO and all impacts have been assessed against improvements or deteriorations from this baseline. It needs to be remembered that droughts are natural events and cannot be prevented, only managed. The '' Do Nothing'' Baseline results are therefore considered to represent what would occur if no drought management action was taken to protect water supplies or the environment.

Acute and Chronic '' Do Nothing'' Baseline results indicated the natural drought event could cause temporary failure of the WFD Good Ecological Status (GES) and Moderate Ecological Status (MES) flow targets. The magnitude of the flow failures is significant, but the deterioration would be short term. The '' Do Nothing'' Baseline results also indicate that a natural drought event could increase the number of days estuary inflows failed to meet the recommended Spring and Neap tide flow targets. However, the actual number of days affected would depend on whether the low flows coincided with Spring and Neap tides.

Implementing the RSDO caused no additional GES or MES deteriorations compared to the '' Do Nothing'' Baseline scenario for either Acute or Chronic modelling. The overall magnitude and duration of deterioration altered slightly, reflecting the greater length of time for which lowered prescribed flows are in place at Bewdley which protects higher minimum flows under both Acute and Chronic droughts. The results also showed operating the RSDO creates no additional Spring or Neap tide inflow target failures at Lower Parting, compared to the '' Do Nothing'' scenario.

The Acute Scenario modelling showed that with prolonged drought the regulation system could fail (sources became too low to support any prescribed flow at Bewdley) even with the RSDO in place. Modelling suggests that implementation of the RSDO could cause regulation system failure at the same time or earlier than if no action were taken. However when regulation failure does occur, the water saved in Clywedog storage then enables a higher residual flow to be maintained during this critical drought period than would be possible under the '' Do Nothing'' Baseline scenario.

Modelling the Chronic condition showed if two consecutive RSDO years occur, utilising the RSDO in the first year would significantly improve the ability to protect the River Severn flow and Severn Estuary inflows in the subsequent year. The water saved by operating the RSDO during the first drought summer, would be available for regulation in the second year. This would delay the need for a RSDO in the second year as Clywedog storage would be higher, and greatly reduce the risk of regulation failure compared to the '' Do Nothing'' Baseline option. These results support the need for operating the RSDO, and allay modelling concerns that no flow benefits would be gained unless Regulation failure was reached.

2.5.12. Discussion and Conclusions of Estuary Inflows

Modelling can only provide a somewhat black and white interpretation of a set of events. Every drought event will be unique and produce different challenges. The reality is all drought events are unique and how we respond operationally will be different to a model, according to what information and confidence we have in forecasts at the time, timing and severity of drought. The flow modelling should only be used as a guide for possible worse case drought events to highlight the risks and help the Environment Agency better plan for drought and water resource management.

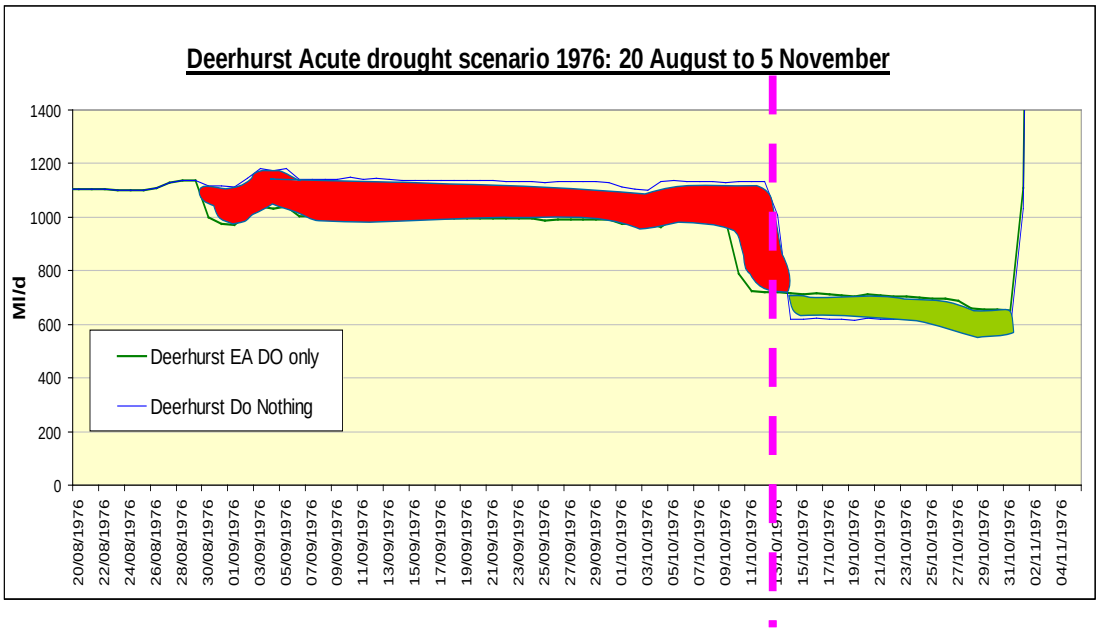
For further discussion of the limitations and assumptions associated with modelling see App 2.

Modelling has helped illustrate how robust the current Severn regulation system is. In order to trigger the need for a RSDO the modelling had to be pushed into droughts of very rare magnitudes. All the actions available to the Environment Agency allow time to be 'bought' to prolong the resource available from Clywedog whilst recharge is awaited, lowering the probability of needing to utilise the RSDO.

Real drought events have shown how the antecedent conditions at the commencement of the regulation season are the critical factor in whether a RSDO will be required if dry weather persists. For the Midlands region, historic droughts have shown that two subsequent dry years are critical in reducing groundwater levels and therefore baseflows to rivers in the second year. Natural baseflow in the catchment is the primary driver for how much regulation support will be required in the absence of rainfall, low and/or below average baseflow will result in high regulation releases being required to supplement the deficit. Once Clywedog is releasing large volumes in the absence of recharge, it is clear from real events (e.g. 1976) and modelling, that storage depletes quickly. Approximately 1% is lost per day when 500 Ml/d is released and consistent releases of over 400 Ml/d can cause Clywedog to cross the RSDO trigger in a single season if dry weather persists, as shown by modelling and the 1976 drought event.

Modelling has also identified that the RSDO could be operated during a drought without flow benefits being immediately achieved. Under the Acute condition, implementation of the RSDO can cause regulation system failure at the same time or earlier, creating additional flow stress during an already stressed period see Figure 6 below. However once regulation failure occurs then higher minimum flows are maintained for longer. The Environment Agency acknowledges this is a risk and would carefully balance this risk against the potential flow damage of not operating the RSDO and in relation to the long term weather forecasts.

Figure 6. Summary of modelling results of RSDO options on estuary inflows based at flows at Lower Parting



Note: Red indicates additional flow stress and green indicates flow benefits into the text box

Modelling the Chronic condition has helped to demonstrate that the resources saved by implementing the RSDO one year could be critical in safeguarding against a consecutive drought or significantly delay regulation failure the following year. Therefore, even though short term savings may not be translated into immediate flow benefits, the RSDO could have an important long term role and potentially be more beneficial in long term droughts than shorter acute events. Modelling suggested the storage savings made during the first RSDO year, could prevent or significantly delay regulation failure in the following drought.

Implementation of the RSDO will reduce Severn corridor flows for a given period, but even under the rare drought magnitudes modelled, it prevents complete regulation failure at Clywedog. Ultimately the water saved early on enables minimum flows to be increased along the whole Severn catchment when the regulation system goes into unavoidable failure as the drought continues. This reduces the severity of drought stress on flows during the most critical period. Importantly, the reduction in flow caused by the RSDO prior to the obvious benefits, does not lower flows below the modelled baseflow (baseflows shown after regulation failure in ' Do Nothing' Baseline scenario), and is therefore still maintaining an artificially elevated flow (above natural) benefit along the River Severn.

Real drought events (e.g. 1976) identify regulation beginning from April to early June, but reservoir storage and/or flows are not considered at significant risk until mid July onwards, when formal RSDO applications were made. Variations of the RSDO typically came into force in early August through into September. Modelling identified that with the additional regulation resources now available, this risk is likely to be delayed towards the end of August/early September, although abstraction demand is an important factor.

Historic drought flows and naturalised flow sequences down to Deerhurst gauging station indicate that implementing the RSDO in the past did not create additional impacts on the main River Severn, compared to what would have naturally occurred. During the worst periods of drought the regulation system was maintaining higher flows than could naturally have occurred, even with the RSDO operational. However flow data is not available further downstream of Deerhurst, so the true impacts of the Gloucester and Sharpness canal abstraction cannot be quantified from flow data. However drought reports state that flows around the channel split and inflows to the Estuary

were reduced to almost zero for short periods in 1976 and 1989 but this was related to the canal abstraction.

Modelled Acute and Chronic conditions have concluded no additional WFD or tidal flow target failures are caused by implementing the RSDO, when compared to the '' Do Nothing'' Baseline scenario. All flow and level reductions would be temporary and short term, with overall flow benefits to the river and estuary resulting from operating the RSDO.

The River Severn channel splits between U/S Sharpness and Lower Parting: monitoring data (spot gaugings between 1977-2007) indicates approximately 40% of flow goes down the East channel and 60% down the West channel, where the Canal & River Trust abstraction takes place. Low flows occurring during the drought would become divided and flow velocity would decrease further, increasing siltation and saline intrusion around this location however this depends on the tidal regime. It is this stretch of the lower tidal Severn that has been identified as potentially being at high risk during a severe drought however none of the modelling has shown that there are increased WFD target failures. There will be further discussion in Section 3.16.3.1 with regards to the Gloucester & Sharpness Canal abstraction.

The impact on the designated Severn Estuary sites will be limited primarily due to the fact that the boundary of the site is 33.5km below Maisemore where the lowest flows have been recorded during drought conditions. When river flows drop below 1000 Ml/d, river water only occupies a volume down estuary as far as about 3km below Maisemore weir i. e. Lower Parting. Therefore the reduction of flows 30km further downstream at the designated Severn Estuary will be minimal and the tidal regime has a major influence (See Section 2.5.13). The habitat and features are adapted to the extreme conditions associated with the tidal regime therefore at the designated site boundary, low flows associated with drought are unlikely to have a significant effect. Implementation of the RSDO and regulating the River Severn for a longer period of time to a lower flow is in fact likely to benefit the designated site.

2.5.13. Estuary Inflows and Water Quality

In terms of water quality an issue of concern related to low flows is reduction in dilution capacity and the resultant changes in nutrient loadings, oxygenation issues and in a worse case scenario toxic contamination. To determine these potential effects the River Severn River Basin District SIMCAT model represented the best option for assessing the water quality impacts of the RSDO options. It is the only current water quality modelling tool available that includes the River Severn corridor from source to estuary, includes the ability to model the inputs from all tributaries and the flow control measures at Vyrnwy and Clywedog reservoirs. The model, rebuilt in 2009 used water quality data from a variety of sources including a total of 499 river monitoring sites, 34 sewage treatment works and 50 industrial discharge sites. It also included data provided from 57 flow gauges throughout the catchment and daily mean flow data provided by Severn Trent Water and 29 major abstractions which could potentially impact on flows.

A 99% percentile assessment of determinants allowed a direct application of the results to extreme conditions and represents an almost worse case scenario. This allows assessment of potential worst case scenarios when river flows are at their lowest and dilution conditions for discharges to the river are at their worst. To simulate the worst possible flow scenario, all natural flows were reduced to zero i.e. flows comprised of just treated effluent discharges and releases from the Vyrnwy and Clywedog reservoirs.

In order to fully assess the impact of the operation of the RSDO on water quality, an assessment of compliance against both WFD targets and Fundamental Intermittent Standards (FIS) was carried out for phosphates, ammonia and biochemical oxygen demand (BOD). A comparative assessment of Total Oxidised Nitrogen is also included for reference. For further detailed information on targets see App 3.

Detailed information with regard to the River Severn SIMCAT model used, data used, limitation of the model and results obtained including graphs and detailed discussion can all be found in App 3.

For the purposes of this assessment of likely significant effect they have been summarised and tabulated in Table 6 below:

Table 6. Summary of water quality modelling results of RSDO options

Acute Condition - triggers the need for a single summer RSDO		**Chronic Condition - triggers the need for two consecutive summer RSDOs**	
' Do Nothing'	**RSDO (EA)**	**' Do Nothing'**	**RSDO (EA)**
	General improvement in WQ predicted although there were a very small number of minor deteriorations high up the system		No significant deterioration of any determinands predicted
	No new failures of ammonia or BOD	No new WFD failures for ammonia or BOD	No new WFD failures for ammonia or BOD.
Increased length of river experiencing phosphate standard failure.	Widespread P failure but concentrations generally reduced compared with the ' Do Nothing' scenario		
It is possible the increasing nutrient concentrations could result in eutrophic conditions, given the right physical conditions in which macrophyte and algal growth could establish.	Even under zero natural flow, ammonia & BOD are within WFD 90% standards		No BOD or ammonia failures predicted in the zero natural flow scenario
	Phosphate concentrations generally improved by RSDO application in the Zero Natural flow scenario	Deterioration in Phosphate concentrations resulting in new failures of the WFD standards.	Phosphate concentrations generally improved by RSDO application in the Zero Natural flow scenario Application of the RSDO would improve water quality in terms of nutrient concentrations even in the zero natural flow scenarios The application of the RSDO can also be seen to improve water quality in terms of nutrient concentrations in the zero natural flow scenarios

The modelling shows that in terms of water quality impact on the estuary, given that the drought flows represent an 82% reduction in mean flows and a 56% reduction during low flows compared with the baseline model output, the deterioration in water quality at the 95%ile concentration is relatively slight. Phosphate concentrations increase from a non-compliant 0.58mg/l to 0.78mg/l whilst the deterioration in ammonia is just 0.04mg/l compared with a baseline of 0.14mg/l. Both of

these ammonia concentrations are compliant with WFD Good Ecological Status requirements. Changes in BOD concentration actually see a predicted 40% improvement. It could be suggested that any further deterioration in quality would be equally slight and would be unlikely to cause any new failures of desired water quality standards. It is possible that the increasing nutrient concentrations could result in eutrophic conditions given the right physical conditions in which macrophyte and algal growth could establish. Application of the RSDO under both the Acute and Chronic condition will improve water quality along the River Severn in comparison to the ' Do Nothing' Baseline scenario.

The worst case, zero natural flow scenario tends to support this assumption. Considering this scenario represented almost zero dilution for treated sewage effluent discharges, the concentrations predicted at Lower Parting would give rise to few concerns with regards to the sanitary determinants, BOD and ammonia. As discussed above, the elevated nutrient concentrations could be of concern only if appropriate growing conditions allow excessive plant growth to occur.

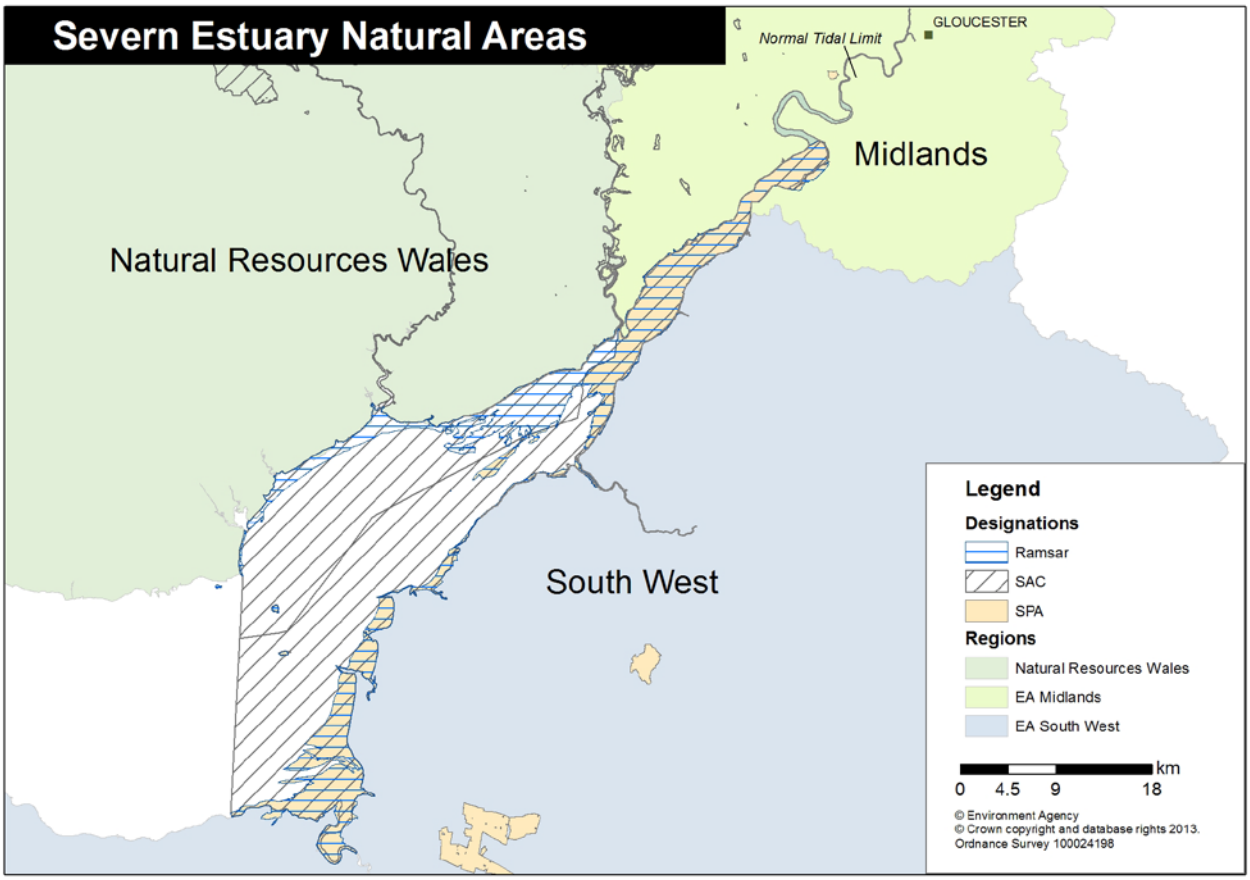
When the findings of this modelling are compared to an actual historic situation, the 1976/77 drought, it is re-assuring to read that the quality of the River Severn during the drought event caused very few concerns, despite the increased percentage of flow originating from sewage effluents. It should be noted, however, that temperatures recorded during the 1976/77 event were very high which aided the biological treatment of polluting loads in terms of both in-river purification and at treatment facilities. It is possible that should a drought period be experienced without these high temperatures then water quality deterioration could be more pronounced.

2.5.14. The Tidal Regime of the Lower Tidal Severn and Estuary

The SIMCAT modelling assessed the effects of water quality and in particular water quality determinants in relation to low flows on the main River Severn down to Lower Parting. However it was also necessary to consider the effects of low river flows and the implementation of the RSDO on the designated Severn Estuary features in terms of the tidal regime of the estuary. The fact that the estuary is tidal, is important in terms of water quality in relation to other issues such as the possibility of conditions of high saline intrusion, elevated suspended solids and resultant reduced dissolved oxygen levels that could occur if residual freshwater flow to the estuary were severely reduced. Such conditions could prevail where residual flows are insufficient to prevent the landward movement of the area of maximum turbidity which is responsible for the drop in dissolved oxygen. This is addressed in some detail since particular concerns were expressed by Natural Resources Wales and Natural England about the effects of saline intrusion in relation to low flow and possible effects on the saline wedge.

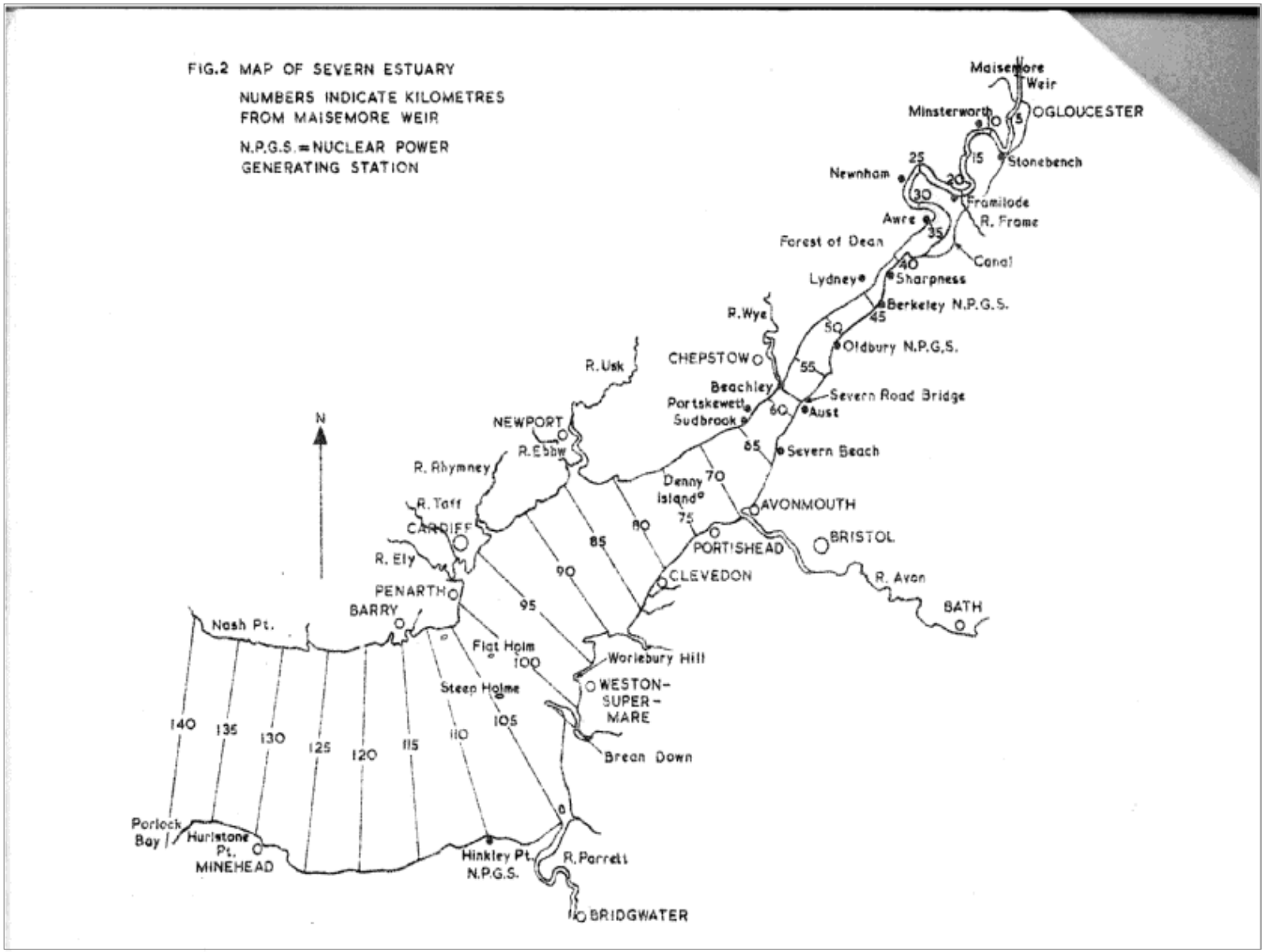
The boundary of the designated Severn Estuary is at Hock Cliff, 33.5 km below Maisemore Weir (see Figure 7).

Figure 7. SAC/SPA boundary in relation to lower tidal Severn and Gloucester



The map shown in Figure 7 below comes from a Water Pollution Research Report (Winters and Barrett 1972) shows the distances down the Estuary channel from Maisemore Weir at 5 km intervals.

Figure 8. Distance down the estuary from Maisemore weir



An important consideration in terms of the designated site and the lower tidal Severn is the tidal regime and the effects of spring (the highest high tides) and neap tides (lowest low tides). The Severn Estuary has an exceptionally large tidal range, with a Mean Spring Tide range of 12.2 m and a Mean Neap Tide range of 6.0 m at Avonmouth. The mean high and low tide levels for Mean Spring and Neap tides relative to Ordnance Datum (Newlyn) going up the Severn Estuary from Avonmouth to Llanthony are shown in Figure 9.

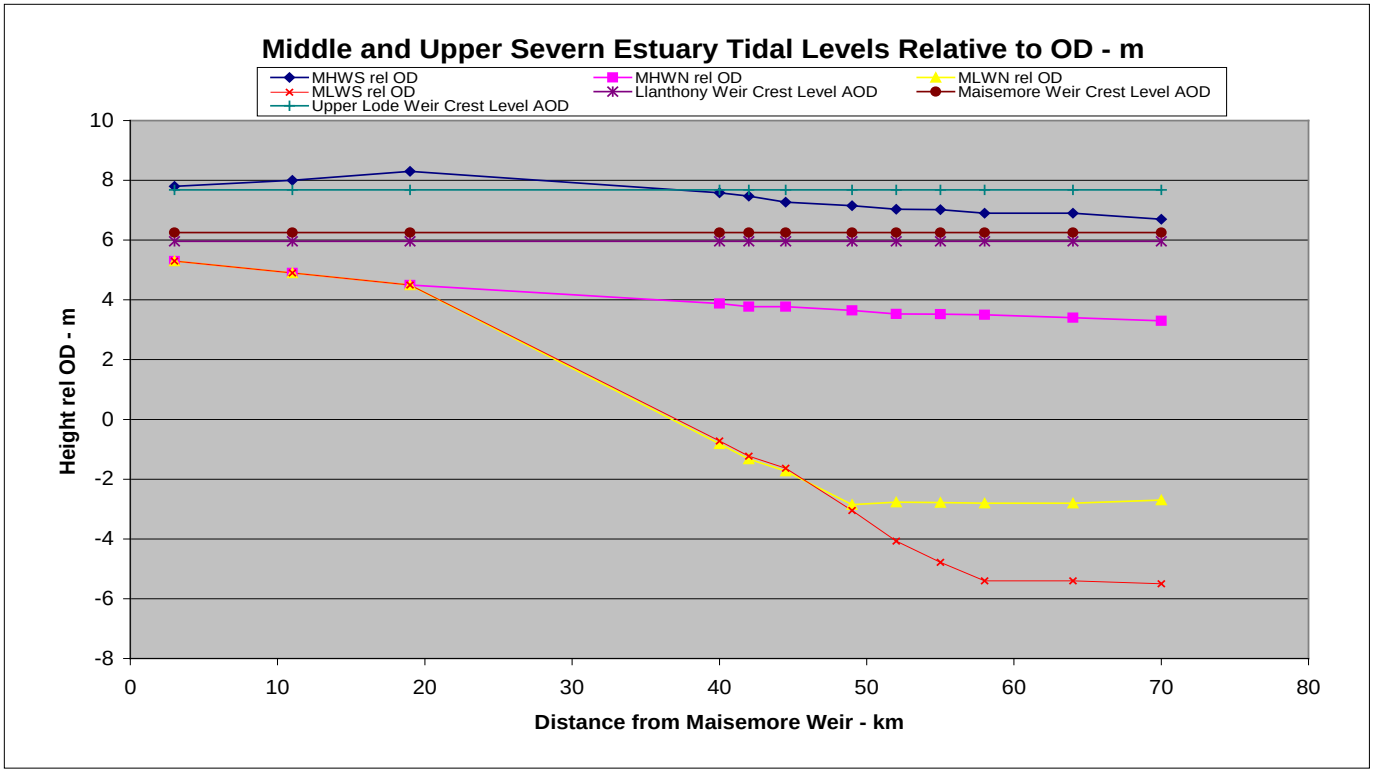
These show how tidal ranges are reduced in the Middle and Upper Estuary in response to the rising levels of the estuary bed. The Low Water Neap tides do not penetrate further up-estuary than about 19 km below Maisemore Weir near Epney whereas Spring tides reach above Haw Bridge, with the limit of flow reversal being near Tewkesbury, about 16 km **above** Maisemore Weir (Severn-Trent Water Authority 1977).

At the SAC/SPA boundary at Hock Cliff which is 33.5km below Maisemore the Mean Spring tidal range is about 7 m, and the Mean Neap tidal range is about 3 m. There is therefore a significant tidal rise and fall at the SAC boundary during both Spring and Neap tides.

It is worth re-iterating that the Tidal River Severn splits for a short distance between Upper and Lower Parting at Gloucester, with a weir in each channel, at Maisemore, near the up-estuary end of the West Channel and at Llanthony, near the down-estuary end of the East Channel. These 2 weirs influence the tidal propagation in the Tidal River Severn. There is also a weir in the lower reaches of the River Severn at Upper Lode, which is just below the confluence of the River Severn and River Avon. The crest heights of the these weirs are shown on Figure 9 relative to the heights of Mean High Water Spring tides and Neap tides. It is clear that both Maisemore and Llanthony weirs can be over-topped by tidal levels reached by even intermediate tides

The cumulative tidal volumes for the Severn Estuary are also shown in Figure 9. These show how the High Water and Low Water Spring and Neap tidal volumes change along the length of the Severn Estuary and into the Inner Bristol Channel. This reflects the change in tidal height in the Middle and Upper Estuary and rapid rise in estuary bed levels between 60 and 20 km below Maisemore Weir, i.e. between Aust and Framilode. Again the data show that Neap tides do not penetrate inland further than about Epney (a short distance above Framilode which is shown in Figure 7). The boundary of the SAC at Hock Cliff is within the area where estuary bed levels are rising, but the tidal volumes above this boundary are still quite large, being about 36 million cubic metres at Mean High Water Spring tide level, and about 15 million cubic metres at a Mean High Water Neap tide level.

Figure 9. Middle and Upper Severn Estuary Tidal Levels



The data in the above figure is derived from information in the Admiralty Tide Tables
MHW S Mean High Water Spring
MHW N Mean High Water Neap
MLW S Mean Low Water Spring
MLW N Mean Low Water Neap

The significance of river flows in relation to the tidal regime in the Severn Estuary has been assessed to provide an indication of what estuary tidal volume could be occupied by river water alone. It can provide an estimate of the saline intrusion but does not take account of stratification processes at high water, particularly a salt wedge effect, whereby saline water can be transported up-channel at the estuary bed, when freshwater is flowing down-channel at the surface.

It is clear that when river flows drop to 1000 Ml/d and below, river water only occupies a volume down-estuary as far as about 3 km below Maisemore Weir, i.e. Lower Parting. The up-estuary transport of brackish water and suspended sediments related to the turbidity maximum is therefore increased during intermediate and spring tides.

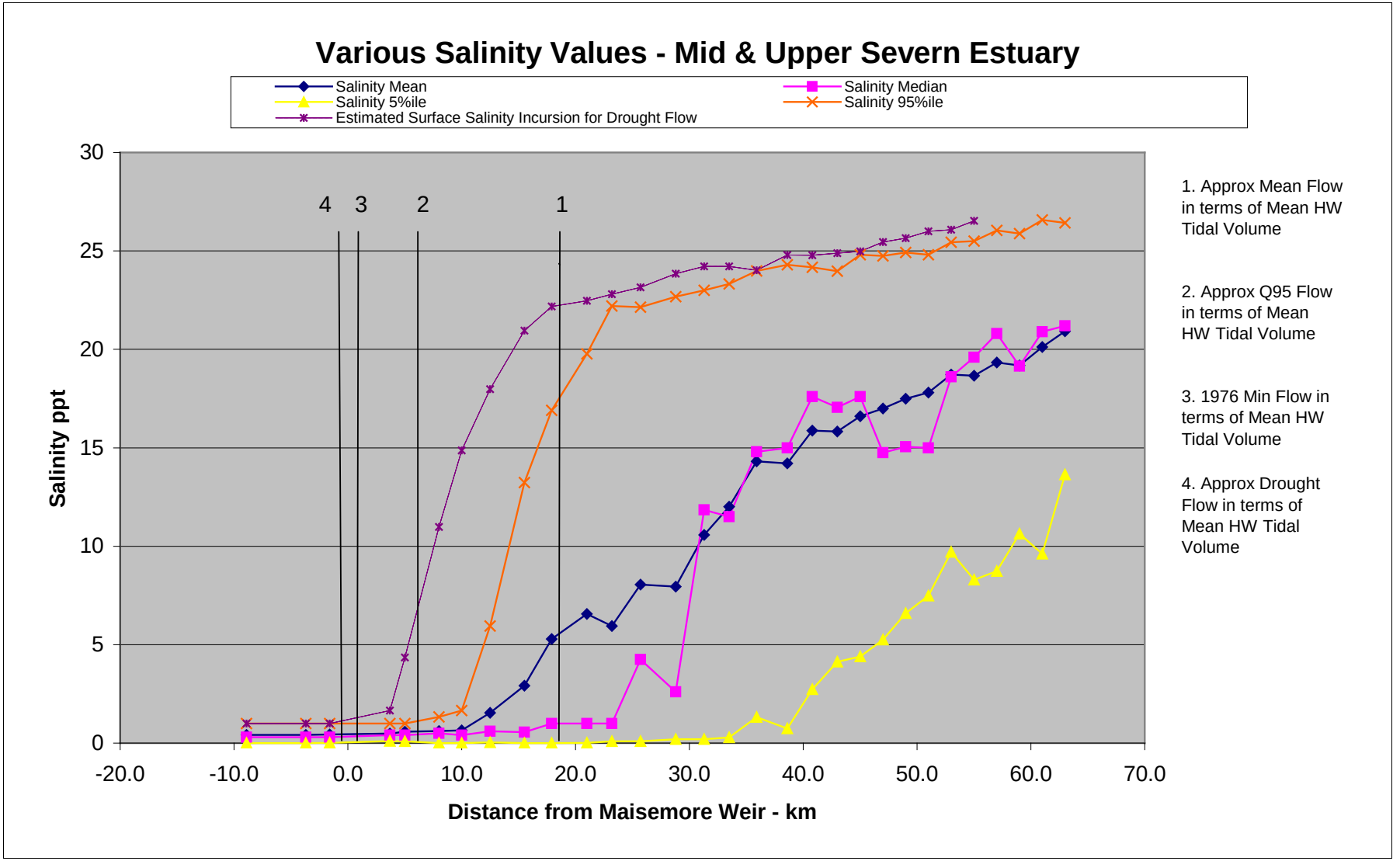
When river flows are very low, less than 1000 ML/d, there is little water available within the low water channel in the lower tidal Severn. The river flow is then split through the East and West Channels below Upper Parting and then further influenced by the weirs at Maisemore and Llanthony. The limited river flow in the two channels is further influenced by the abstraction at Gloucester by the Canal & River Trust to the Gloucester & Sharpness Canal, which is situated in the East Channel a short distance above Llanthony Weir. In the 1976 drought, the abstraction was about 330 Ml/d on average in August, although it peaked at about 500 Ml/d. The resulting flows at Lower Parting were estimated to get as low as about 250 Ml/d. Severn Trent Water Authority also reported that "In 1976, when flows in the river fell to levels lower than previously recorded, the residual (flow) to the estuary at times of peak pumping (by British Waterways) was reduced to a few centimetres over Llanthony Weir; Maisemore Weir being at a higher level was dry at these times." Photographs of the weirs taken on August 20th 1976 (see below) show that there may only be a very small flow over the weir at Llanthony, and no flow over the weir at Maisemore. It should be noted that the estimated drought flows of about 500 Ml/d at Lower Parting in the present RSDO are similar to, or even lower than the minimum flows which were estimated to have occurred at Lower Parting in August 1976.

RIVER SEVERN. – MAISEMORE WEIR and WEST CHANNEL.
20th AUGUST 1976.

RIVER SEVERN. – LLANTHONY WEIR and EAST CHANNEL.
20th AUGUST 1976.

The salinity regime in the middle and upper estuary has been assessed using axial survey data collected between 1977 and 1997 and salinity values for sites between about Severn Beach and Haw Bridge are plotted in Figure 10. The salinity values plotted for each monitoring point are mean salinity, the median salinity, the 5%ile salinity and the 95%ile salinity. It can be seen that salinity decreases from Severn Beach so that under a 'normal' flow regime, the surface salinities near Minsterworth are predominantly freshwater.

Figure 10. Salinity Values



Also plotted on Figure 9 are four vertical lines representing the cumulative tidal volume occupied by the defined freshwater river flow defined in terms of a distance downstream from Maisemore Weir. Line 4 represents an axial salinity profile which represents an estimated surface salinity incursion for 'drought flow'. The main feature of this estimated saline incursion profile is that it suggests that the high water salinity at Hock Cliff (top of designated Severn Estuary boundary) will only increase by about 1, which is not considered to be significant.

This work looking at the tidal regime, salinity regime and river flow compared with cumulative tidal volumes demonstrates that it is the lower tidal Severn that is impacted by low flows during a drought. In particular it is the section of river that splits between Upper and Lower Parting at Gloucester (with each arm of the river also having a weir) that is most impacted by low flows and saline intrusion from Spring tides and this was observed during the 1976 drought. This reflects the nature of the Severn Estuary in the uppermost reaches above the SAC as the greatest changes in bed levels, tidal range, and salinities all occur within this part of the Estuary.The assessment here indicates a similar conclusion, in that very low river flows during a drought will not have a likely significant effect on the designated Severn Estuary and its features, at least in relation to water quality apart from migratory fish and the fish assemblage. **Implementation of the RSDO does not cause a likely significant effect on estuarine inflows.**

2.5.15. Summary of Likely Effects on the Designated Sites (SAC, Ramsar and SPA)

Scoping of likely impacts on the designated sites has resulted in the identification of **low flows** and **water quality** changes as the two key areas for consideration. A key factor in the assessment is that in a drought scenario ecological systems would already be under considerable stress and that this assessment is to address the likely impact of the difference that the implementation of the SDO would make in that context.

Table 4 identifies the range of features and subfeatures which require consideration of the likely significant effect of the implementation of the RSDO (i.e. those identified by green shading).

Those highlighted are relevant because the conservation objectives identify **flows or water quality attributes as a key requirement of favourable condition i.e. of the Estuary feature (and therefore all of its component features and subfeatures) and the migratory fish and fish assemblage features, plus other designated features (birds and bird assemblages of the SPA and Ramsar) for which the estuarine habitats are key supporting habitats. Also see Tables 2 and 3 which provide a generic sensitivity matrix of features in relation to water resources and water quality.**

The consideration of the implications of the RSDO will be considered first at the whole estuary level, then at the level of dependant habitats and species. By first establishing the extent to which the whole estuary **processes** are affected by changes in water flow and water quality, it is possible to then identify which of the habitats and species require further scrutiny.

The assessment will also address the implications of the implementation of the RSDO alone and then in combination with other authorisations/projects.

2.5.16. Summary of Likely Effects on the Estuary Processes

i. Water Flows

The impacts have been considered in three respects:

- Impacts on flows into the estuary (with consequent potential impacts on dependant habitats and species)
- Impacts on the tidal estuary processes (eg effects on water chemistry)

- Impacts on the lower tidal Severn (outside the designated sites boundary but principal water source for the estuary and a supporting habitat for the migratory fish subfeature)

The findings of the water resources modelling shows no additional WFD or tidal flow target failures are caused by implementing the RSDO, when compared to the '' Do Nothing'' Baseline scenario. All flow and level reductions would be temporary and short term, with overall flow benefits to the river and estuary resulting from operating the RSDO. It is therefore considered that the implementation of the **RSDO alone will not have an effect on the inflow into the estuary, the tidal processes of the estuary or to the lower tidal Severn.**

However the findings show that the abstraction for the Gloucester & Sharpness Canal could have implications in combination with the implementation of the RSDO and that this might have particular implications for the movement of migratory fish species. This is assessed and discussed further in Section 3.15.

ii. Water Quality

The findings of the water quality studies (Section 2.5.12) show that the implementation **of the RSDO alone under both the Acute and Chronic conditions will improve water quality along the River Severn in comparison to the ' Do Nothing' Baseline scenario and the water quality of the estuary is not expected to be adversely affected.**

Having established therefore that the general estuary processes would not be significantly affected **it is therefore considered that implementation of the RSDO alone would not have a likely significant effect on the following principle habitats:**

Habitat	**Designated site feature**
Subtidal sandbanks	SAC Subtidal sandbanks feature SAC Estuary feature (*sub feature*)
Intertidal mudflats and sandflats	SAC intertidal mudflats and sandflats feature SAC Estuary feature (*sub-feature*) Ramsar Estuary feature (*estuarine habitat community*)
Atlantic salt meadow	SAC Atlantic saltmeadow feature SAC Estuary feature (*sub-feature*) Ramsar Estuary feature (*estuarine habitat community*)
Reefs of Sabellaria alveolata	SAC Reef feature SAC Estuary feature (*sub-feature*)
Hard substrate habitats (rocky shores)	SAC Estuary feature (*estuarine habitat community*) Ramsar Estuary feature (*estuarine habitat community*)

Similarly having established that the above habitat features and sub-features would not be significantly affected **it is therefore considered that the implementation of the RSDO alone would not have a likely significant effect on the following species and species assemblages.**

Species or species assemblage	**Designated site feature**
Assemblage of waterfowl species	SAC Estuary feature (*notable estuarine species assemblage*) Ramsar Estuary feature (*notable estuarine species assemblage*) SPA feature*
Internationally important populations of : Bewicks swan European white-fronted goose Gadwall Shelduck Dunlin Reshank	All species are : Ramsar features* SPA features *
Vascular plant assemblage	SAC Estuary feature (*notable estuarine species*

	assemblage)

* For which the estuary holds supporting habitats

The above designated habitats and species are all largely restricted to the estuary itself. However the estuary is also designated for a range of fish features.

Species or species assemblage	**Designated site feature**
Assemblage of fish species (*includes 7 migratory fish species listed below*)	SAC Estuary feature (*notable estuarine species assemblage*) Ramsar Estuary feature (*notable estuarine species assemblage*)
River lamprey Sea Lamprey Twaite shad	All species are: SAC features
Assemblage of Migratory fish species (Sea trout, Eel, Salmon, Allis shad, River lamprey, Sea lamprey, Twaite shad)	Ramsar feature

As shown above the Severn Estuary is of particular importance for diadromous (migratory) fish. These fish utilise marine, estuarine and freshwater habitats in an obligate fashion: without access to all necessary habitats they are not able to complete their life cycle. These fish are therefore particularly vulnerable to impacts that prevent or inhibit their migration; some of these fish are also vulnerable to water quality issues. *A rise in water temperature has the potential to impact on both migration and water quality.* The migratory fish may be moving into or be attempting to pass through the lower tidal Severn during drought conditions. Certainly, kills of migratory fish species were recorded during the drought of 1976 and summers of the late 1980s and early 1990s. These mortalities were thought to be due to reduced dissolved oxygen (DO) concentrations and increased intrusion of saltwater into freshwater in spring tides, conditions often associated with drought events. Most of the rest of the estuarine fish assemblage is to some extent, either adapted to cope with highly variable conditions or avoid adverse conditions, by moving further out into the estuary.

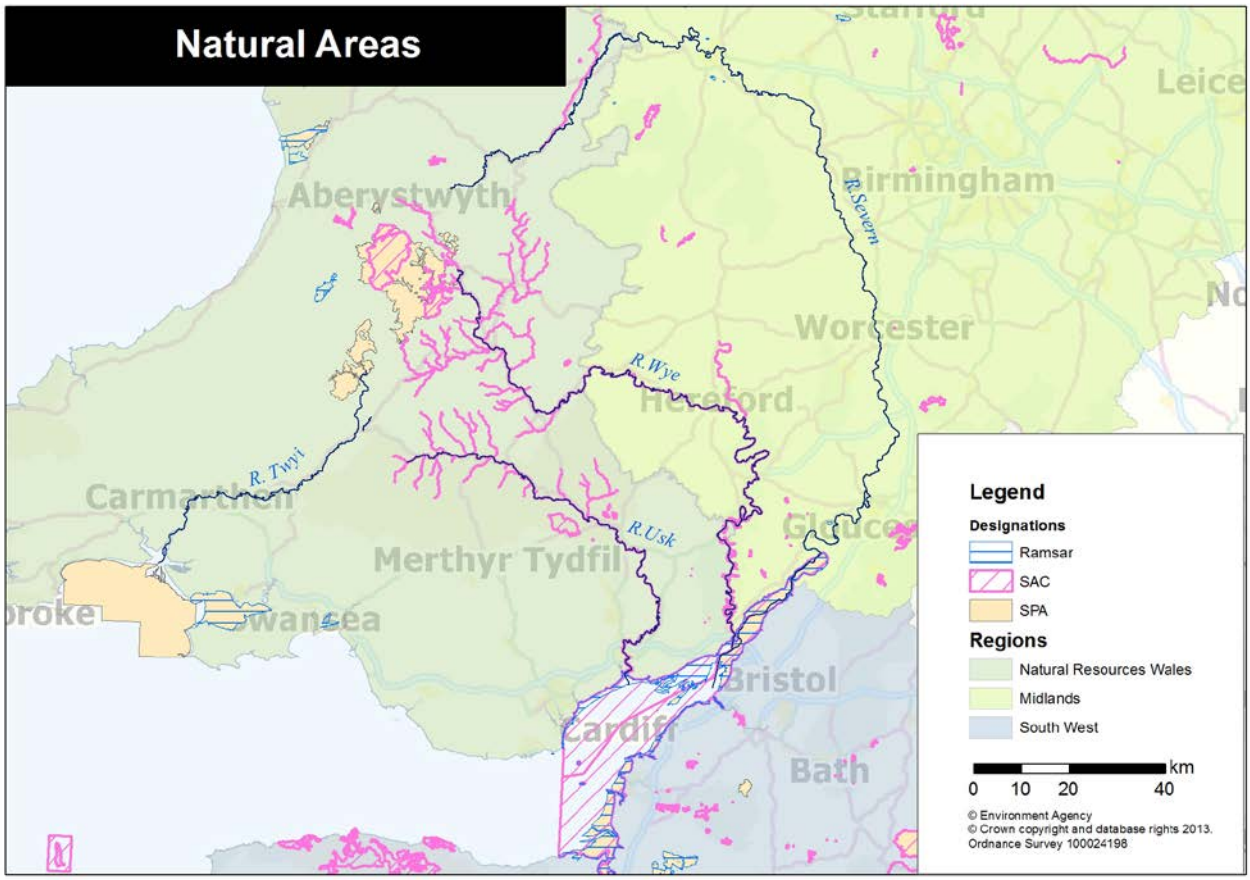
The RoC produced for the designated Severn Estuary concluded that the flows within the River Severn are sufficient for twaite shad, sea and river lamprey with the exception of a **rare** severe drought event. The implementation of a RSDO alone, is a response to a rare and severe drought and from the finding of the water flow and water quality studies it is considered that the **implementation of the RSDO alone could have a likely significant effect on the above features and they will be taken forward to Appropriate Assessment.**

Note: in the case of the assemblage of fish species which is part of an SAC and Ramsar Estuary feature - the assessment will only be undertaken in respect of the 7 migratory fish species rather than the complete assemblage.

2.5.17. Summary of Likely Effects on the River Usk, Wye and Afon Tywi Atlantic Salmon

Atlantic salmon are also designated features of the River Usk, River Wye, Afon Tywi SACs as well as the River Severn. Atlantic salmon spawn in all of these rivers; these spawn in freshwater but spend much of their adult life out at sea where they can range widely. The Bristol Channel and Severn Estuary thus contain a mixed stock of adult Atlantic salmon, potentially from rivers all around the local coasts of the UK.

Figure 11. River Usk, River Wye and Afon Tywi in relation to the Severn EStuary



Many salmon present in the Severn estuary will be in the process of migrating to their natal river. These include the Severn and other rivers along the south coast of Wales such as the Wye, Usk and Tywi SAC sites (see Figure 11). The time and route during migration from sea to river is highly variable and often involves multiple and temporary incursions into various estuaries and sub-estuaries before ascent into their home river. Due to their reliance on the Severn Estuary, any likely significant effects on adult salmon in the Severn Estuary could affect the River Usk, River Wye and Afon Tywi SAC Atlantic salmon feature.

Due to implementation of a RSDO, freshwater flows from the River Severn may be higher than other rivers entering the estuary. It is possible salmon might attempt entering the River Severn to spawn, rather than their natal rivers. However, due to strong home river fidelity and the likely inability of salmon to complete a migration into the River Severn during RSDO flows, the expected percentage of non-Severn salmon entering the Severn to spawn instead of their natal river is considered low. Further low flow impacts in the Severn estuary could result in adult salmon being impacted by poor water quality conditions. However, these would be the same effects of a naturally exceptionally severe drought and, in the conditions in which a RSDO would require implementation, would likely be felt in all estuaries. **Therefore the likely significant effect of implementing the RSDO on Atlantic salmon originating from these other rivers is considered negligible.**

2.6. Overall Summary Conclusion of the Likely Significant Effect Screening Alone

Screening is meant to determine whether implementation of the RSDO alone could have a 'likely significant effect on the designated features'. The HRA process is an iterative process and this assessment has been amended in response to available information and discussions with Natural

England. It has been possible to conclude no 'likely significant effect' on the majority of habitats, species and assemblages as set out in Table 4 with the exception of migratory fish. An assessment of the implementation of the RSDO ‘in combination’ with plans, projects and permits follows. The migratory fish will then be considered alone and 'in combination' in the following Appropriate Assessment.

2.7. In Combination Assessment

Regulation 6(1) of the Conservation of Habitats and Species Regulations 2010 requires the competent authority to consider, any Permission, Plans or Projects (PPPs) which are likely to have a significant effect on a European site, either alone or in combination with other permissions, plans or projects. Even at this screening stage it is necessary to consider the in-combination effects of other permissions, plans and projects.

The in combination assessment is limited to only include those PPPs that can reasonably be expected to affect features identified as at risk from the RSDO. Therefore this in combination assessment has concentrated on other Environment Agency permissions which include other abstractions and discharges and those of a similar and/or different type such as other drought orders or permits.

In combination means the sum of influences acting on a feature from all plans and projects in the context of **prevailing environmental conditions**. Prevailing environmental conditions are reasonably foreseeable impacts arising from any regulated and unregulated anthropogenic sources and natural sources. In this case the natural drought is the prevailing environmental condition.

2.7.1. Environment Agency Permissions, Plans and Projects

All Environment Agency permissions within the functionally specific agreed screening criteria must undergo a Habitats Regulations Assessment. In October 2009, under Regulation 50 of the Conservation (Natural Habitats, &c.) Regulations 1994 (amended to Regulation 63 under the 2010 regulations) the Environment Agency completed its Review of Consents for the Severn Estuary SAC and SPA. All applications for consents, plans or projects that have been submitted to, or undertaken by the Environment Agency since that date have been treated as new permissions and assessed under Regulation 61 of the Conservation of Habitats and Species Regulations 2010 to ensure that they do not have an adverse effect on site integrity.

The effects of abstractions and discharges that were subject to RoC have been further considered during the modelling carried out for this RSDO. Aquator which models water flow has taken all the large abstractions into account individually and also grouped together the smaller abstractions whereas SIMCAT used water quality and water flow data provided by both the Environment Agency and water companies.

2.7.1.1. Shropshire Groundwater Scheme

This is operated by the Environment Agency and instrumental in regulation of the River Severn and particularly during dry and drought conditions and also subject to a RSDO. An environmental report has been produced which has concluded that any environmental impacts are limited and local. During normal regulation it benefits the lower tidal Severn and estuary. When used 'in combination' with the other measures put in place by the RSDO it benefits and reduces the adverse effects of drought on the designated site and features. Operation of the SGS will certainly not have a ‘likely significant effect' on the designated Severn Estuary either 'alone' or 'in combination' with the RSDO. It is also included in the Aquator modelling.

2.7.1.2. Catchment Abstraction Management Strategy (CAMS)

The magnitude of any effect will not be significant when considered in combination with the CAMS, as the CAMS is for the sustainable management of water resources and so is likely to be beneficial for the sites' conservation interest features.

Catchment Abstraction Management Strategies (CAMS) allow us to better manage the water resources of a catchment using a modern regulation approach. This will help us balance the needs of the abstractor's water requirements with those of the aquatic environment.

The main aim of CAMS is to provide a framework for resource availability assessment to produce a licensing strategy. This will help us manage water resources sustainably on a catchment scale. This information will feed into the River Basin Management Plans under the Water Framework Directive (WFD).

2.7.1.3. River Severn Salmon Action Plan 2003

Sets out the objectives and actions for the management of salmon fisheries in the River Severn catchment and can be regarded as beneficial to this migratory fish which is part of the notable species sub-feature of the estuary feature.

2.7.1.4. River Severn Eel Management Plan 1010

Sets out the objectives and actions for the management of eels in the River Severn catchment and can be regarded as beneficial to this migratory fish which is part of the notable species sub-feature of the estuary feature.

2.7.1.5 River Severn Flood Risk Management Plans

There are also other plans such as the Severn Estuary Flood Risk Management Strategy, Severn Estuary Shoreline Management Plan, River Severn Catchment Flood Management Plan and River Severn Flood Risk Strategy which are all concerned with flooding and flood conditions therefore outside the scope of this HRA. All plans, orders and permits associated with drought have already been considered as they were included in the Aquator model.

2.7.2. Permissions Pertaining to Other Competent Authorities

Consideration also has to be given to permissions, plans and projects relating to other Competent Authorities such as water companies. Interestingly abstractions to canals i.e. to the Montgomery Canal and Sharpness & Gloucester Canal are exempt from the abstraction licensing regime in the Water Resources Act 1991 and therefore unlike other abstractions do not come under the control of the Environment Agency. The Gloucester & Sharpness Canal abstraction is discussed in further detail in Section 2.8.2.2 and 3.14 and 3.16.3.

2.7.2.1. Water Company Drought Permits and Order

As well as including all Environment Agency abstractions when modelling drought conditions, Aquator also considers the water companies drought orders and or permits therefore the in combination element of the HRA has already been built into the RSDO. There is a more detailed discussion of this model in Appendix 2.

Water company drought permits/orders for South Staffordshire Water (SSW), Unities Utilities (UU), Severn Trent Water (STW) and Dwr Cymru Welsh Water (DCWW) were added to the model. Small permits/orders (typically <3Mld) on the R.Wye were omitted due to limitations in model

accuracy and the decision to focus effort to produce a good representation of the larger permits/orders.

This is believed to be the first construction of a model which includes all permits/orders in-combination and their effect on flows in the River Severn. Previous studies have considered drought permits/orders in isolation and ignored the interaction between the individual permits and orders. This was important since there is potential for water company permits/orders to conflict with the RSDO. The permits/orders included in the modelling were:

South Staffordshire Water - have proposed two options for a drought permit at Hampton Loade.

United Utilities – have a drought permit relating to a reduction of compensation flow from Lake Vyrnwy.

Severn Trent Water:

- have a drought permit to abstract water from the Wye at Wyeland
- have a drought permit which relates to abstraction at Trimpley.
- have a drought permit which relates to abstraction on the River Leam and River Avon and the storage capacity of Draycote Reservoir.

Dwr Cymru Welsh Water:

- has a drought permit which can be implemented relating to the Elan Valley reservoir
- has a drought order for an unsupported abstraction form the River Wye at Monmouth.

Also included was the Gloucester & Sharpness Canal abstraction. This abstraction does not come under the control of the Environment Agency *because it is exempted from the abstraction licensing regime by section 26 of the Water Resources Act 1991*. This abstraction has been operated by British Waterways but in 2012 they became the Canal & River Trust (the Trust). This abstraction will be discussed separately. It should be noted that this modelling assumed a maximum abstraction of 300 Ml/d for the Gloucester & Sharpness Canal.

Initial in-combination modelling for both Acute and Chronic conditions with the water company drought permits did indicate that the magnitude of flow reductions was increased by the additional water company abstractions, so the impacts would be greater but the duration would remain the same. However it did not lead to any additional WFD deterioration or additional tidal inflow target failures. Therefore it can be concluded that **implementation of the RSDO in combination with the aforementioned water company drought orders and permits has no likely significant effect on the designated Severn Estuary and its features.**

It is also important to highlight the potential risk of not operating the RSDO during severe events when water company drought permits are active. If this was to occur, and the drought extended into regulation failure, then flows would crash to minimums lower than the '' Do Nothing'' Baseline scenario. This would potentially cancel out benefits of not operating the RSDO, by increasing the magnitude of flow reductions and threatening supplies and flows for the following years.

2.7.2.2. Gloucester & Sharpness Canal Abstraction

Under the Water Resources Act 1991 the Canal & River Trust (previously British Waterways) abstraction to the canal is exempt from licensing therefore excluded from the RoC. At the time it was thought that *implementation of the Water Act 2003 was imminent and the canal would become licensable, however this process has been delayed and is currently not expected to come in until April 2014 onwards*.

Whilst carrying out this RSDO work the Environment Agency became aware the Trust has the capacity to abstract up to 691 Ml/d (a maximum of 300 Ml/d was modelled), *although historically this has happened only infrequently and for short periods of time.* During an extreme drought maintained flows at Bewdley could be reduced to 730Ml/d over a 5 day mean. The ability to abstract up to 691Ml/d has the potential to have a likely significant effect on the lower tidal Severn

and the migratory fish feature therefore this will be considered in further detail in the Appropriate Assessment.

2.7.2.3. Severn Thames Water Transfer

This is a potential water company option that is being considered for the future and is therefore outside the scope of this assessment. If implemented it will comply with the Catchment Abstraction Management Strategy and be subject to an individual HRA, alone and in combination with other drought orders and permits to ensure it would not have any additional impact on low flows or drought events.

