JACOBS

River Dee/ Afon Dyfrdwy SSSI Restoration Technical Report

March 2013

NATURAL ENGLAND

Environment Agency

Asiantaeth yr Amgylchedd Cymru
Environment Agency Wales

Cyngor Cefn Gwlad Cymru
Countryside Council for Wales

Noddir gan
Lywodraeth Cymru
Sponsored by
Welsh Government

Document Control Sheet

BPP 04 F8
Version 14 July 2012

Project:	River Dee SSSI Restoration	Project No:	B1867400
Client:	Environment Agency		
Document Title:	Technical Report		
Ref. No:	A02		

	Originated by	Checked by	Reviewed by	Approved by
ORIGINAL	NAME **Alison Flynn**	NAME **Elinor Phillips**	NAME **Jon Barnes**	NAME **Andrew Brookes**
DATE	INITIALS	INITIALS	INITIALS	INITIALS
January 2013	**Document Status: Draft for Client Comments**			

REVISION	NAME **Alison Flynn** **Jon Barnes**	NAME **Lyndon Baker**	NAME **Elinor Phillips**	NAME **Andrew Brookes**
DATE	INITIALS	INITIALS	INITIALS	INITIALS
February 2013	**Document Status Final incorporating client comments**			

REVISION	NAME **Alison Flynn**	NAME **Elinor Phillips**	NAME **Elinor Phillips**	NAME **Andrew Brookes**
DATE	INITIALS	INITIALS	INITIALS	INITIALS
March 2013	**Document Status Final incorporating further client and stakeholder comments**			

REVISION	NAME	NAME	NAME	NAME
DATE	INITIALS	INITIALS	INITIALS	INITIALS
	Document Status			

Executive summary

Background

The Environment Agency (EA) commissioned Jacobs to undertake a joint geomorphology and ecology study of the River Dee/ Afon Dyfrdwy which flows through both Wales and England. The river has a high conservation value being designated as two separate Sites of Special Scientific Interest (SSSIs) which are defined by the national boundary between England and Wales. The River Dee (England) SSSI is in England and the Afon Dyfrdwy (River Dee) SSSI is in Wales. In addition the Dee/ Dyfrdwy and Bala Lake are designated a Special Area of Conservation (SAC) (River Dee and Bala Lake/ Afon Dyfrdwy a Llyn Tegid SAC) which covers both English and Welsh sections. There are a number of features contributing to the SSSI and SAC designations including *Ranunculus* communities, floating water plantain, Atlantic salmon, bullhead, lamprey, otter, club tailed dragonfly and fluvial geomorphology in the meandering section of the main stem Dee across the Cheshire Plain. Currently most of the SSSIs and SAC are judged to be in unfavourable condition, due to a number of historical and current pressures.

The Dee River Basin Management Plan (RBMP), which is produced under the Water Framework Directive (WFD), outlines pressures facing the water environment in this river basin district, and the actions that will be taken to address them. A range of challenges remain, which will need to be addressed to secure predicted improvements. They include:

- diffuse pollution from agricultural and other rural activities
- point source pollution from sewage treatment works
- the physical modification of water bodies
- point source pollution from domestic (non-water industry) activities; and
- diffuse pollution from housing

At present, because of these pressures and the higher environmental standards required by the WFD only 28 per cent of surface waters in the River Dee/ Afon Dyfrdwy catchment are currently classified as Good or High Ecological Status/Potential with many of the water bodies being designated as heavily modified, including the water bodies that constitute the main stem Dee.

Compared with other European rivers, flow in the River Dee/ Afon Dyfrdwy is very highly regulated for public water supply and flood risk by reservoirs Bala Lake/ Llyn Tegid, Llyn Celyn and Llyn Celyn, which are located in the Welsh mountains. This flow regulation has resulted in increased low flows and decreased high flows in the main stem Dee/ Dyfrdwy, which may mean the river is less able to carry out geomorphological processes (such as bank erosion). This effect of flow regulation on geomorphology is a key limitation in choosing suitable restoration measures/ actions for this vision.

The purpose of this study is to develop a restoration vision of the whole river catchment identifying where the main physical pressures are and outlining restoration measures to help achieve favourable condition of the SSSIs and SAC, and also assist in delivering the objectives of the WFD.

Approach

This study involves a desk based assessment and site surveys undertaken in November/ December 2012. It builds on previous reports on the SSSIs and SAC of the River Dee/ Afon Dyfrdwy (notably Hill and Emery (2005) Fluvial Audit and Jacobs (2009) River Dee SSSI Restoration Vision Report) and a visit to the British National Library to obtain available information on historic works carried out within the catchment.

Surveys for the current study were undertaken at locations not covered by the previous reports and at locations where previous surveys had identified significant channel modifications. The river catchment is divided up into four sections based on geology and geomorphology: the Upper Dee (including headwater tributaries), Middle Dee, Lower Dee and River Ceiriog/ Afon Ceiriog. Sites were surveyed for river channel habitat suitability for each of the SSSI/ SAC features and key impacts to habitat suitability were noted across the catchment.

Based on field evidence and data from previous studies, the restoration measures suggested to obtain optimal condition of each reach are classified according to the degree of management/ intervention required. These include: riparian management, natural recovery, assisted natural recovery and significant channel restoration.

Where there are urban (flood risk) constraints to the river, restoration measures have not been recommended as these are considered to be outwith the scope of the restoration vision

Findings

The upland tributaries of the Upper Dee and also most of the upper River Ceiriog have some localised modifications, but are largely natural with geomorphology and ecology habitat suitability judged to be of high quality. Most pressures on habitat suitability on the River Dee/ Afon Dyfrdwy SSSIs are judged to occur on the main stem river.

These include:

- Major weirs which present barriers to migration for lamprey and possibly other fish species (Upper, Middle, Lower Dee and River Ceiriog)
- Minor weirs which do not present significant barriers to migration but are affecting the natural geomorphological processes of the river
- Channel realignment (particularly on the tributaries)
- Historic and current bank protection (particularly extensive in the Upper and Lower Dee) which is preventing geomorphological processes from occurring
- Embankments (present in Upper Dee and extensive in Lower Dee at Dee meanders)
- Poaching from livestock
- Degradation of the riparian zone (particularly where there is intensive grazing animals and historic tree clearance) which has led to accelerated bank erosion and reductions in shading and shelter on the river channel (extensive throughout the catchment)

The majority of reaches in the catchment require riparian management to some degree, including tree planting where the tree line is thin or absent. Increased tree cover provides shading and cover to the channel. Overhanging branches may be utilised as cover and input wood debris into the channel, in turn creating submerged habitat. Managing grazing pressure also encourages tree growth (potentially providing natural bank protection) and addresses poaching problems by grazing livestock. Improving the riparian zone will reduce sediment input into the watercourse thus maintaining interstitial spaces between coarse substrates used for spawning.

Natural recovery restoration actions recommended include allowing the unmanaged retreat of meanders and erosion of embankments (particularly at the Dee meanders). Historical records suggest that embankments along the Lower Dee in particular have been locally protected by stone bank protection, which was found at many locations to have been destroyed in the absence of maintenance. Records also prove that embankments were often built out of natural floodplain materials won from borrow pits. Thus failing embankments would provide ‘natural’ materials back to the channel.

Assisted natural recovery management options include the removal of historic bank protection (particularly in the main stem of the Upper Dee, where much remains in-situ). There is also some potential to remove redundant flood walls and minor weirs along the tributaries.

Significant channel restoration measures recommended include realigning artificially straightened sections to have a more winding course. This action will reduce the gradient of the channel making it more suitable for gravel deposition which may improve salmonid spawning habitat (that may have existed historically) and increase substrate and flow variation for other species. Re-meandering will increase flow variation, promoting natural geomorphological process and the provision of a wider range of aquatic habitat types. There may also be a potential (subject to feasibility) of removing (or improving) larger weirs from along the main stem Dee, thereby improving sediment and flow dynamics, enhancing fish passage and improving connectivity between habitats and opening up more of the upper catchment to utilisation by species. Corresponding reduction of backwater effects created by a weir may also improve habitats. Other significant channel restoration measures include breaching embankments.

There are a few reaches where the river environment is judged to be in optimal condition and therefore no restoration measures are required.

Next steps

Environment Agency Wales, CCW, Environment Agency and Natural England recognise the challenges that land owners and managers face linked to the river throughout the catchment. These include: loss of crops and/or soil due to flood events, field drainage, reducing nutrient runoff and the availability of water to abstract for summer irrigation. The Statutory Bodies want to work with farmers to help them deal with these issues whilst improving and protecting the internationally important river system. They recognise that the implementation of a restoration plan will require effective and positive engagement with land owners, land managers and stakeholders. The restoration actions in the accompanying Management Report are suggested as a means to achieve favourable condition of the SSSIs and SAC and as such the plan will inform future decision making by the Statutory Bodies. The restoration plans (within the accompanying Management Report) could assist in the targeting and uptake of agri-environmental schemes and provide opportunities for farmers to seek financial assistance for adapting their practices; e.g. Environmental Stewardship support to help farmers move to a more sustainable system of land management where fields are subjected to frequent flooding.

The views and concerns of a cross section of stakeholders on the draft strategy are being sought, including: individual land owners, land managers and farmers; representatives from local communities; relevant public bodies; and delivery partners. The comments and information generated through this will shape the final strategy. Future detailed discussions with land owners about specific river reaches will be an essential part of developing reach specific restoration projects in the coming years. A summary record of general comments will be included in the final reports. The Management Report forms part of a long term strategy (perhaps being realised over a period of 20 to 30years, although it is anticipated that some actions can be implemented relatively quickly.

From the 1st April 2013, Natural Resources Wales will take over the functions currently carried out by the Countryside Council for Wales, Environment Agency Wales and Forestry Commission Wales.

JACOBS

Contents

Glossary

Terminology	Definition
Afon Dyfrdwy (River Dee) SSSI	The River Dee/ Afon Dyfrdwy is divided into two SSSIs. The Afon Dyfrdwy (River Dee) SSSI specifically refers to the Welsh SSSI that is managed by EAW and CCW
Berm	Deposit of fine material along the edges of a river channel. This may have formed in the Lower Dee meanders as a result of flow regulation, reducing the capacity of the river to carry sediment, and resulting in deposition
Catchment	Area drained by a river and its tributaries
Deposition	Laying down of part, or all, of the sediment load of a stream on the bed, banks or floodplain. Mostly occurs as high flows recede. The process forms various sediment features such as bars, berms and floodplain deposits
Ecological status	Surface waters are classified as being of good ecological status when each of the quality elements that represent indicators of ecological quality of the water body is classified as being good or high. The quality elements fall into three categories: i) biological quality elements, ii) chemical and physicochemical quality elements and iii) hydromorphological quality elements
Erosion	Removal of sediment or bedrock from the bed or banks of the channel by flowing water. Mostly occurs during high flows and flood events. Forms various river features such as scour holes and steep outer banks
Favourable condition	Description of the condition of the features for which a SSSI or SAC has been designated. Favourable condition means that all of the targets for the mandatory attributes (population and habitat) used to assess a feature have been met. If a SSSI site is in Favourable Condition, it means that the site is being adequately conserved and is meeting its 'conservation objectives'
Floodplain	A floodplain is flat or nearly flat land adjacent to a stream or river, stretching from the banks of its channel to the base of the enclosing valley walls and (under natural conditions) experiences flooding periods of high discharge
Geomorphology	The study of landforms and the processes that create them
Good status	The general objective of the WFD is to achieve ‘good status’ for all surface waters by 2015. ‘Good status’ means the achievement of both ‘good ecological status’ and ‘good chemical status’
Good ecological status	WFD term denoting a slight deviation from ‘reference conditions’ in a water body, or the biological, chemical and physio-chemical and hydromorphological conditions associated with little or no human pressure
Glide	Deeper water flowing smoothly over a river bed. Occasional larger cobbles or boulders on the bed may create some surface disturbance

Terminology	Definition
Planform	River channel pattern when viewed from above. This often referred to as either straight, sinuous, meandering or braided
Pool	Deeper, steadier water. Pools are usually located at bends in watercourses, and depth decreases towards the outside of a bend
Pressure	The direct effect of the driver (for example, an effect that causes a change). Pressures include morphological alterations, abstraction, diffuse source pollution, point source pollution and flow regulation. In the context of the WFD a significant pressure is one that, on its own, or in combination with other pressures, would be liable to cause a failure to achieve the environmental objectives set out under Article 4
Reach	A length of channel which, for example, may have a homogeneous geomorphology (river type) or restoration solution
Reference conditions	For any surface water body type, reference condition is a state in the present or in the past where there are no, or only very minor, changes to the values of the hydromorphological, physico-chemical, and biological quality elements which would be found in the absence of anthropogenic disturbance
Re-profiling	The reshaping of a river bank. May be a reflection of channel modification (impact) or restoration
Riffle	A stream bed accumulation of coarse alluvium linked with the scour of an upstream pool
Riparian Zone	Strip of land along the top of a river bank. Plant communities along the river banks are often referred to as riparian vegetation
River Dee and Bala Lake/ Afon Dyfrdwy a Llyn Tegid SAC	The SAC extends across both English and Welsh sections of the River Dee/ Afon Dyfrdwy
River Dee (England) SSSI	The River Dee/ Afon Dyfrdwy is divided into two SSSIs. The River Dee (England) SSSI specifically refers to the English SSSI that is managed by the EA and NE
Run	Quicker water, deeper than riffles and usually with a stony or rocky bed which creates a ruffled surface
Tributary	A stream or river which flows into a larger river. A tributary does not flow directly into the sea
Unfavourable condition	Description of the condition of the features for which a SSSI or SAC has been designated. Unfavourable condition means that all of the targets for the mandatory attributes (population and habitat) used to assess a feature have not been met
Woody debris	Woody debris are logs, sticks, branches, and other wood that falls into streams and rivers. This debris can influence the flow and the shape of the stream channel

Acronyms	
CCW	Countryside Commission for Wales (which will become part of NRW from 1st April 2013)
CFMP	Catchment Flood Management Plan
CRF	Catchment Restoration Fund
CSF	Catchment Sensitive Farming
DEFRA	The Department for Environment, Food and Rural Affairs
DWPAP	Diffuse Water Pollution Action Plan
EA	Environment Agency
EAW	Environment Agency Wales (which will become part of NRW from 1st April 2013)
ESS	Environmental Stewardship Scheme
EWGS	English Woodland Grant Scheme
FRCM	Flood Risk and Coastal Management
GIS	Geographical Information System
HLS	Higher Level Stewardship
HMWB	Heavily Modified Water Body
NE	Natural England
NRW	Natural Resources Wales (which will form on the 1st April 2013 as an amalgamation of EAW, CCW and the Forestry Commission Wales)
OS	Ordnance Survey
RBMP	River Basin Management Plan
SAC	Special Area of Conservation
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
WFD	Water Framework Directive

1 Introduction

1.1 Background

The River Dee/ Afon Dyfrdwy and its tributaries the River Ceiriog/ Afon Ceiriog, Afon Mynach, Afon Meloch and Tryweryn are designated as a Special Area of Conservation (SAC) (SAC EU code UK0030252) under the EU Habitats Directive.

As parts of the River Dee/ Afon Dyfrdwy lie in both England and Wales the river has been designated as two separate SSSIs under the Wildlife and Countryside Act 1981: the 'Afon Dyfrdwy (River Dee) SSSI' in Wales and the 'River Dee (England) SSSI' in England, herein referred to as the 'Welsh SSSI' and the 'English SSSI', respectively. Both Welsh and English SSSIs are designated due to the important transitions from mesotrophic to eutrophic river types and are currently classed as being in unfavourable condition. In addition, the river is notified for the fluvial geomorphological patterns and processes and range of habitats and species that occur in both the English and Welsh sections.

A condition assessment for all English SSSI units has been completed by Natural England. Many rivers, including the River Dee, were found to have physical, often historical modifications, affecting the natural functioning of the river system and associated habitats for characteristic wildlife communities. These modifications include inappropriate dredging, weirs, dams, other channel structures and flood defence infrastructure that have led to pressures on the designated rivers causing them to be in unfavourable condition under the Habitats Directive. To address these pressures, Natural England (NE) has a programme of SSSI remedies which includes 'River Restoration Projects', whilst Countryside Council for Wales (CCW) has an Actions Database.

Objectives for favourable condition in SSSIs and SACs designated for river habitat have been agreed as a set of Common Standards by UK conservation agencies. Having identified the river type, these objectives aim to provide favourable habitat conditions appropriate to that river type for the characteristic biological community, rather than focusing on restoration to benefit a particular species.

1.2 Rationale for restoration of River Dee/ Afon Dyfrdwy SSSIs and SAC

The English SSSI is divided into four units, three of which are currently in unfavourable – no change condition. Reasons for unfavourable condition are due to the failing of multiple targets including those set for water quality, salmon, bullhead and macrophytes and more generally due to inappropriate weirs, dams and other structures and invasive freshwater species. The English SSSI unit that is currently in favourable condition for geomorphology is the meandering section from Holt to Worthenbury. In this unit "*the river displays the necessary characteristics of a meandering and geomorphologically active river, with obvious undercutting and deposition along the length of the unit*" (Natural England, 2012[1]).

[1] Natural England (2012). *Condition of SSSI units* [online]. Available at: <http://www.sssi.naturalengland.org.uk/special/sssi/reportAction.cfm?report=sdrt13&category=S&reference=2000452> [Accessed on 18/01/13]

CCW are currently in the process of reassessing the Welsh SSSI at a site level and anticipate that many management units will be reported as unfavourable. At present, they have assessed the condition of the features that constitute the whole SSSI.

Restoration of the management units and features currently in unfavourable condition will contribute directly to moving the river towards favourable condition. In England it will also contribute to the Environment Agency (EA) Flood Risk and Coastal Management (FRCM) Outcome measure 4c (length of river improved). In Wales, actions to improve the condition of the Welsh SSSI will also contribute to the Wales Environmental Strategy Outcome 21. The EA Wales and CCW currently have no formal agreement to address physical habitat modifications.

Restoration of the River Dee/ Afon Dyfrdwy SSSIs and SAC will also contribute to the achievement of Good Ecological Status or Potential on water bodies within the protected areas under the Water Framework Directive (WFD). Some of the reasons for the water bodies failing to achieve Good Ecological Status or Potential are related to physical modification of water bodies, point source and diffuse source pollution and flow regulation. These pressures also affect the condition of SSSI and SAC features. Although the current study is concerned with directly restoring the physical modifications to the rivers in the SSSIs and SAC, some measures may indirectly improve water quality (such as improving riparian buffer strips, potentially reducing diffuse pollution from agriculture). More information on the pressures facing the water environment can be found in the Dee River Basin Management Plan (RBMP), which is produced under the WFD. This also outlines mitigation measures to deal with these pressures.

Flow regulation and abstraction regime have not been investigated specifically within this project but it is expected that the findings of this project will be complementary to other programmes of work currently being carried out by the Environment Agency. These include the review of abstraction licences potentially impacting on the River Dee and Bala Lake SAC where required changes are being implemented through the Restoring Sustainable Abstraction (RSA) programme and the investigation of WFD mitigation measures to address physical modifications associated with water storage and supply. Investigations fall into the categories 'investigate cause of failure', 'investigate to confirm failure and/or impact', 'investigate feasible measures' and 'investigate nature and extent of ecological impact'.

More information on the programme of WFD investigations can be found at http://www.environment-agency.gov.uk/research/planning/33106.aspx in the spreadsheet entitled 'Water Framework Investigations programme detail (July 2012)' and details of the RSA programme can be found at http://www.environment-agency.gov.uk/business/topics/water/32026.aspx.

1.3 Project aim and objectives

The project aims to identify river restoration or enhancement options that can help bring the River Dee/Afon Dyfrdwy SSSIs and SAC up to favourable or unfavourable recovering condition. These options should also help the parts of the river currently failing under the WFD to achieve 'Good Ecological Status' or 'Good Ecological Potential' (where the water body is heavily modified). This overall aim includes the following specific objectives:

1. Undertake a geomorphological analysis and ecological interpretation of physical impacts on the River Dee/ Afon Dyfrdwy SSSIs and SAC, comprising a desk study, gap analysis and targeted field survey
2. Produce restoration visions for the Upper, Middle and Lower Dee, identifying river geomorphology and habitat links, including those critical to the achievement of favourable condition
3. Provide an outline restoration plan for the river on a reach-by-reach basis, which is linked specifically to the conservation objectives for species and habitats of the SAC and SSSIs
4. Identify potential delivery mechanisms and provide approximate costs for the different aspects of restoration
5. Assist Natural England, EA (Wales and England), CCW and partners in consultation with stakeholders
6. Produce a final restoration plan, incorporating the results of the consultation event

The plan is intended to provide a framework for the restoration and enhancement of the River Dee/ Afon Dyfrdwy SSSIs and SAC for the next 20 to 30 years.

1.4 Outputs

1. A technical report detailing the geomorphological and ecological appraisal
2. Mapped outputs showing key geomorphological features and management changes (included in the technical report)
3. A GIS database of raw geomorphological data and associated data (e.g. photos)
4. A management report containing the outline restoration plan. The report will detail existing management regimes, restoration options, potential delivery mechanisms and indicative costs
5. A package of consultation material for a stakeholder consultation event
6. A report of the results of the consultation event and a revised restoration plan (contained within the management report)

1.5 Aims and objectives of the Technical Report

This Technical Report is intended for use by river managers and regulating bodies (specifically NE, EA, EAW and CCW[2]) as supporting information for the accompanying River Dee/ Afon Dyfrdwy Restoration Management Report. The aim of the Technical Report is to present the findings of the geomorphological assessment and ecological interpretation of physical impacts on the river (i.e. channel and floodplain modifications) and to determine the types of restoration measures that could be put in place to rectify this. The data collected during the field survey can be viewed on an interactive mapper tool on the CD accompanying this report.

The accompanying Management Report incorporates the geomorphological and ecological findings of the Technical Report and presents the restoration actions that are suggested to achieve favourable condition in the River Dee/ Afon Dyfrdwy SSSIs and SAC. The Management Report will therefore inform future decision making by the EA, EAW, NE and CCW (Statutory Bodies). Implementation of the

[2] From 1 April 2013, National Resources Wales will take over the functions currently carried out by CCW, EAW and Forestry Commission Wales

Management Report, will require effective and positive engagement with stakeholders.

2 Method

2.1 Overview of method

A desk based assessment was undertaken that reviewed a number of reports and studies previously carried out on both the Welsh and English SSSIs, including the Hill and Emery (2005) Fluvial Audit. Using the outputs of the desk based assessment the catchment was divided into four areas for the purposes of this field work and developing restoration visions (Table 2-1).

Table 2-1 Divisions of River Dee/ Afon Dyfrdwy

Section name	Section extents	CCW management units
Upper Dee	Headwaters to Corwen	15, 16, 17, 2, 3 and upstream half of 4
Middle Dee	Corwen to Overton	Downstream half of 4, 5, 6, 7 and 8
Lower Dee	Overton to Chester	9, 10, 11, 12, 13 and 14
River Ceiriog	All of the River Ceiriog	18 and 19

In each of the four sections, parts of River Dee/ Afon Dyfrdwy were surveyed using either the Fluvial Audit method or by carrying out spot checks to summarise sections of the river. The Fluvial Audit approach was originally developed in parallel with the Guidebook of Applied Fluvial Geomorphology (Sear, Newson and Thorne, 2010). Fluvial Audits have been applied to a wide range of purposes and the details of the method tailored to specific project objectives. In this case, the method was amended to investigate potential restoration options for the River Dee. Spot checks were also carried out in places to provide a general overview of the geomorphology, hydrology and ecology of a strategically selected 1km section of the river. Each of these stages is described in more detail below.

2.2 Desk based assessment

The desk study involved a review of catchment scale datasets such as topographic, geological and historical maps, aerial photographs, previous scientific studies on the River Dee and previous geomorphological and ecological surveys carried out on the Dee. These included:

- CCW Core Management Plan for River Dee and Bala Lake/ Afon Dyrfrdwy A Llyn Tegid SAC (Hatcher and Garrett, 2008)
- River Dee SSSI Restoration Vision Report (2009) Jacobs report for Natural England
- Hill and Emery (2005) Fluvial Audit of the River Dee (2005), Geodata Institute report for Countryside council for Wales
- River Dee RBMP (2009), Environment Agency
- Riley (2010) River Dee (England) SSSI Diffuse Water Pollution Plan, Environment Agency
- Dee and Clwyd annual accounts from 1953 to 1974, maintenance and improvement works (source British National Library); and
- Our River Habitats – River habitats in Dee River Basin District: Current State and character, Environment Agency report

2.3 Field survey

2.3.1 Overview

Approximately 50km of field surveys were undertaken between the 13th November and 13th December 2012. The sites surveyed were targeted through a gap analysis of the existing datasets for the River Dee. The field surveys were comprised of Fluvial Audits and spot checks (these are presented in Section 2.4 below). The survey team included an experienced geomorphologist and an ecologist. All observations were made using professional judgement and prior experience of similar river planforms. The area of the River Dee/ Afon Dyfrdwy and its tributaries which have been surveyed through the current study and the Hill and Emery (2005) Fluvial Audit are shown on Figure 2.1. Walkover surveys of the entire main stem Dee and Afon Meloch have been undertaken (note, the headwaters of the Afon Meloch have not been surveyed). Approximately 90% of the Afon Mynach has been covered through spot checks and a walkover survey. Approximately two thirds of the Afon Ceiriog has been surveyed through a combination of a walkover survey and nine spot checks. Only the Tryweryn upstream of Bala Enterprise Park has not been surveyed, although it is anticipated through aerial photographs and an OS map that this tributary displays similar geomorphological and ecological characteristics to the other upland tributaries surveyed.

The Fluvial Audits focused on recording and mapping the following types of information based on visual observations at the time of survey:

- Sediment sources (erosion) and sinks (deposits)
- Bed and bank composition
- Characteristics of the riparian zone
- Channel modifications (straightening, deepening, bank reinforcement, weirs)
- Point sediment sources (such as tributaries)
- Dominant geomorphological function and processes (such as erosion)
- Conservation status
- Sediment and predominant flow types
- Habitat suitability for designated SAC and SSSI species and habitats; and
- Presence of important channel features for designated species (such as woody debris and vegetation stands)

A walkover survey was intended to record the degree of modifications to the channel and its surrounding environment as well as the processes occurring upstream and downstream of that reach. Both of these form a key determinant as to the requirement for and type(s) of physical restoration. By assessing the channel morphology and dominant geomorphological processes alongside the ecological habitat suitability for feature species, determination of physical habitat restoration options can be identified with consideration as to whether such restoration will result in ecological gain or improvement and for which species (or species specific life stages).

The reach function (Table 2-2) and process (Table 2-3) were categorised along with the geomorphological processes. The classification of reach function is based on the geomorphological conditions observed at the time of survey and knowledge from previous surveys and studies.

Table 2-2 Reach function definitions (adapted from Sear, Newson and Thorne, 2003)

Reach Function	Description
Sediment source	Sediment output from the reach is greater than sediment supply from upstream
Sediment transfer	Sediment output is approximately equal to input from upstream. Sediment is transmitted through the reach, which features few sites of active erosion, or deposition either because the channel is adjusted and naturally stable or because the bed and banks have been stabilised artificially
Sediment exchange	Sediment output is approximately equal to input from upstream (as for a transfer reach), but incoming sediment is exchanged with that derived within the reach, which features active erosion and depositional sites
Sediment sink	Sediment input to the reach is greater than sediment output to the next reach downstream
Winterbourne	Flow expected only at high flow, therefore the balance of sediment inputs and outputs is seasonally dependent

Table 2-3 Field indicators of instability and stability – reach process (adapted from Sear, Newson and Thorne, 2010)

Catergory	Indicators	Category	Indicators
Incising	Perched boulder berms Terraces Old channels Old slope failures Undermined structures Exposed tree roots (both banks) Armoured/ compacted bed Deep gravel exposure in banks that are topped with fines	**Aggrading**	Buried structures Buried soils Large uncompacted point bars Eroding banks at shallows Contracting bridge space Deep fine sediment over coarse gravels in bank Many unvegetated point bars Large silt/clay banks
Widening	Bank failures (both banks) Vegetation falling in, or leaning towards the channel on both banks Evolution of a new planform at a lower elevation	**Laterally adjusting**	Significant number of bank erosion areas Significant number of bar formation areas Channel cut-offs
Stable	Vegetated bars and banks Compacted weed covered bed Bank erosion rare Old structures in position	**Narrowing**	Sedimentation on both channel margins

The conservation status of each reach was determined during the Fluvial Audits. Table 2-4 shows the description of each level of conservation status and is based on the degree of modification present within that reach and the level of recovery of the geomorphological features. This was used along with Fluvial Audit data collected to identify and prioritise potential restoration opportunities and sites.

Table 2-4 Conservation Status Score and Descriptions

Conservation Status	Score	Description
High	8-10	Conforms most closely to natural, unaltered state and will often exhibit signs of free meandering and possess well-developed bedforms (point bars and pool-riffle sequences) and abundant bank side vegetation
Moderate	5-7	Shows signs of previous alteration but still retains many natural features, or may be recovering towards conditions indicative of the higher category
Low	2-4	Substantially modified by previous engineering works and likely to possess an artificial cross-section (e.g. trapezoidal) and will probably be deficient in bedforms and bankside vegetation
Channelised	1	Awarded to reaches whose bed and banks have hard protection (e.g. concrete walls or sheet piling)
Culverted	0	Totally enclosed by hard protection
Navigable	-	Classified separately due to their high degree of flow regulation and bank protection, and their probable strategic need for maintenance dredging

(Sear, Newson and Thorne, 2010).

Raw geomorphological and ecological field data and photographs taken during the Fluvial Audits were collected using a hand-held mobile mapping device. The mobile mapping device allows the data to be inputted directly into a Geographical Information System (GIS) for subsequent analysis and comparison with other datasets. In addition sweep up sheets were used to help characterise reaches within each Fluvial Audit.

Spot checks, at least 1km in length, were strategically selected during the desk study. The centre points of these spot checks were usually marked by a road bridge. These allowed for more of the river to be seen in a shorter space of time in comparison to Fluvial Audits. The aim of the spot checks was to characterise the river along the selected 1km for aspects including river channel planform and dimensions, floodplain, bed and bank materials and riparian zone. Photographs and major structures/modifications were recorded on a paper map and digitised onto the interactive mapper tool.

2.3.2 Definition of Fluvial Audit reach

To organise the data collected during the Fluvial Audits and to facilitate the development of outline restoration plans for the SSSIs and SAC, the river was sub-divided into ‘reaches’. These reaches represent sections of the river with specific geomorphological and ecological characteristics that differ from adjoining sections of the river. The reaches were defined during the field survey starting at DEE001, CEI001, MYN001 or MEL001, depending on the river name and a new reach number was allocated where the character of the river and its surroundings changed. Reasons for defining a new reach consisted of a combination of the following:

- Appreciable change in the morphology of the channel, such as a change in planform or cross-sectional form
- Change in the composition and condition of the riparian zone; and
- Change in dominant land use

When assigning sections of river to particular reaches and also during individual spot checks, emphasis was placed on the need for restoration and the potential nature of this restoration.

For the remaining lengths of the River Dee/ Afon Dyfrdwy, this study adopted the findings of the Hill and Emery (2005) Fluvial Audit to assess the need for restoration. The validity of the Hill and Emery (2005) Fluvial Audit was assessed during the field survey upstream of Corwen, over the Dee meanders and downstream of Farndon. The observations of bank protection and erosion that were made during the November/December 2012 surveys were consistent with what was mapped in the Hill and Emery (2005) Fluvial Audit. This suggests that the Hill and Emery (2005) Fluvial Audit is a reliable secondary source of information on which to base many of the restoration plans. However, due to the dynamic nature of rivers, sections where restoration measures have been based solely upon data collected from the 2005 Fluvial Audit should be treated with a degree of caution and will require a site specific feasibility study prior to implementing restoration measures.

2.4 Study area

Development of the River Dee restoration vision has been founded upon information reviewed for the entire catchment of the river and from both English and Welsh sources. The stretches of river targeted for fieldwork are presented in Table 2-5 and Figure 2.1 below.

Table 2-5 Location of walkover survey and spot checks

Division	Identification code	Survey type	Location
River Ceiriog	CEI001SP	Spot check	Centre point - Pentre bridge (SJ136 347)
	CEI002SP	Spot check	Centre point - Llanarmon Dyffryn Ceiriog bridge (SJ158 329)
	CEI003SP	Spot check	Centre point -Tregeiriog bridge (SJ177 335)
	CEI004SP	Spot check	Pen y Bont bridge (SJ187 344) to campsite Coed y glyn Canol (SJ199 355) (about 4km)
	CEI005SP	Spot check	Centre point - Glyn Ceiriog bridge (SJ205 379)
	CEI006SP	Spot check	Centre point - Dolywern/Llwynmawr Bridge (SJ222 374)
	CEI007SP	Spot check	Centre point - Pontfadog car park (SJ235 380)
	CEI008SP	Spot check	Centre point - bridge at Herber Gate (SJ254 380)
	CEI009SP	Spot check	Centre point - Pont-Faen bridge (SJ280 371)
	CEI001 – CEI008	Fluvial Audit	From Chirk Bridge (SJ 290 373) to confluence with River Dee (SJ318 395)
Afon Mynach (Upper Dee)	MYN001SP	Spot check (50m)	Caer garreg at (SH905 437)
Afon Meloch	MYN002SP	Spot check	Hafod yr-Esgob Isaf ford at

Division	Identification code	Survey type	Location
(Upper Dee)		(500m)	(SH906 429)
	MYN001 – MYN004	Fluvial Audit	From Pont (bridge) Mynachddwr to confluence with Afon Tryweryn at Frongoch at (SH906 392)
	MEL001-MEL006	Fluvial Audit	From Confluence of Nant Cwm-Da and Nant Cefn coch (Pentre tai-yn-y-cwm) (SH956 403) to confluence with River Dee at (SH951 367) (Aerfen, Tre'r Llan)
Tryweryn/Dee confluence (Upper Dee)	TRY001SP	Spot check	Confluence of Tryweryn and Dee, downstream of Bala Lake/ Llyn Tegid
River Dee/ Afon Dyfrdwy (Upper Dee)	DEE001SP	Spot check	Centre point - Cynwyd
Upper Dee	DEE001	Fluvial Audit	Area of bank protection upstream of Corwen
Middle Dee	DEE002SP	Spot check	Centre point - Corwen
	DEE003SP	Spot check	Centre point – Plas Hyfred
	DEE004SP	Spot check	Centre point - Horseshoe Falls (SJ198 434)
	DEE005SP	Spot check (1500m)	Centre point – Main road bridge in Llangollen
	DEE006SP	Spot check	Centre point – Manley Hall weir (SJ348 414)
	DEE007SP	Spot check	Centre point – Erbistock weir (SJ354 421)
Lower Dee	DEE008SP	Spot check (500m)	Downstream of Bangor-on-Dee bridge (SJ387 454)
	DEE009SP	Spot check	Dungrey stabilisation scheme, downstereamof Bangor-on-Dee at (SJ401 466)
	DEE002	Fluvial Audit	Dee meanders from Sutton Green (SJ413 478 to SJ420 517)
	DEE003	Fluvial Audit	Stretch downstream of Farndon between SJ40347 55987 and SJ40932 57677
	DEE004	Fluvial Audit	Stretch downstream of Farndon between SJ40932 57677 and SJ41081 58638

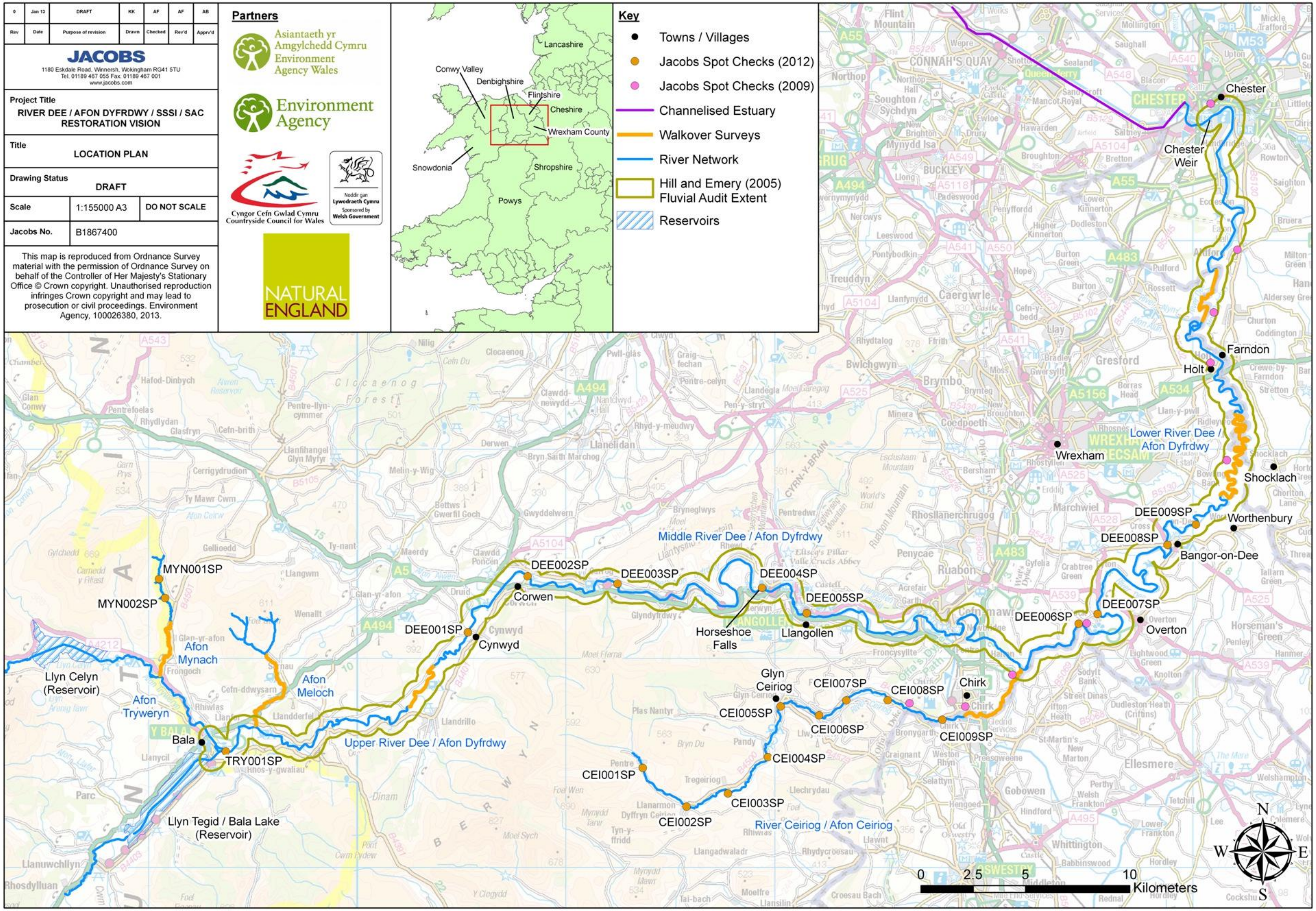


Figure 2.1 Site locations covered by the November/December 2012 surveys, Jacobs (2009) surveys and the Hill and Emery (2005) Fluvial Audit

2.5 Data analysis and reporting

The findings of the desk study and field survey data are presented in this report. The raw geomorphological data recorded using the mobile mapper are in GIS format and can be viewed using the interactive mapper tool on the CD accompanying this report. The photographs taken during the 2012 survey are also geo-referenced in the interactive map. The restoration plans developed for the River Dee/ Afon Dyfrdwy are outlined in the accompanying Management Report. This sets out a vision for the long term restoration of the SSSIs and SAC and provides a series of reach-by-reach proposals.

