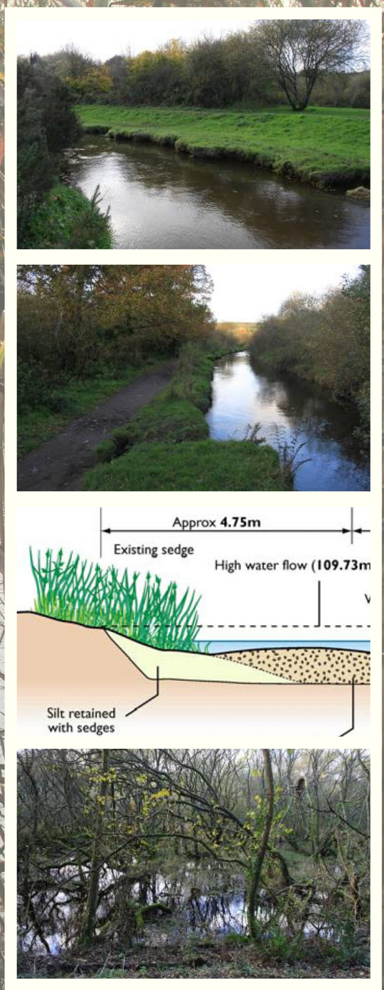
The National Trust
Penrose Estate

Hydrological Study to Inform the Future Management of Loe Valley Carr SSSI

February 2014



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PENROSE ESTATE, WEST CORNWALL
HYDROLOGICAL STUDY TO
INFORM MANAGEMENT OF THE
LOE VALLEY POOL AND CARR SSSI

Penny Anderson Associates Limited
'Park Lea'
60 Park Road
Buxton
Derbyshire
SK17 6SN

Project Manager
Gene Hammond, Principal GIS Consultant and Hydrologist, BSc (Hons), MSc

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This project has been undertaken in accordance with PAA policies and procedures on quality assurance.

Signed: Gene Hammond

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1. INTRODUCTION

1.1 Penny Anderson Associates Ltd (PAA) was commissioned by the National Trust (NT) to complete a hydrological study of the Low Valley Carr, which lies on the lower reaches of the River Cober, south of Helston, West Cornwall.

Scope of this Report

1.2 The specification states that a hydrological study is required, which should build upon both existing and newly-acquired information in order to inform the future management of Loe Valley Carr, on the River Cober, downstream of Helston, West Cornwall. The site forms part of the NT's Penrose Estate, a mixture of rich farmland and woodland around Loe Pool, a natural lake at the confluence of the River Cober and the English Channel.

1.3 This report details the investigations completed by PAA and aims to provide a clearer understanding of the hydrology of the Low Valley Carr. The programme was broken down into a number of key tasks, which were in brief:

- Data scoping and desk study. This involved the review of existing reports, including those related to existing flood defence strategies and infrastructure, hydrological data and information concerning the nutrient levels and sedimentation, the cause of high nutrient levels and the impact on water quality and habitats.

- Site surveys. This included a site walkover survey recording and photographing features, taking local level data and cross-sections of the channel and riparian corridor and completing a hydrological assessment of the River Cober and the wet woodland.

- Data analysis and interpretation. This has involved the analysis of available time series hydrological data for the site and its immediate surroundings. A second phase of analysis has involved a GIS-based study using LiDAR topographic data and GIS analysis.

- Formulation of management options for habitat maintenance and improvement. These mitigation measures were informed by the results of the previous key tasks.

1.4 It is understood that the site has a long history of anthropogenic impact and change, including historical metals mining within the catchment (with associated sediment issues). The unique geography of the Cober Valley, Loe Pool, Loe Bar, combined with historical sedimentation has led to the system being particularly prone to flooding, especially when high rainfall and high tides combine. For these reasons, the River Cober has been channelised, de-silted and straightened in recent years primarily for flood defence purposes.

1.5 The tender brief states that the long-term management objectives for the site include:

- The restoration of a hydrological system within Loe Valley Carr that is as natural as possible within the constraints imposed by the Helston flood defence strategy.

- The implementation of a management strategy that provides conditions for a varied suite of semi-natural wet woodland and associated open water habitats.

- Meeting Natural England’s (NE) Conservation Objectives for this section of the Loe Pool SSSI.

- As far as possible within the constraints imposed by the Helston flood defence strategy, to play a role in controlling transfer of nutrients and sediment into Loe Pool.

- The continuing and possibly enhanced provision of public access along a network of trails, including circular routes.

1.6 Within the framework outlined above, it is understood that the specific project objectives are defined as follows:

- To provide an understanding of the hydrology of Loe Valley Carr that can be used to inform its future management.