2.7.2.4. Walmore Common Water Level Management Plan (WLMP)

Water level management is important for maintaining the condition of Walmore Common SAC. As the WLMP relates to management of the site for the benefit of the sites' conservation interest features i.e. Bewick Swan it should include actions to be implemented when water levels on site are low. The effects of implementation of the RSDO should therefore not be significant when considered in combination with the WLMP.

2.7.3. Other Plans and Projects

There are other plans and projects that have been produced some of which may result in the development of significant infrastructure such as Hinkley Point C nuclear power station. These plans and projects with the resulting pressures put on the River Severn should have been subject to a HRA and should have also considered in combination effects. The likely significant effects of such plans and projects in combination with the RSDO are largely outside the scope of this HRA.

2.7.4. Overall Summary Conclusion of the Likely Significant Effect of Implementing the RSDO in Combination with Other Plans, Projects and Permissions

In line with the screening requirement of the Habitats Directive (1992) and Regulations (1994), an assessment was undertaken to determine the likely significant effect of implementing the RSDO in combination with other plans, projects and permits on the European Sites that are in hydrological continuity with the River Severn as well as the River Usk SAC, River Wye SAC and River Tywi SAC.

All relevant permits and other drought orders and permits (to be implemented by the water companies) were included in the Aquator modelling and this demonstrated that implementation of the RSDO in combination with these other permits would not have a likely significant effect on the designated site and features as shown in Table 4 with the exception of migratory fish. An Appropriate Assessment on the effects of implementation of the RSDO alone and in combination with other plans, projects and permits on migratory fish follows.

The Gloucester & Sharpness Canal abstraction at 691Ml/d **will also have a likely significant effect on the migratory fish** and this is assessed further in the Appropriate Assessment. However this abstraction is problematic since it is outside the control of the Agency.

3. HRA Appropriate Assessment of the River Severn Drought Order

3.1. Introduction

The Appropriate Assessment considers the impacts of implementing the RSDO against the conservation objectives of the migratory fish feature of the Severn Estuary SAC and Ramsar. This is in order to identify whether there are likely to be any adverse effects of the RSDO options, either alone or in combination with other plans and projects, on site features and integrity.

The migratory fish assemblage of the Seven Estuary has been designated a Ramsar feature; this includes sea lamprey (*Petromyzon marinus*) river lamprey (*Lampetra fluviatilis*), allis shad (*Alosa alosa*), twaite shad (*Alosa fallax*) Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*) and European eel (*Anguilla anguilla*). Sea and river lamprey, and twaite shad are a designated feature of the Special Area of Conservation (SAC).

The Seven Estuary is a complex and highly energetic environment with one of the largest tidal ranges in the world. The hydrological regime of this site is therefore affected both by the strong and complex tidal flows and freshwater flowing into it from rivers entering the estuary and their tributaries. The freshwater flows are affected not only by the natural hydrological regime, but also the man-made hydrological regime as the River Severn is highly regulated. Water is removed by abstraction for irrigation, industry and drinking water and returned in different quantities and locations as treated effluent. Additional freshwater can be artificially added from reservoirs and ground water schemes. Changes in the freshwater flow into the tidal river and estuary affects the water budget, salinity, water chemistry, temperature and can have important consequences. A drought is a natural event therefore this assessment looks at the effects of the management of this reduced freshwater input in terms of how it will potentially affect the estuary. It also assesses how this may translate into effects on individual habitat and species features of the designated site and the integrity of the site as a whole.

3.2. Summary of Review of Consents

The Review of Consents (RoC) concluded during the screening process that there were no discharge consents that were likely to have a significant effect on the Severn Estuary designated site and features. However due to the reduced water flows experienced in a drought and the potential this has to affect water quality, particularly in relation to the tidal regime, this will be re-assessed under RSDO conditions.

At the conclusion of Stage 2 of RoC it was determined that the designated migratory fish species of the Severn Estuary were not being impacted by any *licensed* abstractions within Midlands Region therefore no abstractions needed to be progressed to Stage 3. *However, an Assessment of potential impact on migratory fishing resulting form abstraction from the River Severn (Environment Agency 2005) identified the abstraction from the River Severn into the Gloucester & Sharpness Canal as having the potential to have a significant impact alone and in-combination. Stage 2 was signed off March 2008.*

Implementation of the Water Act 2003, requires previously unregulated activities such as dewatering of mines and quarries, trickle irrigation and canal abstractions to become licensable. The ending of these exemptions was expected to come into force in April 2008, with a two year period for submission of applications and determination within five years. They will be processed as new authorisations and any future licence conditions will be subject to assessment under the Habitats Regulations.

It was believed that the Gloucester & Sharpness Canal abstraction would be assessed within the following 12 months. It was therefore determined that it would only be looked at in more detail if we could not conclude that it had a significant effect on freshwater flows from the Severn into the Estuary which was the emphasis of the Stage 3 Appropriate Assessment. Results showed that influenced flow emulates the natural flow at all points very closely and both influenced and natural flow are well above what is considered 'Good ecological status' therefore there are sufficient flows into the estuary. Comparisons also showed that the flows remain almost unchanged as the river flows from Deerhurst to Hock Cliff, even though the Gloucester & Sharpness Canal intake point is situated between the two guaging stations.

As well as concluding that none of the abstractions (including this one) had an effect on freshwater flows into the Estuary, the work on migratory fish also concluded that none of the abstractions had an impact on the integrity on shad and lamprey alone or in-combination.

The Appropriate Assessment for RoC was undertaken with regard to regulated conditions. This assessment was undertaken to assess drought conditions and the implementation of the RSDO i.e. managing the limited available water beyond normal regulation operations. Due to their migration through the lower tidal Severn consideration of the off-site impacts on fish in this stretch of the river was also necessary.

3.3. RSDO Assessment

To assess the potential effects of implementation of the RSDO, the same methods, targets and modelling were used as those employed for RoC. However, in this assessment, models were updated and additional data and information that has since become available have been included (such as reports on the effects of actual droughts). This plan considers the effects of abstraction and flow regulation on the river under average flow regulation conditions and under two drought conditions; Acute and Chronic. It also considers a baseline dataset showing what would happen should drought continue and no restrictions or drought management measures be put in place i.e. a '' Do Nothing'' option. For detailed data, modelling, graphs and discussion see App 2.

3.4. Conservation Objectives

The conservation objectives for all the individual designated migratory fish (river lamprey, sea lamprey and twaite shad) and other species of the assemblage of migratory fish (allis shad, salmon, sea trout and European eel) of the Severn Estuary SAC and Ramsar, are the same. These migratory fish features will be considered in favourable condition when, subject to natural processes, each of the following conditions are met:

i. the migratory passage of both adults and juveniles through the Severn Estuary between the Bristol Channel and any of their spawning rivers is not obstructed or impeded by physical barriers, changes in flows, or poor water quality
ii. the size of the population of the species in the Severn Estuary and the rivers which drain into it, is at least maintained and is at a level that is sustainable in the long term
iii. the abundance of prey species forming the principle food resources for the assemblage species within the estuary, is maintained and
iv. toxic contaminants in the water column and sediment are below levels which would pose a risk to the ecological objectives described above

3.5. General Impacts of Lowering Flows on Migratory Fish

The majority of the fish species living in and using the Severn Estuary are adapted to tolerate high turbidity and a wide range of temperatures, salinity and oxygen concentrations (Bird, 2008). As discussed in Section 2.5.19, it is considered unlikely that the notable estuarine fish species assemblage of the estuary would be significantly affected by the continued low flows under implementation of a RSDO in comparison to the effects of doing nothing under drought conditions. However the diadromous (migratory) fish species that form only a small part of the estuarine fish assemblage utilise marine, estuarine and freshwater to complete their life cycle. These species are therefore likely to be affected by low flows due to their life cycle. The potential adverse effects of implementing the RSDO on the individual species that make up the designated migratory fish assemblage are considered in more detail here.

There are several general effects of low freshwater flows which may occur in different parts of the river system and which could potentially affect diadromous fish. General effects throughout the river include the prevention, inhibition or delay of fish migrations between habitats. The initiation of migration is often triggered by water temperature and high flows, either the downstream freshwater flow, or high tides. A lowering of flows can affect water temperature that will be discussed further. Low flows can also mean that migrations are not triggered at the correct time of year, preventing migration, or delaying it; the effects of this are uncertain, but may include increased mortality, mistiming of spawning or feeding with corresponding effects on future recruitment.

In addition, even when migrations are triggered and attempted, barriers that might be passable to some species at some flows may become impassable to others (although species such as salmon are generally good at passing barriers in comparison to r species). Fish passes can be added onto artificial barriers such as weirs to mitigate their effect but are generally designed for the passage of salmon and trout. Multi-species passes are available but the effectiveness of these structures can be low and dependent on minimum flows. When flows are low, passage for all fish may be delayed or prevented, even when migration is triggered. This leaves these fish vulnerable to predation, poaching, and to the water quality impacts of low flows. Juvenile freshwater stages may also be impacted, in that a reduction in water volume reduces the available habitat. This may increase predation and decrease feeding opportunities, while spawning grounds may be exposed by very low flows.

The potential water quality effects of low flows are probably complex and may vary throughout the river system and throughout the year. The decreased volume and depth of water combined with decreased flows are likely to result in increased warming of the water. This effect would be most intense during a summer drought. The impacts of increased water temperatures on fish have been discussed in detail elsewhere (e.g. Harrod et al., 2009). However, the main effects on aquatic organisms include increased metabolism, increased biological oxygen demand (BOD), triggering of certain life history events (e.g. migration, spawning), and increased stress particularly for cold-adapted species (e.g. salmonids) leaving individuals more vulnerable to disease and less able to cope with other stressors (e.g. pollution, low oxygen). In addition warm water holds less dissolved oxygen than cold water, exacerbating the effects of increased BOD. In the upper reaches of rivers, this may be less of a problem: water is more often shaded; the river may also be more energetic increasing the surface area of the water-air interface and so maximising dissolved oxygen concentrations. However, shallow upper reaches may also be more likely to dry out totally. The lower river is more sluggish and it is likely oxygen here could reach low levels. Certainly the occurrence of dissolved oxygen sags has been implicated in fish kills (Severn Trent Water, 1977).

Low flows have several other impacts. The natural hydromorphological regime of a river involves the transport of sediment downstream. Fast water has more energy and can move all sizes of particles from very small to quite large. As the stored energy is dissipated, successively smaller particles can be carried as water slows and loses energy. This results eventually in fine particles dropping out of suspension and potentially smothering benthic organisms and the river substrate, utilised for spawning or juvenile stages of diadromous fish. Flows also act to flush the river of pollutants and the waste created by biological processes. During low flows there is the potential for pollutants to remain in the system which may directly cause fish kills of sensitive species. Alternately excess nutrients may trigger algal blooms which use up available oxygen and may further increase the levels of toxic waste products such as ammonia. It is well known that the

migration of fish can be held up by physical barriers however chemical barriers can also prevent or delay migration.

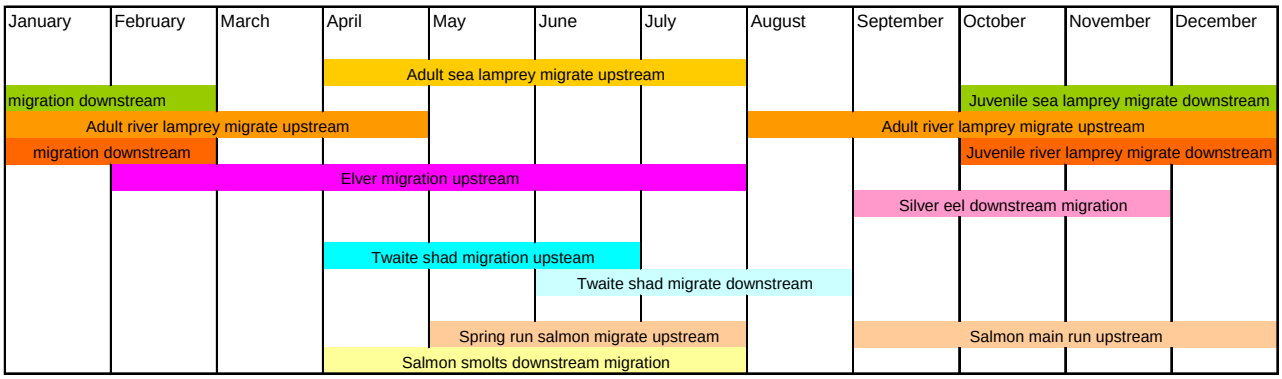
Tidal reaches of rivers respond to low flow in similar ways to lowland freshwater, but the effects of low flow can be more complex as this is a zone of mixing for two waters of very different chemistry in addition to different salinities. This can affect natural biochemical processes and chemical reactions with pollutants or heavy metals; these may be released as biologically available ions, or conversely bound as biologically inert compounds. Some of these reactions require oxygen and so have a chemical oxygen demand. In addition many estuaries exhibit long residence times, leading to exacerbation of any water quality problems.

The situation is further complicated by spring (the highest high tides) and neap tides (the lowest low tides) which occur twice in every 28 day period and can have a large impact in the tidal zone. The extent of the intrusion of a dense salt water wedge into freshwater in the tidal zone is modified by the freshwater flow downstream counteracting the seawater pushing upstream. During low flows, sea water may extend further upstream than usual, particularly during spring tides. This can result in kills of freshwater or freshwater-phase organisms particularly where escape is not possible such as downstream of weirs. Low flows and neap tides can also combine to produce a build-up of fine sediment that would normally be distributed. This silt contains organic material of natural origin, from the effluent discharges upstream and settled sewage from Netheridge STW. Bacterial action in the silt uses up oxygen and produces by-products; these in turn react rapidly when oxygen becomes available when the sediment is re-suspended during higher tides. In this way oxygen may become successively depleted over time and very low dissolved oxygen levels can be reached.

A fish kill event involving salmon, eel and other fish at the end of June 1976 is believed to have been caused by low oxygen concentrations combined with high water temperatures (Severn Trent Water, 1977). Further fish kills were recorded in the Severn Estuary during the late 1980's and early 1990's (Wade, 1992). These were primarily related to low oxygen concentrations and it was concluded that Netheridge STW and abstraction by British Waterways for the Gloucester & Sharpness Canal were the ultimate cause of the fish kills. The majority of these reported fish kills occurred in June and July. Since then water quality has improved in the River Severn as a whole, and at the Netheridge STW in particular. Until the improvements at Netheridge STW, effluent only received primary treatment, which resulted in a considerable oxygen demand in the receiving water. In addition, effluent flows were about 20 Ml/d in 1976. Secondary treatment is now in place, and effluent flows have increased to about 50 Ml/d with a minimum flow of 35 Ml/d. Based on these improvements, the oxygen demand on the receiving waters is about 3 times less than in 1976; fish kills are now a rare event.

Impacts of low flow that might impact diadromous fish are expected throughout the River Severn, rather than only in the designated Severn Estuary. Certainly the conservation objectives include an emphasis on migration between the sea and freshwater habitats and that toxic contaminants should not pose a risk to migration, or abundance of prey species. As the effects would be different depending on the life cycle and habitat use of the fish, the potential effects of drought and the implementation of a RSDO are considered on a species by species basis, both within the SAC and Ramsar boundaries and off site. Figure 11 showing the timing of migration movements follows:

Figure 11. Migration of individual species



3.6. Atlantic Salmon

Atlantic salmon are anadromous fish: they spawn in freshwater but spend much of their adult life at sea. Spawning occurs during late autumn or winter, in areas of suitable well washed gravel (usually at the tail end of a pool) in rivers and tributaries that flow into the Severn Estuary. The female digs a series of redds in which eggs are spawned and immediately fertilised by a male or males. These are then covered over in the building of the next redd. The eggs are vulnerable to poor water quality and particularly low concentrations of oxygen; a continuous flow of water through the sediment in which they are buried is vital. Development of the eggs is temperature dependent with the eggs tending to hatch in early spring.

Newly hatched salmon alevins remain in the gravel feeding on a yolk sac and are similarly vulnerable to chemical changes in the water, or cessation of flow through the gravel; development of the alevins is again temperature dependent. When these fish emerge from the gravel and start feeding, they are termed fry (0+ year fish), these fish tend to remain close to the spawning gravels and are found in shallow fast flowing riffles. After a year of life in freshwater they become parr (1+ year fish), these are territorial and move further from their natal gravels into deeper fast flowing water. Depending on the population, parr can spend several years of life in the river but in the River Severn they tend to smolt after one year as parr. This involves silvering and the start of physiological changes that will allow the fish to adapt to salt water. The downward migration of smolt usually occurs during spring to early summer and is triggered by temperature and changes in daylight. This migration is also dependent on high freshwater flows, and smolts move down to the estuary in relation to the strength of flow. Most are likely to drift passively on tides as they acclimatise to saline conditions and will then swim positively seaward (Tidal barrage report 1989).

Post-smolts spend some time in the estuary then spend varying amounts of time feeding at sea. If these fish return to freshwater to spawn after one winter at sea, these are termed grilse (one sea winter fish). If more than one winter is spent out at sea, these are termed multi-sea winter fish and are larger, produce more eggs and tend to return to freshwater in spring.

Adult salmon typically enter the estuary several months prior to spawning and during most months of the year. The adult salmon in the estuary will be a mixed stock from many different rivers all around the west coast of Britain. The fish, whilst resident, will make multiple temporary ascents and descents from the estuary and sub-estuaries, before leaving to locate and enter their own rivers Atlantic salmon show a high degree of fidelity to their natal river and indeed to the same area of river in which they spent their juvenile pre-smolt period (Hasler 1966; Harden Jones 1968). While a small percentage of individuals stray from their natal river (Stabell 1984; Jonsson et al.1991), this homing instinct is strong enough that differences between populations both between and within rivers are genetically identifiable (Klemetsen et al. 2003; Verspoor et al. 2005; Garcia de Leaniz et al. 2007). There are generally two peaks of fish moving upstream into freshwater in spring and autumn (Fleming et al. 1996; Klemetsen et al. 2003). Some fish move up through the estuary into freshwater very quickly (9 hours) while others have been observed to drift passively with the tide (taking up to 130 days) but the majority appear to take only a few tidal cycles (Tidal barrage report, 1989). Run timing has been associated with several river characteristics including hydrological conditions, temperature regime, length and difficulty of migration and with number of

winters at sea, with grilse (one sea-winter fish) tending to ascend in autumn (Fleming 1996; Klemetsen et al. 2003). Water flow in combination with other environmental factors, appears to be an important factor stimulating entry into rivers from the sea (reviewed by Banks 1969; Jonsson 1991). Certainly Solomon and Sambrook (2004) concluded that high temperatures and low dissolved oxygen concentrations were the major influences for failed river entry. Prolonged estuary residence is also possible in extended low flow periods (Greest, 2009). This hold up of fish in the estuary and river can result in increased mortality, caused by physical barriers (e.g. weirs), chemical barriers (e.g. low oxygen) or by a lack of an environmental trigger for migration. Since mortality is high most Atlantic salmon may spawn repeatedly (Jonsson et al. 1991; Klemetsen et al. 2003).

Summary of possible low flow effects:

- Low flows in spring while eggs and alevins are in the gravel
    - Possible smothering by fine sediments, low oxygen concentrations and during extremely low flows, drying out of redds, all leading to an increase in mortality
    - Possible decrease in developmental times
- Low flow effects on fry, parr and smolts with the primary impact likely during summer
    - Increase in water temperature and low oxygen concentrations, increased concentration of pollutants resulting in an increase in physiological stress and mortality
    - Decrease in habitat resulting in a possible increase in predation and decrease in feeding opportunities (but may in the short-term increase density of prey).
- Low flow effects on smolt migration in spring and summer
    - Delay or prevention of migration due to non-triggering and increased impact of barriers. Possible desmoltification if not able to migrate resulting in a future low return of adults.
    - Delay likely to lead to additional stress during migration, increase in mortality
- Low flow effects on adults, particularly during migration peaks in spring and autumn
    - Water quality effects in the estuary and river can increase mortality and possibly delay migration
    - Increase in water temperature and low oxygen concentrations, increased concentration of pollutants resulting in an increase in physiological stress and mortality
    - Increased impact of barriers and failure of fish passes during low flows
    - Delay of migration, additional stress during migration. Exposure to poor water quality in estuary, increase in mortality in river due to stress, predation, and/or angling pressure can result in a low future return of adults.
    - Prevention of migration, additional stress and lack of spawning. Exposure to poor water quality in estuary, increase in mortality in river due to stress, predation, and/or angling pressure. Possible re-absorption of eggs, may return to sea or remain in river for over a year resulting in a missing future year class, possibly more multi sea winter fish.
    - Possible increase in straying if there is a reduction in attraction flows to natal rivers
    - Kelts (fish which have spawned and then return to sea) may not be able to move back out to sea

Atlantic salmon are likely to be affected by low flows at several life stages with the most important impacts as follows:

Spring migrating salmon have reduced in numbers in the River Severn (pers. comm. Pete Gough 2012), and may be disproportionally affected by a summer drought. These are usually large multi sea-winter fish and so contribute many eggs at spawning. These fish enter the rivers in spring and remain in the river until spawning in winter and if trapped in the river during a severe drought they are likely to experience high mortality.

The ascent of adult salmon on the spring or autumn spawning run is likely to be affected by low flows at these times of year. A reduction in flow is likely to inhibit the start of migration. An

extended residence period in the estuary or lower river during low flows could result in increased stress and mortality but improved sewage treatment at Netheridge STW should minimise water quality issues. If no migration is initiated or possible due to low flows, it is possible that developing eggs may be re-absorbed and an additional year at sea may be experienced by individual fish. Alternatively fish could also migrate upstream as soon as flows increase, either to spawn late in the spawning season or to spend an extended time in freshwater, until the next spawning season. This would result in either a reduced or missing year class and in subsequent years a deficit of adults' returning to spawn. There may also be some additional spawning of multi sea-winter individuals in the next year.

If migration is initiated but adults are trapped between weirs, even where a fish pass is available, this could result in further detrimental impacts. The salmon may be trapped in very low flows, unable to ascend or descend and be more vulnerable to water quality issues, disease, angling pressure and predation. This would result in high mortality, and eggs may be spawned in non-ideal habitat. During less severe droughts than modelled in this study, salmon are not able to pass certain artificial barriers (e.g. Dinham weir, Ludlow in 2011). Although salmon are considered good at passing barriers, this is dependent on flows being maintained. It is therefore likely that some salmon spawning migration may be prevented altogether by an extremely severe drought that coincided with migratory peaks. This would result in a missing year class and in subsequent years a deficit of adults returning to spawn which may not be compensated for by additional spawners being available in the next year. Additional years of drought would have a cumulative effect.

Both the ' Do Nothing' Baseline and the Drought Order Only flows are likely to adversely affect spawning due to the prevention or inhibition of migration. However, mortality due to water quality issues is likely to be minimised over the longer term by the maintenance of a flow under a drought order, in comparison to no flow being available.

3.7. Brown Trout and Sea Trout

Brown trout can be resident or anadromous, the migratory form being known as sea trout. Trout have a similar life history to Atlantic salmon in that they spawn in well washed gravel, building a series of redds to protect their eggs and the newly hatched alevins. Fry and parr remain in freshwater but typically live in slightly slower and deeper water than salmon fry and parr, though there is much overlap between species habitats. The life history forms differ in migration; resident trout remain in freshwater and mature never leaving the river. The migratory form smoltifies and moves down into the estuary with some remaining in the estuary as slob trout, while others move out to sea. Finnock return after one sea-winter, while multi sea-winter sea trout are larger and produce more eggs. The return migration is much the same as for Atlantic salmon and is similarly effected by low flows. While brown trout are also cold-adapted species requiring good water quality, they tend to be more tolerant at all corresponding life stages than salmon. In addition repeat spawning is more usual, thus prevention of one spawning run may not be as disruptive to the population structure as is likely with salmon.

Summary of possible low flow effects:

- Low flows in spring while eggs and alevins are in the gravel
  - Possible smothering by fine sediments, low oxygen concentrations and during extremely low flows, drying out of redds resulting in an increase in mortality
  - High temperatures may decrease developmental times
- Low flow effects on fry, parr and smolts and resident adults with primary impact likely during summer
  - Increase in water temperature and low oxygen concentrations, increased concentration of pollutants resulting in an increase in physiological stress and mortality
  - Decrease in habitat, possible increase in predation and decrease in feeding opportunities, may increase density of prey in the short term.
  - Drying out of tributaries may exclude even resident spawners from accessing historical spawning grounds.
- Low flow effects on smolt migration in spring and summer
  - Delay or prevention of migration e.g. non-triggering or exacerbation of barriers. Possible desmoltification if not able to migrate resulting in a future low return of sea trout.
  - Delay likely to lead to additional stress during migration, increase in mortality
- Low flow effects on adults, particularly during migrations of sea trout
  - Water quality effects in the estuary and river resulting in an increase in mortality and possible delay of migration
  - Increase in water temperature and low oxygen levels, increased concentration of pollutants resulting in an increase in physiological stress and mortality of resident and migratory trout
  - Increased impact of barriers and failure of fish passes during low flows
  - Delay of migration, additional stress during migration. Exposure to poor water quality in estuary, increase in mortality in river due to stress, predation and angling pressure all of which lead to a reduction in year class.
  - Prevention of migration, additional stress and lack of spawning. Exposure to poor water quality in estuary, increase in mortality in river due to stress, predation, angling pressure. Possible re-absorption of eggs, may return to sea or remain in river for over a year resulting in a missing future year class and possibly more multi sea winter sea trout.
  - Possible increase in straying if there is a reduction in attraction flows to natal rivers
  - Kelts may not be able to move back out to sea

The effects of a drought are likely to be similar to those experienced by Atlantic salmon but due to the plastic life history of brown trout (being resident or migratory), they have added resilience to catastrophic events. Whilst increased mortality at different life stages can be anticipated, in the longer term it is expected that numbers would be maintained despite the likely delay or prevention of migration of sea trout. Spawning of the resident forms is likely to go ahead, though many spawning areas may be cut off due to low flows over weirs within the main River Severn and its tributaries. The effects would likely be a reduced year class of trout, and additional years of drought would have a cumulative effect.

3.8. Twaite Shad

Twaite shad are silver fish, about 40 cm in length, and are anadromous members of the herring family. They are sensitive to poor water quality and pollution has excluded them from many of their historical rivers. These fish move into freshwater to spawn on large areas of well washed substrate often at the tail end of pools in the early summer. Usually this is gravel, but suitable substrate can vary from sand to pebbles. Shad spawn in shoals with females moving to the surface and broadcast spawning with eggs being fertilised by pursuing males. This usually occurs at night and results in noisy and vigorous splashing. The eggs can drift long distances, but eventually sink between particles of substrate. The eggs are potentially vulnerable to smothering and poor water quality during incubation. They may benefit from lower flows retaining them close to the suitable substrate of the spawning area but only if water quality is not compromised.

A water temperature of > 16 °C is required for incubation; eggs hatch quickly, usually in about 4 to 6 days. The larvae move down to the lower river and upper estuary to feed and grow. The eggs and larvae are vulnerable to full salinity therefore increased saline intrusion has the potential to adversely affect this life stage. The larvae and juveniles remain in the upper estuary for their first summer, tending to move seaward over winter. Within the lower tidal Severn and estuary there is an abundance of zooplankton prey species (e.g. mysids) and these are particularly important to the juvenile twaite shad population. However, these are also the areas most likely to be affected by poor water quality, and natural chemical reactions due to the mixing of fresh and salt water, and are potentially zones of high chemical oxygen demand. Juveniles move out to sea after one or two years and as they grow their diet includes fish as well as zooplankton

Twaite shad mature after 3 to 5 years and whilst there is some evidence of site fidelity (Jolly et al., 2012), this is not known to be as strong as that demonstrated by salmon. The adults congregate in the Severn Estuary from April to May with the upstream migration to spawning grounds usually triggered by temperatures of > 12 °C (Claridge & Gardner, 1978; Aprahamian, 1982, Belaud et al., 1985). Spawning runs are also influenced by water flow and tides. Twaite shad tend to ascend the river on spring tides and migration is delayed by high freshwater flows (Aprahamian 1982, Steinbach et al. 1986). It should be noted that very low river levels may exclude shad from spawning areas by preventing passage over very shallow areas. Shad are not good at passing barriers such as weirs and may also be excluded from rivers by chemical barriers such as poor water quality. However, twaite shad are able to spawn more than once and so move back out to sea after spawning.

Summary of possible low flow effects:

- Low flows in summer affecting eggs and newly hatched larvae
    - Possible smothering of eggs by fine sediments, low oxygen concentrations leading to an increase in mortality
    - Possible decrease in developmental time which may reduce the impact of localised low flows on spawning grounds
    - Less movement of eggs from spawning area
- Low flow effects on juvenile shad in estuary

    - Increase in water temperature and low oxygen levels and increased concentration of pollutants leading to an increase in stress and mortality
    - Unlikely to be effects on downstream juvenile migration
- Low flow effects on adults, particularly during migrations in summer
    - Water quality effects in the estuary and river, increase in water temperature and low oxygen concentrations and increased concentration of pollutants increasing physiological stress and possible mortality
    - Prevention or delay of spawning migration leading to an increase in stress and mortality.
    - Advancement in timing of spawning run timing due to higher water temperatures; therefore may miss main adverse effects of a summer drought.
    - Easier ascent to spawning areas due to low flow, unlikely to have effect on downstream migration.

Shad are generally not good at passing man-made structures and in the River Severn system twaite shad are not able to migrate past the first barrier (Powick weir) on the River Teme therefore a drought is not likely to make this barrier impact worse. Whereas poor water quality can act as a chemical barrier to migration, low flows and high temperatures may actually benefit this species during their spawning run. During an extreme drought event it is the larvae and juvenile shad in the estuary that are likely to be adversely impacted as shad are intolerant of low quality water conditions and juveniles spend time in the part of the estuary most likely to be affected by mobile zones of low oxygen.

Overall these fish, particularly at the adult stage are probably less likely to be adversely effected by low flows than the other migratory species discussed. It is also likely they would benefit from the maintenance of some flow into the estuary minimising the adverse water quality impacts of long term low flow in this area.

3.9. Allis Shad

Allis shad have a similar life cycle to twaite shad, except they tend to be larger, feed primarily on zooplankton and spawn only once. Whilst adult fish have occasionally been recorded from samples at Oldbury (Bird, 2008), this is a rare event. They are not known to migrate up the River Severn therefore due to the lack of available information about these fish in the designated Severn Estuary, lower tidal Severn and freshwater River Severn it is not possible to determine whether the species would be adversely affected by low flows or implementation of the RSDO.

3.10. Sea Lamprey

Sea lamprey is the largest lamprey species in Britain, growing up to 1 m in length. They are anadromous and spawn in May to June on similar substrate to Atlantic salmon and use much the same well washed spawning areas in the lower to mid reaches of rivers. The spawning occurs in pairs and they build redds in which the eggs are spawned, fertilised and buried.

After hatching, larvae called ammocetes leave the nest and drift downstream settling in suitable silt beds. These larvae filter feed fine particulate matter from the water; the duration of larval life varies, but averages about five years (Maitland, 2003). Due to their habitat, larval sea lamprey are able to tolerate quite low oxygen conditions. Metamorphosis of ammocetes to the migratory form takes place between July and September (Potter 1980). These transformers then move downstream during autumn to winter and these downstream migrants can be affected by poor water quality in the upper estuary.

Little is known about their movements in the estuary and out to sea, but the adult sea lamprey feed parasitically on marine and diadromous fish and occasionally marine mammals, for one or two

years. Prior to their spawning migration, adults enter the estuary from around April. It is not thought that there is a great deal of site fidelity although adults may be drawn to rivers that already contain lamprey ammocetes through olfactory signals. The peak adult migration appears to be closely related to water temperatures which must be > 11 °C. Although sea lamprey migration can be delayed by high flows it should be noted that very low river levels may exclude sea lamprey from spawning areas by preventing passage over very shallow areas. Sea lamprey are not as good at passing barriers such as weirs as some migratory species (e.g. salmonids), but are able to ascend the River Severn up to Shrewsbury at certain flows. They can also be excluded from rivers by chemical barriers such as poor water quality. Artificial barriers and pollution have caused the local extinction of sea lamprey in a number of rivers (Maitland, 2003). The adults die soon after spawning; if the spawning grounds are not reached or adults are trapped below barriers due to low flow they will not recover and spawn again in another year.

Summary of possible low flow effects:

- Low flows in summer effecting eggs and newly hatched larvae
    - Possible smothering of eggs by fine sediments, low oxygen concentrations leading to an increase in mortality
    - Possible decrease in developmental time
    - No wash-off of eggs during spawning or newly-hatched larvae from spawning area
- Low flow effects on sea lamprey ammocetes in river
    - Increased concentration of pollutants leading to an increase in physiological stress
    - Very low flows may reduce filter feeding opportunities
    - Mobile silt beds may remain in place
- Low flow effects on downstsream migration of transformers to estuary
    - Increase in water temperature and low oxygen concentrations, increased concentration of pollutants leading to an increase in physiological stress and mortality
    - Weirs that may have been passable at higher flows may inhibit downstream migration during low flows
- Low flow effects on adults, particularly during migrations in summer
    - Water quality effects in the estuary and river, prevention or delay of spawning migration leading to an increase in mortality.
    - Increase in water temperature and low oxygen concentrations, increased concentration of pollutants leading to an increase in physiological stress and possible mortality
    - Small barriers that may have been passable at higher flows may inhibit migration during low flows
    - Delay or prevention of migration. Additional stress during migration. Exposure to poor water quality in estuary, increase in mortality in river due to stress; and predation. Lamprey trapped in the river are likely to die without spawning. All the above may result in future low return migration of adults.
    - Change in spawning timing due to higher water temperatures.

If low flows result in water quality issues these may have an impact on the adult migration into freshwater. In addition, small structures which are not usually barriers to migration may become impassable. Spawning occurs in summer so sea lamprey spawning may be particularly affected if low flows peak in summer. Adults die after spawning so the exit of spawned adults from the system is not considered an issue. The main impact of low flows is thought to be on returning adults and the prevention of spawning. This may lead to a missing or reduced year class and a low subsequent return of adults (this may be supplemented in future years by sea lamprey strays from elsewhere, as site fidelity is not thought to be very strong).

3.11. River Lamprey

River lamprey are anadromous and spawn in March to April on well washed gravel in the lower to mid reaches of rivers. The spawning occurs in groups, in a shared redd in which the eggs are spawned, fertilised and buried with incubation taking 15 to 30 days depending on water temperature (Maitland, 2003). The ammocetes of all UK species behave in a similar way, remaining in the silt for around five years. River lamprey ammocetes metamorphose to the adult form in late summer and autumn and the transformers then move downstream at night, during autumn to winter. Downstream migrants can be affected by poor water quality in the upper estuary.

Adult river lamprey potentially remain primarily in the estuary, feeding parasitically on estuarine fish species for one or two years. Prior to the spawning migration, adults congregate in the estuary. There are two peaks of spawning migration, one from October to December, and the other in spring just before the spawning period. It is not thought that there is a great deal of site fidelity, but adults may be drawn to rivers that already contain lamprey through olfactory cues. Spawning is related to water temperature, which must be > 10 °C. The problems potentially caused by low flows are similar to those experienced by sea lamprey. River lamprey are not very good at passing barriers such as weirs, but are also excluded from rivers by chemical barriers such as poor water quality. Artificial barriers and pollution have also caused the local extinction of river lamprey in a number of rivers (Maitland, 2003). The adults die soon after spawning and if the spawning grounds are not reached or adults are trapped below barriers due to low flow they are unlikely to leave the river to spawn again in another year.

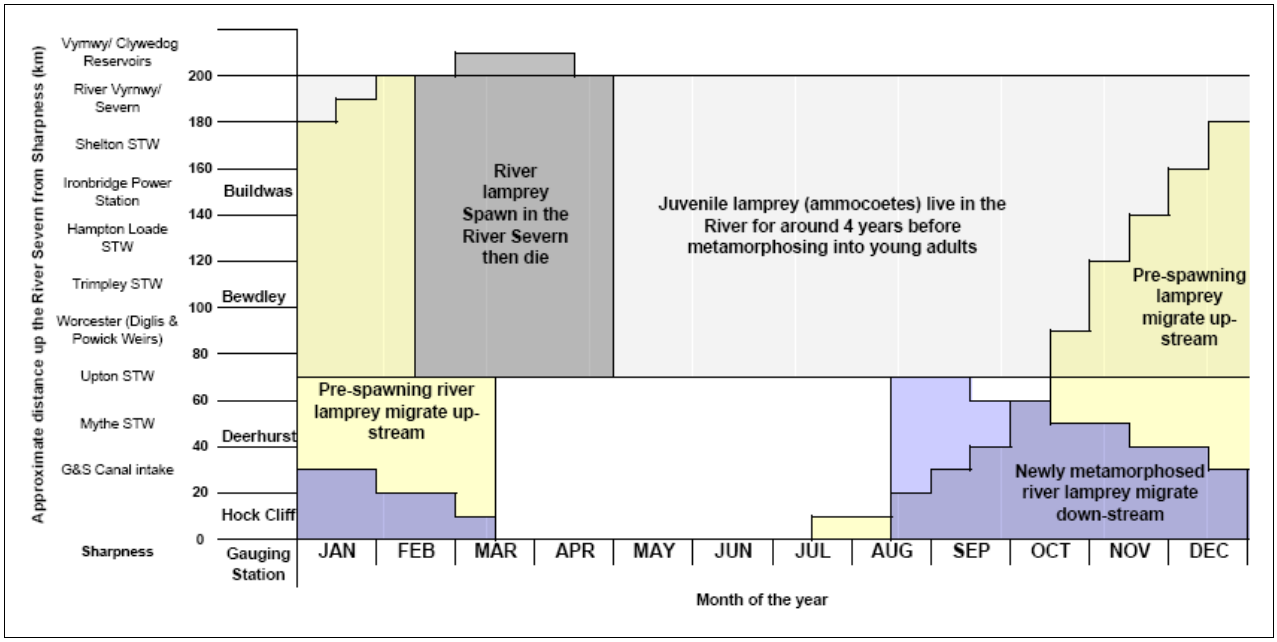
Summary of possible low flow effects:

- Low flows in summer affecting eggs and newly hatched larvae
    - Possible smothering of eggs by fine sediments, low oxygen concentrations leading to an increase in mortality
    - Possible decrease in developmental time
    - No wash-off of eggs during spawning or newly-hatched larvae from spawning area
- Low flow effects on river lamprey ammocetes in river
    - Increased concentration of pollutants leading to an increase in physiological stress and mortality
    - Very low flows may reduce filter feeding opportunities
    - Mobile silt beds may remain in place
- Low flow effects on downstream migration of transformers to estuary
    - Increase in water temperature and low oxygen concentrations, increased concentration of pollutants leading to an increase in physiological stress and mortality
    - Weirs that may have been passable at higher flows may inhibit downstream migration during low flows
- Low flow effects on adults, particularly during migrations in summer
    - Water quality effects in the estuary and river, prevention or delay of spawning migration leading to an increase in mortality.
    - Increase in water temperature and low oxygen concentrations, increased concentration of pollutants leading to an increase in physiological stress and mortality
    - Small barriers that may have been passable at higher flows may inhibit migration during low flows
    - Delay or prevention of migration. Additional stress during migration. Exposure to poor water quality in estuary, increase in mortality in river due to stress, and predation. Lamprey trapped in the river are likely to die without spawning. All of which may result in a future low return migration of adults.

- Change in spawning timing due to higher water temperatures.

The estuarine feeding stage of river lamprey is likely to be vulnerable to water quality issues caused by low flows but they may be able to avoid this. The main impact of low flows is thought to be on returning adults and the prevention of spawning. This could lead to a missing year class and a very low subsequent return of adults. However this would depend on the timing of low flows and can be mitigated by the occurrence of two peaks in spawning migration. As river lamprey adjust their migration in response to the physical conditions in the river adults could ascend to spawning grounds during winter to spawn later in the year (Figure 12). These individuals may also be at risk of increased mortality in freshwater if subject to low flow conditions.

Figure 12. Approximate movements of river lamprey in the River Severn



3.12. European Eel

The European eel is catadromous; these fish spawn at sea but spend much of their adult life in freshwater. The spawning grounds of the European eel are unknown and spawning in the wild has never been observed. The spawning grounds are thought to be in the Sargasso Sea where the youngest larvae have been sampled. Spawning is thought to take place in spring and summer and over a two year period these larvae are swept by ocean currents across the Atlantic Ocean until they reach land on the west coasts of the east Atlantic continents.

The larvae metamorphose into transparent glass eels which migrate into estuaries with the aid of passive tidal transport (Tesch, 1977). There is generally a mid-winter peak in glass eel arrival with the glass eels entering the estuary in large numbers in spring. In the estuary they bury themselves in sand or mud and emerge at night to feed, then metamorphose again to become pigmented elvers which can remain in estuaries to mature although many ascend the rivers and move into freshwater. This migration into freshwater appears to be primarily initiated by water temperature, though river flows may also be important (Tongiorgi et al., 1986; White & Knights, 1997; Edeline et al., 2006; Acou et al., 2009). Temperatures of between 14-16oC are the best predictor of upstream migration within the Severn Estuary (White and Knight 1997). The elvers move upstream on spring tides from mid-February to mid-May and are caught in large numbers by elver fishermen as far upstream as Tewkesbury. During this migration upstream weirs are an obstruction to upstream migration with high tides and flows being required for eels to pass these structures.

During their freshwater phase they are known as yellow eels. These migrate upstream during their river residence which can last several decades, leading to smaller eels generally being found lower

in river systems. They are able to tolerate a wide range of physical and chemical conditions, but are adversely affected by impassable barriers

When they are ready to mature they become silver and their physiology changes in preparation for their migration into salt water. The silver eels migrate downstream into the estuary and out to sea with peaks in migration reported for August to October (Tesch, 2003) although individuals may begin to leave the river at any time of year. The adult eels migrate out of the rivers and are most abundant in the estuary in September and October.

Summary of possible low flow effects:

- Low flows in summer affecting eggs and newly hatched larvae
    - None as eggs and larvae out at sea
- Low flow effects on glass eels and elvers in the estuary and lower river
    - Increase in water temperature and low oxygen concentrations, increased concentration of pollutants leading to an increase in physiological stress and possible mortality
    - Small weirs that may have been passable at higher flows may inhibit upstream migration during low flows. Low flows may reduce eel pass effectiveness.
    - Possible increase in concentration of pollutants leading to an increase in physiological stress and possible mortality
- Low flows effects on yellow eels
    - Increase in water temperature and low oxygen concentrations, increased concentration of pollutants leading to an increase in physiological stress and possible mortality
    - Decrease in habitat, possible increase in predation and decrease in feeding opportunities
    - Small weirs that may have been passable at higher flows may inhibit upstream migration during low flows. Low flows may reduce eel pass effectiveness.
- Low flow effects on adult downstream migration to estuary
    - Increase in water temperature and low oxygen concentrations, increased concentration of pollutants leading to an increase in physiological stress and possible mortality during migration
    - Change in spawning timing due to higher water temperatures. Not able to move downstream due to small barriers (usually passable) becoming impassable.

Adult eels are more tolerant of low dissolved oxygen than other migratory species, but with exceptionally low freshwater flows to the lower tidal Severn there may be small zones of very low dissolved oxygen that could even cause eel mortality. The main effect of low flows is likely to occur during the downstream migration of silver eels during their spawning migration. Eels may move short distances over-land and in this way get downstream of small rural barriers even during low flows but large structures are likely to form an effective barrier at very low flows. It is likely this will delay, rather than prevent a spawning migration and since European eels are not genetically differentiated across Europe will not necessarily result in a reduced future year class.

There will be an effect on upstream migration, with low flows not allowing passage past barriers and reducing the effectiveness of eel passes. *Inhibited migration can lead to a concentration of eel below weirs during low flow thereby increasing the potential for them to be taken for fisheries purposes and by predators taking advantage of the eel concentrations.*

However, while delay downstream of barriers may result in increased mortality due to stress and predation, this is not a spawning migration and will take place throughout the freshwater life stage.

3.13. Drought Conditions

This assessment has been carried out using modelled flows and timings regarding implementation of a RSDO, *please refer to the River Severn Drought Order Environmental Report for details.*

There are limitations associated with this model; the general flows and quantities could be similar during future droughts but the timing may vary from the model in a real life situation. This model has used what is considered to be the most likely scenario, i.e. a summer drought as described below. However, a change in the timings and severity would change the impacts from those considered here.

The *flow* model only takes account of a 300 Ml/d abstraction by the Trust for the Gloucester & Sharpness Canal. This was based on averaging monthly abstraction figures provided by the Trust; however *the maximum pumping capacity of the Trust is 691Ml/d and therefore needs consideration under the Habitat's Directive. As with the majority of abstractions, the Trust is likely to need larger volumes during dry periods to support* an increased need for water in the canal for public water supply and navigation. The in combination *flow* modelling that has been undertaken cannot therefore be considered a worse case scenario *and has been used as a guide, the potential additional impacts have been incorporated when interpretting the results and likely impacts.* It is likely given this situation that the effects of a drought could be more severe immediately below this abstraction, even to the point of no appreciable flow being available in the lower river, *however the Trust have committed to abstracting in accordance with the Operating Agreement as best endeavours.*

Lower Parting is the furthest downstream point for which modelled flows are available and is within the tidal range of the estuary (lower tidal Severn). Any high tides combined with low river flows during a drought could have a severe negative impact on the fish population due to saline intrusion and increased suspended solids causing low dissolved oxygen concentrations. Work completed by Hutcherson and Wade (1992) recommended that a flow of 1800 Ml/d at Haw Bridge would be required to maintain dissolved oxygen levels above 3 mg/l (critical concentration for survival of migratory salmon), prevent suspended solid concentrations of greater than 6000 mg/l and prevent saline intrusion for 94 % of predicted tides. During the Acute drought conditions, modelling shows that this flow would not be attained for 19 % of the year. This suggests potential for fish kills due to the effects of low flow.

However, it should be noted that water quality within the estuary has improved dramatically since the above study was carried out and it is anticipated that lower freshwater flows than 1800 Ml/d at Haw Bridge would now suffice. Nevertheless, in the absence of any other estimate for minimum required flows to avoid fish kills, this figure has been used as a conservative benchmark.

3.13.1. Acute Condition

This represents two dry winters and a dry summer modelled from the 1976 drought, resulting in severe natural drought event over one summer, where the sources will become too low to support prescribed flow at Bewdley. This would trigger a RSDO over one summer.

3.13.1.1. ' Do Nothing' Baseline Option

Flows at Lower Parting were predicted to be maintained above 900 Ml/d until mid October. At this point the freshwater flow was predicted to decrease rapidly to very lows flows of on average 415 Ml/d (minimum 382 Ml/d). This low flow was predicted to be maintained for about 19 days until the beginning of November when winter rain should replenish Llyn Clywedog and Lake Vyrnwy, increase river flow and terminate the drought conditions.

The predicted natural drought conditions would severely impact fish in the designated Severn Estuary, lower tidal Severn and freshwater River Severn. Flows were predicted to be far below the conservative benchmark used to indicate the start of fish kills. This scenario would be likely to impact on the autumn migration upstream to spawning grounds, the autumn river lamprey migration upstream to spawn in spring, and the migration downstream of lamprey transformers and silver eels. Juvenile shad in the estuary may be affected. Impacts would be likely to include fish kills, particularly of Atlantic salmon and delay or inhibition of the migration of all species. Those

Atlantic salmon already on the spawning grounds at this point would be likely to experience higher mortality, but would be likely to spawn unless water quality is severely compromised. Many however would be trapped below weirs and experience very high mortality until the drought ended, at which time the spawning migration could continue. This would be likely to result in a severely reduced year class of Atlantic salmon.

3.13.1.2. Implementation of Drought Order Only

Flows would be reduced below those experienced under natural drought conditions from the very end of August to an average of 760 Ml/d. Freshwater flows were predicted to reduce again in mid October to an average of 505 Ml/day (minimum 459 Ml/day). This low flow was predicted to be maintained for about 22 days until the beginning of November when winter rain should increase flow, terminating the drought conditions.

Implementation of the Drought Order Only would potentially have an adverse effect on fish in the designated Severn Estuary, lower tidal Severn and in the freshwater River Severn. Although the natural drought conditions would initially maintain higher flows and so could be considered better for fish, this is only over the short term. The initial drop in flows was predicted to be less severe but when the natural drought conditions would result in very low flows, flows were predicted to be maintained at a higher level under opertaion of the RSDO. Flows were predicted to be far below the conservative benchmark used to indicate the start of fish kills. Any maintenance of higher flow during this critical life stage of migratory fish species, particularly salmon and eels, (thus allowing them to move to spawning areas), would be beneficial.

This scenario is likely to impact on the same species as under the natural drought conditions: the autumn salmon migration upstream to spawning grounds, the autumn river lamprey migration upstream to spawn in spring, and the migration downstream of lamprey transformers and silver eels. In addition juvenile shad in the upper estuary are also likely to experience poor water quality. Impacts are likely to include fish kills, particularly of salmon and prevention or inhibition of the migration of all species. Those salmon already on the spawning grounds at this point may experience higher mortality, but they are likely to spawn. Many however, may be trapped below weirs until higher flows. However the effects experienced by implementation of the RSDO are likely to be less severe than those experienced under natural drought conditions. Fish kills may be minimised in comparison to natural drought conditions until flows are increased allowing the migration of fish upstream and downstream. This is likely to result in a reduced year class of Atlantic salmon.

3.13.2. Chronic Condition

This represents a two dry winters and an initial drought summer, similar to the Acute condition. This is followed by another dry winter triggering a second summer of severe drought, modelled from the 1976/77 drought. This would trigger two RSDOs over two summers.

3.13.2.1. ' Do Nothing' Baseline Option

The first year of this drought is considered to be close to the Acute drought condition described above. In the second year of a Chronic drought, flows were predicted to be maintained above 888 Ml/d until mid October. At this point the freshwater flow was predicted to decrease rapidly to even lower flows, an average of 344 Ml/day (minimum 304 Ml/day). These very low flows would be expected to last for a longer period than in year one, and indicate minimum flows almost 300 Ml/d lower than the Acute condition. This low flow was predicted to be maintained for 20 days until the beginning of November when winter rain was predicted to replenish the water sources, increase river flow and terminate the drought conditions.

The natural drought conditions would severely impact fish in the River Severn, the lower tidal Severn and potentially the designated Severn Estuary. Flows in both the first and second year were predicted to be far below the conservative benchmark used to indicate the start of fish kills. This condition is likely to severely impact the autumn salmon migration upstream to spawning grounds, the autumn river lamprey migration upstream to spawn in spring, and the migration downstream of lamprey transformers and silver eels. However, the increased length of drought may further impact salmon, both those that have reached spawning grounds and any trapped below weirs. The lower flows would also be likely to delay the date of spawning, and may even prevent some spawning. In addition juvenile shad in the upper estuary are also likely to experience poor water quality. Impacts are likely to include fish kills, particularly of salmon and delay or inhibition of the migration of all species. Those salmon already on the spawning grounds at this point may experience higher mortality, but they are likely to spawn. Many however, may be trapped below weirs and will experience very high mortality until the drought ends and migration can continue. This is likely to result in two reduced year classes of Atlantic salmon and will severely impact numbers of returning adults in the future. A reduction in the number of juvenile salmonids may have unknown ecological impacts on the river. Fish kills in the Tidal Severn are also likely to include juvenile shad.

3.13.2.2. Implementation of Drought Order Only

The impacts of implementation of the Drought Order Only in the first year of this drought are considered to be identical to the Acute drought condition described above. In the second year and under implementation of another RSDO, river flows were predicted to be supported by the additional water saved from the first year of RSDO operation, either preventing or significantly delaying the final rapid flow depletions which would occur under the '' Do Nothing'' scenario if sources were used up. Although the RSDO initially lowers flows below the natural drought (concluded as not significant), a two day low flow minimum of 528 Ml/day is modelled at the end of October, 220 Ml/d higher than the predicted natural drought impacts. At the beginning of November winter rain should increase flow and terminate the drought conditions.

A second year of RSDO conditions would again potentially have an adverse effect on fish in the River Severn, the lower tidal Severn and the designated Severn Estuary. Although the natural drought conditions initially maintain higher flows and so could be considered better for fish, this is only over the short term. The initial drop in flows is predicted to be less severe under the '' Do Nothing'' Baseline scenario but when the natural drought conditions would result in very low flows, flows would be maintained at a higher level under the RSDO. Flows were predicted to be below the conservative benchmark that is used to indicate the start of fish kills. Maintenance of any flow higher than would be experienced naturally during these extreme conditions at this critical life stage of many migratory fish, particularly salmon, shad and eels, would be beneficial.

This scenario is again likely to impact on the same species as would be affected under the '' Do Nothing' Baseline scenario of Chronic Drought Condition: the autumn salmon migration upstream to spawning grounds and the spawning of this species, the autumn river lamprey migration upstream to spawn in spring, and the migration downstream of lamprey transformers and silver eels. In addition juvenile shad in the upper estuary are also likely to experience poor water quality. Impacts are likely to include fish kills, particularly of salmon and prevention or inhibition of the migration of all species. Those salmon already on the spawning grounds at this point may experience higher mortality, but they are likely to spawn. Many however, may be trapped below weirs. However, the impacts are likely to be less severe than those experienced under natural drought conditions (i.e. '' Do Nothing' Baseline scenario. Fish kills may be minimised in comparison to natural drought conditions until flows are increased allowing the migration of fish upstream and downstream. This is likely to result in two reduced year classes of Atlantic salmon, a reduction in the number of juvenile salmonids may have unknown ecological impacts on the river.