2.6 Limitations and assumptions

The scope of the project was to survey approximately 50 km of the River Dee/ Afon Dyfrdwy and tributaries, however the actual total length of rivers making up the designated Welsh and English SSSIs exceeds 160 km. Between the current study, the Hill and Emery (2005) Fluvial Audit and the Jacobs (2009) report the entire main stem Dee has been surveyed between Bala Lake outfall and Chester weir. A walkover survey of the entire Afon Meloch and a section of its headwaters was undertaken as part of this study. Approximately 90% of the Afon Mynach was covered in a walkover survey and 2 spot checks. Approximately two thirds of the Afon Ceiriog, a major tributary of the River Dee/ Afon Dyfrdwy, was covered by a walkover survey and spot checks (from the source to the confluence with the Dee/ Dyfrdwy). Most of the spot checks on the Afon Ceiriog revealed very similar geomorphological and ecological characteristics and therefore it is probable that where there are gaps in survey observations, the river and surrounding environment do not change significantly.

Due to time and financial constraints of this study, the Tryweryn, upstream of the weir at Bala Enterprise Park was not surveyed nor has it been surveyed in other studies. Having gaps in information is a limitation of the study. However, for the Afon Ceiriog most of the spot checks were very similar in geomorphological and ecological characteristics, therefore it is likely that where there are gaps in survey observations, the river and environment do not change significantly. Aerial photographs and OS maps of the Tryweryn were used in place of site surveys to prescribe restoration measures concerning riparian zone and to identify barriers to migration such as weirs. It is assumed that the Tryweryn has similar geomorphological and ecological characteristics of the other upland tributaries surveyed.

The issue of flow regulation has not been investigated in this study. There are currently a number of investigations being carried out under the Water Framework Directive, such as Review of licences (for more information go to http://www.environment-agency.gov.uk/business/topics/water/32026.aspx.) and mitigation measures for water storage and supply (for more information go to http://www.environment-agency.gov.uk/research/planning/33106.aspx), which are addressing the detrimental effects of flow regulation.

This issue of flow regulation is also a key limitation in choosing suitable restoration measures/ actions for this vision due to the underlying effects created by the regulation of flows from the lakes and reservoirs managed for flood control and water supply purposes. Gurnell *et al* (1994) describe how this regulation has increased low flows and decreased high flows. Analysis of river flow records from 1938 to 1992 for the Erbistock/ Manley Hall gauging station identified these two trends and is described in more detail in Section 4.3.1. Within the SSSIs and SAC designations, flow regulation affects the main stem Dee and Tryweryn. The Alwen is also a regulated tributary of the main stem Dee (although this lies outside the SSSIs or SAC boundaries).

Restoration visions are based on a combination of field data collected for this current survey, the original Fluvial Audit carried out by Hill and Emery (2005) and the Jacobs (2009) report. The latter report covers the English sections of the Dee. As such, restoration visions have the following assumptions:

- Recommendations from the 2012 field surveys can be applied elsewhere in the catchment to non-surveyed areas based on the broad catchment understanding gained from the surveyed reaches; and
- Limited change has occurred since the Hill and Emery (2005) Fluvial Audit and Jacobs (2009) report and these are accurate accounts of what exists on the channel today

A number of limitations were identified with conducting field surveys during late autumn / early winter. During November and December 2012 the Dee catchment was subjected to significant rainfall, raising river levels. As such, it is likely that some, otherwise important marginal or mid channel geomorphological features such as side bars, berms and areas of erosion were partially or fully obscured by water levels. Seasonality for ecological receptors was a further limitation, as most of the riparian and aquatic plants had died back. Therefore the full extent of riparian zone and aquatic plants may be underestimated. This limitation has been recognised and accounted for in the analysis of field data.

In addition, the full extent of invasive species such as Japanese knotweed and Himalayan balsam may also be obscured as much of these had also died back at the time of survey.

2.7 Developing the restoration vision and detailed plans

The restoration plans have been developed using a combination of:

- Geomorphological and ecological expertise regarding the type of characteristics the river channel and its surrounding environment should exhibit under natural conditions and the use of this expertise to determine the level of habitat degradation from channel modification
- Secondary source data from the original Hill and Emery (2005) Fluvial Audit, which was assessed in some sections to be accurate and relevant to contemporary conditions
- An understanding of the requirements to meet ecological indicators for feature species and the link between habitat suitability and feature species
- An understanding of how ‘other pressures’ such as flow regulation may be impacting upon the river channels in parallel with morphological pressures
- Guidance on best practice for management of rivers and their surroundings
- Review of widely used river restoration techniques including a consideration of their suitability

3 River Dee/Afon Dyfrdwy SSSIs and SAC

3.1 River Dee/ Afon Dyfrdwy designations and ecological features

The River Dee catchment is very rich in biodiversity with over 16% of the catchment being designated due to its conservation value. The entire River Dee/ Afon Dyfrdwy, including the tributary River Ceiriog/ Afon Ceiriog and upper headwater tributaries Afon Mynach, Afon Meloch and Afon Tryweryn are designated as either the English or Welsh SSSI and a SAC. In addition, although not within the scope of this report, Bala Lake/ Llyn Tegid is also a part of the SAC and has been classed as a Ramsar site. The Dee estuary has a number of designations including Special Protected Area (SPA), SAC and Ramsar (EA, 2010).

The primary reasons for the SAC designation are the Annex I habitat Watercourses of plain to montane levels with *Ranunculus fluitantis* and *Callitricho-Batrachion* communities and Annex II species Atlantic Salmon and floating water plantain. Annex II species present as qualifying features, but not primary reasons for site selection are sea lamprey, brook lamprey, river lamprey, bullhead and otter.

The rivers of the Dee catchment are some of the best in the UK and are designated as nationally important SSSIs. The SSSIs are designated for the following river habitat types (more detail is provided in Table 3-2 below):

- Mesotrophic upland plateau rivers (Type VII)
- Moderate-gradient sand/shale rivers below uplands (Type VIII)
- Middle reaches of upland rivers traversing more base rich strata (Type VI); and
- Clay rivers with diverse substrates and flow patterns (Type II)

These habitats support characteristic species including: Atlantic salmon, otter, club-tailed dragonfly, and fluvial geomorphology.

The River Dee and Bala Lake are also designated as a SAC as a river habitat that supports certain internationally notable aquatic plant communities and populations of sea, river and brook lamprey, Atlantic salmon, and otter.

The meanders from Bangor-on-Dee to Farndon are described as being '*exceptional on a British scale' (Natural England, 2002*[3]*)* and are designated as at Geological Conservation Review Site (GCR 2955). Some features that contribute to SSSI status also contribute to SAC status and are outlined in Table 3-1.

Table 3-1 Summary of special features contributing to SAC and SSSI status of River Dee/Afon Dyfrdwy

Special feature	SSSI	SAC
Type VII Mesotrophic upland plateau rivers	✓	
Type VIII Moderate-gradient sand/shale rivers below uplands	✓	
Type VI: base-rich, mesotrophic rivers in western and northern Britain, with a moderate to fast current.	✓	

[3] Natural England (2002). *River Dee (England) SSSI citation* [pdf]. Available at: <http://www.sssi.naturalengland.org.uk/citation/citation_photo/2000452.pdf> [Accessed on 18/01/13]

Special feature	SSSI	SAC
Type II Clay rivers with diverse subtrates and flow patterns	✓	
Saltmarsh/ freshwater transition habitats	✓	
A range of habitat types qualifying as a mixture	✓	
Floating water plantain *Luronium natans*		✓*
Slender Hare's-ear *Bupleurum tenuissimum*	✓	
Sea Barley *Hordeum marinum*	✓	
Hard-grass *Parapholis strigosa*	✓	
Club tailed dragonfly *Gomphus vulgatissimus*	✓	
A stonefly *Isogenus nubecula* (No common name)	✓	
A weevil *Baris lepidii* (No common name)	✓	
Atlantic Salmon *Salmo salar*	✓	✓*
Sea lamprey *Petromyzon marinus*	✓	✓
Brook lamprey *Lampetra planeri*	✓	✓
River lamprey *Lampetra fluviatilis*	✓	✓
Bullhead *Cottus gobio*	✓	✓
European Otter *Lutra lutra*	✓	✓
Watercourses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation		✓
Geological/Geomorphological SSSI feature		
Holt to Worthenbury section	✓	
Rhewl section	✓	
Dee Bridge	✓	

*Features that are primary reasons for SAC selection of site (the non asterisked SAC features are qualifying features but not primary features for site selection).

As a result of the River Dee/Afon Dyfrdwy being a transboundary river that flows through both Wales and England, the river has been divided into two separate SSSIs; the Welsh Afon Dyfrdwy (River Dee) SSSI and the English River Dee (England) SSSI. The English River Dee SSSI has been divided further into four units by Natural England:

- Unit 1 – Main stem Dee from Farndon to Chester weir (CCW management unit s 12 and 13)
- Unit 3 – River Ceiriog from Bronygarth to Erbistock weir on main stem Dee (CCW management units 19 and part of 8)
- Unit 4 – Dee meanders from Shocklach to Farndon on main stem Dee (within the river channel) (CCW management unit 11 and part of 12); and
- Unit 5 – Dee meanders from Shocklach to Farndon on main stem Dee (Fluvial geomorphological processes/ patters and adjacent floodplain) (CCW management unit 11 and part of 12)

The UK conservation agencies set conservation objectives for SSSIs/ SACs, using agreed national standards, and regularly assess their condition. These objectives are based on a range of chemical, hydrological and physical targets (some quantitative, some descriptive) which enable the habitat to support the characteristic flora and fauna of that habitat type.

Favourable condition (in broad terms) is based on assessment of a habitat or species condition, from a nature conservation perspective. Habitats or species are judged to be in favourable condition when they are being adequately conserved and are meeting their 'conservation objectives'. The draft conservation objectives for the English SSSI units can be viewed online[4].

CCW Core Management Plan (Hatcher and Garrett, 2008) provides the following requirements for the River Dee SAC to be in favourable condition:

1. The ecological status of the water environment should be sufficient to maintain a stable or increasing population of each SAC feature, including elements of water quantity and quality, physical habitat and community composition and structure
2. No deterioration in water quality other than that generated by natural variations in water flow or by variations occurring as a result of the operation of the flow regulations
3. The Dee flow regime should remain within 10% of its actual flow (*presumed to be defined as 20% (+/-10%))*
4. The river planform and profile should be predominantly unmodified
5. Artificial factors restricting each SAC feature to occupy the full extent of its potential range should be modified to allow passage
6. Natural limiting factors such as waterfalls should not be modified
7. Flow objectives in the Dee Catchment Abstraction Management Strategy (flow regulation) will be agreed between the EAW and CCW
8. Nutrient levels to be maintained below levels set by EAW and CCW
9. Levels of water quality parameters, including levels of suspended solids, that affect the distribution and abundance of SAC features to be maintained below levels set by EAW and CCW
10. Potential sources of pollution, nutrient enrichment and/or suspended solids that have not been addressed in the Review of Consents, to be considered by EAW and CCW in assessing plans and projects

3.2 Habitat and species requirements

The four main river types which are major reasons for the designation are shown below in Table 3-2 alongside their characteristics under low anthropogenic impact. These river types support many of the species that are also designated SAC and SSSI features in the Dee/ Dyfrdwy catchment. CCW view these four SSSI river types as underpinning the general SAC feature of *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation communities.

Based on the river characteristics defined for the different river types, the Afon Mynach and Afon Meloch are classified as Type VII and Type VIII, Afon Tryweryn as Type VI, the River Ceiriog as Type VI and II, and the main stem River Dee (Upper, Middle and Lower) is classified as Type II, although there are parts of the main stem that display Type VI, such as the steeper section through Llangollen, Middle Dee.

---

[4] Available at: <http://www.sssi.naturalengland.org.uk/Special/sssi/fct/FCT_2000452_C.pdf> [Accessed on 12/02/13]

Table 3-2 Four river types; major reasons for the SSSI designations of the Dee/Dyfrdwy (taken from information in Mainstone, 2007)

JNCC river type	Characteristics of JNCC river types under conditions of low anthropogenic impacts	Ecological importance
Type II: Clay rivers with diverse substrates and flow patterns Lower Dee and Lower Ceiriog	Low gradient catchment with river channels running over clay or alluvium (sometimes chalk). Stream power variable but generally low. Bed materials likely to be dominated by silts and sands with coarser gravels accumulating at riffles. Flow patterns are likely to be dominated by glide with coarser substrates underlying occasional riffles and finer materials underlying deeper pools	Woody debris accumulations would be expected to contribute to flow type variability in this river type and create refuge habitats and pools for aquatic species. Woody debris is also important for decomposer species. River bed gravels or other coarse substrate provide an essential but generally scant habitat for a wide variety of invertebrate and fish species these river types
Type VI: base-rich, mesotrophic rivers in western and northern Britain, with a moderate to fast current.	Catchments tend to be mid-altitude. Moderate stream gradients have substrates dominated by gravels and pebbles. Outcropping bedrock and boulders are common features creating variable flow types including step-pools, riffles and glides. Exposed side and mid-channel bars both vegetated and unvegetated are common as well as sandy margins with some vegetation. Where there is a floodplain, active meandering can occur with vertical cliffs and point bars	Riparian trees are important for providing a source of woody debris, leaf litter and exposed tree root systems as submerged habitat and refuge areas for fish and invertebrates
Type VII: Mesotrophic upland plateau rivers	Upland catchments with underlying shale, hard limestone and hard sandstone geology. Shallow stream gradient and stable flow regime which results in finer substrates such as exposed gravel bars	Characterised by wetland edge vascular plants such as *Myosotis scorpioides* and *Phalaris arundinacea.* Invertebrates tend to be riffle-dwelling or inhabit vegetated or unvegetated gravel bars
Type VIII: Moderate-gradient sand/shale rivers below uplands	Similar to Type VII although steeper and more energetic, dominated by cobbles, boulders and bedrock	Vegetation is dominated by bryophytes (such as *Rhynchostegium riparioides*, *Chiloscyphus polyanthus* and *Hygrohypnum ochraceum*) with exposed bedrock and chutes ideal for a range of riffle-dwelling invertebrates

Most of the ecological features found within the River Dee/ Afon Dyfrdwy SAC and SSSIs have specific requirements of the ecosystem they are found in. This may include a narrow range of tolerances to physical habitat or flow (substrate type, flow type or variation), spatial linkages between life stages, water quality, riparian zone influences or inputs and hydromorphological requirements. The majority of species may utilise sub optimal conditions within an environment. However to meet the requirements of favourable condition a population must be self sufficient and sustainable. When considering the condition of a population it is essential to appreciate that the distribution of a given species within a catchment is appropriate to the natural geomorphology, and that channel form may naturally preclude certain species from sections, reaches or whole tributaries if underlying conditions are not naturally suitable for that species.

Whilst particular species (including SAC species) may form part of the designation for a site, their requirements would normally only be catered for to an extent by the habitat type. Exceptions to this include: 1) where there is good reason to believe that a higher level of quality is required by a particular designated species and the river is naturally capable of supplying this quality; 2) where a species is the only designation feature and there is good reason to move away from characteristic habitat form and function of the river.

3.2.1 Water crowfoot communities

The Annex II habitat ‘Watercourses of plain to montane levels with the *Ranunclion fluitantis and Callitricho-Batrachion* vegetation’ is a primary reason for the selection of the SAC.

This habitat type is characterised by the abundance of water-crowfoots *Ranunculus* spp., subgenus *Batrachium* (*Ranunculus fluitans, R. penicillatus ssp. penicillatus, R. penicillatus ssp. pseudofluitans, and R. peltatus* and its hybrids). Floating mats of these white-flowered species are characteristic of river channels in early to mid-summer. They may modify water flow, promote fine sediment deposition, and provide shelter and food for fish and invertebrate fauna.

There are several variants of this habitat in the UK, depending on geology and river type. In each, *Ranunculus* species are associated with a different assemblage of other aquatic plants, such as water-cress *Rorippa nasturtium-aquaticum*, water-starworts *Callitriche* spp., water-parsnips *Sium latifolium* and *Berula erecta*, water-milfoils *Myriophyllum* spp. and water forget-me-not *Myosotis scorpioides*. In some rivers, the cover of these species may exceed that of *Ranunculus* species. Three main sub-types are defined by substrate and the dominant species within the *Ranunculus* community.

The key factors affecting aquatic macrophytes (geology, water chemistry and land use; climate and flow regime; geomorphology; and anthropogenic factors such as disturbance, shading and management) are highly interlinked, acting in combination and over varying time scales. It is therefore often difficult to obtain a clear understanding of the relative importance of each. The effects of geology and flow are of primary importance, and this generally determines which plants can occupy specific locations in the channel. Flow velocity is thought to be the single most important control on the condition of *Ranunculus* (Hatton-Ellis and Grieve 2003).

Threats to this habitat include eutrophication, siltation from agriculture, reduced water levels from over abstraction and unsympathetic channel management.

3.2.2 Salmon (*Salmo salar)*

The River Dee is an important salmon spawning river and the salmon is a primary qualifying species of the Dee SAC. Salmon populations on the Dee are well documented and protected via a number of statutory and non statutory instruments (EA and CCW, 2001).

The CCW Core Management Plan (Hatcher and Garrett, 2008) identifies salmon as failing to meet favourable condition as a result of poor adult run (below conservation limit), water quality requirements and unsustainable exploitation. Despite the poor adult run salmon spawning currently meets the condition objectives of favourable condition on the River Dee and its tributaries. The requirement for a higher adult run will ensure long term sustainability of this species. The North Atlantic Salmon Conservation Organisation (NASCO) indicates that salmon on the Dee are 'not threatened with loss' (NASCO, 2012[5]). A joint EA/ CCW study of salmon in the Dee SAC was undertaken in 2001 and demonstrated good utilisation of the headwaters by salmon parr. This indicates the presence of suitable habitat in the headwaters for spawning salmonids (including trout). In total salmonids were recorded at 92% of all surveyed sites. Distribution in the Dee of salmon was influenced by the morphology of the catchment. Very low abundances were recorded in the lower Dee (below the Ceiriog confluence) due to unsuitable habitat whilst the narrower, higher flow velocities in the upper Dee tributaries (Mynach and Meloch) supported significantly higher (>30 fish $100m^{-2}$) juvenile salmon densities. Stocking of salmon fry has been carried out on these upper tributaries for a number of years, which may account for the elevated densities recorded in the upper headwaters. The Ceiriog demonstrated the highest density of salmon parr (>50 fish $100m^{-2}$) with a high proportion of good salmon spawning and nursery habitats.

Atlantic salmon is an anadromous species, spawning in freshwater where they remain as juveniles (1 – 4 years), before migrating to the open sea. They remain in the marine environment until maturity (1 – 3 years) at which point they return to freshwater, migrating upstream to breed in the headwaters. Salmon have specific habitat requirements (flow, substrates, temperature) for spawning and each subsequent life stage. For a population to remain sustainable there is a requirement that a high degree of interconnectivity of physical habitats occurs to ensure successful recruitment from spawning.

Spawning occurs in headwater streams in relatively high energy (between 25-90cm/s), shallow areas (17-76cm) where shallow depressions are created by the adult fish. The gradient is typically less than 3% and the substrate a mix of 2mm-256mm diameter gravel and pebbles. The presence of fine silts is normally low and interstitial spaces need to be kept clear by upwelling flow (Hendry and Cragg-Hine, 2003).

Fry and parr occupy shallow fast flowing water (50-65cm/s) less than 20cm deep, with moderate coarse substrates. Channel cover is very important at all life stages, and for juveniles this can include loose substrate, large rocks, undercut banks, overhanging vegetation and aquatic vegetation.

Adults lie up in deeper holding pools immediately downstream of suitable spawning habitats where they rest after ascending the watercourse prior to spawning. Through

[5] NASCO, (2012). *Atlantic salmon river database* [online]. Available at: www.nasco.int/RiversDatabase.aspx [Accessed on 18/01/13]

the length of the catchment adults use riparian cover, large boulders and areas of deep water during migrations.

Threats to salmon are numerous. Exploitation of adult fish, both at sea and in river, by commercial and recreational operations affects stock numbers. In the 2010 census of rod and line fishing on the Dee 777 adult salmon were caught by recreation anglers, with 421 returned alive to the water (EA, 2012). Changes in substrate composition and siltation of spawning sites can be caused by changes in hydrological conditions or loss of riparian cover, often as a result of flood protection works, abstraction for water supply, forestry, arable cultivation and intense livestock grazing. Ninety eight percent of fine sediment recorded from spawning gravels on the Dee can be traced to catchment sources and land use as the primary cause of channel siltation in the catchment, rather than eroding banks (Walling *et al*, 2002). Alterations to the flow regime can mean the loss of suitable habitats for salmon at various life stages and increase competition among fish for territories. Flow is an important aspect in all life stages, maintaining interstitial spaces in spawning gravels, oxygenating spawning habitats, providing deep water cover and providing suitable water depth and height to ascend structures. Obstructions to migration can include both natural and artificial barriers. Obstructions within the Dee catchment have been specifically identified as causing failure to meet conservation objectives. Pollution, predation, stocking and aquaculture can also affect the salmon populations of freshwater river systems.

3.2.3 Lamprey (*Lampetra* Sp.)

Three lamprey species are known from the River Dee, and all are listed as secondary qualifying features of the River Dee SAC. Despite this there has been very little work on the Dee to determine the distribution or current status of lamprey, and as such there remains a significant uncertainty over the status of these three similar species. Brook and river lamprey are indistinguishable in the field as ammocoetes and as a result the current status of these individual species is difficult to assess. Lamprey (brook and river combined) have been recorded from 61% of surveyed sites on the Dee catchment, however lamprey distribution is required to be from a minimum of 66% of sites to reach favourable status. Natural obstructions (steep gradients or high flows) may prevent utilisation of suitable habitats in the headwaters of some catchments. The upper limit for sea lamprey species was identified in the CCW Core Management Plan (Hatcher and Garrett, 2008) as being the Horseshoe Falls Weir, whilst river and brook lamprey are found upstream of this. A 2001 EA/ CCW study into lamprey distribution indicated that lamprey were found at only 13 of 84 sampled sites, although the presence of lamprey was closely related to suitable habitat being present. It is thought that the majority of ammocoetes recorded were brook lamprey, therefore unlikely to undertake significant migrations through the lower catchment.

Ecologically sea and river lamprey differ from brook lamprey by undertaking migrations between freshwater spawning and juvenile habitats and marine environments.

The three lamprey species require a juxtaposition of suitable habitats for different life stages (Maitland, 2003), which vary slightly between species. Optimum lamprey spawning habitats are similar to salmon, as described above. Substrate at these sites is usually gravel (9.5-50.8mm diameter) with flows around 1-2m/s and typically 2-40cm deep, although sea lamprey will utilise deeper water. Spawning is temperature driven and differs between the three species (15°C for sea lamprey, 8.5-12.0℃ for river lamprey and 10-11℃ for brook lamprey). Lamprey juveniles (ammocoetes) drop down from the spawning site, favouring silt or sand beds held in marginal area, back waters or slow flowing channels. These fine sediments are often associated with high organic content and allow the ammocoetes to burrow. Velocity preferences for lamprey ammocoetes ranges from <0.1m/s (river lamprey) to 0.5m/s (brook lamprey). Macrophyte presence also provides cover for the young lampreys. The interconnectivity between habitats for different lamprey life stages is important in maintaining population dynamics, with separation of life stages often reducing the viability of a population.

All lamprey species are adversely affected by a range of anthropogenic activities. Although direct exploitation has decreased in recent years channel modification can damage suitable habitat and remove spawning/nursery habitat through sediment mobilisation and alteration to flow regimes. Lamprey are indicative of good water quality and pollution and eutrophication can influence lamprey migration. Abstraction and flow management may affect the fish passage of physical barriers and engineering directly affect populations by creating obstructions to migration along the river course. This is particularly important to the sea lamprey, which does not readily ascend over structures as the river lamprey and as such is often restricted to lower river habitats.

3.2.4 Bullhead *(Cottus gobio)*

Bullhead are a secondary qualifying species within the River Dee SAC and are currently failing to meet the conservation objectives outlined in the CCW Core Management Plan (Hatcher and Garrett, 2008). The following criteria are not currently met: adult population density, distribution within the catchment, biological water quality and nutrient (phosphate) levels. The 2001 EA/ CCW study indicated good bullhead populations throughout the catchment, present in many of the locations that support salmon nursery and parr habitats. Bullhead were identified as absent or in very low densities in the upland catchments of the Upper Dee, where water velocity and steep gradients prevent habitat utilisation and are largely absent form the deeper, slower flowing sections of the lower Dee.

Bullhead are small, spiny fish, common to sections of river where the depth is greater than 5cm, with moderate flow, coarse gravel substrate and <40% macrophytes (Tomlinson and Perrow, 2003). Favoured habitats are usually sinuous in form, with pool-riffle sequences, slack water refuges during spate flow, naturally wooded riparian margins and exposed roots in the channel. The substrate at spawning sites is coarse with large stones. Bullhead larvae are found in the shallower riffle areas of the channel, and adults in sheltered sections where debris, tree roots, macrophytes or large stones provide sufficient cover.

Bullhead are adversely affected by aquatic pollution, habitat deterioration (siltation), fragmentation of populations, changes to flow regimes and sediment dynamics and changes in dissolved oxygen levels. Removal of hard substrate, in-channel vegetation and/or riparian trees can be detrimental to bullhead populations by decreasing suitable habitats and increasing exposure to predators. The presence of this species is indicative of good water quality.

3.2.5 Otter *(Lutra lutra)*

Otter *Lutra lutra* habitat requirements include potential den/holt sites which are usually under exposed root systems along the river banks (Chanin, 2003). The presence of ash, sycamore, oak and elm often provides such features as the river erodes sediment and substrate from around the roots. Otters favour areas of river with a high amount of cover created by bankside trees, woodland and scrub where they can lay up during the day. Otters require access to an adequate resource of prey, which is dominated by fish and also includes amphibians, young birds and small mammals.

Threats to otter include disturbance through habitat destruction; pollution from agricultural practices; introduced species such as mink *Mustela vison* increasing competition, predation of otter cubs, etc.; disease (possibly spread by mink); road fatality; and acidification lowering fish numbers as a food source.

3.2.6 Club-tailed dragonfly *(Gomphus vulgatissimus*)

Club-tailed dragonfly is found in medium to large slow flowing rivers with areas of silty substrate (in which they burrow as larvae) and adjacent tree cover (utilised by adults). In riverine habitats larvae favour areas of silt deposited within meander bends, often associated with clumps of emergent vegetation (British Dragonfly Society, 2007[6]). It may also occur in some meres and pools. After a larval period of 3-5 years they emerge in late May to early June.

The club-tailed dragonfly needs sparsely-vegetated banks to haul out on when it is emerging from its exuvium (cast off skin). Fine sediment deposition is therefore important but it is also crucial that these are kept open by stock access as the nutrient level and silt load quickly facilitates rapid vegetation growth on the banks of the Dee. The club-tailed dragonfly also needs silty conditions in the river channel for the larvae to develop in so a continued supply of suitable sediments sizes in the lower Dee is required. Changes to land management, such as reducing stock access to the river bank should, therefore, not remove all sources of silt and fine sediment.

Threats include loss and disturbance of emergence habitat, aquatic pollution, changes to sediment and hydrological regime, channel and riparian maintenance. The species is known to occur in good numbers on the River Dee between Shocklack and Aldford in Cheshire.

3.2.7 A stonefly (*Isogenus nubecula*)

Isogenus nubecula is a rare stonefly (*Plecoptera*) which has only been recorded in the UK in the River Dee in Flintshire. Habitat requirements include fast flow, a depth of 25-30cm and a substrate of unstable cobbles and gravel. The species was recorded within a 45km stretch of the Dee between Newbridge and the confluence with the River Alyn. Flow regulation on the Dee has been identified as a possible cause for the suitable habitat conditions found on this water body. However, it has not been recorded in any surveys undertaken since 1995. Further research is required to investigate the impact of flow regulation on this species[7] and whether it is contributing to its assumed extinction.

[6] British Dragonfly Society, (2007). *The Common Club-tail – Gomphus vulgatissimus (Draft Management Fact File)* [pdf]. Available at <http://www.british-dragonflies.org.uk/sites/british-dragonflies.org.uk/files/gomphus%20vulgatissimus.pdf> [Accessed on 18/01/13]

[7] Further investigation would also contribute to understanding similar effects of flow regulation on the fresh water pearl mussel *(Margaritifera margaritifera).*

Other threats to the stonefly include agricultural and industrial pollution, eutrophication, removal of riparian tree cover and channel modification (such as poaching, gravel extraction and bank reinforcement). This species is further threatened by high and low flow events (Buglife 2011).

3.2.8 A weevil *(Baris lepidii)*

The weevil *Baris lepidii* requires sandy exposed riverine sediment (ERS) and hence the supply and deposition of sand in the system is a major process that dictates the status of this species (and many other ERS invertebrates).

Baris lepidii is threatened by gravel extraction, poaching and nutrient enrichment of the gravels by livestock (CCW, undated). It has been recorded in the lower reaches of the River Dee.

3.2.9 Plant species

Floating water plantain *Luronium natans* occurs in a variety of wetlands in northwest England and Wales but thrives best in open areas of clear water with a moderate degree of disturbance. Mainly found in lakes, ponds and canals Threats include increased turbidity from boat traffic and eutrophication resulting in increased competition from emergent macrophytes. Floating water-plantain occurs in the slow flowing water in the outflow of Llyn Tegid, above the sluice gates which regulate the flows from Llyn Tegid and the Celyn Reservoir (CCW, undated).

Slender hare's ear *Bupleurum tenuissimum*, sea barley *Hordeum marinum* and hard grass *Parapholis strigosa* occur in the saltmarsh transitional habitats on the Dee estuary. They are dependent on the mixing of fresh and salt water and are therefore susceptible to changes in the flow regime of the river, as well as general water quality.

3.3 SSSI condition status

3.3.1 River Dee (England) SSSI

Three of the four English SSSI units are currently assessed as being unfavourable – no change condition, whilst one which is in favourable condition (Table 3-3).

Table 3-3 River Dee (England) SSSI units and condition assessment status. Note, unit 2 has been superceded by units 4 and 5

Unit and location	CCW management units	Condition status	Reason for condition status
1 – River Dee (England) From Farndon to Chester Weir	**12 and 13**	**Unfavourable – no change**	Failing of many targets including water quality due to pollution from agriculture/runoff and water pollution discharge (phosphate), salmon, bullhead and macrophyte assessments
3 – River Ceiriog from Bronygarth to main stem Dee at Erbistock	**19 and part of 8**	**Unfavourable – no change**	No change to diffuse water pollution levels and inappropriate structures such as weirs, dams and other

Unit and location	CCW management units	Condition status	Reason for condition status
			structures
4 – Shocklach to Farndon (Within the river channel)	**11 and part of 12**	**Unfavourable – no change**	Fails water quality targets, macrophyte assessment and salmon targets. Freshwater invasive species
5 – Farndon-Shocklach (Fluvial geomorphological patterns/ processes and adjacent floodplain)	**11 and part of 12**	**Favourable**	The river displays the necessary characteristics of a geomorphologically active river, with obvious undercutting and deposition along the length of the unit

The meandering section that runs from approximately Shocklach to Holt has been assessed as being in favourable condition for geomorphology, however the section is thought by Natural England to be unfavourable in terms of ecology. The favourable condition is more a reflection of geomorphological form of the channel (e.g. the importance of the planform of the Dee meanders) whilst the unfavourable condition for ecology in the same length is partly a reflection of geomorphological processes (e.g. movement and re-distribution of fine silt) and also of water quality issues. Unfavourable condition for ecology may also be because this section is used as a transit section for migratory species moving from sea to upland areas. There is limited suitable spawning habitat for the ecological features expected here as species only move through this section. Therefore optimum habitats will not be found.

Although water quality (e.g. diffuse pollution) is an important contextual issue to consider in the development of a Restoration Vision it is not part of this current study and is being addressed elsewhere (e.g. as part of WFD actions). It is also useful to cross-reference the condition assessments given in Table 3-3 and Table 3-4 with the WFD hydromorphological status of the relevant water bodies in Table 3-5. In particular Unit 4 Farndon – Shocklach (within the river channel) on the main stem Dee 'fails water quality targets, macrophyte assessment and salmon targets' and is in unfavourable condition. However the equivalent water body (Dee – Confluence with Ceiriog to Chester Weir) although heavily modified because of drinking water, flood protection, water regulation (impoundment release) is at good status for phosphate. This is therefore a water body requiring water quality issues to be addressed beyond WFD provisions.

3.3.2 Welsh Afon Dyfrdwy (River Dee) SSSI

There are currently no completed condition assessments on the SSSI features on the Welsh Afon Dyfrdwy (River Dee) SSSI. However, some of the SSSI features that are also SAC features (e.g. *Salmo salar*, *Lutra lutra*) have been assessed for their condition. For this report the SAC condition assessment has been applied to the relevant SSSI features.

3.4 River Dee and Bala Lake / Afon Dyfrdwy a Llyn Tegid SAC condition status

CCW has assessed the condition of each SAC feature at whole river scale, rather than on a management unit basis. From these condition assessments, it is anticipated that a large number of the Welsh management units will be in unfavourable condition.

The 19 Welsh management units (Figure 3.1), which include the English SSSI units (Figure 3.2) have been defined by CCW based on the following (Hatcher and Garrett, 2008):

- SSSI boundaries
- Tributary confluences
- Natural hydromorphology
- Artificial barriers where they mark a change in river character
- National boundaries
- Unitary Authority Boundaries; and
- The tidal and navigational limits

The CCW Core Management Plan (Hatcher and Garrett, 2008) includes conservation objectives for each of the SAC features on the River Dee/ Afon Dfrdwy. Within each of the 19 management units, the features that make up the SAC have been assessed using performance indicators set against an overall vision for the feature to be in favourable condition. Table 3-4 shows the condition status for each SAC feature and the management units that should be managed for this species (based on Hatcher and Garrett, 2008). The SAC features are attributed to each management unit as either a Key Species (KS) or Key Habitat (KH) that each management unit should be managed specifically for.