- To seek to influence the development of the new Helston flood defence strategy in ways that enable improvements to the hydrology and wildlife of this section of the River Cober and surrounding valley carr.

- To outline and review options for the future management of this section of the Cober Valley that would further the site objectives provided above; this work to be carried out in the context of the developing Helston flood defence review and as far as possible to seek to improve connectivity between the River Cober and this section of its floodplain.

- To consider rates and patterns of sediment/deposition/erosion and their likely impact on the carr and lake under the hydrological options explored.

- To provide recommendations and proposals for the way ahead.

Background

1.7 The Loe Valley Carr forms part of the NT's Penrose Estate. It is at the head of the Loe Pool and within the wider catchment of the River Cober. The River Cober is approximately 16km in length and drains an area of 43km^2 rising at 250mAOD to the north of the town of Helston. It flows to the south passing through Helston and the Loe Valley before entering the 50ha freshwater lake of Loe Pool, which has formed behind Loe Bar, a coastal sand and shingle bank that closes the mouth of the drowned river valley (ria). The Loe Carr Valley forms part of the Loe Pool SSSI that incorporates the Pool and the shingle bar. The site and its surroundings are illustrated in Figure 1.1.

1.8 The Loe Valley Carr covers an area of 20ha and consists largely of grey willow (*Salix cinerea*), alder (*Alnus spp*.) with common reed (*Phragmites australis*) locally dominant (NVC W2, wet woodland). Siltation along the valley and the formation of the wet woodland habitat is attributed to tin miming in the late 19th and 20th Centuries in the upper catchment and high sediment loading in the River Cober and its tributaries of the Rivers Medlyn, Releath and Trevano. Historic maps from 1771 to the present record the extension of the floodplain and the establishment of the wet woodland. It is a relatively young feature of the valley but it has high biological interest representing one of the largest Wet Woodland UK BAP Priority Habitats in West Cornwall.

1.9 As part of flood alleviation works for Helston, the River Cober that flows through the carr, was straightened and channelised in 1946 and considerably reprofiled in 1988. This involved de-silting and bed lowering downstream of Zachary's Bridge to Loe Pool. The river was subsequently de-silted in 1992 and 1998. This has resulted in the loss of 'normal' river function and a reduced capacity to meander. The channel does not display the characteristic sinuosity associated with natural river systems e.g. riffle and pool sequences, erosional and depositional landforms indicative of active fluvial processes. Confined for the most part to the incised channel the river has been hydrologically disconnected from its floodplain.

1.10 Larger flood events do result in overbank flow but there is concern that the reduction in overbank flooding following the channel alignment and reprofiling of the River Cober has lead to accelerated drying of the carr. A survey by the NT (1989) reported evidence of drying and the consequent increase in colonisation by oak (*Quercus* sp.) and sycamore (*Acer pseudoplatanus*). Short hydrological studies by students of Plymouth University also concluded there is drying, more particularly in the summer between the boardwalk and Loe Pool

- The NT report (2009) makes a number of management recommendations that are considered later in this report. In short, it sees the restoration of a more natural river system and flooding regime as desirable, and recognises that a whole catchment approach is needed to address the underlying problems of nutrient enrichment and sediment mobilisation to watercourses, acknowledging that an improvement in water retention in the catchment would also contribute to flood risk management.

1.11 Some more recent changes in the river management regime have benefited riparian and in-channel habitats. This includes reaching agreement with the EA to reduce bankside management so that trees and shrubs have been allowed to colonise the river margins and fallen trees have been left in the channel. This has added coarse woody debris, increase flow pattern variety and deflected flow to banks to promote erosion. There has also been a reduction in de-silting. Nevertheless, the channel remains largely straight, incised with steep banks with little submerged or emergent aquatic vegetation. This is particularly the case for the reach between Zachary's Bridge and the footpath/boardwalk mid way down the carr.

Current Maintenance Agreements

1.12 It is understood that the EA supports the principle of identifying habitat improvement options for the Loe Valley Carr. Recent communication with the EA (January 2014, Skinner et. al. pers. comm.) led to the release of the following statement from the Agency:

"...It is (the Agency's aim) to reduce maintenance to the lowest level possible commensurate with the our flood risk management duties.

We believe this is where we have been with our interim regime for the last 7 years. The two issues with this regime that need to be revisited is the channel erosion along right bank where it is beginning to affect maintenance access, and the fallen trees that have been allowed to remain in the channel in the lower section of the Carr.