The effects of the differing drought scenarios including the ' Do Nothing' on the individual migratory fish species are summarised in the following Table 7 below *and Table 8 shows the critical periods of sensitivity for fish.*

	Acute Condition		Chronic Condition		Conclusion	Full In-Combination (includes maximum Glos & Sharpness Canal Abstraction)	
Feature	**' Do Nothing'**	**RSDO**	**' Do Nothing'**	**RSDO**		**' Do Nothing'**	**Full In-Combination**
Migratory Fish							
Atlantic Salmon Adults only	Best option until mid Oct then a crash in flows in the lower tidal Severn Impacts of low flows will depend on whether they coincide with spring tides Autumn migration could be delayed or in worse case scenario prevented. Potentially increased mortality Severely reduced year class of Atlantic salmon in the future	Flows in the lower tidal Severn will fall 4 days earlier in Oct. If this fall coincides with a spring tide it could impact adult salmon. Then would have more freshwater entering the system than under the ' Do Nothing' option Autumn migration could be delayed or in worse case scenario prevented. Potentially increased mortality Severely	The best option until mid Oct however flows will then crash to lower levels and for even longer in the lower tidal Severn This is likely to result in large fish kills particularly since it will probably coincide with Spring Tides Autumn migration could be delayed or in worse case scenario prevented Severely reduced year class of Atlantic salmon in the future	Flows would be reduced in the lower tidal Severn for much of the second year therefore fish would be at increased risk for 2-3 months. There would be no crash in October (until the very end of the month) which would protect the salmon waiting in the lower tidal Severn to migrate In comparison to the ' Do Nothing' option the effects would be minimised especially over the prolonged drought that	Low flows are unlikely to have an effect on the designated site and features. However low flows will impact on the lower tidal Severn therefore this has to be considered an off-site impact on this fish spp. The impact of an ongoing drought (over 2 years) as modelled in the Chronic condition will have a very severe impact on Atlantic salmon with reduced year classes in future years	As a natural drought progresses freshwater flow in the lower tidal Severn would be reduced and with 300 Ml/d being taken for this abstraction this reduces flows further but modelling has demonstrated that this does not lead to WFD deterioration or additional tidal inflow target failures. If >300 Ml/d and certainly larger amounts up to the permitted 691 Ml/d was taken there would be very little freshwater flow in the lower tidal Severn which would have an adverse effect on the migratory fish feature.	It is the extreme conditions and low flows associated with drought that has an adverse effect on migratory fish. Implementation of the RSDO also lessens or minimises the impacts of what is a natural event. In particular it provides resilience should there be an ongoing drought. If >300 Ml/d and certainly larger amounts up to the permitted 691 Ml/d was taken there would be very little freshwater flow in the lower tidal Severn which would have an adverse effect on the migratory fish feature

	Acute Condition		Chronic Condition		Conclusion	Full In-Combination (includes maximum Glos & Sharpness Canal Abstraction)	
Feature	**' Do Nothing'**	**RSDO**	**' Do Nothing'**	**RSDO**		**' Do Nothing'**	**Full In-Combination**
Migratory Fish							
		reduced year class of Atlantic salmon in the future In comparison to the ' Do Nothing' option the above effects would be minimised especially over a prolonged drought	Effects would be more severe than under the Acute Condition	this situation represents			
Twaite shad	Juveniles likely to be vulnerable when flows crash	Juveniles likely to be vulnerable when flows fall but in comparison to ' Do Nothing' option effects minimised	Juveniles likely to be more vulnerable when flows crash and through prolonged drought	Juveniles likely to be vulnerable when flows fall but will benefit especially over a prolonged drought	Juvenile shad feeding in the estuary might move further upstream during low flows therefore likely to be vulnerable		
Allis shad					No known spawning sites in the Severn therefore unlikely to be impacted by low flows		

	Acute Condition		Chronic Condition		Conclusion	Full In-Combination (includes maximum Glos & Sharpness Canal Abstraction)	
Feature	**' Do Nothing'**	**RSDO**	**' Do Nothing'**	**RSDO**		**' Do Nothing'**	**Full In-Combination**
Migratory Fish							
Sea Lamprey		Lower flows earlier in the year might limit spawning distribution		Lower flows earlier in the year might limit spawning distribution			
River Lamprey	Possible delay to migration downstream to sea or even prevention Autumn migration upstream delayed or prevented but to the end of October only	In comparison to ' Do Nothing' effects would be minimised	Possible delay to migration downstream to sea or even prevention Autumn migration upstream delayed or prevented but to the end of October only Effects would be more severe than under the Acute Condition	In comparison to the ' Do Nothing' option the effects would be minimised especially over the prolonged drought that this situation represents	Highly adaptable to flows but favour high flows Oct to March when low flows less of an issue. Vulnerable to any dissolved oxygen sags down in the estuary		
Sea Trout	Effects are the same as for salmon but water quality is likely to have a less severe impact	In comparison to ' Do Nothing' effects would be minimised	Effects would be more severe than under the Acute Scenario	In comparison to the ' Do Nothing' option the effects would be minimised especially over	Although the effects would be similar to those experienced by salmon, they are not as vulnerable due to the fact		

	Acute Condition		Chronic Condition		Conclusion	Full In-Combination (includes maximum Glos & Sharpness Canal Abstraction)	
Feature	**' Do Nothing'**	**RSDO**	**' Do Nothing'**	**RSDO**		**' Do Nothing'**	**Full In-Combination**
Migratory Fish							
				the prolonged drought that this situation represents	that the resident forms do not take part in migration		
Eel	Possible delay to migration downstream to sea or even prevention	In comparison to ' Do Nothing' effects would be minimised	Possible delay to migration downstream to sea or even prevention Effects would be more severe than under the Acute Condition		Migrate upstream mid Feb to mid May and migration upstream most likely to be impacted by barriers. As their migration upstream is not competed in one year impacts of drought and SDO scenarios negligible. Downstream migration peaks which occur Aug-Oct could be affected by drought Are more tolerant of dissolved oxygen sags. Vulnerable if trapped in shallow pockets of water but would occur in natural drought		

	Acute Condition		Chronic Condition		Conclusion	Full In-Combination (includes maximum Glos & Sharpness Canal Abstraction)	
Feature	**' Do Nothing'**	**RSDO**	**' Do Nothing'**	**RSDO**		**' Do Nothing'**	**Full In-Combination**
Migratory Fish							
					conditions		

Table 7. Summary of potential imacts of implementation of RSDO on individual designated migratory fish

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Resident fish species of note													
Brown trout (Salmo trutta morpha fario)	Adults	x	x	x	x	x	x	x	x	x	x	x	x
	Spawning										x	x	x
	Egg incubation	x	x									x	x
	Fry			x	x	x	x	x	x	x	x	x	x
	Parr	x	x	x	x	x	x	x	x	x	x	x	x
Migratory Fish of note													
Atlantic salmon (Salmo salar)	Spring run u/s migration					x	x	x					
	Main u/s migration									x	x	x	x
	Redds	x	x	x									x
	Fry	x	x	x	x	x	x	x	x	x	x	x	x
	Parr	x	x	x	x	x	x	x	x	x	x	x	x
	Smolt d/s migration				x	x	x	x					
Sea trout (Salmo trutta morpha trutta)	Upstream migration				x	x	x	x	x	x			
European eel (Anguila anguila)	Elver u/s migration		x	x	x	x	x	x					
	Silver eel d/s migration									x	x	x	
Severn Estuary Annex II migratory species (SAC status)													
Twaite shad (Alosa fallax) *not necessarily vulnerable to low flows whilst in freshwater therefore downstream migration is not impacted	Upstream migration				x	x	x						
	Downstream migration						*	*	*	*			
	Spawning					x	x						
River lamprey (Lampetra fluviatilis)	Adult u/s migration	x	x	x						x	x	x	x
	Juvenile d/s migration	x	x								x	x	x
	Spawning		x	x	x	x							
Sea lamprey (Petromyzon marinus)	Adult u/s migration				x	x	x	x					
	Juvenile d/s migration	x	x								x	x	x
	Spawning					x	x	x					

Table 8. Critical periods of sensitivity for fish

3.14. Conclusion of the Appropriate Assessment of Implementing the RSDO Alone on Migratory Fish

For the migratory fish features of the Severn Estuary SAC and Ramsar to be in favourable condition the Conservation Objectives state that:

- *"the migratory passage of both adults and juveniles through the Severn Estuary between the Bristol Channel and any of their spawning rivers is not obstructed or impeded by physical barriers, changes in flows, or poor water quality."*

  The modelling used in this Appropriate Assessment has shown that the migratory phases of Atlantic salmon, eels and river lamprey could be disproportionately impacted by the scenarios as modelled. Primarily this would be due to prevention of migration and in particular by artificial barriers (e.g. weirs) of which there are several along the River Severn. Even weirs with fish passes are not likely to be passable as these fish passage solutions require minimum flows which would not be available under these drought conditions. The problem of fish passage would also be combined with increased mortality and stress associated with water quality issues, increased predation and disease.
- *the size of the population of the species in the Severn Estuary and the rivers which drain into it, is at least maintained and is at a level that is sustainable in the long term.*

  As well as adult fish being held up in their migrations, the estuarine and lower tidal Severn life history phases are also likely to experience higher mortality due to water quality issues, e.g. juvenile shad. The conditions caused by such a severe drought could also lead to the possibility of reduced year classes of Atlantic salmon which would severely impact numbers of returning adults in the future therefore there could be a short term reduction in the size of some populations such as salmon
- *the abundance of prey species forming the principle food resources for the assemblage species within the estuary, is maintained.*

  The prey species forming the principle food resources for the assemblage species within the estuary are extremely well adapted to the conditions associated with the particular tidal regime therefore more tolerant to low flow conditions. However within the estuary where fresh and saline water meet there is an abundance of prey species (mysids) and these are particularly important to the juvenile twaite shad population. Their actual position varies according to the state of the tide and volume of freshwater input to the estuary. The low flows likely to affect the salinity regime of the estuary (particularly in relation to tidal conditions) would in turn impact the distribution of these prey species and potentially cause the juvenile shad to move further upstream during low freshwater flows as in the Acute or Chronic drought conditions. The juvenile shad would then be vulnerable to the lower freshwater flows and possible intermittent decreases in dissolved oxygen sags occurring in the lower tidal Severn. Although the abundance of prey species is unlikely to be affected the change in their distribution is likely to have an indirect effect on juvenile shad.
- *Toxic contaminants in the water column and sediment are below levels which would pose a risk to the ecological objectives described above.*

  It has to be emphasised that water quality has improved dramatically since the previous recorded droughts and fish kills are now rare. However given the low flows that would be experienced in a drought of a magnitude to trigger a RSDO there would be potential for decreases in dissolved oxygen sags to affect migratory fish both in the River Severn and lower tidal Severn but probably not in the designated Severn Estuary.

In Section 4.1.1.1 of the Severn Estuary SAC, SPA and Ramsar Site: Regulation 33 Advice from Natural Resources Wales and Natural England, June 2009 it states that ‘A failure to meet these conditions, which is entirely a result of natural process will not constitute unfavourable condition, but may trigger a review of the definition of favourable condition.’ The Regulation 33 advice recognises variable weather conditions, tidal surges and the fact that estuaries are dynamic

systems and that particular communities can have short term disappearances or crashes. The impacts on the designated migratory fish will be experienced under both the extreme natural drought and RSDO conditions. Drought is a natural event and will cause low flows which will result in the various effects and in particular an adverse effect on fish migration. This has been demonstrated to be the major issue and unlikely to be improved without removal of barriers to migration. Implementation of the RSDO in combination with the improvements that have taken place at Netheridge STW will reduce the risk of fish mortalities due to water quality issues.

As previously stated it is extreme drought conditions that will have an adverse effect on the migratory fish and implementation of the RSDO would lessen or minimise those impacts. In particular implementation of the RSDO during the first year provides resilience should there be an ongoing drought. **Therefore on balance it can be concluded that implementation of the RSDO alone (Drought Order Only scenarios), does not have an adverse effect on the designated migratory fish features of the Severn Estuary SAC and Ramsar.**

This Appropriate Assessment has been carried out based on a specific model of drought conditions and as each drought is an individual event the impacts on the different fish species in relation to the timing of a future drought may be different to what has been outlined in this assessment.

3.15. In Combination Assessment

3.15.1. Introduction

An in-combination assessment is also necessary for this Appropriate Assessment and this in combination assessment has concentrated on those permissions, plans and projects that can reasonably be expected to affect the migratory fish features. More details of the individual plans are discussed in Section 2.8.

To determine the effects of the natural drought and implementation of the RSDO, Aquator and SIMCAT modelling was used and the results considered in relation to the migratory fish species are given above in Sections 3.12 and 3.13. The following are included in these modelling tools:-

All relevant Environment Agency permissions e.g. discharge consents, abstractions and data such as gaugings and flow data.

Shropshire Groundwater Scheme is also included in the Aquator modelling.

Water Company Drought Permits and Orders – Aquator included the water company drought orders and permits for South Staffordshire Water, United Utilities, Severn Trent Water and Dwr Cymru Welsh Water. This means that all permits or orders and the interaction between their operation has been considered in relation to the effect on flows in the River Severn.

3.15.2. Gloucester & Sharpness Canal Abstraction

The Gloucester & Sharpness Canal abstraction was also included although it does not come under the control of the Environment Agency. For the modelling, a maximum abstraction of 300 Ml/d was assumed. The initial in-combination modelling for both Acute and Chronic conditions with the water company drought permits and canal abstraction at 300 Ml/d indicated that although the flow reduction was increased by these abstractions it did not lead to any additional WFD deterioration or tidal inflow target failures. As stated throughout the assessments it is the extreme drought conditions that will be having an adverse effect on the migratory fish and **on balance implementation of the RSDO in combination with the other drought permits and canal abstraction of up to a maximum of 300 Ml/d should not have an adverse effect on the designated migratory fish features of the Severn Estuary SAC and Ramsar.**

The Trust operate the canal in accordance with an Operating Agreement (1998) with the Environment Agency, which acts to safeguard the Severn Estuary inflows under routine flow regimes (supported by RoC Stage 3 assessment). *Clause 7 of the Operating Agreement provides that neither party can be held liable if it is not possible to meet the obligations under drought conditions. The Trust have committed to using best endeavours to continue to adhere to the Operating Agreement. If circumstances resulted in a failure under Clause 7, the lower tidal Severn and Estuary could be at potential risk. Therefore under the 'Full In-Combination' assessments (Acute and Chronic Conditions) it was necessary to account for the precautionary worst case abstractions (maximum abstraction up to 691 Ml/d) when concluding the potential environmental impacts.*

The potential impact of the the Trust's abstraction to the Gloucester & Sharpness Canal is large. This abstraction is exempt from licensing at present and can abstract up to *a maximum pump capacity* of 691Ml/d. It has been used close to its maximum rate for short periods during historic drought conditions, when abstraction and navigation demands have been highest. There are reasons why the maximum amount would not be abstracted even during drought, *such as environmental responsibilities1, siltation and saline intrusion on high tides (which impact on the Bristol Water drinking water abstraction from the canal). In summary it is reasonable to suppose the Trust would not abstract up to the maximum 691 Ml/d capacity if there were a future drought, however there remains the potential at low tides for the rate of pumping to be at its maximum, which would leave very little freshwater in the lower tidal Severn.*

In both the Acute and Chronic Conditions, under the In Combination scenarios an abstraction close to 691 Ml/d has the potential to have an adverse effect on the migratory fish population of the lower tidal Severn. Depending on discharge back into the estuary there is also the potential for an adverse effect on the SAC. For the ' Do Nothing' management option coupled with maximum abstraction, theoretically there would be times when no freshwater flow would be entering the lower tidal Severn: the repercussions for the fish fauna could be very significant. At high tides saline intrusion would increase although saline intrusion would halt abstraction into the canal whereas at low tides increased sediment deposition and fish trapped in pools would be at risk from rapidly rising water temperature, reduced dissolved oxygen concentrations and predation. With implementation of the RSDO the exceptionally low freshwater flows predicted under the ' Do Nothing' approach would not be reached. In fact during the 1975/76 drought, implementation of the RSDO continued to elevate flows above what would have naturally occured. However, significantly reduced flows to almost zero at Maisemore and Llanthony weir were related to maximum pumping.

It can be concluded that Gloucester & Sharpness Canal abstractions around the potential maximum 691 Ml/d could have the potential to have an adverse effect on the migratory fish features of the Severn Estuary SAC and Ramsar site alone, and in combination with the River Severn Drought Order and water company drought orders. The adverse effects will be particularly experienced by migratory fish in relation to their passage through the lower tidal Severn. However it has to be noted that this abstraction is outside the control of the Environment Agency.

The sensitivity around what exact flow and water level conditions would start causing a problem is very difficult to determine without more data.

3.15.1.1. Discussion of Outstanding Issue of Gloucester and Sharpness Canal Abstraction

This Appropriate Assessment determines whether, in view of the European site's conservation objectives, the implementation of a RSDO 'either alone or in combination with other plans or projects' would have an adverse effect on the integrity of the site. Where adverse effects are

[1] *The Trust is a competent authority for the purposes of Habitats Regulations 1994, has statutory environmental duties under the British Waterways Act 1995 and the Natural Environment and Rural Communities Act, and have charitable objectives relating to the protection of the environment.*

identified, which cannot be avoided or mitigated for, alternative options or solutions must be considered.

If it is not possible to identify mitigation or alternatives, consideration should be given to whether the sites host priority habitats or species, and if there are important human health or safety considerations 'imperative reasons of overriding public interest' (IROPI). If IROPI are determined, then compensatory measures must be designed, assessed and put in place, prior to the commencement of the plan. This is not considered a standard part of the process and will only be carried out in exceptional circumstances.

It can be argued that implementation of the RSDO is in fact a measure put in place to mitigate against the effect of drought which is a natural occurrence. It should also be noted that during a drought severe enough to warrant implementation of this RSDO, water companies with abstsractions from the Severn catchment would also be implementing drought permits/orders. This allows measures to be put in place which ensure that the limited water available is best managed to balance the competing demands of public water supplies and protecting the aquatic environment.

The *main* outstanding issue of RoC and this HRA is that the *potential maximum* Gloucester & Sharpness Canal abstraction *of 691 Ml/d could have an* adverse effect alone and in combination with the RSDO on the migratory fish feature of the Severn Estuary SAC and Ramsar and in particular in relation to their passage through the lower tidal Severn.

As previously stated the abstraction of 300 Ml/d in combination with the RSDO is not predicted to cause a likely significant effect on the designated Severn Estuary and its features. Given that the designated Severn Estuary (and features) is 35km downstream and the major influences on it are tidal, even with the maximum of 691 Ml/d abstracted for the Gloucester & Sharpness Canal, theoretically any effects should be limited and short term. There are no reports of the designated Severn Estuary being impacted during the 1975/7 droughts however following the 1989 drought it was concluded that residual outflows into the Severn Estuary are sensitive to the the Trust's pumping rate during periods of low river flow.

This abstraction is un-licensed but covered by a licence held by the Trust for Bristol Water with a Section 20 agreement. At the completion of RoC it was thought that the situation would be corrected shortly thus allowing all controlled input to the canal to be licensed. Of concern is the fact that the existing licence/operating agreement has the potential for a maximum of 691Ml/d to be abstracted from the River Severn and near maximum amounts have been abstracted *for short periods* during *historic* drought events *(1970s and 1980s)*, with flows having been significantly reduced as a result. Low flows combined with tides, particularly neap tides mean saline intrusion and sedimentation are the only *physical* factors that inhibit abstraction at the maximum amount. *However the Trust is a Competent Authority under the Habitat's Directive and has other environmental commitments which make it very unlikely the potential maximum volumes would be taken during furtuer drought events.*

The Canal & River Trust and the Environment Agency entered into an Operating Agreement in 1998 regarding the safe environmental management of the canal, to help alleviate the known impacts and protect the Natura 2000 site from derogation. Essentially the agreement restricted abstraction according to specific tide heights and flows at Deerhurst flow gauge, although it is important to note clause 7;

“Neither party shall be liable to the other under this Agreement for the failure to observe any of its obligations under this Agreement due to any cause beyond its reasonable control including without limitation any act of God, sudden or threatened loss of water from the Canal, drought, flood or major pollution.”

The effect of Clause 7 is that the Trust must still use its best endeavours to adhere to its obligations but there will be no cause of action if it misses those obligations. It also means that whereas the Environment Agency would be implementing the RSDO to protect supplies and the environment, any benefits *in the lower tidal Severn and Severn Estuary* could be negated *by abstractions significantly above the modelled 300 Ml/d*.

The Trust currently consider voluntarily closing the canal to navigation when flows at Deerhurst reach 1150 Ml/d or less (The Canal & River Trust pers comms 2012), which can be used as a guide for the main impact on the canal abstraction. Using this as a basis, under the Acute condition the RSDO modelling produced a period of 106 days where flows were <1150 Ml/d at Deerhurst, from 2 July to 1 November. *When compared with the 'Drought Order Only' scenario and the 'Full In-Combination', 38 of these days coincided with the activation of the River Severn Drought Order. Looking to a subsequent drought year in the Chronic condition identified another similar period of potential restrictions for both the 'Do Nothing' and 'Drought Order Only' scenarios. Owing to the consistency compared to the 'Do Nothing' scenarios and period of River Severn Drought Order operation, no additional canal closures would be caused as a result of activating the drought order.*

The consistency between the <1150 Ml/d flows at Deerhurst under the ' Do Nothing' Baseline scenario and RSDO scenarios (Acute and Chronic) suggests no direct benefits but more importantly no additional canal closures would be caused from activating the RSDO. This does offer scope for closure of the canal to navigation as a mitigation measure during these extreme drought conditions.

A further complication relating to this canal abstraction relates to Bristol Water's reliance on the canal for its own PWS (public water supply) abstraction. The Purton licence entails its own flow and tide height restrictions, which would naturally vary throughout the year. For both the Acute and Chronic conditions, abstraction for the Gloucester & Sharpness Canal was modelled as being continuous whereas in reality it could be scaled back or stopped once trigger flows were reached at Deerhurst. If this did occur and the canal was closed to navigation sufficient abstraction would still be needed to support this PWS abstraction at Purton.

The operating agreement for the canal abstraction contains flow controls that protect the river environment during normal conditions, but does contain a *limited* disclaimer for extreme droughts. The Trust have identified a trigger flow at Deerhurst for closing the canal to navigation but at present this remains a voluntary act and there is a requirement to protect the PWS abstraction from the canal. In the absence of any regulatory powers, the *potential* maximum abstraction remains a risk and could also be considered as negating the benefits obtained from implementation of the RSDO.

It should be noted that the Canal & River Trust are a competent authority under the Habitats Regulations 2010 and have a number of other environmental obligations. The consultation excercise has highlighted that this abstraction is recognised as an outstanding issue and there is a lot of good will amongst all interested parties to work together to find a balanced solution.

3.15.1.2. Mitigation

The environmental assessments identified the Full In-Combination scenarios (for Acute and Chronic Conditions) posed a high risk to the Lower Tidal Severn and a medium risk to the Severn Estuary Natura 2000 site (summarised in section 13.1 of the River Severn Drought Order Environmental Report). As a competent authority under the Habitat's Directive, we have to consider ways to mitigate against potential environmental harm or prove grounds of Imperative Reasons of Overriding Public Interest.

The conclusions within this report identified the biggest uncertainty and risk was posed by the potential for the Canal & River Trust to abstract up to 691 Ml/d. The most appropriate option to balance water abstraction needs and the requirements of the Habitat's Directive was found to be limiting the abstraction to the Gloucester & Sharpness Canal, as part of the drought order application.

The Habitats Regulations Assessment used historic data and reports from previous drought order events, alongside current data analysis tools, methods and expert knowledge to assess the potential impacts. Existing data enabled the assessment of an abstraction to the Gloucester & Sharpness Canal up to 300 Ml/d to be concluded as not having a likely significant effect on the

Natura 2000 site and its designated species. Historic evidence was used to assess the potential impact of the canal abstracting close to the 691 Ml/d maximum for short periods, concluding a significant impact could result. Insufficient data and evidence to justify further investigation to date has prevented sensitivity testing of abstraction volumes between these values.

The initial draft environmental reports went out to public consultation during the summer of 2013 identifying a potential in combination impact on the Natura 2000 site, and that further collaborative work was needed to resolve this issue. Consultation representations received through this process expressed concern with this outstanding issue (HRA specific representations contained in Appendix 6, for the complete representation refer to the River Severn Drought Order Environmental Report's Appendix V), highlighting that until a mitigation option was identified the River Severn Drought Order should not be used in combination or we would be in breach of the Habitats Regulations 2010.

Leaving the River Severn without a drought order option in the interim posed an unacceptable risk to the people and environment which rely on the water. Based on the Habitats Regulations Assessment work, a new abstraction cap of 300 Ml/d (figure subject to change) will form part of the application for a River Severn Drought Order. The abstraction cap from the River Severn to the Gloucester & Sharpness Canal, will only apply when flows at Deerhurst gauge fall below 1200 Ml/d and the River Severn Drought Order is active.

Because our consultation draft reports did not include this abstraction cap condition, the Canal & River Trust did not have an opportunity to respond to the impact in their consultation representation. We have been in discussions and held a meeting with the Canal & River Trust since the official consultation period closed to enable them to submit a more informed representation, and to identify future work. The Canal & River Trust raised concerns that 300 Ml/d could pose a risk to their operation of the canal and their confidence in being able to supply water to Bristol Water for its Purton abstraction. The Canal & River Trust have also expressed concern that their abstraction would be disproportionately restricted under the River Severn Drought Order when compared to conditions applied to the other abstractors. Appendix V within the River Severn Drought Order Environmental Report contains the Canal & River Trusts responses, alongside all the representations we received.

The Environment Agency have committed to working with the Canal & River Trust to investigate their concerns further. If sufficient evidence can be provided to show a higher abstraction is justified, the Environment Agency is committed to reviewing the restriction volume in the future.

Based on the new Gloucester & Sharpness Canal abstraction cap being in force when a River Severn Drought Order is active, the potential risk under the Full In-Combination scenarios was re-assessed. A higher certainty could be used to conclude the Severn Estuary would no longer be at medium risk of impact, and the risk to the Lower Tidal Severn was reduced from high to medium risk (refer to the River Severn Drought Order Environmental Report).

With the Gloucester & Sharpness Canal restriction measure in force, the Habitat Directive requirements are satisfied under the Full In-combination scenarios. The Natura 2000 site and species would benefit from the prolonged regulation period enabled by the River Severn Drought Order implementation, providing greater protection than under the 'Do Nothing (Baseline)' scenarios.

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Appendices

Appendix 1:

Likely Significant Effects (LSE) Screening (Incoporating Full In-Combination Assessment)

Appendix 1: Likely Significant Effects (LSE) Screening (Incoporating Full In-Combination Assessment)

European sites within or in hydrological continuity with the River Severn

Site	Designation	Relationship to River Severn
Berwyn and South Clwyd Mountains	SAC	Headwaters of the River Vyrnwy which provides a component of the River Severn Regulation
Montgomery Canal	SAC	In direct hydrological connectivity with the River Severn as it is fed by water taken from River Severn and River Tanat. This is allowed under an Act of Parliament not an abstraction
River Clun	SAC	In direct connectivity with the River Teme which is a major tributary of the River Severn. Salmon which are a feature of the Severn Estuary are a feature of the Freshwater Pearl Mussel life cycle.
Downton Gorge	SAC	River Teme which is a major tributary of the River Severn flows through this site. Salmon migrate up the River Teme to get to the River Clun where they are a feature of the Freshwater Pearl Mussel life cycle
Walmore Common	SAC & Ramsar	In direct hydrological connectivity with the River Severn via ditches
Severn Estuary	SAC, SPA & Ramsar	In direct hydrological connectivity with the River Severn
River Wye	SAC	Although not linked to the River Severn linked to the Severn Estuary
River Usk	SAC	Although not linked to the River Severn linked to the Severn Estuary
River Tywi	SAC	Although not linked to the River Severn linked to the Severn Estuary

The likely significant effects of the Drought Options on the above listed European sites have been assessed. This assessment records the reasoning behind why some of the above sites have been screened out. It should be noted that the Severn Estuary SAC estuarine feature will be assessed and other component features screened individually.

European Site Name and Status	Qualifying Features of International Importance	Potential Hazard
Berwyn and South Clwyd Mountains SAC	**European priority interest** 7130 Blanket bog **Additional proposed interest** 8120 Calcareous and calcshist screes of the montane to alpine levels (*Thlaspietea rotundifolii*) 8210 Calcareous rocky slopes with chasmophytic vegetation 4030 European dry heaths 6211 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) 7140 Transition mires and quaking bogs	Change in water levels or table

Potential exposure to hazard and mechanism of effect/impact if known:	
The blanket bog and transition mires and quaking bog for which much of the site is designated, give rise to the headwaters of the River Vyrnwy therefore it is in hydrological continuity with the Vynrwy Resevoir and river which form a component of the River Severn Regulation. However both Lake Vyrnwy and the River Vyrnwy are downstream of the site. In terms of applying for a RSDO, antecedent circumstances will be considered and it could be possible that there is rainfall over the Welsh Uplands in which case the site would be unaffected. If not, the site would naturally be suffering from reduced precipitation and increased evaporation.	
Risk of Likely Significant Effect (LSE)	No
In combination with other Agency Permissions, plans or projects	No
In combination with permissions, plans or projects of other Competent Authorities	No and Vyrnwy and United Utility Drought Plan have been considered in the modelling
Conclusion: Is the proposal likely to have a significant effect 'alone and/or in combination' on a European site. **Is an Appropriate Assessment required.**	No – but see above No

European Site Name and Status	Qualifying Features of International Importance	Potential Hazard
Montgomery Canal SAC	2.1 Floating Water Plantain	Change in water levels or table Change in flow or velocity

Potential exposure to hazard and mechanism of effect/impact if known:

The Canal is fed by water taken from River Severn and River Tanat. The British Waterways abstraction for the Montgomery Canal at Newtown is exempt from (Water Resources Act 1991) licensing. However, under the Montgomery Canal Agreement 1988, flows entering the canal are regulated during periods of high regulation and drought periods. Once the RSDO is activated, British Waterways can only abstract a maximum 16.43 Ml/d or 115 Ml in 7 days at Newtown. In addition, the 1988 agreement states if Llyn Clywedog storage drops below 25%, then British Waterways must stop abstracting. This reduced change in available water will lead to reduced water levels and flow therefore there is the potential of a likely significant effect.

Floating Water Plantain is a plant of clear, usually still or slowly flowing, fairly permanent water, ideally sufficiently shallow (less than 60cm) for its submerged rosettes to produce floating leaves and flowers. It can also persist in a non-flowering state for may years in deep water down to 2m, as well as being able to grow on the exposed damp mud of draw down zones. It seems to be able to tolerate a range of base and nutrient levels from low and fairly high. The plant has thrived in the canal in recent years because there has been minimum disturbance from boats, but sufficient maintenance to keep the waterway clear of invading reedswamp. It often reaches great abundance a few seasons after dredging operations and then gradually declines. The most relevant Conservation Objective is : The ecological status of the water environment, including elements of water quality, depth and clarity, will be sufficient to support species-rich canal vegetation with a variety of submerged, floating and marginal species and the populations of locally rare or uncommon species in favourable condition.

The view of CCW (Ken Perry pers comm. 13/12/2011) and BW (Stuart Moodie pers comm.14/12/2011) was that the direct impact of low flows would be limited and relate to the section of canal that was being affected. Water from the Severn only flows as far as the Wern and the biggest concentration of plants is found at Red House. This stretch of the canal has good shade cover and therefore there is low risk of this stretch being impacted, unless it should run completely dry. When the Manchester canals were being restored, water levels were dropped during works and the Luronium natans present adapted to its amphibious state. Once the water level was raised again the plant adapted back to its aquatic mode. For the Montgomery Canal it is anticipated that if levels were reduced low enough this is what would occur and it would also trigger the plant to flower.

The indirect impact of a change in water levels and resultant change in flow also needs to be considered. British Waterways recognise that water flow through the canal is an issue in the summer. Maintenance is required to reduce emergent growth in the canal to free up flow from the inlet to the outlet, and remove accumulated sediment at Penarth to allow flow through the inlet. If available water was reduced, water flow through the canal would be reduced and maintaining sufficient through flow could be an issue. The result of this would be stagnant water which would be less favourable for Luronium natans and more favourable for more aggressive plants unless additional weed clearance and dredging was carried out which has resource implications.

In a ‘worse case scenario’ in which the canal dried up, if aggressive species such as marginals were removed the plant should recover. Lower flows which would be experienced in the canal, particularly if abstraction ceased, could trigger flowering and seed production which could benefit the plant. Therefore due to the fact that the effect of a drought should only be short lived ie the species should recover and there is also the possibility that the plant could benefit from drought conditions, it can be concluded that there is no likely significant effect.

Otter (protected under Schedule 2 of the Habitats Regulations 2010) are present along the Montgomery Canal but are not thought likely to suffer any

significant adverse impacts associated with drought. They are able to travel long distances along watercourses and their holts and quiet lying-up sites will remain available and unaffected. It is flood rather than drought events that impact on otter. With water levels dropping in the canal it is likely that otter may find it easier to catch fish present in the canal and benefit from a drought. Water Vole (fully protected under Schedule 5 of the Wildife and Countryside Act 1981) have been recorded on the Montgomery Canal. They can survive at dried out sites but are vulnerable to terrestial and avian predators. Bankside and emergent vegetation cover is very important with the best sites having a continuous swathe of tall luxuriant riparian plants. During an ongoing drought the presence of bankside and emergent growth along the Montgomery Canal should provide a level of protection for water vole. There are sluices which can be used to control water levels in the canal and in the event of a severe ongoing drought the management of the available water to protect the structure of the canal, the Floating Water Plantain and water voles would have to be considered by the Canal & River Trust.	
Risk of Likely Significant Effect (LSE)	No in fact the low flows could have a positive effect on the plant
In combination with other Agency Permissions, plans or projects	No
In combination with permissions, plans or projects of other Competent Authorities	No
Conclusion: Is the proposal likely to have a significant effect 'alone and/or in combination' on a European site. Is an Appropriate Assessment required.	No No

European Site Name and Status	**Qualifying Features of International Importance**	**Potential Hazard**
River Clun SAC	2.6 Freshwater Pearl Mussel *Margaratifera margaratifera*	Change in flow or velocity regime
Potential exposure to hazard and mechanism of effect/impact if known:		
The freshwater pearl mussel is distributed from the Arctic and temperate regions of western Russia through Europe to the northeastern seaboard of North America. Formerly widespread and abundant in England and Wales most former populations are now virtually extinct. The River Clun holds the most viable southerly population of pearl mussels in the UK, and is considered one of the last low latitude, less oligotrophic sites left in Europe. The species has a symbiotic relationship with Atlantic salmon *Salmo salar* and brown or sea trout *Salmo trutta* during the annual reproductive phase (acting as a host for glochidae), on reaching maturity at age 10-15 years. Exploitation, poor water quality, particularly eutrophication and siltation of rivers, and a decline in migratory salmonids are all considered contributory factors in the decline of the species. Although the site is not designated for salmon it has to be considered a feature of the site. Since the salmon will migrate through the estuary and up the River Severn and River Teme (major tributary of the Severn) to get to the River Clun, the river is considered relevant in terms of its hydraulic continuity to the Severn Estuary. The River Clun is interesting in that glochidae use both salmon and brown trout as hosts: samples of both species taken from the Clun have illustrated this and it has been a noticeable feature of the population of River Clun mussels kept at the Windemere Hatchery. As well as glochidae being found on both fish species in the different locations, the infestations have been heavy. If due to lower flows a lower number of salmon migrate up the rivers to the River Clun the FWPM found in the River Clun are not compromised since they don't rely on salmon alone. The FWPM are also at		

less risk as good populations of Brown Trout are found in the River Clun and don't migrate/move to the same extent as Salmon.	
Risk of Likely Significant Effect (LSE)	No
In combination with other Agency Permissions, plans or projects	No
In combination with permissions, plans or projects of other Competent Authorities	No
Conclusion: Is the proposal likely to have a significant effect 'alone and/or in combination' on a European site. Is an Appropriate Assessment required.	No No

European Site Name and Status	**Qualifying Features of International Importance**	**Potential Hazard**
Downton Gorge SAC	1.6 *Tilio-Acerion* ravine woodlands	Change in flow or velocity regime
Potential exposure to hazard and mechanism of effect/impact if known:		
This site was included as being relevant since the River Teme (a major tributary of the River Severn) flows through the site and salmon migrate up the River Teme and through the gorge to get to the River Clun. However the designated feature of this site is woodland and therefore not dependent on the riverine habitat or any aquatic species.		
Risk of Likely Significant Effect (LSE)	No	
In combination with other Agency Permissions, plans or projects	No	
In combination with permissions, plans or projects of other Competent Authorities	No	
Conclusion: Is the proposal likely to have a significant effect 'alone and/or in combination' on a European site. Is an Appropriate Assessment required.	No No	

European Site Name and Status	Qualifying Features of International Importance	Potential Hazard
Walmore Common SAC & Ramsar	SPA This site qualifies under **Article 4.1** of the Directive (79/409/EEC) by supporting populations of European importance of the following species listed on Annex I of the Directive: **Over winter:** Bewick's Swan *Cygnus columbianus bewickii* - 104 individuals representing at least 1.5% of the wintering population in Great Britain (5 year peak mean 1991/2 - 1995/6) Ramsar Bewick's Swan Cygnus columbianus bewickii, NW Europe - 43 individuals, representing an average of 0.5% of the GB population (5 year peak mean 1998/9-2002/3)	Change in water levels or table

Potential exposure to hazard and mechanism of effect/impact if known:

This is a peaty wetland occupying a low-lying area in the Severn Vale subject to annual winter flooding. The site is in hydrological continuity with the River Severn by open water ditches. The site is largely dependent on precipitation and the site being flooded during the winter, although water levels can be maintained on the site by means of a tilting weir and tidal flaps. During a drought, evaporation would be exceeding precipitation and the soil and peat would already be drying out. Due to the presence of tilting weir and tidal flaps there may be scope for limited management of the site. Theoretically the site is more likely to be impacted if the RSDO was evoked during the winter months as that is when Bewick swan are found on the site. If the site is in sub-standard condition for the swans prior to the winter (which it could be, if the habitat is dried out due to drought) they will use other sites since they are not site dependent on Walmore. Since the swans are not reliant on this site, a change in water levels in the River Severn and any accompanying management of the site will not affect the swan population.
It should be noted that Bewick swan numbers are dropping across Europe and declining in Britain and an issue relating to all sites designated for this feature.

Risk of Likely Significant Effect (LSE)	No
In combination with other Agency Permissions, plans or projects	No
In combination with permissions, plans or projects of other Competent Authorities	No
Conclusion: Is the proposal likely to have a significant effect 'alone and/or in combination' on a European site. Is an Appropriate Assessment required.	No No

European Site Name and Status	Qualifying Features of International Importance	Potential Hazard
River Wye SAC	7140 Transition mires and quaking bogs 3260 Floating vegetation of Ranunculus of plain and submountainous rivers Allis Shad Twaite Shad Atlantic salmon Brook Lamprey, River Lamprey and Sea Lamprey Bullhead White-clawed crayfish Otter	Change in flow or velocity regime

Potential exposure to hazard and mechanism of effect/impact if known:

Agreed by both Natural England (NE) and Countryside Council for Wales (CCW) that potential effects on the River Wye SAC will not be directly considered as part of the assessment. However the site will be considered in relation to the Severn Estuary migratory fish feature, specifically in relation to Atlantic salmon, shad and sea lamprey.

The Bristol Channel and Severn Estuary contain populations of adult Atlantic salmon returning to their home rivers and they arrive in the estuary in most months of the year. These fish use tidal transport mechanisms to ascend the estuary. The adult fish are a mixed stock of fish from different rivers, ranging from the Severn itself to those along the south coast of Wales including the Wye, Usk and Tywi SAC sites and the recovering industrial rivers such as the Rhymney, Taff, Ogmore, Neath and Tawe. There is some evidence of fish derived from even further away.

The salmon present in the Severn Estuary are in the process of identifying their home rivers and a high level of fidelity to those rivers has been widely documented. However, the fish, whilst resident, will make multiple temporary ascents and descents of the estuary and may make temporary excursions into sub-estuaries before leaving to locate and enter their own rivers.

Under conditions which would trigger the implementation of a RSDO, low flows would not just be localised to the River Severn but be a national problem. Therefore freshwater flows from all the watercourses entering the Severn Estuary will be expected to be significantly reduced. This will result in salmon staying in the estuary for a longer period and under worse case scenario may not make their journey upstream to spawn. Due to regulation of the River Severn freshwater flows within the Severn may be higher than from other rivers entering the estuary which could lead to a small percentage of salmon entering the Severn rather than their natal river however their migration up stream would be limited by weirs.

This would be an exceptional drought situation, flows in other rivers would also be affected, but the expected percentage of fish entering the Severn instead of the Wye or other rivers, is low. Therefore the likely significant effect of implementing the RSDO on Atlantic salmon originating from the Wye is negligible.

Risk of Likely Significant Effect (LSE)	No
In combination with other Agency Permissions, plans or projects	No
In combination with permissions, plans or projects of other Competent Authorities	No
Conclusion: Is the proposal likely to have a significant effect ‘alone and/or in combination’ on a European site. Is an Appropriate Assessment required	No No

European Site Name and Status	Qualifying Features of International Importance	Potential Hazard
River Usk SAC	3260 Floating vegetation of Ranunculus of plain and submountainous rivers Allis Shad Twaite Shad Atlantic salmon River Lamprey and Sea Lamprey Bullhead Otter	Change in flow or velocity regime

Potential exposure to hazard and mechanism of effect/impact if known:

Agreed by both Natural England (NE) and Countryside Council for Wales (CCW) that potential effects on the River Usk SAC will not be directly considered as part of the assessment but it will be considered in relation to the Severn Estuary migratory fish feature, specifically in relation to Atlantic salmon, shad and sea lamprey.

The Bristol Channel and Severn Estuary contain populations of adult Atlantic salmon returning to their home rivers and they arrive in the estuary in most months of the year. These fish use tidal transport mechanisms to ascend the estuary. The adult fish are a mixed stock of fish from different rivers, ranging from the Severn itself to those along the south coast of Wales including the Wye, Usk and Tywi SAC sites and the recovering industrial rivers such as the Rhymney, Taff, Ogmore, Neath and Tawe. There is some evidence of fish derived from even further away. The salmon present in the Severn Estuary are in the process of identifying their home rivers and a high level of fidelity to those rivers has been widely documented. However, the fish, whilst resident, will make multiple temporary ascents and descents of the estuary and may make temporary excursions into sub-estuaries before leaving to locate and enter their own rivers.

Under conditions which would trigger the implementation of a RSDO, low flows would not just be localised to the River Severn but be a national problem.

Therefore freshwater flows from **all** the watercourses entering the Severn Estuary will be expected to be significantly reduced. This will result in salmon staying in the estuary for a longer period and under worse case scenario may not make their journey upstream to spawn. Due to regulation of the River Severn freshwater flows within the Severn may be higher than from other rivers entering the estuary which could lead to a small percentage of salmon entering the Severn rather than their natal river.

This would be an exceptional drought situation, flows in other rivers would also be affected, but the expected percentage of fish entering the Severn instead of the Usk or other rivers, is low. Therefore the likely significant effect of implementing the RSDO on Atlantic salmon originating from the Wye is negligible.

Risk of Likely Significant Effect (LSE)	No
In combination with other Agency Permissions, plans or projects	No
In combination with permissions, plans or projects of other Competent Authorities	No
Conclusion: Is the proposal likely to have a significant effect 'alone and/or in combination' on a European site. Is an Appropriate Assessment required.	No No

European Site Name and Status	Qualifying Features of International Importance	Potential Hazard
River Tywi SAC	Allis Shad Twaite Shad Atlantic salmon River Lamprey and Sea Lamprey Bullhead Otter	Change in flow or velocity regime

Potential exposure to hazard and mechanism of effect/impact if known:

Countryside Council for Wales (CCW) advised that potential effects to the River Tywi SAC will not be directly considered as part of the assessment but should be considered if effects arise in relation to the Severn Estuary migratory fish feature, specifically in relation to Atlantic salmon, shad and sea lamprey

The Bristol Channel and Severn Estuary contain populations of adult Atlantic salmon returning to their home rivers and they arrive in the estuary in most months of the year. These fish use tidal transport mechanisms to ascend the estuary. The adult fish are a mixed stock of fish from different rivers, ranging from the Severn itself to those along the south coast of Wales including the Wye, Usk and Tywi SAC sites and the recovering industrial rivers such as the Rhymney, Taff, Ogmore, Neath and Tawe. There is some evidence of fish derived from even further away.

The salmon present in the Severn Estuary are in the process of identifying their home rivers and a high level of fidelity to those rivers has been widely documented. However, the fish, whilst resident, will make multiple temporary ascents and descents of the estuary and may make temporary excursions into sub-estuaries before leaving to locate and enter their own rivers.

Under conditions which would trigger the implementation of a RSDO, low flows would not just be localised to the River Severn but be a national problem. Therefore freshwater flows from **all** the watercourses entering the Severn Estuary will be expected to be significantly reduced. This will result in salmon staying in the estuary for a longer period and under worse case scenario may not make their journey upstream to spawn. Due to regulation of the River Severn freshwater flows within the Severn may be higher than from other rivers entering the estuary which could lead to a small percentage of salmon entering the Severn rather than their natal river. This would be an exceptional drought situation, flows in other rivers would also be affected, but the expected percentage of fish entering the Severn instead of the River Tywi which is a considerable distance further along the coast would be very low. Therefore the likely significant effect of implementing the RSDO on Atlantic salmon originating from the Tywi is negligible.

Risk of Likely Significant Effect (LSE)	No
In combination with other Agency Permissions, plans or projects	No
In combination with permissions, plans or projects of other Competent Authorities	No
Conclusion: Is the proposal likely to have a significant effect 'alone and/or in combination' on a European site. Is an Appropriate Assessment required.	No No

Severn Estuary SAC, SPA and Ramsar

Feature	SAC	SPA	Ramsar Site	SSSI (Nationally important feature)
Estuary	Yes	Supporting habitat to designated bird interests	Yes	(Yes)
Subtidal sandbanks	Yes	No – outside boundary of SPA	No – outside boundary of Ramsar Site	No – outside boundary of SSSI
Interridal Mud and Sandbanks	Yes	Supporting habitat to designated bird interests	Component of Ramsar “estuaries” feature and supporting habitat to designated bird interests	Yes
Atlantic salt meadow/salt marshes	Yes	Supporting habitat to designated bird interests	Component of Ramsar “estuaries” feature and supporting habitat to designated bird interests	Yes
Reefs	Yes	No	Intertidal Sabellaria contiguous with subtidal reefs is a component of the hard substrates	No – outside boundary of SSSI
Migratory fish (river & sea lamprey & twaite shad)	Yes	No	Yes	(Yes)
Migratory fish (salmon, eel, sea trout and Allis Shad)	Part of notable species sub-feature of estuary feature	No	Yes	(Yes)
Assemblage of fish species (>100 species)	Notable species sub-feature of estuary feature	No	Notable species sub-feature of estuary feature)	(Yes)
Internationally important populations of migratory bird species	Notable species sub-feature of estuary feature	Yes	Yes Internationally important populations of waterfowl	Yes
Internationally important populations of wintering bird species	Notable species sub-feature of estuary feature	Yes		Yes
Assemblage of nationally important populations of waterfowl	Notable species sub-feature of estuary feature	Yes	Yes	Yes
Hard substrate habitats (Rocky shores)	Notable species sub-feature of estuary feature	Supporting habitat to designated bird interests	Component of Ramsar “estuaries” feature and supporting habitat to designated bird interests	Yes

Freshwater grazing marsh / Neutral grassland	No	Supporting habitat to designated bird interests within SPA but outside European Marine Site and therefore not addressed in this Regulation 33 advice document	Yes (currently England only)

European Site Name and Status	Qualifying Features of International Importance	Potential Hazard
Severn Estuary SAC Severn Estuary SPA Severn Estuary Ramsar	*The table above shows the relationship and interrelationship between features and site designations*	Change in freshwater flow to the estuary Change in water quality Change in salinity Change in oxygenation

Potential exposure to hazard and mechanism of effect/impact if known:

Change in water flow – The impacts considered were the impacts on flows into the estuary, tidal estuary processes and lower tidal Severn which is outside the designated site boundary but is the principal water source for the estuary and a supporting habitat for the migratory fish subfeature. The water resources modelling showed that no additional WFD or tidal flow target failures are caused by implementing the RSDO. All flow and level reductions would be temporary and short term, with overall flow benefits to the river and estuary resulting from implementing the RSDO. **It is therefore considered that implementation of the RSDO alone will not have an effect on the inflow into the estuary, tidal processes of the estuary of the lower tidal Severn.**

Change in salinity – there is the potential for low flows to result in increased saline intrusion (or saline intrusion to go further up the river). However also have to consider that habitats and species already coping with huge variations of salinity associated with tides.

Changes in oxygenation – intermittent oxygen sags naturally occur in the estuary and oxygen sags following on from storms/flood events are certainly recognised as an issue. Recognised that communities are adaptable to changing conditions but fish are sensitive therefore this issue is given further consideration.

Changes in water quality – finding showed that implementation of the RSDO will improve water quality along the River Severn in comparison to the ' Do Nothing' scenario and therefore the water quality of the estuary is not expected to be affected.

Have therefore established that the general estuary processes would not be affected it is considered that implementation of the RSDO would not have likely significant effect on the estuary and following principle habitats, species and species assemblages:-

Habitat	Designated site feature
Subtidal sandbanks	SAC Subtidal sandbanks feature SAC Estuary feature (*sub feature*)
Intertidal mudflats and sandflats	SAC intertidal mudflats and sandflats feature SAC Estuary feature (*sub-feature*) Ramsar Estuary feature (*estuarine habitat community*)
Atlantic salt meadow	SAC Atlantic saltmeadow feature SAC Estuary feature (*sub-feature*) Ramsar Estuary feature (*estuarine habitat community*)
Reefs of Sabellaria alveolata	SAC Reef feature SAC Estuary feature (sub-feature)
Hard substrate habitats (rocky shores)	SAC Estuary feature (*estuarine habitat community*) Ramsar Estuary feature (*estuarine habitat community*)

Species or species assemblage	Designated site feature
Assemblage of waterfowl species	SAC Estuary feature (*notable estuarine species assemblage*) Ramsar Estuary feature (*notable estuarine species assemblage*) SPA feature*
Internationally important populations of : Bewicks swan European white-fronted goose Gadwall Shelduck Dunlin Reshank	All species are : Ramsar features* SPA features *
Vascular plant assemblage	SAC Estuary feature (*notable estuarine species assemblage*)

Risk of Likely Significant Effect (LSE)	No

In combination with other Agency Permissions, plans or projects	All relevant abstractions were considered 'alone' and 'in combination' for RoC and any abstractions permitted after October 2009 will have been considered a new permission and subject to an assessment of Likely Significant Effect. All relevant Agency permits and authorisations were included in the Aquator and SIMCAT modelling therefore this in combination element has already been built in.
In combination with permissions, plans or projects of other Competent Authorities	RSDOs and Permits produced by the water companies were also included in Aquator therefore this in combination has already been considered as part of the modelling process. The Sharpness & Gloucester Canal Abstraction is not an abstraction authorised by the Environment Agency but allowed by an Act of Parliament. Due to this fact the effects of this abstraction were not considered in RoC. Since this abstraction has potential to have an adverse effect on the estuary and will be taking water from the river when flows are substantially diminished, the effect of this abstraction will be considered separately. This abstraction (at 300 Ml/d) was also included as part of the in Aquator therefore this in combination has already been considered as part of the modelling process.
Conclusion: Is the proposal likely to have a significant effect 'alone and/or in combination' on a European site. Is an Appropriate Assessment required.	No – implementation of the RSDO alone will not have a likely significant effect on the Severn Estuary No – implementation of the RSDO in combination with the water company RSDOs and permits will not have a likely significant effect on the Severn Estuary No – implementation of the RSDO in combination with the water company RSDOs and permits and the Sharpness & Gloucester Canal abstraction at 300 Ml/d it would be unlikely to have a significant effect on the Severn Estuary. However even if 691Ml/d was abstracted it is unlikely that there would be a likely significant effect on the designated Severn Estuary but it would increase the potential of the site and features being exposed to the hazards associated with low flows.

European Site Name and Status	**Qualifying Features of International Importance**	**Potential Hazard**
Severn Estuary SAC Severn Estuary Ramsar	River Lamprey Lampetra fluviatilis, Sea Lamprey *Petromyzon marinus Twaite Shad Alosa fallax* **Assemblage of migratory fish species** : Sea Lamprey,River Lamprey,Twaite Shad, Allis Shad,Salmon,Sea Trout,Eel	Change in water levels, Change in freshwater flow to the estuary Change in salinity regime Reduced dilution capacity
Potential exposure to hazard and mechanism of effect/impact if known:		
The fish fauna of the Severn Estuary is very diverse and is of particular importance for migratory fish such as those listed above. The Estuary supports the important run of migratory salmon and sea trout as they pass through the estuary on their way to and from their spawning grounds in the upper reaches of the rivers and the open sea. Flows from the river into the estuary must be sufficient to allow migration therefore timing of drought and passage of lamprey up the river likely to determine LSE. There is also the potential of reduced flows leading to reduced dissolved oxygen which could affect the fish species. The RoC for the Severn Estuary concluded that there sufficient flows within the River Severn for Twaite shad, sea and river lamprey with the exception of a rare severe drought event. The implementation of a RSDO is a response to a rare and severe drought drought and from the finding of the water flow and water quality studies it is considered that the **implementation of the SDO alone could have a likely significant effect on the above features and they will be taken forward to Appropriate Assessment**.		
Risk of Likely Significant Effect (LSE)	Potentially yes therefore needs Appropriate Assessment to determine effects.	
In combination with other Agency Permissions, plans or projects	As above	
In combination with permissions, plans or projects of other Competent Authorities	As above and particularly in relation to maximum that could be abstracted for the Gloucester & Sharpness Canal	
Conclusion: Is the proposal likely to have a significant effect 'alone and/or in combination' on a European site. Is an Appropriate Assessment required.	As above	

Ramsar features (for which Conservation Objectives have been written)	**Revised Criteria (2005)** (criteria currently used on JNCC website)	**Potential Hazard** Change in water levels, Change in freshwater flow to the estuary Change in salinity regime Reduced dilution capacity
* *The wider estuarine fish assemblage is covered as a "notable species assemblage" sub feature of the SAC "Estuaries" feature*	**Criterion 8** : qualifies as the fish assemblage of the whole estuarine and river system is one of the most diverse in Britain, with over 110 species recorded.	

Potential exposure to hazard and mechanism of effect/impact if known:

The Ramsar designation also recognises the large diversity of fish within the estuary. Many of these fish are found lower down the estuary and a study by Potter et al (2001) concluded that annual recruitment strength of the fish assemble of the estuary was not related to water temperature or changes in salinity therefore it can be assumed that implementation of the RSDO will not have a likely significant effect on the fish assemblage. The Appropriate Assessment will only be undertaken in respect of the 7 migratory fish species.

Risk of Likely Significant Effect (LSE)	No
In combination with other Agency Permissions, plans or projects	No
In combination with permissions, plans or projects of other Competent Authorities	No
Conclusion: Is the proposal likely to have a significant effect 'alone and/or in combination' on a European site. Is an Appropriate Assessment required.	No

Appendix 2:

Estuary Inflow modelling and assessment

Appendix 2: Estuary Inflow modelling and assessment

Background and methodology

Deerhurst and Haw bridge represent the last downstream flow gauges on the River Severn. The sites (Haw Bridge and Deerhurst) represent the furthest downstream location from which flow data can be accurately measured and Severn regulation operation can be assessed with confidence. All downstream flow and Severn Estuary inflows are assessed using computer models, which provide the best available information based on known abstractions and discharges.

Haw Bridge records go back to 1971 and record the impacts of historic droughts however the site is impacted by tidal back water. Deerhurst was operational from 1995, constructed to cope with the tidal influences experienced in this section. Flow data from the gauging stations is plotted and assessed for upstream comparison, however the downstream modelled location 'Lower Parting' represents the Estuary inflows used to assess the overall impact on the Severn Estuary.

In order to assess the impact of the RSDO on the Severn Estuary, flow targets were used to provide a guide on how significant the flow decreases could be to the environment. This only provides a guide on flow quantity, what this 'looks like' on the ground and how it impacts the ecology remains very difficult to assess and historic drought events need to be used to inform final conclusions.

Stage 3 RoC used the WFD transitional waterbody flow targets (2008 report by SNIFFER) as an aid to assess the current flow regime, assessing gauged and modelled (Low Flows 2000) natural flows to conclude no likely significant effect. The WFD Sensitivity Ranking (sensitivity to abstraction) for the Severn Estuary came out as low, reflecting the large tidal range and area involved.

WFD and CAMS both calculate recommended 'Environmental Flow Indicator' (EFI) targets based on the expected natural flow (removal of abstractions and discharges) and how sensitive a watercourse ecosystem is perceived to be to abstraction (based on ecological and biological evidence). The sensitivity of the ecosystem determines how far below the natural flow duration curve (FDC) the EFI will be set, providing an indication of a minimum flow requirement before environmental damage 'could' start to occur.

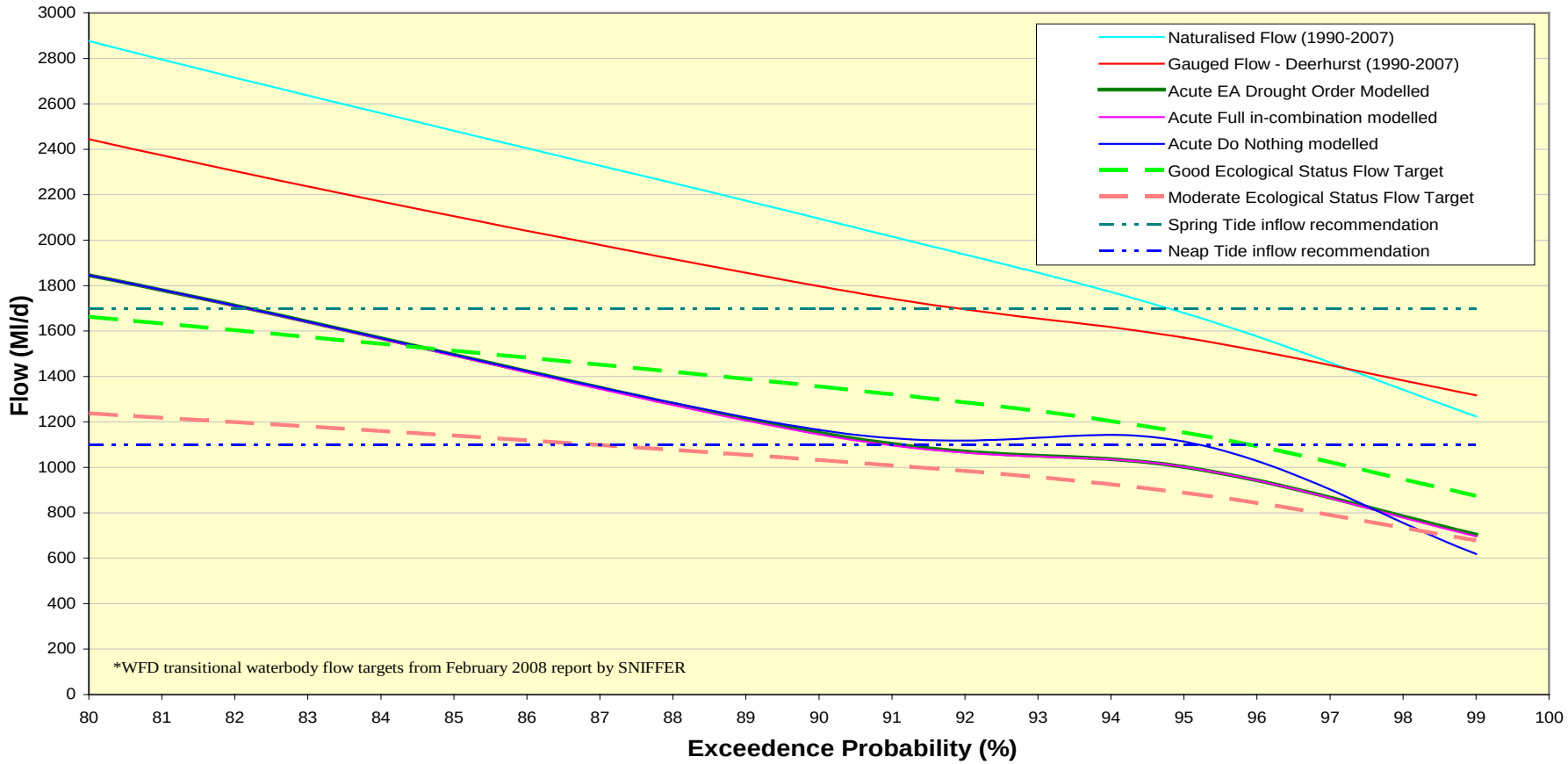
Using the same methodology as the Review of Consents (RoC), both the Good and Moderate ecological status EFI's were updated with current natural data (naturalised via decomposition at Deerhurst and modelled Low Flows Enterprise data at Lower Parting/Elmore) and plotted against the modelled drought condition's. It is important to note that as with all the flow assessment work, the drought condition FDC's are based on short time periods which skew the whole FDC towards lower flows, realistically only the values from the 90th percentile will be useful to this investigation.