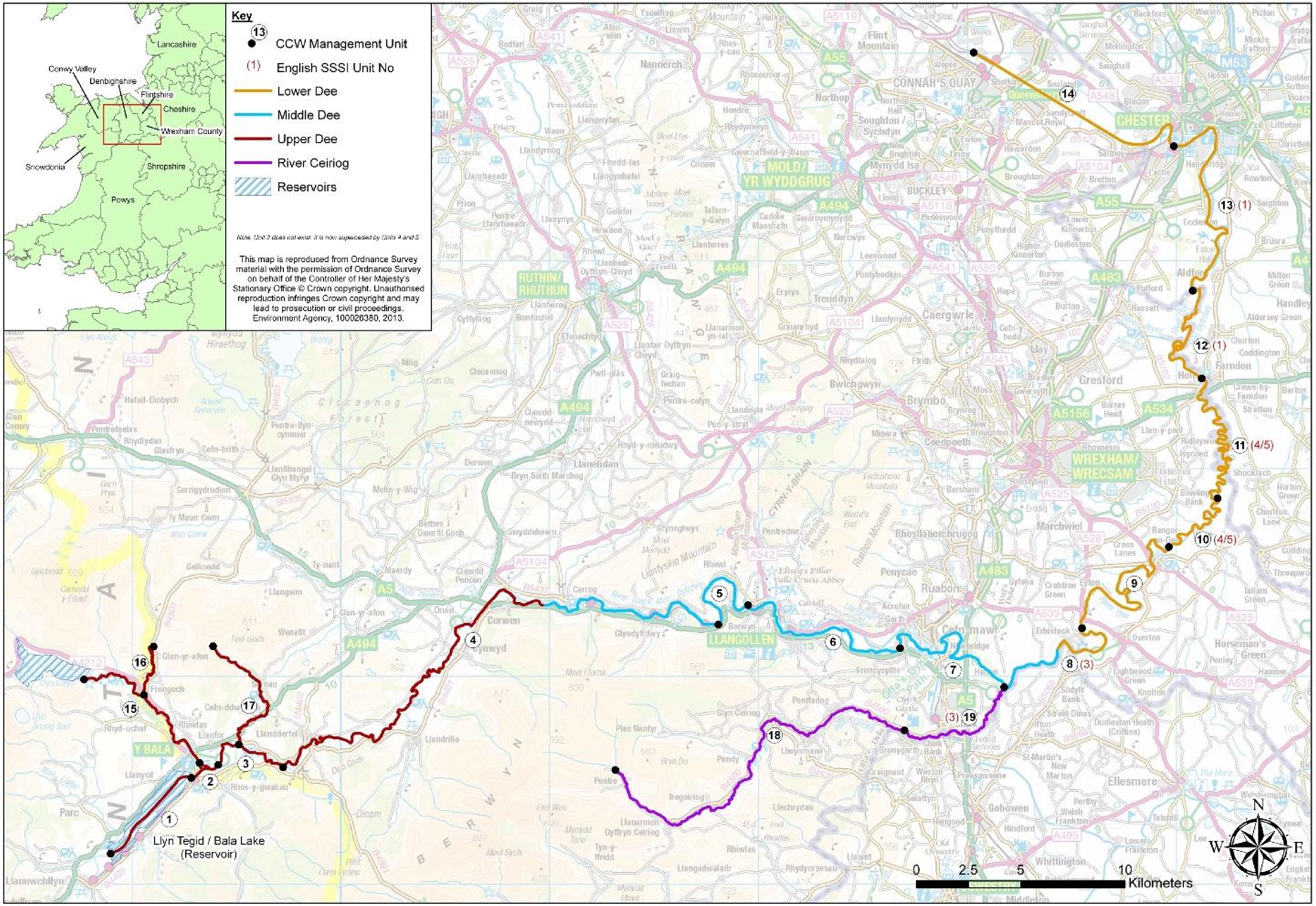


Figure 3.1 ***CCW Management units and river divisions (numbers in red brackets indicate the equivalent English SSSI unit***

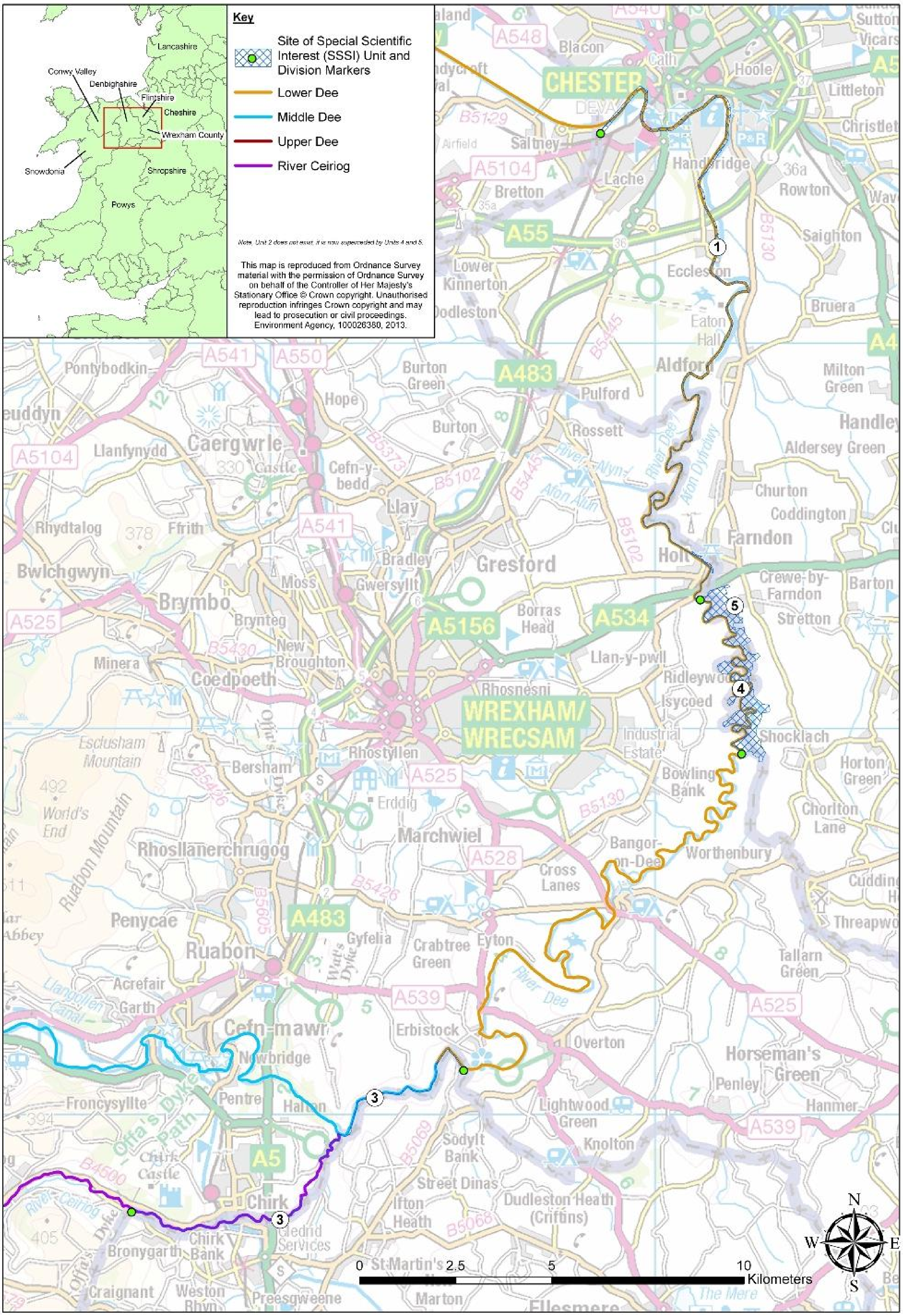


Figure 3.2 English SSSI unit boundaries

Table 3-4 SAC features and condition status including their relevant management units (KH: key habitat, KS: key species)

SAC feature	Condition status	Key habitat (KH)/Key species (KS) and management unit	Reasons for condition status
1. Watercourses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	**Unfavourable – unclassified**	KH in units 2-13 and 15-19	Due to data gaps and flooding problems during last survey by Scarlett *et al.* (2003) the habitat distribution is unknown. Precautionary approach to assume this condition status
2. Atlantic salmon *Salmo salar*	**Unfavourable**	KS in units 2-19	Fish survey (Pisces Conservation Ltd. (2007)) recorded fails in the following criteria: • Adult run population • All parameters of water quality; and • Environmental disturbance – management objectives, sustainable exploitation
3. Floating water plantain *Luronium natans*	**Favourable - unclassified**	KS in unit 2	Partial baseline data means not possible to make trends. Records of this feature date back to 1780. No reason to suppose current operations are causing a decline in numbers
4. Sea lamprey *Petromyzon marinus*	**Unfavourable - unclassified**	KS in units 9-14 and	Monitoring by APEM (2006) showed that this species did not reach the ammocoete density target. Concern over barriers to migration. Suggested that Erbistock weir marks boundary between sea lamprey and brook lamprey
5. Brook lamprey *Lampetra planeri*	**Unfavourable – unclassified**	KS in units 2-13 and 15-19	APEM (2006) monitoring showed that this species failed JNCC target. However as it is difficult to identify between Brook and River lamprey in field results may be misleading and therefore a precautionary approach is to assume that this species is in unfavourable condition
6. River lamprey *Lampetra fluviatilis*	**Unfavourable unclassified**	KS in units 5-14 and 15-19	Same as above

SAC feature	Condition status	Key habitat (KH)/Key species (KS) and management unit	Reasons for condition status
7. Bullhead *Cottus gobio*	**Unfavourable - unclassified**	KS in units 2-13 and 15-19	Survey (by Pisces Conservation Ltd (2007)) showed this species to fail due to: • Adult population densities • Distribution with the SAC; and • Water quality parameters (Biological GQA and soluble reactive phosphorous). Due to small sample size more data is required to verify this condition
8. European Otter *Lutra lutra*	**Favourable - unclassified**	KS in units 2-13 and 15-19	Based on Phil Morgan survey (Morgan, 2004). Unclassified as no trend can be determined until further surveys take place. Otter survey of England and Wales 2009-2010 recorded evidence of otters at 93% of the 59 sites in the Dee catchment which were surveyed. Evidence was recorded at 78% of these sites during the 2002 survey

3.5 Water Framework Directive

Improvements to the condition of the SSSIs and SAC are required both by the Habitats Directive and the Water Framework Directive (WFD). As the River Dee/ Dyfrdwy is an SAC, the measures required to meet WFD objectives must have been operational by the end of 2012, and the site must be meeting its SAC and WFD objectives by 2015. Where the SAC objectives are higher than WFD objectives, the SAC objectives must be met.

The River Dee and its tributaries fall within the Dee River Basin District (RBD). To meet the WFD objectives and address the pressures on the water bodies, a River Basin Management Plan (RBMP) has been created for each RBD. As part of the Dee RBMP, the Environment Agency have undertaken a programme of investigations to improve our understanding on why certain waterbodies are failing their WFD objectives and what actions could be taken to improve the status of the water bodies. A range of issues have been identified and one of the actions is to investigate what measures are feasible to address physical modification associated with water storage and supply. A range of mitigation measures have been considered including volume and timing of flow releases from impoundments for fish migration.

Through the requirements of the Conservation of Habitats and Species Regulations 2010 (commonly known as the 'Habitats Regulations') the Environment Agency has reviewed abstraction licences potentially impacting on the River Dee and Bala Lake SAC and required changes are being implemented through the Restoring Sustainable Abstraction (RSA) programme.

Flow regulation and abstraction regime have therefore not been investigated as a pressure specifically within this project but it is expected that the findings of this project will be complementary to the above programmes of work.

More information on the programme of investigations can be found at http://www.environment-agency.gov.uk/research/planning/33106.aspx (in the spread sheet entitled 'Water Framework Directive investigations programme detail (July 2012)') and details of the RSA programme can be found at http://www.environment-agency.gov.uk/business/topics/water/32026.aspx.

RBMPs have been prepared under the WFD to address pressures on the water environment that are a result of human activities. The RBMP identifies specific actions to address the pressures. It sets out what improvements are possible by 2015 and how the actions will make a difference to the local environment. The plan also highlights a programme of investigations to be undertaken, identifying further actions (particularly those associated with diffuse pollution), for delivery during the first cycle. Actions incorporate raising awareness of catchment issues through education and advice campaigns and guidance forums, statutory codes of practices and best practices, byelaw enforcement and environmental reviews and studies.

The River Dee and its tributaries define the Dee River Basin District (RBD), which has its own RBMP. The Dee RBMP (EAW, 2009) states that only 28% of surface waters are currently classified as Good or better ecological status or potential. 51% of assessed surface water bodies are at Good or better biological status now, although it is expected that this will change to 48% once all water bodies have been assessed. The RBMP states that the key pressures needing to be addressed to improve status include:

- Diffuse pollution from agricultural and other rural activities
- Point source pollution from sewage treatment works
- The physical modification of water bodies
- Point source pollution from domestic (non-water industry) activities; and
- Diffuse pollution from housing.

There are ten water bodies within the River Dee/ Afon Dyfrdwy SSSIs (Table 3-5). Six of these (including the River Dee) are heavily modified (variously for water storage, flood protection, drinking water or water regulation). The HMWB's have to achieve Good Ecological Potential by either 2015 or where this is not possible through implementation of mitigation measures by 2027. The remaining four (covering the Meloch, Mynach and Ceiriog) are not designated as Artificial or Heavily Modified. The Meloch and Mynach are at Moderate Ecological Status and have to achieve Good Ecological Status by either 2015 or through a programme of measures implemented to ensure Good Status by 2027. The two water bodies for the Ceiriog are currently at Good Ecological Status and need to maintain this status by 2015.

Table 3-5 Hydromorphological status of the water bodies along the River Dee/ Afon Dyfrdwy SSSIs and SAC

Water body ID	Name	Hydromorphological status	Reason for A/HMWB designation	Water body status	Parameters less than good	Status for individual quality elements
GB11106705 1990	Afon Mynach	Not Designated A/HMWB		Moderate Ecological Status	Overall specific pollutants quality - copper	Fish – Moderate Phosphate – High Quantity and dynamics of flow – Supports Good Morphology – Supports Good
GB11106705 1960	Afon Meloch	Not Designated A/HMWB		Moderate Ecological Status	Overall specific pollutants quality - copper	Fish – Good Invertebrates - Good Phosphate – High Quantity and dynamics of flow – Supports Good Morphology – Supports Good
GB11106705 1980	Tryweryn – Hesgin to Llyn Celyn	Heavily Modified	Flood Protection; Water Storage – non-specific	Moderate Ecological Potential	Mitigation measures assessment	Phosphate - High
GB11106705 1920	Tryweryn – Mynach to Hesgin	Heavily Modified	Water Storage – non-specific	Good Ecological Potential	n/a	Phosphate – High
GB11106705 1900	Tryweryn – Mynach confluence to Dee confluence	Heavily Modified	Water Storage – non-specific	Moderate Ecological Potential	Overall specific pollutants quality – copper, zinc	Fish – Good Invertebrates – Good Macrophytes – Good Phosphate –High Quantity and dynamics of flow – Supports Good Morphology – Supports Good
GB11106705 2240	Dee – Alwen to outlet Llyn Tegid/ Bala Lake	Heavily Modified	Water Storage – non-specific	Good Ecological Potential	Biological quality - fish	Fish – Moderate Invertebrates – High Phosphorous – High
GB11106705 2060	Dee – Alwen to confluence with Ceiriog	Heavily Modified	Water storage – non-specific	Moderate Ecological Potential	Overall specific pollutants quality - copper	Fish – Good Invertebrates – Good Macrophytes – Good

Water body ID	Name	Hydromorphological status	Reason for A/HMWB designation	Water body status	Parameters less than good	Status for individual quality elements
						Phosphate – High
GB11106705 1610	Ceiriog – upstream of Teirw	Not Designated A/HMWB		Good Ecological Status	n/a	Fish – High Phosphate – High Quantity and dynamics of flow – Supports Good Morphology – Supports Good
GB11106705 1910	Ceiriog – Teirw to confluence with Dee	Not Designated A/HMWB		Good Ecological Status	n/a	Fish – Good Invertebrates – Good Phosphate – High Quantity and dynamics of flow – Supports Good Morphology – Supports Good
GB11106705 7080	Dee – confluence with Ceiriog to Chester weir	Heavily Modified	Drinking water, flood protection, water regulation (impoundment release), Water Regulation (strategic transfer)	Moderate Ecological Potential	Biological quality - Macroinvertebrate community composition	Invertebrates – Moderate Phosphate – Good Quantity and dynamics of flow – Supports Good

4 Catchment characteristics

The source of the River Dee/Afon Dyfrdwy is in the mountains of Snowdonia National Park. The river flows generally in an easterly direction through the steep valley sides of the Vale of Llangollen until Worthenbury. From Worthenbury it flows north through open lowland to the estuary at Chester. Chester weir demarcates the tidal limit, except during the highest tides when it is overtopped, however tidal influences can occur as far upstream as the downstream end of the Dee meanders, due to freshwater backing up from the tide. The catchment of the Dee/ Dyfrdwy includes the River Ceiriog, which flows through both the Welsh and English SSSI (See Figure 3.1). The catchment of the Ceiriog is mountainous with steep slopes. The length of the River Dee/Afon Dyfrdwy from Bala Lake to Chester weir is approximately 130km and the length of the Ceiriog is approximately 30km.

4.1 Geomorphological background

The course and topography of the River Dee/ Afon Dyfrdwy has been largely influenced by glaciers. Below Bala Lake and down to Chester the River Dee/ Afon Dyfrdwy flows over predominantly sedimentary bedrock consisting of mudstones, sandstones and siltstones. These range from the Silurian to Triassic periods with progressively younger underlying bedrock with distance downstream. The catchment of the Dee above Bala gauging weir is predominantly comprised of impermeable Cambrian and Ordovician rocks overlain with thin, semi-permeable soil. The river flows east through Llangollen where there are Carboniferous limestone outcrops and coal measures. Much of the bedrock is overlain with unconsolidated drift deposits (till) up to 100m thick and glacial sands and gravels reported at up to 28m thickness from past glaciation and post-glacial environments. These form important potential sources of sediment for the modern river. The catchment of the Ceiriog consists of mainly low permeability rock with low and medium permeability superficial deposits. The lower Ceiriog has cut down through overlying till into red sandstone.

Buried channels that have been found in the Dee estuary could be evidence of earlier pre-glacial river channel courses (before the last Devensian glacial period around 18000 years ago). They are noted, for example, as part of the Dee Meanders SSSI unit description. Following the retreat of the last glacial ice sheet back to the Irish Sea, rivers in this area have cut through the huge expanse of glacial debris that had accumulated around the margins and underneath the ice sheet. The glacial debris provides extensive sediment sources, which have been reworked during higher discharges in Holocene times. Today they are often temporarily stored in floodplains.

Previous geomorphological and academic studies on the River Dee have revealed information about the history of the catchment. Geomorphological studies have been undertaken by the Geodata Institute on behalf of the CCW (Gurnell *et al.*, 1993; Maddy *et al.* 1996). Academic studies by Higgs (1997), Downward et al.,1994 and Gurnell (1997a and b) have investigated the Dee at Llangollen, Denbighshire and the Dee meanders respectively. The findings of these studies are incorporated into the descriptions below.

4.1.1 River Dee along the Vale of Llangollen, Denbighshire (Higgs, 1997)

This section of the River Dee extends for about 15km in the valley of Llangollen and is characterised by incised meanders with cliff-like outer bends and sloping inner bends. The incised meanders are likely to have originated in a pre-glacial period, possibly in the Tertiary, and are likely to have been subsequently incised by glacial melt waters with very high discharges. This is suggested as an explanation as the present day discharge would not be sufficient to cut meanders into bedrock on this scale (Higgs, 1997). The Rhewl meander is an example of an incised, ingrown meander of which there are many along this section of the River Dee. The valley at the Rhewl meander is asymmetrical due to a combination of lateral and vertical erosion processes. The adjacent land to this meander is also designated as a SSSI.

There is evidence of abandoned incised meanders up to 45m above the present day river level. These features were perhaps formed prior to the rapid incision which has shaped the present channel. Alternatively (or in combination) a glacier may have carved troughs across the old meanders which the post-glacial course of the river Dee may have followed, thereby truncating pre-glacial meanders. The scouring action of glacial melt water could have deepened the current River Dee channel and left the pre-glacial meanders 'hanging' several metres above the present channel (Higgs, 1997).

4.1.2 River Dee, Holt to Worthenbury, Wrexham and Cheshire

This highly sinuous section of the Dee is approximately 18km long and is governed by upstream fluvial influences and the backing up of freshwater downstream due to tidal cycles. The downstream end of this reach is also permanently influenced by backwater from Chester Weir. There is evidence of historical channel movement in the form of palaeochannels and borehole data. In addition as it is thought that the course of the Dee originally formed the national boundary then channel migration can be deduced from map evidence. This section of the river has been designated as a Geological Conservation Review Site (GCR 2955) due to its national importance for studies on fluvial geomorphology. Evidence suggests that, certainly over the last century, the River Dee has been very stable with very little lateral movement, but also that this stability may extend back to approximately 300 years ago (Gurnell,1997a and b).

Aerial photographs suggest that particularly from the 1960s onwards, the channel has gradually become narrower downstream and this is perhaps a result of the extensive flow regulation that has taken place in the upstream reaches of the River Dee, reducing discharges overall and inducing sedimentation.

4.1.3 Zones of planform change along the Dee

Widespread channel change along the Dee appears to have occurred over the last 120 years according to Maddy *et al.* (1996). However this has been confined to small sections within reaches where there has been channel instability over a long period of time. According to Hill and Emery (2005) the most active areas in terms of historical planform change are between the Bala Lake outfall and Corwen (Upper Dee) and also the Dee meanders (Lower Dee). The least active areas of historic planform change are Farndon to Chester weir (Lower Dee) and Glyndyfrdwy to Overton (Middle Dee).

Gurnell *et al.* (1993) noted that widespread bank adjustment from fluvial erosion had taken place along lengths of the Lower Dee, in particular the Dee meanders, although this has not led to recent meander migration. Hill and Emery (2005) Fluvial Audit also found this to be true of the Lower Dee where the meanders were reported to be relatively stable. In contrast, the meanders in the Upper Dee appear to be actively migrating and changing, within the constraints of the steep valleys sides (Hill and Emery, 2005).

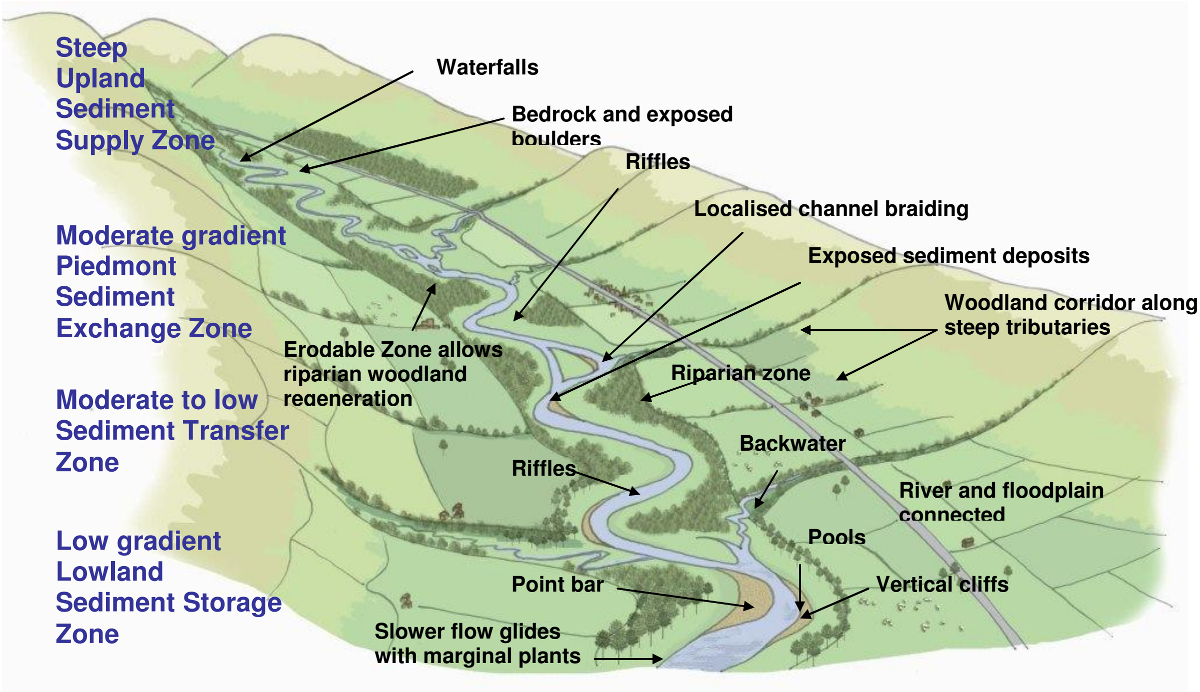
4.1.4 Characterisation of the Dee Catchment based on sediment transport characteristics

As with any catchment the Dee can be usefully divided into three components (see Figure 4.1): sediment supply (sources), sediment transport (or transfer) and sediment storage (sink), operating as a continuum from the headwaters to the Estuary (where a different sediment system operates). The dominance of supply, transport or storage does not occur uniformly over a stream bed, leading to deformation of the bed and banks resulting in a range of different river morphologies (types):

1. The supply of sediment to the upstream channel network is potentially derived from a range of sources covering soil erosion across extensive tracts of the catchment to a local eroding bank. The amount of supply of sediment will vary spatially but is considered ubiquitous across the entire Dee catchment

2. Sediment transport or transfer occurs when the stream energy is sufficient to overcome the resistant forces acting on particles comprising the stream bed and/or banks. Sediment transport can be usefully divided into suspended load (silts, clays and fine sands) and the bedload (dominated by gravels and cobbles). Sediment transport zones were identified on the Upper and Middle Dee, the Meloch, Mynach and Ceiriog

3. Sediment storage can be observed in the form of siltation/ shoaling and is most evident on the Middle and Lower Dee, as well as the lower sections of tributaries where the gradient is flatter just before they join the main stem Dee. Deposits can be short term (e.g. a period of low flows leading to the temporary accumulation of sediments as bars) to long term deposits, such as floodplain deposits that are only reactivated in a large magnitude flood. In the Lower Dee (above Chester Weir) fine sediments are dominant and are characterised by overbank storage and the development of in-channel berms. Ironically on the Lower Dee many sections are embanked, divorcing the channel from the adjacent natural floodplain and containing high sediments in the channel



4.1 Sediment transport characteristics of upper, middle and lower zones, similar to that displayed by the River Dee/ Afon Dyfrdwy

4.1.5 Characterisation from capital and maintenance records

As part of this study a search was made of records held in the British Library (London) for the Dee and Clwyd River Board and its successor the Dee and Clwyd River Authority. The Annual Reports and Accounts of these organisations give information on the range of capital and maintenance works actually carried out by the government authority each year. These types of work would probably have extended from about 1930 (when Catchment Boards were first set up) to 1980-1990. Although records were only available for the period 1953 to 1973, when the River Authority was set up, this nevertheless provides a 20 year window of records, allowing characterisation of the river in terms of the historic needs for channel works. The items of work, together with a brief description, are held in Appendices A (capital works) and B (maintenance). Some of the capital river works, for example involving channel straightening, relate directly to schemes for flow regulation such as the Bala Lake Scheme. The maintenance records vary from year to year in terms of the details that are prescribed. However from this information it is possible to discern different types of works applied to different parts of the catchment, reflecting the local differences in river type. In broad terms:

(a) Upper tributaries and Dee (above Bala Lake/Llyn Tegid)

The main stem River Dee and tributaries in the upper part of the catchment (above Bala Lake/ Llyn Tegid) are relatively high energy rivers with active erosion and transport processes which cut into alluvium. Bala Lake has created erosion problems (due to wind waves and knickpoints progressing up feeder tributaries). However there are capital and maintenance records for localised gravel removal, bed and bank protection (e.g. using gabions) and tree and woody debris clearance.

(b) Main stem Dee (Dyfrdwy) from Bala to Bangor on Dee

This section is characterised by moderate energy rivers general cut into alluvium with occasional rock outcrops and a relatively confined floodplain. Below the Horseshoe Falls at Llangollen the channel is cut into bedrock and there is a very narrow and in some place, non-existent floodplain. There are few records of works to the main stem Dee/ Dyfrdwy in this section, probably due to the limited floodplain (and hence minimal impact of flooding on farmland). However there are relatively local schemes involving some bank protection along the alluvial reaches (but not the rock bound reaches).

Several tributaries join the Dee along this length and there are records of maintenance being required to remove gravels that have dropped out on the relatively flat Dee floodplain during floods.

(c) Main stem Dee (Dyfrdwy) from Bangor on Dee to Chester (including the Dee Meanders)

As the Dee crosses the Cheshire Plain, and also where tributaries cross the relatively flat Dee floodplain to meet the main stem Dee, there is a relatively low energy river system with wider floodplain. There are many records of embankment repair and raising (using materials won from floodplain borrow pits and not channel dredging). Records show there have been extensive river bank protection instalments (often using stone pitching) to prevent lateral movement of river into embankments and river training works (e.g. at Sutton Green). There are also records of woody debris removal and some vegetation/ tree clearance. Some gravel clearance from Dee (especially in the upper part of this length). Where main tributaries cross the relatively flat Dee floodplain then they too require embankment schemes (sometimes associated with channel realignment). Examples are the Pulford Brook, River Alyn and Worthenbury Brook. There are records of pumped drainage schemes in these lower parts.

(d) Dee below Chester Weir (estuarine)

This section of the Dee is characterised by estuarine processes and fine siltation. There have been very intensive works involving embankment raising, the protection of embankments from river erosion (e.g. through the use of stone pitching) and general maintenance (such as eradication of burrowing animals and weed cutting/ tree clearance). An example scheme is the Northern Embankment at Sealand.

4.2 Land Use

Land use in the Upper Dee catchment, including the Ceiroig is predominantly grassland with some woodland and mountain heaths and bogs. On the Ceiriog there are some large industrial sites at Chirk. Areas of poor quality soil, generally within the Upper and Middle Dee, are used for sheep farming and commercial forestry. In the Lower Dee, where soil is more fertile, intensive dairy farming takes place. Only around 6% of the whole Dee catchment is urbanised with over 60% of the population being concentrated in Wrexham, Chester and Deeside. Smaller villages are scattered throughout the Dee catchment and are important for tourism. There are also a number of industrial and commercial activities which are very important for the local economy (EA, 2010).

4.3 Hydrology and flood risk

4.3.1 Hydrology

The catchment area of the River Dee/ Afon Dyfrdwy to Chester Weir is circa 1,817km^2 and the mean river flow is approximately 37m^3/s (Hill and Emery, 2005). Rainfall is significantly lower in the lowland reaches compared to the upper catchment. Also in the lowland reaches, the river Dee and tributaries have slower flow rates and a greater groundwater contribution than in the upper catchment reaches.

Data from the Centre for Ecology and Hydrology River Flow Archive has been used to compile Table 4-1 below. This table shows the catchment area, average annual rainfall and mean flows at various gauging stations along the Dee and Ceiriog.

Table 4-1 Hydrology information take from Centre for Ecology and Hydrology website

River and location	Grid reference	Catchment area (km^2)	Average annual rainfall (mm)	Mean flow (m^3/s)
Dee at Bala	SH942357	261.6	1843	13
Dee at Manley Hall	SJ348415	1013.2	1369	31.1
Dee at Iron Bridge	SJ418600	1674.1	1143	37.9
Dee at Chester suspension bridge	SJ409659	1816.8	1111	33.2
Ceiriog at Brynkinalt weir	SJ295373	113.7	1197	3.1

Several major lakes and storage reservoirs are situated in the upper part of the basin, including Llyn Tegid which is the largest natural lake in Wales. The storage reservoirs are used to control flood risk in the lower lying parts of the catchment adjacent to the Dee. They are also used to regulate river flows in drier periods to sustain abstractions for public supply and industry, the navigational water requirements of the Shropshire Union Canal and fisheries interests in the lower Dee. The reduction in mean flow on the Dee between Iron Bridge and Chester suspension bridge (illustrated in Table 4.1) could be explained by abstraction (See 4.4.1).

4.3.2 Flood risk

Bala Lake/ Llyn Tegid provide natural storage of rainfall, thereby reducing flood peaks in the upper catchment. Upstream of Bala Lake, the channel is narrow and cut down into bedrock. Whilst immediately downstream the channel is wider with a floodplain of around 1km width. At the Vale of Llangollen the channel becomes narrower and confined to a deep rock cut valley until Erbistock, just upstream of Bangor-on Dee. Downstream of Bangor-on-Dee, the floodplain is very wide and the topography much gentler than that further upstream (EA, 2010).

The River Dee Catchment Flood Management Plan (CFMP) identifies areas at risk of a flood with a 1% chance of occurring in any given year. Those areas at high risk include Chester, Deeside, Bala, Bangor-on-Dee, Whitchurch, Wrexham, Mold, Flint, Holywell, Cefn Mawr Area, New Broughton and Sealand. In addition infrastructure is at risk, including a number of 'A' roads, railways, railway stations, schools, telephone exchanges, sewage/water treatment plants and electricity and gas plants. EA modelling has also shown that due to climate change, in the next century, Llangollen may also become at risk of flooding.

Fluvial (river) flooding occurs quite frequently in the Upper Dee catchment but affects few properties. In the Lower Dee catchment, as the floodplain is wider, flooding affects larger areas including agricultural land and the towns of Wrexham, Mold, Chester, Deeside and Sealand.

The CFMP deals with changing priorities for floods. For example the Middle Dee CFMP Unit extends from its confluence with the River Ceiriog to downstream of the confluence with the River Clywedog. It includes the communities of Overton, Whitchurch, Tattenhall and Malpas. Approximately 220 properties are at risk. Here the EA has adopted Policy Option 2 – areas of low to moderate flood risk where generally a reduction of existing flood risk management actions can take place. The EA vision is to reduce reliance and expenditure on the agricultural defences over time.

The Lower Dee is mainly a rural area downstream of Worthenbury. It contains much of the Dee Meanders, and several settlements including Holt, Farndon, Rossett, Aldford and Eccleston. Approximately 50 properties are at risk of flooding, mainly from the Dee. Policy Option 3 – areas of low to moderate flood risk where we are generally managing existing flood risk effectively is given to this Unit. The EA vision here is to ensure its actions are appropriate and proportionate to the risks, now and in the future. They will continue to maintain their defences, but it may not be justifiable to increase their height in the future.

As priorities change, then there may be opportunities to deliver river restoration measures/ actions. For example if the EA plans to cease maintaining a flood bank there will be an agreed withdrawal period, to give land owners a chance to consider future options. This may provide an opportunity for a change of approach, helping to deliver the type of measures outlined in this Report.

When a combination of extreme high tide and high river flow occurs, freshwater can back up and cause fluvial flooding as far upstream as Shocklach. Pluvial (surface) and sewer flooding has also occurred in the Lower Dee catchment.

Historically defence against flooding has taken the form of hard engineering defences and water regulation. There are a number of flood defence schemes in the Dee catchment (See Appendix A for a list of major channel modifications). For example, downstream of Chester weir, the river was canalised (for navigation) around 2 centuries ago and flood defences were built to protect the land against tidal flooding.

4.4 Water resources

4.4.1 Water abstraction

(a) Background

The River Dee is one of the most regulated rivers in the whole of Europe and its flow is managed to provide drinking water (and flood relief, see above) for a large number of number of settlements in north-west England and north east Wales. The Environment Agency Wales (EAW) regulates under a set of rules (Dee General Directions), as required by the Dee and Clwyd River Authority Act 1973. Therefore any change to flow regime requires assessment under Regulation 48 of the Habitats Regulations 1994.

The flow of the River Dee is strongly controlled by four reservoirs located within the headwater area of the catchment. These reservoirs are Llyn Tegid (Bala Lake), Alwen reservoir, Llyn Celyn and Llyn Brenig. The total catchment area of the reservoirs is approximately 20% of the Dee catchment ($370km^2$) however they generate approximately 40% of the total normal runoff at Chester Weir ($16m^3/s$). This is only an average and may differ throughout the year depending on licence conditions and requirements. The Afon Tryweryn, is a regulated tributary of the Dee and is also part of the Welsh SSSI. This transports water from Llyn Celyn and joins the main Dee just beneath the outlet of Bala Lake. The Alwen is also a regulated tributary, but is not included in either SSSI or SAC designation.

The earliest form of regulation at Bala Lake occurred in the early 1800s when Thomas Telford constructed a weir at the outlet to Llyn Tegid to maintain flows in the Llangollen Union canal. At the Horseshoe Falls water from the River Dee is diverted into this canal.

In the 1950s the Bala Lake Scheme was constructed, involving a number of adjustments to the natural river and lake. These included the lowering of the outlet by 2 metres, the building of sluice gates and diversion of the Afon Tryweryn to create a confluence downstream of Bala Lake. The main changes in flow regulation relate to the closure of the impounding Alwen Reservoir during the 1920s; the regulation of Bala Lake in the 1950s; the completion of the regulating reservoir Llyn Celyn in 1965 and the completion in 1979 of the regulating reservoir Llyn Brenig.

Water abstraction for public water supply, industry and/or agriculture significantly affects flow at the Manley Hall gauging weir. In addition flow at Chester is significantly lower than flow upstream at Iron Bridge due to abstraction.