The regime we have had in place has dramatically reduced the amount of dredging required, indeed had the fallen trees been removed the channel would have been able to sustain its capacity for another 5 or more years before a review was required. Removal of the fallen trees may self cleanse the channel again. It should however be noted that de-silting may be required again at some time in the future particularly as the hydraulic gradient reduces due to the delta extending into the pool. (Note: A summary of the current Maintenance Schedule is included in this report as Appendix 5).

The modelling associated with the review of the Flood Risk Management scheme has yet to be completed so we are not yet able to make a final comment in this regard..."

Helston Flood Risk and Existing Catchment Management Plan

1.13 Dinsdale 2009 provides a succinct summary of the key issues concerning the River Cober and its relationship with the Loe Valley Carr SSSI. This summary is used here to set the overall context of the project:

1.14 *..."Managing flood risk for Helston continues to rely on a traditional engineered scheme. The Environment Agencies proposed changes to the River Cober maintenance regime are likely to bring benefits to the quality of the riverine and riparian habitat within the lower reaches of the River. A number of additional alterations to the river maintenance regime are recommended to further assist a natural recovery of the River's form and function.*

1.15 *There has been a recent shift in national flood policy, away from a framework based on flood protection towards one based on sustainable catchment-scale flood risk management. The main drivers are the EU Water Framework and Flood Directives. At the national level, the EA recognises the need to work with natural processes to successfully manage flood risk.*

1.16 *It is suggested that rehabilitation of the River Cober now requires a two-pronged approach, based around the concept of assisted natural recovery. Good progress has been achieved towards reach-based restoration activities and these should continue alongside a whole river catchment approach, which is recommended to resolve river restoration issues at source as far as possible.*

1.17 *The engineered approach to flood risk management in Helston continues to meet the original design brief (EA, 2007b). The lower River Cober delivers flood waters rapidly and efficiently through the town and into Loe Pool. However, these rapidly delivered flood waters carry high levels of nutrients and fine sediments into the Pool. Within a naturally functioning river system a proportion of these sediments and nutrients would be deposited within the floodplain. The flood alleviation scheme, therefore, has a negative impact on the water quality of the River Cober and exacerbates the eutrophication of Loe Pool (Haycock & Vivash, 1999). The physical disturbance of the de-silting maintenance is also detrimental to riverine and riparian habitats and species (Wilson & Dinsdale, 1998; Haycock & Vivash, 1999; Stewart, 2000). The Helston flood alleviation scheme, therefore, facilitates the delivery of nutrients and sediment into the Pool and as a consequence hinders progress towards the LPCMP environmental targets and objectives.*

1.18 *Given the current policy and research situation, a two-pronged approach is recommended to reconcile flood risk management for Helston with the rehabilitation of the River Cober and Loe Pool. The ongoing, reach-based restoration activities should continue and alongside the development of a whole river catchment initiative, based around the concept of assisted natural recovery.*

1.19 *The Loe Pool Catchment Management Plan Review 2003 recommended the development of a river floodplain restoration scheme for the lower reaches of the River Cober below Helston. This river restoration scheme included the development of an alternative management strategy for this section of the River Cober (Dinsdale 2003).*

1.20 *It was expected that opportunities to progress this management measure would present themselves through the full review of the Helston flood alleviation scheme (from Lowertown to the Loe Bar outfall) proposed in 2003. However, this flood alleviation scheme review was put on hold and has still not yet been delivered in its final form, though is under review at the present time (January 2014).*

1.21 *Some environmental improvements have been incorporated into the EA's river maintenance regime for the lower Cober since the last major river de-siltation in 1998. A revised river channel maintenance document was released in draft format March 2007 (EA, 2007b) and is referred to several times in this study. The changes proposed by the EA within this document were generally welcomed by the Forum but a final version of the document has yet to be agreed between the EA, NT and NE. NE has not yet been given notice formally of the maintenance regime under section 28H of the Wildlife and Countryside Act. The NT and NE have been working with the EA towards a mutually beneficial end point, meeting regularly to discuss the review of River Cober maintenance and wider issues.*

1.22 *A number of changes to the maintenance regime have brought, or are likely to bring in the near future, benefits to the quality of the riverine and riparian habitat within these lower reaches of the River. The last reach of the River (0-665m from Loe Pool; below the last footbridge and boardwalk) has seen substantial in-channel and bankside habitat improvements, created by trees and shrubs extending to the waters edge and reaching over and into the river channel itself. This natural recovery of the lowest reach of the watercourse has been assisted by the reduced frequency of de-silting and cutting of bank-side vegetation in recent years. The EA's (2007b) proposal to reduce the level of de-silting maintenance in the second reach (from 665m to 1150m from Loe Pool; downstream of the two-stage channel and predominantly on NT property and within the SSSI) is also seen as a very positive step forward.*