In an attempt to provide more context around the modelled drought impacts, additional FDC's were plotted at Deerhurst to show what the WFD flow targets 'would be,' using the ' Do Nothing' condition's as the alternative natural/baseline flow (Aquator design makes it difficult to separate a truly naturalised flow sequence). However these were not included as the flow reductions permitted were unrealistic and potentially damaging to the environment.

WFD flow targets provide a general guide to Estuary sensitivity to abstraction and freshwater inflows, however site specific targets should be utilised where available. An investigation was undertaken (Hutcherson and Wade) into the residual flow requirements to the Upper Severn Estuary in 1992, concluding the tide height to be highly influential (due to saline water movement) on how much freshwater inflow would be required to restrict the amount of saline intrusion up the River Severn. A Neap tide flow target of 1200Ml/d and Spring tide flow target of 1800Ml/d were recommended to help support the Severn Estuary environment, and protect freshwater abstractions. These flow targets have also been included in the assessment for completeness.

Acute Condition: Deerhurst Assessment Point 6 Deerhurst

ACUTE SCENARIO:
Deerhurst FDC (Q80 onwards) against WFD Good and Moderate Ecological Status Flow Targets*



The above graph shows how under the current flow regime (abstractions and discharges as they exist today), Severn Regulation operation supports flows above the Severn Estuary's Good Ecological Status (GES) FDC at all times/flows, and above what would naturally occur from the 97th percentile. This supports the RoC findings and confirms that Severn Regulation is supporting WFD achievement and raising the lowest and most drought related flows above what would naturally occur at the Deerhurst location.

Testing against the residual flow targets, the graphs demonstrate that even under natural conditions the Spring Tide inflow target would be failed by up to 576 Ml for 5% (Q95) of the time (approximately 37 days over the 2 year period). The current flow regime slightly increases this period to 8% (Q92) of the time (average 58 days), but reduces the magnitude of failure to 483 Ml, an improvement of 93 Ml. Both natural and current flows consistently support the Neap Tide inflow target at Deerhurst.

Acute Condition: Haw Bridge/Deerhurst

' Do Nothing'

This investigation is primarily concerned with flows during the severe drought scenarios modelled. The 1990-2007 flow records from Haw Bridge and Deerhurst gauging station were used for comparison, in line with CAMS and RoC, but its important to note the most significant drought represented was 1995/96 (owing to the time period used), when the RSDO was not used. This will make the modelled drought scenario's appear disproportionately more severe than ever recorded before, however the Deerhurst gauge represents the best available data for this investigation.

At Deerhurst, using the gauged record (1990-2007) for comparison, a drought of acute magnitude could be reducing the expected Q95 low flows by up to 670Ml, a 43% reduction. The minimum flows modelled following regulation failure suggest flows could drop as much as 980Ml lower, a 74% reduction. These flow reductions should only be used as a worse case indication of the magnitude of flow reduction possible during a severe drought.

Using the existing WFD EFI's as a guide, the Acute condition drought event could cause deterioration from GES for approximately 15% of the 2 year period being considered, equating to about 110 days in total. There is some marginal deterioration below MES for approximately 2% of the period, approximately 15 days over 2 years.

The range of flow deterioration varies, taking account of only the 90th percentile and higher; deterioration from GES is between 155-200Ml. In context of the sensitivity of the Severn Estuary, the magnitude of deterioration and the length of time it occurs for should not be significant. Short term impacts will vary according to the time of year deterioration occurs, which cannot be accurately predicted although is more likely between September and November.

WFD allows for movement within a band, and the 2% (15 days) change into MES would be very short term and in context of modelling errors, would not be considered conclusive. WFD directive article 4.6 also allows for temporary deterioration caused by exceptional natural events, such as prolonged droughts. The ' Do Nothing' scenario represents the closest to baseline and unavoidable drought events as we can currently model, and therefore results are considered to fall under article 4.6.

Assessing flows against the Spring and Neap Tide targets shows some failures, as expected during a natural drought event. The Spring Tide inflow target could be at risk of failure for an additional 10% or 73 days over the 2 year period (from Q82), a total 131 days. Risk of failing the Neap Tide inflow target, possibly more significant, could occur for 5% (Q95) of the time, approximately 37 days. It is important to note the risk is increased, but would only impact the environment if the low flows occurred in conjunction with the relevant tidal conditions. These failure risks would mainly translate into allowing further upstream movement of saline water during natural tidal fluctuations, and alter the amount of inundation along the River Severn channel.

Impacts are likely to vary according to channel variations and be short term in nature. The main impacts (saline intrusion and reduced wetted perimeter) are likely to be experienced along the lower tidal Severn channel, outside of the Natura 2000 designated site. The impacts under the ' Do Nothing' scenario demonstrate the majority of these impacts would be of natural cause.

RSDO

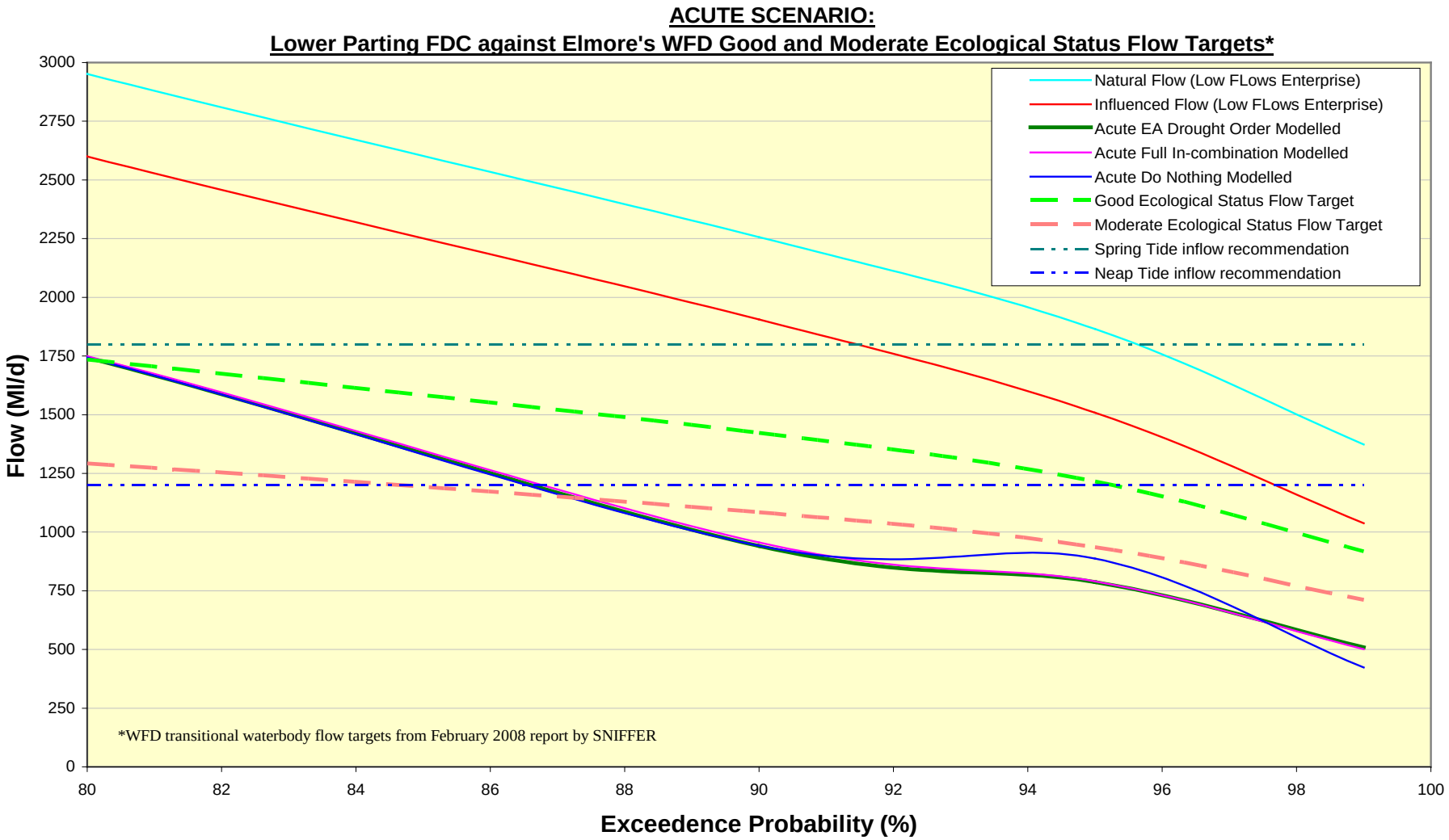
The RSDO causes no additional GES deterioration or failures of the Spring Tide inflow target. The overall magnitude of deterioration does alter slightly, reflecting the lowered prescribed flow at Bewdley for a greater length of time whilst protecting a higher minimum flow. Operating the RSDO prevents any potential deterioration below MES, an improvement on the ' Do Nothing' scenario.

Operating the RSDO and lowering the prescribed flows does increase the risk of failing the Neap Tide inflow target by an additional 4% (Q91) compared to the ' Do Nothing' scenario. This could increase risk up to 9% over the 2 year period, a total 66 days (a 29 day increase), actual impacts would vary according to when Neap tides occurred in relation to the low flows.

Full In-combination

The full in-combination FDC is very similar to the RSDO, reflecting how the majority of ‘other’ influences have already been incorporated. No additional WFD deterioration is caused, only a slight increase in magnitude, and no additional Neap Tide inflow target failure is created.

Assessment Point 7 U/S Sharpness and Assessment Point 8 Lower Parting



U/S Sharpness is located upstream of the Gloucester & Sharpness Canal and therefore reflects the more natural flow accretion as the catchment area increases. Lower Parting is located downstream of the large abstraction for the Gloucester & Sharpness Canal, the large decrease in flows demonstrates the magnitude of impact this abstraction has. It is important to note a maximum 300 Ml/d abstraction has been modelled based on recent actual information, however the Canal & River Trust (was British Waterways) have confirmed a maximum 691 Ml/d could be abstracted if needed. This higher figure will be considered under the in-combination scenario's assessment.

Low Flows Enterprise has been used to model a natural and influenced (with abstractions and discharges) FDC at Lower Parting (no gauging stations present) for comparison, the error margin will be higher than at Deerhurst due to the lack of real data for calibration, but does represent the best available data at this time.

The graph above of flows at Lower Parting suggest under current conditions, Severn Regulation operation still supports flows above the Severn Estuary's Good Ecological Status (GES) FDC at all times/flows. Unlike Deerhurst, low flows are not restored to being higher than would naturally occur. This represents the influence of large abstractions for the Gloucester & Sharpness Canal, and subsequently to Bristol Water (from the canal) at Purton.

As with Deerhurst, the graphs suggest that even under natural conditions the Spring Tide inflow target would be failed at certain times of the year. Lower Parting flows, and therefore freshwater inflows to the Estuary, fall below the Spring Tide inflow target by up to 427 Ml for 4% (Q96) of the time (approximately 15 days a year). As shown at Deerhurst, the modelled influenced flow regime increases this period to 8% (Q92) of the time (approximately 29 days a year); however, unlike Deerhurst the magnitude of failure is increased to 762 Ml. Modelled natural flows appear to support the Neap Tide inflow target at all times, however the modelled influenced data suggests a risk of 2% (average 7 days per year) failure by up to 162 Ml, which is a deterioration from flow conditions at Deerhurst.

Acute Condition: Estuary inflows

' Do Nothing'

Comparing the U/S Sharpness FDC against the Lower Parting highlights the impact the Gloucester & Sharpness Canal abstraction can have during low flows, and the risk it could pose during a severe drought. As this assessment is focusing on the Severn Estuary impacts the Lower Parting FDC will be used to represent the potential worse case.

Using the WFD EFI's as a guide, the Acute '' Do Nothing'' Baseline scenario drought event could cause deterioration from GES for approximately 20% of the 2 year period being considered, equating to about 146 days in total. Deterioration below MES could also occur for approximately 13% of the period, approximately 95 days over 2 years. It is difficult to conclude how much of the failure is genuinely additional to Deerhurst, and how much the short time period used skews the results, however it is evident that flows would be significantly lower at this location as a result of the additional large abstraction to the Gloucester & Sharpness Canal.

The range of flow deterioration varies, taking account of only the 90th percentile and higher; deterioration from GES is between 480-621Ml and deterioration from MES is between 142-387Ml. Assessing flows against the Spring and Neap Tide targets shows additional failures expected during a natural drought event. The Spring Tide inflow target could be at risk of failure for an additional (compared to normal flow regime) 13% or 95 days over the 2 year period (from Q79), a total 153 days. Risk of failing the Neap Tide inflow target could occur for an additional 11% (Q87) or 80 days over the 2 year period (from Q87), a total 95 days.

RSDO

The RSDO causes no additional GES or MES deteriorations, or additional Spring or Neap Tide inflow target failures. Results indicate the RSDO would not create a significant extra burden on the Severn Estuary environment, beyond the stress already resulting from the natural drought event. Should regulation failure occur, benefits would be achieved for the Severn Estuary by increasing the minimum flows experienced.

Full In-combination

The full in-combination FDC is very similar to the RSDO, no additional WFD deterioration is caused, or additional Tidal inflow targets failed. However the graphs only represent the recent actual abstractions from the Gloucester & Sharpness Canal as a maximum 300 Ml/d. The Trust have confirmed the pumps could take a maximum 691 Ml/d, and reports from the 1976 and 1989 drought events highlight large canal abstractions over brief periods reducing the Estuary inflows to almost zero. If this situation were repeated for a longer period, then likely significant effects cannot be ruled out.

Severn Estuary Conclusions: Acute Condition

The Severn Estuary, being the furthest downstream section of the River Severn, will be impacted by the greatest number of accumulated abstractions and discharges of all the assessment points considered. The size of the catchment, significance in terms of water resource supply, and variation of habitat environment make it difficult to assess with great accuracy.

The droughts of 1976 and 1989 have shown that inflows to the Severn Estuary can be seriously depleted for short periods, as a result of reduced rainfall and a combination of abstractions from the River Severn. The worst impacts were observed from the natural channel split in Gloucester down to the Severn Estuary. The channel split divides flows, with the Canal & River Trust abstracting from the East channel at varying quantities. Significant flow reductions at this location have depleted water levels to the extent where little to no flows were passing over the downstream weirs.

Slower flows during low flow periods increase the amount of sediment deposition and evidence shows the lower section of the River Severn is the most vulnerable to short term siltation problems.

Previous drought reports found evidence to indicate the Severn Estuary Natura 2000 site is not highly sensitive to changes in the freshwater inflows, with impacts being largely restricted to the lower tidal River Severn, outside the designated site.

To assess the Severn Estuary freshwater inflows Haw Bridge/Deerhurst flows were considered initially, then modelled data from U/S Sharpness and Lower Parting. Haw Bridge and Deerhurst are the furthest downstream flow gauges with continuous flow records, enabling calibration of models and accurate assessment of the regulation system. Deerhurst was constructed to cope with the tidal influences of the Severn Estuary, and currently provides the best available flow data. However it is over 45 km (in channel) upstream of the Severn Estuary Natura 2000 site and excludes the significant abstraction for the Gloucester & Sharpness Canal (and subsequent Bristol Water abstraction from the canal at Purton). U/S Sharpness was modelled to provide an indication of possible flows just upstream of the abstraction point and channel split, while Lower Parting was modelled as the main assessment point for the impacts on the Severn Estuary, incorporating the canal abstraction and representing the most likely inflows to the Natura 2000 site.

Comparing the U/S Sharpness flow duration curve (FDC) against the Lower Parting FDC clearly demonstrates the impact the Gloucester & Sharpness Canal abstraction can have as part of the accumulative in-combination effects. As highlighted in the main River Severn conclusions, the greatest modelling uncertainty remains around the Gloucester & Sharpness Canals varying abstraction and its in-combination impacts on the lower River Severn during a severe drought.

An average monthly abstraction profile was calculated from recent actual data provided by the Canal & River Trust; however there is the potential for greater or lesser abstraction than was modelled. While the abstraction remains exempt from licensing regulation, a pragmatic approach has been adopted. The recent actual data has been used to represent the abstraction within modelling, however for the in-combination assessment the 691 Ml/d worse case figure (provided by the Canal & River Trust) has been considered. This approach is a balance between what is likely to occur under current legislation (e.g. Habitat's Directive), and what is theoretically possible (e.g. 1976 and 1989 drought reports highlight large canal abstractions being taken for brief periods, reducing flows into the Severn Estuary to nearly zero).

' Do Nothing'

The ' Do Nothing' scenario represents the possible flows if no RSDOs or permits were applied to help manage the developing drought, but all normal abstractions and discharges continue (includes Gloucester & Sharpness Canal 300 Ml/d abstraction), as would be expected in reality. Modelling has shown that initial flow conditions would be better under the '' Do Nothing'' scenario, however if the drought continued and resources ran out, flow crashes and subsequent minimum flows would be severe and resilience for the following year greatly reduced by not operating the RSDO.

Comparing the modelled drought flows at Deerhurst to the gauged record (1990-2007) illustrates some of the potential flow reductions that could be considered unavoidable during a severe drought event. Deerhurst Q95 flows could fall by up to 670Ml, a 43% reduction. If a drought were to continue long enough for regulation resources to be exhausted, then comparisons indicate minimum flows could drop as much as 980Ml, a 74% reduction. The potential magnitude of flow reduction in the lower reaches of the River Severn is significant, through the natural lack of baseflow and runoff, and exasperated by the in-combination impacts of upstream abstractions.

' Do Nothing' Results indicate the natural drought event could cause temporary failure of the WFD Good Ecological Status (GES) and Moderate Ecological Status (MES) flow targets. Inflows to the Severn Estuary (as modelled at Lower Parting) could experience short term (20% of 2 year period, equating to 146 days) deterioration from GES, ranging from 480-621Ml from the 90th percentile. Of this period, 95 days (13% over 2 year period) of 142-387Ml MES deterioration could also be experienced. The magnitude of the failures is significant, but the WFD flow deterioration would be temporary and as a direct result of an exceptional natural drought event (covered by WFD Directive article 4.6), as proven by the consistent GES maintained during normal flows and the same abstractions.

' Do Nothing' Results indicate the natural drought event could increase the number of days Estuary inflows failed to meet the recommended Spring and Neap tide flow targets. At Deerhurst, the Spring Tide inflow target could be at risk of failure for an additional 10% or 73 days over the 2 year period (from Q82), and 5% (Q95) or 37 days for the Neap Tide inflow target, when compared to the normal flow regime. Once the Gloucester & Sharpness Canal abstraction is accounted for at lower Parting, the risk of failures increases. The Spring Tide inflow target could be at risk of failure for an additional (compared to normal flow regime) 13% or 95 days over the 2 year period (from Q79), a total 153 days. Risk of failing the Neap Tide inflow target could occur for an additional 11% (Q87) or 80 days over the 2 year period (from Q87), a total 95 days.

It is important to note the 'risk' from tidal inflow target failures is increased, but potential impacts would only result if the low flows arrived in conjunction with the relevant tidal conditions. These failure risks would mainly translate into allowing further upstream movement of saline water during natural tidal fluctuations, and alter the amount of inundation along the River Severn channel. Evidence from previous droughts and the sensitivity of the Severn Estuary would indicate that lower freshwater inflows would not have a significant effect on the Natura 2000 site itself, especially considering the short term and temporary nature of the lowest flows.

In terms of river levels, although it is not possible to accurately predict the decrease in levels at this time, using the 1976 drought event as a benchmark, it is likely that flows around the natural

channel split could be particularly low and hardly passing over the weirs. Low and slow flows would also increase silt deposition and cause the channel to become clogged until high rainfall and flows returned. This would mainly impact the lower tidal River Severn and have obvious impacts to fish migration and navigation in the short term.

The '' Do Nothing'' scenario provides the benchmark comparison for assessing whether the RSDO would have any additional positive or negative impacts on the Severn Estuary Natura site. Modelling shows some temporary deterioration below the transitional waterbody WFD flow targets, and some increased Spring and Neap tide flow targets are to be expected.

RSDO

The RSDO causes no additional GES or MES deteriorations compared to the '' Do Nothing'' scenario. The overall magnitude of deterioration does alter slightly, reflecting the lowered prescribed flow at Bewdley for a greater length of time whilst protecting higher minimum flows.

Operating the RSDO creates no additional Spring Tide inflow target failures compared to the '' Do Nothing'' scenario. At Deerhurst, the risk of failing the Neap Tide inflow target is increased by 4% (Q91) compared to the ' Do Nothing' scenario, however no additional increase is observed at Lower Parting due to the lower flows already being experienced under the '' Do Nothing'' scenario.

If regulation failure were to occur (sources became too low to support any prescribed flow at Bewdley), the results show the RSDO would maintain higher minimum flows during the critical drought period than possible under the '' Do Nothing'' scenario. This benefit supports the RSDOs design purpose, and would support both abstractors and the environment.

The Severn Estuary has a low sensitivity to freshwater inflows, and results show no additional harm (based on existing flow targets) would be caused beyond the naturally occurring drought effects. Benefits could also be achieved by operating the RSDO, if the event out lasted the remaining water resources. **No likely significant effect is concluded.**

Full In-combination

The full in-combination FDC is very similar to the RSDO, based on the Gloucester & Sharpness Canal still abstracting a maximum of 300 Ml/d. Compared to the '' Do Nothing'' scenario, these results show no additional WFD deterioration, or additional Tidal inflow target failures. The magnitude of flow reductions does increase compared to the RSDO in isolation, so the magnitude of short term impact would be greater although the length of time this might be experienced for remains the same.

As discussed, the difference in flows between the U/S Sharpness and Lower Parting locations, as well as Deerhurst, clearly indicate the biggest impact at these locations is the Gloucester & Sharpness Canal abstraction. The in-combination affects from this abstraction (at a maximum 300 Ml/d) pushes the FDC into MES WFD deterioration under all scenarios.

The Trust are currently exempt from licensing and have the capacity to abstract up to 691 Ml/d (a maximum of 300 Ml/d was modelled). The 1976 and 1989 drought reports identified large abstractions for short periods, which had significant impacts (e.g. water levels and siltation) along the lower tidal River Severn, leaving almost zero freshwater inflow to the Severn Estuary. Fish kills within the Severn Estuary did not correlate with the abstractions, and the impacts were short term and temporary.

Under current legislation the canal abstraction remains exempt from licensing, although the Bristol Water abstraction at Purton, which relies on the canal, is licensed. The operating agreement for the canal abstraction contains flow controls that protect the river environment during normal conditions, but does contain a disclaimer for extreme droughts. The Trust identify a trigger flow at Deerhurst for closing the canal to navigation, which the Environment Agency would strongly encourage, but at present this remains a voluntary act. In the absence of any regulatory powers, the maximum abstraction remains a potential risk and could reduce the modelled Estuary inflows

to almost zero. **For this reason, the in-combination investigation cannot confidently conclude no likely significant effect on the Natura 2000 site and designated species.**

Chronic Condition

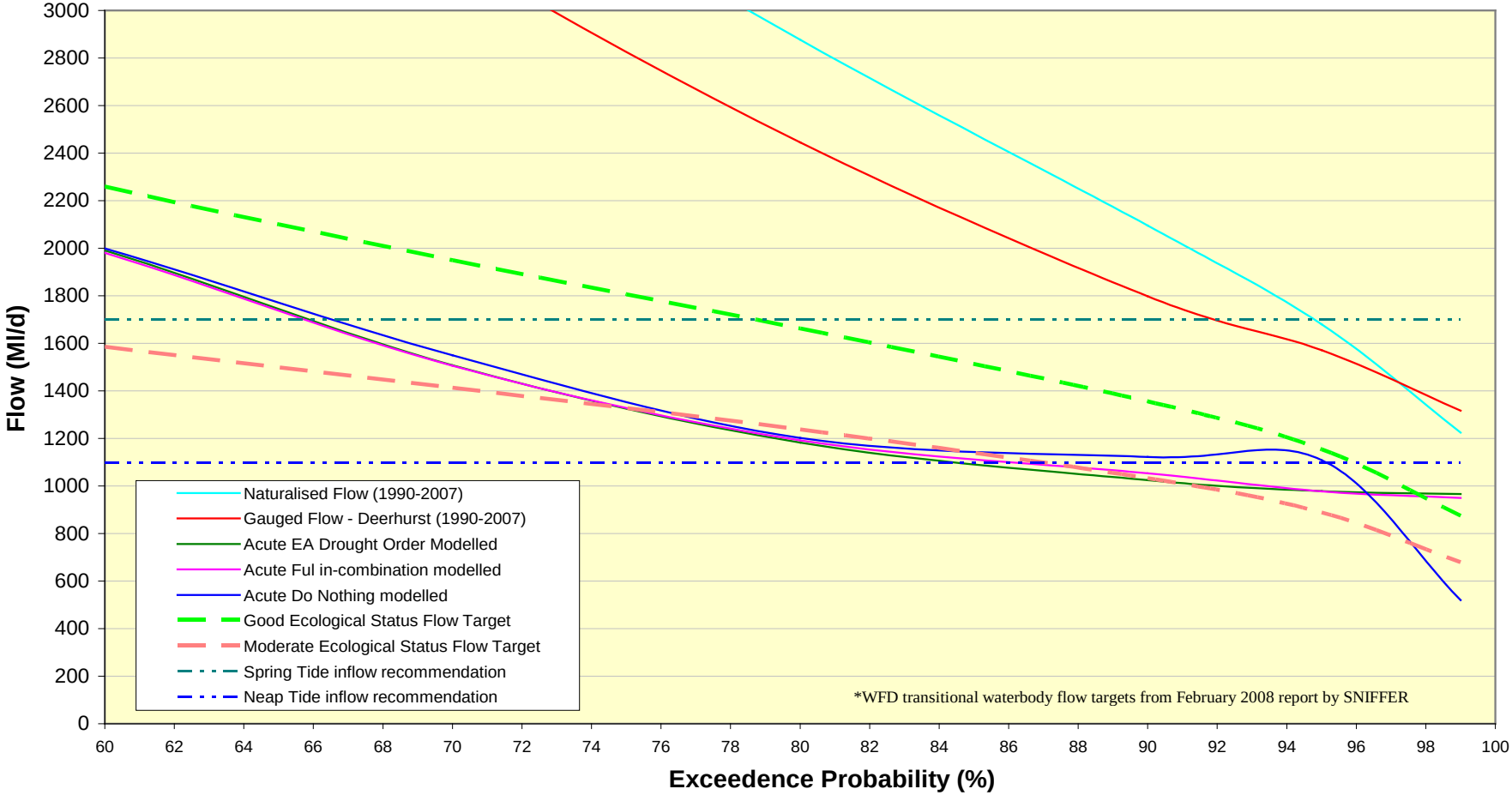
The modelled Chronic drought condition's represent what could happen if an acute drought year were followed by a further dry winter and second severe drought summer. Where appropriate (e.g. excluding the '' Do Nothing'' scenarios) the RSDO is operated during both summers. The duration of the initial acute drought summer has been reduced to exclude obvious flow benefits from the first year to test the long term value and regulation implications of the RSDO.

Assessment Point 6 Deerhurst

Modelling errors were identified with the Chronic condition, differing between the RSDO and Full In-combination modelling, where the RSDO activates on and off falsely before the operation curves indicate a need. Due to this greater uncertainty the Chronic results will be assessed more generally for guidance and flow behaviour trends, rather than specific details and duration of impact, as the uncertainty is too high to use with confidence.

CHRONIC SCENARIO:

Deerhurst FDC (Q80 onwards) against WFD Good and Moderate Ecological Status Flow Targets*



' Do Nothing'

At Deerhurst a drought of this magnitude, compared with the gauged record (Haw Bridge/Deerhurst1990-2007), could be reducing the expected Q95 low flows by up to 463 Ml (30% reduction) and the minimum flows by 797 Ml (61% reduction). The greater magnitude compared to the Acute modelling reflects the greater length of time for which the Chronic drought (condition) is predicted to last.

As with the Acute condition, it's important to note the gauged record used for comparison only includes the 1995/96 drought event, and all modelled flow reductions should only be used as a guide.

The existing WFD EFI's suggest the Chronic '' Do Nothing'' scenario drought event could cause deterioration from GES for approximately 60% of the 2 year period being considered, reflecting the long term lack of runoff being simulated and two consecutive drought events exasperating the natural underlying event. There is some marginal deterioration below MES between Q76-84, but the more reliable deterioration would be for a minimal 3% (Q97) of the 2 year period, when flows crash as the regulation sources are exhausted.

Assessing flows against the Spring and Neap Tide target shows more potential failures than under the Acute condition, representative of a more prolonged/reoccurring drought. Comparing the flows against the gauged (Haw bridge/Deerhurst1990-2007) record suggests the Spring Tide inflow target could be at risk of failure for an additional 25% over the 2 year period (33% in total, from Q67). Risk of failing the Neap Tide inflow target could increase to 5% (Q95) of the 2 year period. It is important to note the risk is increased, but would only impact the environment if the low flows occurred in conjunction with the relevant tidal conditions. The impacts on the ground would be very similar to those discussed for the Acute condition, largely impacting the lower tidal River Severn.

RSDO

Due to the false activations of the RSDO during modelling the slight drift away from ' Do Nothing' prior to around Q80 should be discounted. The FDC general trend after Q80 is likely to be similar to what could be expected, reflecting the lead in time when the RSDO is lowering prescribed flows by approximately 140 Ml/d. This is followed by clear flow benefits when the water saved from the previous years RSDO usage can be returned to the system to prevent/greatly reduce the flow crash observed if the RSDO were not activated in the first year.

No additional WFD deterioration is caused, some minor increases in duration are evident but not significant in context of modelling uncertainty. Most significantly, the FDC suggests that during the most critical low flow periods (second summer) of the Chronic condition, the RSDO would be protecting and returning flows above GES, and therefore complying with WFD at the height of drought. This cannot be concluded with great confidence, but the flow trend suggests the benefits to downstream flow and the Estuary, measured at Deerhurst, could be very beneficial to the Severn Estuary opposed to taking no action and allowing the drought to run its course.

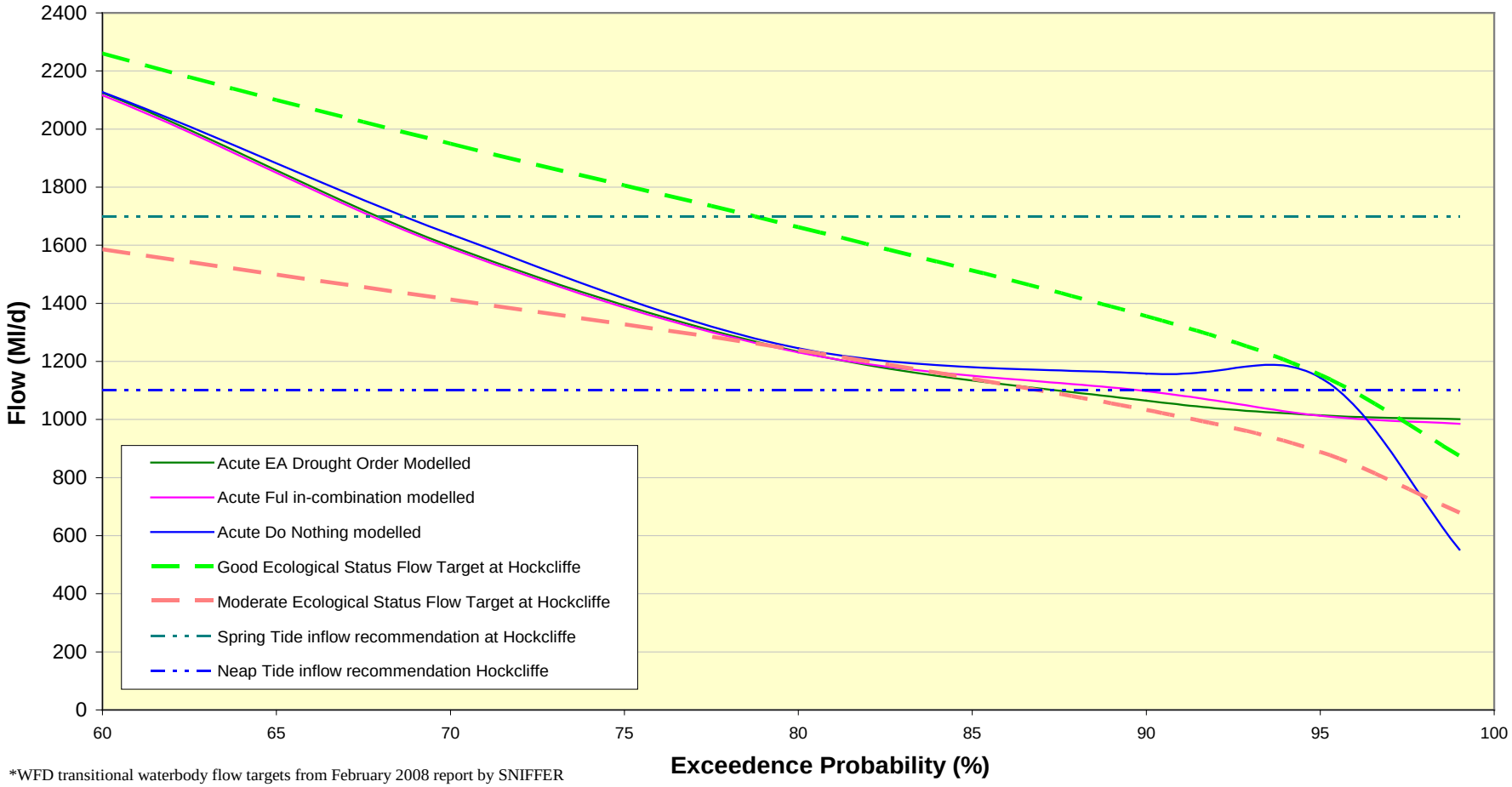
Operating the RSDO and lowering the prescribed flows does increase the risk of failing the Neap Tide inflow target by an additional 10% (Q85) compared to the ' Do Nothing' condition. This could increase risk up to 15% over the 2 year period, but again the actual impacts would vary according to whether the Neap tides occurred at the same time as the low flow events.

Full In-combination

The full in-combination FDC is very similar to the RSDO. No additional WFD deterioration is caused (slight alterations in magnitude) while very similar benefits are observed. Risk of Neap Tide inflow failure is increased by a further 1%.

Assessment Point 7 U/S Sharpness and Assessment Point 8 Lower Parting

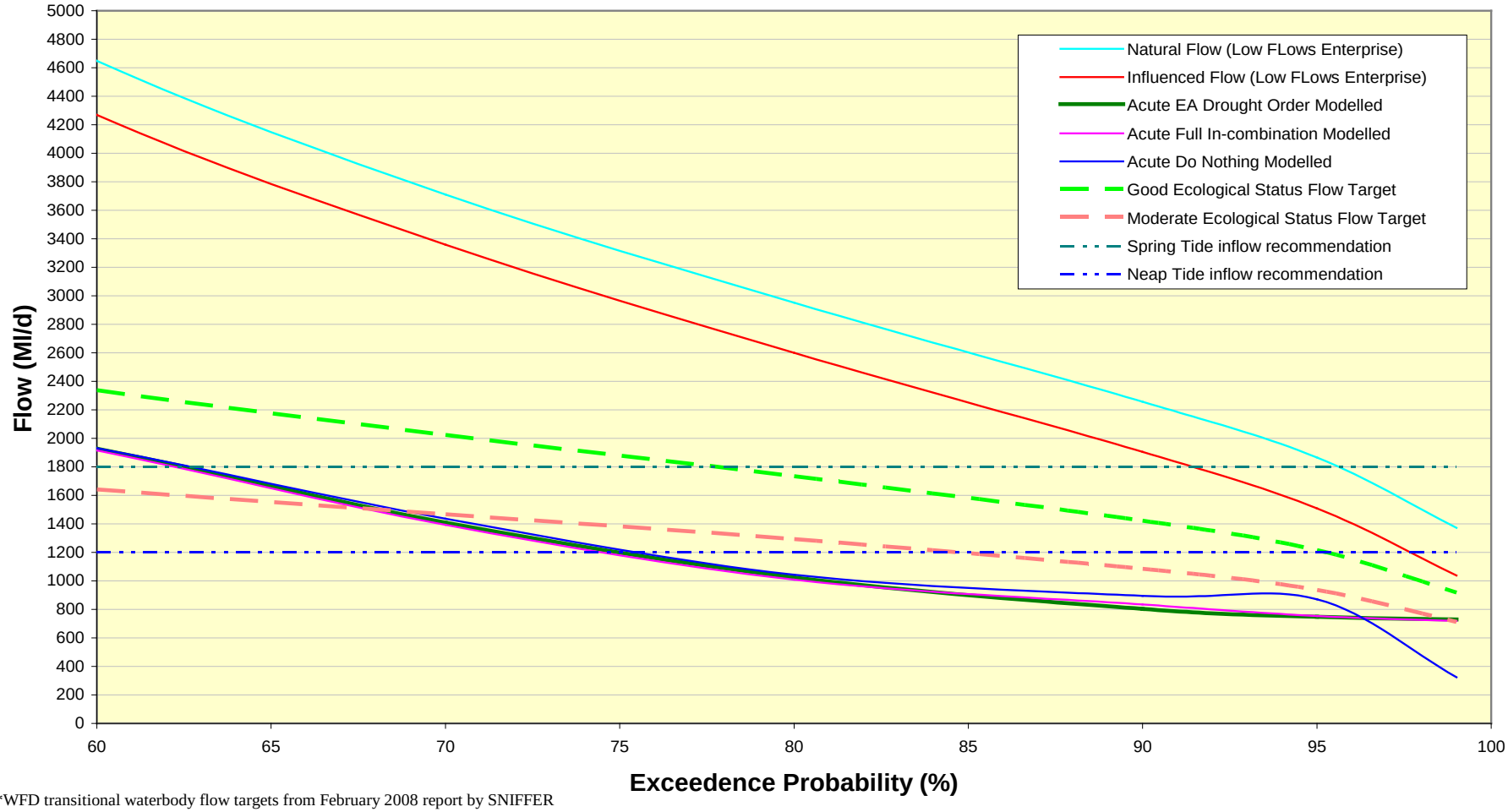
CHRONIC SCENARIO:
U/S Sharpness FDC against Elmore's WFD Good and Moderate Ecological Status Flow Targets*



*WFD transitional waterbody flow targets from February 2008 report by SNIFFER

CHRONIC SCENARIO:

Lower Parting FDC against Elmore's WFD Good and Moderate Ecological Status Flow Targets*



*WFD transitional waterbody flow targets from February 2008 report by SNIFFER

As previously discussed (current environment section and Acute Condition), U/S Sharpness is located upstream of the Gloucester & Sharpness Canal abstraction and Lower Parting is located downstream, therefore representing more realistic Severn Estuary inflows. Natural and influenced data plotted is modelled from Low Flows Enterprise, as no continuous flow gauges exist this far into the tidal influences of the Severn Estuary.

' Do Nothing'

Once again, comparing the U/S Sharpness FDC against the Lower Parting clearly demonstrates the impact the Gloucester & Sharpness Canal abstraction can have during low flows/drought conditions.

The WFD EFI's suggest the Chronic scenario drought event could cause deterioration from GES for approximately 62% of the 2 year period being considered, with 31% accounting for deterioration below MES. Compared to Deerhurst, the MES deterioration at Lower Parting is more conclusive, although due to modelling errors the duration is likely to be an over estimate.

Using the Low Flows Enterprise influenced data as a comparison, the Spring Tide inflow target could be at risk of failure for an additional 29% over the 2 year period (37% in total, from Q67). Risk of failing the Neap Tide inflow target could increase to 25% (Q95) over the 2 year period.

RSDO

Due to the modelling errors the slight drift away from ' Do Nothing' prior to around Q80 should be discounted.

Compared to the benchmark '' Do Nothing'' scenario, no additional WFD deterioration is caused but some minor increases in duration are evident, but not significant in context of modelling uncertainty. Flows at Deerhurst suggested the lowest flows could achieve GES for the Severn Estuary by operating the RSDO. However Lower Parting illustrates how the large abstraction for the Gloucester & Sharpness Canal could significantly reduce the benefit of operating the RSDO to the Severn Estuary, as flows hardly achieve MES at this location.

Operating the RSDO creates no additional risk of Spring or Neap tide inflow targets.

Compared to the '' Do Nothing'' scenario, there are still obvious flow benefits experienced during the most critical periods of the drought. The regulation failure identified in the '' Do Nothing'' scenario is almost avoided, and without modelling errors is likely to have been prevented by operating the RSDO.

Full In-combination

Assuming a maximum canal abstraction of 300 Ml/d, the full in-combination FDC is very similar to the RSDO. No additional WFD deterioration, Spring or Neap tidal inflow target failure is caused (slight alterations in magnitude). The flow benefits show the same trend as the RSDO scenario, with a slightly lower magnitude of benefit owing to the higher water company abstractions.

As discussed under the acute condition, the potential for the Trust to abstract a maximum of 691 Ml/d needs to be taken into account under the in-combination assessment. If this quantity were to be abstracted during a severe drought, then inflows to the Severn Estuary would be reduced significantly more.

Severn Estuary Conclusions: Chronic Condition

The Chronic condition represents a theoretical dry winter (1975) followed by a drought summer (1976) where the RSDO triggers are crossed. In scenarios where the RSDO is operated, no flow benefit is gained in the first year due to the arrival of autumn recharge. Winter rainfall remains below average, resulting in a subsequent severe drought summer (1977) where the RSDO is triggered again.

Modelling errors were identified with the Chronic condition, differing between the RSDO and Full In-combination modelling, where the RSDO activates falsely, well before the operation curves indicate a need. Due to this greater uncertainty the Chronic results were assessed more generally for guidance and flow behaviour trends, rather than specific details and duration of impact as the uncertainty is too high to use results with confidence.

The specific impacts likely on the ground for the Severn Estuary Natura 2000 site, and lower tidal Severn if a Chronic drought occurred, are likely to be very similar to those discussed for the Acute condition. The same areas would be at high risk from the same issue's, such as saline intrusion, sediment deposition, lowered water levels reducing passage over weirs and reduced habitat at watercourse margins. However the environment would have been stressed to differing degree's over two subsequent summer drought events, and several dry winters. The accumulated stress on the environment and limited water resources is therefore likely to be greater, although the activation of the RSDO in the first year has been shown to safe guard water for a subsequent drought year sufficiently enough to make significant flow benefits compared to the '' Do Nothing'' option.

As previously highlighted, the greatest modelling uncertainty remains around the Gloucester & Sharpness Canal abstraction and its in-combination impacts on the lower tidal River Severn during a severe drought. There is the potential for greater or lesser abstraction than modelled, and close liaison would be required during a real event to manage all the conflicting interests to balance the water user and environment needs appropriately.

' Do Nothing'

The ' Do Nothing' scenario represents the possible flows if no RSDO or water company drought permits were operated to manage the developing drought. All normal abstractions and discharges continue (Gloucester & Sharpness Canal 300 Ml/d abstraction included), and the Severn Regulation system is operated to continue maintaining 850 Ml/d at Bewdley. As with the Acute condition, initial flow conditions appear better under the '' Do Nothing'' scenario, however if the drought continued and resources ran out, flow crashes and subsequent minimum flows would be severe.

The main difference with the Chronic two summer drought scenario, is the resilience for the second/following years drought is greatly reduced by not operating the RSDO. Resources are allowed to expire during the first drought, significantly reducing the refill capacity of Clywedog and therefore entering the subsequent drought with insufficient resources to cope.

Comparing the modelled drought flows at Deerhurst to the gauged record (1990-2007) suggests Q95 flows could fall by up to 463Ml, a 30% reduction. If the drought continued long enough to exhaust regulation resources, comparisons indicate minimum flows could fall by up to 797Ml, a 61% reduction. When compared against the Acute condition, the reductions are smaller, which reflects the longer term nature of the Chronic condition and how the duration spreads the impacts over the FDC. Even so, the potential magnitude of flow reduction in the lower reaches of the River Severn is significant and likely to have temporary adverse impacts.

' Do Nothing' Results indicate the natural drought event could cause temporary failure of Good Ecological Status (GES) and Moderate Ecological Status (MES) flow (WFD transitional waterbody) targets. Deerhurst could experience deterioration from good ecological status (GES) for up to 60%

(Q40) of the 2 year period, some marginal deterioration below MES between Q76-84 but the more reliable deterioration would be for a minimal 3% (Q97) of the 2 year period. However in terms of inflows to the Estuary, Lower Parting needs to be used, reflecting the Gloucester & Sharpness Canal abstraction. Inflows to the Severn Estuary could deteriorate below GES for 62% of the 2 year period being considered, with 31% of time accounting for deterioration below MES. It is important to note that higher or lower abstraction is possible for the canal.

Assessing flows against the recommended Spring and Neap Tide flow target shows more potential failures than modelled under the Acute condition, to be expected over the more prolonged period of a Chronic drought. Comparing Deerhurst flows against the gauged (1990-2007) record suggests the Spring Tide inflow target could be at risk of failure for an additional 25% over the 2 year period (33% in total, from Q67). Using Low Flows Enterprise influenced data as a comparison for Lower Parting and the Estuary inflows, the Spring Tide inflow target could be at risk of failure for an additional 29% over the 2 year period (37% in total, from Q67). At Deerhurst, risk of failing the Neap Tide inflow target could increase to 5% (Q95) over the 2 year period, and 25% (Q95) at Lower Parting and into the Severn Estuary.

It is important to note the ‘risk’ of failure is increased, but would only translate into impacts to the environment if the low flows occurred in conjunction with the relevant tidal conditions. The impacts on the ground would be very similar to those discussed for the Acute scenario, largely impacting the lower tidal River Severn. Evidence from previous droughts and the sensitivity of the Severn Estuary would indicate that lower freshwater inflows would not have a significant effect on the Natura 2000 site itself.

RSDO

Due to the false activations of the RSDO during modelling the slight drift away from ' Do Nothing' prior to around Q80 should be discounted. The FDC general trend after Q80 is likely to be similar to what could be expected, reflecting the lead in time when the RSDO is lowering prescribed flows by approximately 140 Ml/d, followed by clear flow benefit when the water saved from the previous years RSDO usage can be returned to the system to prevent/greatly reduce the flow crash observed if the RSDO is not activated.

No additional WFD deterioration is caused, some minor increases in duration are evident but not significant in context of modelling uncertainty. Flows at Deerhurst suggested the lowest flows could achieve GES for the Severn Estuary by operating the RSDO, however due to the large abstraction for the Gloucester & Sharpness Canal, Lower Parting shows the scale of this benefit to the Severn Estuary has reduced to only just achieving MES. When compared to the option to ' Do Nothing', the benefit is still clear and with mitigation work with the Canal & River Trust this benefit could be increased to the Severn Estuary if abstraction could be significantly reduced at critical periods.

Operating the RSDO and lowering the prescribed flows does increase the risk of failing the recommended Neap Tide target at Deerhurst by an additional 10% (Q85) compared to the ' Do Nothing' scenario. However by Lower Parting there is no additional failure compared to the ' Do Nothing' scenario, suggesting the underlying drought and the in-combination abstractions have already caused the failures that would directly impact on the Severn Estuary.

Results show no additional harm (based on existing flow targets) beyond the naturally occurring drought effects would be caused by operating the RSDO. Significant flow benefits would be achieved during the second years summer drought, when water saved during the initial years RSDO operation could be used for regulation, delaying the need for a second RSDO operation and potentially preventing regulation failure from occurring. No likely significant effect is concluded.

Full In-combination

The full in-combination FDC is very similar to the RSDO, based on the Gloucester & Sharpness Canal still abstracting a maximum of 300 Ml/d. No additional WFD deterioration is caused (slight alterations in magnitude) while very similar benefits are observed. Risk of Neap Tide inflow failure at Deerhurst is increased by a minor 1%, however no change is observed at Lower Parting, which represents the Estuary inflows.

As previously discussed, the Trust are currently exempt from licensing and have the capacity to abstract up to 691 Ml/d (a maximum of 300 Ml/d was modelled). The operating agreement for the canal abstraction contains flow controls that protect the river environment during normal conditions, but does contain a disclaimer for extreme droughts. In the absence of any regulatory powers, the maximum abstraction remains a potential risk and could reduce the modelled Estuary inflows to almost zero (based on 1976 and 1989 drought reports). The in-combination investigation cannot confidently conclude no likely significant effect on the Natura 2000 site and designated species.

Overall Severn Estuary Conclusions

Flow modelling incorporates all normal abstractions and discharges, what could happen if no RSDOs or permits were operated, if the RSDO but no water company drought permits were operated, and what could happen if the RSDO and all known Drought Permits were operated in-combination. The results cannot account for temperature variations or sudden storm events, likely during a real event, but not predictable or quantifiable at this stage. It is understood that prolonged high temperatures and sudden high rainfall events would further exasperate the stresses already being encountered.

To assess the Severn Estuary inflows, Deerhurst was considered but modelled data for Lower Parting was used for the final conclusions, due to its location and consideration of the Gloucester & Sharpness Canal abstraction. Water framework Directive (WFD) ‘transitional waterbody’ flow targets (in line with RoC) and the 1992 Spring and Neap tide flow recommendations were used to assess the likely flow impacts on the Severn Estuary, from the RSDO.

Acute and Chronic '' Do Nothing'' results indicate the natural drought event could cause temporary failure of the WFD Good Ecological Status (GES) and Moderate Ecological Status (MES) flow targets. The magnitude of the flow failures is significant, but the deterioration would be short term. The '' Do Nothing'' results also indicate the natural drought event could increase the number of days Estuary inflows failed to meet the recommended Spring and Neap tide flow targets. However, the actual number of days affected would depend on whether the low flows occurred on the same days as the Spring and Neap tides.

The River Severn channel splits between U/S Sharpness and Lower Parting, monitoring data (spot gaugings between 1977-2007) indicates approximately 40% of flow goes down the East channel and 60% down the West channel, where the Canal & River Trust abstract. Low flows occurring during the drought would become divided and flow velocity would decrease further, encouraging siltation and saline intrusion around this location. The magnitude of flow reductions is likely to be significant to the lower tidal Severn in the short term, however once recharge returns the flows would be expected to recover and WFD targets would be restored and maintained. The lower tidal River Severn has been identified as potentially being at high risk during a severe drought, however this reach is outside the Natura 2000 designation area.

The impact on the Severn Estuary Natura 2000 site will be limited to localised dependence on freshwater inflows and impacts on Hydromorphology, as the freshwater channel wetted perimeters and general flow velocity would be reduced. Only features and species intolerant to salinity or dependant on freshwater inundation are likely to be impacted. In context of the sensitivity of the Severn Estuary, the high magnitude deteriorations would be short term and therefore unlikely to

have a significant impact. The degree of impact to migratory species will vary according to the time of year the deterioration occurs (more likely between September and November) and what other weather conditions occur (e.g. high temperatures).

The risks and failures modelled under the '' Do Nothing'' scenario's (acute and Chronic droughts) represent the natural drought effects, which are considered a direct result of an exceptional natural drought event and come under article 4.6 of the WFD. These results have therefore been used as the benchmark for what impacts could occur during acute or Chronic droughts, and used to assess what additional impacts the RSDO and in-combination water company drought permits could have.

The RSDO caused no additional GES or MES deteriorations compared to the '' Do Nothing'' scenario for either Acute or Chronic modelling. The overall magnitude and duration of deterioration altered slightly, reflecting the lowered prescribed flow at Bewdley for a greater length of time whilst protecting higher minimum flows under both Acute and Chronic droughts. The results also showed operating the RSDO creates no additional Spring or Neap tide inflow target failures at Lower Parting, compared to the '' Do Nothing'' scenario.

If regulation failure were to occur (sources became too low to support any prescribed flow at Bewdley), the results show the RSDO would maintain higher minimum flows during the critical drought period than possible under the '' Do Nothing'' scenario. This illustrates how lowering the prescribed flow can prolong the remaining storage in Clywedog, leaving some water for regulation during the most critical period of the drought event. This would benefit both abstractors and the environment.

Modelling the Chronic condition showed if two consecutive RSDO years occur, utilising the RSDO in the first year would significantly improve the ability to protect the River Severn flow and Severn Estuary inflows in the subsequent year. The water saved by operating the RSDO during the first drought summer, would be available for regulation in the second year. This would delay the need for a RSDO in the second year as Clywedog storage would be higher, and greatly reduce the risk of regulation failure compared to the '' Do Nothing'' option.

These results support the need for operating the RSDO, and allay modelling concerns that no flow benefits would be gained unless Regulation failure was reached.

It is also important to highlight the potential risk of not operating the RSDO during severe events when water company drought permits are active. If this were to occur, and the drought extended into regulation failure, then flows would crash to minimums lower than the '' Do Nothing'' scenario. This would potentially cancel out benefits of not operating the RSDO, by increasing the magnitude of flow reductions and threatening supplies and flows for the following year/s.

Modelling in-combination with the water company drought permits identified no additional WFD deterioration, or additional tidal inflow target failures, assuming a maximum 300 Ml/d abstraction for the Gloucester & Sharpness Canal. The magnitude of flow reductions does increase compared to the RSDO in isolation, so the magnitude of short term impact would be greater, although the length of time this might be experienced for remains the same.

The difficulty with in-combination assessment is under current legislation the Canal & River Trust are exempt from licensing, but have the capacity to abstract up to 691 Ml/d (a maximum of 300 Ml/d was modelled). The operating agreement for the canal abstraction contains flow controls that protect the river environment during normal conditions, but does contain a disclaimer for extreme droughts. The Trust identify a trigger flow at Deerhurst for closing the canal to navigation, which the Environment Agency would strongly encourage, but at present this remains a voluntary act. In the absence of any regulatory powers, the maximum abstraction remains a potential risk. If the full quantity were abstracted, the modelled (Aquator) Estuary inflows could be reduced significantly more.

Historic drought flows and naturalised flow sequences down to Deerhurst gauging station indicate RSDO has not created a significant extra burden on the main River Severn, compared to what would have naturally occurred in the past. During the worst periods of drought the Regulation system was maintaining higher flows than could naturally have occurred, even with the RSDO

operational. However flow data is not available further downstream of Deerhurst, so the true impacts of the Gloucester & Sharpness Canal cannot be quantified from flow data. Several drought reports state flows around the channel split and inflows to the Estuary were reduced to almost zero by the canal abstraction for short periods in 1976 and 1989.

Modelled Acute and Chronic scenarios have concluded no additional WFD or tidal flow target failures are caused by activating the RSDO, when compared to the '' Do Nothing'' scenario. All flow and level reductions would be temporary and short term, with flow benefits to the environment by operating the RSDO. Therefore, no likely significant effect is concluded for the RSDO in isolation.

Initial in-combination modelling for both acute and Chronic scenario's concluded no additional WFD or tidal inflow target failures occurred, although the amount of flow reduction (i.e. greater short term impact) was increased. Modelling originally assumed a maximum Gloucester & Sharpness Canal abstraction of 300 Ml/d; however the Trust confirmed 691 Ml/d could be taken. Due to evidence in previous drought reports, and the Environment Agency having no legal powers to control the abstraction, the report must conclude that likely significant effects could be caused to the Severn Estuary from in-combination activities. Large abstractions from the channel split during such critical drought flows could have locally significant impacts on the lower tidal Severn, which could subsequently impact downstream on inflows and navigation pathways for migratory species of the Natura 2000 site.

Appendix 3:

Water Quality Modelling and Assessment

Appendix 3: Water Quality Modelling and Assessment

As the only current water quality modelling tool available that includes the River Severn corridor from source to estuary, including the ability to model the inputs from all tributaries and the flow control measures at Vyrnwy and Clywedog reservoirs, the newly constructed River Severn River Basin District SIMCAT model represented the best option for assessing the RSDO options.

SIMCAT is a proven modelling tool for water quality planning and has been used by the Environment Agency for over two decades. It has been developed as a software package that can represent point and diffuse source inputs as well as in-river decay. SIMCAT is and can be used for the calculation of water quality statistics (usually mean and 90th percentiles) and for the determination of discharge consent conditions.

The model, rebuilt in 2009 using the most up to date data available, was deemed fit for purpose in terms of both quality and quantity calibration at the time of it's completion. SIMCAT models are constructed using mean and standard deviation quality data and mean and 95% low flow data for flow.

The model operates on the relatively simple principles of mass balance calculations in which upstream loads and discharge loads are mixed to provide a downstream estimate of load, it is possible that it does not necessarily represent the best way of assessing extreme low flows as experienced during drought conditions. It is, however, the best suited water quality modelling tool available for a whole catchment assessment and, as such, the best available tool for the RSDO water quality assessment.

In terms of flow data, the model has been built on data provided from 57 flow gauges throughout the catchment and daily mean flow data provided by Severn Trent Water where available for the discharges included in the model. Where actual data was not available, the permitted discharge volumes were used.

Major abstractions are also included in the SIMCAT model where it was felt they had a significant impact upon the flows in the environment (29 sites in total). Where applicable, the appropriate hands-off flows can be incorporated in order to limit how much water can be taken from the environment at times of very low flow. The model, however, does not incorporate drought permit requirements at any features.