(b) Effect of flow regulation on flows

Regulation by the reservoirs has increased low flows and decreased high flows. Analysis of river flow records from 1938 to 1992 for the Erbistock/ Manley Hall gauging station identified these two trends. First, monthly instantaneous maximum flows show a steady decline in their annual mean and standard deviation over the entire record. Using the Gumbel (EVI) probability distribution, Gurnell et al (1994) found that the magnitude of the mean annual flood fell from 269 to 231 cumecs between 1946-1963 and 1965-1992, a reduction of 14%. The annual maximum and minimum of the monthly instantaneous maximum flows decreased in variability after the mid-1960s with the magnitude of the former declining and the latter increasing over the same time period. Secondly, the range in mean monthly flows shows decreasing variability through the period. The annual mean, median and maximum of the mean monthly flows fluctuate around a relatively stable level through the 1938 -1992 period, but there is a marked increase in minimum mean monthly flows, particularly after the mid-1960s. Prior to 1966 the minimum annual mean monthly flow frequently fell below 5 cumecs but since 1966 a flow below 8 cumecs has been rare (Gurnell et al., 1994).

Regulation of flow, either for abstraction for drinking water or maintaining levels for flood defence plays a crucial part in the distribution of aquatic habitats. The removal of peak and low flow events reduces the ability of the catchment to self regulate, allowing deposition (which would normally be cleaned out in high flows) to occur, potentially smothering spawning beds and reducing the flow variation. This in turn reduces the diversity of in-channel habitats, reducing the potential for connectivity between co-habiting life stages of key conservation species (such as salmon or lamprey) although may improve vegetation.

(c) Potential geomorphological impacts of flow regulation

As described earlier in this section flow regulation has increased low flows and decreased high flows. Gurnell (1997) looked at the impacts of flow regulation on channel change in the Lower Dee for a distance of 18km upstream of Chester Weir. Gurnell (1997) found that there is a spatial pattern of decreasing channel width in a downstream direction within the study reach, and of greater channel widths near meander crests than on straighter sections of channel and at points of inflexion. In the same study a temporal trend of decreasing channel width was observed, particularly since the mid-1960s, the period of strongest flow regulation. Decreases in channel width appear to occur later in the downstream sections of the reach than in the upstream sections, giving some further evidence to support an earlier paper (Gurnell et al. (1994)) that found channel narrowing to be gradually propagated downstream.

The storage capacity of the reservoirs/ lakes damps down the flood peaks to a degree dependent on the size of the reservoir relative to its catchment area, as well as the operating regime. For flood control purposes planned releases may result in reduced overbank flows in the immediate downstream reaches. Peak events are more likely to be reduced in summer as a consequence of the storage capacity being greater than in winter. Potential impacts are likely to extend for many kilometres downstream. As bankfull discharge is generally the most geomorphologically effective flow then any reduction is likely to impact on the restoration measures. For example, there may be less competence of the river to naturally recover (i.e. erode its banks into embankments and bank protection) and also retain active geomorphological features. However in those reaches in the Lower Dee identified by Gurnell (1994) with channel narrowing, it is likely that bankfull discharge will be at a lower discharge than pre-Regulation.

The lakes and reservoirs also act as sediment sinks, depriving the downstream reaches of a normal sediment load. This discontinuity in sediment movement has also been a factor in considering appropriateness of restoration measures/ actions.

Whilst it is accepted that flow regulation acts as a major pressure on the geomorphology of the river, changes to outflow regimes were not investigated as part of this project. It is accepted that there may be more morphologically beneficial outflow regimes that could be investigated. Current investigations by the EA include the review of abstractions and mitigation measures for water storage and supply, the results of which are expected to complement the findings of this project.

4.4.2 Water quality

Water quality plays a significant role in supporting conservation features, with both physical water quality factors (such as temperature, turbidity, pH and dissolved oxygen) and chemical quality (metals, nutrients, and industrial compounds) important in determining the presence and distribution of aquatic species. Many of the conservation species on the Dee have specific water quality requirements at different life stages and the maintenance of an optimum range of conditions is maximised through reducing anthropogenic influence on the quality and quantity of water present.

Water quality on the River Dee has a varied history of impacts from a range of sources down its length. Examples of this in the upper catchment include: Bala Lake/ Llyn Tegid has previously been subject to phosphate-enrichment from diffuse pollution which has resulted in blue-green algal blooms. Some of the tributaries (including both the Meloch and Mynach) in the upper catchment have been affected by pesticides from farming, acidification and elevated metals, particularly copper, of which the effects are still observed today in WFD status (see below). In the mid catchment, and with the increase in urbanisation, runoff from industrial processes can affect water quality, for example elevated zinc levels on the River Clywedog, from the Minera mine in the headwaters. Where the river reaches the Cheshire Plains, additional water quality pressures come from excess nutrients from rural diffuse pollution and point source discharges such as sewage outlets (EAW, 2009).

Currently copper is recorded as failing WFD chemical standard in the Upper Dee between Alwen and the Ceiriog confluence (WFD Water body GB111067052060), and headwater tributaries in the Afon Meloch and Mynach. No chemical failures are recorded on the Afon Ceiriog or Middle Dee (Alwen to Chester Weir).

Actions for dealing with water quality issues are summarised in the River Dee RBMP. There is also a draft Diffuse Water Pollution Plan for the English sections of the Dee.

4.5 Fish

The River Dee and its tributaries are renowned for their excellent fish communities. The Dee is one of Wales' most important rivers for Atlantic salmon, supporting a strong run of this migratory species into its headwaters. The Afon Ceiriog, Afon Mynach and Afon Meloch are the most important spawning tributaries in the Dee catchment and are therefore included in the SSSI designations. A survey commissioned by CCW in 2007 concluded that Atlantic salmon populations are currently failing to achieve favourable condition. This was mainly attributed to failings in adult run population below the conservation limit, all parameters of water quality and environmental disturbance.

Other migratory fish found in the River Dee include sea trout, European eel, river lamprey and sea lamprey. A survey in 2006 on sea lamprey, brook lamprey and river lamprey showed that each of these species also failed to achieve favourable condition. As CCW have assessed for features for the whole Welsh SSSI rather than on a management unit basis, it is assumed at the moment that species are failing in all management units where they are present.

Non-migratory species are also supported by the Dee including brown trout, grayling, bullhead and brook lamprey and a range of coarse (cyprinid) species.

The current WFD status for water-bodies within the wider River Dee catchment indicated that fish populations are failing to meet Good Ecological Status in the Afon Mynach and Upper Dee (Bala to Alwen – GB11106701990) catchments. Good Ecological Status (or Potential for HMWB) is being met by the Afon Ceiriog, the

Meloch and from Alwen on the main stem Dee to Chester Weir. Reasons for failure to meet good status or potential in the head of the Dee catchment may be obstructions to migration, variable water quality or physical habitat modification, as shown earlier in Table 3-5.

4.6 Birds

Habitats throughout the entire River Dee system support a wide range of breeding birds. Kingfisher *Alcedo atthis* and sand martin *Riparia riparia* nest in earth cliffs created by erosion of banks. Areas of fast flowing water alongside vegetative cover along the banks provide the dipper *Cinclus cinclus* and grey wagtail *Motacilla cinerea* with suitable habitat. Stretches of slower flow are favoured by mute swan *Cygnus olor* and yellow wagtail *Motacilla flava*.

The Lower Dee floodplains provide breeding grounds for waders including lapwing *Vanellus vanellus*. When these areas flood they provide vital over-wintering sites for the pintail *Anas acuta*.

4.7 Alien invasive species

Several non-native invasive species are present within the River Dee in certain areas. The North American signal crayfish *Pacifastacus leniusculus* is relatively abundant in the river, particularly near Llangollen. Signal crayfish can limit fish recruitment as they predate on fish eggs and compete through predation of the macro-invertebrate food resource. There is also widespread distribution of non-native invasive plant species throughout the Dee river basin district (EA, 2009). Both Japanese knotweed *Fallopia japonica* and Himalayan balsam *Impatiens glandulifera* were recorded during the field visits.

4.8 Agri-environment schemes

In Wales Glastir agri-environment scheme, which replaces a number of other agri-environment schemes, pays for the delivery of specific environmental goods and services aimed at combating climate change, improving water management and maintaining, enhancing biodiversity and helping meet WFD targets. It is designed to deliver measurable outcomes at both a farm and landscape level in a cost effective way. In England the Environmental Stewardship agri-environment scheme (ESS) for English farmers is very similar to Glastir. It was launched in March 2005 and replaced the Hill Farmers Allowance, Countryside Stewardship scheme, Environmentally Sensitive Areas scheme and Wildlife Enhancement scheme. Contracts are held for five years, with the exception of the Higher Level Stewardship (HLS). It is intended to deliver simple and effective environmental management across a complete farm, complementing existing farming operations and allowing the creation of a practical environmental management programme.

In England there are a number of Natural England HLS target areas in the catchment. For example the Dee Target Area contributes to the wider Higher Level Stewardship objectives of Biodiversity and Historic Environment. This target area extends south of Chester to approximately Shocklach and lies along the Welsh border including a section of the English SSSI where it meanders across the Cheshire plain. Riparian woodlands and areas of the floodplain are nationally important habitats of interest for lowland breeding waders, arable birds and the nationally scarce SSSI feature, club-tailed dragonfly. In addition the Shocklach area is valued as a historic designed landscape due to the high concentration of ridge and furrow. Land management activities encouraged in this area include the creation/maintenance/restoration of semi-natural woodland and riparian corridors.

Due to CAP reform, current schemes in England are under review and details of new schemes are not yet available. There is uncertainty as to how they may contribute to the delivery of restoration actions in future.

5 Contemporary river characteristics

5.1 Summary of Dee catchment

The tributaries of the Dee surveyed in November 2012 (Afon Meloch, Afon Mynach and River Ceiriog) generally have sinuous, relatively inactive planforms that are relatively stable due to the bedrock and glacial boulder lined channels. Rock steps and boulder pools are found where the channel is cut into the bedrock. The sinuosity of the channels may have formed in late glacial times when there were higher discharges and less vegetation. Typically the three tributaries are tree-lined, although there were sections where trees were absent. Tree roots bind the soil together and act as natural bank reinforcement, thereby increasing the resistance of the banks to fluvial erosion and stabilising the channel planform. These rivers predominantly transport sediment downstream as a result of being largely confined by bedrock geology.

The Upper Dee (from Bala outflow to Corwen) has a more active meandering planform but this is restricted in places by valley sides which limits meander development. Where there has been floodplain development, land is very flat with some reaches lined with trees. The trees locally act as natural bank protection. The Middle Dee (from Corwen to Overton) runs through the Vale of Llangollen where the floodplain is extremely narrow and remains in a confined meandering planform that runs from valley side to valley side. The Lower Dee (from Overton to Chester weir) has a very wide floodplain, expanding into the vast Cheshire Plain. Here the Dee is a relatively low energy river that has a regular, unconfined meandering planform. Although scientific papers seem to indicate that although there may be local erosion, the channel is not today an "actively meandering channel".

The principal causes of erosion on the River Dee, as recorded by the Hill and Emery (2005) Fluvial Audit, are due to fluvial action (7.6% of total main stem Dee length) and poaching (6.3% of total main stem Dee length). The Hill and Emery (2005) Fluvial Audit found that the greatest proportion of erosion occurs in the Lower Dee around the Dee meanders and in the Upper Dee from Bala Lake outflow to Corwen. Historic records show that these areas were subject to extensive stone pitching for bank protection. Much of the historic bank protection still remains in the Upper Dee but appears to have washed away at the Dee meanders. The greatest proportion of bank stability occurs along the Middle Dee, where the Hill and Emery (2005) Fluvial Audit recorded the least amount of erosion. This is partially attributed to the greater proportion of bedrock banks and concrete reinforcement that occurs along the river at places such as Llangollen. Hill and Emery (2005) also noted that dominant sediment size tended to increase in a downstream progression; from coarse gravel in the Upper Dee, cobbles in the Upper-Middle Dee, and bedrock in the Middle Dee. Bed material in the Lower Dee then becomes predominantly finer consisting of sand and earth.

5.1.1 Flow types

The variations in flow types along the Ceiriog, Mynach and Meloch are typical of those found in upland British rivers and show a similar flow distribution to the variation in bed topography. These include step-pool sequences where there are very steep gradients and rock-bound reaches to fast runs and riffles where there is limited floodplain development. The River Dee from Bala outflow flows over a relatively low gradient along the base of the main glacial valley. Due to the width, depth and gradient the main flow types observed here include glides and runs. The depth of water in the Dee obscures most of the bed topography.

The current study concurs with the findings of Hill and Emery (2005) Fluvial Audit in terms of flow types. On the main stem River Dee from Bala Lake outflow to Chester weir, the dominant flow type was glides (39.5% of the total main stem Dee). The second most common flow type was pool-riffle sequence followed by run (34.3% and 23.3% respectively). Hill and Emery (2005) found the pool-riffle flow type as being particularly favourable to the *Ranunculus* community, one of the primary SAC features. Other ecological features have specific flow requirements which are supported by the flow variation identified within the main stem of the Dee.

5.1.2 Wood

Woody debris, in-channel trees and exposed tree roots can provide an important source of flow variation and habitats in rivers (Gurnell et al., 2002). Observations of woody debris (defined as collections of woody debris as opposed to single particles of wood) were made on all visits to the River Ceiriog, Afon Mynach and Afon Meloch and in some site visits to the Upper, Middle and Lower Dee. The amount of woody debris accumulation reflects a combination of adequate supply of wood from riparian cover upstream and the presence of flows sufficient to transport the wood and promote the formation of accumulations. Fewer woody debris accumulations along the main stem Dee suggest the riparian zone is a smaller proportion to the channel than the upland tributaries. In the upper catchment gravels are seen to accumulate between woody debris adding substrate diversity to the channel.

Exposed tree roots extensively line the banks of the tributaries Afon Mynach, Afon Meloch and River Ceiriog creating submerged habitats for fish and otters. The presence of exposed tree roots, woody debris and trees within the channel further promotes the development of depositional features. This creates a variation in bed topography and consequently alters flow patterns. Figures 5.2 and 5.3 (of the River Ceiriog) show good examples of the importance of wood, such as trees in channel trapping sediment and debris that has come from upstream. Accumulations of sediment and debris can cause flow to speed up adjacent to the feature and create sheltered areas on the lea (downstream) side. The sheltered and covered areas are good for adult fish as they wait to migrate or spawn and provide refuge locations from predators or high flows. Bullhead may utilise submerged tree roots as spawning habitat. Invertebrates such as the larvae of caddis flies, stoneflies and water beetles utilise the protection provided by exposed tree roots. These in turn, are preyed upon by fish including salmon and brown trout. Exposed tree roots also provide otters with suitably protected and undisturbed den sites.

5.2 River Ceiriog characteristics

The River Ceiriog is generally a headwater stream exhibiting few signs of morphological adjustment, with a high to medium gradient that flows through a concave valley and is confined in places by the steep glacial valley sides. There are areas in the middle sections where the floodplain is relatively large, approaching ten river widths. Due to the confinements of the valley sides, this floodplain tends to alternate from bank to bank. Bank profiles range from being relatively gentle to vertical, particularly where the river has cut into bedrock.

The bed of the upper Ceiriog is a mixture of bedrock, cobble and coarse gravel (Figure 5.1). Sediment size was observed to decrease in a downstream direction, from cobbles and pebbles upstream to more mobile gravels and silts downstream. This was also found by Jacobs (2009). The cobble bed showed little sign of recent morphological adjustment and potentially only minor localised re-distribution of smaller gravel sizes occurring during flood events. Consolidated substrates provide limited spawning opportunity in the upper catchment for fish and lamprey species although the variability in bed and flows support good parr habitats.

.

Figure 5.1 Typical section of Ceiriog, rock bound with boulders and cobbles making up bed.

Due to the moderate gradient, flow types range between run-riffle and glides. There are also steeper sections where step pools / cascades are present. These higher energy flows and steeper gradient are likely to form a natural barrier to migration to lamprey and prevent movement of bullhead within the watercourse. Step pools will not prevent access to the upper catchment for salmonids. There are exposed tree roots along a vast proportion of the Ceiriog which suggests these are providing natural bank protection, whist also providing cover and refuge areas for adult and juvenile fish. The 2012 walkover identified limited spawning potential for salmon in the upper Afon Ceiriog, reducing the connectivity between spawning and juvenile habitats. Salmon may however utilise sub optimal cobble substrates where mobile coarser gravels are not available due to sediment transfer. This would support the findings of the 2001 EA/ CCW survey which identified high salmon parr densities in the Ceiriog.

The river follows an inherent winding pattern with localised areas of artificial bank protection, which appear to have very little overall geomorphological impact. The upper reaches of the Ceiriog are generally sediment transfer zones, transporting sediment from the upstream catchment area to the downstream reaches. Although side bars, comprised mainly of cobbles, were present in all spot checks and along the continuous Fluvial Audit from Chirk Bridge to the River Dee confluence. These are potentially re-mobilised during extreme flow events since most bars are unvegetated.

From approximately 2km upstream to the confluence of the Ceiriog and Dee there is evidence of increased deposition, including silt bars and over bank deposits (see Deposits Map, Appendix C). This suggests that this area acts as a sediment sink due to the flatter gradient coinciding with the main stem Dee floodplain. The lower gradient causes deposition of large amounts of cobble and fine material, which has resulted in mid-channel islands and secondary channels. This deposition of fine material may create suitable spawning and parr habitat for salmonids and optimum bullhead conditions. Ammocoete habitat would be expected in the slower flow marginal areas where silts are deposited. In particular, there are a high number of large woody debris accumulations which have resulted in alterations to flow types across the channel and increased deposition where these occur, forming these islands (Figures 5.2 and 5.3).

Figure 5.2 Large woody debris accumulations which have resulted in formation of chute flow and accumulation of sediment in front of and behind large woody debris, River Ceiriog

Figure 5.3 Islands and deposits forming as a result of large woody debris accumulations, River Ceiriog

Land use either side of the Ceiriog is typically rough pasture used for grazing (where there is floodplain) or broadleaved woodland (where the topography is generally steeper). The dominant species recorded include alder *Alnus glutinosa,* sycamore *Acer pseudoplanatus*, ash *Fraxinus excelsior*, and willow sp. *Salix* sp. Exposed tree root systems, overhanging trees and coarse woody debris were frequently recorded, providing channel shading and cover for fish. The riparian zone along the Ceiriog is good where broadleaf woodland is present. However the riparian vegetation is sparse and poaching occurs where the banks are unfenced and accessible to livestock. Poaching is fairly widespread along the Ceiriog. However previous research on the source of sediment in interstitial spaces suggests that bank erosion contributes only a small percentage of the overall sediment (approximately 2%) in the Dee catchment (Walling, Collins and McMellin, 2002).

The Ceiriog offers a valuable foraging resource for otters. There are extensive stretches of bank that provide suitable refuge habitat for otter with many exposed root systems, mid-stream islands, and woodland/vegetated banks. However, riparian cover is sparse along much of the upper river.

Ranunculus vegetation would be expected in the middle and lower reaches where the flow velocity is suitable. The Ceiriog does not offer suitable habitats for the other qualifying features; natural flow velocities are too high for floating water-plantain and club-tailed dragonfly.

5.2.1 Channel modifications

The surveyed reaches of the Ceiriog were predominantly unmodified. There are localised areas of bank reinforcements typically associated with infrastructure such as roads, bridges and flood protection in towns (see Channel Modification Map,

Appendix C). Bank protection was also recorded along fields of rough pasture. Channel modifications result in a loss of natural bank but this represents a very small percentage of the total bank and is unlikely to adversely affect the favourable condition of any of the designated features.

Two major weirs were recorded, an unnamed weir upstream of the fish hatchery near Pont Faen, and Brynkinalt weir. The unnamed weir diverts water into the fish hatchery and at the time of survey caused flow to pond approximately 70 metres upstream. Brynkinalt weir is a gauging weir which is 1m high by 3m long, with approximately 30m of bed protection on the upstream side (see Table 7-2). It caused water to pond approximately 20m upstream, Brynkinalt weir had a fish pass but both weirs would likely restrict upstream migration of lamprey and movement of bullhead between populations.

Figure 5.4 indicates an artificially straightened section in spot check CEI002SP, where incision appears to have occurred, limited by the development of an armoured cobble bed. It is likely that this channel was straightened to increase slope and stop gravels dropping out. This will be detrimental to all fish species as straightening reduces flow and bed substrate variation, depriving gravel deposition (important for spawning) and the loss of other important in-channel and riparian habitat necessary to support diverse fish assemblages.

Figure 5.4 Example of straightened section with incision in spot check CEI002SP, Afon Ceiriog

The dominant land use of sheep grazing has resulted in a reduction in riparian vegetation and the prevalence of short grass along most of the banks. This may lead to increases in pollutants in run-off such as silt, which can lead to degraded spawning habitats for salmonids, as well as adverse impacts on *Ranunculus*.

Japanese knotweed was recorded around Glyn Ceiriog. This can also result in increases in silt input when it replaces natural vegetation then dies back in the winter, leaving the banks without any vegetation cover.

5.3 Afon Mynach

The Afon Mynach is a typical upland tributary of a British river. It is predominantly a sediment source and transfer zone throughout. However there is some localised and restricted floodplain development where sediments are temporarily stored. These reaches are characterised by mid-channel islands and some evidence of fresh erosion due to channel migration into banks where tree lining is absent (Figure 5.5).

The Afon Mynach follows a confined meandering pattern, which becomes sinuous where it meets more resistant bed and bank material such as bedrock and boulders. The bed of the Afon Mynach is variable throughout its length, mainly comprised of coarse gravel, sand and silt with a distinct bedrock bound section that is dominated by large glacial boulders and step-pool flow with very few deposits. In the upper reaches, there is evidence that the gravel bed is relatively active due to the presence of unvegetated side and point bars of gravel or sand/silt and frequent pockets of erosion (see Deposits and Sediment Sources Map, Appendix C).

The river channel characteristics provide fast shallow runs and riffles with cobble and pebble substrates, offering suitable spawning and juvenile habitat for salmonid fishes. Vegetated boulders and mid-channel bars were recorded. Gradient generally increases downstream in areas creating a step-pool flow. No barriers to fish movement were identified along the Afon Mynach.

Suitable salmon spawning and juvenile habitat is present in the middle reaches where the gradient is lower and coarse gravel substrate has deposited. These habitats are positioned so that there is good interconnectivity between life stages. Deeper areas suitable for adult salmon were not recorded. Access to the Afon Mynach is restricted for some of the qualifying features due to obstructions on the main stem River Dee. In particular, Horseshoe Falls Weir represents the upstream extent for migratory lamprey species. Suitable spawning habitat for lampreys is present in the middle and lower reaches of the Afon Mynach and there are some silt/sand deposits which offer suitable ammocoete habitat. This suggests that populations could be sustained should access to the upper catchment be improved. Suitable habitat for all life stages of bullhead is present throughout the middle and lower reaches however the natural gradient is likely to affect the utilisation of the upper reaches of the watercourse to bullhead. No significant barriers to fish movement were identified along the Afon Mynach, although large aggregations of woody debris may restrict some fish passage in the upper catchment.

Ranunculus vegetation would be expected in the middle and lower reaches where the flow velocity is suitable. The Afon Mynach does not offer suitable habitats for the other qualifying features; natural flow velocities are too high for floating water-plantain and a lack of suitable flows and substrate restrict the distribution of the club-tailed dragonfly. The latter of these species would not naturally be expected to inhabit this tributary based on the physical habitat observed.

Where bank material was recorded as exposed, it was comprised of earth and gravel. Large sections of bank material were obscured by stable bank vegetation such as grass and bryophytes (mosses). The riparian zone was very thin or absent in areas where the adjacent land had been used for sheep or cattle grazing. Some bog and rush pasture was recorded along the upper reaches. Although poaching is not a major pressure in this tributary, much of the river is unfenced and grazing livestock has had an effect on tree line density. The banks of the river are generally low (<2m) and gentle sloping. Vegetation along the banks is lacking along some sections or limited to grasses and rushes. Tree cover (dominated by willow (*Salix* sp) and alder (*Alnus glutinosa*)) and scrub species along the banks increase downstream. Bracken (*Pteridium* sp.), dock (*Rumex obtusifolius*) and bramble (*Rubus fruticosus* agg.) coverage increases in areas of more dense vegetation. Areas of dense scrub and bracken offer good lying-up habitat and foraging habitat for otter (*Lutra lutra*). Otter spraint was recorded confirming presence of the species.

Figure 5.5 Active section with erosion and channel cut islands, Afon Mynach

5.3.1 Channel modifications

The Afon Mynach is relatively unmodified and is classed as having a very high conservation status in terms of geomorphology.

The main modifications recorded are in the upper reaches, where woody debris and piled boulders have been wired together to act as bank protection (Figure 5.6a) and in the final 200m before the Afon Mynach-Treweryn confluence where there is a straightened section that is still incising due to the artificially steep slope (Figure 5.6b). These modifications are not considered to be significantly affecting the favourable condition of any of the designated features. However, it would be good to address them to conserve/enhance the reaches.

a)

b)

Figure 5.6 a) Woody debris and boulder bank protection; b) Straightened section that may still be incising, Afon Mynach

Grazing livestock (sheep and cattle) has resulted in a reduction in riparian vegetation and the prevalence of short grass along most of the banks. This may lead to increases in pollutants in run-off such as silt, leading to degraded spawning habitats for salmonids, as well as adverse impacts on *Ranunculus*.

Japanese knotweed (*Fallopia japonica*) was recorded. This can also result in increases in silt input when it replaces natural vegetation then dies back in the winter, leaving the banks without any cover.

5.4 Afon Meloch

The Afon Meloch is a typical upland headwater tributary of a British river. The natural sections exhibit little evidence of activity in terms of lateral and vertical movement of the channel and are typed as either rock-bound channel sections or tree-lined gravelly sections. There is a general absence of point bars and mid-channel bars which confirm this degree of inactivity (see Deposits Map, Appendix C). The Meloch is generally winding and has probably inherited this pattern from previous times when there was less vegetation post-glaciation and therefore more runoff able to activate and carve channels. There is one short length with limited floodplain development, possibly indicative of more recent channel activity. Some evidence of small point bar development is present. These reaches may serve as local sediment sinks (temporary storage) for sediments transported from upstream.

The predominant function of the river is a sediment transfer, with some localised deposits of gravels and cobbles behind obstructions such as woody debris and tree boughs. This localised deposition is probably indicative of past floods and is likely to be temporary as eventually woody vegetation will rot away. There are areas with recent deposits of finer materials such as fine gravel and silt. These will have formed through the transport of gravel and silt along the upper section of the Afon Meloch. There is relatively little evidence of erosion, which is an indication of channel inactivity, although there are small-scale changes in a few locations.

There are a variety of flow types present on the Afon Meloch. The predominant flow types are in a run-riffle sequence (Figure 5.7a) or step-pool sequence (Figure 5.7b), indicating variations in bed topography and substrate along the river. Cascades are also present in the second surveyed reach (MEL002), which are a result of the marked increase in gradient (Figure 5.7c).

Figure 5.7 a) Run-riffle sequence; b) Step pool sequence (indicated by red arrow); c) Cascades, Afon Meloch.

The high gradient limits the availability of suitable salmonid spawning habitats with coarse consolidated substrates dominating the upper reaches of the Meloch. Isolated suitable areas were recorded in the middle and lower reaches. Channel, substrate and flow diversity offer suitable spawning and juvenile habitats for bullhead.

Suitable spawning habitat for lampreys is present in the middle and lower reaches but the soft sediment (silt/sand) marginal habitat favoured by lamprey ammocoetes was lacking from the catchment. Despite the favourable habitat lamprey are expected to be absent from the Meloch due to obstructions to migration in the main stem Dee preventing ascension into the headwaters. The natural high gradient of the watercourse may further restrict fish passage under lower flows of the Meloch, although the consolidated substrate and minor obstructions to free movement will restrict adult populations in the upper Meloch.

Ranunculus vegetation would be expected in the middle and lower reaches where the flow velocity is suitable and shading is not too high. The Meloch does not offer suitable habitats for the other qualifying features; natural flow velocities are too high for floating water-plantain and club-tailed dragonfly.

Bank materials are generally cohesive, being held together by vegetation (mainly grass and tree roots) however there were some areas where bare soil was exposed and it was evident that bank material was comprised of a mixture of earth (sand, silt and clay) and fluvial deposited cobbles. Land use along the course of the Meloch is dominated by improved and semi-improved grassland grazed by sheep. Riparian tree cover ranges from continuous to scattered/absent. The dominant tree species recorded were ash, elder, willow sp. and hawthorn, providing extensive channel shading in places. Woodland is present in steep valley sections. Ground flora was dominated by bramble and dog's mercury (*Mercurialis perennis*).

Fences preventing livestock from reaching the watercourse are intermittent along the reaches. At these locations the amount of grass and herb species increases. It is generally apparent in unfenced sections that shrub species are lacking with poaching being evident.

Numerous exposed tree root systems are evident along the surveyed sections being notably more apparent in the upper reaches. These offer suitable refuge habitat for otter and sub optimum spawning habitat for bullhead where suitable substrate and flow conditions are not met. Submerged root systems and woody debris play an important role in the providing cover and a food resource for adult fish, both up the channel and resident species. Where the channel has been straightened aquatic habitats, including flow and substrate types are more uniform and riparian vegetation is lacking. The reduction in physical habitat diversity is typified by a loss of suitable habitats for quantifying species or an increase in sub-optimal habitats. Both of these reduce the conservation significance of the water-course for aquatic receptors. Good foraging habitat for otters is present throughout the Meloch.

5.4.1 Channel modifications

There are minimal man-made influences in those reaches classed as relatively inactive and all affected have very localised impacts only (see Modifications Map, Appendix C). These include an artificial weir (5-6m wide and 0.5m high) used to create a water supply, with little downstream or upstream impact given the high gradient on the channel (Figure 5.8a). This is unlikely to impede salmonid migration under most flow conditions but would further prevent the ingress of lampreys or the localised movement of bullhead, potentially isolating populations if present. Given the height of the structure it may well be drowned out in high flow, allowing passage to those species able to ascend under higher flow velocities.

There is also a small number of sheep watering access points but these appear to be protected to prevent sheep being washed downstream and therefore any poaching (given the cohesive and static glacial geology) is negligible (Figure 5.8b). Equally bridges and localised artificial bank protection on the outside of bends have minimal impact on geomorphology. In reach MEL006 there is a wall on the right bank where the river runs adjacent to the main road (Figure 5.8c; see Channel Modifications Map, in Appendix C). This also has minimal impact on the overall river geomorphology and is vital to ensure the protection of the road.

There is an artificially straightened section in reach MEL004 (Figure 5.8d) that is embanked along the left bank and has few trees and a recent (less than 10 years old) continuous fence line on both banks (Figure 5.8e). No records were found for maintenance or capital works by the Dee and Clwyd River Board or River Authority (1953-1974). This may be a more recent scheme, intended to straighten the channel and keep gravels and cobbles in transport. There is also evidence of dredging spoil on the left-bank, suggesting periodic maintenance. Channel straightening has the effect of keeping sediment in transport and therefore possibly causes the removal of salmonid spawning habitats that would have existed pre-straightening. Higher energy flow types, increased mobilisation of sediments and a reduction in the diversity of aquatic habitats reduces spawning opportunities for all fish and lamprey species and furthermore affects the interconnectivity between habitats and localised populations.

Finally, just upstream of the confluence with the Dee, water is being abstracted via a sluice for a small-scale run of river hydropower scheme for domestic use and returned to the river immediately downstream of the road bridge (Figure 5.8f). This affects approximately 180m of the lower section of the Afon Meloch and is considered to have a relatively minor impact on water resources and river morphology.

It is not considered that any of the other modifications recorded on the Afon Meloch are likely to be significantly affecting the favourable condition of any of the designated features.

a)

b)

c)

d)

e) f)

Figure 5.8 a) Weir for water supply; b) managed water access point for livestock; c) bank protection on outside of bend; d) straightened section; e) embanked section (probably using spoil taken from new course) and f) sluice for domestic hydropower scheme, Afon Meloch

5.5 Upper and Middle Dee (Bala Lake outfall to Overton)

The main stem Dee from Bala Lake outfall to Overton is confined by a glacial valley with a relatively wide floodplain in the Upper Dee (Figure 5.9) and very narrow floodplain along the Vale of Llangollen after the Horseshoe Falls (Figure 5.10). The narrow valley restricts the scope for meander development and leads to confined patterns. There are examples of incised meanders along the Vale of Llangollen which are likely to have originated in a preglacial period and subsequently incised by glacial melt waters with very high discharges. The Rhewl meander is an example of such a meander where the valley is asymmetrical due to a combination of lateral and vertical erosion processes. The adjacent land to this meander is also designated as a feature for the Welsh SSSI. This site was not visited during the November/December 2012 field surveys.

During the November/ December 2012 surveys the bed material was found to be obscured by the water depth but the observed bank material was earth (silt, sand and clay) with a mix of glacial till. The banks are mainly vegetated with grass, which corresponds to a predominant land use of rough pasture for livestock. The riparian zone is generally fragmented with patches of woodland, some thin tree lining or absence of trees entirely (Figure 5.9).

Figure 5.9 Typical section of Upper Dee with floodplain confined by steep valley sides

Figure 5.10 Steep valley sides of the Middle Dee downstream of Horseshoe Falls. Red arrow indicates the Llangollen canal feeder, the offtake of which is just above the Horseshoe Falls; River Dee/ Afon Dyfrdwy is to right of photo

Channel width is relatively uniform all the way down the Upper and Middle Dee, approximately of 35m (ranging between 25m and 45m). The banks are approximately 1-2m high in the upper reaches and increase to 2-4m in the mid sections. The channel is relatively inactive, however there is localised erosion and cobble side and point bars reflecting the tendency for lateral movement of the channel. The sections surveyed on the Upper and Middle Dee were found to have submerged and emergent macrophytes along the edges of the channel. Large woody debris deposits were found to be infrequent along the Upper and Middle Dee, perhaps due to the lack of riparian zone upstream. Where large woody debris deposits were found (in particular immediately downstream of the Horseshoe Falls) these resulted in silt deposition and creation of marginal deadwater.

In the upper reaches there are glides, riffles and runs near Cynwyd and slow flowing areas associated with areas of poaching. Downstream in the mid section the gradient is higher and runs and rapids are present. The substrate was largely obscured due to the water depth, but areas of gravel and cobbles were present on the inside of bends. Silt deposits were also recorded from this section. Fallen trees and small mid-stream islands offer refuge areas for fish. Macrophytes (*Callitriche* sp.) were recorded in small patches on certain stretches.

The general land use along the river is improved grassland grazed by sheep or cut for silage. Some areas of semi-natural grassland exist where livestock has been excluded. Patches of scrub have grown in these areas typically comprising gorse *Ulex Europaeus*, bramble, blackthorn, bracken and willow sp. The banks are generally unfenced, apart from some fields in the mid section. Where livestock can reach the watercourse vegetation is generally low with grasses and rushes *Juncus* sp. with poaching and erosion evident in places. Broad-leaved woodland is present on steep slopes along higher banks of the river and smaller areas of mixed woodland typified by sycamore, holly and evergreen species.

Scattered tree lines dominated by ash and alder are present on both banks. Overhanging trees providing a degree of channel shading are fairly extensive. Exposed root systems are present, offering suitable refuge habitat for otter.

Good habitats for all salmonid life stages are present in the Upper Dee. Suitable spawning and juvenile lamprey habitat was also present. A single salmonid was observed in the river near Hendwr Caravan Park and fishing signs were present elsewhere.

Floating water-plantain occurs in the slow flowing water in the outflow of Bala Lake/Llyn Tegid, above the sluice gates which regulate the flows from Llyn Tegid and the Celyn Reservoir (CCW, undated). *Ranunculus* vegetation would be expected where the flow velocity is suitable. The Upper Dee does not offer suitable habitats for the other qualifying features; natural flow velocities are too high for club-tailed dragonfly.

5.5.1 Channel modifications

The altered flow regime, as a result of water regulation (for flood control and public water supply) is a potentially significant pressure on the River Dee/ Afon Dyfrdwy that acts in combination with direct morphological pressures The main reservoirs that affect flow on the main stem Upper and Middle Dee are Bala Lake/Llyn Tegid, Llyn Celyn and Llyn Brenig. Flow regulation affects river geomorphology over time in the Upper/Middle Dee due to the damping down the flood peaks to a degree. Although not observed during the 2012 surveys due to high flows, the likely consequence of such an artificial flow regime is increased deposition along the channel sides and channel narrowing downstream. Berm development in the Dee meanders (Lower Dee) is attributed to flow regulation in the Upper/Middle Dee (Changxing *et al*. 1999; Gurnell, 1997b). Basically with a reduction in flood peaks, the channel is no longer in equilibrium with the Regulated range of flows, and adjusts to a more natural size by reducing its width.

Flow regulation is a major factor affecting the ecology of the river. The floating-water plantain which is a primary feature of the SAC is reportedly only found in the slow flowing water in the outflow of Bala Lake/Llyn Tegid, above the sluice gates which regulate the flows from Llyn Tegid and the Celyn Reservoir (CCW, undated).