1.23 *There are a small number of additional alterations to the river maintenance regime which would further assist a natural recovery of the form and function of the lower reaches of the River, whilst operating within the confines of both the current Helston flood alleviation scheme and the current nutrient and sediment loads carried by the River The next steps to take which would deliver best benefit to in-channel and bank-side habitat are:*

- *Ensure channel de-silting is kept to a minimum. Within their draft maintenance plan, the EA propose to maintain de-silting, cutting vegetation and clearance of trees and debris close to Zachary's Bridge (third reach, 1150m to 1650m from Loe Pool; within and directly adjacent to the CC amenity area), but reduce active maintenance on NT land. The river nearer Loe Pool will become relatively undisturbed: within the lower reach (0m to 665m from Loe Pool) river bed levels will be allowed to increase to 0.4m above 1988 design levels; and within the second reach (665m to 1150m from Loe Pool) the river bed levels will be allowed to increase to 0.2m above 1988 design levels (EA, 2007b). These limits will mean that the EA may not have to remove silt for some years over these two lower reaches and the reduced de-silting frequency will assist the restoration of habitat stability and permit habitat recovery.*

- *Allow and encourage the establishment of tree cover on both bank sides within the second reach (665m to 1150m from Loe Pool). This presents a potential point of conflict with the draft River Cober maintenance plan. Over-hanging tree canopies would enhance the river habitat quality, shade the watercourse and lower water temperature in the summer and tree roots would improve bank stability (Haycock & Vivash, 1999; Skinner, 2005). Flood risk modelling has illustrated that increased 'roughness' of this section of the river (with roughness defined as the growth of long grass or reeds, scattered saplings and vegetation) has no effect on flood risk upstream of the A394 County Bridge (EA, 2007b). However, the EA aim to continue to cut back woody vegetation on the right bank*

- *Retain woody debris in stream where this does not increase flood risk. The importance of woody debris to the healthy functioning of freshwater ecosystems is becoming increasingly recognised, with benefits including: stabilising river banks and beds by resisting and deflecting flows, adding habitat complexity to the channel, and enhancing the process of change in channelized rivers and their floodplains (Mott, 2005; Sear,* *2007). Woody debris has traditionally been seen as a nuisance and woody debris dams are often still referred to as 'blockages', however, research has shown that the flood impacts of both large woody debris (entire trees, large limbs and branches) and coarse woody debris (accumulation of smaller branches, twigs and leaf litter) have often been misunderstood or exaggerated in the past. Despite the installation of additional litter screens and improved street cleaning in Helston, the accumulation of litter (including plastic bags, cans, bottles) in association with the woody debris within this watercourse remains a potential issue (Operations Delivery Technical Support, EA, comment on Draft, 5 May 2009). Awareness of this issue could be raised within the Town as part of the community education programme.*

- *Allow natural river processes, including bank erosion, to develop unhindered. As an interim measure, low willow 'fences' have been put in place around the collapsing sections of riverbank. These are considered to be an ideal solution, improving public safety by guiding pedestrians around the edge, increasing bank-side tree cover but not restricting natural river processes.*

- *Continue to seek Local Nature Reserve (LNR) designation CC continues to lead on the creation of a LNR, working in partnership with HTC. It is recommended that this action continues to be progressed following the formation of the new unitary authority in April 2009.*

1.24 *It is considered that these recommended additional alterations to the river maintenance regime are unlikely to have an impact on flooding in Helston (see EA, 2007b). The EA have investigated the impact of a variety of different factors on flood levels, including channel bed level, growth of vegetation and size of channel. It has been demonstrated that flood levels in Helston, upstream of the A394 County Bridge, are relatively insensitive to change within the River Cober bed and channel where it flows through the willow carr habitat on NT property, but more sensitive to changes closer to Zachary's Bridge. The reason given for this is that a significant proportion of the flood flow is carried, albeit slowly, through the carr (EA, 2007b).*

1.25 *It is recommended that the NT consider adopting their riparian owner's management rights along the lower Cober, and take responsibility for vegetation cutting along the first and second reaches (from 0m to 1150m from Loe Pool). With NT staff based within the Penrose Estate, they may be in a better position to deliver the more sensitive vegetation management required to facilitate the River's assisted natural recovery.*

1.26 *There is a long documented history of the desire to see improved connection between the river channel and the river floodplain (Wilson & Dinsdale, 1998; Haycock & Vivash, 1999; Dinsdale, 2003). Within a natural river system the silt and nutrients carried by a river in flood are deposited within the river's floodplain. Reconnection of the River Cober's floodplain to its channel would allow these natural processes to be restored and this could deliver substantial water quality improvements for Loe Pool. However, such use of the floodplain's ecosystem services must be sustainable in the longer term.*