The quality data used to build the final SIMCAT model came from a variety of sources including a total of 499 river quality sites, 334 sewage treatment works and 50 industrial discharge sites.

A series of correlation exercises were completed to determine the degree of relationship between certain model parameters. These included investigating the relationship between river flow and river quality, effluent flow and quality and effluent flow and river flow. How each parameter relates to each other was then incorporated into the final model.

In terms of flow calibration, all sites satisfied the primary goal of predicting mean and 95%ile river flows within one standard deviation of the measured data provided during the model build. Calibration against the secondary, and more stringent, test of remaining within 10% of the observed data was less successful, however, only seven of the 57 flow gauge locations failed to achieve this criteria. Many of these sites were in areas of low flow meaning that any small error is often exaggerated in term of percentage error but that the actual difference between calculated and observed values are often quite small.

Locations of poorer calibration of most interest with regards to the output of this assessment are as follows:

1. River Severn, Buildwas -13.2% difference in 95%ile (predicted = 779.3Ml/d, Observed = 897.3Ml/d)
2. River Severn, Bewdley - 16.4% difference in Mean (predicted = 6054.5Ml/d, Observed = 5202.0Ml/d)

3. River Severn, Saxons Lode -16.2% difference in 95%ile (predicted = 1324.1Ml/d, Observed = 1580.0Ml/d)

Table 1 – Percentage of water quality points calibrated to within one standard deviation

Parameter	Statistic	No. of Water Quality Points	% of Water Quality Points within Criteria
BOD	Mean	483	92
BOD	95%ile	483	60
Ammonia	Mean	486	72
Ammonia	95%ile	486	43
Dissolved Oxygen	Mean	486	95
Dissolved Oxygen	95%ile	486	80
Phosphate	Mean	485	78
Phosphate	95%ile	485	41
Nitrogen	Mean	486	81
Nitrogen	95%ile	486	81

These figures represent the results from manual calibration and, in terms of theoretical water quality modelling, can be regarded as having a achieved a 'good match'. The performance of the model was further improved, however, through the use of auto-calibration where the model automatically adds or removes load from the model in order to improve the match between predicted and observed data.

In terms of the use of the model for the assessment of the RSDO, however, the manually calibrated model was used to assess the relative performances of the different scenarios to be tested. Although this may appear strange given the improved nature of the model following auto-calibration, there were two key reasons for this decision:

1. When running what-if scenarios in an auto-calibrated model, it is very difficult to eliminate the effects of the 'adjusted' loads from all locations in the model. It is often unknown why this should occur and so, as a safeguard, it was decided to use the manually calibrated model in this assessment.
2. As the assessment of the RSDO options was a straight forward comparison of river quality as opposed to an assessment of compliance or an exercise to set permit limits, it was felt that perfect calibration was not required, especially given the potential errors that could occur as detailed in 1 above.

The original modelling brief involved a two stage process:

Stage 1: Representation of drought conditions in the model under an Acute and Chronic scenario

Stage 2: Modelling the impact of invoking the Environment Agency's RSDO for both stage 1 scenarios

Stage 1 – Representation of drought conditions in SIMCAT

From a starting point of the original model representation of mean and Q95 low flows, the original aim was to reduce flows to match those modelled in Aquator, simulating two theoretical drought events of greater magnitude than the 1976 drought.

This was to be achieved through a catchment-wide reduction in flows in line with prescribed ratios derived from the Aquator flow modelling scenarios. A full table of the adjustment factors can be found in Table 2 below:

Table 2. Drought condition adjustment factors

Headwater reference location			Flow headwater adjustments			
			Acute		Chronic	
			mean	95%	mean	95%
2001	Bewdley	R.Severn_13	8.39	8.43	1.64	1.68
2003	Vyrnwy Weir	R.Vyrnwy	see below			
2032	Saxon's Lode	R.Severn	8.39	8.43	1.64	1.68
2057	Haw Bridge	R.Severn	8.07	6.36	1.46	1.97
2109	Bryntail	R.Clywedog	see below			
2134	Buildwas H	R Severn	18.13	6.77	3.12	2.36
2134	Buildwas S	R. Severn	6.48	5.23	1.77	1.79
2606	Deerhurst	R.Severn	8.07	6.36	1.46	1.97
n/a	Hook Cliffe	R. Severn	8.07	6.36	1.46	1.97

Having assigned all headwater flows included in the SIMCAT model to the relevant flow gauge included in Table 2, the appropriate flow was reduced by the corresponding factor in the same table, depending upon the severity of drought condition being modelled (Acute or Chronic).

The same process was applied to diffuse flows entering the model and also tributary flows included in the model but not specifically modelled for water quality.

In order to further represent the drought conditions, all discharge inputs to the model were reduced to represent just their dry weather flow as opposed to the inclusion of storm water runoff. This was further enhanced by the reduction of the standard deviation of this data to zero in order to represent a prolonged dry period.

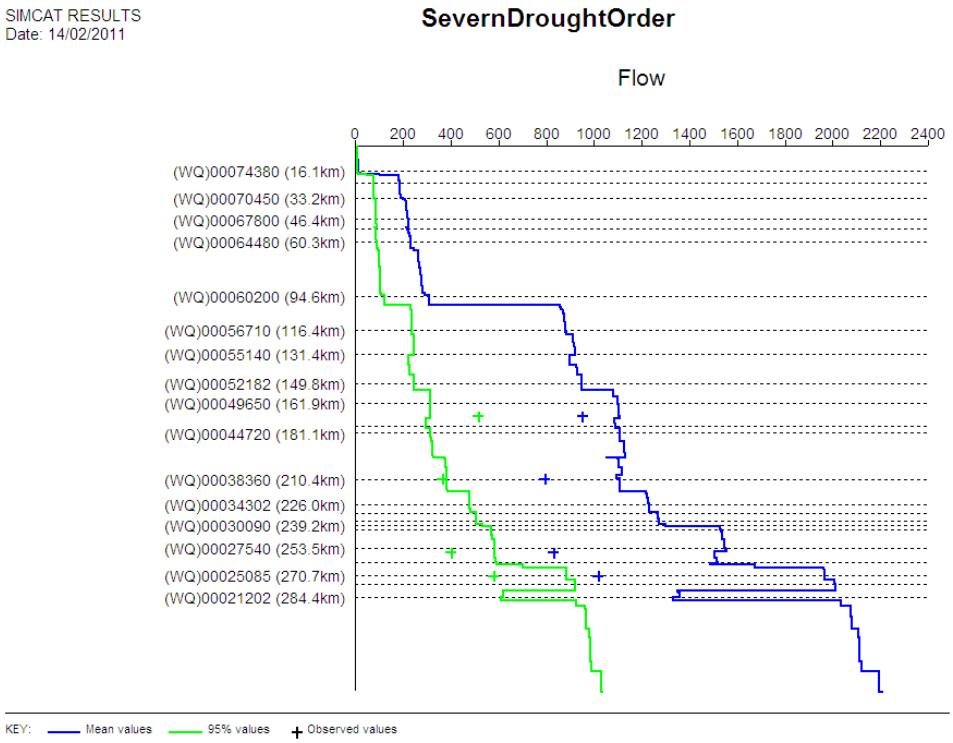
The intention of these initial reductions was to match the prescribed flows detailed in Table 3 below:

Table 3. Prescribed Flow Gauge flows based on Modelled drought scenarios

River Flows	Acute				Chronic (2nd summer)			
	With DO		' Do Nothing' scenario		With DO		' Do Nothing' scenario	
	mean	95%	mean	95%	mean	95%	mean	95%
Clywedog Reservoir	142.03	75.88	222.83	8.87	253.32	18.20	108.07	12.39
Vyrnwy Reservoir	145.03	45.00	145.03	45.00	82.55	25.00	58.16	25.00
Buildwas C Flow	869.87	605.93	950.07	512.69	1020.02	911.19	1610.17	638.01
Bewdley C Flow	727.42	456.77	791.23	363.30	834.82	711.14	1441.64	443.60
Saxon Loade CF	774.46	513.60	828.93	400.10	956.04	765.21	1719.37	581.90
Haw Bridge C Flow	962.64	692.35	1014.77	577.05	1173.54	915.96	2057.80	794.55
Lower Part CF	746.99	499.15	789.42	371.34	997.70	693.29	1870.58	532.95

Figure 1 below represents the results of this initial adjustment under acute, non RSDO conditions with the coloured crosses representing the target flows listed in Table 2.

Figure 1. SIMCAT output following initial flow adjustments



It is clear from the SIMCAT output in Figure 1 that the initial adjustments made failed to achieve the required flow reduction throughout the model. Although flow representation in the upper Severn corridor matched prescribed flows accurately enough, an ever increasing margin of error was evident with distance downstream.

Consultation with the originators of the forecasted flows suggested that the model may be wrongly estimating the many abstractions that occur between Buildwas and Bewdley and that these should be checked to ensure the abstracted volumes were correct.

Completion of this exercise showed that the model represented the full licensed volumes and, therefore, the worst possible impact in terms of flow reduction. Removal of the hands-off flows associated with these abstractions was trialled although this further complicated the results with a practical ‘bottoming-out’ of the Q95 flow and a persistent over-estimation of the mean flow. Specific drought permit parameters cannot be integrated into the SIMCAT model and as such, will not be a factor in the calibration of the drought condition model.

Further investigation into the input flow data showed up obvious areas of error that could be approached to try to improve the match between predicted and observed data. These are included in Table 4 below:

Table 4. SIMCAT/AQUATOR Prediction errors

Tributary Name	SIMCAT Predicted Flow (Ml/d)	AQUATOR Predicted Flow (Ml/d)
Afon Vyrnwy	547.0Ml/d	145.0Ml/d
River Stour	111.5Ml/d	85.1Ml/d
River Teme	233.3Ml/d	6.11Ml/d
River Avon	439.8Ml/d	239.9Ml/d

Further investigation into the four key tributaries showed no immediate errors so an exercise to further reduce the headwater and diffuse flows was undertaken to try to create a better match between predicted and observed data.

Problems were immediately encountered on the River Stour where it became apparent that population growth in the catchment since the mid 1970s had been considerable and that discharge flows under dry weather conditions alone exceeded the target flow suggested by AQUATOR.

Assuming this would be the case throughout the model, it became further apparent that trying to achieve the target flows in the River Severn corridor would entail making adjustments in flow that would not represent reality and would no longer be defendable in terms of the RSDO justification.

Consequently, it was decided to just make logical adjustments to the Severn River Basin District SIMCAT model flow parameters which could be backed up and fully justified. These can be summarised as:

1. Adjustment of headwater, diffuse and tributary flow inputs in line with the Table 2 adjustment factors
2. Reduction in licensed discharge volumes to the measured dry weather flows
3. Reduction of the discharge standard deviations to zero.

Figure 2 below illustrates the final acute, non- RSDO representation of flows whilst Figures 3 (mean flow) and 4 (Q95 flow) compares this final situation with the flow conditions represented in SIMCAT during non-drought periods.

Figure 2. final acute drought condition representation

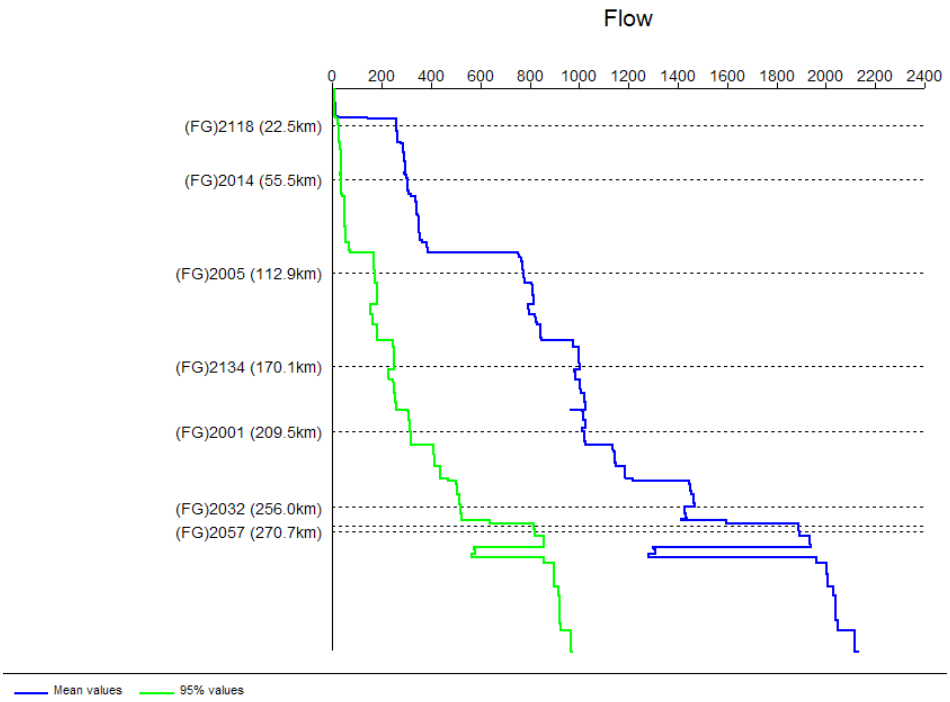


Figure 3. Acute drought / Non-drought mean flow condition comparison

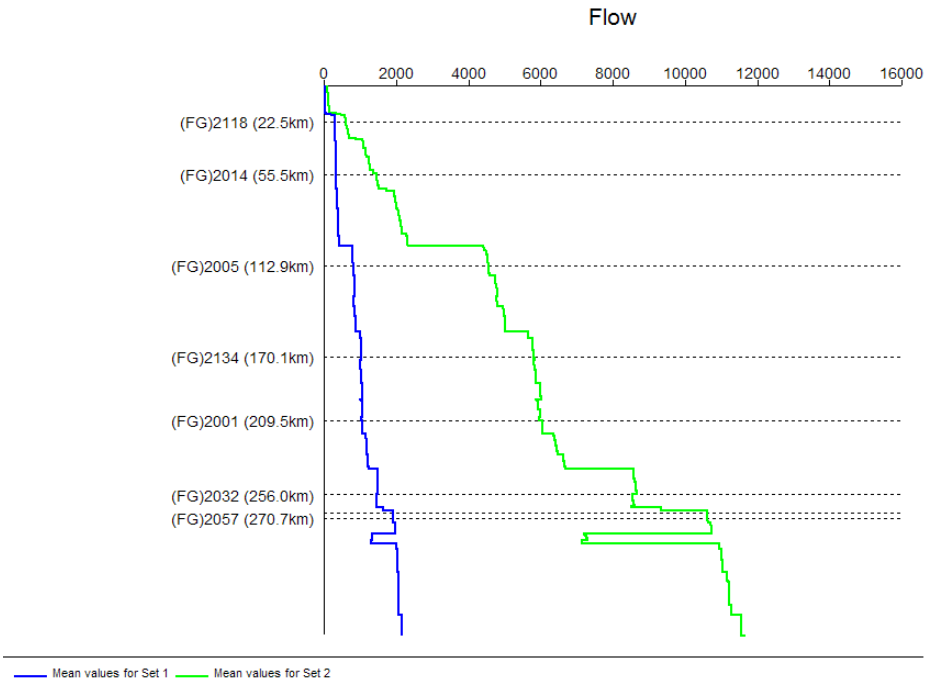
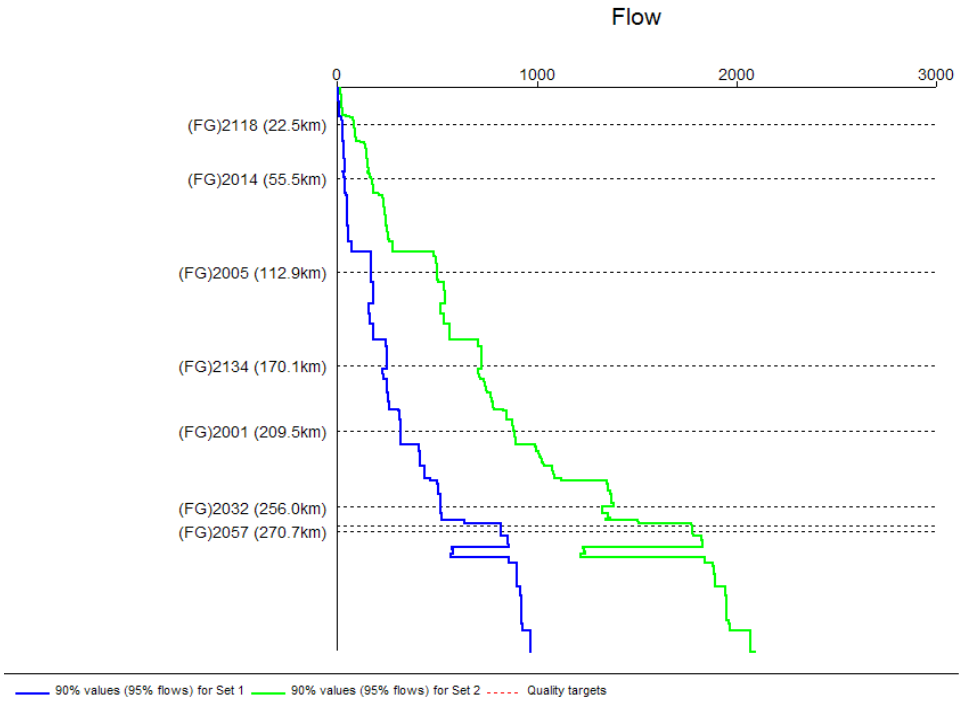


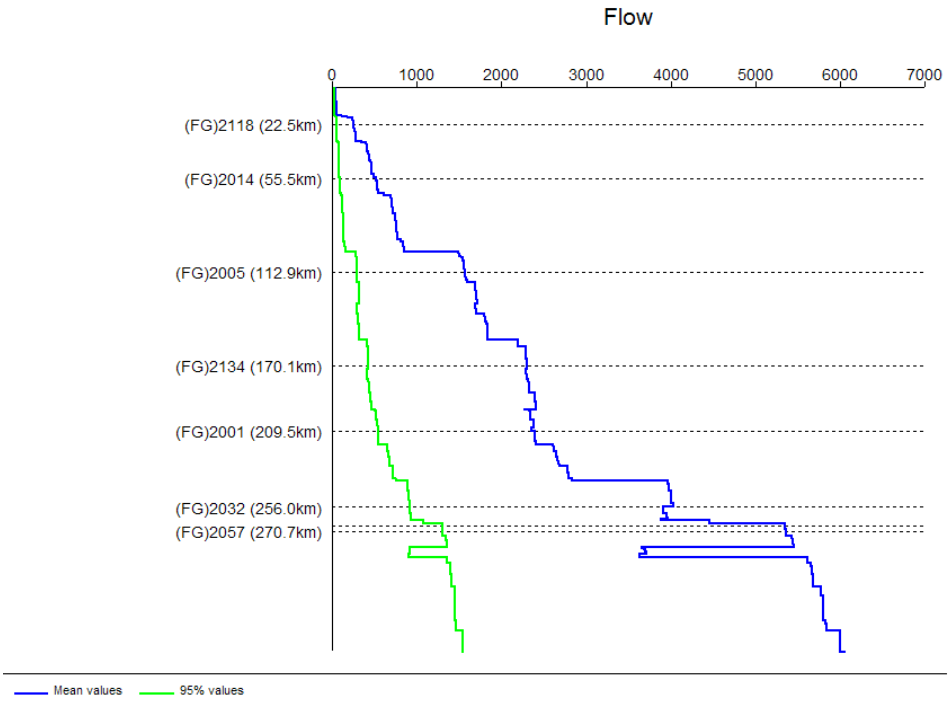
Figure 4. Acute drought / Non-drought Q95 flow condition comparison



Having established that further refinement of the model was unrealistic and undefendable, work could also progress on the Chronic drought condition representation in SIMCAT. The same process was followed to establish the non- RSDO scenario, using the Chronic mean and Q95 adjustment factors from Table 2 in place of the corresponding acute scenario figures.

Figure 5 below represents the final, adjusted SIMCAT flows for Chronic drought conditions.

Figure 5. final Chronic drought condition representation



Similar to the graphs produced for the acute drought situation, Figures 6 (mean flow) and 7(Q95 flow) compares the final acute situation with the flow conditions represented in SIMCAT during non-drought periods.

Figure 6. Chronic drought / Non-drought Mean flow condition comparison

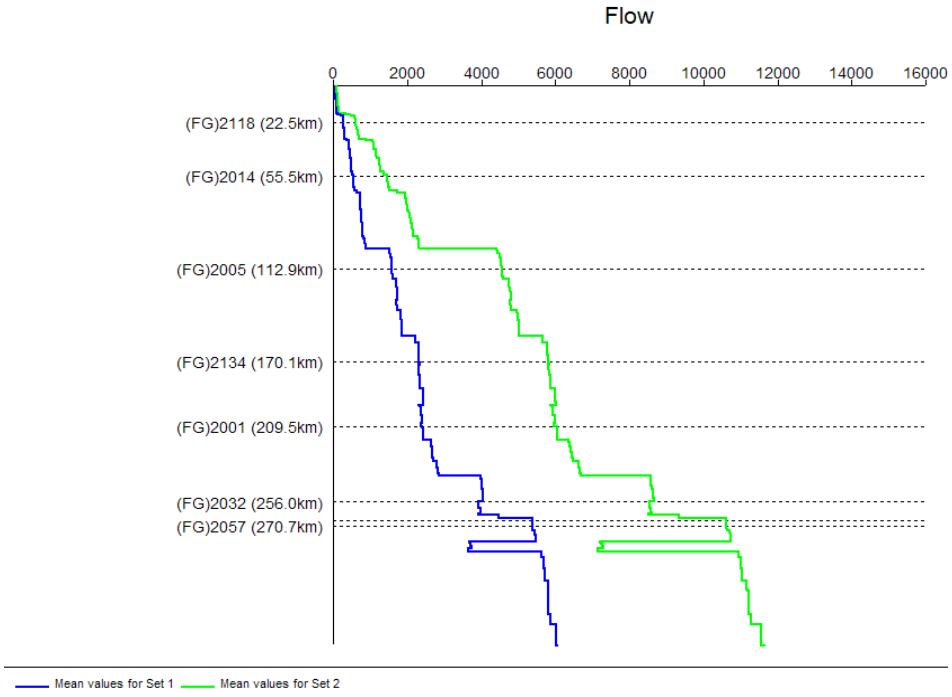
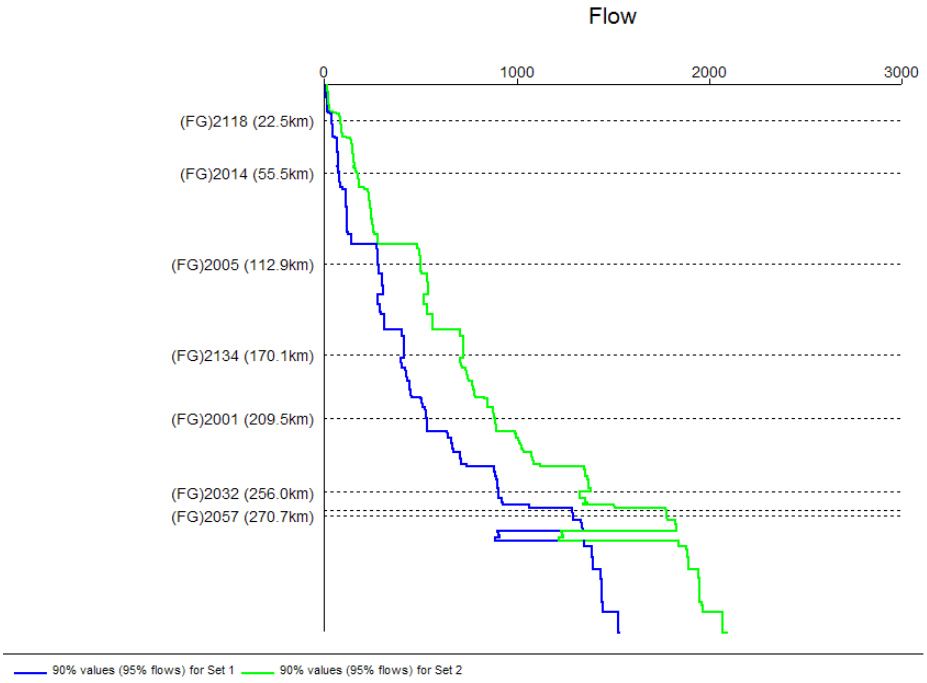


Figure 7. Chronic drought / Non-drought Q95 flow condition comparison



Despite the assumption that the adjustments made to the model to reduce flows to represent drought conditions have been accepted as the best possible attempt whilst remaining within realistic bounds, it was also decided to simulate a worst possible flow scenario in SIMCAT by reducing all natural flows to zero.

By reducing all headwater flows and all diffuse inflows to the Severn catchment to zero, the modelling exercise effectively simulated a situation where flows comprised of just treated effluent discharges and the releases from Vyrnwy and Clywedog reservoirs.

Figures 8 and 9 below illustrate how these changes are reflected in the model for both acute and Chronic flow scenarios compared with the predicted Aquator flows.

Figure 8 - Acute Drought Scenario, Zero Natural Flow

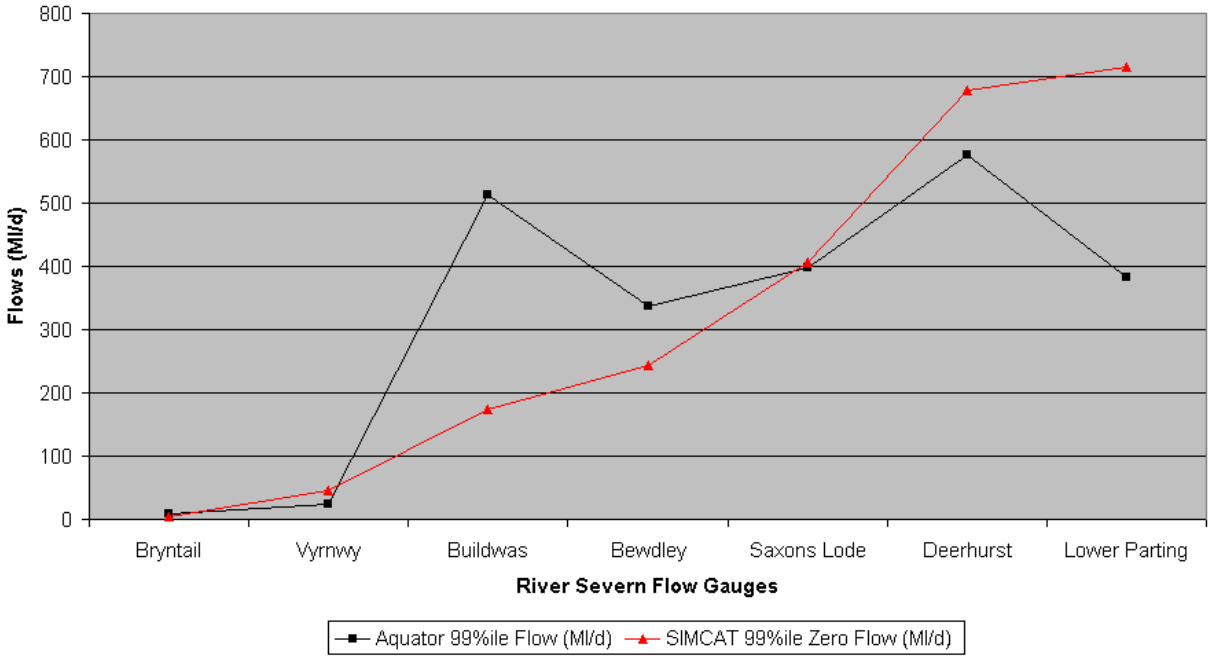
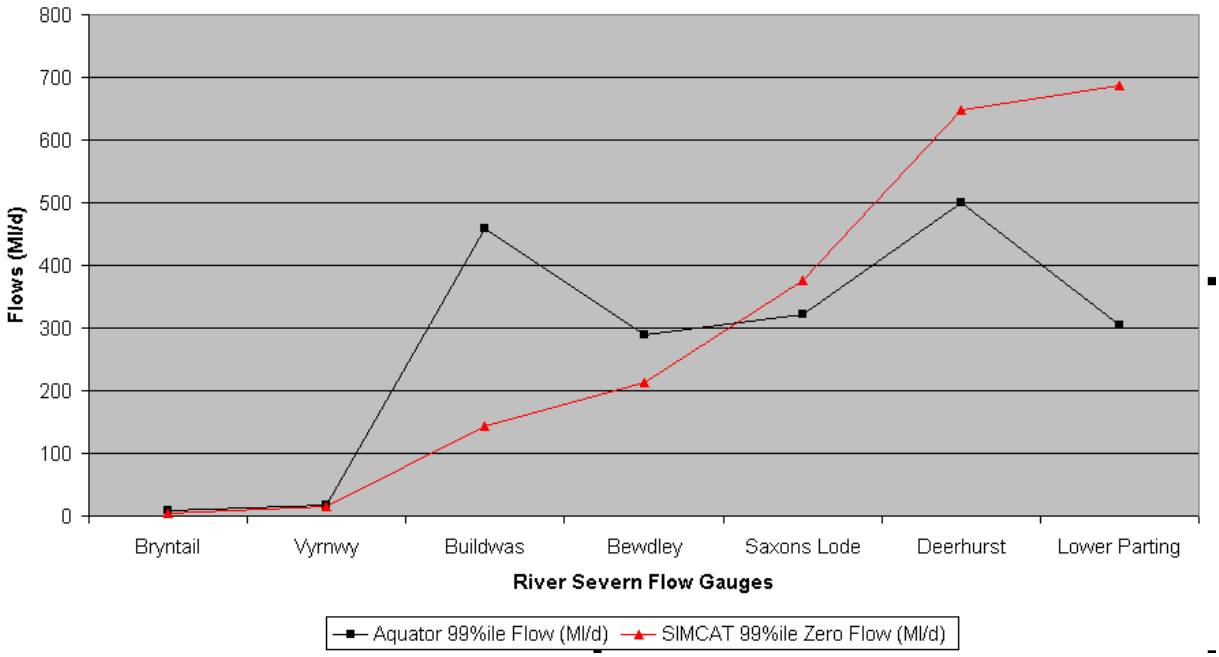


Figure 9 - Chronic Drought Scenario, Zero Natural Flow



Despite remaining in excess of the predicted Aquator flows beyond Saxons Lode in both cases, the overall difference is much reduced and flows predicted by SIMCAT at the head of the Severn Estuary are much lower compared with the previous calibration attempts.

This would appear to better represent the required flows throughout the model but it should be recognised that the adjustments made are unrealistic and should only be applied for the purpose of portraying a worst case water quality scenario.

Stage 2 – Water Quality Assessment following application of the Environment Agency's RSDO

Having previously established the SIMCAT data files to represent both Acute and Chronic drought conditions throughout the River Severn catchment, the only alterations required to the data files in order to simulate the impact of the RSDO were changes to the key control locations at Vyrnwy and Clywedog reservoirs.

Table 5 below summarises in bold the key changes required in order to represent the varying control measures in the catchment. In both reservoir cases, the required flows were represented by making factored changes to the headwater and diffuse flow inputs in order to match the Table 5 flow figures at Bryntail (for Clywedog) and Vyrnwy Reservoir flow gauges.

Table 5. RSDO Flow Gauge Measurements

River Flows	Acute				Chronic (2nd summer)			
	With DO		Without DO		With DO		Without DO	
	mean	95%	mean	95%	mean	95%	mean	95%
Clywedog Reservoir	**142.03**	**75.88**	222.83	8.87	**253.32**	**18.20**	108.07	12.39
Vyrnwy Reservoir	**145.03**	**45.00**	145.03	45.00	**82.55**	**25.00**	58.16	25.00

Representation of the revised releases and their impact on flows throughout the River Severn corridor can be seen in Figures 8 to 11 below.

With regards to the acute drought scenario in figures 10 and 11, the managed and reduced mean reservoir release from Clywedog results in a reduction in the mean flow throughout the river corridor (no RSDO in blue, RSDO in green) whilst the increase in the released Q95 flow sees an improved situation along the same length of river.

Figure 10. Acute drought comparison including RSDO operation (mean flow)

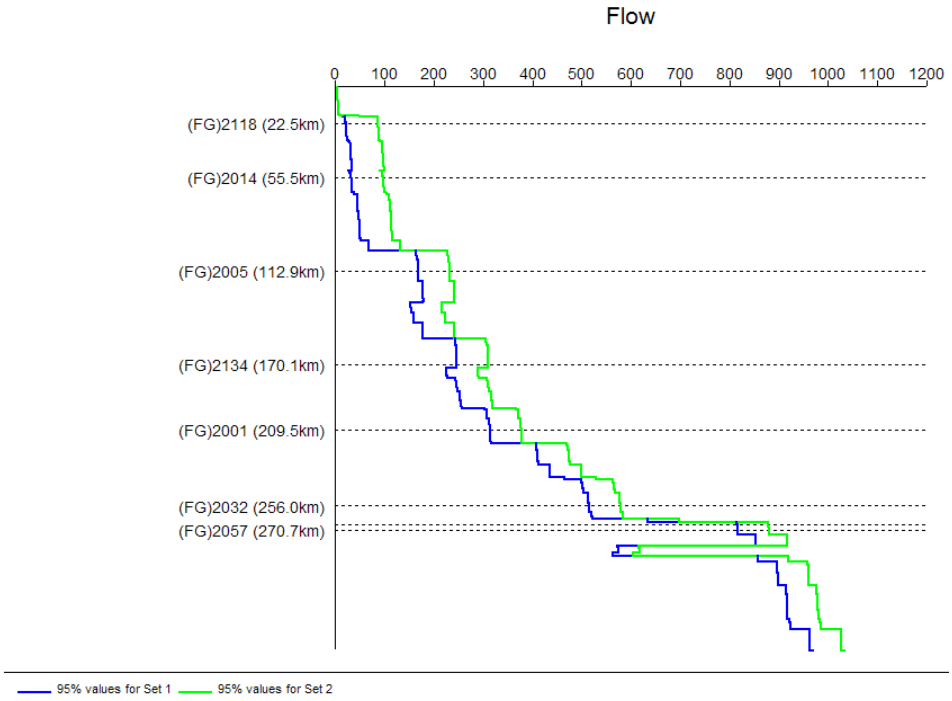
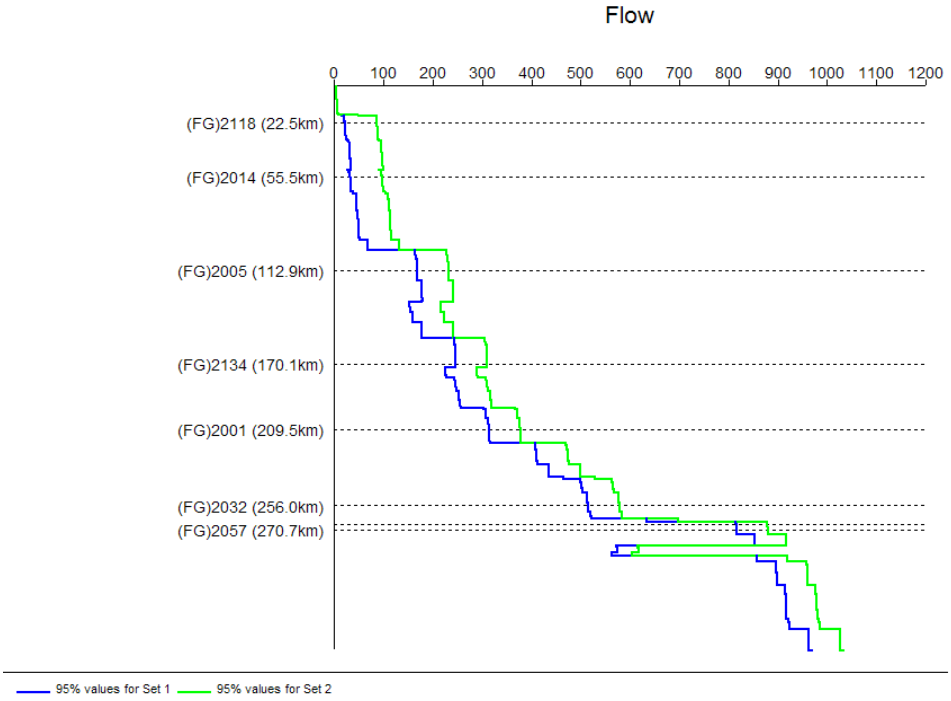


Figure 11. Acute drought comparison including RSDO operation (Q95 flow)



Applying the same logic to the changes required for the Chronic drought scenario (Figures 12 & 13 – no RSDO, blue, RSDO, green), the comparison shows barely any difference in the Q95 flows (the managed scenario effectively tracks the drought conditions) whereas the Chronic mean flows show significant benefit from the increased releases from both reservoirs.

Figure 12. Chronic drought comparison including RSDO operation (mean flow)

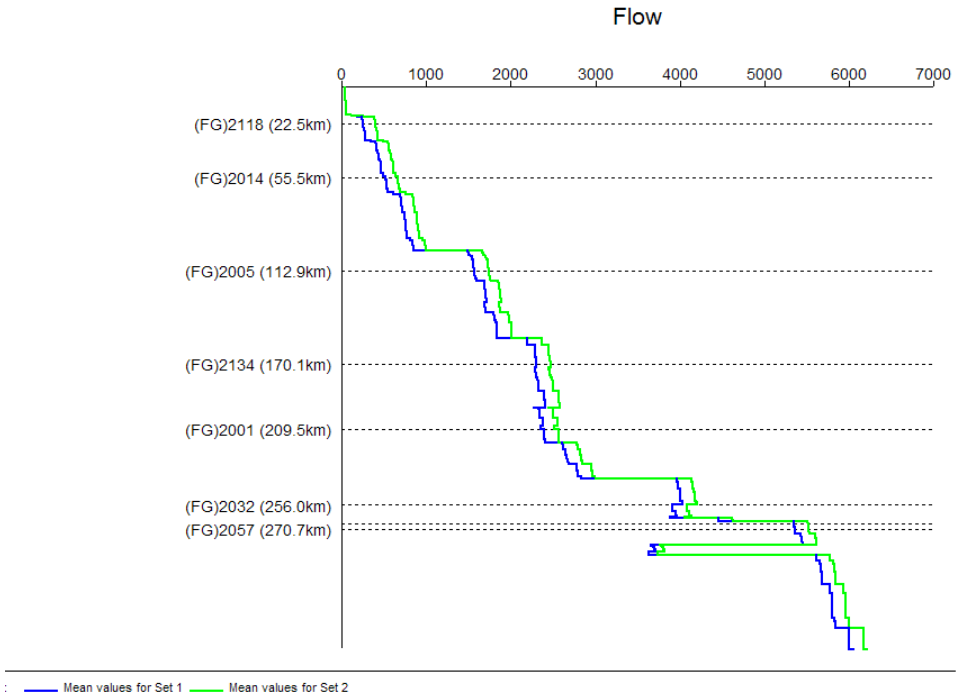
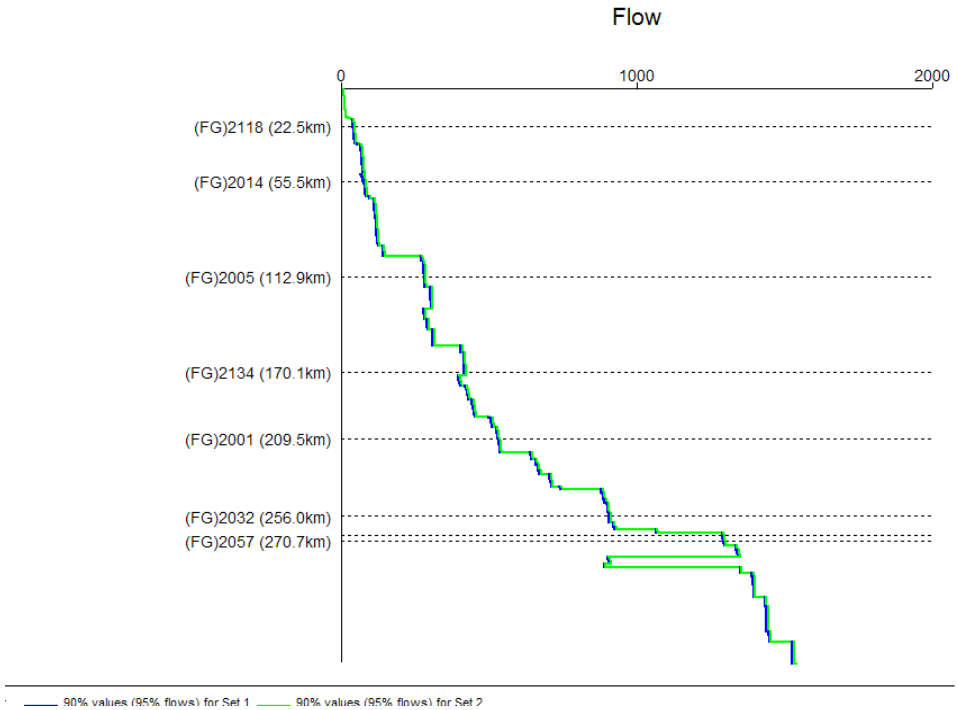


Figure 13. Chronic drought comparison including RSDO operation (Q95 flow)



In order to fully assess the impact of the operation of the RSDO on water quality, an assessment of compliance against both Water Framework Directive targets and Fundamental Intermittent Standards was carried out for phosphates, ammonia and biochemical oxygen demand (BOD). A comparative assessment of Total Oxidised Nitrogen is also included for reference.

From the same graphs, it is possible to determine the relative impact in terms of water quality concentration as a result of the operation of the RSDO.

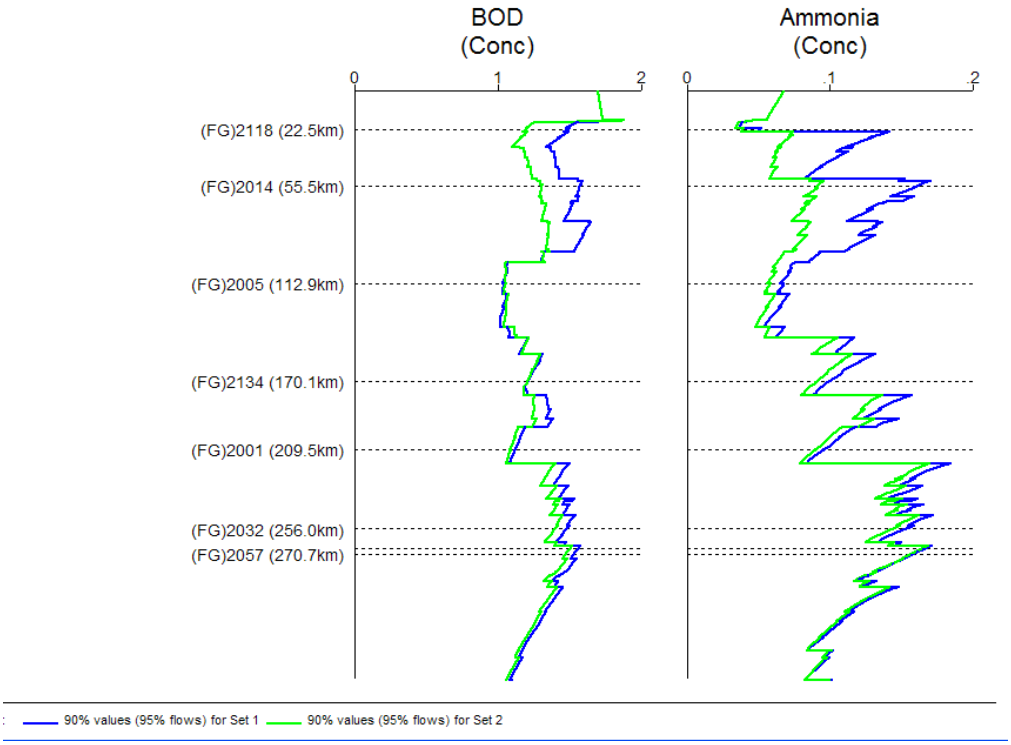
The relative standards for the various sections of the River Severn corridor can be found in Table 6 below.

Table 6. Water Framework Directive Targets and Fundamental Intermittent Standards

River Severn Stretch	Parameter	WFD Good (mg/l)	FIS 99%ile (mg/l)
Llanidloes Felindre Bridge to Caerhowell	Ammonia	0.3	0.6
Caerhowell to Llandrinio	Ammonia	0.6	0.6
Llandrinio to Gloucester	Ammonia	0.6	1.5
Llanidloes Felindre Bridge to Llandrinio	BOD	4	5
Llandrinio to Gloucester	BOD	5	9
Llanidloes Felindre Bridge to Aberbechan	Phosphate	0.04	n/a
Aberbechan to Gloucester	Phosphate	0.12	n/a

Figure 14 below displays both BOD and ammonia concentrations throughout the River Severn corridor for the Acute scenario and compares the relative water quality under the '' Do Nothing'' (blue line) and EA RSDO (green line) scenarios. The first obvious observation is that there are only very limited areas of deterioration as a result of the RSDO operation and that, generally, water quality in the RSDO scenario (green line) is improved compared with the unmanaged situation.

Figure 14. 90%ile assessment for BOD and Ammonia in acute drought conditions



The only areas of minor deterioration in either determinand can be summarised as follows:

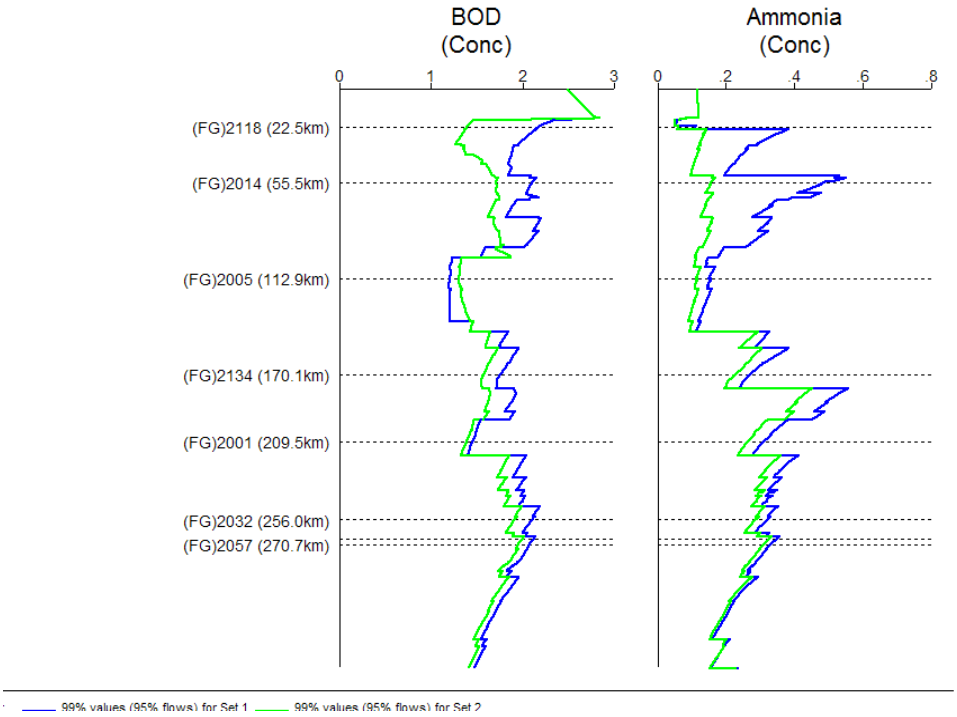
- BOD - Maximum 5% deterioration between Montford Bridge and Cross Houses on the River Severn
- BOD - Minor deterioration at Caerhowell on River Severn (1.5%)
- Ammonia – 25% increase in concentrations on the Afon Vyrnwy d/s of Llansantffraid

In none of the above locations, however, was the deterioration great enough to cause any failure of WFD targets. In fact, Figure 14 above illustrates that no failures of the respective WFD target would be recorded in either the managed or un-managed drought scenario.

Figure 15 below displays the same two determinands (BOD and ammonia) as 99 percentiles. Use of such high percentiles allows a direct application of the results to extreme conditions. For example, Figure 15 effectively represents the concentrations which are exceeded for just 1% of the time or, the equivalent of just 3.65 days/year.

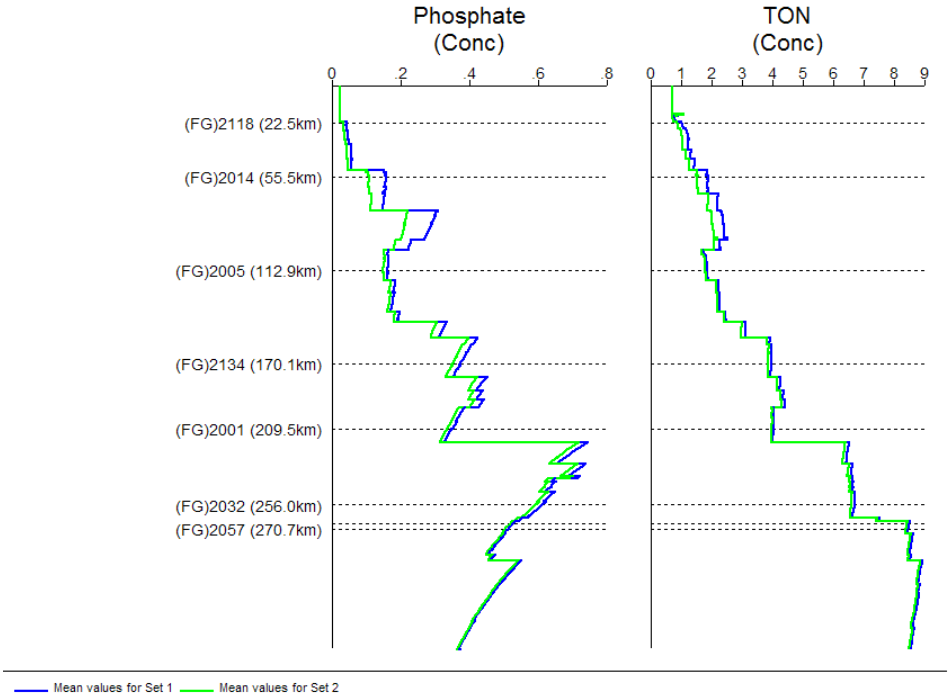
Use of such standards allows assessment of potential worst case scenarios when, one could assume, river flows are at their lowest and dilution conditions for discharges to the river are at their worst.

Figure 15. 99%ile assessment for BOD and Ammonia in acute drought conditions



Comparison of the results portrayed in Figure 15 with the required standards in Table 6 shows that at no point on the River Severn are concentrations predicted to exceed the 99th percentile regarded as representing a threat to the aquatic environment.

Figure 16. Mean assessment for Phosphate and TON in acute drought conditions

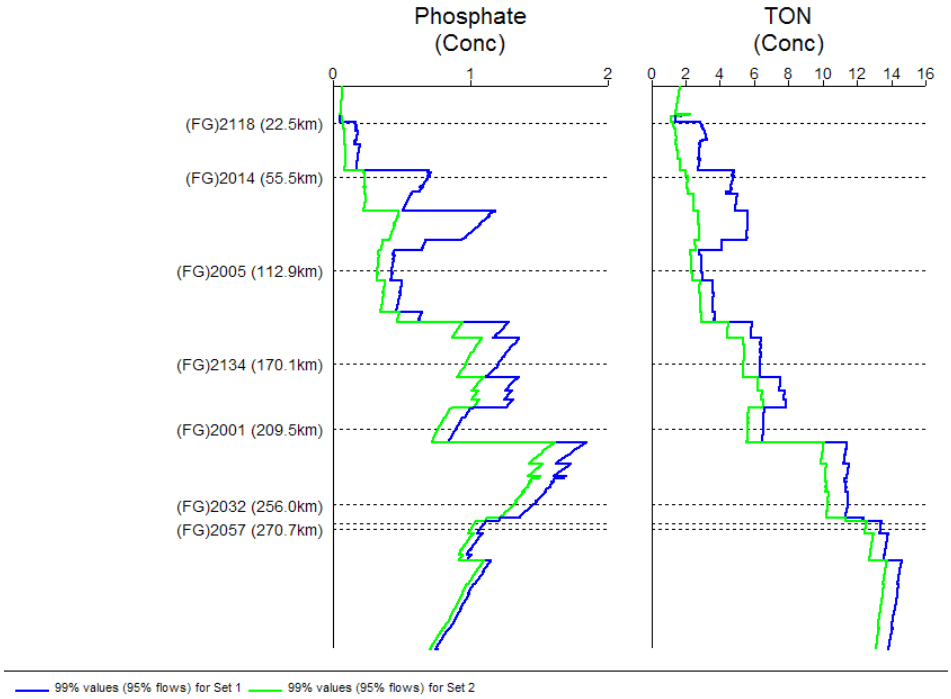


Although it is immediately evident that phosphate concentrations exceed WFD standards in both acute drought scenarios, this is of lesser concern considering WFD compliance for phosphate along the River Severn corridor is currently less than good at all locations downstream of Cressage. On the graph in Figure 16 this effectively equates to locations downstream of FG2005 (Montford Bridge).

Consequently, there would appear to be a significant length of new WFD standard failure for phosphate in the River Severn during drought conditions but crucially, operation of the RSDO generally improves concentrations throughout the Severn corridor compared with the unmanaged scenario.

The same can be said for Total Oxidised Nitrogen concentrations in that they do not appear to deteriorate following commencement of the RSDO operations.

Figure 17. 99%ile assessment for Phosphate and TON in acute drought conditions

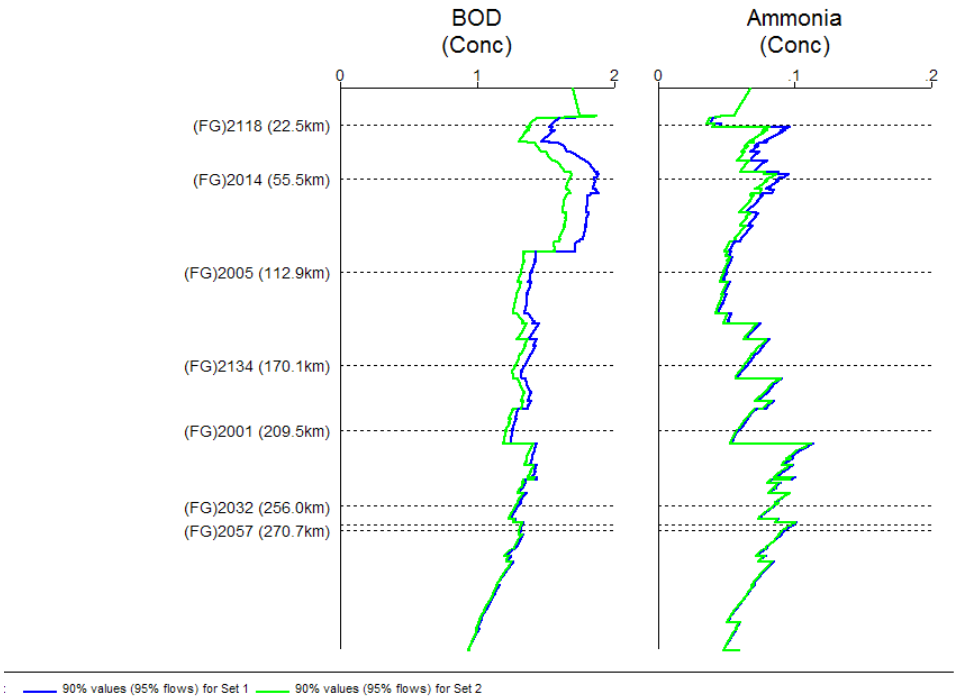


In terms of an almost worse case scenario, Figure 17 demonstrates that concentrations of both nutrients will reach quite high levels during the lowest flow situations. This is inevitable given the lack of dilution in these cases but, once again, it is noticeable that the RSDO operation will only help to improve the situation and reduce the potential impact on the aquatic ecosystems.

Consideration of the Chronic drought scenario shows a very similar situation. Figures 18 to 20 below demonstrate no significant deterioration in any determinand at any point in the Severn or Vyrnwy catchments as a result of the revised releases from Vyrnwy and Clywedog Reservoirs under operation of the RSDO.

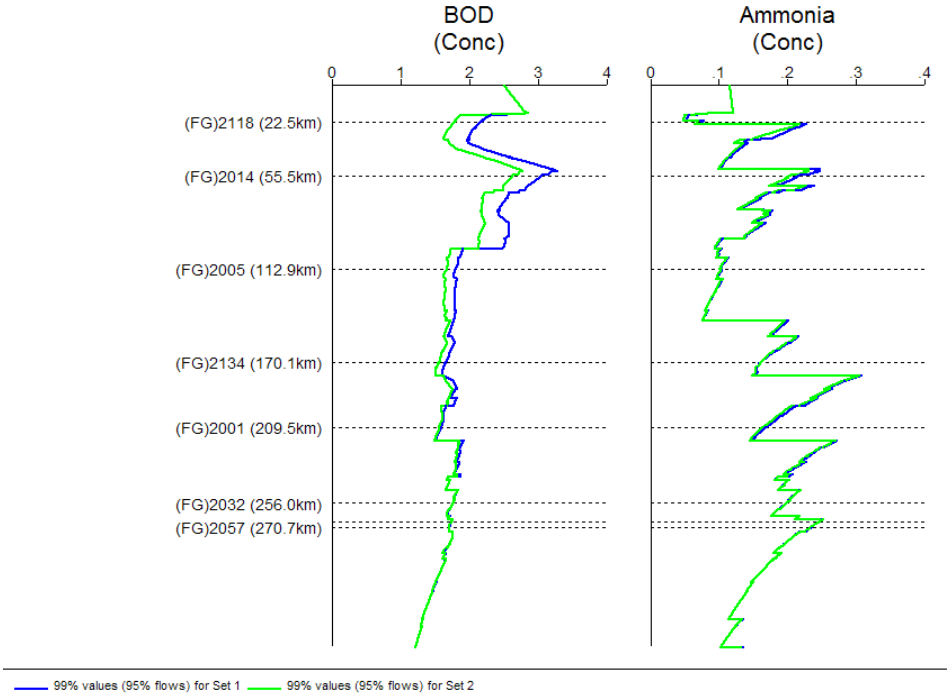
This is of no real surprise given the increased flows assessed throughout the catchment as part of this drought scenario and the fact that operation of the RSDO would result in greater mean and Q95 flows released from Clywedog and mean flows from Vyrnwy.