Major construction works have taken place on the Upper/Middle Dee associated with flow regulation. At the Bala Lake/ Llyn Tegid outfall there has been major channel straightening and realignment to accommodate the Bala Lake system for water regulation (Figure 5.11a-d). The Dee and Treweryn confluence was recorded as having a low conservation status because the channelisation works have created a uniform morphology and significantly affected the fluvial processes. At the Bala lake outlet there is a sluice gate (Figure 5.11b), salmon steps (Figure 5.11c), weir (Figure 5.11d) and access bridge. The sluice has five metal gates that can be operated independently. The concrete weir (Figure 5.11d) is circa 1.5m high and spans the width of the river which is approximately 25m wide upstream of the weir and 60m downstream. The river flow is restricted through a 5m section of the weir. The salmon steps (Figure 5.11c) are constructed from concrete and stone and are approximately 15m wide and 2m high. The salmon steps may restrict upstream migration of lamprey.

a) 
b) 
c) 
d) 

Figure 5.11 Structures at Treweryn confluence; a) Side channel right bank probably for flood storage, b) Sluice gate to control flow rate in Dee c) Salmon Steps and d) Weir by Bala Enterprise park

There are a number of other major weirs along the Upper/Middle Dee, five of which were visited during the field survey in November 2012: Horseshoe Falls, two weirs at Llangollen, Manley Hall gauging weir and Erbistock weir.

There are areas of extensively placed bank protection to protect adjacent farmland. Parts of this are now washed away, however there still remains a significant proportion and this is mapped in detail by the Hill and Emery (2005) Fluvial Audit. The Hill and Emery (2005) Fluvial Audit assessed bank protection as a modification but did not include other modifications such as channel realignment and major in-channel structures such as weirs. There were extensive but fragmentary pockets of bank protection in the Upper Dee along management units 2, 3 and 4 in the form of rip rap. In addition, an old railway line embankment that runs along the right bank in places in the Upper Dee prevents the river from migrating laterally in places where protected.

In addition, where the Dee flows through urban areas, such as at Llangollen and Froncysyllte, the channel is constrained by flood walls and bank protection (brick and laid stone). Downstream of Froncysyllte there are very few areas of bank protection. There is however the occasional embankment for localised protection and areas with concrete to reinforce road bridges.

At Llangollen the Dee is constrained by bank protection, embankments or walls. However, there was evidence that some geomorphological processes are still occurring, with the presence of mid-channel silt and gravel deposits, some of which are vegetated (Figure 5.12). Diverse habitats were still present, although marginal habitats of value to juvenile fish and lampreys are generally absent in areas of reinforcement. Himalayan balsam was recorded along the upper reaches and along the banks within the town of Llangollen.

Figure 5.12 River Dee at Llangollen with vegetated mid-channel islands

Two bridges were surveyed: one at Cynwyd and one near Corwen. These could not be assessed closely, but appeared not to have any detrimental effect on the ecology of the area. There is a ford downstream of Cynwyd used for tractor access from the farm on the left bank to the fields on the right. This has the potential to be negatively impacting habitats for salmonids and lamprey if it disturbs spawning grounds or regular use re-suspends fine silts in significant quantities. The river was approximately 1m deep at the ford so it does not present a restriction to fish migration.

5.6 Lower Dee (From Overton to Chester weir)

This section of the River Dee/ Afon Dyfrdwy was surveyed as a combination of spot checks and walkover surveys from Bangor-on Dee as far downstream as the tidally influenced section of Churton (near Farndon). Historically this section was navigable, back to Roman times, although there was very little remaining physical evidence of this at the time of survey.

From Bangor-on-Dee to Chester weir the River Dee/ Afon Dyfrdwy flows in an unconfined meandering pattern across an extensive floodplain, part of the Cheshire Plain. The section from Shocklach to Farndon is a designated SSSI feature for in channel geomorphology and floodplain due to the tortuous meanders that are some of the most spectacular and intricately developed meanders in the UK. There are indications of palaeochannels around the Dee meanders area based on analysis of aerial photographs. This is perhaps from a time pre-regulation when, under a natural flow regime, there were more active geomorphological processes due to greater variety of flows, including a greater proportion of high energy flows with the potential for scour. Under the current artificial flow regime, there is still evidence of localised movement of meanders in places. Most of the specific bank protection works documented from the British Library (see Appendices A and B) have presumably been destroyed over time and washed away. However in general the Lower Dee the river is relatively inactive and does not appear to be migrating laterally, except in localised areas. There have been a number of scientific (published) studies on the meanders which have identified a discontinuous berm, which is thought to have resulted from fine sediment dropping out along channel sides due to flow regulation and this has led to progressive channel narrowing downstream (Gurnell 1994; Gurnell, 1997a and b; Changxing *et al.* 1998). Due to the water level the November 2012 survey, these berms were not observed in their entirety.

The channel is generally wide and reaches a width of 50m on some stretches. The water appeared to be deep and high water levels and turbidity made assessment of channel substrate difficult. The gradient of the Lower Dee is very gentle and results in flow types that alternate between fast flowing sections (riffles and runs); an example being the Dee at Bangor-on-Dee (Figure 5.13a), and deep slow flowing sections (pools and glides) at the Dee meanders (Figure 5.13b). Deep pools and runs offer suitable holding areas for adult salmon and a range of coarse species, however only sub-optimal spawning and juvenile habitat was recorded. Water depth and reduced higher energy flow types is generally unsuitable for bullhead, however some sub optimum habitat was identified. *Ranunculus* vegetation would be expected where the flow velocity is suitable but may be limited by high turbidity.

a) b)

Figure 5.13 Different flow types on the Lower Dee; a) run-riffles at Bangor-on-Dee; and b) glide at Dee meanders

Along the majority of the Lower Dee, particularly throughout the Dee meanders and downstream of Bangor-on-Dee, the banks are on average 2m high with extensive erosion resulting in exposed sandy soil. Bank vegetation is generally sparse along the meanders and areas elsewhere on the river where erosion and undercutting has occurred.

The main bank erosion processes are on the outside of bends. Geotechnical failures, such as local slumping and cantilever failure, are also occurring (see Sediment Sources Map, Appendix C). Over bank deposits are also occurring locally, although embankments preclude this natural process and fine sediments confined to the channel may also be contributing to accelerated berm development. Due to the nature of the meanders and the erosion features identified, areas of low velocity flow were present that have allowed the deposition of silt and sand. These areas offer suitable habitat for lamprey ammocoetes, and this reach represents the largest proportion of lamprey ammocoete habitat in the catchment. Given the obstructions to fish movement upstream, the Lower Dee could be an important resource for lamprey unable to utilise suitable habitats in the upper catchment. Side pools have been created further downstream offering refuge areas for fish species.

There is some in-channel vegetation in the form of reeds and rushes which are colonising the berms. The presence of areas of slow flow and silty substrates with adjacent woodland/riparian tree lines offer suitable habitat for club-tailed dragonfly. However, tree cover is limited throughout much of the Lower Dee beyond the headwater reaches. Bank vegetation is mainly grass, but should include trees also. Trees would have been routinely removed as part of maintenance by the River Board/ River Authority to prevent the failure of embankments at the Dee meanders (see Appendix B for historic records of channel maintenance).

The majority of the land use either side of the Lower River Dee is improved and semi-improved grassland grazed by livestock. In the lower reaches of the Dee meanders, arable fields increase in number downstream on the left bank and there is some semi-natural grassland and broad-leaved woodland on the right bank. Near Churton there is plantation woodland and bank tree line of poplar (*Populus* sp.) opposite a stretch of small dwellings with landing platforms and associated amenity grassland. Scattered trees (predominantly willow and alder) are present and frequently overhang the river. Scattered scrub is common, dominated by hawthorn. Along stretches where erosion has not occurred the banks have minimal vegetation comprising mainly grasses with some patches of bramble, common nettle (*Urtica dioica*), broad-leaved dock (*Rumex obtusifolius*), common ragwort (*Senecio jacobaea*), hogweed (*Heracleum sphondylium*) and teasel (*Dipsacus fullonum*). Himalayan balsam (*Impatiens glandulifera*) is present along the left bank near Churton. Only a small section of bank is fenced along this reach of the river.

Generally habitat suitability for riparian mammals is lacking, except for downstream near areas of woodland that offer potential den sites. A mink was observed near Churton whilst other numerous signs of other small mammals were found on all surveyed stretches. Otter and badger prints were found in deposited sediments along the banks along the Dee meanders. Probable sand martin (*Riparia riparia*) burrows were recorded in the exposed cliff banks created in areas of erosion. Several trees with features offering bat roosting potential were also recorded.

5.6.1 Channel modifications

Of the sites visited in the Lower Dee, the main channel modifications are embankments, which are particularly prominent at the Dee meanders (see Channel Modifications Map, Appendix C). The section surveyed had almost continuous embankments on both right and left banks. The Hill and Emery (2005) Fluvial Audit also recorded this for the full extent of the meanders from just downstream of Bangor-on-Dee (unit 10) all the way along unit 10, 11 and part of 12 at Farndon. Embankments are also present downstream of Farndon but these are fragmentary according to Hill and Emery (2005) and end approximately at the Crook of Dee. There are historic records of localised bank protection on the Dee meanders mainly on the outsides of bends, presumably to prevent lateral migration of meanders but this appears to have largely failed and washed out. However as the flow was still high on the date of survey it was not possible to assess any toe protection (if it existed). Figure 5.14a and b shows an example of natural retreat of banks into an embankment, where there may have once been bank protection but this has long since washed away. This shows that although the Dee meanders appear to be relatively static (i.e. not generally migrating laterally), there are still active geomorphological processes occurring and that allowing these natural processes to occur is a form of restoration (natural recovery) management.

a) b)

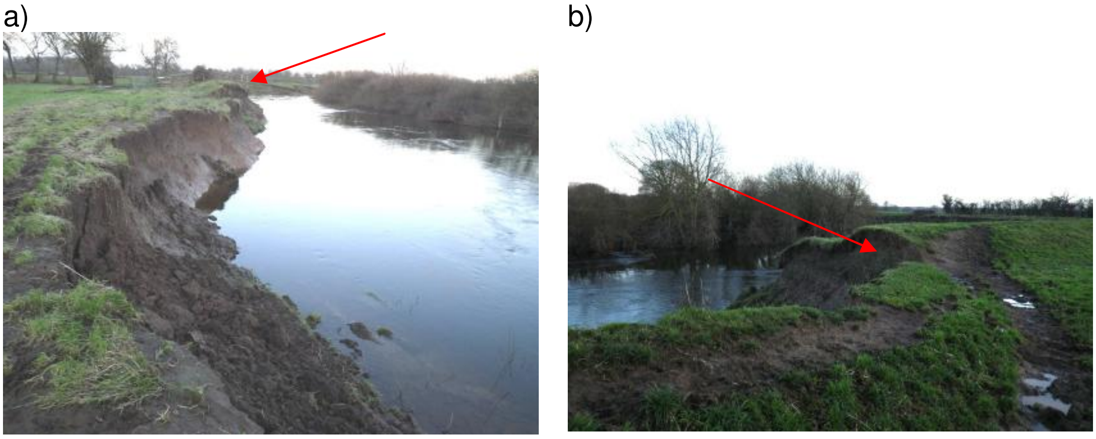


Figure 5.14 a and b) Unmanaged retreat of channel banks into embankments at Dee meanders (red arrows show truncated ends of embankments due to fluvial erosion)

There were no barriers to fish migration identified from surveys or OS maps along the Lower Dee downstream of Erbistock weir, however the influence of Chester weir extends as far upstream as Farndon in the form of freshwater back up from tides at

Chester weir. This may also aid the formation of depositional berms along the Dee meanders by reducing river flow velocities.

It appears that there has been extensive tree removal along parts of the Lower Dee, particularly along the Dee meanders (Figure 5.15a) and also in the section surveyed below Farndon (Figure 5.15b). This would have been to protect embankments from failing due to mechanical erosion from tree roots. This has reduced habitat suitability for otters and possibly club-tailed dragonfly.

Analysis of aerial photographs also identified some straightened sections in the Lower Dee, mainly for settlements of Farndon and Chester. The Hill and Emery (2005) Fluvial Audit also identified an extensive section of concrete bank protection on the right bank as the river flows through Chester towards the Chester weir. Just upstream of the Chester weir, the river is completely confined on both banks by brick/laid stone (left bank) and concrete (right bank).

a)

b)

Figure 5.15 Embankment on Lower Dee with lack of trees; a) at the Dee meanders; and b) Downstream of Farndon

6 Existing ecological condition

Following the 2012 survey work the catchment habitat suitability for SSSI and SAC species have been summarised in Sections 6.1 – 6.10 and Tables 6.1 – 6.5 below. Parts of the survey were carried out during periods of high flow which may have obscured habitat features, therefore results should be viewed with that in mind.

Compared with many rivers in Britain the River Dee has not been extensively affected by morphological modification pressures. Locally there are some impacts that would benefit from restoration measures/ actions, but generally following the 2012 survey work the catchment was found to have habitat suitability for all SSSI and SAC species where appropriate. It is clear that flow regulation can potentially have adverse downstream impacts on species. For example a SNIFFER (2012) study describes the ecological indicators of the effects of abstraction on flow regulation in a series of conceptual models. There are many studies over the past five decades describing impacts of altered flow regimes on hydraulics and morphology and in turn on macroinvertebrates, fish and macrophytes. However, this Restoration Vision is directly concerned with morphological impacts and only considers flow regulation as a baseline condition rather than consideration of mitigation actions such as optimisation of flow releases from water storage.

6.1 Water crowfoot communities

The River Dee generally offers suitable habitat for communities of *Ranunclion fluitantis and Callitricho-Batrachion.* The faster flow conditions of riffles, runs and glides recorded in the Upper Dee and its tributaries, especially where substrate consists of gravels, pebbles and cobbles, offer suitable habitat for these communities. However, stretches of increased shade and bed instability can limit growth, and grazed banks often prevent marginal plants from thriving. No modifications are likely to be negatively affecting the favourable condition of water crowfoot communities. The pressures most likely to be affecting Ranunculus communities are controlled flow regime, which can reduce flows to those preferred by some species, and silt input, which can increase turbidity and epiphyton.

Table 6-1 Summary of habitat suitability recorded for Ranunculion fluitantis and Callitricho-Batrachion vegetation

SAC feature	River	Suitable Habitat Present
Watercourses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	Afon Ceiriog	Some suitable habitat recorded
	Afon Mynach	Extensive suitable habitat recorded
	Afon Meloch	Extensive suitable habitat recorded
	Upper and Mid River Dee	Some suitable habitat in the upper reaches of faster and shallower flow
	Lower Dee	Limited suitable habitat present due to high turbidity and silty substrate

6.2 Floating water-plantain (*Luronium natans*)

The flow types recorded within the tributaries and the upper and middle reaches of the main River Dee are generally unsuitable for floating water-plantain, which prefers still to sluggish waters. In the Lower Dee there are more areas of slack water due to the sinuous nature of the channel. However, turbidity appears to be quite high due to the high level of sediment input. No modifications are likely to be negatively affecting the favourable condition of floating water-plantain. This species is recorded in the slow flowing waters in the outflow of Llyn Tegid, above the sluice gates which regulate the flows from Llyn Tegid and the Celyn Reservoir (CCW, undated) and it seems likely that the species' presence in the Dee is dependant on these modifications and control.

Table 6-2 Summary of habitat suitability recorded for Floating water-plantain

SAC feature	River	Suitable Habitat Present: Spawning habitat	Suitable Habitat Present: Larvae/juvenile habitat	Suitable Habitat Present: Adult habitat
Floating water-plantain *Luronium natans*	Upper Dee	Suitable habitat present in areas of slower flows, above the sluice gates which regulate the flows from Llyn Tegid and the Celyn Reservoir (CCW, undated) Floating water-plantain is not expected anywhere else in the Welsh SSSI or SAC		

6.3 Atlantic salmon

Spawning and juvenile habitat is present in the middle and lower reaches of the tributaries and the Upper Dee. The naturally steep gradient in the upper tributaries means suitable velocities and unconsolidated substrates are naturally lacking. Deeper holding areas for adult fish are infrequent in the tributaries and it is likely that fish will spawn soon after migrating to them. The main stem offers good habitat for adult salmon ascending and descending the River Dee.

Weirs are unlikely to be significantly restricting upstream migration of salmon, although several fish were observed to be failing to ascend Erbistock Weir during the survey. The Horseshoe Falls has also been identified as a significant weir, ascension over which may be restricted during periods of lower than average flow. The straightened channels recorded in the lower reaches of the tributaries may have removed sediment sinks and subsequently suitable spawning habitat. This may be negatively affecting the favourable condition of Atlantic salmon by limiting recruitment.

The distribution of salmonid habitats appears to be natural throughout the length of the catchment, with limited adverse affects from physical channel modification. Riparian zone management may improve cover and bank side habitat for juvenile salmon, however there is currently good connectivity between spawning and parr habitats, where spawning habitats are observed. This is also recognised in the current condition objectives that indicate a good spawning stock of salmon in River Dee tributaries. Improvements to the status of this species will be gained through increasing the adult run of salmon into the Dee. This will be achieved through ensuring sustainable exploitation of adult fish into the river, improving fish passage and generic improvement to water quality by removal or modification of in-channel obstructions. This may include a review of current industrial and urban discharges in the middle and lower reaches and improvements to farming practice (such as riparian management) in the rural, predominantly grazed upland areas.

Table 6-3 Summary of habitat suitability recorded for Atlantic salmon

SAC feature	River	Suitable Habitat Present		
		Spawning habitat	Larvae/ juvenile habitat	Adult habitat
Atlantic salmon *Salmo salar*	Afon Ceiriog	Present in middle and lower reaches	Extensive	Present
	Afon Mynach	Present	Extensive	Present
	Afon Meloch	Present	Extensive	Present
	Upper and Mid River Dee	Present	Present	Extensive
	Lower Dee	Present (sub optimal)	Present	Extensive

6.4 Lamprey

Suitable spawning habitat is present throughout the lower reaches of the tributaries, where un-consolidated beds and flow types form discrete optimum areas for spawning. Despite this access to these areas is likely to be significant reduce, especially on the Upper Dee and Afon Meloch and Mynach due to the presence of weirs at Horseshoe Falls and Erbistock. Within the headwaters natural steep gradients would naturally restrict the distribution of all lamprey species to the lower reaches. There may be suitable habitats in the lower end of the Afon Ceiriog where connectivity between habitats (due to substrate and flow diversity) maintains a more sustainable lamprey population.

Optimum larval habitat is generally lacking in the headwaters due to the high energy flow types and hard substratum. The Lower Dee offers extensive suitable larval habitats, with lower flow velocities, deeper water and significantly greater depositions of fine material however it is likely to be underutilised due to the distance between spawning and juvenile habitats.

Table 6-4 Summary of habitat suitability for Lamprey sp.

SAC feature	River	Suitable Habitat Present		
		Spawning habitat	Larvae/ juvenile habitat	Adult habitat
Lamprey species	Afon Ceiriog	Present	Very limited	Limited (upstream migration)
	Afon Mynach	Present	Very limited	Limited (upstream migration)
	Afon Meloch	Present (mid and lower)	Very limited	Limited (weirs may prevent upstream migration)

SAC feature	River	Suitable Habitat Present		
		Spawning habitat	Larvae/ juvenile habitat	Adult habitat
	Upper and Mid River Dee	Present	Present	Present (weirs)
	Lower Dee	Present	Present (extensive)	Present (no barriers)

6.5 Otter (*Lutra lutra*)

High quality habitat for otter was recorded throughout the catchment. The fish populations of the Dee and its tributaries offer a high quality foraging resource. Refuge habitat from exposed tree roots and dense riparian vegetation is extensive along the tributaries but less frequent along the main stem. Modifications are not assessed as negatively affecting the favourable condition of otter in the catchment.

Table 6-5 Summary of habitat suitability for otter

SAC feature	River	Suitable Habitat Present
Otter *Lutra lutra*	Afon Ceiriog	Extensive high quality habitat available
	Afon Mynach	Extensive high quality habitat available
	Afon Meloch	Extensive high quality habitat available
	Upper and Mid River Dee	Generally good habitat. Riparian vegetation sparse in places, limiting availability of refuge habitat
	Lower Dee	Good foraging habitat. Riparian vegetation sparse in places, limiting availability of refuge habitat

6.6 Bullhead (*Cottus gobio*)

Suitable habitat for bullhead is widespread throughout the tributaries and upper reaches of the Dee. Habitats are supported by the natural geomorphology of the catchment and the limited channel and bank modification is not seen to significantly affect bullhead populations. Where the gradient steepens in the upper tributaries natural barriers to migration may prevent the further utilisation of water-bodies to this species. Weirs, both natural and manmade (where present), are likely to prevent the localised movement of bullhead and create sub populations, isolated from the wider populations on the Dee.

Distribution of habitats on the Dee appears to be largely natural. Bullhead is currently failing to meet conservation objectives due to the distribution of populations throughout the catchment and poor water quality. Improving accessibility between populations, particularly in the lower headwater reaches will increase the distribution and sustainability of this species. There are however few artificial barriers in these stretches indicating a natural constraint on population size and distribution, with an element of isolated, or sub populations likely to be the norm for this part of the catchment. Reviewing urban and industrial discharges through conurbations, and improvements to riparian zones in rural areas will increase water quality and further enhance bullhead populations.

Table 6-6 Summary of habitat suitability for Bullhead

SAC feature	River	Suitable Habitat Present		
		Spawning habitat	Larvae/ juvenile habitat	Adult habitat
Bullhead *Cottus gobio*	Afon Ceiriog	Present	Present	Extensive
	Afon Mynach	Present	Present (in moderate flow reaches)	Present (good in lower reaches)
	Afon Meloch	Extensive	Present (in moderate flow reaches)	Present (in moderate flow reaches)
	Upper and Mid River Dee	Present	Present	Present (weirs may prevent upstream migration)
	Lower Dee	Limited (unsuitable substrate)	Limited (unsuitable substrate)	Limited (unsuitable substrate)

6.7 Club Tailed Dragonfly *(Gomphus vulgatissimus)*

Suitable habitat for the club-tailed dragonfly exists within the wide, slow flowing stretches of channel with silty substrate and bank side vegetation, particularly in the Lower Dee. It is unlikely that the mid and Upper Dee (and its tributaries) would naturally develop suitable habitats to support this species due to the higher flow velocities, shallower depths and consolidated beds. The maintenance of natural silt deposits associated with emergent vegetation and the connectivity to adult foraging woodland habitat will be an important aspect in sustaining the club-tailed dragonfly population.

6.8 A Stonefly (*Isogenus nubecula*)

Stretches of fast flowing, shallow water consisting of cobble and gravel substrate suitable for the stonefly are found throughout the tributaries and upper reaches of the river. Modifications to geomorphology are limited in the headwaters are unlikely to adversely affect this species. Maintenance of preferential flow regime and prevention of water pollution (including sedimentation) will increase the likelihood of this population remaining viable on the Dee.

6.9 Slender Hare's Ear, Sea Barley and Hard Grass

Slender hare's ear *Bupleurum tenuissimum*, sea barley *Hordeum marinum* and hard grass *Parapholis strigosa* occur in the saltmarsh transitional habitats on the Dee estuary. They are therefore unlikely to be affected by modifications further upstream. The survey did not cover any estuarine/ saltmarsh habitats.

6.10 A Weevil *(Baris lepidii)*

Gravel shoals suitable for the weevil are found in the lower reaches of the Lower Dee.

JACOBS

Table 6-7 Habitat suitability on the River Ceiriog/ Afon Ceiriog

	Afon Ceiriog	Suitable Habitat Present		
SAC feature	Habitat Requirement	Spawning habitat	Larvae/juvenile habitat	Adult habitat
Watercourses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	Fast flow conditions of riffles, runs and glides. Gravel, pebble and cobble substrate. Low shade and influence of grazing. High bed/bank stability From Hatton-Ellis and Grieve (2003)	Some suitable habitat recorded		
Atlantic salmon *Salmo salar*	**Water depth**: Variable **Velocity**: Variable **Macrophytes**: Some (all life stages) **Channel:** Juxtaposition of life stage habitats **Spawning**: Gradient <3%. Velocity 25-90cm/s. Water depth 17-76cm. Cobble/pebble substrate (2-256mm diameter) with <20% fine sediment. Transitional zone between pool and riffle where flow accelerates and depth decreases. Cover important **Larvae**: Water depth <20cm. Flow 50-65cm/s. Gravel/cobble substrate (16-64mm diameter) and cobble/boulder substrate (64-256mm diameter). Cover essential (e.g. loose substrate, large rocks, undercut banks, overhanging vegetation, aquatic vegetation) **Adult**: Deeper water for holding pools. Downstream of spawning gravels From Hendry and Cragg-Hine (2003)	Present in middle and lower reaches Cobble and gravel bed, with finer gravels at downstream end of catchment. Good flow variation Limited suitable habitat upstream due to naturally high gradient	Extensive Variation in water depth and speed Provision of in-channel and bank cover	Present Deeper holding areas appear scarce
Floating water-plantain *Luronium natans*	Clear water with moderate levels of disturbance. Low nutrient status. Sparse emergent vegetation. Variety of wetlands. Mainly slow flowing rivers/canals/meres From Landsdown and Wade (2003)	No suitable habitat recorded Flow velocities too high		
Sea lamprey *Petromyzon marinus*	**Water depth**: Variable **Velocity**: Variable **Channel:** Large streams/rivers. Pollution sensitive **Spawning**: Temperatures <15oC. Medium flow. Gravel (9.5-50.8mm in diameter) with some sand content. Tails of pools	Present Cobble and gravel bed, with finer gravels at downstream end	Very limited. Isolated soft sediment deposits in lower catchment	Limited. Weirs likely to may prevent upstream migration

SAC feature	Afon Ceiriog Habitat Requirement	Suitable Habitat Present Spawning habitat	Larvae/juvenile habitat	Adult habitat
	Larvae: Low velocity (0.2-0.3m/s) near edge of streams/rivers. Clay, silt sand substrate with high organic content. Shade. Stream gradient 1.9-5.7m/km. Slowing current where deposition of silt and sand occur. 30cm deep substrate **Adult**: Suitable spawning areas From Maitland (2003)	of catchment. Good flow variation Limited suitable habitat upstream	Natural river velocity likely to be too high	
Brook lamprey *Lampetra planeri*	**Water depth**: Variable **Velocity**: Variable **Macrophytes**: Some (during larval stage) **Channel:** No barriers to migration. Average gradient 0.2-0.6m/km. Pollution sensitive **Spawning**: Water depth usually 3-30cm. Near edge of stream/rivers. Temperatures between 10-11oC. Stones and gravel substrate. Lower end of pools **Larvae**: Flow 0.5m/s. Mud, silt, or silt and sand substrate with high organic content. Some macrophytes **Adult**: Stones and vegetation to hide among. Suitable spawning areas From Maitland (2003)	Present	Very limited Isolated soft sediment deposits in lower catchment Natural river velocity likely to be too high	Limited Weirs may prevent upstream migration Water velocities high
River lamprey *Lampetra fluviatilis*	**Water depth**: Variable **Velocity**: Variable **Channel:** No barriers to migration. Average gradient 0.2-0.6m/km. Pollution sensitive **Spawning**: Water depth usually 20-150cm. Flow 1-2m/s. Near edge of stream/rivers. Temperatures between 8.5-12.0oC. Variable particle size, normally gravel with sand (at tails of pools) **Larvae**: Low velocity (<10cm/s). Mud, silt, or silt and sand substrate with high organic content **Adult**: Short runs with suitable spawning areas From Maitland (2003)	Present	Very limited Isolated soft sediment deposits in lower catchment Natural river velocity likely to be too high	Limited Weirs may prevent upstream migration Water velocities high

SAC feature	Afon Ceiriog Habitat Requirement	Suitable Habitat Present Spawning habitat	Larvae/juvenile habitat	Adult habitat
Bullhead *Cottus gobio*	**Water depth**: >5cm **Velocity**: Moderate **Macrophytes**: <40% **Channel:** Sinuous, pool-riffle sequence, naturally wooded riparian margins, exposed roots in the channel **Breeding**: Coarse substrate with large stone **Larvae**: Shallow, stony riffles **Adult**: sheltered sections (debris, tree roots, macrophyte cover or large stones) From Tomlinson and Perrow (2003)	Present Cobble substrate in upper reaches Flow velocity may be too high	Present Good variation in flow and bed providing cover	Extensive Weir will prevent movement of species between populations
European otter *Lutra lutra*	Adequate fish biomass to provide food resource. Presence of exposed tree roots and cavities. Cover (riparian vegetation) From Chanin (2003)	Extensive high quality habitat available		

Table 6-8 Habitat suitability on Afon Mynach

	Afon Mynach	Suitable Habitat Present		
SAC feature	**Habitat Requirement**	**Spawning habitat**	**Larvae/juvenile habitat**	**Adult habitat**
Watercourses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	Fast flow conditions of riffles, runs and glides. Gravel, pebble and cobble substrate. Low shade and influence of grazing. High bed/bank stability From Hatton-Ellis and Grieve (2003)	Extensive suitable habitat recorded		
Atlantic salmon *Salmo salar*	**Water depth**: Variable **Velocity**: Variable **Macrophytes**: Some (all life stages) **Channel:** Juxtaposition of life stage habitats **Spawning**: Gradient <3%. Velocity 25-90cm/s. Water depth 17-76cm. Cobble/pebble substrate (2-256mm diameter) with <20% fine sediment. Transitional zone between pool and riffle where flow accelerates and depth decreases. Cover important **Larvae**: Water depth <20cm. Flow 50-65cm/s. Gravel/cobble substrate (16-64mm diameter) and cobble/boulder substrate (64-256mm diameter). Cover essential (e.g. loose substrate, large rocks, undercut banks, overhanging vegetation, aquatic vegetation) **Adult**: Deeper water for holding pools. Downstream of spawning gravels From Hendry and Cragg-Hine (2003)	Present Coarse gravel substrate Suitable flows and substrate in middle and lower reaches	Extensive Variation in water depth and speed Provision of in-channel and bank cover	Present Deeper holding areas appear scarce Obstructions to migration downstream (some fish passage)
Floating water-plantain *Luronium natans*	Clear water with moderate levels of disturbance. Low nutrient status. Sparse emergent vegetation. Variety of wetlands. Mainly slow flowing rivers/canals/meres From Landsdown and Wade (2003)	No suitable habitat recorded Unsuitable due to high energy flow characteristics		
Sea lamprey *Petromyzon marinus*	**Water depth**: Variable **Velocity**: Variable **Channel:** Large streams/rivers. Pollution sensitive **Spawning**: Temperatures <15oC. Medium flow. Gravel (9.5-50.8mm in diameter) with some sand content. Tails of pools **Larvae**: Low velocity (0.2-0.3m/s) near edge of streams/rivers. Clay, silt sand substrate with high organic content. Shade.	Present Coarse gravel substrate Suitable flows in middle and lower	Very limited Upland river typology with limited fine sediment deposition	Limited No barriers to migration recorded on Afon Mynach, although

	Afon Mynach	Suitable Habitat Present		
SAC feature	Habitat Requirement	Spawning habitat	Larvae/juvenile habitat	Adult habitat
	Stream gradient 1.9-5.7m/km. Slowing current where deposition of silt and sand occur. 30cm deep substrate **Adult**: Suitable spawning areas From Maitland (2003)	reaches	Natural river velocity likely to be too high	barriers on River Dee prevent egress into Mynach catchment
Brook lamprey *Lampetra planeri*	**Water depth**: Variable **Velocity**: Variable **Macrophytes**: Some (during larval stage) **Channel:** No barriers to migration. Average gradient 0.2-0.6m/km. Pollution sensitive **Spawning**: Water depth usually 3-30cm. Near edge of stream/rivers. Temperatures between 10-11°C. Stones and gravel substrate. Lower end of pools **Larvae**: Flow 0.5m/s. Mud, silt, or silt and sand substrate with high organic content. Some macrophytes **Adult**: Stones and vegetation to hide among. Suitable spawning areas From Maitland (2003)	Present Coarse gravel substrate Suitable flows in middle and lower reaches	Very limited Upland river typology with limited fine sediment deposition	Limited Unlikely to be suitable due to high gradient
River lamprey *Lampetra fluviatilis*	**Water depth**: Variable **Velocity**: Variable **Channel:** No barriers to migration. Average gradient 0.2-0.6m/km. Pollution sensitive **Spawning**: Water depth usually 20-150cm. Flow 1-2m/s. Near edge of stream/rivers. Temperatures between 8.5-12.0°C. Variable particle size, normally gravel with sand (at tails of pools) **Larvae**: Low velocity (<10cm/s). Mud, silt, or silt and sand substrate with high organic content **Adult**: Short runs with suitable spawning areas From Maitland (2003)	Present Coarse gravel substrate Suitable flows in middle and lower reaches	Very limited Upland river typology with limited fine sediment deposition	Limited No barriers to migration recorded on Afon Mynach, although barriers on River Dee prevent egress into Mynach catchment
Bullhead *Cottus gobio*	**Water depth**: >5cm **Velocity**: Moderate **Macrophytes**: <40%. **Channel:** Sinuous, pool-riffle sequence, naturally wooded riparian margins, exposed roots in the channel **Breeding**: Coarse substrate with large stone **Larvae**: Shallow, stony riffles **Adult**: sheltered sections (debris, tree roots, macrophyte cover or	Present	Present in reaches with more moderate flow	Present Good habitat in lower reaches of watercourse. Upstream movement restricted by

	Afon Mynach	Suitable Habitat Present		
SAC feature	**Habitat Requirement**	**Spawning habitat**	**Larvae/juvenile habitat**	**Adult habitat**
	large stones). From Tomlinson and Perrow (2003)			natural barriers
European otter *Lutra lutra*	Adequate fish biomass to provide food resource. Presence of exposed tree roots and cavities. Cover (riparian vegetation) From Chanin (2003)	Extensive high quality habitat available		

Table 6-9 Habitat Suitability on Afon Meloch

	Afon Meloch	Suitable Habitat Present		
SAC feature	**Habitat Requirement**	**Spawning habitat**	**Larvae/juvenile habitat**	**Adult habitat**
Watercourses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	Fast flow conditions of riffles, runs and glides. Gravel, pebble and cobble substrate. Low shade and influence of grazing. High bed/bank stability From Hatton-Ellis and Grieve (2003)	Extensive suitable habitat recorded		
Atlantic salmon *Salmo salar*	**Water depth**: Variable **Velocity**: Variable **Macrophytes**: Some (all life stages) **Channel:** Juxtaposition of life stage habitats **Spawning**: Gradient <3%. Velocity 25-90cm/s. Water depth 17-76cm. Cobble/pebble substrate (2-256mm diameter) with <20% fine sediment. Transitional zone between pool and riffle where flow accelerates and depth decreases. Cover important **Larvae**: Water depth <20cm. Flow 50-65cm/s. Gravel/cobble substrate (16-64mm diameter) and cobble/boulder substrate (64-256mm diameter). Cover essential (e.g. loose substrate, large rocks, undercut banks, overhanging vegetation, aquatic vegetation) **Adult**: Deeper water for holding pools. Downstream of spawning gravels From Hendry and Cragg-Hine (2003)	Present Coarse gravels found through catchment, often associated with in-channel obstruction (woody debris and temporary structures). Good flow variation	Extensive Moderate energy upland stream with good flow and substrate diversity. Mixed riparian cover	Present Deeper holding areas appear scarce in the upper sections Possible natural obstructions to migration
Floating water-plantain *Luronium natans*	Clear water with moderate levels of disturbance. Low nutrient status. Sparse emergent vegetation. Variety of wetlands. Mainly slow flowing rivers/canals/meres From Landsdown and Wade (2003)	No suitable habitat recorded Generally unsuitable due to high energy flow characteristics		
Sea lamprey *Petromyzon marinus*	**Water depth**: Variable **Velocity**: Variable **Channel:** Large streams/rivers. Pollution sensitive **Spawning**: Temperatures $<15^{o}C$. Medium flow. Gravel (9.5-50.8mm in diameter) with some sand content. Tails of pools **Larvae**: Low velocity (0.2-0.3m/s) near edge of streams/rivers. Clay, silt sand substrate with high organic content. Shade.	Present in the middle/lower reaches Gradient too high in upper reaches	Very limited Upland river typology with limited fine sediment deposition	Limited Weirs will restrict upstream migration to spawning habitat