1.27 *The gross levels of silt and nutrients carried by the River in flood, and the potential impact of directing these into the Loe Valley willow carr have been a concern in the past (Dinsdale, 2003). Proposals to release flood water from River Cober channel into the Loe Valley willow carr were put on hold in 2003 until P-stripping at Helston STW was in place (Dinsdale, 2003).*

1.28 *Following the installation of P-stripping plant at the STW, the water quality of the River Cober, and particularly the level of sediment carried, continues to be of some concern. When released into the willow carr, the river water may have an impact on the habitat quality and ecosystem services provided by the carr. The high nutrient status of the river flood waters is likely to* *encourage the growth of ruderal species such as nettle (Urtica dioica), broad-leaved dock (Rumex obtusifolius) and hemlock water-dropwort (Oenanthe crocata). The high silt content may affect flood storage capacity; increasing silt levels across the carr by 0.4m would be likely to have a significant impact on flood risk in Helston (EA, 2007b). However, taking this into consideration, it remains highly desirable from a nature conservation perspective to re-wet the carr (J. Lister, NT Regional Nature Conservation Advisor, pers. comm.).*

1.29 *Skinner (2005) put forward a recent proposal to lower short sections of the riverbank and allow flood flows to pass out into the floodplain, in order to trial the re-establishment of river and floodplain interactions. This proposed location for this trial is very close to the mouth of the River Cober, where the carr is already in close hydrological links to the lake (see Barratt, 2000).*

1.30 *The environmental outcomes for the WFD RBD Management Plans include reducing the environmental impact of flood defence schemes and river maintenance regimes. The actions prescribed to deliver this outcome in the South West include increasing habitat morphology and diversity and improving connection between rivers and their floodplains. This project will, therefore, contribute towards the SW WFD targets" (extracted from Dinsdale, 2009). Again, refer to Appendix 5 for a summary of the current EA Maintenance Schedule for the River Cober downstream of Helston to Loe Pool".(Dinsdale 2009)*

1.31 The work presented here builds upon the existing body of information and attempts to provide a greater understanding of the hydrology of the site, together with more detailed options for sustainable management now and into the future.

1.32 It has been shown in recent years that the capacity of the current outfall at Loe Bar is inadequate for very high flows and high pool water levels experienced during extreme storm events and very prolonged wet periods. In these conditions, water levels back up in Loe Pool and combined with flow coming off catchment may contribute to localised flooding in the St. John's Close area of Helston. Proposals have been put forward to increase the rate at which water can drain from Loe Pool, hence controlling water levels and flood risk upstream, by means of a new, higher capacity outlet pipe, evacuating flow from Loe Pool into the sea (EA 2013 Cober Appraisal - Long List of Options, Option 8) . Other, similar options include the maintenance of a permanent breach through Loe Bar itself (Appraisal Options 6 and 7).

1.33 All of these options are considered either potentially too expensive or else unacceptable in terms of environmental sustainability and so the Cober Appraisal is currently reviewing other options for flood risk management.

1.34 Increasingly, there has been a change in focus of flood risk management from a downstream, engineering approach, to one of upper catchment management, now aptly termed 'upstream thinking'. Several high profile catchment flood management demonstration projects are in progress nationally which were conceived to test the idea that flood risk can be mitigated by changes in land management in upper catchment areas, whilst simultaneously delivering multiple benefits in terms of habitat and biodiversity enhancements, improved agricultural practice and soil resource conservation.

1.35 Three demonstration projects are currently in progress:

- The Defra Multi-Objective Flood Management Demonstration Project, the National; Trust Holnicote Estate, North Somerset;
- The Defra Making Space for Water Project, the Upper Derwent Catchment, North Derbyshire and South Yorkshire Supported by the Environment Agency and Moors for the Future Partnership; and,

- The Slowing the Flow at Pickering Project, Vale of Pickering, North Yorkshire, supported by the Forestry Commission.

1.36 An additional project of note has recently been concluded, where a farmer-led catchment approach to sustainable catchment management in the uplands has been taken. The project has examined in detail the beneficial effects on re-naturalised hydrological processes and flood risk on the Pontbren Catchment, Wales.

1.37 At a policy level, the benefits of adopting an upstream approach to flood risk management are considerable and now no longer in dispute (Pitt Review 2008, Flood and Water Management Act 2010). However, this approach requires a unified approach to land management over wide areas of land with multiple owners and so is often notoriously difficult to achieve.