Figure 18. 90%ile assessment for BOD and Ammonia in Chronic drought conditions



As with the acute drought scenario, no new WFD failures are recorded in either BOD or ammonia as a result of the environment experiencing drought conditions. The same is true of the 99 percentile standard applicable to River Severn corridor as demonstrated in Figure 19 below where the maximum concentrations predicted in the worst case scenario both largely remain below 3mg/l and 0.3mg/l for BOD and ammonia respectively (tightest applicable targets = 5mg/l and 0.6mg/l)

Figure 19. 99%ile assessment for BOD and Ammonia in Chronic drought conditions



Not unexpectedly, achievement of WFD Good Status for phosphates is made harder during the modelled periods of drought with a general increase in nutrient concentrations across the board (Figure 20). As with the acute conditions, however, the biggest comfort remains that application of the RSDO marginally improves the situation with increased dilution reducing both phosphate and TON concentrations (Figures 20 & 21).

Figure 20. Mean assessment for Phosphate and TON in Chronic drought conditions

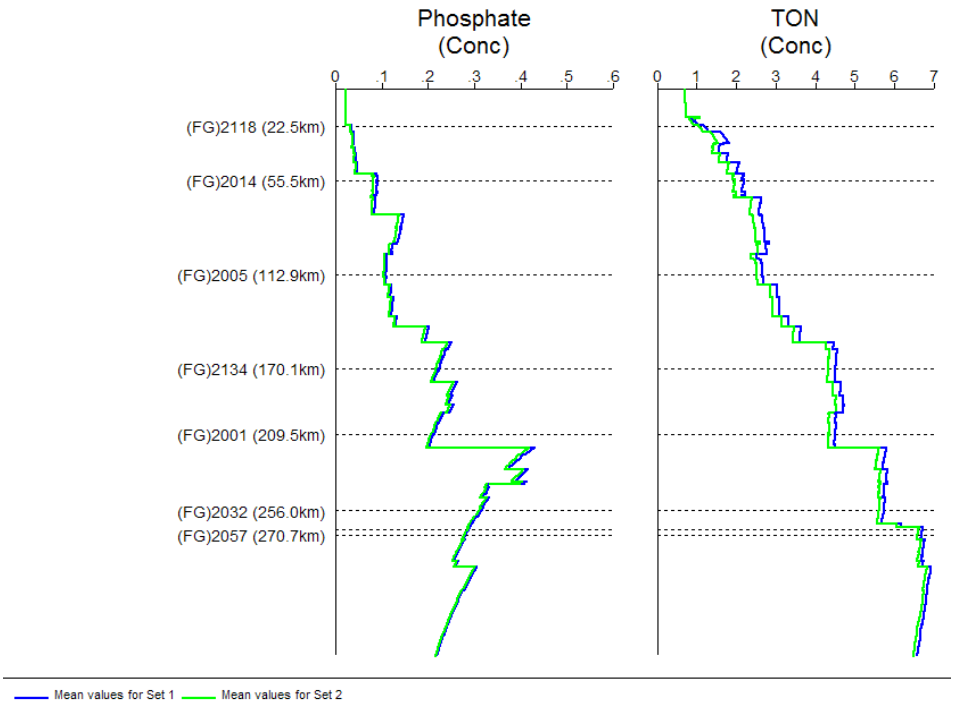
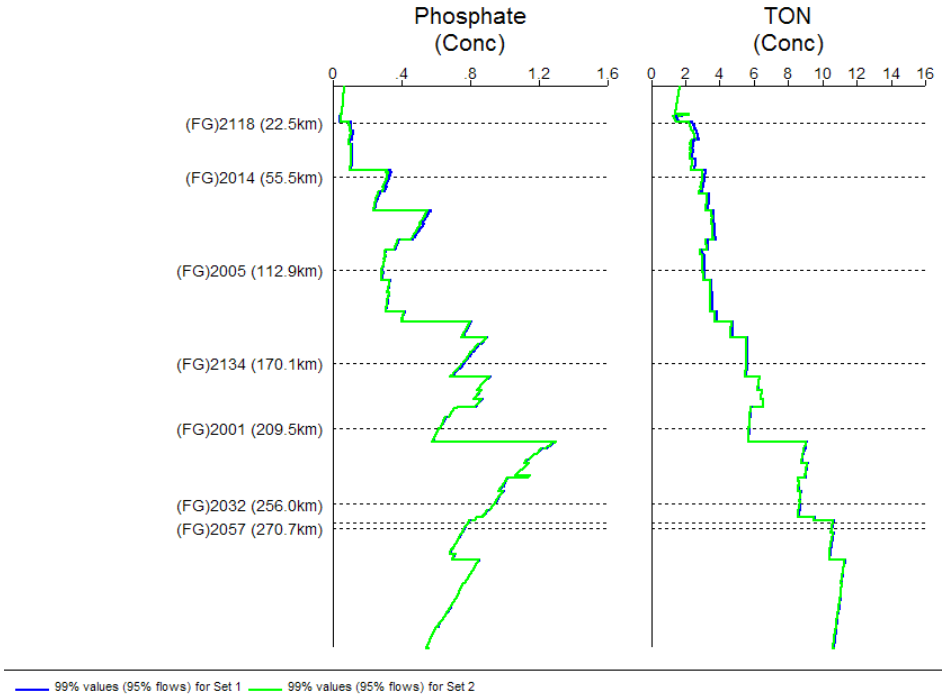


Figure 21 – 99%ile assessment for Phosphate and TON in Chronic drought conditions



Consideration of the zero natural flow scenario shows a similar situation for both ammonia and BOD in both Acute and Chronic drought conditions. Comparison with the previous work (Figures 15 & 19) suggests that predicted concentrations for both determinands in this scenario are not particularly elevated and, as such, do not record failures of the required Water Framework Directive Standards. This is reassuring considering the lack of natural dilution, even when measured at the 99%ile (Tables 7 & 8) and additional comfort is offered by the prediction that application of the RSDO only improves the predicted water quality.

Table 7. BOD and Ammonia predicted concentrations in acute drought conditions with no natural flows

		No RSDO		RSDO	
Flow Gauge Location	**FG Ref**	**BOD 99%ile (mg/l)**	**Ammonia 99%ile (mg/l)**	**BOD 99%ile (mg/l)**	**Ammonia 99%ile (mg/l)**
Bryntail	2109	1.6	0.05	1.6	0.05
Vyrnwy	2003	1.67	0.03	1.67	0.03
Buildwas	2134	2.13	0.36	1.84	0.31
Bewdley	2001	1.61	0.47	1.36	0.36
Saxons Lode	2032	2.32	0.45	2.1	0.38
Deerhurst	2057	2.28	0.39	2.17	0.36
Lower Parting		2.08	0.35	1.96	0.33

Table 8. BOD and Ammonia predicted concentrations in Chronic drought conditions with no natural flows

		No RSDO		RSDO	
Flow Gauge Location	**FG Ref**	**BOD 99%ile (mg/l)**	**Ammonia 99%ile (mg/l)**	**BOD 99%ile (mg/l)**	**Ammonia 99%ile (mg/l)**
Bryntail	2109	1.6	0.05	1.6	0.05
Vyrnwy	2003	1.67	0.03	1.67	0.03
Buildwas	2134	2.42	0.43	1.88	0.35
Bewdley	2001	1.73	0.48	1.42	0.37
Saxons Lode	2032	2.44	0.46	2.18	0.4
Deerhurst	2057	2.35	0.41	2.23	0.37
Lower Parting		2.12	0.36	2	0.33

The application of the RSDO can also be seen to improve water quality in terms of nutrient concentrations in the zero natural flow scenarios. Although maximum concentrations are predictably higher in this situation compared with the more realistic scenarios discussed earlier (Figures 17 & 21), it is noticeable in Tables 9 and 10 below that concentrations are reduced once revised regulation of the flows from Clywedog and Vyrnwy are employed.

Table 9. Predicted nutrient concentrations in acute drought conditions with no natural flows

		No RSDO		RSDO	
Flow Gauge Location	**FG Ref**	**Phosphate 99%ile (mg/l)**	**TON 99%ile (mg/l)**	**Phosphate 99%ile (mg/l)**	**TON 99%ile (mg/l)**
Bryntail	2109	0.06	1.07	0.06	1.07
Vyrnwy	2003	0.06	0.58	0.06	0.58
Buildwas	2134	1.39	7.14	1.27	5.93
Bewdley	2001	1.07	6.69	0.97	6.1
Saxons Lode	2032	1.69	12.95	1.6	11.73
Deerhurst	2057	1.21	15.73	1.17	15.01
Lower Parting		1.11	15.56	1.07	15.04

Table 10. Predicted nutrient concentrations in Chronic drought conditions with no natural flows

		No RSDO		RSDO	
Flow Gauge Location	**FG Ref**	**Phosphate 99%ile (mg/l)**	**TON 99%ile (mg/l)**	**Phosphate 99%ile (mg/l)**	**TON 99%ile (mg/l)**
Bryntail	2109	0.06	1.07	0.06	1.07
Vyrnwy	2003	0.06	0.58	0.06	0.58
Buildwas	2134	1.61	8.18	1.4	6.52
Bewdley	2001	1.21	7.4	1.05	6.6
Saxons Lode	2032	1.79	13.49	1.66	12.34
Deerhurst	2057	1.24	16.02	1.19	15.16
Lower Parting		1.14	16.06	1.09	15.28

Summary

Acute Flow Scenario

- **Application of the RSDO generally results in an improvement in the water quality. There are some local areas of deterioration, notably**
  - Phosphate - Afon Vyrnwy d/s of Llansantffraid - 33% increase in concentrations - no resultant failure of WFD targets.
  - BOD - Maximum of 5% deterioration between Montford Bridge and Cross Houses. Minor deterioration at Caerhowell on River Severn (1.5%) - no new WFD failures.
  - Ammonia - Afon Vyrnwy d/s of Llansantffraid - 25% increase in concentrations - no resultant failure of WFD targets.
  - Nitrogen - General deterioration in concentrations throughout the Vyrnwy catchment.
- No new failures to achieve Water Framework Directive good ecological status for ammonia or BOD although widespread phosphate failures persist.
- No failures of the 99% targets associated with the river reach classes imposed under the River Ecosystem Classification and representative of extreme events

- Even under zero natural flow scenarios, maximum ammonia concentrations are predicted to equal 0.47mg/l with BOD pollution topping out at 2.32mg/l, both well within the WFD 90%ile standards.
- Nutrient concentrations continue to breach the required standards and are, indeed, elevated further without the benefit of any natural dilution flow for the treated effluent discharges.
- In all four cases, however, application of the RSDO improves concentrations throughout the Severn catchment.

Chronic Flow Scenario

- No significant deterioration for any determinands at any point in the Severn or Vyrnwy catchments as a result of the RSDO.
- No new failures to achieve Water Framework Directive good ecological status for ammonia or BOD although widespread phosphate failures persist.
- No failures of the 99% targets associated with the river reach classes imposed under the River Ecosystem Classification and representative of extreme events even under the worst case scenario of zero natural flow.

Severn Estuary – Water Quality and Flow assessment.

It has proved impossible to accurately calibrate the flows in the SIMCAT model to match the prescribed flows from the freshwater River Severn system to the Severn Estuary. The original attempt to adjust the model flows in accordance with ratio'd headwater flows and diffuse flows resulted in an over-estimation of almost 1250Ml/d in the mean flow at Lower Parting at the head of the estuary and bottom of the SIMCAT model. This modelling error manifested itself as an error of almost 350Ml/d at low flows, giving a predicted SIMCAT flow at almost twice the value suggested by AQUATOR.

The margin of error was duplicated in the second calibration exercise when all natural flows were removed from the SIMCAT model. This would suggest that treated effluent discharges into the catchment alone would contribute more flow to the head of the estuary than is expected by the AQUATOR modelling.

Given that the discharge flow figures were based on actual measured volumes during dry weather, it would appear that the SIMCAT model is incapable of achieving the prescribed freshwater flows to the estuary without forcing a fit through use of unrealistic abstraction and discharge data.

In terms of water quality impact on the estuary, however, given that the drought flows represent an 82% reduction in mean flows and a 56% reduction during low flows compared with the baseline model output, the deterioration in water quality at the 95%ile concentration is relatively slight. Phosphate concentrations increase from a non-compliant 0.58mg/l to 0.78mg/l whilst the deterioration in ammonia is just 0.04mg/l compared with a baseline of 0.14mg/l. Both concentrations being compliant with WFD Good Ecological Status requirements. Changes in BOD concentration actually see a predicted 40% improvement.

Extrapolating this data forward to the much lower flows predicted by AQUATOR, it could be suggested that any further deterioration in quality would be equally slight and would be unlikely to cause any new failures of desired water quality standards. It is possible, however, that the increasing nutrient concentrations could result in eutrophic conditions given the right physical conditions in which macrophyte and algal growth could establish.

The worst case, zero natural flow scenario would tend to support this assumption. Considering this scenario represented almost zero dilution for treated sewage effluent discharges, the concentrations predicted at Lower Parting in tables 7 and 8 represent little concern with regards to the sanitary determinands, BOD and ammonia. As discussed above, the elevated nutrient concentrations could be of concern if appropriate growing conditions allow excessive plant growth to occur.

Referring the findings of this modelling to an actual historic situation, the 1976/77 drought, it is re-assuring to read that the quality of the River Severn during the drought event caused very few concerns, despite the increased percentage of flow originating from sewage effluents. It should be noted, however, that temperatures recorded during the 1976/77 event were very high which aided the biological treatment of polluting loads in terms of both in-river purification and at treatment facilities. It is possible that should a drought period be experienced without these high temperatures then water quality deterioration could be more pronounced.

Of greater concern in terms of water quality is the possibility of conditions of high saline intrusion, elevated suspended solids and, as a result, reduced dissolved oxygen levels that could occur if residual freshwater flow to the estuary were severely reduced. Such conditions could prevail where residual flows are insufficient to prevent the landward movement of the area of maximum turbidity which is responsible for the drop in dissolved oxygen.

Mitigation options

Judging by the fact that water quality is not predicted to significantly deteriorate under the perceived worst case scenario of zero natural flows and that, under the same conditions, the predicted 99%ile quality remains within WFD concentration criteria for ammonia and BOD, there appears to be little benefit in employing mitigation measures for water quality in drought conditions.

With regards to phosphate and nitrogen, the drought is likely to cause a further increase in concentrations. As water quality standards are already breached and environmental damage is already likely to be occurring in non-drought conditions, continuation of the current regime of work to reduce nutrient enrichment is seen to be the best way forward with no further mitigation measures required.

Modelling Limitations

Throughout the exercise to determine the impact of drought conditions on the water quality of the River Severn corridor and also the impact of managing the flows through implementation of the RSDO, it became obvious that the SIMCAT models at our disposal were not necessarily the right tools for the job.

The verification exercise initially attempted to match predicted and observed drought flows at the various assessment points proved to be fraught with difficulty and was eventually abandoned in favour of a number of logical assumptions. This was predominantly due to the fact that the current SIMCAT models are based on current day populations rather than those present at the time of the drought situations attempting to be matched (1976/77).

Being a spatial rather than a temporal model, it also proved impossible to provide the data for ecological appraisal in the form that was required. Whereas the ecological impact would be best assessed using an indication of the varying ammonia and BOD concentrations at one location with time and flow (temporal model), SIMCAT was only able to provide a worst case scenario for the entire length of river with no immediate link to the flows at the corresponding time. In other words, an assumption had to be made that the 99th percentile value for each determinand represented the worst case scenario when, in fact, higher concentrations would be present for a maximum of 4 days in a year.

SIMCAT is also a tool more suited to representing more stable conditions and can struggle to represent prolonged, extreme events such as droughts. By it’s nature of representing mean and standard deviation statistical input, it is not inherently designed to predict environmental conditions in extreme, worst case scenarios.

Although a specific modelling tool cannot be recommended, any tool which is better suited at representing a temporal link between flow and pollutant concentration would probably be better suited to the tasks required in this water quality assessment.

The SIMCAT model itself could be improved by more sophisticated and numerous water quality and flow monitoring. Currently, the model is based upon the known input data, in other words measured data from flow gauges, water quality monitoring points, measured discharge volumes and quality. From this data, the model must make assumptions on the source of any errors that may occur following mixing of all the known data.

Without enhanced monitoring, much larger data sets encompassing all possible sources of pollution and diffuse flow inputs and highly detailed knowledge of the catchment, this calibration process can be fraught with problems. The SIMCAT models employed in this assessment have been signed off and accepted as the best possible representation of the environment given the data available but it also has to be recognised that the model contains numerous locations where accurate representation of the environment was not possible. Calibration errors such as this can only successfully be rectified through the use of greater amounts of top quality monitoring of all potential sources of pollution and flow.

Future Recommendations & Monitoring Requirements

The underlying SIMCAT model used to predict the baseline water quality can always be improved through a thorough investigation of all polluting or diluting sources and subsequent data collection exercise of the entire catchment, focussing predominantly on the areas highlighted as being of poor calibration.

Such an exercise is likely to improve the model calibration but it would not be a foregone conclusion given the complicated nature of environmental interactions and the fact that it is notoriously difficult to balance a large catchment model. Quite often, what would appear to be an improvement in data quality in one location can deteriorate calibration in other locations in the catchment.

In terms of the RSDO, the report earlier highlighted the limitations of the SIMCAT model in terms of flow and water quality at strategic locations on the River Severn. Improvement of this calibration is, unfortunately, not as easy as improving data quality at the same locations as, quite often, it is a lack of data from feeding tributaries that impose a greater influence on the model. As discussed above, the model needs to be seen as a holistic tool where data quality and catchment knowledge would need to be improved at all locations in order to achieve a better calibration.

With regards to the improved representation of drought conditions, SIMCAT would need to be fundamentally changed to be able to better represent the intricate operation of the major abstractions in terms of hands of flows and RSDOs. In most cases, the model is already built based on measured abstracted flows although the representation of this data could probably be improved.

In short, it is not felt that SIMCAT is the best modelling tool for the job given the limitations discussed earlier in the report. In order to fully understand and better replicate the impacts of drought flows, a specifically developed water resource model capable of accurately representing current and drought conditions would be the recommended way forward. Perhaps a water quality function could be incorporated within AQUATOR.

All SIMCAT models are initially calibrated for flow followed by a water quality calibration exercise based upon the accurate representation of the flow characteristics. Any work beyond this point tends to be in the form of ‘what-if’ scenarios. In other words, what will happen to the quality if we halve the flow?

Providing the initial calibration is as accurate as possible, any change in the model with regards to flow should give a suitably accurate prediction of the impact on quality. What is lacking in SIMCAT is the functionality to represent the complicated flow controls in the River Severn. If this could be rectified in SIMCAT (or any other model for that matter, then an accurate water quality prediction in drought conditions should be possible.

In an ideal modelling world, a tool capable of predicting both temporal and spatial changes in water quality and flow would be available with the capability to represent any number of different flow situations. Providing it was then fully calibrated in terms of water quality in ‘normal’ conditions, reactive predictions in water quality at any location or time could be possible.

Appendix 4:

Tidal estuary assessment. A Brief Review of the Impact of Low River Flows on the Water Quality of the Severn Estuary

Appendix 4: Tidal estuary assessment. A Brief Review of the Impact of Low River Flows on the Water Quality of the Severn Estuary

Introduction

This note has been written to inform the RSDO, and its associated Habitats Regulations Assessment, which are being prepared by EA Midlands Region. It provides an initial assessment of the response of the Severn Estuary to low flows within the River Severn, and the area most impacted by these low flows.

There have been past reports looking at the impact of low river flows on the Tidal River Severn, and the residual flow requirements to the Tidal River Severn (see eg. Hutcherson and Wade 1992, Wade et al. 1983, and Severn-Trent Water Authority 1977). The impact of low river flows on the water quality in the Severn Estuary above the SAC (herein termed the Tidal River Severn) has been clearly established. The main concerns are:

- the increased occurrence of low dissolved oxygen levels,
- fish kills arising from low DO levels,
- increased saline intrusion,
- increased intrusion of the turbidity maximum and therefore high suspended sediment levels,
- decreased water quality in the British Waterways abstraction to the Gloucester & Sharpness Canal which is a major source of water for Bristol Water,
- reduced dilution for major discharges to the Tidal River Severn, notably Gloucester (Netheridge STW).

This present review is an initial assessment of the consequences of low river flows under drought conditions on the Severn Estuary SAC and SPA, the boundary of which is at Hock Cliff, 33.5 km below Maisemore Weir (see Figure 1). The SAC and SPA boundary is almost the same as the boundary between the Upper Severn and Middle Severn Transitional Water Framework Directive Waterbodies.

To put the following discussion into context, a sketch map of the Severn Estuary and Inner Bristol Channel is given in Figure 2. This map which comes from a Water Pollution Research Report (Winters and Barrett 1972) shows the distances down the Estuary channel from Maisemore Weir at 5 km intervals. These distances from Maisemore Weir have been used as the basis of all the plots showing changes in variables down the Severn Estuary.

The first part of the note describes certain basic aspects of the Severn Estuary above Avonmouth, from which some initial conclusions can be drawn on the area of impact due to low river flows. These conclusions relate to water quality, and most of the interest features of the SAC, except fish and birds. There remain various gaps in the assessment which need to be addressed further, together with some recommendations on some additional data which would be helpful to the assessment.

Tidal Regime

The Severn Estuary has an exceptionally large tidal range, with a Mean Spring Tide range of 12.2 m and a Mean Neap Tide range of 6.0 m at Avonmouth. The mean high and low tide levels for Mean Spring and Neap tides relative to Ordnance Datum (Newlyn) going up the Severn Estuary from Avonmouth to Llanthony are shown in Figure 3. The data are derived from information in the Admiralty Tide Tables.

These show how the tidal ranges are reduced in the Middle and Upper Estuary as a response to the rising levels of the estuary bed. The Low Water Spring tidal levels start to rise inland of Beachley by the older Severn Bridge, 58 km below Maisemore Weir, while the Low Water Neap tidal levels start to rise from just north of Oldbury Power Station, about 49 km below Maisemore Weir. Neap tides do not penetrate further up-estuary than about 19 km below Maisemore Weir near Epney. Spring tides in contrast penetrate above Haw Bridge, at least in terms of back water effects, with the limit of flow reversal being near Tewkesbury, about 16 km above Maisemore Weir (Severn-Trent Water Authority 1977). There is also a tidal bore which occurs in the Tidal River Severn on big Spring tides.

It is stated in the Admiralty Tide Tables that low water levels in the upper part of the Estuary, above about 55 km below Maisemore Weir, are significantly affected by the river flows in the Severn and its tributaries, and can be raised by up to a metre during high river flows. In contrast, high water levels are hardly affected by river flows, except under exceptional circumstances.

At the SAC/SPA boundary at Hock Cliff, the Mean Spring tidal range is about 7 m, and the Mean Neap tidal range is about 3 m. There is therefore a significant tidal rise and fall at the SAC boundary during both Spring and Neap tides.

The Tidal River Severn splits for a short distance between Upper and Lower Parting at Gloucester, with a weir in each channel. One is at Maisemore, near the up-estuary end of the West Channel, and the other is at Llanthony, near the down-estuary end of the East Channel. These 2 weirs influence the tidal propagation in the Tidal River Severn. There is also a weir in the lower reaches of the River Severn at Upper Lode, which is just below the confluence of the River Severn and River Avon. The crest heights of the these weirs are shown on Figure 3 relative to the heights of Mean High Water Spring tides and Neap tides. It is clear that both Maisemore and Llanthony weirs can be over-topped by tidal levels reached by intermediate tides, or tides exceeding a height above chart datum (CD) of about 7.8 m at Sharpness for Llanthony weir and 8.1 m for Maisemore weir. This critical value of 7.8 m above CD for tidal heights at Sharpness is agreement with the value quoted in Hutcherson and Wade 1992.

Cumulative Tidal Volumes

The cumulative tidal volumes for the Severn Estuary and Inner Bristol Channel are shown in Figure 3. These show how the High Water and Low Water Spring and neap tidal volumes change along the length of the Severn Estuary and into the Inner Bristol Channel. The data are based on a Figure in Winters and Barrett 1972. The data for cumulative volumes could probably do with re-assessing using more recent bathymetric and cross-section data for the Estuary, but they suffice for the present assessment.

The data reflect the changes in tidal heights in the Middle and Upper Estuary, and the rapid rise in estuary bed levels between 60 and 20 km below Maisemore Weir, ie. between Aust and Framilode. Again the data show that Neap tides do not penetrate inland further than about Epney. The boundary of the SAC at Hock Cliff is within the area where estuary bed levels are rising, but the tidal volumes above the boundary are still quite large, being about 36 million cubic metres at Mean High Water Spring tide level, and about 15 million cubic metres at a Mean High Water Neap tide level. This tidal volume for Spring tides is similar to that for the Exe Estuary.

River Flows Compared with the Cumulative Tidal Volumes

The significance of river flows in relation to the tidal regime in the Severn Estuary has been assessed by comparing the river flow as a volume over a tidal cycle (12.42 hours) with the cumulative tidal volumes in the Estuary (see Figures 5, 6, & 7). This assessment provides an indication of what estuary tidal volume could be occupied by river water alone. It therefore provides an estimate of the saline intrusion. However, this simple assessment does not take account of stratification processes at high water, particularly a salt wedge effect, whereby saline

water can be transported up-channel at the estuary bed, when freshwater is flowing down-channel at the surface (see discussion on salinity regime in Section 5 below).

The river flows considered in this assessment cover a range from 21,600 Ml/d (250 m3/s) down to 500 Ml/d (5.8 m3/s). The flows are given in the Table below, with an indication of what they represent.

Flow in Ml/d	Flow in m3/s	
21,600	250.0	Approximately Q10 at Haw Bridge
17,280	200.0	Approximately Twice the ADF at Haw Bridge
8,640	100.0	Approximately Average Daily Flow at Haw Bridge
2500	28.9	
2000	23.1	Slightly more than Q95 at Haw Bridge
1500	17.4	Slightly less than Q95 at Haw Bridge
1000	11.6	
750	8.7	Approximately 7-day Average Minimum Flow at Haw Bridge in August 1976
500	5.8	Estimated drought flow at Lower Parting

Looking at these Figures, it is clear that when river flows drop to about 1000 Ml/d and below, the river water only occupies a volume down-estuary as far as about 3 km below Maisemore Weir, ie. Lower Parting. During intermediate and spring tides therefore, the up-estuary transport of brackish water and suspended sediments related to the turbidity maximum is increased. The levels of suspended solids in this turbidity maximum can reach over 50 g/l (Uncles 2010). These conclusions on the up-estuary transport of salinity and suspended solids accord with the observations reported by Hutcherson and Wade (1992).

What is also clear from these Figures is that when river flows are very low, less than 1000 ML/d, there is little water available within the low water channel in the Tidal River Severn. The river flows through the East and West Channels below Upper Parting are also influenced by the weirs at Maisemore and Llanthony. The limited river flow in the 2 channels is further influenced by the abstraction at Gloucester by British Waterways to the Gloucester & Sharpness Canal, which is situated in the East Channel a short distance above Llanthony Weir. In the 1976 drought, the abstraction was about 330 Ml/d on average in August, although it peaked at about 500 Ml/d (Figs 6 & 10 in Severn-Trent Water Authority July 1977). The resulting flows at Lower Parting were estimated to get as low as about 250 Ml/d. The effects of these low river flows and the British Waterways abstraction during the 1976 drought are reflected in a different report by the Severn-Trent Water Authority (October 1977). In this report, it is stated that “In 1976, when flows in the river fell to levels lower than previously recorded, the residual (flow) to the estuary at times of peak pumping (by British Waterways) was reduced to a few centimetres over Llanthony Weir; Maisemore Weir being at a higher level was dry at these times.” This situation is shown in photographs of the weirs taken on August 20th 1976 (Figures At very low river flows therefore, it is apparent that there may only be a very small flow over the weir at Llanthony, and no flow over the weir at Maisemore. It should be noted that the estimated drought flows of about 500 Ml/d at Lower Parting in the present RSDO are similar to, or even in excess of, the minimum flows which were estimated to have occurred at Lower Parting in August 1976.

Salinity Regime

The salinity regime in the middle and upper estuary has been assessed using axial survey data collected between 1977 and 1997. These data are part of a larger set of data predominantly collected at about high water from sites extending from Haw Bridge along the estuary channel out into the Inner Bristol Channel. Various salinity values for sites between about Severn Beach and Haw Bridge are plotted in Figure 8. The salinity values plotted for each monitoring point are mean salinity, the median salinity, the 5%ile salinity and the 95%ile salinity.

These data show that at Hock Cliff, the mean high water salinity of 12.0 is similar to the median high water salinity of 11.5, and that the 5%ile to 95%ile range is from 0.3 to 23.3.

Down-estuary into the SAC, all the salinity values increase, so that off Severn Beach, the mean high water salinity is now 20.9, and the median high water salinity 21.2, while the 5%ile to 95%ile range is from 13.6 to 26.4.

Meanwhile up-estuary, all the salinity values decrease, so that near Minsterworth, the mean high water salinity is 0.7, the median high water salinity 0.4, and the 5%ile to 95%ile range is from 0 to 1.7. These indicate that under a 'normal' flow regime, the surface salinities near Minsterworth are predominantly freshwater.

Also plotted on Figure 8 are four vertical lines, 1 to 4, and an axial salinity profile which represents an estimated surface salinity incursion for 'drought flow'. The four vertical lines represent the cumulative tidal volume occupied by the defined freshwater river flow defined in terms of a distance downstream from Maisemore Weir. Line 1 represents mean river flow; line 2 Q95 river flow; line 3 the 1976 minimum flow; and line 4 the current estimated drought flow. The estimated salinity incursion profile has been drawn by moving the measured 95%ile salinity profile inland by the distance between lines 2 and 4.

The main feature of this estimated saline incursion profile is that it suggests that the high water salinity at Hock Cliff will only increase by about 1, which is not considered to be significant.

There is little data to define how the low water salinities vary in the middle and upper estuary. However, low water salinities affect a relatively small proportion of the estuary cross section both above and within the SAC, so that low water salinities are considered to be less significant in relation to their impact.

Discussion and Conclusions

The main part of the Severn Estuary which is impacted by any low flows during a drought is the section above the SAC boundary. This area of impact was observed during the 1976 drought. This reflects the nature of the Severn Estuary in its uppermost reaches above the SAC, as the greatest changes in bed levels, tidal range, and salinities all occur within this part of the Estuary.

However, it is also clear that during very low flows that there is little water available within the low water channel in the Tidal River Severn, and that this reduced flow can extend into the SAC. There will also be less freshwater available for diluting the effluent discharged from Gloucester (Netheridge) STW. It is therefore not possible to conclude that the low flows in the River Severn during a Drought do not have a Likely Significant Effect on the integrity of the SAC.

The question then is, whether there is an adverse effect on the integrity of the SAC due to these very low river flows during a Drought. In relation to water quality, perhaps the main concern is related to the dilution available for Gloucester (Netheridge) STW, and the impact of poor water quality on the SAC. In the 1976 drought, the water quality in the Tidal River Severn was certainly affected by the discharge from Gloucester (Netheridge) STW, which at that time only had primary treatment, and therefore resulted in a considerable oxygen demand in the receiving waters. The effluent discharge from Gloucester (Netheridge) STW in August 1976 was about 20 Ml/d (Figure 7 in Severn-Trent Water Authority July 1977). The measured average discharge flow from Gloucester (Netheridge) STW at present is about 50 Ml/d, while the minimum flow is about 35 Ml/d. The present level of treatment is secondary. Based on the improved treatment, but taking account of the increase in flows, the oxygen demand input by the current discharge compared with 1976 is therefore about 3 times less.

In addition, assuming that the Drought flow will be about 500 Ml/d at Lower Parting, and that this flow is the main flow diluting the discharge, the available dilution for the minimum flow from Gloucester (Netheridge) STW is about 15, which represents a reasonable dilution. However, it is recognised that the water quality of this river water during the Drought is not known, so that the downstream water quality after diluting the discharge from Gloucester (Netheridge) STW is also

not known. Probably the more important aspect though, as stated above, is that the current discharge inputs an oxygen demand about 3 times less than that in 1976, so that its impact will also be about 3 times less.

While the discharge from Gloucester (Netheridge) STW imparts a pollutant load, the actual flows in the Tidal River Severn below Lower Parting are augmented by the flow from Gloucester (Netheridge) STW at very low river flows. In addition, some small streams and small treated discharges from other sewage treatment works also provide some further flow. In this context, the minimum flow of about 35 Ml/d from Gloucester (Netheridge) STW represents 7% of a very low river flow of 500 Ml/d to the Tidal River Severn.

The most important evidence relating to the impact of very low flows on the SAC comes from the impact of the 1976 drought. From the available evidence at that time, it was concluded in the Severn-Trent Water Authority Report dated July 1977 that the 1976 drought had no immediate effect on the Severn Estuary, apart from the saline intrusion at Gloucester (with its potential impact on water supplies taken from the Gloucester & Sharpness Canal). This would suggest that the Estuary either was not impacted or recovered from whatever impact there was due to the low flows. This is not unexpected, since the uppermost reaches of the Estuary are those which are subject to the greatest variation in conditions, and therefore the ecology will have developed to accommodate these changes. These uppermost reaches of the Estuary certainly have a more restricted community of benthic organisms compared with that of the SAC (see eg. Boyden and Little 1973).

The assessment here indicates a similar conclusion, in that very low river flows during a drought will not have an adverse effect on the integrity of the SAC, at least in relation to water quality, and most of the interest features of the Site, apart from migratory fish and the fish assemblage, and birds, which are outside the scope of this assessment.

The following aspects need to be considered in relation to this conclusion. The duration of very low flows during a drought is a significant factor in the level of impact on the Tidal River Severn and therefore potentially the SAC. Obviously, the longer the duration of very low flows, the greater the probable impact. However, this may simply result in the recovery period to any impact being longer. How long very low flows could occur during a drought is not easy to predict, but some consideration may need to be given to this, and therefore the potential recovery period.

Recommendations for Further Work

1. Consideration needs to be given to all the potential minor sources of flow into the Tidal River Severn which could augment the limited flow from the River Severn.
2. The role of the abstraction by British Waterways at Gloucester on river flows in the East and West Channels needs to be re-assessed.
3. Any further monitoring data on conductivity (salinity) and turbidity (suspended solids) being undertaken by British Waterways or the Port of Gloucester also needs to be obtained, and the work of Hutcherson and Wade (1992) reviewed.
4. Time Series data and vertical profiles on the levels of Dissolved Oxygen at various locations in the Tidal River Severn during low river flows is needed to assess the impact of the current discharge from Gloucester (Netheridge) STW.
5. The recent bathymetric study of the upper reaches of the Severn Estuary by Gloucester Harbour Trustees should be obtained, if it has not been already. The data from this study would provide information on the nature of the low water channel from Gloucester down to the SAC, as well as allow a re-assessment of the tidal volumes.
6. Recent cross-sections of the River Severn above Lower Parting would be helpful in defining how very low flows occupy the river channel.
7. The benthic ecology of the Tidal River Severn and the upper part of the SAC needs to be assessed in detail, using available information. If necessary, this information could be

supplemented by some survey transects looking at seasonal variations in the upper Estuary, which would provide some data on the response of the benthic ecology to changes in river flows. .

8. In the long-term, a numerical model of the upper reaches of the Severn Estuary, looking at saline intrusion and the up-estuary transport of suspended sediments could be developed, to allow actual flow and tidal conditions to be modelled.

Figure 1

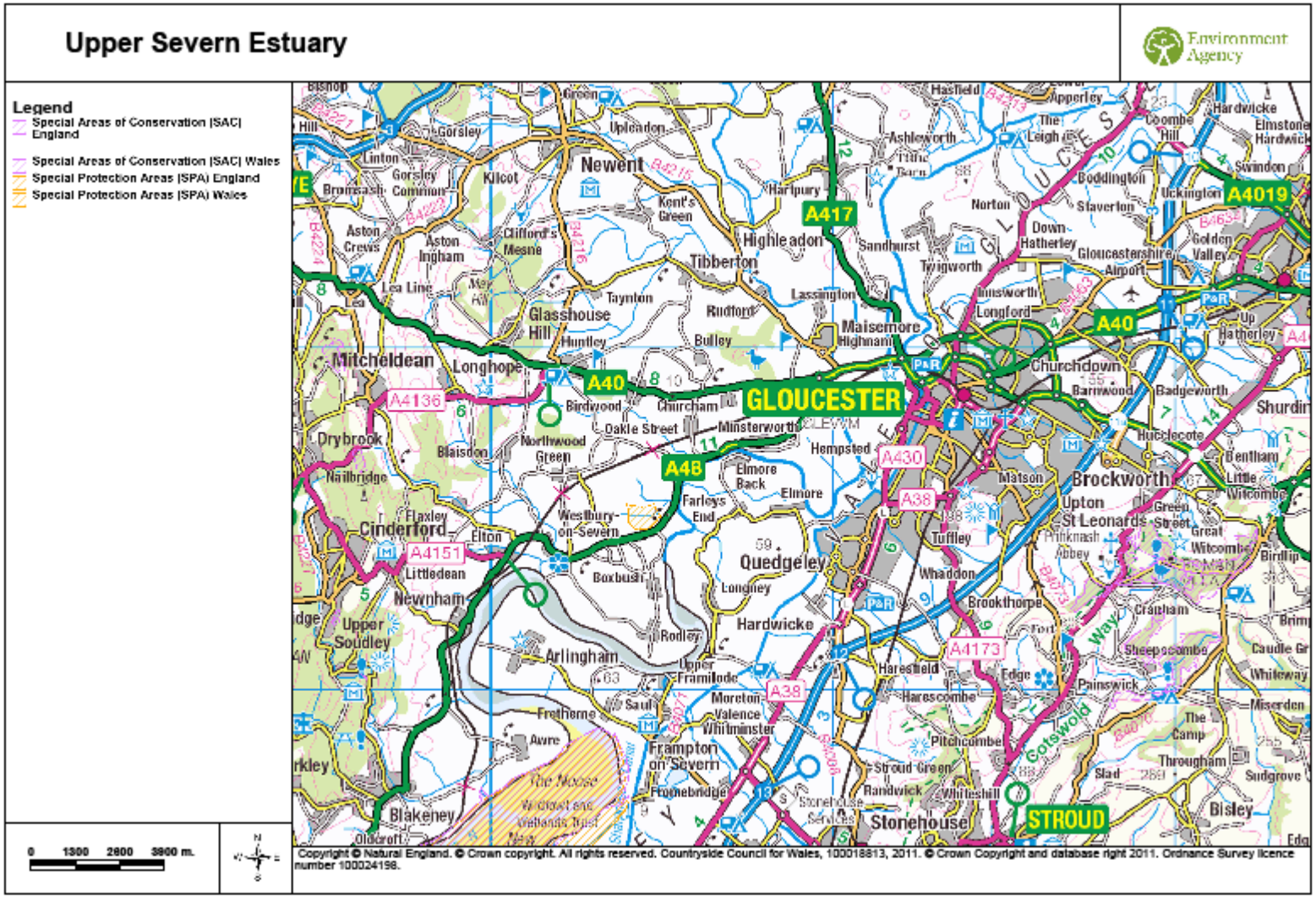

Upper Severn Estuary
Environment Agency
Legend
Special Areas of Conservation (SAC) England
Special Areas of Conservation (SAC) Wales
Special Protection Areas (SPA) England
Special Protection Areas (SPA) Wales
GLOUCESTER
STROUD
Newent
Highleadon
Maisemore
Churchdown
Brockworth
Mitcheldean
Cinderford
Quedgeley
Hardwicke
Frampton on Severn
Arlingham
Stonehouse
Bisley
Blakeney
A40
A417
A38
A48
A430
A4019
A4136
A4151
A4173
0 1300 2600 3900 m.
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Figure 2


FIG.2 MAP OF SEVERN ESTUARY
NUMBERS INDICATE KILOMETRES FROM MAISEMORE WEIR
N.P.G.S. = NUCLEAR POWER GENERATING STATION
N
Maisemore Weir
Minsterworth
GLOUCESTER
Stonebench
Newnham
Framilode
R. Frome
Awre
Forest of Dean
Canal
Lydney
Sharpness
Berkeley N.P.G.S.
R. Wye
Oldbury N.P.G.S.
CHEPSTOW
R. Usk
Beachley
Severn Road Bridge
Portskewett
Sudbrook
Aust
NEWPORT
R. Ebbw
Severn Beach
R. Rhymney
Denny Island
AVONMOUTH
R. Taff
CARDIFF
PORTISHEAD
BRISTOL
R. Ely
CLEVEDON
R. Avon
PENARTH
BARRY
BATH
Nash Pt.
Flat Holm
Worlebury Hill
Steep Holme
WESTON-SUPER-MARE
Brean Down
Porlock Bay
Hurlstone Pt.
MINEHEAD
Hinkley Pt. N.P.G.S.
R. Parrett
BRIDGWATER
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
125
130
135
140

Figure 3

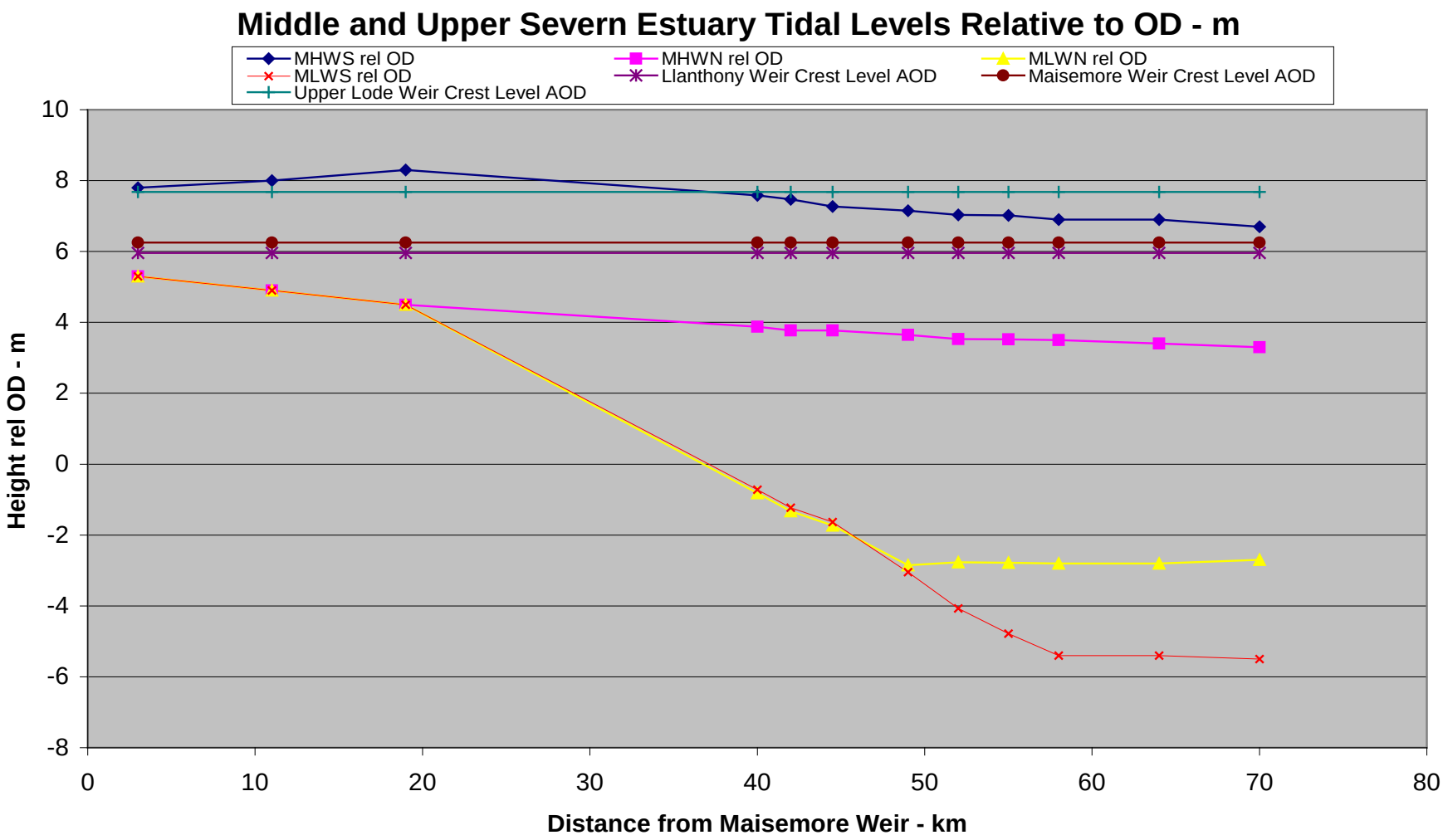

Middle and Upper Severn Estuary Tidal Levels Relative to OD - m
MHWS rel OD
MHWN rel OD
MLWN rel OD
MLWS rel OD
Llanthony Weir Crest Level AOD
Maisemore Weir Crest Level AOD
Upper Lode Weir Crest Level AOD
Height rel OD - m
10
8
6
4
2
0
-2
-4
-6
-8
0
10
20
30
40
50
60
70
80
Distance from Maisemore Weir - km

Figure 4

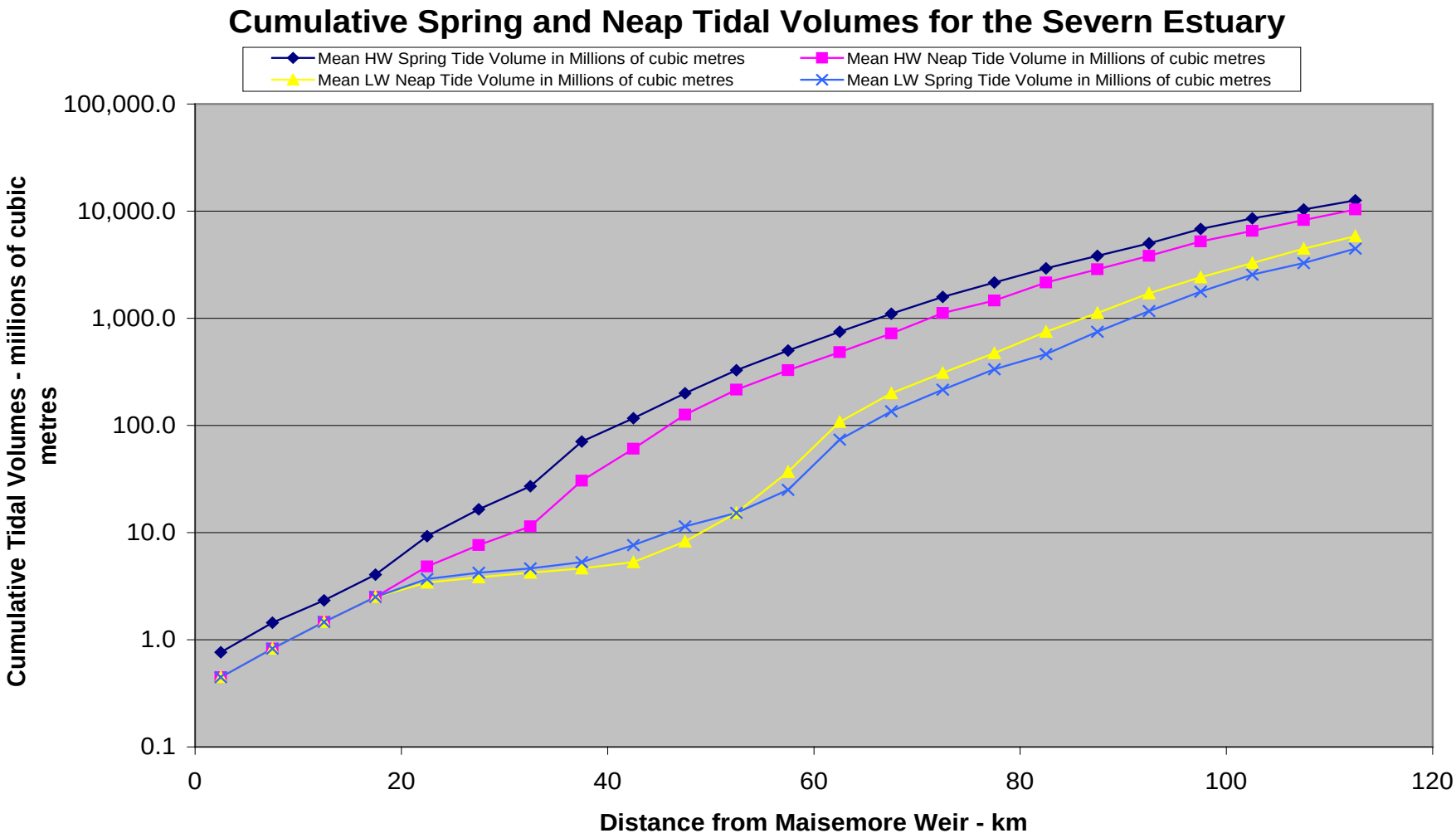

Cumulative Spring and Neap Tidal Volumes for the Severn Estuary
Mean HW Spring Tide Volume in Millions of cubic metres
Mean HW Neap Tide Volume in Millions of cubic metres
Mean LW Neap Tide Volume in Millions of cubic metres
Mean LW Spring Tide Volume in Millions of cubic metres
Cumulative Tidal Volumes - miillions of cubic metres
100,000.0
10,000.0
1,000.0
100.0
10.0
1.0
0.1
0
20
40
60
80
100
120
Distance from Maisemore Weir - km

Figure 5

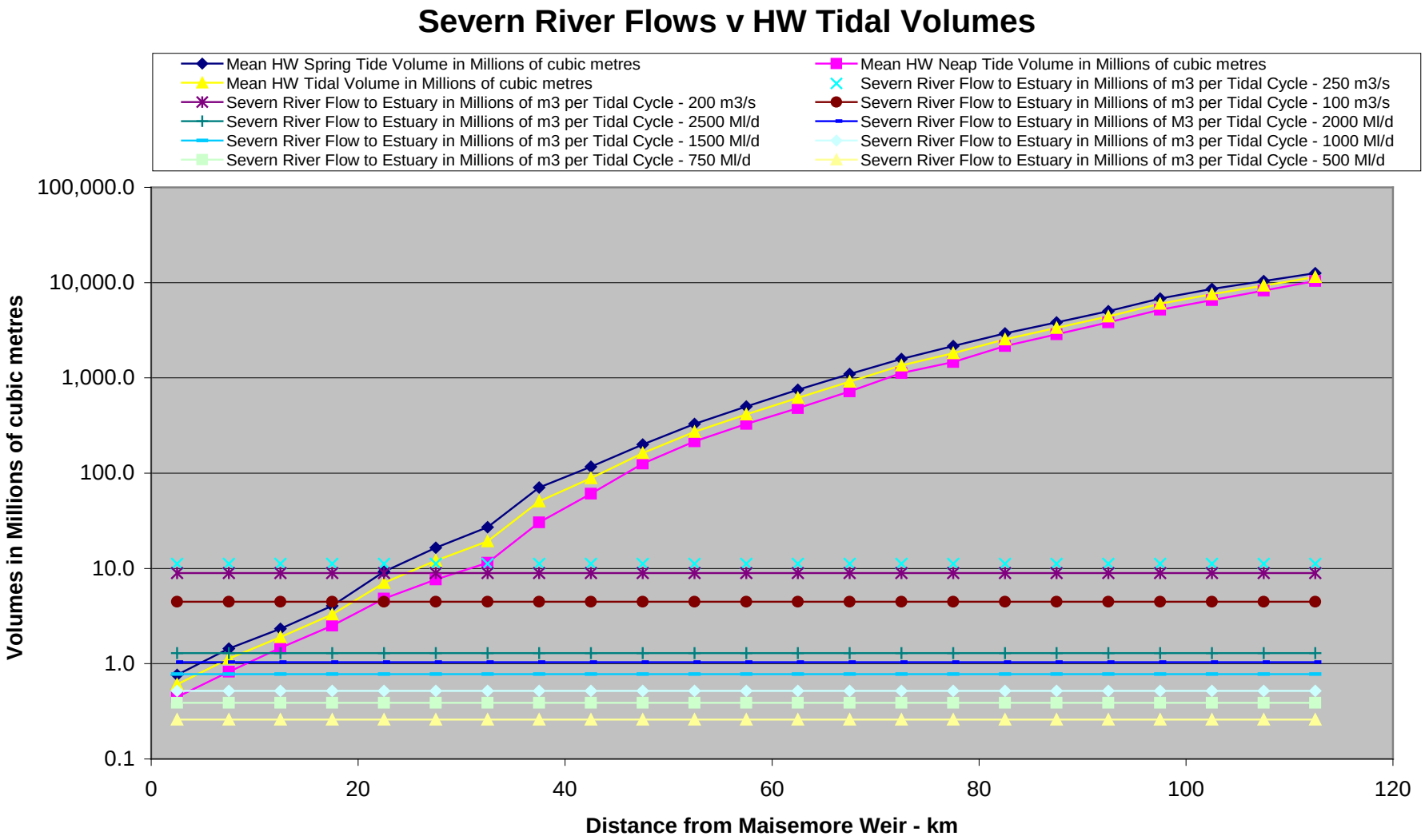

Severn River Flows v HW Tidal Volumes
Mean HW Spring Tide Volume in Millions of cubic metres
Mean HW Neap Tide Volume in Millions of cubic metres
Mean HW Tidal Volume in Millions of cubic metres
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 250 m3/s
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 200 m3/s
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 100 m3/s
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 2500 Ml/d
Severn River Flow to Estuary in Millions of M3 per Tidal Cycle - 2000 Ml/d
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 1500 Ml/d
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 1000 Ml/d
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 750 Ml/d
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 500 Ml/d
100,000.0
10,000.0
1,000.0
100.0
10.0
1.0
0.1
Volumes in Millions of cubic metres
0
20
40
60
80
100
120
Distance from Maisemore Weir - km

Figure 6

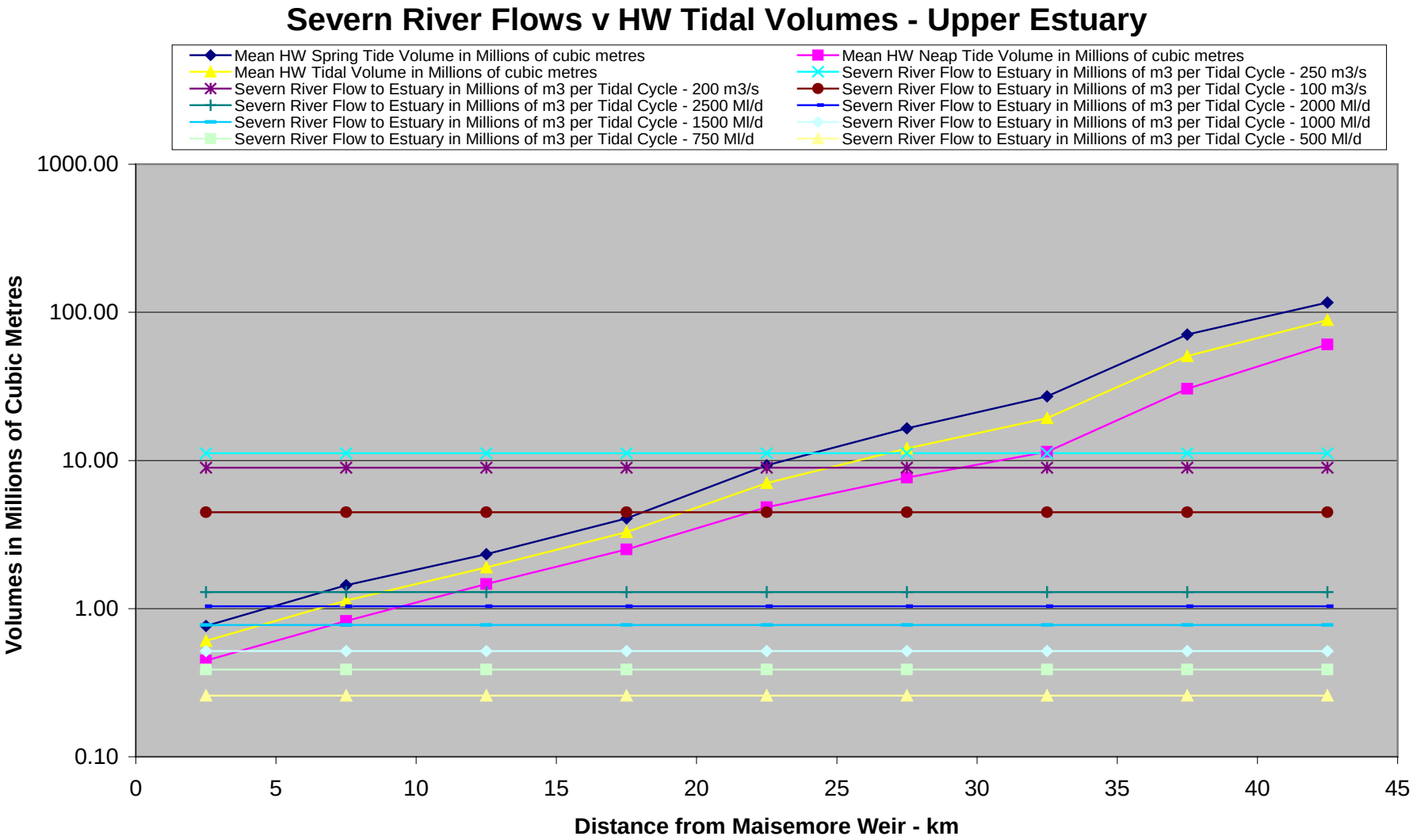

Severn River Flows v HW Tidal Volumes - Upper Estuary
Mean HW Spring Tide Volume in Millions of cubic metres
Mean HW Neap Tide Volume in Millions of cubic metres
Mean HW Tidal Volume in Millions of cubic metres
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 250 m3/s
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 200 m3/s
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 100 m3/s
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 2500 Ml/d
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 2000 Ml/d
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 1500 Ml/d
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 1000 Ml/d
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 750 Ml/d
Severn River Flow to Estuary in Millions of m3 per Tidal Cycle - 500 Ml/d
1000.00
100.00
10.00
1.00
0.10
Volumes in Millions of Cubic Metres
0
5
10
15
20
25
30
35
40
45
Distance from Maisemore Weir - km