SAC feature	Afon Meloch Habitat Requirement	Suitable Habitat Present Spawning habitat	Larvae/juvenile habitat	Adult habitat
	Stream gradient 1.9-5.7m/km. Slowing current where deposition of silt and sand occur. 30cm deep substrate **Adult**: Suitable spawning areas From Maitland (2003)			
Brook lamprey *Lampetra planeri*	**Water depth**: Variable **Velocity**: Variable **Macrophytes**: Some (during larval stage) **Channel:** No barriers to migration. Average gradient 0.2-0.6m/km. Pollution sensitive **Spawning**: Water depth usually 3-30cm. Near edge of stream/rivers. Temperatures between 10-11°C. Stones and gravel substrate. Lower end of pools **Larvae**: Flow 0.5m/s. Mud, silt, or silt and sand substrate with high organic content. Some macrophytes **Adult**: Stones and vegetation to hide among. Suitable spawning areas From Maitland (2003)	Present in the middle/lower reaches Gradient too high in upper reaches	Very limited Upland river typology with limited fine sediment deposition	Limited Unlikely to be suitable due to high gradient Natural barrier to movement in headwaters
River lamprey *Lampetra fluviatilis*	**Water depth**: Variable **Velocity**: Variable **Channel:** No barriers to migration. Average gradient 0.2-0.6m/km. Pollution sensitive **Spawning**: Water depth usually 20-150cm. Flow 1-2m/s. Near edge of stream/rivers. Temperatures between 8.5-12.0°C. Variable particle size, normally gravel with sand (at tails of pools) **Larvae**: Low velocity (<10cm/s). Mud, silt, or silt and sand substrate with high organic content **Adult**: Short runs with suitable spawning areas From Maitland (2003)	Present in the middle/lower reaches Gradient too high in upper reaches	Very limited	Limited Weirs may restrict upstream migration to spawning habitat
Bullhead *Cottus gobio*	**Water depth**: >5cm **Velocity**: Moderate **Macrophytes**: <40% **Channel:** Sinuous, pool-riffle sequence, naturally wooded riparian margins, exposed roots in the channel **Breeding**: Coarse substrate with large stone **Larvae**: Shallow, stony riffles **Adult**: sheltered sections (debris, tree roots, macrophyte cover or large stones) From Tomlinson and Perrow (2003)	Extensive	Present in reaches with more moderate flow	Present in reaches with more moderate flow

SAC feature	Afon Meloch Habitat Requirement	Suitable Habitat Present Spawning habitat	Larvae/juvenile habitat	Adult habitat
European otter *Lutra lutra*	Adequate fish biomass to provide food resource. Presence of exposed tree roots and cavities. Cover (riparian vegetation) From Chanin (2003)	Extensive high quality habitat available		

Table 6-10 Habitat Suitability on Upper and Middle Dee

SAC feature	Upper and Middle Dee Habitat Requirement	Suitable Habitat Present Spawning habitat	Larvae/juvenile habitat	Adult habitat
Watercourses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	Fast flow conditions of riffles, runs and glides. Gravel, pebble and cobble substrate. Low shade and influence of grazing. High bed/bank stability From Hatton-Ellis and Grieve (2003)	Some suitable habitat in the upper reaches of faster, shallower flows Watercourses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation Fast flow conditions of riffles, runs and glides Gravel, pebble and cobble substrate. Low shade and influence of grazing. High bed/bank stability		
Atlantic salmon *Salmo salar*	**Water depth**: Variable **Velocity**: Variable **Macrophytes**: Some (all life stages) **Channel:** Juxtaposition of life stage habitats **Spawning**: Gradient <3%. Velocity 25-90cm/s. Water depth 17-76cm. Cobble/pebble substrate (2-256mm diameter) with <20% fine sediment. Transitional zone between pool and riffle where flow accelerates and depth decreases. Cover important **Larvae**: Water depth <20cm. Flow 50-65cm/s. Gravel/cobble substrate (16-64mm diameter) and cobble/boulder substrate (64-256mm diameter). Cover essential (e.g. loose substrate, large rocks, undercut banks, overhanging vegetation, aquatic vegetation) **Adult**: Deeper water for holding pools. Downstream of spawning gravels From Hendry and Cragg-Hine (2003)	Present Suitable substrate and flow upstream of riffles	Present Diverse range of flow types and substrate	Extensive Abundance of deeper runs and pools
Floating water-plantain *Luronium natans*	Clear water with moderate levels of disturbance. Low nutrient status. Sparse emergent vegetation. Variety of wetlands. Mainly slow flowing rivers/canals/meres From Landsdown and Wade (2003)	Limited suitable habitat present in areas of slower flows, above the sluice gates which regulate the flows from Llyn Tegid and the Celyn Reservoir (CCW, undated)		
Sea lamprey *Petromyzon marinus*	**Water depth**: Variable **Velocity**: Variable **Channel:** Large streams/rivers. Pollution sensitive **Spawning**: Temperatures <15oC. Medium flow. Gravel (9.5-50.8mm in diameter) with some sand content. Tails of pools **Larvae**: Low velocity (0.2-0.3m/s) near edge of streams/rivers. Clay, silt sand substrate with high organic content. Shade. Stream gradient 1.9-5.7m/km. Slowing current where deposition of silt and sand occur.	Present Suitable substrate likely to be present towards tails of pools	Present Silty margins present	Present Weirs will restrict upstream migration to spawning habitat

SAC feature	Upper and Middle Dee Habitat Requirement	Suitable Habitat Present Spawning habitat	Larvae/juvenile habitat	Adult habitat
	30cm deep substrate **Adult**: Suitable spawning areas From Maitland (2003)			
Brook lamprey *Lampetra planeri*	**Water depth**: Variable **Velocity**: Variable **Macrophytes**: Some (during larval stage) **Channel:** No barriers to migration. Average gradient 0.2-0.6m/km. Pollution sensitive **Spawning**: Water depth usually 3-30cm. Near edge of stream/rivers. Temperatures between 10-11oC. Stones and gravel substrate. Lower end of pools **Larvae**: Flow 0.5m/s. Mud, silt, or silt and sand substrate with high organic content. Some macrophytes **Adult**: Stones and vegetation to hide among. Suitable spawning areas From Maitland (2003)	Present Suitable substrate likely to be present towards tails of pools	Present Silty margins present	Present Weirs may restrict upstream movement between habitats
River lamprey *Lampetra fluviatilis*	**Water depth**: Variable **Velocity**: Variable **Channel:** No barriers to migration. Average gradient 0.2-0.6m/km. Pollution sensitive **Spawning**: Water depth usually 20-150cm. Flow 1-2m/s. Near edge of stream/rivers. Temperatures between 8.5-12.0oC. Variable particle size, normally gravel with sand (at tails of pools) **Larvae**: Low velocity (<10cm/s). Mud, silt, or silt and sand substrate with high organic content **Adult**: Short runs with suitable spawning areas From Maitland (2003)	Present Suitable substrate likely to be present towards tails of pools	Present Silty margins present	Present Weirs may restrict upstream migration to spawning habitat
Bullhead *Cottus gobio*	**Water depth**: >5cm **Velocity**: Moderate **Macrophytes**: <40% **Channel:** Sinuous, pool-riffle sequence, naturally wooded riparian margins, exposed roots in the channel **Breeding**: Coarse substrate with large stone **Larvae**: Shallow, stony riffles **Adult**: sheltered sections (debris, tree roots, macrophyte cover or large stones) From Tomlinson and Perrow (2003)	Present Shallow reaches with coarse substrate and woody debris/exposed tree roots	Present Good habitat availability	Present Weirs likely to prevent upstream migration

SAC feature	Upper and Middle Dee Habitat Requirement	Suitable Habitat Present Spawning habitat	Larvae/juvenile habitat	Adult habitat
European otter *Lutra lutra*	Adequate fish biomass to provide food resource. Presence of exposed tree roots and cavities. Cover (riparian vegetation) From Chanin (2003)	Generally good habitat. Riparian vegetation sparse in places, limiting availability of refuge habitat		

Table 6-11 Habitat suitability for the Lower Dee

	Lower Dee	Suitable Habitat Present		
SAC feature	**Habitat Requirement**	**Spawning habitat**	**Larvae/juvenile habitat**	**Adult habitat**
Watercourses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	Fast flow conditions of riffles, runs and glides. Gravel, pebble and cobble substrate. Low shade and influence of grazing. High bed/bank stability From Hatton-Ellis and Grieve (2003)	Limited suitable habitat present due to high turbidity and silty substrate		
Atlantic salmon *Salmo salar*	**Water depth**: Variable **Velocity**: Variable **Macrophytes**: Some (all life stages) **Channel:** Juxtaposition of life stage habitats **Spawning**: Gradient <3%. Velocity 25-90cm/s. Water depth 17-76cm. Cobble/pebble substrate (2-256mm diameter) with <20% fine sediment. Transitional zone between pool and riffle where flow accelerates and depth decreases. Cover important **Larvae**: Water depth <20cm. Flow 50-65cm/s. Gravel/cobble substrate (16-64mm diameter) and cobble/boulder substrate (64-256mm diameter). Cover essential (e.g. loose substrate, large rocks, undercut banks, overhanging vegetation, aquatic vegetation) **Adult**: Deeper water for holding pools. Downstream of spawning gravels From Hendry and Cragg-Hine (2003)	Present Limited to shallow reaches with faster flow run-riffle Likely to be sub-optimum habitat	Present Shallower reaches with faster flow run-riffle characteristics Limited cover (bank/marginal) although water depth will provide cover	Extensive Deeper runs and pools for adults to hold up in
Floating water-plantain *Luronium natans*	Clear water with moderate levels of disturbance. Low nutrient status. Sparse emergent vegetation. Variety of wetlands. Mainly slow flowing rivers/canals/meres From Landsdown and Wade (2003)	Limited suitable habitat present in areas of slower flows. High turbidity may be a limiting factor		
Sea lamprey *Petromyzon marinus*	**Water depth**: Variable **Velocity**: Variable **Channel:** Large streams/rivers. Pollution sensitive **Spawning**: Temperatures <15oC. Medium flow. Gravel (9.5-50.8mm in diameter) with some sand content. Tails of pools **Larvae**: Low velocity (0.2-0.3m/s) near edge of streams/rivers. Clay, silt sand substrate with high organic content. Shade. Stream	Present Shallower reaches with faster flow run-riffle characteristics	Present Extensive silt deposits	Present No barriers to upstream migration recorded

SAC feature	Lower Dee Habitat Requirement	Suitable Habitat Present Spawning habitat	Larvae/juvenile habitat	Adult habitat
	gradient 1.9-5.7m/km. Slowing current where deposition of silt and sand occur. 30cm deep substrate **Adult**: Suitable spawning areas			
Brook lamprey *Lampetra planeri*	**Water depth**: Variable **Velocity**: Variable **Macrophytes**: Some (during larval stage) **Channel:** No barriers to migration. Average gradient 0.2-0.6m/km. Pollution sensitive **Spawning**: Water depth usually 3-30cm. Near edge of stream/rivers. Temperatures between 10-11oC. Stones and gravel substrate. Lower end of pools **Larvae**: Flow 0.5m/s. Mud, silt, or silt and sand substrate with high organic content. Some macrophytes **Adult**: Stones and vegetation to hide among. Suitable spawning areas	Present Shallow reaches with faster flow run-riffle characteristics	Present Extensive silt deposits	Present No barriers to upstream migration recorded
River lamprey *Lampetra fluviatilis*	**Water depth**: Variable **Velocity**: Variable **Channel:** No barriers to migration. Average gradient 0.2-0.6m/km. Pollution sensitive **Spawning**: Water depth usually 20-150cm. Flow 1-2m/s. Near edge of stream/rivers. Temperatures between 8.5-12.0oC. Variable particle size, normally gravel with sand (at tails of pools) **Larvae**: Low velocity (<10cm/s). Mud, silt, or silt and sand substrate with high organic content **Adult**: Short runs with suitable spawning areas	Present Shallow reaches with faster flow run-riffle characteristics	Present Extensive silt deposits	Present No barriers to upstream migration recorded
Bullhead *Cottus gobio*	**Water depth**: >5cm **Velocity**: Moderate **Macrophytes**: <40% **Channel:** Sinuous, pool-riffle sequence, naturally wooded riparian margins, exposed roots in the channel **Breeding**: Coarse substrate with large stone **Larvae**: Shallow, stony riffles **Adult**: sheltered sections (debris, tree roots, macrophyte cover or large stones) From Tomlinson and Perrow (2003)	Limited Generally unsuitable due to substrate and depth	Limited Generally unsuitable due to substrate and depth	Limited. Generally unsuitable substrate and lack of coarse woody debris and vegetation
European otter *Lutra lutra*	Adequate fish biomass to provide food resource. Presence of exposed tree roots and cavities. Cover (riparian vegetation) From Chanin (2003)	Good foraging habitat. Riparian vegetation sparse in places, limiting availability of refuge habitat		

7 Restoration Potential

7.1 Summary of channel modifications observed

The current form of river channels in the Dee catchment reflects the complex interaction of geology, topography, climate, land use and abstraction activities. However compared with some other British river systems there are relatively few direct channel modifications along the surveyed reaches of the Dee. Those that were observed included the major weirs on the Dee at Llangollen, Erbistock, Manley Hall, Horseshoe Falls and on the Ceiriog at Brynkinalt weir and an unnamed weir above the fish hatchery near Pont Faen. Other river channel modifications observed included some sections of channel planform modifications (such as straightening), bank protection, embankments, evidence of sediment removal and potentially tree and debris clearance

For each of the surveyed tributaries, such modifications are a small proportion of the overall channel length. The tributaries are also judged to be relatively inactive in terms of lateral and vertical movement. Therefore it is suggested that the majority of reaches in the upper tributaries are in favourable condition for geomorphology, with a few exceptions. However some of the more major modifications may significantly affect the features of the designated sites. For example, the major weirs are likely to represent barriers to upstream migration of salmon, lampreys and bullhead. Channel straightening, which is present in sections on all tributaries surveyed, increases gradient and therefore stream power, which in turn increases the sediment carrying capacity of the river and reduces the volume of gravels from being deposited in the straightened section. This can be detrimental for salmonids which need gravelly deposits for spawning.

7.2 Catchment pressures

Table 7-1 outlines the main morphological ‘pressures’ on each CCW management unit identified from targeted field work in November 2012, the Hill and Emery (2005) Fluvial Audit, Jacobs (2009) Dee SSSI vision report and the CCW Core Management Plan (Hatcher and Garrett, 2008). Poaching from livestock and lack of riparian zone are key pressures. However, major weirs, remaining bank protection and embankments, although not common in the reaches surveyed, are also important morphological pressures to consider.

Table 7-1 Pressures affecting each CCW management unit (corresponding English Units shown in parenthesis)

CCW management unit	Name	Pressures potentially affecting unit
2	Upper Dee - Treweryn confluence	Flow regulation Channel straightening Major weirs Bank reinforcement Degradation of riparian zone Flood plain disconnection
3	Upper Dee - Gauging weir to Denbighshire and Gwynned unitary authority boundary	Flow regulation Major weir (gauging weir)
4	Upper/Middle Dee - (Denbighshire and Gwynned unitary authority boundary to Rhewl section)	Flow regulation Bank reinforcement Riparian zone degradation Invasive species
5	Middle Dee - Rhewl section to Horseshoe Fall	Flow regulation Major weir (Horseshoe Falls)
6	Middle Dee - Horseshoe Falls to Denbighshire and Wrexham unitary authority boundary (including town of Llangollen)	Flow regulation Major weirs (2 at Llangollen) Bank reinforcement Invasive species
7	Middle Dee - Denbighshire and Wrexham unitary authority boundary to the River Ceiriog/ Afon Ceiriog confluence	Flow regulation
8 (part of 3)	Middle Dee - River Ceiriog/ Afon Ceiriog confluence to Erbistock weir	Flow regulation Major weirs (Erbistock and Manley Hall) Possible straightening
9	Lower Dee - Erbistock weir to start of Holt to Worthenbury Section (including town of Bangor-on-Dee)	Flow regulation Bank erosion
10	Lower Dee, Dee meanders – Welsh side of Holt to Worthenbury SSSI section	Flow regulation Poaching Riparian zone degradation
11 (4 and 5)	Lower Dee, Dee meanders – Holt to Worthenbury section	As above

CCW management unit	Name	Pressures potentially affecting unit
	from Shocklach to Holt	
12 (1 and part of 4 and 5)	Lower Dee - End of Holt to Worthenbury section to England (including town of Farndon)	Flow regulation Berm development Channel straightening Invasive species
13 (1)	Lower Dee – From Aldford to Chester weir (Section Entirely within England)	Flow regulation Major weir (Chester weir) Channel straightening Bank reinforcement Embankments
14	Esturarine Dee – Below Chester weir and out to estuary	Bank reinforcement Channel straightening
16	Upper Dee - Afon Mynach	Channel straightening Riparian zone degradation Poaching Invasive species
17	Upper Dee - Afon Meloch	Channel straightening Embankment Water abstraction (small-scale but at downstream extreme of river) Poaching
18	River Ceiriog/ Afon Ceiriog - Upper	Poaching Riparian zone degradation Channel straightening Invasive species
19 (3)	River Ceiriog/ Afon Ceiriog - Lower	Major weirs (Brynkinalt and unnamed weir above fish hatchery) Fish hatchery Poaching Riparian zone degradation Invasive species

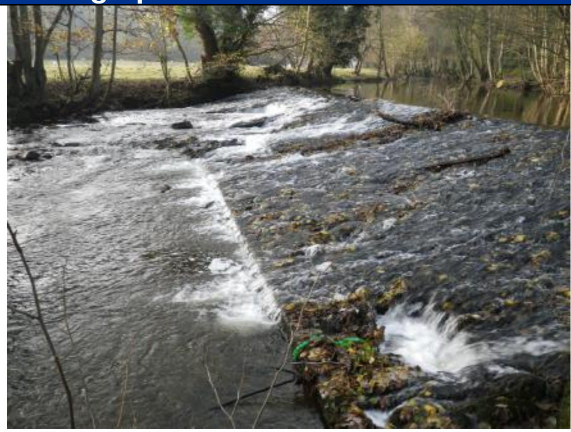
The major weir modifications that are present within the SSSIs and SAC of the River Dee/ Afon Dyfrdwy are outline in Table 7-2.

Table 7-2 Description of major weirs

Location	Photograph of weir	Description	Ecology
Weir at Bala Lake scheme (SH931 359) Upper Dee – Tryweryn Management unit - 15		Approximately 1.5m high, 3m wide. In low-moderate flows, flow is diverted through the 3m wide section and into deflectors. High flows will overtop weir Adjacent land use is rough pasture (left bank) and recreational walk (right bank) Weir is part of the Bala Lake Scheme	Unlikely to pose a significant obstruction to salmonid passage under most flow conditions due to water depth and weir height being suitable for all fish species to navigate
Salmon Steps (SH932 356) Upper Dee – Tryweryn confluence Management unit – 2/15		Approximately 2m high, 2m wide and 4m long section in the centre of the structure that is designed as a fish pass The sections flanking the fish pass are approximately 2m high, 7m wide and 4m long each Adjacent land use is Bala Lake Scheme works (left bank) recreational (right bank) Salmon steps accommodate fish passage through the Bala Lake Scheme	Fish pass will ensure fish passage under most flow conditions. Unlikely to be suitable for lamprey or bullhead passage due to the velocity of water over the fish pass, leading to use of sub-optimal spawning habitats and potentially a reduction or failure to spawn
Bala gauging weir (SH942 357)	Not surveyed	Crump weir and cross path, approximately 20m across	

Location	Photograph of weir	Description	Ecology
Upper Dee – Main stem Dee/ Afon Dyfrdwy Managment unit – 2/3		The weir is still used for flow gauging and also to stop the surges of water that come down the Tryweryn from Llyn Celyn carrying on down the Main stem Dee/ Dyfrdwy	
Horseshoe Falls (SJ195 433) Middle Dee – Main stem Dee/ Afon Dyfrdwy Management unit – 5/6		Approximately 1m high, 100m wide. Cuts diagonally across river channel. Glide flow type upstream of weir and cascades and runs downstream, suggesting that the weir is having a significant effect on upstream flows by levelling out the gradient Adjacent land use is rough pasture for grazing Weir is still used to divert and maintain water in the Llangollen Canal	Potential obstruction to salmonid migration due to the vertical steepness of the weir. However, it may be passable under higher flow conditions. Delays in migration and increased holding time beneath the structure may lead to increased concentration of fish, increase exploitation rates and lowering of water quality. This can cause a reduction of fish condition through disease and result in fish using sub-optimal habitats or failing to spawn at all if outside of the main run. Unlikely to allow lamprey and bullhead to ascend due to the vertical steepness of the weir

Location	Photograph of weir	Description	Ecology
Llangollen weir (upstream of road bridge) (SJ213 421) Middle Dee Management unit - 6		Approximately 1m high and 100 metres wide. Cuts diagonally across the river channel. Due to the moderate/steep gradient of upstream channel, there is limited ponding effect and water cascades over the weir into a steeper, cascading section Adjacent land use is urban The weir was used in the past to divert water into a corn mill on the right bank, which is now a public house	Potential obstruction to salmonid migration due to flow rate, but passable under higher flow conditions. Delays in migration and increased holding time beneath the structure may lead to increased concentration of fish and lowering of water quality. This can cause a reduction of fish condition through disease and result in fish using sub-optimal habitats or failing to spawn at all if outside of the main run. Unlikely to allow lamprey and bullhead to ascend due to the steepness and fast flow of water over the weir at most times
Llangollen weir (downstream of road bridge) (SJ215 421) Middle Dee Management unit - 6		Approximately 1m high and 33m wide. Due to the steep gradient and cascading flow upstream there is no ponding effect on this weir Adjacent land use is urban	Potential obstruction to salmonid migration, but passable under most flow conditions. However, delays in ascending multiple weirs through Llangollen reduce the time available after ascending the structures to find suitable spawning habitat leading to selection of sub-optimal spawning habitat. Unlikely to allow lamprey and bullhead to ascend due to fast flow of water over the weir

Location	Photograph of weir	Description	Ecology
Weir upstream of fish hatchery near Pont Faen (SJ 270 373) Afon Ceiriog/ River Ceiriog – lower Management unit - 19		Approximately 1.75m high and 3m long. Ponding effect extends approximately 70m upstream Adjacent land use is rough pasture for grazing (right bank) and broadleaf woodland and main road (left bank). Downstream of the weir the fish hatchery is on the left bank. Weir is used to divert water via a sluice on the left bank to feed into the downstream fish hatchery	Potential obstruction to salmonid migration particularly in low flow conditions, but passable under higher flow conditions. Delays in migration may increase concentration of fish below the structure, increase predation or exploitation, increase the chance of disease among fish leading to reduced fish condition and result in fish using sub-optimal habitats or failing to spawn at all
Brynkinalt gauging weir (SJ295 373) Afon Ceiriog/ River Ceiriog – lower Management unit - 19		Compound broad crested weir. 2 levels each approximately 0.5m high, 4m long in total and 11.5m wide. Upstream bed is reinforced with concrete upstream of weir and the ponding effect extends upstream for approximately 20m Adjacent land use is rough pasture for grazing (right bank) and broadleaf woodland (left bank). Gauging weir is used for measuring flow and water level	Potential obstruction to salmonid migration particularly in low flow conditions, but passable under higher flow conditions. Delays in migration may increase concentration of fish below the structure, increase predation or exploitation, increase the chance of disease among fish leading to reduced fish condition and result in fish using sub-optimal habitats or failing to spawn at all. Unlikely to allow lamprey and bullhead to ascend, especially in low flow conditions

Location	Photograph of weir	Description	Ecology
Manley Hall gauging weir (SJ348 415) Middle Dee – Main stem River Dee/ Afon Dyfrdwy Management unit 8		2 compound crump weirs approximately 1m high, 3m long, 15m and 20m wide. Used as a gauging weir, upstream flow type is a glide and downstream a run. Ponding and reducing flow velocities approximately 200m upstream Adjacent land use is rough pasture for grazing on both banks Gauging weir is still used for measuring river flow	Potential obstruction to salmonid migration, but passable under higher flow conditions. Delays in migration may increase concentration of fish below the structure, increase predation or exploitation, increase the chance of disease among fish leading to reduced fish condition and result in fish using sub-optimal habitats or failing to spawn at all. Unlikely to allow lamprey and bullhead to ascend
Erbistock weir (SJ354 421) Middle/Lower Dee – Main stem River Dee/ Afon Dyfrdwy Management unit 8/9		Approximately 2.5m high, 3m long and 65m wide (diagonally crosses channel which is approximately 52m across There is a gentler sloping section of the weir at the right bank where fish were observed to be attempting to swim upstream Ponding effect and reduces flow velocities extended upstream for at least 200-300m Adjacent land use is rough pasture for grazing (both banks)	Potential obstruction to salmonid migration due to weir height, but passable under higher flow conditions. Delays in migration may reduce fish condition, increase concentration of fish below the structure and increase exploitation rates. Significant obstruction to lamprey migration due to flow velocity and weir height

Location	Photograph of weir	Description	Ecology
		Post medieval weir built to provide water to Erbistock Mill.	
Chester weir (SJ407 658) Lower/ Esturaine Dee Management unit – 13/14		Approximately 9m high, 7-17m long, 153m wide (cross channel diagonally) Adjacent land use urban (Chester) Historic weir originally built to serve medieval mills and then restored for hydroelectric power in the early 20th century. Now used for abstractions and to prevent tidal ingress for all but highest tides	Fish pass will ensure fish passage under most flow conditions

7.3 Summary of pressures to be addressed

A key pressure identified along the River Dee and upland tributaries is the impact of land use on the river. River channels and their surrounding floodplains are linked systems and these floodplain land use practices have had a number of potential impacts on the river channel. Channel modifications have already been discussed in Chapter 5.

The principal morphological pressures that were identified from the field surveys can be grouped into six categories:

1. Flow regulation resulting in reduced flood peaks and increased low flows, thus a smoothing out of the expected natural flow duration curve that would allow for the full natural range of geomorphological processes to occur (e.g. reduces proportion of time in the year there are high scouring flows)
2. Installation of structures (bank reinforcement, weirs and embankments) which prevent natural adjustment and floodplain connection
3. Modifications to channel planform and cross-section (primarily through channel straightening in some reaches)
4. Poaching and degradation of the riparian zone leading to accelerated bank erosion rates and reductions in marginal shelter and shading
5. Routine maintenance activities (e.g. dredging) to promote an artificial channel morphology
6. Tree clearance and debris removal

Actions for dealing with water quality are summarised in the River Basin Management Plan for the river basin district. A draft Diffuse Water Pollution Plan exists for the English sections of the Dee. Actions include:

- Avoid clearing field drains with direct connectivity to river to minimise this pathway for nutrient / sediment delivery
- Reduce sediment runoff using riparian buffer strips in arable areas with fencing as a last resort, to address siltation pressures; and
- Address non-DWP pressures such as point source sewage discharges where the remedy is AMP improvements

.

Invasive species (Japanese knotweed, Himalayan balsam and Rhododendron) also occur along the length of the sections surveyed. Rhododendron was particular prominent along the lower Ceiriog through Brynkinalt Estate. Presence of these species affects the favourable condition of the site and therefore measures to control their spread are required to address this and also to benefit the nature conservation status of riparian habitats generally. In some CCW management units water quality is a compounding factor in failure to meet favourable condition and should be addressed in the future.

7.3.1 Upland tributaries

The principal morphological pressures are confined to relatively local areas on the upland tributaries - the Afon Mynach, Afon Meloch and River Ceiriog. Overall, the channels are relatively inactive and the lengths affected by pressures are insignificant on a whole river scale. These channels are not regulated and appear to be in favourable condition for habitats and geomorphology on a river scale and therefore it is suggested that further assessment of SAC/SSSI features is undertaken to place more certainty on condition status. The lack of geomorphological pressure on qualifying species and habitats indicates that constraints on the abundance and distributions of ecological features are largely natural in the upland tributaries, and as such channel morphology is not contributing to a failure of condition status. There are however some restoration measures that may be undertaken in some reaches and spot checks to address local issues. These are shown in Table 7-4. The overarching restoration recommendation is to restore/improve riparian zones where they have become degraded, mainly due to adjacent land use such as livestock grazing. Banks, bed, planform and flow are all relatively natural and are in favourable geomorphological condition.

7.3.2 Main stem River Dee

(a) Flow

Due to the width and depth of the Dee channel over a continuous length from the outfall at Bala Lake to Chester weir, the flow types are predominantly low energy glides that alternate with high energy run-riffle sequences. Within the steep, bedrock reaches, such as that in the Vale of Llangollen, cascades occur due to the steep gradient.

The key pressure on the main tem River Dee is the regulated flow regime. The main geomorphological impacts of this are evident in the Dee meanders and in the lower tidally influenced section of the Dee where a discontinuous berm has formed below the natural bank top from fine sediment dropping out and narrowing the channel (Changxing *et al.* 1999). Despite this, the Dee meander reach has been classed as being in favourable condition for geomorphology. Aside from flow regulation, the main morphological pressures are the major weirs by the Tryweryn confluence, Horseshoe Falls, Manley Hall and Erbistock, which are likely to restrict upstream migration of fish and lamprey.

(b) Planform

The main stem Dee has a largely natural planform with the exception of the extensively straightened sections from Aldford to Chester estuary. The confined meanders in the Upper Dee have extensive patches of historic bank protection (which is mapped in detail by the Hill and Emery (2005) Fluvial Audit). Although the river appears to be gradually recovering naturally in places, these areas of bank protection are currently preventing the river from adjusting in places. The valley of the Middle Dee is generally very narrow with only isolated properties in rural sections and thus there have been no works such as channel straightening on this section for flood control purposes. The exceptions are settlements such as Llangollen, where the river banks are extensively reinforced to prevent movement and flooding. The Lower Dee, from Overton displays tortuous meanders which have historically been embanked. It was concluded from the 2012 site surveys and from scientific literature that the channel planform is relatively inactive at the current time with only very localised lateral movement of meanders. As the river flows through Farndon and Chester it becomes highly modified for flood prevention purposes and appears to have historically involved some straightening.

The English SSSI comprises a meandering reach of the River Dee between Holt in the north and Worthenbury in the south and is considered to be in favourable condition. The area is of national importance for studies of fluvial geomorphology, including the meanders, the adjacent floodplain, palaeochannels and in-channel gravel and sand bars. The Citation also states that although the channel has changed in position markedly during the Holocene, the last few hundred years have been characterised by relatively limited movement. The Citation also recognises that the banks and bed of the modern channel are now evolving in response to changing flow and sediment regimes induced by upstream regulation and other human modifications to the fluvial system. Although the river is considered to be in favourable condition it is obvious that there are anthropogenic pressures affecting the channel.

(c) Banks

As with planform, banks along the river Dee are largely natural, except where historic bank protection remains (in the Upper Dee and through urban areas). Records show that bank protection was placed in the Dee meander section. However this could not be seen during the 2012 surveys as water levels were relatively high but more likely that it has washed away (the Hill and Emery (2005) Fluvial Audit did not record many areas of bank protection along the meanders). Bank protection severely restricts natural channel processes such as erosion and the natural channel morphological diversity is reduced. Banks along the Dee meanders and in some sections of the Upper Dee are higher than they would be naturally due to the raising of adjacent embankments to prevent flooding of fields. There is evidence of unmanaged retreat of banks into embankments at the Dee meanders and, subject to further feasibility studies, this could be allowed to continue at some locations.

(d) Bed

Due to the high flows during the 2012 surveys, the bed of the main stem Dee was obscured by deep and turbid water. The predominance of the glide flow type suggests that the channel is uniformly deep and that the gradient is low. In the Upper and Middle Dee side bars are evident and comprise of cobbles, pebbles and coarse gravel. In the Vale of Llangollen bed material is predominantly bedrock. In some areas where there are riffle-runs, bed material was comprised of mainly cobbles and coarse gravel.

The Hill and Emery (2005) Fluvial Audit found that bed material sediment size increased from coarse gravel and cobbles in the Upper Dee to cobbles, boulders and bedrock in the Middle Dee. The dominance of large substrate size and consolidated bed are likely to reduce spawning habitat although provide suitable habitats for adult and juvenile fish. The lack of depositional areas and silt beds minimise the opportunity for lamprey ammocoetes. From the start of the Lower Dee, bed sediment size gets progressively smaller. Coarse and fine gravel and fine sediment in the upstream section of the Lower Dee (from Overton to Farndon) becomes predominantly fines and sands (from Farndon to the Dee estuary). The bed structure of the Lower Dee is likely to be more suitable for lamprey ammocoetes and those areas of coarse gravel in faster flowing sections for salmonid and lamprey spawning. The pattern of sediment graduation in the Lower Dee is presumably a result of tidally influenced freshwater as far upstream as Farndon.

(e) Riparian zone

The riparian zone is degraded throughout the both SSSIs and SAC due to adjacent land use practices, predominantly livestock farming and as a result there are potential opportunities for improvements in almost every reach. There is a degree of variation in the degradation of riparian zone in each reach/ spot check. Generally, the riparian (non agricultural) vegetation is restricted to a relatively narrow corridor along the top of each bank. In some areas there are broad leaf woodlands that run alongside the river channel but mainly the riparian zone consists of a line of trees and shrubs. It is apparent that livestock may have exacerbated the degradation of the riparian zone in places and that reducing grazing pressure to prevent the poaching and degree of grazing of the riparian zone would be beneficial. Riparian shading is important to SAC feature species with fish and lamprey requiring marginal shading and benefiting from the seasonal input of woody debris and organic material. Tree lining is important in reducing in-channel macrophyte and algal growth.

There is some research that allows quantification of the degree of shading required in various situations (see Brookes, 1988, pp205-206). The effect of natural shade is governed by a number of factors, including the relationship between the position and size of the marginal vegetation and the general stream morphology and orientation. The light available also depends on the degree of overhang of tree branches and the orientation of the stream relative to the course of the sun is fundamental.

7.4 'Room for the river' approach

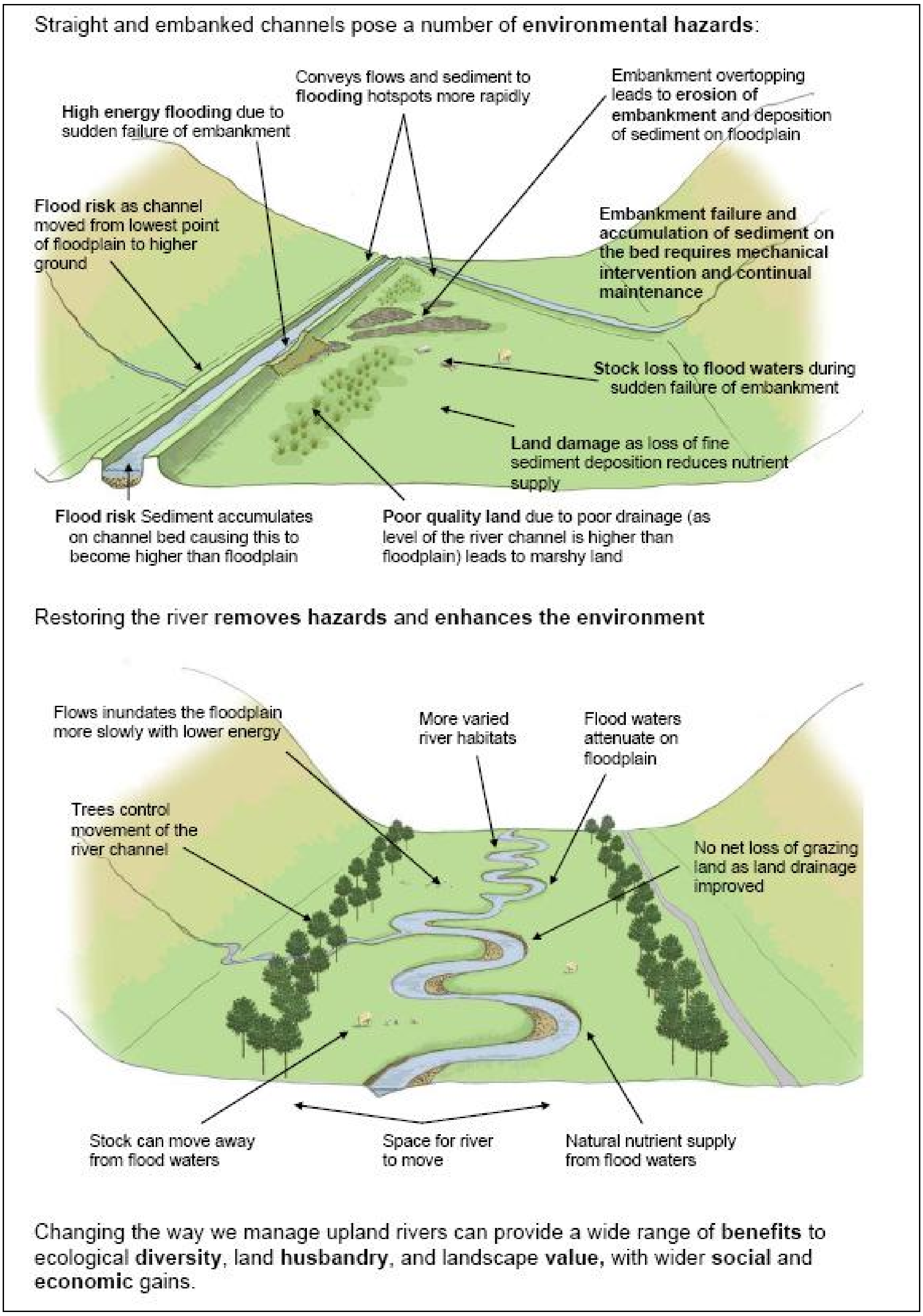
Potential restoration measures for the Dee/ Dyfrdwy have been suggested based on the 'Room for the River' approach. Room for the river type approaches to flood and erosion risk management and habitat restoration are increasingly being used across continental Europe, including a national programme in Holland, and on powerful rivers such as in the Rhine, Meuse, Danube and Loire, primarily as a way to manage flood risk (Ruimte voor de rivier, 2013).