1.38 This is also the case for the Cober Catchment, where many farms produce crops and rear livestock over large areas of the upper catchment. Recent intensification of agricultural practices has almost certainly led to an increased flood risk at Helston, a pattern observed over many catchments nationally. An example of this is the NT's Holnicote Estate on the fringes of Exmoor near Minehead, North Somerset. Here, the low lying villages of Bossington and Allerford, in Porlock Bay frequently flood in high flows, a situation exacerbated by streamflow ponding up behind a large shingle beach, which acts as a hydraulic barrier to flow in an almost identical manner to that of Loe Bar. Again, a combination of high stream flow and high tides leads to extensive inundation in the villages, a problem which is currently being tackled by novel land management approaches.

1.39 As no such option is currently available or practical for the Cober catchment, other methods have to be sought and it is critical that any proposed management for SSSIs that are either close to or associated with flood-prone watercourses, are managed in such a way as to be complimentary to both existing and future flood defence schemes.

1.40 It is within the context of this ongoing review and in light of previous studies and earlier work, that this hydrological study to inform the future management of Loe Valley Carr SSSI is set.

2. SCOPING AND FIELD SURVEYS

Data Scoping

2.1 An initial data scoping and desk study was undertaken in order to collate and review all existing, relevant information regarding the SSSI and its surroundings. Particular importance has been paid to literature that describes the present processes, form and behaviour of the main river (River Cober), valley carr and riparian corridor, with respect to hydrology, flooding and sediment transfer.

2.2 The historical aspects have also been considered, including changes in land and site use and management, such as channel straightening, regular de-silting and the construction of a two stage flood storage channel downstream of Zachary's Bridge as part of flood alleviation works in 1988. The affects of mining and other recent historical land use activities within the catchment and the effect this has had on the valley carr were also considered.

2.3 GIS data has also been assembled, together with hydrometric data and hardcopy reports, to build up a picture of the SSSI and the key controls on hydrology.

2.4 Figure 1.1 shows the SSSI in its geographical context, including its proximity to the town of Helston, the Loe Pool and Loe Bar coastal shingle bar, which blocks the entrance to the pool and largely controls the hydrology of the basin, together with the artificial outfall through Loe Bar.

Cober Valley Geology and Soils

2.5 Solid geology of the study area is identified as the Devonian Mylor Slate Formation i.e. slate and siltstones with some areas of metamorphosed hornfelsed slate and siltstone within the catchment. There are some igneous intrusions (Devonian to Carboniferous) mainly microgabbro and basaltic dykes and sills (BGS 2013).

2.6 Superficial geological deposits are confined to the river valleys only and consist of Quaternary alluvium (clay, silt, sand and gravel). This is almost certainly the principal deposit underlying the Loe Valley carr.

2.7 Superimposed on top of these recent Quaternary deposits are anthropogenic deposits associated with mining upstream in the Cober Catchment. These consist of small gravels and fines produced by mining activities and rock milling (crushing) for metals extraction.

2.8 Soils in the immediate catchment are identified as predominantly Soil Association 'Denbigh 1' – well-drained fine loamy and fine silty soils over rock. Although these will produce fine silty sediments into the river system. The alluvium and recent mining deposits are of greater relevance to this study (Mackney at al 1983).

2.9 Lying on top of the alluvium deposits, a very shallow and variable layer of wet peat has very recently formed in areas of the willow carr, from the in-situ decomposition of carr vegetation since vegetative succession.

Topography and Hydrology

2.10 Figure 2.1 shows the 0.5m resolution LIDAR digital terrain model (DTM) dataset, which has been used to illustrate 'bare' surface topography across the entire site, running up to the break of slope where the floodplain meets the valley sides. The LIDAR DTM clearly illustrates the microtopography of the site and shows relict channel features as well as more elevated areas of the woodland carr, where drier conditions are experienced (refer to Section 3).