Figure 7

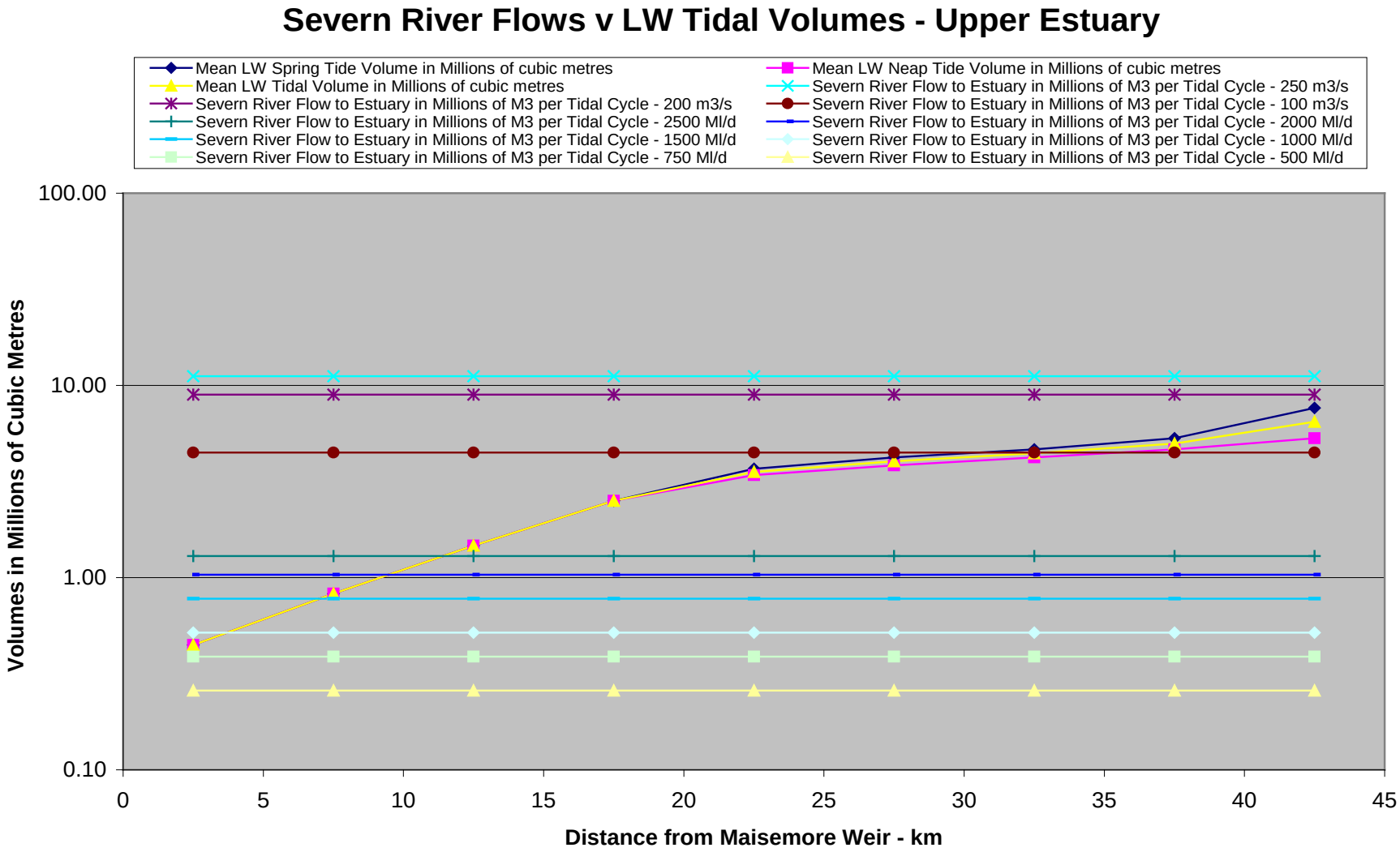

Severn River Flows v LW Tidal Volumes - Upper Estuary
Mean LW Spring Tide Volume in Millions of cubic metres
Mean LW Neap Tide Volume in Millions of cubic metres
Mean LW Tidal Volume in Millions of cubic metres
Severn River Flow to Estuary in Millions of M3 per Tidal Cycle - 250 m3/s
Severn River Flow to Estuary in Millions of M3 per Tidal Cycle - 200 m3/s
Severn River Flow to Estuary in Millions of M3 per Tidal Cycle - 100 m3/s
Severn River Flow to Estuary in Millions of M3 per Tidal Cycle - 2500 Ml/d
Severn River Flow to Estuary in Millions of M3 per Tidal Cycle - 2000 Ml/d
Severn River Flow to Estuary in Millions of M3 per Tidal Cycle - 1500 Ml/d
Severn River Flow to Estuary in Millions of M3 per Tidal Cycle - 1000 Ml/d
Severn River Flow to Estuary in Millions of M3 per Tidal Cycle - 750 Ml/d
Severn River Flow to Estuary in Millions of M3 per Tidal Cycle - 500 Ml/d
100.00
10.00
1.00
0.10
Volumes in Millions of Cubic Metres
0
5
10
15
20
25
30
35
40
45
Distance from Maisemore Weir - km

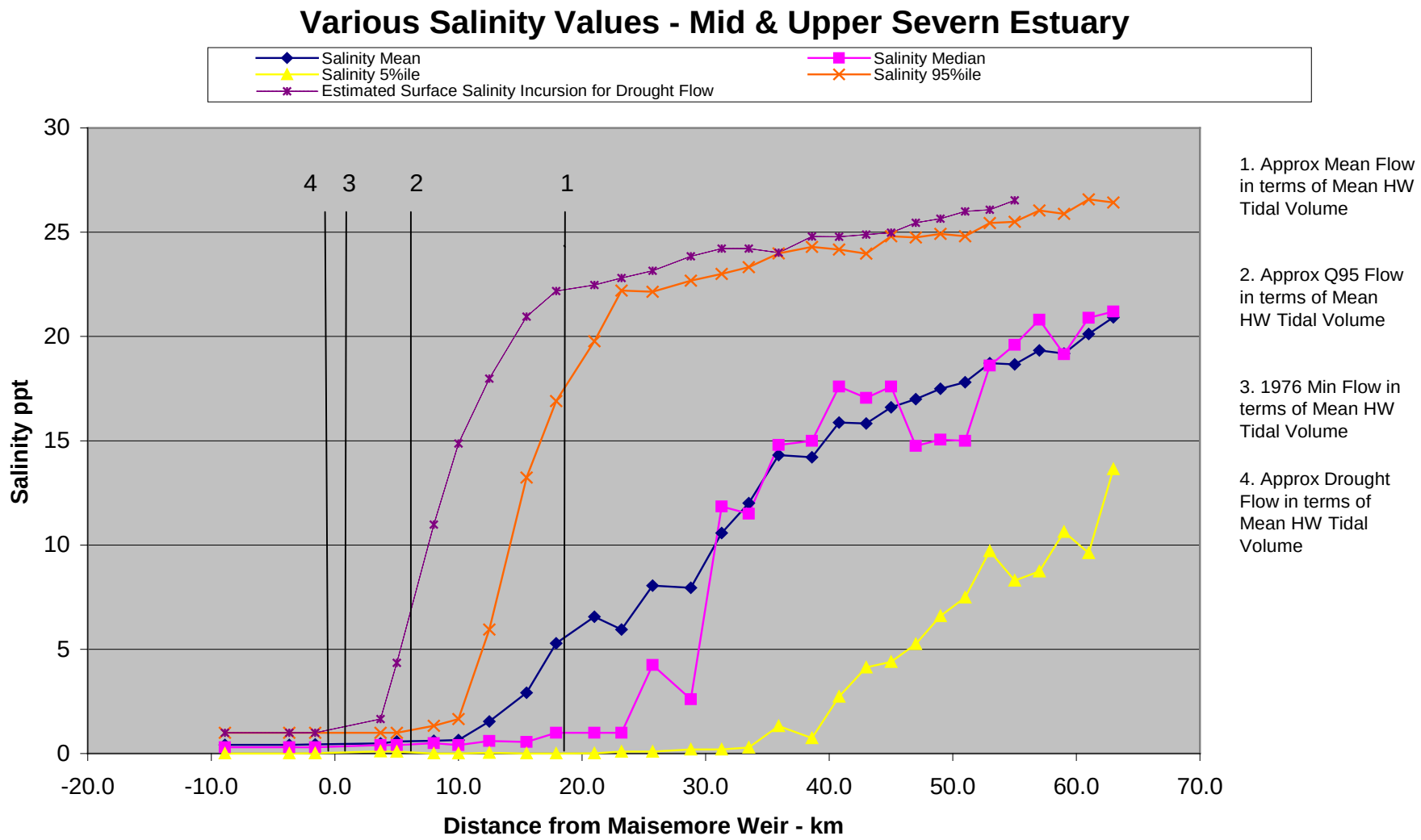
Figure 8


RIVER SEVERN. – LLANTHONY WEIR and EAST CHANNEL.
20th AUGUST 1976.

Figure 9


RIVER SEVERN. – MAISEMORE WEIR and WEST CHANNEL.
20th AUGUST 1976.

Figure 10



1. Approx Mean Flow in terms of Mean HW Tidal Volume

2. Approx Q95 Flow in terms of Mean HW Tidal Volume

3. 1976 Min Flow in terms of Mean HW Tidal Volume

4. Approx Drought Flow in terms of Mean HW Tidal Volume

Appendix 5:

Additional Fisheries information

Appendix 5: Additional Fisheries information

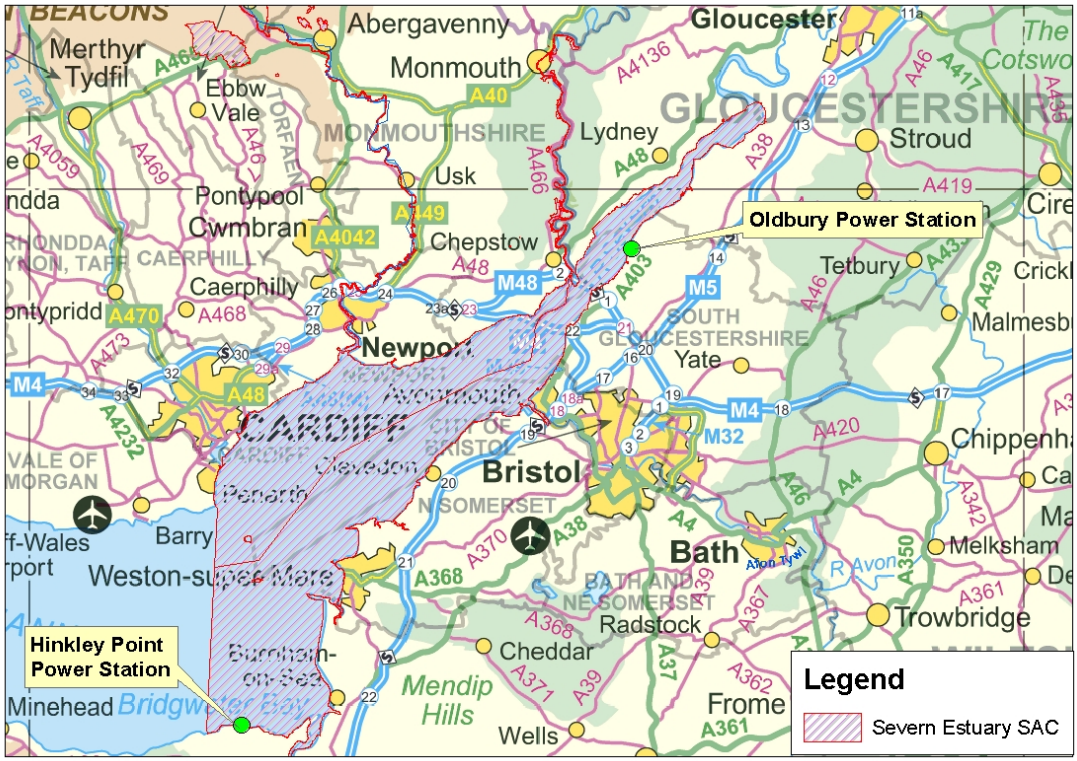
Introduction

The Severn Estuary is one of Europe's most important estuarine nursery areas for fish, even with the issues caused by its unique character. The level of primary production in the Severn Estuary is severely impacted by poor light penetration due to high sediment loads. These turbid waters limit the production of both phytoplankton and attached algae (potential food source). Added to this the high bed shear stresses and instability of the estuary bed has a major impact on the sub tidal invertebrates (another potential food source). However, in areas where the substrate is more stable populations of invertebrates flourish ensuring an important food source for the fish of the estuary.

The Severn Estuary is important for its migratory fish, which assisted in its designation as a SAC. The Annex II species found within the estuary include twaite shad (Alosa fallax), river lamprey (Lampetra fluviatilis) and sea lamprey (Petromyzon marinus). The Severn also has the following notable migratory species: Atlantic salmon (Salmo salar), sea trout (Salmo trutta morpha trutta) and European eel (Anguilla anguilla).

Also the large fish assemblage within the estuary is one of the important features in the designation of the estuary as a RAMSAR site.

Figure 1. Map of Severn Estuary SAC with power station sampling points



Available Data

Due to the enormous size of the Severn Estuary monitoring of the fish population is extremely difficult. The best fish data collected to date has been from the power station intakes at Oldbury (ST 60633 94448) and Hinkley Point (ST 21155 46107) Power Stations. Individuals become entrained on the cooling water-intake screens used at power stations these are washed off into metal cages and can then be counted. Obviously this form of monitoring has an element of bias as

only fish swimming near location of intakes are entrained and pelagic species have a better chance of avoiding the intake. Also juvenile fish are generally slower and weaker swimmers so more likely to be entrained. However, this long term data set (especially at Hinkley Point) is invaluable as an estimate of the fish community of the Severn Estuary.

Another source of information is from the Severn netsmen. These fishermen use traditional methods almost unique to the River Severn to catch Atlantic salmon. The Environment Agency also has a Transitional fish sampling programme for the Severn Estuary mainly using fyke and seine netting.

Table 1. Environment Agency tidal lower Severn and upper estuary transitional monitoring sites

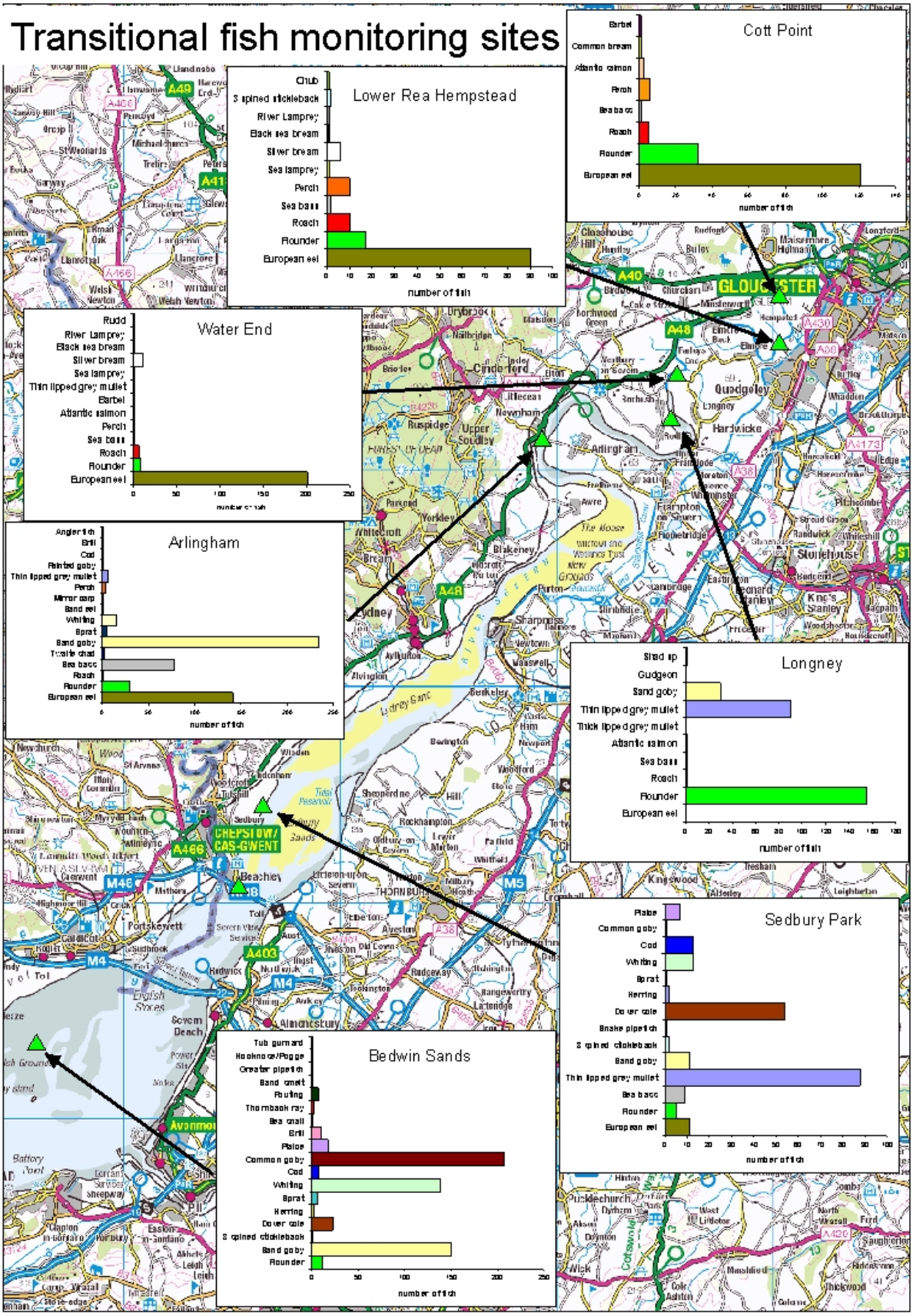
Site Name	Method	NGR	First Surveyed
Bedwin Sands	Otter Trawl	ST4602383542	2007
Sedbury Park	Seine Net	ST5650994499	2008
Arlingham Passage	Fyke Net	SO6937011428	2007
Longney	Seine Net	SO7536212378	2008
Lower Rea Hempstead	Fyke Net	SO8033315876	2008
Water End	Fyke Net	SO7560814407	2008
Cott Point	Fyke Net	SO8033018051	2008

There has been limited success in radio tracking fish within the Severn Estuary due to the difficulty in catching large enough numbers.

There is unfortunately no fish counter on the lower River Severn either to assess movement of migratory fish.

More research papers and Government documents have been produced recently due to the interest in harnessing the tidal power of the estuary for electricity generation. This has increased understanding of this system and provided access to more information.

Figure 2. Map showing locations and numbers of fish caught at transitional monitoring sites within the lower tidal Severn and upper estuary (EA)



Fish Population Present

A list of fish species recorded in Bridgewater Bay are displayed in Table 2. This shows the wide diversity of fish present in the estuary with their corresponding functional group:

- Marine Migrant – species where adults live and breed in marine environments, with juveniles frequently found in estuaries in large numbers. Juveniles can be opportunistic (i.e. can find suitable conditions within or outside estuaries), or dependant (i.e. require estuarine types of habitat).
- Marine Straggler – generally marine species abundant in the marine environment but occurring infrequently in the Severn Estuary
- Estuarine Species – species that typically occur and breed in estuaries
- Freshwater Straggler – species that typically occur and breed in freshwater but are found in low numbers in the Severn Estuary
- Anadromous – species that migrate from the sea into freshwater to breed
- Catadromous – species migrating from freshwater into the sea to breed

The majority of the fish species in this list are highly mobile and will move up and down the estuary with changing tides and seasons. Results from Oldbury (Table 3) show that the main fish caught at this point of the estuary over a long period tend to be sprat, whiting, sand goby and bass. Variations overtime have been noted for certain species by Hendersen and Bird (2010) with some changes related to recent warming (water temperature) and the North Atlantic Oscillation. Species such as the European eel have seen a national decline caused possibly by excessive fishing for elvers, freshwater habitat degradation, barriers to migration and the introduction of parasite Anguillicola crassus from Asia (Hendersen, Seaby and Somes, 2007). What is interesting is that at Oldbury the European eel was still ranked 9th in the 1972 to 1977 and the 2006 to 2011 catches. This could suggest that numbers in this part of the estuary have not seen as marked a decline. However, reports by Hendersen, et al. (2007) have highlighted major concerns with falling eel numbers at Hinkley Point.

Table 2. List of species recorded within from Hinkley Point and functional group

(taken from Severn Tidal Barrage Scoping Topic Paper, 2008)

Species	Functional Group	Species	Functional Group
Anchovy *Engraulis encrasicolus*	MARINE STRAGGLER	Norway pout Trisopterus esmarkii	MARINE STRAGGLER
Angler fish *Lophius piscatorius*	MARINE STRAGGLER	Painted goby Pomatoschistus pictus	MARINE STRAGGLER
Ballan wrasse *Labrus bergylta*	MARINE STRAGGLER	Pearlsides Maurolicus muelleri	MARINE STRAGGLER
Bass *Dicentrarchus labrax*	MARINE MIGRANTS	Perch Perca fluviatilis	FRESHWATER STRAGGLER
Black goby *Gobius niger*	ESTUARINE SPECIES	Pilchard Sardina pilchardus	MARINE STRAGGLER
Black sea bream *Spondyliosoma cantharus*	MARINE MIGRANTS	Piper Trigla lyra	MARINE STRAGGLER
Blonde ray *Raja brachyura*	MARINE STRAGGLER	Plaice Pleuronectes platessa	MARINE MIGRANTS
Blue whiting *Micromesistius poutassou*	MARINE STRAGGLER	Pollack Pollachius pollachius	MARINE MIGRANTS
Brill *Scophthalmus rhombus*	MARINE STRAGGLER	Poor cod Trisopterus minutus	MARINE MIGRANTS
Cod *Gadus morhua*	MARINE MIGRANTS	Pout Trisopterus luscus	MARINE MIGRANTS
Common goby *Pomatoschistus microps*	ESTUARINE SPECIES	Raitt's sandeel Ammodytes marinus	MARINE STRAGGLER
Common sand eel *Ammodytes tobianus*	MARINE STRAGGLER	Red mullet Mullus surmuletus	MARINE STRAGGLER
Common sea snail *Liparis liparis*	MARINE MIGRANTS	River lamprey Lampetra fluviatalis	ANADROMOUS
Conger eel *Conger conger*	MARINE STRAGGLER	Rock cook Centrolabrus exoletus	MARINE STRAGGLER
Corkwing wrasse *Crenilabrus melops*	MARINE STRAGGLER	Rock goby Gobius paganellus	MARINE STRAGGLER
Crystal goby *Crystallogobius linearis*	MARINE STRAGGLER	Saithe Pollachius virens	MARINE STRAGGLER
Cuckoo wrasse *Labrus mixtus*	MARINE STRAGGLER	Salmon Salmo salar	ANADROMOUS
Dab *Limanda limanda*	MARINE STRAGGLER	Sand goby Pomatoschistus minutus	ESTUARINE SPECIES
Dover sole *Solea solea*	MARINE MIGRANTS	Sand smelt Atherina boyeri	ESTUARINE SPECIES
Dragonet *Callionymus lyra*	MARINE STRAGGLER	Scaldfish Arnoglossus laterna	MARINE STRAGGLER
Eel *Anguilla anguilla*	CATADROMOUS	Sea lamprey Petromyzon marinus	ANADROMOUS
Fifteen-spined stickleback *Spinachia spinachia*	MARINE STRAGGLER	Small eyed ray Raja microocellata	MARINE STRAGGLER

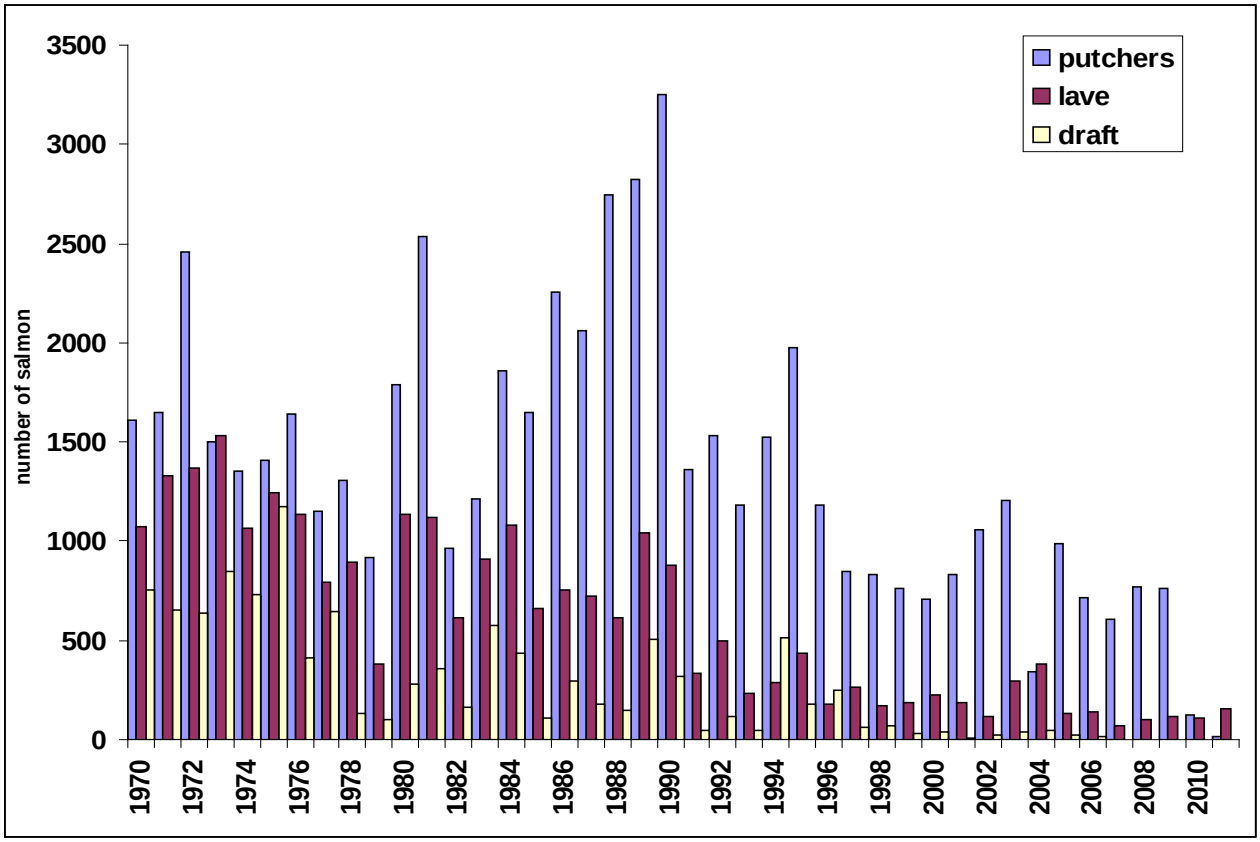
Species	Functional Group	Species	Functional Group
Five-bearded rockling *Ciliata mustela*	MARINE MIGRANTS	Snake pipefish Entelurus aequoreus	MARINE STRAGGLER
Flounder *Platichthys flesus*	MARINE MIGRANTS	Solenette Buglossidium luteum	MARINE STRAGGLER
Garfish *Belone belone*	MARINE MIGRANTS	Sprat Sprattus sprattus	MARINE MIGRANTS
Golden mullet *Liza aurata*	MARINE MIGRANTS	Tadpolefish Raniceps raninus	MARINE STRAGGLER
Goldsinny wrasse *Ctenolabrus rupestris*	MARINE STRAGGLER	Thicklipped grey-mullet Chelon labrosus	MARINE MIGRANTS
Greater pipefish *Syngnathus acus*	MARINE STRAGGLER	Thinlipped grey-mullet Liza ramada	MARINE MIGRANTS
Greater sand eel *Hyperoplus lanceolatus*	MARINE MIGRANTS	Thornback (roker) ray Raja clavata	MARINE STRAGGLER
Grey gurnard *Eutrigla gurnardus*	MARINE STRAGGLER	Three-bearded rockling Gaidropsarus vulgaris	MARINE STRAGGLER
Hake *Merluccius merluccius*	MARINE STRAGGLER	Three-spined stickleback Gasterosteus aculeatus	ESTUARINE SPECIES
Herring *Clupea harengus*	MARINE MIGRANTS	Tompot blenny Parablennius gattorugine	MARINE STRAGGLER
Hooknose (Pogge) *Agonus cataphractus*	MARINE STRAGGLER	Topknot Zeugopterus punctatus	MARINE STRAGGLERS
Horse mackerel *Trachurus trachurus*	MARINE STRAGGLER	Transparent goby Aphia minuta	MARINE STRAGGLER
John dory *Zeus faber*	MARINE STRAGGLER	Trigger Fish Balistes capriscus	MARINE STRAGGLER
Lemon sole *Microstomus kitt*	MARINE STRAGGLER	Tub gurnard Chelidonichthys lucernus	MARINE MIGRANTS
Lesser spotted dogfish *Scyliorhinus caniculus*	MARINE STRAGGLER	Turbot Psetta maxima	MARINE STRAGGLER
Lesser weaver *Trachinus vipera*	MARINE STRAGGLER	Twaite shad Alosa fallax	ANADROMOUS
Ling *Molva molva*	MARINE STRAGGLER	Whiting Merlangius merlangus	MARINE MIGRANTS
Lumpsucker *Cyclopterus lumpus*	MARINE STRAGGLER	Witch Glyptocephalus cynoglossus	MARINE STRAGGLER
Nillson's pipefish *Syngnathus rostellatus*	MARINE MIGRANTS	Worm pipefish Nerophis lumbriciformis	ESTUARINE SPECIES
Northern rockling *Ciliata septentrionalis*	MARINE MIGRANTS		

Table 3. Top ten ranked fish caught at Oldbury Power Station over different time periods

	1972 to 1977	1998 to 1999	2006 to 2011
Sand Goby	1	2	4
Whiting	2	3	1
Flounder	3	8	6
Bass	4	4	2
Sea snail	5	5	7
Poor cod	6		
Thin lipped grey mullet	7	7	10
Twaite shad	8		
European eel	9		9
Herring	10	6	
Sprat		1	3
5 bearded rockling		9	
Cod			5
Snake pipefish			8
Dab		10	

Salmon catches within the estuary are displayed in Figure 3. A general reduction in numbers of salmon caught was noted through the 1990's, with a slight recovery in the early part of the 2000's. Fishing effort in the salmon net fishery has reduced nationally over the past two decades, partly as a result of the phasing out of fisheries that target mixed stock. This could account for some of the decline. However, with water quality improvements the Severn netsmen believe that there have been marked improvements in salmon runs over last 10 years (pers comm. John Powell 13/12/11).

Figure 3. Annual salmon catch return data for commercial putchers, lave and draft nets in the River Severn



The transitional fish monitoring programme for the Severn Estuary involves results mainly from fyke and seine netting. Sites used were mainly in the Upper Estuary (Figure 2) as this is anticipated to be the area most likely to show any impact from low freshwater flows. The most upstream site (Cott Point) is dominated by freshwater species and within the section we call Tidal Lower Severn. The only estuarine or marine species caught were flounder and sea bass. The European eel dominates these sites with general lengths around 400mm. At Bedwin Sands (below Severn crossing) estuarine and marine migrants dominate (common and sand goby and whiting)

Table 4. Fish species occurring in transitional fish surveys by EA from 2007 to 2011 (with top 10 caught fish numbered)

3 spined stickleback	Herring	Sea snail
Angler fish	Hooknose/Pogge	Shad sp
Atlantic salmon	Mirror carp	Silver bream
Barbel	Painted goby	Snake pipefish
Black sea bream	Perch	Sprat
Brill	Plaice 9	Thick lipped grey mullet
Chub	Pouting	Thin lipped grey mullet 5
Cod	River Lamprey	Thornback ray
Common bream	Roach 10	Tub gurnard
Common goby 4	Rudd	Twaite shad
Dover sole 8	Sand eel	Whiting 6
European eel 1	Sand goby 2	
Flounder 3	Sand smelt	
Greater pipefish	Sea bass 7	
Gudgeon	Sea lamprey	

Figure 4. Number of fish caught at Cott Point using fyke nets 2008 to 2011

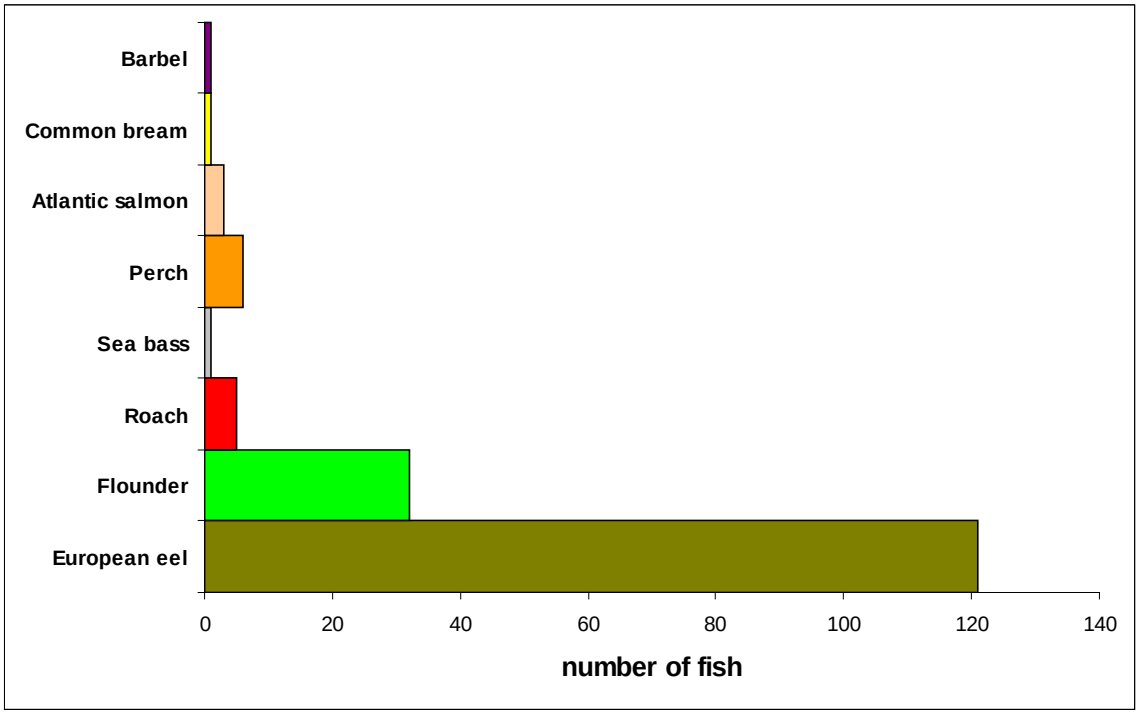


Figure 5. Number of fish caught at Lower Rea Hempstead using fyke nets 2008 to 2011

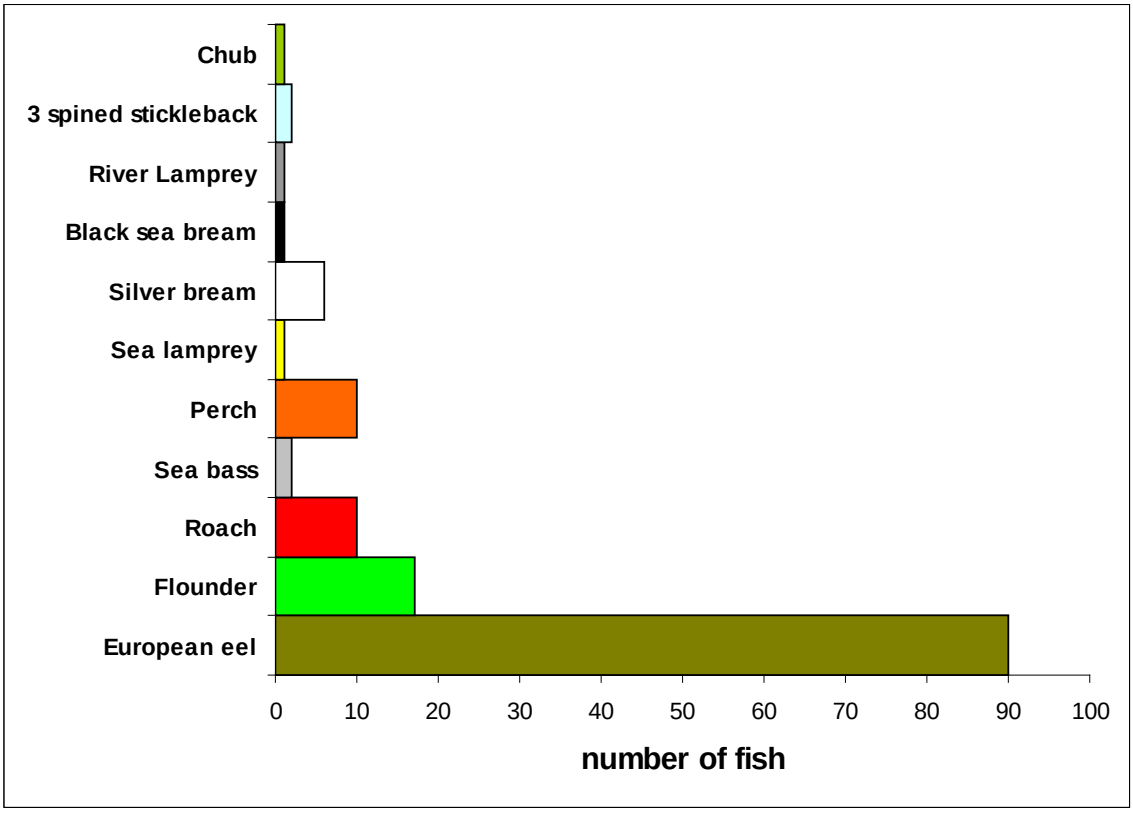


Figure 6. Number of fish caught at Water End using fyke nets 2008 to 2011

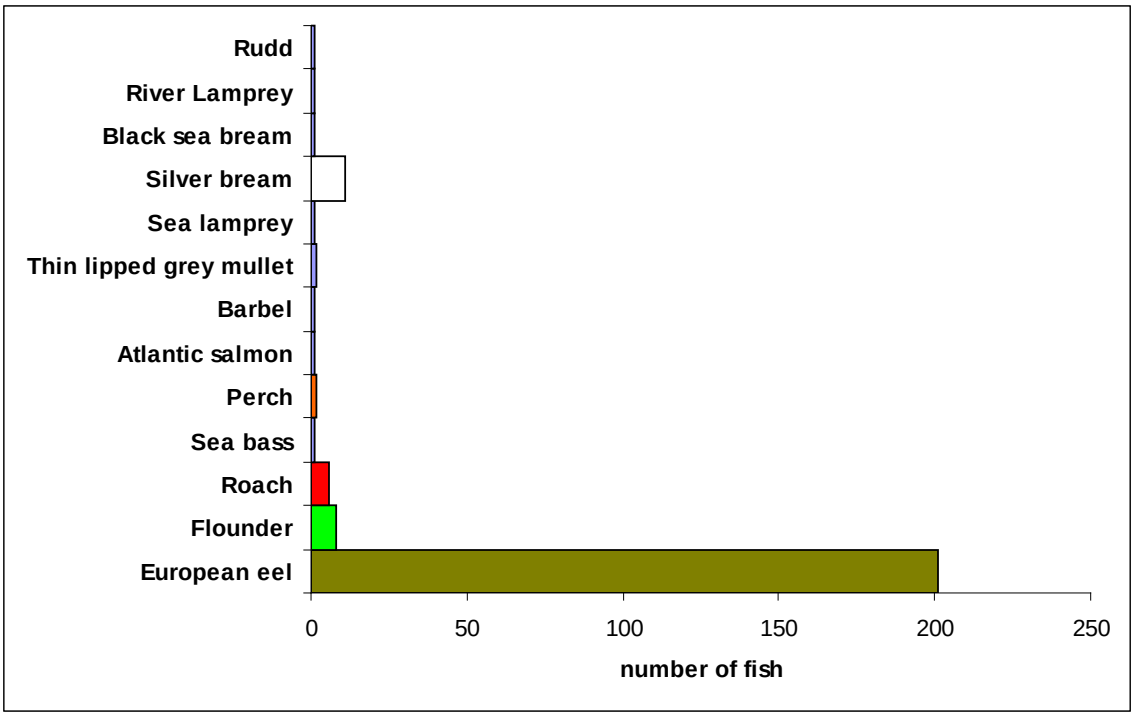


Figure 7. Number of fish caught at Longney using seine nets 2008 to 2011

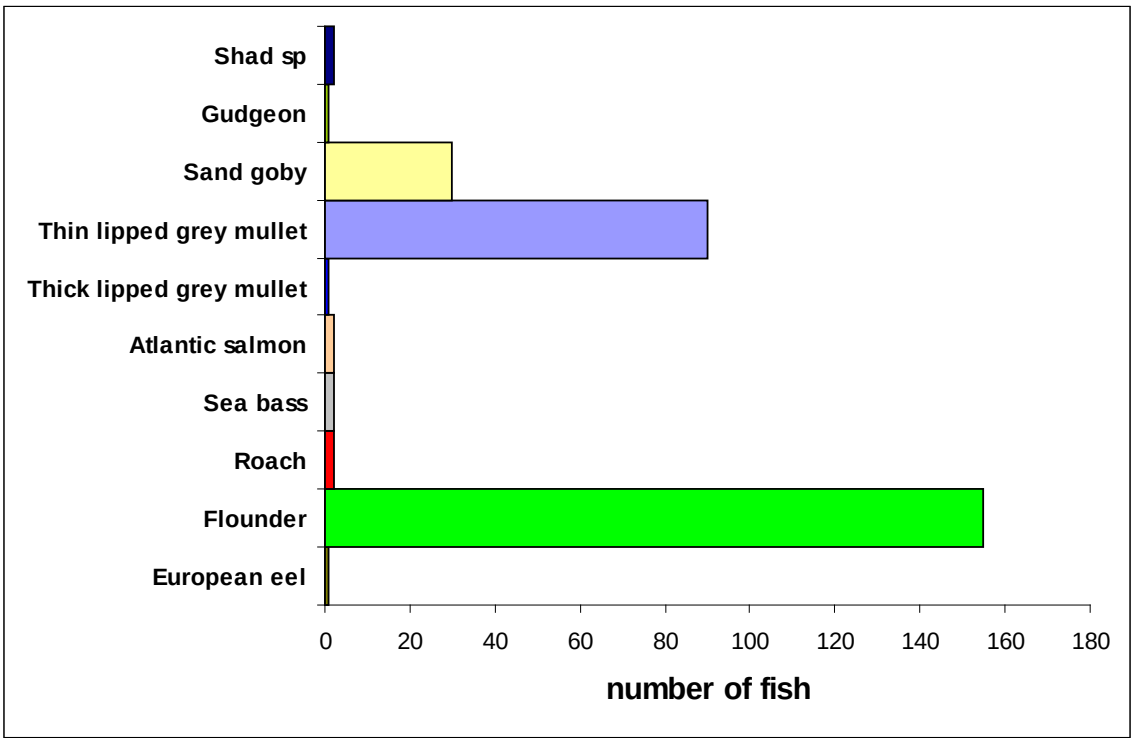


Figure 8. Number of fish caught at Arlingham Pass using fyke nets 2007 to 2011

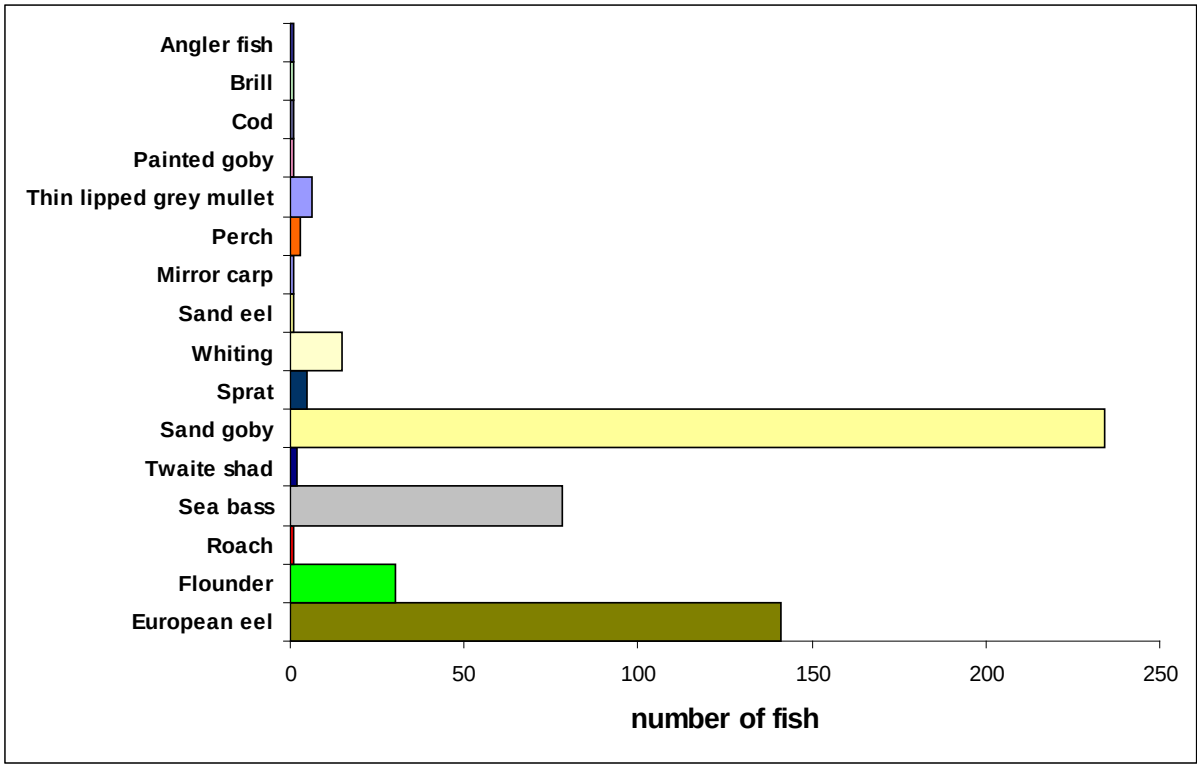
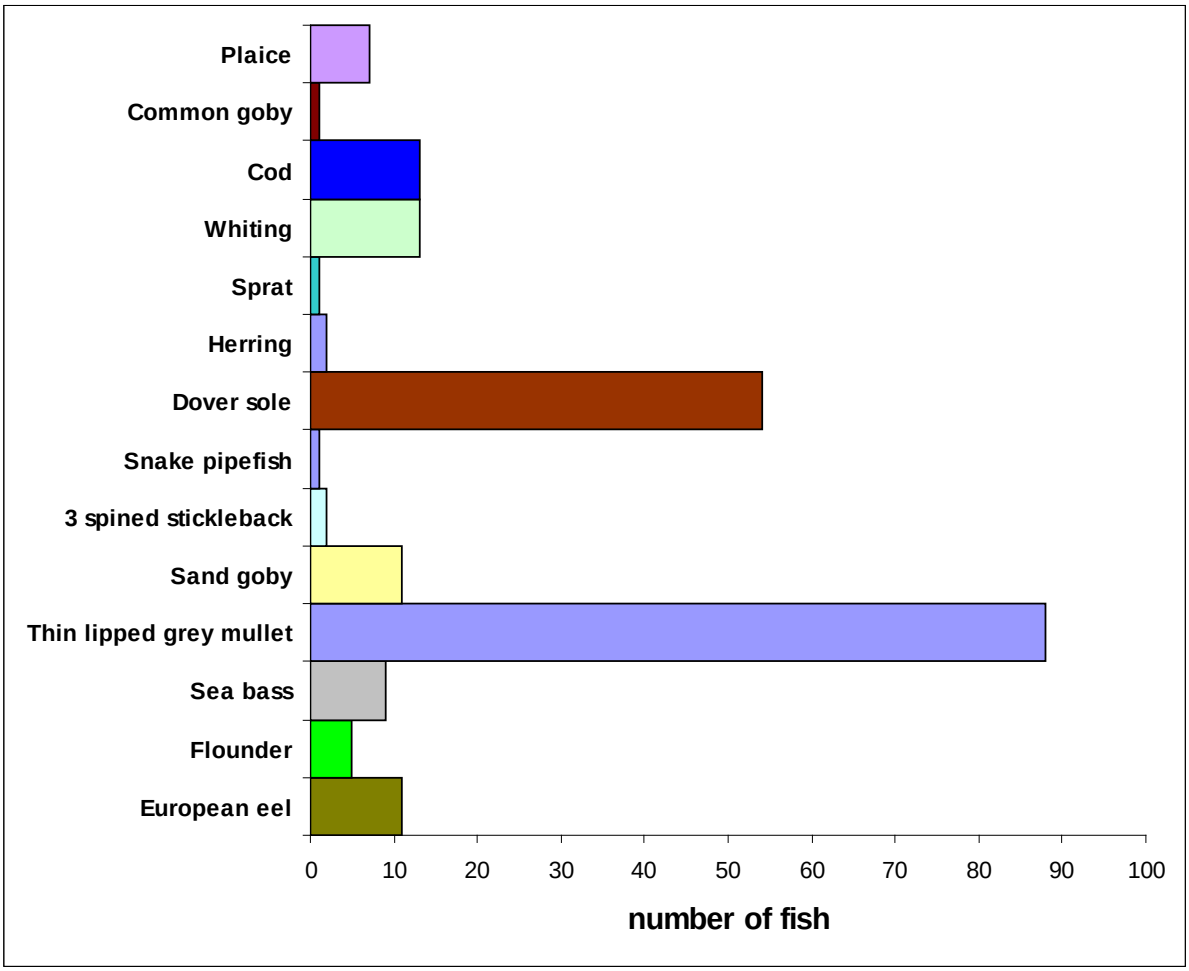


Figure 9. Number of fish caught at Sedbury Park using seine nets 2008 to 2011



Impacts of Lowering Flows

Tidal reaches respond to flow in similar ways to lowland freshwater reaches but are also vulnerable to changes in salinity due to the interactions between freshwater flows, winds and tides. Many tidal reaches exhibit long residence times for the water in them, leading to exacerbation of water quality problems. Tidal rivers are hence vulnerable to low freshwater flows during several periods of the year. In summer the impacts are likely to be associated with water quality, typically the development of mobile zones of low oxygen and high ammonia that can be lethal to fish especially in summer when temperatures are also high. This is especially relevant to salmonids attempting to pass through these zones. Low flows allow the ingress of seawater during spring tides, particularly when exacerbated by storm conditions. These can lead to fish kills especially where fish are unable to escape upstream into freshwater due to physical barriers, or where they become trapped in off-channel areas such as marinas or dykes. As with freshwater lowland reaches, tidal river reaches are commonly heavily modified and these modifications interact with the impacts of flow regimes to exacerbate problems for fisheries.

The Severn Estuary is used extensively by juvenile fish and the majority of these move into deeper water in winter (with higher freshwater flows entering the estuary), but sprat and eel appear to do the opposite and move into the estuary. Many of the fish species living in the Severn Estuary are adapted to tolerate high turbidity and a wide range of temperatures, salinity and oxygen concentrations (Bird, 2008). Therefore these are unlikely to be impacted by slight changes in freshwater flows. The species most likely to be impacted by the lowering of freshwater flows are those that migrate from sea to freshwater as part of their lifecycle (Twaite shad, sea and river lamprey, Atlantic salmon, sea trout and European eel).

The main impacts in the estuary caused by a lowering of freshwater flows could be an increase in the occurrence of dissolved oxygen sags and increase saline intrusion. The reason for the dissolved oxygen sags in the estuary are as follows.

During neap tides, fine silt accumulates. This silt contains organic material of natural origin and from the effluent discharges upstream in addition to the settled sewage from Netheridge. Bacterial action in this silt rapidly uses up available oxygen. It then produces chemicals able to react rapidly with oxygen which becomes available when the silt is re-suspended during spring tides by high inflowing velocities. This reaction causes a rapid depletion of the dissolved oxygen. The effect is repeated on successively low tides, each of which re-suspends more sediment, until very low dissolved oxygen levels can be reached. These effects combined with high water temperatures caused the death of many salmon, eels and other fish at the end of June 1976. (Severn Trent Water, 1977).

In the late 1980’s and early 1990’s large fish kills were noted in the Severn Estuary. Wade (1992) listed fish kills recorded during this period (see below).

25/6/89 River Severn, Longney 114 salmon, 2 eels, 1 twaite shad, 1 bream and sea lamprey. Cause thought to be low dissolved oxygen (<0.5ppm), fish from Parting to Bollow

10/7/89 River Severn, Epney 45 salmon. Low dissolved oxygen associated with storm water from Netheridge

26/6/90 River Severn, Minsterworth minimum of 30 salmon. High temperatures, low freshwater flows, high spring tides and low dissolved oxygen

7/7/92 River Severn at Kadam Pool, Weir Green and Longney 27 salmon (minimum). Low dissolved oxygen with spring tide influence

He concluded that Netheridge Water Reclamation Works and the abstraction by British Waterways for the Gloucester & Sharpness Canal were having a detrimental impact on dissolved oxygen levels and hence the cause of fish kills. The majority of these reported fish kills and those from the 1976 drought tended to occur in June and July, which is before the main impacts of the modelled

drought scenarios. Water quality has improved significantly at Netheridge and now salmon deaths are very rarely recorded.

All the evidence discussed so far in hydrology and saline intrusion section of this document suggests that the main area of concern regarding impacts from a drought and the impact of a River Severn Drought Order would be in the lower tidal Severn i.e. above the Severn SAC. Therefore the main fish to be impacted are likely to be freshwater and migratory fish.

Specific Fish of Importance to Estuary

Table 5. List of important migratory fish and their key prey species

Prey species Assemblage Species	Key prey species
Twaite shad	Small crustaceans, especially mysids and copepods, small fish, especially sprats and anchovies, and fish eggs (Maitland, P.S. & Hatton-Ellis 2003).
Allis shad	Small crustaceans, especially mysids and copepods, small fish, especially sprats and anchovies, and fish eggs (Maitland, P.S. & Hatton-Ellis 2003).
Sea lamprey	Eel *Anguilla anguilla*, cod *Gadus morhua*, and haddock *Melanogrammus aeglefinus* are all potential prey species for the sea lamprey found within the Severn Estuary (Bird 2008)
River lamprey	Sea trout *Salmo trutta*, shad *Alosa fallax/Alosa alosa*, herring *Clupea harengus*, sprat *Sprattus sprattus*, flounder *Platichthys flesus* and small gadoids such as whiting *Merlangius merlangus* and pout *Trisopterus luscus* are all potential prey species for the river lamprey found within the Severn Estuary (Bird 2008).
Salmon	While at sea, salmon feed on a variety of fish (e.g. herring, sprat, sand eel, mackerel, and various gadoids) and crustaceans (e.g. euphausiid shrimps, prawns, gammarid amphipods and various crabs). (Bird, 2008)
Sea trout	The diet of this species at sea has not been much studied but is believed to include a range of fish species including sprat, young herring and sand eels as well as crustaceans such amphipods (e.g. Corophium), gammarids, decapods such as Crangon and mysid shrimps. Many of these prey items also occur in estuaries where sea trout are known to feed extensively. (Bird, 2008)
Eel	A range of benthic organisms that include crustaceans and small fish. (Bird, 2008)

Twaite Shad

Adult twaite shad enter the Severn Estuary between April and June with males generally migrating upstream first followed by females one or two weeks later (Maitland and Hatton-Ellis, 2003). Adults appear to move up estuaries on spring tides when freshwater flows are not too high (Aprahamian, 1982) and hence this upstream migration is not expected to be impacted by any of the management options.