The 'Room for the River' approach takes into account the following:

- Dynamic fluvial systems such as that of the Dee/ Dyfrdwy are often unable to adapt naturally to changes in rainfall because they are constrained by traditional flood defence structures. Climate change is likely to mean more intensive rainfall, resulting in increased river flooding and changes in patterns of erosion. Traditional flood management solutions will continue to have a key role but alone may not always be effective or sustainable in the face of increasing flood and erosion risk over the next century, as acknowledged by the Government's strategy "Making Space for Water" and the Pitt Review.

- The risks caused by the historic and current management of mobile rivers, and a potential "room for the river", or "making space for water" restoration approach is illustrated in Figure 7.1. Where critical infrastructure is a constraint, a similar "erodible corridor" approach may be taken. The erodible corridor concept "consists of defining a corridor in the alluvial floodplain, within which decision-makers will not seek to control erosion using engineered protections. At its simplest, the concepts tries to balance the environmental benefits of allowing the river to move freely (within the corridor), and allowing sedimentary processes to occur and the economic benefits derived from protecting property and infrastructure (outside the corridor) (Piégay et al. 2005).

Figure 7.1 *Risks relating to embankment and reinforcement on mobile rivers (top), and potential benefits of restoration and making room for the river (bottom)*



7.5 Potential restoration measures

To restore favourable condition in the main stem River Dee, the potential restoration measures can be grouped into two main categories: those which involve restoring the channel and rehabilitating degraded sections and those which require restoration of the riparian zone.

These measures include:

Channel restoration/rehabilitation

- Remove hard bank protection to allow natural channel adjustment
- Removing or improving weirs that present barriers to fish passage
- Breach or remove embankments to restore floodplain connectivity and function where this action does not conflict with the CFMP Policy for the Unit
- Promote natural channel adjustment and allow it to continue where present (including deterioration of bank protection and erosion of embankments)
- Consider re-meandering straightened reaches in the tributaries to re-establish depositional processes which may result in deposits conducive to fish spawning; and
- Reduce or cease channel maintenance

Riparian zone restoration

- Improve riparian zone to reduce accelerated sediment supply, to provide more shade to the channel to benefit fish and to provide the means for large woody debris accumulation downstream which will enhance riverine habitats and flow types; and
- Increasing riparian vegetation would also enhance allocthonous organic input which may benefit larval lampreys

Flow regulation needs to continue as it is a means to public water supply and also flood control. For the purposes of this project the licensed abstraction is taken as a given pressure. However, it may be that improvements can be made to the outflow regime of each reservoir to bring them in line with the natural flow regime of the river. This would perhaps bring back (at least in part) the geomorphologically and ecologically important flow variations that would have been naturally present pre-impoundment. Alternatively restoration actions can be developed which allow for the complex interactions between combined pressures (e.g. allowing the channel in the Lower Dee to 'recover' through channel narrowing.

The re-establishment of natural river process and form is in line with the objectives of the CCW catchment management plan as is the modification of artificial factors such as weirs, bridge sills etc that affect SSSI/SAC features. Riparian zone replenishment will partially address water quality issues arising from diffuse pollution as this will improve the buffer zone at the land/water interface.

The re-establishment of natural river processes is also compatible with the CFMP Policy Units, as promoting floodplain connectivity, in rural areas and increasing length and diversity (which may arise from bank protection removal) will attenuate flood flows in urban areas such as Bangor-on-Dee, Wrexham and Chester.

Some initiatives such as High Level Stewardship (HLS) in England and Glastir in Wales are actively encouraging changes to farming practices which can include large buffer strips and livestock fencing.

7.6 Classification of restoration measures

Restoration measures have been classified into five categories based on the level of restoration needed, have each been assigned a colour code (Table 7-3). A summary of the morphological pressures and potential restoration actions for each surveyed reach and spot check is given in Table 7-4. The restoration actions are presented in more detail in the accompanying Management Report. These categories are as follows:

1. ***Significant channel restoration***, where the river has been extensively modified by major structures such as weirs, channel straightening and extensive lengths of bank reinforcement
2. ***Assistance of natural channel recovery*** where the river has started to recover a natural morphology, or displays the ability to recover, to past channel modifications, but the ability of the river to adjust fully or within a short time scale is considered unlikely without human intervention. There is typically less disturbance to the river in the short term compared to 'significant channel restoration'
3. ***Natural recovery (no active restoration)*** where the river channel is actively recovering a natural morphology from past channel modification. Natural fluvial processes are altering the channel bed and banks and improved habitats are developing. Optimal channel morphology is considered likely to develop without human intervention
4. ***Riparian zone management*** where riparian zone is degraded or where invasive species are growing (including tree planting and woody debris installation)
5. ***No restoration required (optimal condition)*** in reaches with no or very few modifications which do not have impacts on fluvial processes and channel form. These reaches are classed as providing 'optimal' habitat.
6. ***Outwith scope of restoration vision (urban)*** reaches within urban areas that are constrained by development, infrastructure and are considered high flood risk areas. These reaches have not been considered in the restoration plans

Table 7-3 Restoration option classification

Category	Colour code	Description
Significant channel restoration	Red	Opportunities for weir removal, weir improvement, or the removal of extensive bank reinforcement. Also to realign or re-meander sections
Assisted natural channel recovery	Orange	Removal of minor channel structures (localised or short sections), such as bank reinforcement. breaching embankments
Natural recovery	Yellow	The channel is currently adjusting towards favourable condition and no intervention is required or very minor improvement like riparian zone replenishment could be implemented
Riparian Zone Management	Blue	The geomorphological processes are optimal, however the riparian zone could be improved with grazing managment, buffer strips and/or planting and tree management and installation of woody debris
No restoration required (optimal condition)	Green	Considered in optimal condition
Urban	Grey	Urban constraints prevent restoration

Table 7-4 Summary of the morphological pressures and the potential restoration actions for each reach or spot check surveyed (for locations refer to maps in Appendix C)

CCW unit	Reach/ Spot check	Conservation status	Morphological pressures	Restoration actions	Ecological improvements
18	CEI001SP	High	• Poaching in fields used for grazing, where fencing is absent	Grazing management to restore riparian zone and reduce poaching	Reduced fine sediment input from surface run off and increased marginal cover for fish
	CEI002SP	Moderate	• Realigned, straightened section of river • Localised areas of bank protection • Riparian zone degradation	Remeander straightened section to mimic downstream natural meanders but also to re-create a sediment sink.	Improved deposition of gravels (connectivity between salmonid spawning and parr habitats). Increased diversity in flow and substrate types
				Remove bank protection	Improves bank habitat
				Grazing management and tree planting to restore riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
	CEI003SP	High	• Riparian zone degradation • Poaching	Grazing management and tree planting to restore riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
				Grazing management to control water access points and reduce poaching by animals	
	CEI004SP	Moderate/High	• Embankments and flood walls in settlements such as Pandy • Riparian zone degradation	Remove wall at Pandy which is adjacent to field	Improves bank habitat
				Grazing management and tree planting to restore riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
	CEI005SP	Moderate	• Bank protection and walls through the town of Glyn Ceiriog	Urban area so restoration measures are limited	N/A
				Invasive species management	Improved diversity of riparian zone
	CEI006SP	Moderate/High	• Bank protection to protect Cheshire Home grounds, fields and road • Straightened section parallel to road • Invasive species (Japanese knotweed)	Remove bank protection adjacent to fields with livestock	Improves bank habitat
				Invasive species management	Improved diversity of riparian zone

CCW unit	Reach/ Spot check	Conservation status	Morphological pressures	Restoration actions	Ecological improvements
	CEI007SP	Moderate	• Bank protection for road • Riparian zone degradation • Poaching	Grazing management and tree planting to restore riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
				Grazing management to reduce poaching	
	CEI008SP	High	• Over-widened section • Bank protection for adjacent field • Poaching • Riparian zone degradation	Allow natural recovery of over-widened section. Deposition is occurring within and along the sides of the channel	Allow deposition of coarse sediments for spawning and juvenile life stages
				Remove bank protection by field	Improve connectivity between channel and riparian zone
				Grazing management to reduce poaching and encourage growth of riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
				Tree planting to restore riparian zone	
19	CEI009SP	Moderate	• Major weir upstream of fishery by Bronygarth. The water is diverted into fishery There is a fish pass • Failing bank protection (adjacent to fishery) • Failing flood walls • Embankment • Riparian zone degradation	Remove weir above Bronygarth fishery	Improve fish passage and habitat connectivity
				Remove old bank protection	Improve connectivity between channel and riparian zone / floodplain
				Remove flood walls	
				Remove embankment	
				Tree planting to restore riparian zone	Reduced fine sediment input and increased marginal cover for fish
				Grazing management to encourage growth of riparian zone	
	CEI001	Moderate/High	• Widespread bank protection on both banks to protect adjacent farmland • Tree-lining is thin • Poaching	Remove bank protection.	Improve connectivity between channel and riparian zone
				Invasive species management	Improved diversity of riparian zone
				Tree planting to restore riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
				Grazing management to reduce poaching and encourage growth of riparian zone	
	CEI002	Moderate	• Brynkinalt weir and	Remove Brynkinalt weir	Improve fish passage and

CCW unit	Reach/ Spot check	Conservation status	Morphological pressures	Restoration actions	Ecological improvements
			associated bank and bed reinforcement • Additional bank protection • Sewage works on right bank • Invasive species (Japanese knotweed)	Remove reinforced bed and bank upstream of Brynkinalt weir	connectivity between habitats Increase substrate availability
				Remove walls	Improve connectivity between channel and riparian zone
				Invasive species management	Improved diversity of riparian zone
	CEI003	Moderate/High	• Two stretches of extensive bank protection • Outfall that may be contributing to water quality issues • Riparian zone degradation • Ford (sediment source)	Remove bank protection	Improve connectivity between channel and riparian zone
				Improve riparian zone, grazing management.	Reduced fine sediment input from surface runoff and increased marginal cover for fish
				Prohibit the use of ford	
	CEI004	Moderate/High	• Building debris left behind, perhaps from building of the bridge • Riparian zone is fragmentary • Forestry track is a potential sediment source during high rainfall	Remove bank protection	Improves bank habitat
				Remove building debris	Reduced fine sediment input from surface runoff and increased marginal cover for fish
				Tree planting to restore riparian zone	
				Grazing management to encourage growth of riparian zone	
				Buffer strip or drainage channel for forestry track	
	CEI005	High	• Localised bank protection • Forestry tracks are a potential sediment source during high rainfall • Invasive species (Japanese knotweed, Himalayan balsam and Rhododendron)	Remove bank protection	Improves bank habitat
				Buffer strip or drainage channel for forestry track	Remove fine sediment from surface runoff to prevent siltation of substrates
				Invasive species management	Improved diversity of riparian zone
	CEI006	High	• Poaching in fields used for grazing, where fencing is absent	Grazing management to reduce poaching and encourage growth of riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
				Tree planting to restore riparian zone	
	CEI007	High	• None	Reach is in optimal condition	N/A

CCW unit	Reach/ Spot check	Conservation status	Morphological pressures	Restoration actions	Ecological improvements
	CEI008	High	• Poaching	Grazing management to reduce poaching and encourage growth of riparian zone Tree planting to restore riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
2/15	TRY001SP	Very Low	• Highly channelised area for Bala Lake System • Weirs • Riparian zone degradation	Tree planting to restore riparian zone Grazing management to encourage growth of riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
16	MYN001	High	• Riparian zone degradation • Poaching	Tree planting to restore riparian zone Grazing management to reduce poaching and encourage growth of riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
	MYN002	High	• Riparian zone degradation • Poaching	Tree planting to restore riparian zone Grazing management to reduce poaching and encourage growth of riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
	MYN003	High	• Riparian zone is fenced off from livestock, although could be improved. • Bank protection for bridge and house	Tree planting to improve riparian zone Protection needed for house and bridge – urban constraint	Reduced fine sediment input from surface runoff and increased marginal cover for fish
	MYN004	Moderate	• Bank protection • Riparian zone degradation	Realign channel to recreate a winding course and recreate a sediment sink	Improve flow and substrate diversity
				Remove bank protection	Improves bank habitat
				Tree planting to restore riparian zone Grazing management to encourage growth of riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
17	MEL001	High	• Minor weir for water supply • Bank protection (small	Removal of minor weir Removal of bank protection	Improve fish passage and connectivity of habitats

CCW unit	Reach/ Spot check	Conservation status	Morphological pressures	Restoration actions	Ecological improvements
			section) • Thin tree line	Tree planting to improve riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
				Grazing management to encourage growth of riparian zone	
	MEL002	High	• None	Reach is in optimal condition	N/A
	MEL003	High	• Generally good riparian zone, although broken and non-existent in parts	Tree planting to improve riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
				Grazing management to encourage growth of riparian zone	
	MEL004	Moderate	• Embankment • Channel realignment • Riparian zone degradation	Removal of embankment	Increase connectivity of channel with floodplain
				Remeander straightened section to mimic downstream natural meanders but also to re-create a sediment sink.	Improved deposition of gravels (connectivity between salmonid spawning and parr habitats). Increased diversity in flow and substrate types
				Tree planting to improve riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
				Grazing management to encourage growth of riparian zone	
	MEL005	High	• Riparian zone degradation • Poaching	Tree planting to improve riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
				Grazing management to reduce poaching and encourage growth of riparian zone	
	MEL006	High	• Sluice (just above Dee confluence for small-scale hydropower or water supply) • Riparian zone degradation • Poaching	Remove sluice and fill in mill lade	Improve fish passage
				Tree planting to improve riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
				Grazing management to reduce poaching and encourage growth of riparian zone	
4	DEE001	Moderate/High	• Localised bank protection	Remove embankment	Increase channel connectivity to

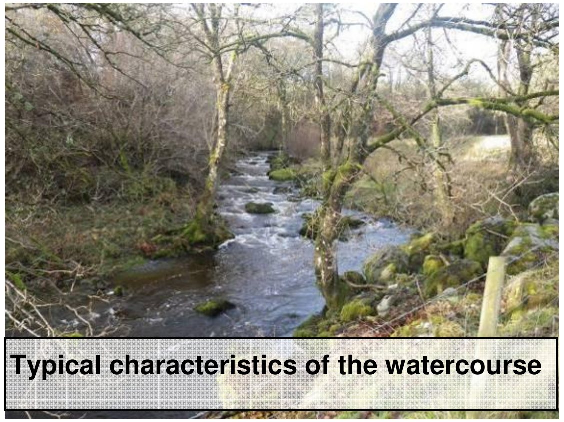
CCW unit	Reach/ Spot check	Conservation status	Morphological pressures	Restoration actions	Ecological improvements
			• Embankment • Riparian zone degradation • Poaching		floodplain
				Remove historic bank protection	Improves bank habitat
				Tree planting to improve riparian zone Grazing management to reduce poaching and encourage growth of riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
	DEE001SP	Moderate	• Poaching where fields are grazed and fencing is absent • Riparian zone degradation	Tree planting to improve riparian zone Grazing management to reduce poaching and encourage growth of riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
	DEE002SP	Moderate	• Poaching where fields are fencing is absent • Riparian zone degradation • Bank protection and in-channel piers associated with Corwen Bridge	Tree planting to improve riparian zone Grazing management to reduce poaching and encourage growth of riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
	DEE003SP	High	• Simple riparian zone on both banks • Minor poaching (fields grazed by sheep during 2012 survey)	Tree planting to improve riparian zone and vary the age (condition) of trees Grazing management to reduce poaching and encourage growth of riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
6	DEE004SP	Moderate	• Horseshoe Falls weir • Riparian zone degradation • Poaching	Remove/improve Horseshoe Falls for ecological pressure)	Improved fish passage and habitat connectivity
				Tree planting to improve riparian zone Grazing management to reduce poaching and encourage growth of riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish

CCW unit	Reach/ Spot check	Conservation status	Morphological pressures	Restoration actions	Ecological improvements
	DEE005SP	Low	• Flood walls exist along both banks to protect the town • Weirs at Llangollen • Invasive species (Himalayan balsam)	Urban area so restoration options limited Remove/improve Llangollen weirs for ecological and geomorphological pressures) Continue to allow natural depositional processes to continue to occur within the channel at Llangollen Invasive species management	N/A Improved fish passage and connectivity between habitats Improve potential spawning and juvenile habitats for species using high flow environments Improved diversity of riparian zone
8	DEE006SP	Moderate	• Manley Hall weir and associated bank protection • Poaching • Riparian zone degradation	Remove/improve Manley Hall weir Tree planting to improve riparian zone Grazing management to reduce poaching and encourage growth of riparian zone	Improved fish passage Reduced fine sediment input from surface runoff and increased marginal cover for fish
8/9	DEE007SP	Moderate	• Erbistock weir • Riparian zone degradation • Invasive species (Rhododendron)	Remove/improve Erbistock weir Tree planting to improve riparian zone Grazing management to reduce poaching and encourage growth of riparian zone Invasive species management	Improved fish passage Reduced fine sediment input from surface runoff and increased marginal cover for fish Improved diversity of riparian zone
9	DEE008SP	Moderate	• Continuous low level embankment on left bank • Limited riparian zone on right bank • Fencing is located along bank top, but not set back from channel	Allow unmanaged retreat of meanders Set back fencing and encourage a diversity of species to grow in the riparian zone	Natural processes putting sediments into channel for spawning and juvenile habitats Increase in flow variation with return to naturalised channel Improved diversity of riparian zone
10	DEE009SP	Moderate	• Embankments on both banks (eroding on left bank). • Poaching and riparian zone degradation from livestock	Allow unmanaged retreat of meanders and continued erosion of embankments	Natural processes putting sediments into channel for spawning and juvenile habitats Increase in flow variation with

CCW unit	Reach/ Spot check	Conservation status	Morphological pressures	Restoration actions	Ecological improvements
			grazing		return to naturalised channel
				Grazing management to reduce poaching and encourage growth of riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
11	DEE002	Moderate	• Extensive embankments • Riparian zone degradation • Poaching	Remove embankments where necessary	Reconnect channel with floodplain
				Allow unmanaged retreat of meanders and continued erosion of embankments	Natural processes putting sediments into channel for spawning and juvenile habitats Increase in flow variation with return to naturalised channel
				Tree planting to improve riparian zone Grazing management to reduce poaching and encourage growth of riparian zone	Reduced fine sediment input from surface runoff and increased marginal cover for fish
12	DEE003	Moderate	• Informal boat moorings and holiday homes (caravans and stone houses) • Embankments on left bank (eroding). Localised areas of embankments on right bank. Note, flooding was recorded in fields on right bank	Allow unmanaged retreat of meanders and continued erosion of embankments	Natural processes putting sediments into channel for spawning and juvenile habitats Increase in flow variation with return to naturalised channel
	DEE004	Moderate	• Shrub lined embankments along left bank (no signs of erosion). Note. flooding was observed behind embankments, but likely to have arisen due to tributaries (including Pulford Brook) over topping due to the head of water in the Dee.	Remove or set back embankments	Increase connectivity of channel with floodplain

8 Watercourse summaries

Each watercourse has been summarised in terms of geomorphological and ecological characteristics, which were observed during the 2012 surveys, and presented in the tables below. Key issues affecting geomorphology and habitats and potential restoration measures are identified for each watercourse. The restoration potential within each of the SSSI units and at a more detailed scale for each reach is described in more detail within the accompanying Management Report.

Afon Mynach	CCW management unit - 16
Geomorphological summary: ***Overview:*** This is a typical upland headwater tributary of a British river. Predominant river types alternate between relatively inactive tree-lined gravelly river, relatively inactive rock bound and an active braiding-like section with possible lateral adjustment. The river has confined irregular meanders in MYN001 and MYN002 then as it moves downstream it becomes relatively inactive, sinuous as it reaches a bedrock lined channel ***Key Characteristics:*** **Flow types:** Fast runs and cascades, step-pool sequences **Bed and Bank Sediments**: Bedrock to glacial deposits (including till and cobbles/ boulders). Also a high variety of finer sediments ranging from discrete sand/silt deposits to fine and coarser gravel. MYN001 and MYN002 are active sections where erosion and deposition into side and point bars is frequent. Along these reaches farmers have instated bank protection in the form of fixed woody debris and boulders along these reaches **Sediment transport characteristics:** the upper reaches of the Mynach are predominantly exchange reaches, where both active erosion and sediment deposition are occurring within the same reach. The lower half of the river is predominantly a transfer zone with only localised deposition behind obstructions **Planform:** The upper reaches exhibit confined irregular meandering whilst in the lower reaches the river becomes sinuous, except where straightened in the lead up to the confluence. This sinuosity in the lower reaches is possibly inherited from former times when vegetation cover was lower and runoff higher. Evidence of secondary channels in MYN001 and MYN002 where the river is more active **In-Channel Vegetation:** Emergent reeds/sedges/rushes, exposed tree roots and large woody debris **Bank vegetation:** Trees which are possibly the last vestiges of a wooded post-glacial landscape and simple communities, consisting of grass and shrubs  **Typical characteristics of the watercourse**	**Ecology/Habitat suitability:** • Extensive otter habitat for foraging and lay-up sites • Channel, substrate and flow diversity offer suitable spawning and juvenile habitats for salmonid fishes and deeper sections for adults. Optimum spawning habitat confined to lower reaches. Naturally constrained in upper catchment by high flows and steep gradients limiting optimal spawning habitat • Extensive habitat present suitable for *Ranunculus* communities • Bank side vegetation lacking in upper reaches, but increases downstream • Himalayan balsam present • No barriers to fish movement within Mynach catchment but obstructions are present on the main stem Dee (predominantly for all three lamprey species and bullhead) **Key issues:** • Poaching • Bank reinforcement (albeit soft reinforcement – wired fixed tree branches) • Straightened section • Bank reprofiling in MYN001 • Riparian zone degradation **Potential restoration options:** • Grazing management for riparian zone replenishment and to reduce poaching (particularly important for active reaches MYN001 and MYN002) • Manage livestock access points to water • Re-meander straightened section immediately upstream of Tryweryn confluence

JACOBS

Afon Meloch	CCW management unit - 17
Geomorphological summary: ***Overview:*** This is a typical upland headwater tributary of a British river. Predominant river types alternate between a relatively inactive rock bound and a relatively inactive tree-lined gravelly river ***Key Characteristics:*** **Flow types:** Step-pool and run-riffle sequences **Bed and Bank Sediments**: Bedrock to glacial deposits (including till and cobbles/ boulders). Glacial deposits have formed terraces along significant lengths of the channel **Sediment transport characteristics:** it is predominantly a transfer zone, only localised deposition has occurred obstructions) **Planform:** except where straightened the winding pattern has possibly been inherited from former times when vegetation cover was lower and runoff higher. Little evidence of secondary currents (i.e few point bars and eroding bends except in middle reaches close to where straightening has occurred). In lower reach MEL006 mid channel bars are occurring **In-Channel Vegetation:** mosses and bryophytes **Bank vegetation:** Trees which are possibly the last vestiges of a wooded post-glacial landscape and simple communities, consisting of grass and shrubs **Ecology/Habitat suitability:** • Very good otter habitat including exposed tree root systems, vegetated banks, presence of ash and sycamore, possible den sites • Channel, substrate and flow diversity offer suitable spawning and juvenile habitats for salmonid fishes and deeper sections for adults, particularly in the lower reaches • Extensive habitat present suitable for *Ranunculus* communities • Bankside vegetation is minimal where poaching by livestock is apparent • A small weir may restrict upstream migration of lamprey and bullhead. However lamprey are unlikely to reach the Meloch with significant barriers to migration on the main stem Dee. Very limited depositional features suitable for lamprey ammocoetes • Suitable bullhead habitat recorded • Straightened section offers minimal appeal to riparian species	**Key issues:** • Straightened section running through field in MEL004 with embankment probably constructed from spoil won when new channel dug. This could be relatively recent as fence appears to be less than 10 years old • Poaching, where livestock are able to access river, although this is not extensive • Bank reinforcement for infrastructure (i.e. roads, bridges) • Water abstraction for small, domestic, run-of-river hydropower scheme near Aerfen **Potential restoration options:** • There are no obvious restoration actions required for relatively inactive, stable stream channel types as modifications that are present along these reaches are having a minimal effect on geomorphology • For the straightened section, restoration actions could include re-meandering to the old course however this may re-activate the reach as a sediment trap. Obviously gravels deposited here could form (and possibly re-create) a useful habitat for spawning fish as the substrate in the straightened course contains larger grain sizes. A feasibility study would be required to look at all benefits and disbenefits • Grazing management and tree planting where riparian zone is degraded **Rock bound channel and exposed tree roots** 

Afon/River Ceiriog	CCW management units – 18 (upper Ceiriog) and 19 (lower Ceiriog)
Geomorphological summary: ***Overview:*** Winding channel, confined by glacial valley sides. Channel alternates between active and relatively inactive sections and bed material is predominantly cobbles and boulders. There is a braided section just upstream of the confluence with the Dee (CEI007) where the slope is lower and wet woodland habitat exists ***Key Characteristics:*** **Flow types:** Run for the majority of the river, but with riffles and glides. There are also areas of rapids where there are large glacial boulders and bedrock outcrops in the channel **Sediment transport characteristics:** The upper reaches of the Ceiriog are predominantly transfer zones carrying sediment into the lower reaches, although cobble/gravel side and point bars are common. From Chimney Farm downstream, in the lower reaches of the Ceiriog there are a high proportion of deposits comprised of fine sediment such as sand and silts and a braided section with significant amounts of large woody debris **Planform:** Winding planform alternating between active and relatively inactive sections. Becomes braided in the lower reaches where fine sediment has been deposited and mid channel islands have formed, some with mature broadleaf trees **In channel vegetation:** Extensive exposed tree roots and large woody debris throughout. Moss and lichens also present in most parts **Bank vegetation:** Largely tree-lined or with wooded areas, mainly deciduous **Ecology/Habitat suitability:** • Extensive habitats present suitable for otter (exposed roots, lay up sites, woodland/vegetated banks). Evidence of badger • Riffles and runs offer suitable spawning and juvenile habitat for salmon, predominantly in the lower reaches where there is greater flow and substrate diversity and habitats are well connected. Silt/sand substrate for larvae of lamprey species. Areas of protected refuges and overhanging vegetation • Some habitat present suitable for *Ranunculus* communities • Potential barriers to fish movements on the main stem of the Dee	**Key issues:** • Two major weirs: Brynkinalt weir (gauging weir) and weir upstream of fish hatchery (by Pont Faen) • Poaching • Straightening (CEI002SP) • Bank reinforcement through settlements • Invasive species (Rhododendron, Japanese Knotweed and Himalayan Balsam) **Potential restoration options:** • Weir removal, modification or fish pass installation (neither weir appeared to have a fish pass) • Grazing management to encourage riparian zone replenishment and address erosion caused by poaching • Re-meander straightened sections (to potentially re-create a sediment sink and spawning redds) • Remove bank protection that does not conflict with CFMP • Manage invasive species **Riparian zone degradation** 

Upper Dee / Middle Dee

CCW management units – 2, 3, 4, 5, 6, 7, upstream half of 8 and 15,

Geomorphological summary:

Overview: Confined meandering due to steep glacial valley sides of the Upper Dee

Key Characteristics:

Flow types: Glides and runs

Sediment transport characteristics: Erosion (sediment sources) are more widespread than deposition. Erosion is mainly a function of fluvial action or geotechnical failure. Deposition occurs mainly at point locations and there are a few mid-channel bars that are vegetated. Difficult to ascertain bed material as river was relatively deep at time of survey. Likely to have cobble bed, however deposits comprised of mainly coarse gravel and bank material was observed to be mainly earth

Planform: Confined meandering due to steep glacial valley sides of the Upper Dee

In-channel vegetation: Marginal vegetation comprises of emergent reeds and grass. There is also the occasional mid-channel bar that is vegetated with grasses/reeds

Bank vegetation: Mainly uniform with grass, however where there are trees, these form a thin tree-line along the river bank. Proportionally a very small riparian buffer strip, but they prevent livestock from entering channel and causing erosion through poaching

Ecology/Habitat suitability:

- Bankside woodlands offer suitable habitats for riparian mammals, with suitable exposed root systems and cover
- Salmonids observed in the river. Variation in channel habitats is suitable for fish species with runs, riffles and pools present in certain locations. Silt is present in pools and gravel/cobbles evident on inside of bends. Macrophytes offering fish refuges are present
- Significant barriers to lamprey migration at Erbistock and Horseshoe Falls although these weirs are passable to salmon
- Some habitat present suitable for *Ranunculus* communities, and for floating water plantain immediately below Bala Lake outlet where it is expected
- Himalayan balsam present
- Walls and riprap near Llangollen less suitable for riparian ecology

Key issues:

- This survey area was strategically selected due to the extensive mapping of bank protection in the Hill and Emery (2005) Fluvial audit. Therefore the main issues in this area are the bank protection consisting predominantly of laid stone and/or large boulders which are altering the natural geomorphology processes that would be occurring if this was not present. There is also poaching along this surveyed area, however this is not extensive
- Riparian zone is indefinite (sparse) along most of this surveyed section
- Historic piers in one location are causing the build up of sediment between the structures, however this is fairly localised

Potential restoration options:

- This section of bank protection was selected as an example section to investigate the feasibility of bank protection removal. The main options along reaches similar to this are to remove bank protection completely to reinstate natural geomorphological processes and to plant trees along the bank
- Grazing management and tree planting to encourage riparian zone replenishment

Marginal vegetation and single tree line on left bank

Lower Dee	CCW management unit – Downstream sections of 8, 9, 10, 11, 12, 13 and 14
Geomorphological summary: ***Overview:*** Predominant river type is an unconfined channel with an extensive alluvial floodplain and evidence of historical migration of channels. Likely to locally be an active channel although the channel is unlikely to move freely and significantly across its floodplain in modern times as a result of flow regulation (i.e. reduced peak flows over time). Unmanaged lateral movement of meanders is occurring in some parts, where presumably recorded bank protection has been washed away, leading to erosion and/or failure of flood embankments ***Key characteristics:*** **Flow types:** alternating between shallow fast flowing sections (riffles and runs) and deep slow flowing sections (pools and glides). Also a highly regulated flow, leading to channel adjustment through narrowing with berm formation **Sediment transport characteristics:** transport appears to be predominantly clay, silt and fine sand (in suspension) although there may be some limited gravel bedload transport. However this reach is a sediment sink. River under natural conditions would deposit overbank on the adjacent floodplain. Due to regulation fine sediment also drops out to accelerate the formation of berms and may also obscure gravel substrate **Planform:** meandering planform with potential to migrate laterally, although with regulation such channel adjustments are now likely to be very localised and occur much less frequently **In channel vegetation:** Locally reeds and rushes colonising the berms. Occasional mid-channel islands with trees **Bank vegetation:** would be trees and woody debris in the channel (historically removed as part of maintenance programmes) **Ecology/Habitat suitability:** • Habitat suitable for riparian mammals is generally lacking except in areas of woodland. High prevalence of badger along the course of the meanders • The form of the river creates a range of substrate and flow conditions suitable for adult salmon and lamprey ammocoetes. Side pools offer refuge areas for fish. Limited opportunity for spawning on key species due to a lack of coarse substrates • Limited habitat present suitable for both *Ranunculus* communities • Bank side vegetation generally lacking. Himalayan balsam present • No barriers to fish movements recorded	**Key issues:** • Historic bank reinforcement that was instated to stabilise meanders appears to have been washed out, however there are still patches of laid stone present that will affect local geomorphology processes • There is a lack of tree-line or riparian zone along these meanders as trees and shrub growth would have been historically removed to prevent embankments from failing through mechanical erosion from tree root growth **Potential restoration options:** • Assist natural recovery by allowing unmanaged retreat of meanders into embankments • Plant bands and clumps of trees and introduce grazing management to encourage riparian zone regrowth which would both improve connectivity along the river corridor and provide shading for the channel, thus improving in-channel habitats **Erosion of embankments** 

8.1 Reach-scale restoration plans

The restoration potential of each reach surveyed (Table 7-4) together with information derived from the Hill and Emery (2005) Fluvial Audit and the Jacobs (2009) River Dee SSSI Restoration Vision report will form the basis of the reach-by-reach restoration plans which will be provided in the accompanying River Dee/ Afon Dyfrdwy Restoration Management Report.

8.2 Stakeholder involvement

The restoration actions presented in the Management Report are required in order to achieve favourable condition in the SSSIs and SAC of the River Dee/ Afon Dyfrdwy. Therefore the accompanying the Management Report will inform future decision making by the Environment Agency, Natural England and CCW (Statutory Bodies). Implementation of the Management Report (comprising the restoration plans) will require effective and positive engagement with stakeholders.

The views and concerns of a cross section of stakeholders on the draft strategy are being sought, including: individual land owners, land managers and farmers; representatives from local communities; relevant public bodies; and delivery partners. To facilitate the involvement of land owners and other stakeholders the Statutory Bodies have taken steps to inform the community and other stakeholder groups, including a preliminary consultation event. The comments and information generated through this will shape the final strategy. Future detailed discussions with land owners about specific river reaches will be an essential part of developing reach specific restoration projects in the coming years. A summary record of general comments will be included in the final strategy.

9 Other plans and delivery mechanisms

9.1 Wales Diffuse Water Pollution Action Plan

A Wales Diffuse Pollution Action Plan (DWPAP) has been drafted. A draft DWPAP also exists for the English Sections of the SSSI. There are also more recent investigations of fine silt along the Welsh sections of the Dee, including a walkover survey for WFD purposes. Diffuse pollution has been identified as a significant water management issue for the Dee River Basin District, for both rural and urban areas. In rural areas many of the significant issues are associated with diffuse pollution from agriculture, which is one of the dominant land uses in the District. High levels of nutrients, pesticides (sheep dip) and metal pollution can all be associated with sediment sources. It is estimated that about 80 per cent of river water bodies are affected by diffuse pollution in rural areas. The Tryweryn and Mynach are particularly affected by high levels of the pesticide Cypermethrin (sheep dip). The Lower Dee is periodically affected by high levels of nitrates and phosphorous, resulting in excessive growth of macrophytes (such as water crowfoot).

A range of specific actions can be implemented to reduce diffuse water pollution in the catchment, these include:

- Reducing sediment supply to the river by enhancing riparian habitats along the river corridor
- Reduced sediment runoff from fields
- Reduced sediment runoff from livestock poaching; and
- Reduction of unconsented pollution incidents

The measures complement the River Dee Management Report, which is developed in this Report. Indeed some of the restoration actions included in the Management Report associated with reducing land use pressures and improving the riparian zone will help to deliver the objectives of the DWPAP. Mechanisms to deliver these improvements include the Environmental Stewardship schemes (Entry Level and Higher Level Schemes in England and Glastir in Wales), Catchment Sensitive Farming (CSF), Catchment Restoration Fund (CRF) and Utilities environmental improvement programmes associated with Asset Management Period 5 (2010-2015).

9.2 The Welsh Dee Trust

The Welsh Dee Trust is an independent environmental charity established to protect, conserve, promote and enhance the River Dee and all its indigenous species of fish, animals, birds and plants. They also aim to increase awareness and understanding of the management of water bodies and the wider environment[8]. Rivers Trusts generally rely on public funding, but many have successfully applied for European Union structural funds such as Interreg and Objectives One, Two and 5b or Lottery funds. The Welsh Dee Trust lists works that they have completed in the headwaters using European Funding (EISWF Project – Tranche 1 Projects). These include pool formation, parr habitat creation, removal of obstructions to fish passage and fencing (to reduce fine sediment input from erosion).

[8] More information available at: <http://www.welshdeetrust.com> [Accessed on 18/01/13]

9.3 Delivery mechanisms

Whole river restoration plans are based on multi-partner working, time horizons suited to the nature and scale of each site's problems and solutions (typically 20-50 year time horizons), a negotiated settlement to any disagreements, and a best endeavours approach to implementation. Funds need to be secured to maintain best endeavours over time, including rolling bids to obvious budgets such as EA/ EAW Flood and Coastal Risk Management (FCRM) capital works, Catchment Restoration Funds, and Environmental Stewardship, but also opportunistic bids to a range of other funding sources including European programmes. Work in-kind from third parties, including 'third sector' partners such as the Rivers Trusts has a vital part to play.

There are a number of potential delivery mechanisms for the River Dee/ Afon Dyfrdwy restoration plans; these are (for England and/or Wales):

- The Welsh Dee Trust contribution in kind
- Catchment Restoration Fund
- Glastir agri-environment scheme
- Nutrient Management Plan funded actions
- European funding
- Environmental Stewardship
- Catchment Sensitive Farming
- Forestry Commission England Woodland Grant Scheme
- National Forest; and
- Planning gain/ developer contributions

Further details on each of these mechanisms are provided in the accompanying River Dee/ Afon Dyfrdwy Restoration Management Report. Restoration costs have been estimated based on published information and experience but these are very rough cost bandings currently to guide future funding and resources, and will be revised over time as the Project develops.