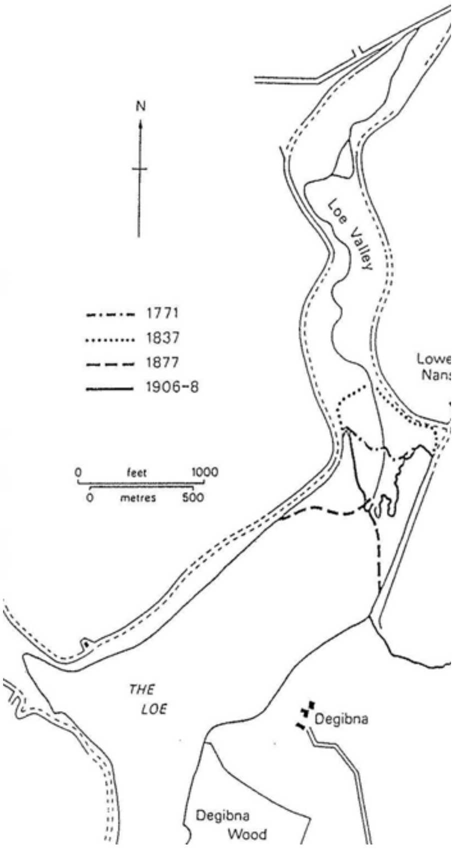
2.11 Figure 2.2 illustrates the major controls on surface hydrology, gained from site walkover surveys and the DTM. The floodplain area is broadly classified in this study into areas of hydrological 'similarity' based on topography. Also, as the River Cober is channelised and over-deepened, the hydrological connectivity between main river and floodplain has been lost to a large extent and so other sources of surface water that 'feed' the carr become very important. These additional sources of flow are illustrated in Figure 2.2 and represent flow from adjacent sub-catchments that feed directly into the valley floodplain at several locations. The walkover survey determined that a significant volume of water is supplied to the carr from these sources, especially during the winter months. These water sources are important in that they represent opportunities to re-distribute or divert surface water to areas of the carr that may require it. They are also important in the context of nutrient budget as represent one of the primary sources of nutrient enrichment to the valley carr and Loe Pool itself. Water quality sampling for nutrients has not formed part of this study. However, recent survey work has been undertaken on the Pool and the feeder streams and is presented as the Loe Tributary Sampling Survey, which was undertaken by Brey Utilities (2007-2008) and presented by McCaffrey 2008. In this study, six streams were identified as supplying water to Loe Pool (including the River Cober itself), of which only two notable streams supply water directly to the valley carr itself (Nansloe and Degibna).

2.12 Figure 2.3 shows the locations of existing Environment Agency hydrometric monitoring stations, together with the GPS locations of notable features, identified during the fluvial geomorphological and hydrological walkover surveys. It may be noted that many of the latter are restricted to more accessible areas of the carr woodland, as the very dense vegetation and saturated ground conditions at the time of survey made access to large areas of the carr extremely difficult. Taking the shallow gradient of the River Cober into consideration, together with the proximity of gauging stations, only two hydrometric gauging stations were deemed of direct relevance to this study. These were the stage and flow meter on the River Cober at Helston boating lake (now called Helston Gauging Station) and the Loe Pool water level (formerly measured at the Loe Pool boating lake, latterly measured at the Loe Bar outfall, via EA monitoring equipment).

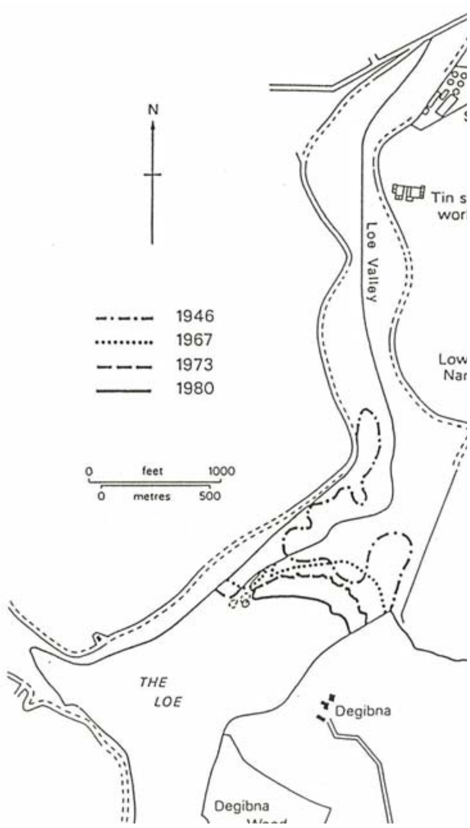
2.13 In terms of existing habitats, Figure 2.4 illustrates current known habitat type and condition, as determined in the most recent NT habitat survey (NT Biosurvey). The Phase 1 Habitat survey records the valley carr as dense scrub, whilst a fringing swamp habitat is recorded at the end of the valley carr where the floodplain meets Loe Pool.

2.14 As part of this scoping process, historical maps have been reviewed that show the evolution of the valley carr in recent times (refer to Figures 2.5a and 2.5b). This work, together with analysis of GIS datasets and walkover surveys, has enabled the identification of historical channel features that have been in-filled or lost, together with other features of interest. Figures 2.5a and 2.5b shows that the valley floodplain developed primarily due to the deposition of sediment fines from mining activity in the upstream catchment and that by 1771, the valley was largely infilled with sediment. Figure 2.5b shows that the downstream end of the floodplain shifted position over many years until achieving its present position. Evidence from the study by Shoulders (1999) suggests however, that the woodland carr habitat is a comparatively recent development on the site, with some recorded evidence to suggest that the current wet woodland has developed from 1920 onwards, making the site unusual in this respect.