Juveniles migrate down to the estuary and remain in the upper estuary for their first summer, tending to move seaward over winter. Within the estuary where fresh and saline water meet there is an abundance of prey species (mysids) and these are particularly important to the juvenile twaite shad population. The actual position varies according to the state of the tide and volume of freshwater input to the estuary. Therefore it must be assumed that any activity that affects the

salinity regime of the estuary would in turn impact the distribution of these prey species (taken from The Severn Estuary European Marine Site). This might cause the juvenile shad to move further upstream during low freshwater flows as in the Acute or Chronic drought scenarios. With the low freshwater flows intermittent dissolved oxygen sags would occur in the Severn and the juvenile shad would be vulnerable. This would be more of an issue in the ' Do Nothing' management option where flows seriously crash in the late summer. Also if British Waterways were to abstract their maximum quantity it is possible that there would be virtually no freshwater flow entering the estuary.

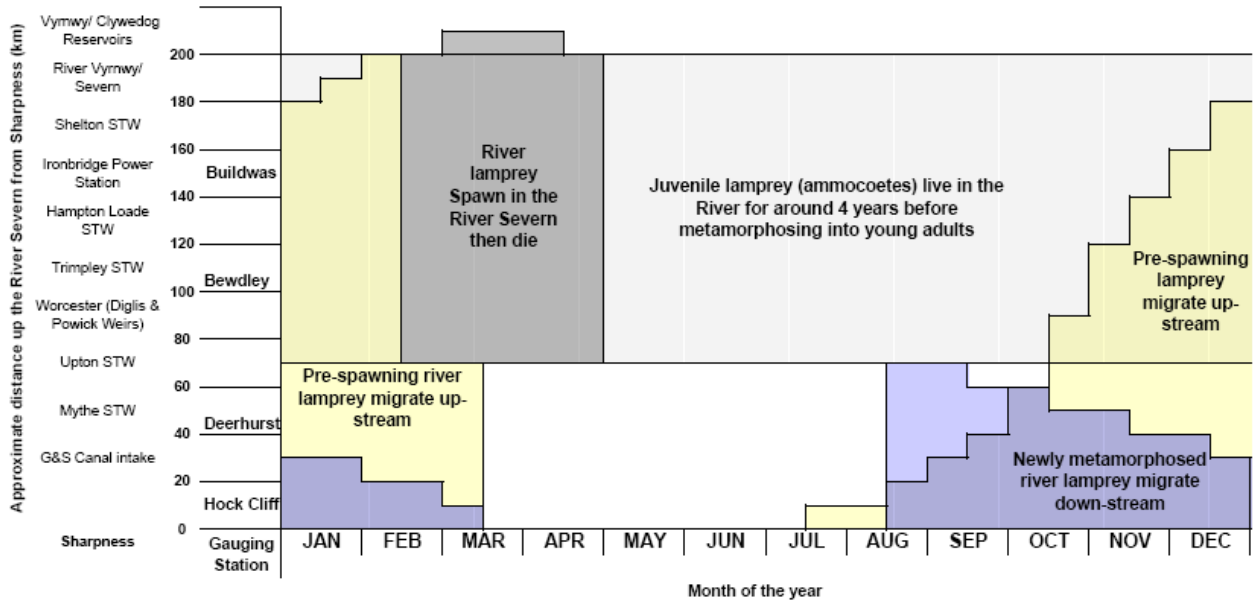
Allis shad are very similar to twaite shad except they tend to be larger and migrate further upstream during migration. Adult fish have occasionally been recorded from samples at Oldbury (Bird, 2008), but this is a rare event. There are no confirmed spawning sites for allis shad in the UK (Maitland,2003) and so it is unlikely that this species would be impacted by low freshwater flows.

Lamprey

Sea and river lamprey are both anadromous and migrate into freshwater to breed. Through the Review of Consent for the estuary it was decided that there would be no impact on sea lamprey by low flows. The best conditions for high recruitment might be relatively high water from April to June to aid upstream migration and increase the areas of spawning gravel available, followed by lower flows from June onwards, which would help larvae to disperse across suitable habitat downstream, but not wash them away (Maitland 2003). This could mean that the lowering of the flow earlier in the year with the RSDO and full in combination for the Chronic scenario might limit spawning distribution.

The life history of river lamprey is different (see Figure 11) with migration through the estuary and up the River Severn taking place primarily in October to March. The fish adjust their migration to respond to the physical conditions in the river. This means that river lamprey are highly adaptable to flow conditions, but would favour higher flows during the upward migration period of October to March when flows are not considered to be an issue. It is suggested that adult river lamprey do not move far from the coast during adult feeding stage as main fish to have been attacked by lamprey being migratory or brackish water species (see Table 5). The adult river lamprey while feeding in the estuary would be vulnerable to the intermittent dissolved oxygen sags that might increase in frequency in drought conditions.

Figure 11. Approximate movements of river lamprey in River Severn (Taken from RoC)



Atlantic Salmon

Atlantic salmon are anadromous and migrate into freshwater to breed. Adult salmon returning to their home rivers arrive in the estuary in most months of the year, although those entering between January - April inclusive - the so-called spring salmon - have become much depleted over the past few decades (pers. comm. Pete Gough 2012). As salmon enter their natal river estuaries their behaviour appears to be very variable. Some fish move up through the estuary into freshwater very quickly (9 hours) while others have been observed to drift passively with the tide (taking up to 130 days). However, the majority of fish appear to take only a few tide cycles (Tidal barrage report, 1989). High freshwater flows are a key mechanism in triggering upstream migration, although temperature and water quality also have an impact. Solomon and Sambrook (2004) describe the uncertainty and interconnection of various influences upon salmon, with flow being a central factor but not necessarily the strongest influence over successful entry to river. Their study, concluded that high temperatures and at time low dissolved oxygen levels were the major influences for failed river entry during the study period.

Salmon smolts move down into estuary relative to strength of freshwater flows (December to June). Most likely drift passively on tides as acclimatise to saline conditions and then will swim positively seaward. (Tidal barrage report 1989)

Adult salmon within the estuary awaiting to migrate upstream are vulnerable to dissolved oxygen sags, caused by low freshwater flows, and large numbers of salmon were killed during the droughts of 1976 and 1989 usually in June and July within the section tidal lower Severn. One possible reason for salmon deaths in this section during June and July might be due to weaker spring run fish that did not make it up into main river were then caught out by high tides and as already stressed succumbed to low dissolved oxygen levels. Salmon kills are not as frequent in estuary after 1990's improvements on water quality (Netheridge WRW).

A study by Greest (2009) on the impact of freshwater flows into salmon entry to the Rivers Wye and Usk used a statistical model of salmon migration and flow to demonstrate that any reduction in freshwater flow reduces the number of salmon successfully entering freshwater. Greest (2009) also concluded that water quality is a significant factor at low flows, with flow reductions likely to exacerbate poor water quality.

What needs to be appreciated is that the Bristol Channel and Severn Estuary (SAC) contain populations of salmon derived from a number of salmon-producing rivers. The probability of salmon entering their home river is dependent on freshwater discharge: in high flows this might be prompt however during low flows delay within the estuary or sub-estuary will occur and increased natural loss or mortality then occurs. Prolonged estuary residence is possible in extended low flow periods. The adult fish are a mixed stock of fish from different rivers, ranging from the Severn itself to those along the south coats of Wales including the Wye, Usk and Tywi Natura 2000 sites, to the recovering industrial rivers (Rhymney, Taff, Ogmore, Afan, Neath and Tawe. there is some evidence for fish derived from even further away. The salmon present in the estuary are in the process of identifying their home rivers and a high level of fidelity to those rivers has been widely documented. The fish, whilst resident, will make multiple temporary ascents and descents of the estuary, and may make temporary excursions into sub-estuaries before leaving to locate and enter their own rivers (pers. comm. Pete Gough 2012). Therefore the potential reduction in freshwater flow in the River Severn would reduce attraction of Severn salmon to their home river and hence an extended residence period in the estuary and lower probability of their eventual successful entry to the River Severn. The large scale of the droughts being assessed that would require the implementation of the RSDO would presumably be impacting the other rivers flowing into the Severn Estuary creating further issues of salmon residing within the estuary for longer. Some salmon waiting to ascend the River Severn tend to wait down below the second Severn crossing (pers. comm. John Powell 2011) while waiting for migratory trigger. This is below the section where impact is to be expected from altering freshwater flows.

Sea Trout

Sea trout are anadromous and a migratory form of the brown trout and breed in rivers from October to February. Very few observations have been made of sea trout within the Severn

Estuary with very limited angling interest. Sea trout smolts tend to remain longer in estuarine waters before heading out to sea.

It will be the adults waiting for increased winter flows to begin upstream migration and the smolts feeding in the estuary that are most likely to be impacted by an acute or Chronic drought. As salmonids they require good water quality and so would be vulnerable to dissolved oxygen sags.

European Eel

The European eel is catadromous and is believed to breed in the Sargasso Sea. The adult eels migrate out of the rivers and are most abundant in the estuary in September and October. Spawning takes place out at sea in spring and summer. The planktonic larvae (leptocephali) migrate across the Atlantic via ocean currents (two to three years) and metamorphose into transparent glass eels once they reach the continental shelf (White and Knight, 1997). Due to the south westerly orientation and funnel shape of the Severn Estuary the glass eels enter in large numbers in spring. They then metamorphose again within the estuary to become elvers. While in the estuary they bury themselves in sand or mud and emerge at night to feed. Estuarine migration upstream is slow with some eels staying in the estuary until they migrate back out to sea to breed.

Temperatures of between 14-16oc have been statistically proven to be the best predictor of upstream migration within the Severn Estuary (White and Knight 1997). The elvers move upstream on spring tides from mid-February to mid-May and are caught in large numbers by elver fishermen up to Tewkesbury. During this migration upstream weirs are an obstruction to upstream migration and hence need high tides to get over them. The timing of this migration means that the impacts of the RSDO would be negligible. Adult eels are more tolerant of low dissolved oxygen than salmonids, but with the exceptionally low freshwater flows (in the ' Do Nothing' management option) to the lower tidal Severn there may be small pockets with dissolved oxygen sags that could even cause eel mortality.

Wider Fish Assemblage

The Severn Estuary has been designated as a RAMSAR site due to its fish assemblage. The large diversity of fish (especially for juveniles) within the estuary has been recognised as internationally important and so as a whole needs to be assessed for their response to lowering freshwater flows. A study by Potter et al. (2001) concluded that annual recruitment strengths of the fish assemblage of the Severn Estuary were not correlated to water temperature or changes in salinity. The alteration of freshwater flows impacts the salinity of the estuary and therefore it can be assumed that freshwater flow is not impacting annual recruitment strength.

Hendersen and Bird (2010) highlighted that for fish in the estuary species richness and total abundance reach a maximum in late summer and autumn. This is when any impact of reduced freshwater flows to the estuary from both the drought scenarios (acute and Chronic) would be at its peak. However, as shown in results from transitional fish surveys by the Environment Agency (Figures 4 to 10) the fish within the section most likely to be impacted by low freshwater flows and therefore dissolved oxygen sags are freshwater and migratory fish.

All this evidence suggests that the wider fish assemblage of the Severn Estuary will not deteriorate with lowering of freshwater flows as modelled.

Drought Scenarios

It should be noted that these are just modelled flows and timings could vary in a real life situation. Also the model only takes account of a 300Ml/d abstraction by British Waterways for Gloucester and Sharpness Canal which could be double that quantity, especially in periods of drought (stage two assessment).

Lower Parting

This is the furthest downstream point with modelled flows and is within the tidal range of the estuary (lower tidal Severn). Any high tides combined with the low flows of a drought could have a very negative impact on the fish population. This will be due to saline intrusion and increased suspended solids causing low dissolved oxygen levels. Work completed by Hutchinson and Wade (1992) recommended that a flow of 1800Ml/d at Haw Bridge would be required to maintain dissolved oxygen levels above 3mg/l (critical concentration for survival of migratory salmon), prevent suspended solid concentrations of greater than 6000mg/l and prevent saline intrusion for 94% of predicted tides. During the acute drought model for example this flow is not attained for 19% of the year. This suggests potential for fish kills (mainly salmonids). However, water quality within the estuary has been improved dramatically since this study and it is anticipated that lower freshwater flows than 18000Ml/d at Haw Bridge would now suffice.

In the two scenarios the RSDO and full in-combination are similar so will be discussed together.

Acute

' Do Nothing' – This is the best option for fish up until mid October. Then the freshwater flow crashes very quickly to very low flows (down to 382Ml/d) for a short period. This would impact fish populations in this area, especially salmonids that would be waiting to migrate upstream. As described previously low freshwater flows increase saline intrusion and dissolved oxygen sags.

RSDO and Full in-combination – At the end of August the freshwater flows drop lower than the ' Do Nothing' management option and stays lower for a month and a half. The initial drop is unlikely to have any different impact on the fish community than the ' Do Nothing'. However, freshwater flows fall lower in October four days earlier than the ' Do Nothing' option. This would be a critical period and if it coincided with a high tide could cause increased saline intrusion and dissolved oxygen sags (with consequences discussed previously). After this period this option is above the ' Do Nothing' management option providing extra freshwater flow and hence buffering impacts of saline intrusion and dissolved oxygen sags. Timing of these events would be critical for implications on the fish community.

Chronic

' Do Nothing' – In the second year of the Chronic drought this option is again preferable for the fish population until October. This crash is even lower and longer than the acute scenario (as low as 310Ml/d for 3 weeks). These low freshwater flows for that length of time could cause large fish kills in this section of the River Severn (chances of a spring tide falling in this period are high). Again salmonids would be most vulnerable to dissolved oxygen sags, but flows so low other species likely to be impacted e.g. shad and eel.

RSDO and Full in-combination -- Flows would be reduced for much of the second year compared to the ' Do Nothing' management option. It would be anticipated that saline intrusion and dissolved oxygen sags would be a greater problem than with the ' Do Nothing' option for two to three months. However, this time there is no flow crash in October (except at very end of month). This is where these management options really assist the ecology of the estuary.

Canal & River Trust

The potential impact from the Canal & River Trust abstraction for Gloucester & Sharpness Canal is large. This abstraction is exempt from licensing at present and can abstract up to 680Ml/d (Wade,1992) and would be used to its maximum in drought conditions. Reasons this figure might not be abstracted would be due to siltation and saline intrusion on high tides (Bristol Water drinking water abstraction from canal). Therefore at low tides rate of pumping would be at its maximum leaving very little freshwater in the lower tidal Severn.

In both scenarios an extra 300Ml/d would be exceedingly bad for fish within the lower tidal Severn (and dependent on discharge back into the estuary) possibly the SAC as well. For the ' Do Nothing'

management option there would be times when no freshwater flow could theoretically be entering the lower tidal Severn. The repercussions on fish fauna could be disastrous. At high tides saline intrusion would increase (although saline intrusion would halt abstraction into canal). At low tides increased sediment deposition and fish trapped in pools would be at risk from rapid rising of water temperature, lowering dissolved oxygen and predation. With the RSDO and full in-combination the exceptionally low freshwater flows of the ' Do Nothing' approach are not reached.

Conclusions

The Water Authority Joint Committee on the river Severn Estuary concluded that, apart from saline intrusion at Gloucester, the drought of 1976 had virtually no immediate effect on the estuary (Severn Trent Water 1977). In fact the evidence from the 1976 drought is that moderate increases and decreases in the regulated flow at Bewdley would have little effect on the river or the estuary (Severn Trent Water 1977). The droughts modelled for this report were based on the 1976 drought, but extended. The impacts on fish caused by the different management options are only within the lower tidal Severn and not the Severn SAC. However migratory fish that are part of the designation of the estuary as a SAC that might be impacted are:

- Atlantic salmon – during a drought adult salmon migrating upstream are likely to reside for longer in the estuary increasing possibility of them not entering the River Severn to spawn. The main impact likely in lower tidal Severn section will be where dissolved oxygen sags could cause mortalities. In both scenarios the ' Do Nothing' approach is beneficial up until October. However, then in October the ' Do Nothing' approach causes a crash in freshwater flows to the lower tidal Severn which could cause mortalities to salmon within this section.
- Twaite shad – juvenile twaite shad feed at the saline wedge before migrating to sea at winter. The location of this saline wedge is impacted by tides and quantity of freshwater. Therefore in the lower tidal Severn these fish could be vulnerable to dissolved oxygen sags, especially with the very low freshwater flows in the ' Do Nothing' management options.

The fish assemblage of the estuary (qualifying feature of RAMSAR) are generally unlikely to be impacted by the changes in freshwater flows as modelled in the various management options.

There is considerable scope for the abstraction by British Waterways for the Gloucester & Sharpness Canal to cause further damage to the fish population of the lower tidal Severn and even the fish within the SAC.

Mitigation

Ensuring an agreement with British Waterways on their abstraction from the Severn or change of legislation to bring their licence under control

Any other sources of freshwater for the estuary at times of severe drought.

If large losses of salmon recorded possibility of restocking salmon

Future Monitoring

A fish counter down at Upper Loade/Deerhurst would give a better understanding of salmon migration and could be used to produce a statistical model to assess impact of changes in flows.

Radio tracking migratory fish within different sections of the estuary would be very difficult but give a better understanding of movements within the estuary and could be used in conjunction with fish counter data in production of statistical model

Continued monitoring at Oldbury Power Station

Appendix 6:

Statement of Response: HRA specific comments

Appendix 6: Comments from Consultees on HRA of the River Severn Drought Order

The Environment Agency responses have been made in *green italics* in the table below for the full representation we received and our complete Statement of Response refer to Appendix V of the River Severn Drought Order Environmental Report;

Document page/ section/paragraph number/table	**Organisation making a representation**
	Natural England advice/representations - *refer to River Severn Drought Order Environmental Report, Appendix V for the full representation and our Statement of Response.*
Key Issue	Analysis of the modelling outputs in relation to the predicted impacts on the designated interest features could be much clearer, allowing a more straightforward comparison of consequences of implementing or not implementing the RSDO. *Tables have been changed for clarification.*
Sections 3.5 to 3.12 **Tables 5 & 7**	Use of key 'assessment criteria' could be applied as row titles thus enabling clear demonstration of fish species requirements in relation to hydrological and water quality predictions resulting from modelling. *Tables have been changed for clarification.* These criteria could include flow and water quality targets and other key requirements of individual species through their life history stages and at critical periods. *Tables have been changed for clarification.*
Table 7	Columns should match the modelling scenarios outlined in the report. Unclear why 'Glos and Sharpness Canal Abstraction' has been added as a separate column heading. *Column headings changed accordingly.*
Section 3.14 to 3.15	Would seem appropriate to draw out the key conclusions arising from the comparisons made in Table 7 to assess whether implementation of the RSDO will increase or decrease the risk on adverse effect on the integrity of the Severn Estuary SAC/SPA/Ramsar. Much of the discussion appears to be around potential impacts of drought. *It is clearly stated in the text that impacts are mainly related to the baseline drought itself and implementation of RSDO allows lower flow to continue over a longer period but prevents the critically low flows expected without the RSDO, especially during an extended drought event. It is difficult to separate the impacts of implementing the drought order in isolation as a drought would be well underway and we would already be seeing the environmental effects of this by the time we'd be implementing a drought order. It is important that we include this detail and stress the point for context.* *HRA conclusions in section 3.14 and 3.15 contain the clarification requested; that*

	implementation of the RSDO, alone, does not have an adverse effect on the designated migratory fish features of the Severn Estuary SAC and Ramsar. This Appropriate Assessment has been carried out based on a specific model of drought conditions and we also recognise that each drought is an individual event and the impacts on the different fish species in relation to the timing of a future drought may be different to what has been outlined in this assessment.
Gloucester & Sharpness Canal abstraction	We understand that the EA's HRA concludes that an abstraction rate of 300Ml/day into the Gloucester-Sharpness Canal does not represent an adverse effect on the integrity of the Severn Estuary SAC/SPA/Ramsar either alone, or in combination with the RSDO and all other existing drought orders and permits. However, we note that the abstraction agreement held by the Canal and Rivers Trust allows a take of up to 691Ml/day, even under drought conditions. In relation to this issue, the HRA also concludes that 'abstraction over 300 Ml/d and particularly within the region of 691Ml/d alone, and in combination with implementation of the RSDO and other drought orders or permits, will have an adverse effect on the migratory fish features of the Severn Estuary SAC and Ramsar'. It is our understanding that the Canal abstraction was only included in the modelling to a level of 300 Ml/day. On this basis we would like the EA to clarify the information underpinning their conclusion above. Based on the information presented it would appear that further modelling and assessment work is required to assess the potential impacts of the abstraction across a range up to 691Ml/day. However, we strongly support the need for further talks with the Canal and Rivers Trust to identify suitable options for ensuring that the features of the Severn Estuary SAC/Ramsar are protected under drought conditions. The additional modelling outlined above would seem to be essential to inform these discussions. The results of this work would also need to be considered by Bristol Water when reviewing their Drought Management Plan. *The Canal & River Trust is exempt from abstraction licensing, the operating agreement between ourselves and the Canal & River Trust forms voluntary rules that allow abstraction to vary according to the tide and flows, which the Canal & River Trust are committed to adhering to. The flow modelling work included a maximum Gloucester & Sharpness canal abstraction of 300 Ml/d. After discussions with the Canal & River Trust it was recognised that 300 Ml/d did not fully represent their legal ability to take up to 691 Ml/d. This higher figure contains large uncertainty and assessment of the potential environmental impacts resulting from flow and level reductions greater than what we modelled, was based on historic reports (i.e. recorded impacts based on high abstractions), current data and expert interpretation. In response to feedback concerning the in-combination potential impacts of the Canal & River Trust abstraction for the Gloucester & Sharpness Canal, we have added an abstraction restriction to the Drought Order application, which would be legally enforceable if granted by Defra. The abstraction figure will be set at 300 Ml/d when flow at Deerhurst drops below 1200 Ml/d and the RSDO is in force. However the Environment Agency is committed to ongoing collaborative*

	work with the Canal & River Trust to test the sensitivity around this maximum abstraction volume. If evidence can justify and support higher abstraction during severe drought conditions, the abstraction cap will be reviewed.
Future Recommendations and Monitoring Requirements	The 'Future Recommendations and Monitoring Requirements' set out in the HRA is somewhat inconclusive and does not reflect the recommendation in the Environmental Report. *The HRA is a supporting document to the main RSDO report, to avoid too much duplication we have avoided reproducing the same information in both reports where possible. Therefore there is no Future Recommendations and Monitoring Requirements section in the HRA but there is a Mitigation section which is somewhat different and primarily centres on a discussion of the Gloucester & Sharpness Canal abstraction. In the main RSDO, Section 9.6 refers to the HRA monitoring gaps and limitations, then please refer to Section 15 for the complete monitoring programme and Section 17 for Future Recommendations.* NE also recognise the need to enhance the fish monitoring programme and particularly for shad. *The development of specific shad monitoring has been identified and recommended as an area of future work.*
	Natural Resources Wales advice/representations **(HRA only -** *refer to River Severn Drought Order Environmental Report, Appendix V for the full representation and our Statement of Response.***)**
Executive Summary	We note the reference within this Executive Summary to the potential abstractions for the Gloucester & Sharpness Canal. Clarification would be welcomed as to whether the options for major abstraction between the Severn and the Thames (presented in Thames Water's draft Water Resource Management Plan 2014 as feasible options) have also been considered within this assessment process. Whilst it is accepted that the Severn Thames transfer options are not identified within Thames Waters' preferred options, it is suggested that it might be useful to maintain a watching brief on this draft Water Resource Management Plan in the event that these options are brought forward and/or change status. *Thank you for this feedback. We have included additional text in the HRA Section 2.7.2.3 In Combination Assessment to address this representation. If the Severn Thames transfer option is progressed it will be subject to its own HRA. We have also added a brief summary to the new 'future considerations' section to help ensure future updates account for any changes.*
Key Issue	We note with concern the potential for the Canal and River Trust's maximum abstraction (in combination with the Severn Drought Order and water company Drought order operations) to have an adverse effect on the lower tidal Severn and the Severn Estuary SAC/Ramsar sites. While we acknowledge the difficulties in reconciling this issue and the commitment to finding 'a solution to protect the Severn Estuary designation before a drought order application is needed', it should be pointed out that the Habitats Directive embodies the precautionary

	principle and that unless 'no likely significant effect' can be demonstrated in respect to these 'in combination' effects, it would not be possible to implement the Drought Order without consideration of IROPI issues, alternatives and compensatory measures. . We would therefore suggest that a caveat be inserted into the River Severn Drought Order acknowledging that the Full 'In Combination' scenario cannot be implemented until such time as outstanding issues and challenges related to the Gloucester and Sharpness canal abstraction have been fully assessed and appropriate and robust avoidance and mitigation measures put in place. Given the unpredictability of drought conditions and the need to implement drought measures without delay, it is suggested that a timetable for these discussions be drawn up as a matter of urgency and a provisional deadline for resolution of issues established. We would be happy to enable the progression of these negotiations, if considered appropriate and to assist in any way that brings the discussions to a swift and transparent/equitable conclusion. *Thank you for the offer of assistance and the suggestion of setting a timetable and provisional deadline.* *We recognise the implications, to satisfy the Habitat's Directive and reduce the risk to the Severn Estuary the precautionary principle has now been adopted and text amended. We have been in discussions with the Canal & River Trust, involving legal representatives from both organisations. The Environment Agency have introduced a new abstraction cap of 300 Ml/d, to come into force only when the drought order is active and flows at Deerhurst drop below 1200 Ml/d. The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operation of the Gloucester & Sharpness Canal and the Bristol Water abstraction it supports, which the Trust are investigating. We have agreed that if sufficient evidence is provided to show a higher abstraction is justified then the 300Ml/d limit will be reviewed.*
Section 1.1	In the interests of transparency, particularly with respect to the need for water companies to subject their Drought Plans to the full SEA process, it is suggested that the full transcript of the SEA screening determination for the River Severn Drought Order be published within the final version of the 'Order' itself. *Strategic Environment Assessments are not a statutory requirement, and would be more appropriate for the main RSDO report than the HRA. In response to yours and similar feedback we have added an SEA to the Future Work recommendations section of the main RSDO report.*
Section 1.2	Reference should be made to the latest version of the Birds Directive. *Text has been amended accordingly*
Fig 1	Clarification would be welcomed regarding the origin of this flow chart for assessing 'likely significant effects' given that this is not the version issued or referenced to in Tan 5 or 'Guidance for Plan Making Authorities in Wales: The appraisal of Plans under the Habitats Directive. *This flow chart is from the Environment Agency's own Operational Instruction 183_01 v.8 Habitats Directive: Taking a new permission, plan or project through the*

	regulations. Since this is an Agency plan and given the cross border and regional nature of the Severn Estuary this flow chart appropriately demonstrates the approach taken to determining 'likely significant effect'. It was originally acknowledged as a footnote but got deleted during the various editing processes. It is now referenced in the text.
Section 1.4	Reference should be made to Regulation 102 of the Conservation of Habitats and Species Regulations 2010 (as amended) given that this Regulation applies to plans. *This HRA has been undertaken for a Drought Order which relates to the management of water resources whereas Regulation 102 refers to Land Use Plans which has been taken to refer to Development Plans, Mineral Plans etc.*
Section 2.0	We would suggest that reference is made to the precautionary nature of the HRA process and the requirement, where it is not possible to demonstrate no likely significant effect on a European Site, for the process to progress to 'appropriate assessment'. *Additional text has been included to address this representation.*
Section 2.1	We would suggest that specific reference be made to eels and sea trout in the context of migratory fish features of the Severn Estuary Ramsar site. *Table 4 contains this specific detail. This section refers to SACs, SPAs and Ramsar sites in terms of their designations and forms an introduction rather than high level detail.*
Table 2	Given that the HRA process requires consideration of significant effects on specific features of any European Site, we would not recommend the use of generic sensitivities or the grouping together of features. The potential for and significance of effects is dependent on the particular sensitivities of the receiving environment and/or species. Whilst grouped species e.g. migratory fish, may appear to have common or generic sensitivities, in reality they may have considerably different responses to different stressors and at different spatial and temporal scales. *It is difficult to represent detail in summary tables; we believe the groupings used in Table 2 are appropriate for this purpose and were based on Agency guidance. We can confirm that each designated fish species has been taken through the Appropriate Assessment in its own right and their differing life cycles and requirements accounted for, we also have to consider a range of hazards and sensitivities for the different designated habitats and features, not just migratory fish. We can clarify that it was because of the different responses to different stressors and the passage of migratory fish up and down the river and estuary that they were taken through for Appropriate Assessment.* *To provide confidence, we have addressed the individual suggestions;* Displacement of species – *we have considered this in some detail in the Appropriate Assessment* Changes in presence/status of invasive and alien species and pathogens – *An additional section and text has been included in the RSDO Environmental Report*

	Habitat damage *– was considered under the physical damage and habitat loss aspects of the sensitivity matrices* Changes in water temperature *– table amended to reflect this, also considered in relation to water quality within the Appropriate Assessment*
Section 2.4.5	We note and in principle, accept the findings of this assessment. In respect of the potential 'issues' discussed with maintaining channel flow (removal of emergent growth and silt removal), clarification would be welcomed as to whether the site's Core Management Statement includes any specific management proposals in the event of drought, changes in water levels and maintenance of flow in drought conditions. *There is no reference to management related to any of the above conditions in the Core Management Statement.* In additional, clarification would be welcomed as to whether it is envisaged that such issues could adversely affect European Protected species in and using the Montgomery Canal e.g. water vole. *Additional text relating to water vole and otter in the Montgomery Canal can now be found in App 1.* The statement that the effect of drought 'should only be short lived' is noted however, clarification would be welcomed as to what is understood by 'short lived'. *We consider short lived to be in accordance with natural drought recovery, therefore you may expect to see an impact on populations the following 1-2 years, but full recovery is expected.*
Section 2.5.3	Clarification would be welcomed as to whether the RSDO and HRA have taken and will take into consideration the policies and recommendations made by the UK TAG draft recommendations 'River flow for good ecological potential' (June 2013). The UK Technical Advisory Group on the Water Framework Directive (UKTAG) first published guidance on the classification of ecological potential in 2008. For water bodies used for water supply, storage and power generation guidance was produced on the downstream flows requirement. With the exception of providing a low flow component of the downstream flow, little advice was provided on flows required for the rest of a baseline flow regime, flows to enable fish migration and flows to maintain river habitats. The purpose of the draft recommendations is to fill this gap in knowledge and are of relevance to this assessment process and the RSDO. *These documents are still only draft recommendations and were still out for consultation during the RSDO consultation; therefore they have not been taken into consideration for the RSDO or HRA reports, which took an approach consistent with the RoC. We have provided internal consultation feedback on the UK TAG reports, and highlighted them in the new 'Future Considerations' section in the RSDO report.*
Section 2.5.16	We agree in principle with the summary of likely significant effects on the Severn Estuary however, clarification would be welcomed as to the exclusion of water temperature from the assessment process. *Additional line of text has been included; it is also referred to in the Appropriate Assessment.*

Section 2.7.1.3	Reference should be made to relevant Eel Management Plans and licensing. *Additional text has been included to reference the River Severn Eel Management Plan. The Eels Regulations 2010 have not been included as they are not a permission, plan or project.*
Section 2.7.2.1	See comments on the Executive Summary regarding the potential need to consider Thames Water's options for bulk transfer of water from the Severn to the Thames. *Thank you for this feedback. We have included additional text in the HRA Section 2.7.2.3 In Combination Assessment to address this representation. If the Severn Thames transfer option is progressed it will be subject to its own HRA. We have also added a brief summary to the new 'future considerations' section to help ensure future updates account for any changes.*
Severn Trent Water	As far as we are aware, Severn Trent water have not yet completed their appropriate assessments for the River Wye at Wyelands and Trimpley abstractions. *We have included the permits/orders for our modelling based on best available information at the time. We acknowledge this may change and need updating in the future, but we wanted to ensure that all known cumulative impacts were incorporated to comply with the Habitat's Regulations.*
Section 2.7.4	We note with concern the potential for the Canal and River Trust's maximum abstraction (in combination with the Severn Drought Order and water company Drought order operations) to have an adverse effect on the Lower Tidal Severn and the Severn Estuary SAC/Ramsar sites. *To satisfy the Habitat's Directive and reduce the risk to the Severn Estuary the precautionary principle has now been adopted and text amended. We have been in discussions with the Canal & River Trust, involving legal representatives from both organisations. The Environment Agency have introduced a new abstraction cap of 300 Ml/d, to come into force only when the drought order is active and flows at Deerhurst drop below 1200 Ml/d. The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operation of the Gloucester & Sharpness Canal and the Bristol Water abstraction it supports, which the Trust are investigating. We have agreed that if sufficient evidence is provided to show a higher abstraction is justified then the 300Ml/d limit will be reviewed.*
Section 3.2	We note with disappointment that the abstraction for the Gloucestershire and Sharpness Canal was 'believed to have the potential to impact on residual flows' but that no Stage 3 assessment (appropriate assessment) was undertaken because the abstraction is authorised by Act of Parliament. Given the requirement under the Habitats Directive for plans and projects likely to have significant effects on European Sites to be subject to appropriate assessment, the avoidance of assessment for this abstraction is unfortunate and appears to be contrary to the 'spirit', if not the word of the Habitats Directive. *We have gone back and looked through all the RoC documentation and found it was not completely excluded from Stage 3 as we had reported - additional text has now been included in the reports to reflect the additional information and that this abstraction was considered at Stage 3 of the RoC..*

	We agree with this Report's premise that 'there is a requirement to find a solution' to this issue and that it 'needs to be in place well in advance of a River Severn Drought Order application'. Given the unpredictability of drought conditions and the need to implement drought measures without delay, it is suggested that a timetable for these discussions be drawn up as a matter of urgency and a provisional deadline for resolution of issues established. It is further suggested that these discussion be 'mediated' by an appropriate and independent authority in order to bring the discussions to a swift and transparent/equitable conclusion. *To satisfy the Habitat's Directive and reduce the risk to the Severn Estuary the precautionary principle has now been adopted and text amended. We have been in discussions with the Canal & River Trust, involving legal representatives from both organisations. The Environment Agency have introduced a new abstraction cap of 300 Ml/d, to come into force only when the drought order is active and flows at Deerhurst drop below 1200 Ml/d. The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operation of the Gloucester & Sharpness Canal and the Bristol Water abstraction it supports, which the Trust are investigating. We have agreed that if sufficient evidence is provided to show a higher abstraction is justified then the 300Ml/d limit will be reviewed.*
Section 3.7	We would recommend that, in order to avoid confusion, this section be re-titled Brown Trout/Sea Trout. *Text amended accordingly.*
Section 3.12	Additional consideration should be given to the potential effects of 'fisheries' and enhanced predation on eel during low flows. Given the potential for inhibited migration and concentration of eel below barriers during low flow, there is the potential for eel fisheries (licensed and unlicensed) and predators to take advantage of eel concentrations. *We agree there is the potential for increased pressure on eels, as with other fish species. This consideration has been covered within the reports and some text has been amended for clarity and greater detail; however a quantified assessment of the impact cannot be made at this time. There are too many other factors (e.g. number of predatory species moving in or out of estuary, densities of predators, predator prey interactions, etc) involved, and too little conclusive data available at this time to make more detailed assessments.*
Section 3.15.2	We note with concern the potential for the Canal and River Trust's maximum abstraction (in combination with the Severn Drought Order and water company Drought order operations) to have an adverse effect on the lower tidal Severn and the Severn Estuary SAC/Ramsar sites. While we acknowledge the difficulties in reconciling this issue and the commitment to finding 'a solution to protect the Severn Estuary designation before a drought order application is needed', it should be pointed out that the Habitats Directive embodies the precautionary principle and that unless 'no likely significant effect' can be demonstrated in respect to these 'in combination' effects, it would not be possible to implement the Drought Order without

	consideration of IROPI issues, alternatives and compensatory measures. . We would therefore suggest that a caveat be inserted into the River Severn Drought Order acknowledging that the Full 'In Combination' scenario cannot be implemented until such time as outstanding issues and challenges related to the Gloucester and Sharpness canal abstraction have been fully assessed and appropriate and robust avoidance and mitigation measures put in place. Given the unpredictability of drought conditions and the need to implement drought measures without delay, it is suggested that a timetable for these discussions be drawn up as a matter of urgency and a provisional deadline for resolution of issues established. It is further suggested that these discussion be 'mediated' by an appropriate and independent authority in order to bring the discussions to a swift and transparent/equitable conclusion. *To satisfy the Habitat's Directive and reduce the risk to the Severn Estuary the precautionary principle has now been adopted and text amended. We have been in discussions with the Canal & River Trust, involving legal representatives from both organisations. The Environment Agency have introduced a new abstraction cap of 300 Ml/d, to come into force only when the drought order is active and flows at Deerhurst drop below 1200 Ml/d. The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operation of the Gloucester & Sharpness Canal and the Bristol Water abstraction it supports, which the Trust are investigating. We have agreed that if sufficient evidence is provided to show a higher abstraction is justified then the 300Ml/d limit will be reviewed.*
	Dwr Cymru Advice/representations - *refer to River Severn Drought Order Environmental Report, Appendix V for the full representation and our Statement of Response.*
High level comments	Generally we thought that the Report and HRA were well written. They will provide a helpful model for water companies when preparing similar reports. That said, their length (a total of over 800 pages, including the appendices) significantly hampered our ability to consider the papers in detail. We wonder whether other relevant parties, such as farmers, will realistically be able to engage in the consultation (although we note that their representative groups are incorporated within your communications plan in the event of it looking likely that a Drought Order might be sought). *Thank you for this feedback. We appreciate the documents involved remain a significant size; this is due to the catchment size and complex variety of water resource interests involved. The main reports have been significantly slimmed down and executive summaries provided to help reduce the burden, moving a lot of technical detail into the Appendices. As you identify, during a developing drought the key interest groups will be targeted early via the communication plan, and should an application be made, it would be fully publicised and meetings held to help explain the key messages and reasons behind the application. We can also provide some confidence through the receipt of consultation responses from two National Farmers' Union's, both which have grasped the RSDO and not commented on the document size. We are positive the different communication paths we*

	have used and identified will be sufficient going forward. *Additional HRA specific: The length of the HRA report reflects the complexity of the Severn Estuary, migratory fish life cycle and whereas general effects of low flows are understood, determining the effects of river regulation and then implementing a drought order is difficult. The RoC process and documentation was similarly complex and assessment and reports equally lengthy.*
High level comments	You say that you are not obliged to prepare a Strategic Environmental Assessment in respect of the Drought Order. A SEA would have been a useful tool to ensure that the in-combination impacts are more thoroughly explored, including in relation to Dŵr Cymru's abstractions from the Rivers Teme and the Wye. *In response to yours and similar feedback we have added an SEA to the Future Work recommendations section. Abstractions for the Wye were considered under the RoC process and investigations have taken place with regard to abstraction on the Upper Teme. Under the drought conditions leading up to application of the RSDO all relevant restrictions would already be in place and depending on the nature of the drought, options relating to the River Wye would also be under consideration.*
High level comments	It is likely that a number of relevant abstraction licences will be amended in the years ahead to reflect the outcome of relevant Habitats Directive Review of Consents, including those for the Rivers Wye and Usk. You might want to note in your Report that some of the licences - and thus the potential impact of the relevant abstractions on the River Severn and downstream estuary - are likely to change in the next few years. *Thank you for this information. We have added a brief summary to the new 'future considerations' section to help ensure future updates account for any changes. No abstraction licences for the River Severn were amended as a result of the Severn Estuary RoC. The River Wye enters the Severn Estuary >20 km below, and the River Usk 45km below the top limit of the designated site therefore any changes to abstractions from these rivers are unlikely to have an impact on either the River Severn or downstream estuary. It should be noted that the effects of drought and benefits of implementation of the RSDO are experienced high up the Lower Tidal Severn and above the designated estuarine site.* *It was agreed with NE and NRW at the beginning of the HRA process that the Rivers Wye and Usk would not be included apart from a migratory fish perspective*
High level comments	Given that much of the report and supporting documents centre on the potential impact on adjacent Natura 2000 sites, we were surprised that for the hydrological assessment the Environmental Flow Indicators were used as opposed to the more stringent Habitats Directive Ecological River Flow. *We have followed the same principals and methods as used in the Review of Consents (RoC) work on the Severn, which were agreed with Natural England and*

	the Countryside Council for Wales (now part of Natural Resources Wales). Consultation has not identified any concern with this approach for the RSDO. To provide some confidence, in comparison to the River Wye, the River Severn Estuary has a very large tidal range. The Severn Estuary designations are largely adapted to saline water and less dependent on freshwater than the main River Wye environment, therefore using river flow targets would not be appropriate for this site.
High level comments	The Environmental Report notes that the Habitats Regulations Assessment (HRA) concluded that there was likely to be a significant effect on the fisheries feature of the Severn Estuary SAC. That being so, we were concerned that you seem to rule out the possibility of a knock-on impact on the protected fish species in the Rivers Wye and Usk SACs. The HRA itself explains (in paragraph 2.1) that "It was agreed by both Natural England (NE) and the Countryside Council for Wales (now Natural Resources Wales) pers comm. that potential effects to the Rivers Usk, Wye and Afon Twyi SACs will not be directly considered as part of the assessment. However they will be considered in relation to the Severn Estuary migratory fish feature, specifically in relation to Atlantic Salmon, shad and sea lamprey." It could be argued that, in the absence of firm evidence to the contrary, the precautionary principle requires that the impact on the protected species in the Rivers Wye and Usk SACs should have been included. We feel that these important decisions about the impact to the Rivers Wye and Usk should have been made following a proper assessment. *The precautionary principle required that the migratory fish feature of the Rivers Wye, Usk and Taf were considered. On the basis of technical advice it was determined that implementation of the RSDO would not have a 'likely significant effect'. Migratory fish were included in the RoC of the Wye and Usk and will be a major consideration of any drought permit work relating to the Wye and Usk. It was agreed with NE and NRW at the beginning of the HRA process that this approach would be taken.*
High level comments	One theme that emerges from the report is concern about the impact, particularly on migratory fish, of the potential abstraction into the Gloucester and Sharpness Canal and the apparent lack of adequate regulatory controls. For example, the main report says (at section 9.3.3) "The HRA found Gloucester and Sharpness canal abstractions of >300Ml/d in the lower tidal Severn, particularly the maximum 691 Ml/d, could have the potential to have an adverse effect on the migratory fish features of the Severn Estuary SAC and Ramsar site in combination with the River Severn Drought Order and water company drought orders." However, the HRA notes (page 56) "This abstraction was therefore put through to Stage 3 for Appropriate Assessment but then discounted because it is authorised by Act of Parliament and is therefore not under Environment Agency control." *We have gone back and looked through all the RoC documentation and found it was not completely excluded from Stage 3 as we had reported - additional text has now been included in the reports to reflect the additional information and*

	that this abstraction was considered at Stage 3 of the RoC. In relation to inflows to the estuary and migratory fish, the approach taken was agreed by NE and NRW at the time. The potential effect of this is to put an unfair share of restrictions onto the other abstractors, a point that is not made in the report. It should also be noted that the discounting of the impacts in this way also contrasts with the stance that the (then) Environment Agency Wales took in the Usk Review of Consents when considering the impact of the Canal and Rivers Trust's local abstractions. *Environment Agency Wales and the Countryside Council for Wales (now part of Natural Resources Wales) were actively involved in the RoC of the Severn Estuary. The Environment Agency carried out RoC's for a number of sites in Wales (due to the organisational boundaries at the time); therefore throughout the RoC process there was regular liaison with Environment Agency Wales and the Countryside Council for Wales's colleagues. At no time was there an overall discussion on abstraction to the different canals and we suggest any perceived discrepancy relates to the fact that each of the sites are very different and have their own site specific issues.*
High level comments	Unless and until the regulators are given more levers over the Gloucester and Sharpness Canal abstraction, you may need to start preparing the case to demonstrate imperative reasons of overriding public interest and consider possible compensatory measures: time to undertake this (difficult) work would be very limited in the event of a Severn Drought Order being warranted. *We agree that IROPI needs careful consideration and pre-planning. We have considered the case for IROPI for the RSDO, but felt it could not be justified without first imposing an abstraction cap on the Canal & River Trust to demonstrate to Defra that all possible options have been explored. A drought order, if granted by Defra, would give us the legal powers to enforce an abstraction restriction for the duration of the drought order operation. The HRA identified safe levels of in-combination abstraction that would prevent significant impact on the Severn Estuary, avoiding the need for IROPI. Therefore, to satisfy the Habitat's Directive and reduce the risk to the Severn Estuary the precautionary principle has now been adopted and text amended. We have been in discussions with the Canal & River Trust, involving legal representatives from both organisations. The Environment Agency have introduced a new abstraction cap of 300 Ml/d, to come into force only when the drought order is active and flows at Deerhurst drop below 1200 Ml/d. The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operation of the Gloucester & Sharpness Canal and the Bristol Water abstraction it supports, which the Trust are investigating. We have agreed that if sufficient evidence is provided to show a higher abstraction is justified then the 300Ml/d limit will be reviewed.*
	United Water Utilities - *refer to River Severn Drought Order Environmental Report, Appendix V for the full representation and our Statement of Response.*

Non-technical summary; Summary of Environmental Effects; Severn Estuary (Natura 2000 site); Page 17	We feel you need to explain what will happen if a River Severn drought order is required prior to agreement with the Canal and River Trust over mitigation as the in-combination Appropriate Assessment is unable to conclude no significant effect on migratory fish. *To satisfy the Habitat's Directive and reduce the risk to the Severn Estuary the precautionary principle has now been adopted and text amended. We have been in discussions with the Canal & River Trust, involving legal representatives from both organisations. The Environment Agency have introduced a new abstraction cap of 300 Ml/d, to come into force only when the drought order is active and flows at Deerhurst drop below 1200 Ml/d. The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operation of the Gloucester & Sharpness Canal and the Bristol Water abstraction it supports, which the Trust are investigating. We have agreed that if sufficient evidence is provided to show a higher abstraction is justified then the 300Ml/d limit will be reviewed.*
	South Staffs Water - *refer to River Severn Drought Order Environmental Report, Appendix V for the full representation and our Statement of Response.*
High level comments	South Staffordshire Water supports the need for the Severn Drought Order and regards it as a vital tool in protecting both the environment and public water supply abstractions along the River Severn under severe drought conditions. It supports the programme of collaborative mitigation, in particular the flexible use of abstraction and raw and raw water storage to optimise use of short term higher river flows and/or low customer demands that intersperse typical droughts. The Company welcomes the commitment to improve understanding of environmental impacts, particularly in the lower reaches and Severn Estuary. This should explore ways of demonstrating the likelihood whether the impacts experienced in 1976 will be repeated under any reasonably foreseen scenario. *Future work and modelling, including the separate climate change testing, will help to clarify the return periods and current pressures on the system.* The Company regards the protection afforded the large abstraction at Gloucester and Sharpness under both normal river regulation and the Drought Order to be anomalous. It welcomes the intention to mitigate these by exploring better forms of agreement wit he Canal and River Trust. These may be best delivered by revision of the regulation arrangements set up in 1979 and the setting of minimum flows at specified points in the catchment. *To satisfy the Habitat's Directive and reduce the risk to the Severn Estuary the precautionary principle has now been adopted and text amended in the environmental reports, specifically relating to drought conditions (not normal river regulation, which is outside the remit of these reports). We have been in discussions with the Canal & River Trust, involving legal*

	representatives from both organisations. The Environment Agency have introduced a new abstraction cap of 300 Ml/d, to come into force only when the drought order is active and flows at Deerhurst drop below 1200 Ml/d. The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operation of the Gloucester & Sharpness Canal and the Bristol Water abstraction it supports, which the Trust are investigating. We have agreed that if sufficient evidence is provided to show a higher abstraction is justified then the 300Ml/d limit will be reviewed.
	Severn Trent Water - *refer to River Severn Drought Order Environmental Report, Appendix V for the full representation and our Statement of Response.*
High level comments	We are also interested that on page 138 the report shows that the EA only consider that it is necessary to design, assess and put in place "compensatory measures" in connection with 'Imperative Reasons of Overriding Public Interest' in exceptional circumstances. We support this and have taken a similar approach in our revised draft drought plan. *Please note, the mitigation requirement under the Habitats Directive which is covered in section 9.5 states that where an impact cannot be ruled out, alternatives and mitigation must first be considered. Only if evidence shows no alternatives or mitigation can be found, can a case for IROPI then be considered. If IROPI can be proved, then mitigation options are required. The wording around 'exceptional circumstances' is in reference to proceeding down the road of applying for IROPI. We just wanted to ensure this message is not misunderstood.*
	NFU West Midlands & NFU Wales *- refer to River Severn Drought Order Environmental Report, Appendix V for representation and our Statement of Response.*
	River Severn Drought Order We have noted carefully how the Environment Agency currently operates its Drought Order (subject to ministerial approval). Whilst the Order has no direct impact on spray irrigated crop farming, we support the proposal to reduce support flows in extreme conditions thereby making water in the Llyn Clywedog reservoir last longer. This seems to be a sustainable option. We note the risks of 'in combination' effects of Orders and Permits and would expect the Agency, NRW and public supply companies to jointly manage the situation to overcome any potential pitfalls. We support the Agency and NRW in your efforts to reach agreement with the Canal and River Trust on sustainable management of the Trust's exempt activity during drought conditions. We presume that Defra (and Welsh Government?) will move shortly to bring this exempt activity into the licensing regime. *The current timetable to begin licensing abstraction exemptions is from April 2014. This report and the drought order are only intended for drought conditions. To satisfy the Habitat's Directive and reduce the risk to the Severn Estuary the precautionary principle has now been adopted and text amended in the environmental reports, specifically relating to drought conditions (not normal river regulation, which is outside the remit of these reports). We have been in discussions with the Canal &*

	River Trust, involving legal representatives from both organisations. The Environment Agency have introduced a new abstraction cap of 300 Ml/d, to come into force only when the drought order is active and flows at Deerhurst drop below 1200 Ml/d. The Canal & River Trust has raised concerns that 300 Ml/d could pose a risk to their operation of the Gloucester & Sharpness Canal and the Bristol Water abstraction it supports, which the Trust are investigating. We have agreed that if sufficient evidence is provided to show a higher abstraction is justified then the 300Ml/d limit will be reviewed.
	Canal & River Trust - consultation representation (August 2013)
Specific HRA comments	We have no specific comments to add on the Habitats Regulation Report: Annex 1, providing any errors found in the RSDO Environmental Report and comments noted in this consultation response are taken on board as relevant to all associated documents i.e. Appendices and Annexes 1 and 2. *Refer to River Severn Drought Order Environmental Report, Appendix V for representation and our Statement of Response. It is important to note that the Canal & River Trust are also a Competent Authority under the Habitat's Directive, and have a legal obligation to ensure their operations do not damage the Natura 2000 site.*
	Canal & River Trust - post consultation comments and representation (December 2013)
High level comments - HRA & RSDO reports	We are concerned that some sections of the reports, as written, state that abstraction "above 300 Ml/d" could not be concluded to have no adverse effect, whereas in fact there are only two abstraction points that have been modelled/assessed (300 Ml/d [causes no effect] and 691 Ml/d [causes effects]). The answer therefore is logically between these numbers, which is not the same as stating that anything >300 Ml/d will have an adverse effect. *Text amended to clarify the two separate conclusions and that no sensitivity testing between these approximate values has been undertaken.*
High level comments - HRA & RSDO reports	The Canal & River Trust is concerned that the impact of Clause 7 of the Operating Agreement has been overplayed, to portray the risk of us making the full 691Ml/d abstraction a presumption, as soon as a drought event is deemed to be occurring. We have made a number of edits/comments to explain why we think this is simply not the case. Whilst there is some evidence that significant abstractions took place in previous historical droughts, these pre-date the modern legislative landscape and the Operating Agreement. In fact the Trust would still be required to endeavour to meet the obligations of the Operating Agreement in the event of a drought – Clause 7 in no way allows it to entirely disregard its obligations under the agreement, it allows the Trust to "miss" those obligations where this is outside of its control. In addition, the Trust is a competent authority under the Habitats Regulations and has its own environmental duties under section 22 of the British Waterways Act 1995. In addition, the Trust, is a charity with objects that include protection and enhancement of the environment. It is therefore entirely unrealistic to suppose the Trust would ever take up to the maximum theoretical pumped capacity in a future drought of the severity that the RSDO is intended to

	mitigate, and it is absolutely essential to us that the report acknowledges this. *Text has been clarified in an attempt to remove any perceived overplay and details of the Trust's environmental obligations have been included within a footnote. However, reference to Clause 7 remains because it is significant to the in combination work. As explained, the Habitat's Directive requires the precautionary principle to be applied when assessing likely significant effect. The Trust's intent to no longer abstract at this volume during a drought is recognised and supported, however in the absence of a licensed and therefore enforceable abstraction volume limit, we are required to assess what the Trust is capable of taking. Clause 7 and historic evidence reinforce but do not drive the need to consider the maximum potential abstraction, in their absence we would still be required to assess this precautionary volume.*
Throughout HRA - references to the Trust's 'potential maximum' abstraction of 691 Ml/d (track change comment)	Track change comments from the Canal & River Trust requested altering all references of 'potential' maximum abstraction to 'theoretical maximum pumping capacity.' *We recognise the Trust's concern with quoting an abstraction volume which is rarely taken, only recorded in the 1970s and 1980s, and which their current environmental obligations would strongly discourage them from taking. We have inserted text and footnotes to help further clarify the difference between what is likely and what is precautionary, and to outline the Trust's commitment to the Environment and its obligations. However, we believe the reference to 'potential' fairly acknowledges this volume as something which could possibly (not would) be taken and remains within the Trusts capability to take again, rather than something which will inevitably occur. The term theoretical suggests a hypothetical volume which has never and will never be abstracted; however historic records show that for short periods these volumes were pumped and the pumping capacity still exists.*
High level comments - HRA (track change comment)	The whole assessment relies too heavily on what happened in 1975/6 drought which in no way reflects what the Trust would realistically do today. *We recognise your concern. For the 1975/76 event (also 1984 and 1989) we have baseline environmental impact data which provides a benchmark or reality test for our current modelling. These drought order operations are the only time we have been able to record and assess the environmental response to drought flows along the River Severn being regulated below the current 850 M/ld (or historic 730 Ml/d) statutory requirement. Until we have a repeat drought order event, we cannot update this evidence, as we are not legally permitted to allow River Severn flows to reduce to these levels. The 1975/76 event has been predominately used as it represents the most severe drought event we have on record, the minimum flows are therefore the closest we have on record to the minimum flows we have modelled for the River Severn Drought Order environmental reports. We recognise the abstraction regimes have changed since this event, but the Habitat's Directive requires the precautionary principle to be applied when assessing likely significant effect.*
High level comments - HRA & RSDO	Overall, it is our view that the reports give a disproportionate amount of emphasis to the

reports	theoretical risk of our abstraction (and then present the restriction at Gloucester as the only possible solution), and both reports come across as more of a justification of why the Canal & River Trust abstraction cannot be left untouched, rather than a balanced overall assessment of the impact of the RSDO on the River Severn European Site and how all abstractors will be affected by the RDSO. Any impact on the River Severn European Site is the result of the total water being taken by all of the abstractions from the river, not purely the one for the Gloucester & Sharpness Canal, and there is no recognition at all of that in the HRA report, which appears to include these other abstractions as part of the "do nothing" baseline. *We recognise there is collaborative work needed going forward to bring all the in combination organisations together to help identify and resolve the remaining potential conflicts. We have made it clear to all our consultee's that the River Severn Drought Order Environmental Report and supporting documents will remain a working draft until an application is needed, with a regular review programme having also been set. The public consultation process we have held, although not required at this stage, has been a valuable tool for collecting any outstanding concerns. This should allow all the organisations involved to work together and make improvements in advance of a real drought event.* *For the HRA report we have tried to clarify text where appropriate to address this concern. However it is important to highlight the HRA is not intended to be read in isolation of the RSDO Environmental Report. To prevent duplication and the unnecessary increased size of each document, all the modelling scenario detail is contained within the RSDO Environmental Report. Section 4.4 and 4.5 clearly explain what each drought condition (Acute and Chronic) and drought scenario (Do Nothing (Baseline), Drought Order Only and Full In-Combination) involves. The HRA then forms the assessment and discussion around the main influences and uncertainties impacting upon the Habitat's Directive sites.*
	Severn Rivers Trust
Unable to respond	We did want to make a response and were hoping to have a get together to discuss before we sent in our comments, however we simply ran out of time with so much work and projects to deliver before the Autumn. ..... there is 169 pages of the report to go through plus another 479 pages of appendix, which we just didn't have the resources to go through, plus we do feel the consultation period was too short. If there is to be any kind of follow up or open meetings to discuss the order before it's finalised please let us know as we would definitely wish to be involved. *We appreciate the document size can present a challenge when time/resources are limited. The public consultation we ran during 2013 was a voluntary exercise to gather comments and any concerns to help inform future revisions of the reports. Once the report is published on our website it will be available for you to download. If you would like to send any comments*

	on this version of the report we would accept them, and try to build them into future revisions. When a River Severn Drought Order application is made, there would also be a formal public consultation period.

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