9.4 Prioritisation and costs

9.4.1 Prioritising

The order in which the proposals recommended in this plan are implemented is likely to be influenced by opportunities arising over time such as land owner cooperation and funding. However, to maximise the degree of improvement to the SSSIs and SAC that can be realised in the short-term, those actions that will deliver the greatest benefits should be prioritised. Priority should also be given to schemes that deliver multiple benefits particularly those that:

- Secure improvements to multiple biological quality elements (e.g. fish, plant communities and invertebrates)
- Make additional improvements to non-biological quality elements e.g. improvements to water quality or low flows (this makes a good link across to WFD); and
- Contribute toward sustainable flood risk management

Maximising short-term gains will be essential for meeting the immediate SAC conservation objectives. Restoration actions that will deliver maximum benefits are those which involve:

- Removing redundant structures within the channel (which have a high impact on channel morphology or longitudinal connectivity), including weirs
- Breaching or managed retreat of embankments (allowing natural river erosion and local re-connection of the channel to the floodplain)
- Creating or re-creating fish spawning locations (e.g. in reaches which have been artificially straightened); and
- Restoration of reaches most adversely affected by pressures through tree planting (to create shade, diversify riparian vegetation structure and manage rate of channel change) and managing grazing pressure or fencing (to help restrict ingress of fine sediment and removal of riparian vegetation)

Fencing may provide a large benefit at an early stage, restricting fine sediment input to the channels. Fishery managers tend to advocate fencing but from a conservation (maintaining species diversity), landscape, flood risk and maintenance perspective, fencing is not the preferred option and should be limited only to certain places where there are no other options to reduce grazing pressure. Managing grazing pressure through controlling stock access/ grazing regime may include grazing of fencing only at certain times, with permanent fencing as a last resort. If fencing is used as a measure to improve riparian zone then management then management of the vegetation inside the fence line should be considered.

Local removal of weirs can help allow free movement of aquatic fauna and flora, and natural river dynamics to re-establish within parts of the river. Those reaches which are most adversely affected by pressures are generally those which show the least evidence of natural recovery. For example in the Lower Dee many historical embankments are still in place, due in part to bank protection preventing river erosion. There is also little sign of natural recovery (e.g. re-meandering) of straightened reaches present on the Mynach, Meloch and Ceiriog. Those reaches where no natural recovery is occurring should be prioritised, as these are likely to be the least favourable sections of river. Restoring these reaches will bring greater benefits than resorting to those which have already begun to recover. Other sections of the Lower Dee do show natural recovery, with the failure (in the absence of ongoing maintenance) of some of the embankments through bank erosion.

The prioritisation of actions outlined above, does not preclude opportunities which arise to rehabilitate or restore those reaches at an earlier time than that envisaged. For example, opportunities presented by the participation of farmers and land owners in agri-environmental schemes, successful funding applications or other third party activities (e.g. utility companies) should be explored wherever possible, irrespective of the previously envisaged prioritisation.

The prioritisation of the restoration options is summarised in the Management Report.

9.4.2 Costs

Costs to carry out this restoration work have been estimated based on similar measures on other projects and on past experience by Jacobs. Minimum and maximum costs have been provided for each type of restoration measure suggested in the Plan which gives a price range for restoring each reach. Costs will be site specific and will vary according to a number of factors including, for example, the need for further investigations, external contractors, access, reuse or disposal of materials, local import of materials etc. There are also a number of assumptions attached to the costs which relate to the percentage of reach length that needs to be restored, for example, 10% of channel length requiring bank reprofiling and 50% for riparian improvement) (Table 9-1).

The likely annual HLS costs have also been calculated per hectare but are based on the 12m buffer width for riparian improvement (but this could be more or less). HLS is only suitable for small scale woodland planting (1 ha per wood, 3 ha maximum on a holding), for larger scale tree planting in England the English Woodland Grant Scheme (EWGS). Glastir may provide grants in areas in Wales needing tree planting.

HLS will be closed at the end of 2013 after which new scheme rates will be coming in. Therefore HLS is used here as an illustration, but new schemes that are currently in development may have different rates. These figures have been used in constructing approximate costs for the individual measures/ restoration actions suggested in the Management Plan. The Management Plan also provides a delivery lead for each measure/ action. However there are a number of actions that are suitable for implementation by angling clubs, the river and wildlife trusts. The EA, EAW and NE/ CCW will seek to work in partnership with a range of external parties to deliver the actions.

Table 9-1 Assumptions made when calculating costs NB. HLS costs based on 2012 rates, and subject to change and acceptance into scheme (HLS illustration only as scheme is closed at the end of 2013 and details of new scheme in England are not agreed yet); Glastir cost in parenthesis where available

Action	Min Cost	Max Cost	Assumptions	HLS cost (Glastir cost)
Remove bank reinforcement	£75/m	£138/m	Cost based on length of reinforced bank	
Remove embankment	£2/m	£138/m	Cost based on length of reinforced bank. Disposal costs of material not included	
Remove minor weir	£5,000	£19,000	Minor weir, land owner or local contractor to undertake work. No detailed assessment likely to be necessary	
Remove major weir (and associated walls)	£60,000	£120,000	Feasibility and detailed design necessary and included in costs. Disposal costs of demolition materials not included	
Replace artificially straightened channel with a	£250/m	£550/m	Based on experience of projects circa one kilometre in length. Assumed rural area	

Action	Min Cost	Max Cost	Assumptions	HLS cost (Glastir cost)
more sinuous channel to create fish spawning habitat			and no major services diversions required	
Fill gaps in riparian vegetation by planting	£7/m	£7/m	Assume 50% of channel length (between both banks).	Based on 12m riparian width and £400/hectare (£345/hectare)
Improve riparian corridor (including tree planting)	£7/m	£7/m	Assume 100% of channel length (divided between both banks)	Based on 12m riparian width £400/hectare (£379.80/hectare)
Fencing (both banks)	£2.50/m	£13/m	Assume 50% of reach (divided between left and right bank)	
Field gate (£149 each)	£298	£894	Assumes 2 as minimum and 6 as maximum	

9.5 Implementation – next steps

A consultation event with land owners and other stakeholders is proposed to be held near Llangollen in February 2013 Feedback from this event will be taken on board and used, where applicable, to refine the proposals included in the River Dee/ Afon Dyfrdwy overall restoration plan (contained within the Management Report). Following publication of the final plan NE, EA, EAW and CCW will work with stakeholders to take forward the actions contained in the plan, and will refer back to relevant specific comments provided by land owners and other stakeholders during the consultation period. Whilst some restoration options will be able to be implemented relatively quickly over the next few years, other measures will take longer to develop. This plan is a long term restoration strategy likely to be realised over the next two to three decades by working in partnership with interested parties, and using a range of delivery mechanisms.

10 Conclusions

10.1 Geomorphological and ecological assessment

The geomorphological and ecological assessment of the SSSIs and SAC of River Dee River/Afon Dyfrdwy has identified a range of different pressures, affecting different riverine features summarised below:

Riparian zone:

- Degradation of the riparian zone (particularly where there are grazing animals), leading locally to accelerated bank erosion. Historic tree clearance has also had a permanent impact with corresponding reductions in shading and shelter on the river channel (extensive throughout the catchment).

Banks:

- Historic and current bank protection (extensive in the Upper and Lower Dee, preventing geomorphological processes from occurring and degrading bank vegetation); and
- Poaching from livestock.

Bed:

- Lack of morphological diversity due to removal of woody debris/ trees and as a result of backwaters created by large weirs; and
- Localised channel re-sectioning (especially on some tributaries).

Planform:

- Channel realignment (particularly on the tributaries) leading to uniform substrate and diminished salmon spawning habitat.

Flow (pattern and velocity):

- Major weirs affecting the natural geomorphological processes of the river and which present barriers to migration for lamprey and possibly other fish species (Upper, Middle, Lower Dee and River Ceiriog)
- Minor weirs which do not present significant barriers to migration but are affecting the natural geomorphological processes of the river
- Embankments (present in Upper Dee and extensive in Lower Dee at Dee meanders) causing lack of floodplain connectivity; and
- Lack of woody debris.

10.2 Potential restoration activities

A range of different potential restoration activities have been identified based on these findings. Restoration potential is dealt with on a reach-by-reach basis in the accompanying River Dee River/ Afon Dyfrdwy Restoration Management Report. The reach-scale plans are grouped according to the types of restoration measure/ action that might be suited to a particular reach, broadly as follows:

- Channel restoration/ rehabilitation - including significant channel restoration, minor channel restoration, assistance of natural channel recovery and natural recovery (no active restoration); and
- Riparian zone restoration.

Those reaches identified for riparian zone restoration exhibit good channel morphology. However, whilst the channel is relatively good, compared to other reaches, the quality of the riparian zone could be improved further.

Riparian zone restoration techniques include:

- Filling gaps in the existing riparian vegetation; and
- Restoring a riparian zone parallel to the river channel.

Natural recovery actions include:

- Allowing bank protection to deteriorate in the absence of maintenance; and
- Allowing the river to meander naturally and erode artificial embankments.

Assistance of natural channel recovery measures include:

- Removal of minor weirs
- Removal of failing bank protection, together with bank re-profiling; and
- Introduction of woody debris.

Significant channel restoration measures include:

- Modification or removal of major weirs
- Removal of bank protection, together with bank re-profiling
- Re-meandering of artificially straightened reaches; and
- Re-profiling river banks.

These actions are described in more detail in the accompanying River Dee/ Afon Dyfrdwy Restoration Management Report.

The restoration actions identified for each reach form components or building blocks from which to build a restoration vision for the entire river incorporation both SSSIs and SAC. This vision will describe how the river will function and behave following implementation of the restoration plan (contained in the Management Report).

The EA, NE, EAW and CCW (statutory bodies) recognise that implementation of a restoration plan will require effective and positive engagement with land owners, land managers and stakeholders. The restoration actions in the Management Report are required to achieve favourable condition and as such the plan will inform future decision making by the statutory bodies. To facilitate the involvement of land owners and other stakeholders these statutory bodies have taken steps to inform the community and other stakeholder groups. The plan is a long term strategy (perhaps being realised over a period of 20-30 years, although it is anticipated that some actions can be implemented relatively quickly

11 References

APEM (2006) Lamprey Survey on the River Dee & Tributaries. APEM Scientific Report, Environment Agency 849.

British Dragonfly Society (2007) *The Common Club-tail – Gomphus vulgatissimus (Draft Management Fact File)*

Brookes, A (1988) *Channelized Rivers: Perspectives for Environmental Management*. John Wiley and Sons, Chichester

Buglife (2011) Species dossier: *Isogenus nubecula* Rare medium stonefly. [online]. Available at www.buglife.org [accessed on 04/01/13]

Countryside Council for Wales (CCW) (undated) Site of Special Scientific Interest: Management Statement. Afon Dyfwrdwy (River Dee)

Centre for Ecology and Hydrology (CEH) 67001 Dee at Bala [online], Available at: http://www.ceh.ac.uk/data/nrfa/data/spatialdata.html?67001 [Accessed on 07/11/12]

Chanin P. (2003) Ecology of the European Otter. Conserving Natura 2000 Rivers Ecology Series No. 10. English Nature, Peterborough

Changxing S., Petts G. and Gurnell A. (1999) Bench development along the regulated, Lower River Dee, UK, *Earth Surface Processes and Landforms*, **24:** 135-149

Downward, S.R., Gurnell, A, and Brookes, A. (1994) – A methodology for quantifying river channel planform change using GIS, *Variability in Stream Erosion and Sediment Transport* (Proceedings of the Canberra Symposium). IAHS Publ. no. 224, pp 449 – 456

Environment Agency (EA) (2009) River Basin Management Plan for the Dee River Basin Management District

Environment Agency (EA) (2010) Summary River Catchment Flood Management Plan

EA (2012) Annual Assessment of Salmon Stocks and Fisheries in England and Wales 2011, EA and Cefas

Environment Agency Wales (EAW) (2009) Water for Livelihoods River Basin Management Plan

Environment Agency and Countryside Council for Wales. (2001) SAC River Fish Surveys: Report B Fish Surveys

Gurnell A.M., Piégay H., Swanson F.J. and Gregory S.V. (2002) Large wood and fluvial processes, *Freshwater Biology*, **47:** 601-619

Gurnell A.M. Clark M.J., Hill C.T., Downward S.R., Petts G.E., Scaife R. and Wainwright J. (1993) The River Dee Meanders (Holt to Worthenbury): a hydrological and geomorphological study. Report prepared for the Countryside Council for Wales

Gurnell A.M., Downward S.R. and Jones R. (1994) Channel planform change on the River Dee meanders, 1876–1992, *River Research and Applications*, **9**(4): 187-204

Gurnell A.M. (1997a) Channel change on the River Dee meanders, 1946-1992, From the analysis of air photographs, *Regulated Rivers: Research and Management*, **13:** 13-26

Gurnell A.M. (1997b) River Dee, Holt to Worthenbury, Wrexham and Cheshire (SJ 402464 – SJ 410534). In: K. J. Gregory, ed. (1997). *Fluvial Geomorphology of Great Britain.* London: Chapham and Hall, Ch.3, pp.159-163

Higgs G. (1997) River Dee at Llangollen, Denbighshire (SJ182425 – SJ177443 – SJ 191433). In: K. J. Gregory, ed. (1997). *Fluvial Geomorphology of Great Britain.* London: Chapham and Hall, Ch.3, pp.132-134

Hatcher D. and Garrett H. (2008) *Core Management Plan (including conservation objectives) for the River Dee and Bala Lake/ Afon Dyfrdwy A Llyn Tegid SAC*, Report for Countryside Council for Wales

Hatton-Ellis T.W. and Grieve N. (2003) Ecology of Watercourses Characterised by Ranunculion fluitantis and Callitricho-Batrachion Vegetation, Conserving Natura 2000 Rivers, Ecology Series No. 11

Hendry K & Cragg-Hine D. (2003) Ecology of the Atlantic Salmon. Conserving Natura 2000 Rivers Ecology Series No. 7. English Nature, Peterborough

Hill C.T. and Emery J.C. (2005) *Fluvial Audit of the River Dee*, Report UC0690, GeoData Institute

Jacobs (2009) *River Dee SSSI Vision Report,* Report for the Environment Agency

Lansdown RV. and Wade PM. (2003) *Ecology of the Floating Water-plantain,*Luronium natans. Conserving Natura 2000 Rivers Ecology Series No. 9. English Nature, Peterborough

Maddy D., Scaife R., Sear D. and Hill C.T. (1996) *Upper Dee Fossil Channel Appraisal Bala to Carrog*. GeoData Institute. Report to the National Rivers Authority

Mainstone C. (2007) Rationale for the physical restoration of the SSSI river series in England. Draft V.3. Unpublished Natural England Report

Maitland PS. (2003) Ecology of the River, Brook and Sea Lamprey. Conserving Natura 2000 Rivers Ecology Series No. 5. English Nature, Peterborough

NASCO (2012) *Atlantic salmon river database* [online]. Available at: www.nasco.int/RiversDatabase.aspx [Accessed on 18/01/13]

Piégay, H, Darby, S.E, Mosselman, E and Surian, N (2005) A review of techniques available for delimiting the erodible river corridor: a sustainable approach to managing bank erosion. *Rivers Research and Applications*, 21, (7), 773-789. (doi:10.1002/rra.881).

Pisces Conservation Limited (2007) A review and assessment of the status of salmon (*Salmo salar*) and bullhead (*Cottus gobio*). Available at: http://www.irchouse.demon.co.uk/index.html?2-project037[Accessed on 09/02/13]

Riley (2010) River Dee (England) SSSI Diffuse Water Pollution Plan, Environment Agency

Ruimte voor de riviere (2013) Available at: http://www.ruimtevoorderivier.nl/meta-navigatie/entglish [Accessed on 27th March 2013]

Scarlett, P. M., Shirley, C. L. R., Henville, P., Hornby, D.D. and Dawson, F. H., (2003) *A Resurvey of the Afon Dyfrdwy / River Dee and Selected Tributaries for Aquatic Macrophytes.* A report produced for CCW

Sear, Newson and Thorne (2010) *Guidebook of Applied Geomorphology*, Thomas Telford, London

SNIFFER (2012) Ecological indicators of the effects of abstraction and flow regulation; and optimisation of flow releases from water storage reservoirs, WFD21d, Final Report

Tomlinson M,L. and Perrow M,R. (2003) Ecology of the Bullhead. Conserving Natura 2000 Rivers Ecology Series No. 4. English Nature, Peterborough

Walling, D.E., Collins, A.L. and McMellin, G.K. (2002) Provenance of interstitial sediment retrieved from salmonid spawning gravels in England and Wales: A Reconnaissance Survey Based on the Fingerprinting Approach. A R&D Technical Report (W2-046/TR3) published by the Environment Agency. Research Contractor: Dept. of Geography, University of Exeter.

Appendix A Records of major channel improvements works

(Sourced from the Dee Annual Reports accounts 1953 - 1974, British National Library)

Year	Item of Work	Description
Year ended 31st March 1953	River Dee (Afon Dyfrdwy)	A new channel has been constructed at the junction with the Afon Lliw at Llanuwchllyn
	River Ceidog	Regrading and realignment of the river channel below Llandrillo Station
	Northern Embankment (River Dee) at Sealand	100 yards at Bees Nurseries has been checked by strengthening the Embankment with stone pitching
Year ended 31st March 1954	Northern Embankment (River Dee) at Sealand	Further work to strengthen the Embankment near the Higher Ferry
	Bala Lake	A start was made on a dual purpose scheme to reduce flooding and to supplement the dry weather flow in the River Dee (involving realigned channels on the Dee and the Tryweryn) and sluices etc
	River Dee	A scheme for stabilising the right bank of the River at Shocklach was completed
Year ended 31st March 1955	Northern Embankment (River Dee) at Sealand	Works continued at Higher Ferry and Wood Farm to strengthen the Embankment. Comprised filling eroded bays and stone protection
	Bala Lake	Realignment of the Tryweryn in progress. Sluices/ gates installed
Year ended 31st March 1956	River Dee at Bangor-on-Dee	Right bank strengthened together with reconstruction and realignment of floodbanks near Dungery Farm
	River Dee at Sutton Green	Training groynes and revetment walling was started at Sutton Green
	River Dee at Wood Farm, Sealand	Progress in reconstructing a section of the Northern Embankment at Wood Farm
	Bala Lake	Works progressed (see previous year)
Year ended 31st March 1957	River Dee at Sutton Green	Continuation of 1956 works (see above)
	Northern Embankment	At Higher Ferry and Wood Farm (Sealand) Embankment strengthening took place
	Bala Lake	Works nearing completion (see previous year)
	Afon Camddwr at Rug Lake, Corwen	A scheme carried out to restore river to its pre-war state
Year ended 31st March 1958	River Dee at Wood Farm, Sealand	Continued work on strengthening and improvement of a tidal embankment
	Bala Lake	See previous year
Year ended 31st	River Dee at Wood	Works completed this year (see

Year	Item of Work	Description
March 1959	Farm, Sealand	previous year accounts)
Year ended 31st March 1960	River Dee at Wood Farm, Sealand	Second phase of works involving stone pitching to protect the Embankment
	River Dee at Cynmyd	Work to right bank
Year ended 31st March 1961	No improvement works listed (only sluices and pumping schemes)	
Year ended 31st March 1962		
Year ended 31st March 1963	Sealand Drainage Improvement Scheme: Thornleigh Drain and Manor Drain	New sluices etc
	Northern Embankment: Deeside Cottage Scheme	Comprehensive scheme to improve the tidal emankment
	Bangor-on-Dee Flood Protection Scheme	Raise and strengthen existing embankments
	Llanasa Embankment Improvement Scheme	Raise and strengthen an existing embankment
Year ended 31st March 1964	Bangor-on-Dee Flood Protection Scheme	Raise and strengthen existing embankments
	Llanasa Embankment Improvement Scheme	Raise and strengthen an existing embankment
	Northern Embankment (River Dee)	Protection works to the tidal embankment on the right bank of the Dee between Queensferry and Chester
Year ended 31st March 1965	Bangor-on-Dee Flood Protection Scheme	Raise and strengthen existing embankments
	Llanasa Embankment Improvement Scheme	Raise and strengthen an existing embankment
	Northern Embankment (River Dee)	Protection works to the tidal embankment on the right bank of the Dee between Queensferry and Chester
Year ended 31st March 1966	Bangor-on-Dee Flood Protection Scheme	Embankment works downstream of Bangor were completed (some concrete walling)
	Llanasa Embankment Improvement Scheme	Raise and strengthen an existing embankment
	Trevalyn Meadows Flood Protection Scheme	Raising and strengthening of flood banks along the River Dee and the Pulford Brook and River Alyn where they cross the floodplain.
	Northern Embankment (River Dee) Schemes – Higher Ferry to Thornleigh Sluice	Protection of right bank of the Dee (tidal embankment) between Chester and Queensferry. Furnace slag or rubble is tipped into eroded bays and then the face pitched with 12 inches thickness of limestone
Year ended 31st March 1967	Bangor-on-Dee Flood Protection Scheme	Embankment works downstream of Bangor were completed (some concrete walling)
	Llanasa Embankment	Raise and strengthen an existing

Year	Item of Work	Description
	Improvement Scheme	embankment
Year ended 31st March 1967	Trevalyn Meadows Flood Protection Scheme	Raising and strengthening of flood banks along the River Dee and the Pulford Brook and River Alyn where they cross the floodplain.
	Northern Embankment (River Dee) Schemes – Higher Ferry to Thornleigh Sluice	Protection of right bank of the Dee (tidal embankment) between Chester and Queensferry. Furnace slag or rubble is tipped into eroded bays and then the face pitched with 12 inches thickness of limestone
	Afon Wenffrwd	Resectioning has been undertaken in 1968 but it was found necessary to install gabion check weirs to further reduce flow velocities
Year ended 31st March 1968	Trevalyn Meadows Flood Protection Scheme	Raising and strengthening of flood banks along the River Dee and the Pulford Brook and River Alyn where they cross the floodplain.
	Northern Embankment (River Dee) Schemes – Thornleigh to Wood Farm	Protection of right bank of the Dee (tidal embankment) between Chester and Queensferry. Furnace slag or rubble is tipped into eroded bays and then the face pitched with 12 inches thickness of limestone
	Afon Wenffrwd	Resectioning has been undertaken in 1968 but it was found necessary to install gabion check weirs to further reduce flow velocities
Year ended 31st March 1969	Trevalyn Meadows Flood Protection Scheme	Raising and strengthening of flood banks along the River Dee and the Pulford Brook and River Alyn where they cross the floodplain.
	Northern Embankment (River Dee) Schemes – Thornleigh to Wood Farm	Protection of right bank of the Dee (tidal embankment) between Chester and Queensferry. Furnace slag or rubble is tipped into eroded bays and then the face pitched with 12 inches thickness of limestone
	Afon Wenffrwd	Resectioning has been undertaken in 1968 but it was found necessary to install gabion check weirs to further reduce flow velocities
Year ended 31st March 1970	Trevalyn Meadows Flood Protection Scheme	Raising and strengthening of flood banks along the River Dee and the Pulford Brook and River Alyn where they cross the floodplain.
	Northern Embankment (River Dee) Schemes – Thornleigh to Wood Farm and Sealand Sluice to	Protection of right bank of the Dee (tidal embankment) between Chester and Queensferry. Furnace slag or rubble is tipped into eroded

Year	Item of Work	Description
	Cottages	bays and then the face pitched with 12 inches thickness of limestone
Year ended 31st March 1970	Nant Hafesp Improvement Scheme	Resectioning and regrading this tributary of the River Dee. Involved removal of large quantities of gravel carried from upper reaches.
	Burton Meadows Improvement Scheme	Construction of flood embankments etc
	Finchett's Gutter Improvement Scheme	Channel enlargement to accommodate flows from a new sewage treatment works
Year ended 31st March 1971	Northern Embankment (River Dee): Sealand Sluice to Deeside Section	Protection works to the tidal embankment on the right bank of the Dee between Queensferry and Chester
	Nant Hafesp Improvement Scheme	Resectioning and regrading this tributary of the River Dee. Involved removal of large quantities of gravel carried from upper reaches.
	Burton Meadows Improvement Scheme	Construction of flood embankments etc
	Afon Nug Improvement Scheme	Regrading and resectioning to allow drainage.
	Finchett's Gutter Improvement Scheme	Channel enlargement to accommodate flows from a new sewage treatment works
	Trevalyn Meadows Flood Protection Scheme	Raising and strengthening of flood banks along the River Dee and the Pulford Brook and River Alyn where they cross the floodplain.
Year ended 31st March 1972	Northern Embankment (River Dee): Sealand Sluice to Deeside Section	Protection works to the tidal embankment on the right bank of the Dee between Queensferry and Chester
	Burton Meadows Improvement Scheme	Construction of flood embankments etc
	Finchett's Gutter Improvement Scheme	Channel enlargement to accommodate flows from a new sewage treatment works
Year ended 31st March 1973	Trevalyn Meadows Flood Protection Scheme	Raising and strengthening of flood banks along the River Dee and the Pulford Brook and River Alyn where they cross the floodplain.
	Finchett's Gutter Improvement Scheme	Channel enlargement to accommodate flows from a new sewage treatment works
	Northern Embankment (River Dee): Sealand Sluice to Deeside Section	Protection works to the tidal embankment on the right bank of the Dee between Queensferry and Chester
	Nant Ffrauar Improvement	Confluence of River Dee and

Year	Item of Work	Description
	Scheme	Alwen – improvements including some flood embanking
Year ended 31st March 1974	Burton Meadows Improvement Scheme	Construction of flood embankments etc
	Finchett's Gutter Improvement Scheme	Channel enlargement to accommodate flows from a new sewage treatment works
Year ended 31st March 1974	Cynwyd Drains	River Dee near Corwen – regarding and re-sectioning of drains

Appendix B Records of historic channel maintenance

(Sourced from the Dee Annual Reports accounts 1953 - 1974, National Library)

Year	Location	Description of works
Year ended 31st March 1953	General	50 men use of dragline excavators and other mechanical plant; clearance of debris and vegetation growth; removal of overhanging trees and bushes; protection and restoration of river banks and 'making up' of flood banks where necessary; maintenance of training walls and maintenance of the navigation in the tidal river
	River Dee (Northern Embankment (below Chester)	Strengthening and restoration of two sections of the Northern Embankment at Bumper's Lane and near the Welsh Land Settlement where erosion had formed cavities and embayments in the river face which was made up to a normal section by layer stone pitching
	River Dee (Middle Level)	At Is-y-Coed, Sutton Green, Bangor-on-Dee and Worthenbury – where erosion has occurred weak spots have been strengthened by a stone facing, the banks restored to a normal section and overhanging trees/ bushed removed where necessary. New flood banks have been reseeded
	River Dee below Corwen	Left bank stabilised near Rhaggatt Hall using 80 yards of pitched face up to 9 feet high
	River Dee at Llangollen	Construction of a fish pass and strengthening the weir
	Pulford Brook	Between Pulford Bridge and the outfall to the River Dee the channel was regraded and deepened to give greater capacity and assist land drainage
	River Ceriog at Chirk	Erosion checked with a stone protective face on the left bank and obstructing trees have been removed from the channel
	River Terrig	Regrading of the bed and filling spoil behind the flood banks above the junction with the River Alyn
	River Alyn	Two improvements involving stone pitching to protect the banks from erosion. Carried out at Llong and upstream of Pentre Bridge (Mold)
Year ended 31st March 1954	General	56 men assisted by 6 land based excavating machines, five dumper trucks. Only examples of the works carried out are given
	River Alwen	Construction of a system of training groynes for the purposes of checking erosion of the left bank at the confluence with the Dee at Corwen.
	River Alyn	Usual operations of removing shoals and fallen timber. At 3 locations bank erosion was checked by repairing the banks and

Year	Location	Description of works
		constructing stone revetments
Year ended 31st March 1954	River Ceiriog	Below Brynkinalt Hall near Chirk 80 yards of masonry walling and the restoration of the river to its old channel at the point where there was shown to be a serious tendency to meander. At Castle Mill, Chirk, 6 groynes were installed to train the river in the desired location
	River Dee	Tidal embankments on the Northern side of the River between Chester and Connah's Quay called for almost constant attention (including extermination of burrowing vermin) Repair of flood banks in Shocklach Meadows and at the Wern, Worthenbury were carried out (at weak spots) At Llandrillo stone protection was placed on the left bank of the River and downstream of Corwen Bridge a training groyne containing over one hundred tons of stone was installed
	River Terrig	The improvement an realignment of a section of river upstream of the main road bridge at Leeswood was carried out. Obstructing trees and shoals were removed and minor alterations to the wing wall on the downstream side of the road bridge were carried out
Year ended March 31st 1955	River Alyn	Stone revetments constructed at Mold and Caergwrle to strengthen weak places in the embankments and to stabilise the channel
	Black Brook, Padswood (a tributary of the Alyn)	Subject to a thorough cleaning for half a mile from the junction with the Alyn. Routine weed clearance on the remainder of the brook
	River Dee	Where necessary obstructing trees and gravel shoals removed and stone protection afforded to banks where strengthening necessary. Normal maintenance at numerous points between Chester and Bala. At Pickhill suspension bridge near Bangor-on-Dee the left abutment of the bridge was stabilised by use of wire cages filled with stone and revetments works using dry stone pitching
	Pulford Brook	Channel was resectioned and regraded between Pulford Bridge and the mainline railway bridge to allow tributaries to drain
	Shotwick Brook	Routine dredging with an excavator
	River Terrig	At Leeswood shoals and obstructing timber was removed
	Worthenbury Brook	Flood embankments which had been damaged by floods in the previous winter were restored
Year ended 31st March 1956	General	50 men engaged in general maintenance including use of dragline excavators (examples only are illustrated in the Annual Report)

Year	Location	Description of works
Year ended 31st March 1956	River Alyn	Clearing of gravel beds and the removal of obstructing timber (especially the reach below Rossett Bridge). Above the sewage works at Rossett protective walling was installed on the left bank. Near Harwoods Lane four training groynes were installed. At Rhydymwyn near Mold the left bank was strengthened and protected with stone pitching at the site of a footbridge
	River Ceriog	Routine maintenance and strengthening works to weir and fish pass at Brynkinalt. A section of the left bank below Brynkinalt Hall was strengthened
	River Dee	Clearing of gravel beds and obstructing trees were carried out on various reaches. At Is-y-Coed revetments were installed and various sections of floodbanks were strengthened and restored to prevent overspill during floods. Similar works on 'The Wern' ar Worthenbury (downstream left bank). Bank strengthening at Pickhill bridge (right bank). Mill end weir was removed at Llangollen
	Dungrey Brook	A comprehensive improvement scheme was carried out on the Upper Reaches to prevent flooding
	Worthenbury Brook	From the confluence with the Dee to Brook Farm, Worthenbury, gravel beds and other debris were removed. Ingrowing trees were also removed where necessary and spoil was used to locally increase the height of low spots in the embankments
Year ended 31st March 1957	General	Work was restricted this year due to high flows. Up to 48 men were engaged
	River Alyn	Lower reaches: clearance of gravel beds and shoals and removal of trees and the restoration of low spots in flood embankments. Stone revetments was constructed at Ithell's Bridge, Trevalyn and channel improvement work to increase flow capacity downstream of the bridge
	Coddington Brook	A length was regraded and resectioned to improve flood capacity
	River Dee	Removal of obstructing trees and gravel beds and the restoration of weak spots in the embankment. At Worthenbury a large breach in right bank was filled and faced with stone and the Embankment was raised locally. On left bank below Almere Ferry a stone revetment was built and the floodbank restored. At Pickhill and Althrey Hall obstructing trees and timber were removed

Year	Location	Description of works
	Dungrey Brook	Upstream and downstream of Potter's Bridge (Bangor-on-Dee) regarding and realignment of the channel took place with associated stone revetment work
Year ended 31st March 1957	Garden City Drain, Sealand Main Drain and Shotwick Brook	Extensive clearance and improvement of these 3 channels along various reaches using dragline excavators. Culvert replaced.
Year ended 31st March 1958	General	Up to 53 men involved with removal of obstructing trees and gravel beds and the restoration of weak spots in the embankment. The construction of training walls to check meandering, the weeding of channels and the removal of mud and gravel. 9 draglines, five dumpers, a tractor fitted with a winch for removing timber and boats used etc.
Year ends 31st March 1959	General	Up to 53 men. Most effort concentrated on cutting weeds during the summer in the smaller watercourse. Rest of year involved with maintenance of flood banks and repair to eroded lengths of river bank with stone pitching, clearing gravel shoals and cutting back overhanging trees (increased expenditure on previous year)
Year ended 31st March 1960	General	Up to 47 men involved in summer weed cutting in the smaller watercourse and repairing flood embankments, protecting eroded sections of banks with stone pitching and improving capacity by clearing gravel shoals
	River Llafar and Nant-pant-y-March, Bala	Check dams constructed in these 2 watercourses to prevent erosion of the bed and banks by downcutting (when the lake levels are low)
	Floodbank at Rowen, Bala	Flood bank face protected with substantial stone pitching (wind waves from the lake had caused erosion)
	Sealand Main Drain	Works to sluices etc
	Dolfechlas Brook	Draglines used to clear this watercourse and a meander was cutoff by straightening
	Garden City Drain, Sealand	For a quarter of a mile from the aerodrome the bed and banks have been protected with stone pitching
Year ended 31st March 1961 to Year ended 31st March 1964	General	Up to 45 men working on most watercourses (works are listed comprehensively in Annual report)

Channel maintenance records continue in table below. There is a change to the format of the table to accommodate a change to the format of historic records.

Year	Location	Description of works
Year ended 31st March 1961 to Year ended 31st March 1964	Afon Ceirw (Maerdy Mill) River Dee (Llanndderfel & Gwerclas) Alyn at Mold Alyn at Ithels Bridge Aldford Brook at Churton Dee – Chester to Erbistock Dungrey Brook at potters Bridge	Tree clearance from banks and bed
	Alwen at Glan Alwen Dee at Junction Pool	Repairs to groynes
	Bala Lake at Nant Pant-y-March	Repairs to check dams
Year ended 31st March 1961 to Year ended 31st March 1964	Bala Lake (Ty Isaf bala and Rowen) Alyn at Mold Alyn at Almere Applebys Sluice at Farndon Dee at Isycoed, Worthernbury, Lower Hall, Castletown, Shocklach, Almere	Repairs to flood banks
	Afon Hirnant (Berth Lafar) Alyn at Cooks Bridge Alyn at Gresford	Repairs to banks
	Afon Camddwr Brad Brook at Burton Meadows Black Brook at Padeswood Pool Finchetts Gutter (Chester) Garden City Drain (Sealand) Northern Embankment (Sealand) Sealand Main Drain	Mowing weeds
	River Dee at Refail Isaf Llanfor	Protection with stone picthing
	Aldersey Drain Moor Drain at Burton Meadows Mere Brook at Aldersey Meadows	Dredging
	Tributaries of the River Dee	Removal of gravel shoals
Year ended 31st March 1965 Year ended 31st March 1966 Year ended 31st March 1967 Year ended 31st March 1968	River Dee River Alwen Afon Llafar Afon Hirnant Afon Lliw Afon Twrch Camddwr Afon Dyfyrdwy Llandderdel streams River Alyn Ceriog Balderton Brook Pulford Brook Aldford Brook Worthenbury Brook and numerous tributaries	Removal of obstructions such as fallen trees, gravel shoals and weed growths and the repair of banks

Year	Location	Description of works
Year ended 31st March 1969	Bala District (99 miles): River Dee River Alwen Nant Ffrauar Llandderfel Mill Stream Afon Hirnant Afon Wenffrwd Afon Tryweryn Afon Twrch Afon Glyn Afon Lliw Afon Ceriog	Removal of fallen trees, gravel, shoals and weed growth and the repair of banks. Specifically further river training works and repairs to gabions, groynes and check dams.
	Chester District (241 miles): River Dee Sandycroft Drain Balderton Brook Fingerpost Gutter, Shotwick Brook (east), Shotwick Brook (west). Garden City Drain, Sealand Main Drain, Manor Drain, Waterloo Drain, Thornleigh New Cut, Finchetts Gutter, Pulford Brook, Stringers Brook, Moor Drain, Brad Brook, River Alyn, Black Brook (Padeswood), Dolfechlas Brook, Plowley Brook, Edgerley Brook, Mere Brook, Goldborne Brook, Keys Brook, Mill Brook (Tattenhall), Coddington Brook, Dungrey Brook, River Ceriog, Black Brook (Erddig), Worthenbuty Brook, Flannen's Brook, Dolennion Brook	Removal of fallen trees, gravel, shoals and weed growth and the repair of banks
Year ended 31st March 1969	River Dee Erbistock to Chester	Repair of flood embankments caused by floods in 1964, 1965 and 1966.
Year ended 31st March 1970	All locations as per previous year	All works as per previous year
Year ended 31st March 1971	All locations as per previous year	All works as per previous year
Year ended 31st March 1972	All locations as per previous year	All works as per previous year
Year ended 31st March 1973	All locations as per previous year	All works as per previous year
Year ended 31st March 1974	All locations as per previous year (with the addition of Cynwyd Ditches)	All works as per previous year