2.15 a



2.16 b



Figures 2.5a and 2.5b Historical Maps indicating the Evolution of Loe Valley Floodplain and Woodland Carr through time 1771-1980. (After O'Sulliven and Chord unpub.)

2.17 The data review and scoping has also considered the available time series hydrological data related to the site. The list of key datasets supplied are included in Section 3 and include river levels and flow data flow for the River Cober at Helston and other accounts of local flooding (magnitude, duration, frequency etc.). Figure 2.3 illustrates the locations of the hydrometric monitoring stations.

2.18 The final element of this scoping and review process has examined the current flood defence strategy for Helston and how this may have affected the site over time. The potential role of any future flood defence strategy (EA Cober Appraisal 2013) has also been considered and is reported on later in this report.

The River Cober

2.19 The lower reaches of the River Cober, from just above St. John's Bridge have been heavily engineered in order to alleviate flooding in the town of Helston. The river was straightened and channelised in 1946 and substantially re-profiled in 1988 (Wilson and Dinsdale 1998). As a consequence the river system does not function naturally. The River cannot meander across its floodplain through the natural processes of erosion and deposition and it is confined to its channel, save during occasional extreme flood events. The current flood alleviation scheme requires regular de-silting of the river below Helston; since 1988, de-silting has been carried out on three occasions (EA 2007).

2.20 As stated in many earlier reports relating to the site (refer to Dinsdale 2009), the canalisation and re-profiling of the River Cober channel has compromised the ecological function of the watercourse and separated the river from its floodplain. It is suspected that this in turn has led to an accelerated drying of certain areas of the valley carr and a subsequent change of vegetation.

2.21 Some more recent changes in the river management regime have benefited riparian and in-channel habitats. This includes reaching agreement with the EA to reduce bankside management so that trees and shrubs have been allowed to colonise the river margins and fallen trees have been left in the channel. This has added coarse woody debris, increase flow pattern variety and deflected flow to banks to promote erosion. There has also been a reduction in de-silting. Nevertheless, the channel remains largely straight, incised with steep banks with little submerged or emergent aquatic vegetation. Knight (2003) reports that a consequence of low physical diversity has been the relatively reduced diversity of invertebrate fauna recorded.

Loe Valley Carr - A Review of Existing Evidence of Drying

2.22 W2 Wet woodland carr requires a very specific hydrological regime to be sustained. The principal requirement is for a water table at or near ground level throughout the year. The English Nature 1997 publication "Water Level Requirements of Selected Plants and Animals" states that wet willow carr requires an annual soil water table level at or around surface level, with an absolute deviation, both above and below ground level of no more than 0.1 metres.

2.23 It is suspected that channelisation of the river channel in the 1940s, combined with successive, repeated de-silting has over-deepened the channel bed so disconnecting the river from its floodplain and causing the carr to dry out in places. This in turn is impacting the vegetation across the site as carr, which requires perennially wet conditions.

2.24 Lower magnitude, higher frequency rainfall events which at one time may have overbanked, causing localised ponding across the carr, may now be greatly restricted, with associated drying out of the site. However, it is likely that the pattern is considerably more complex than this and so the scoping would provide the evidence baseline into which evidence gained from site survey may be added.

2.25 There is concern that the reduction in overbank flooding following the channel alignment and re-profiling of the River Cober has lead to accelerated drying of the carr. A survey by the NT (1989) reported evidence of drying and the consequent increase in colonisation by oak (*Quercus* sp.) and sycamore (*Acer pseudoplatanus*). However, a repeat survey in 1996 recorded no significant change in community composition or development dry ground flora such as gorse and brambles and the NT report (2009) reiterates that oak and sycamore incursion does not appear to be accelerating and may have stopped.

2.26 Short studies by students of Plymouth University involved the installation of a network of dipwells in the carr, upstream and downstream of the boardwalk built by the NT in 1987 to improve public access (Collins 1999, Shoulders 1999, Barratt 2000). The duration and frequency of monitoring water table fluctuations was limited and longer and more detailed recording would be needed to check the findings (refer to Section 3). These studies concluded that drying was more apparent in the carr woodland between Zachary's Bridge and the boardwalk and less pronounced between the boardwalk and Loe Pool. The water table could be related to rainfall events and the upper section was particularly prone to drying in the summer.

2.27 Examination of the LIDAR DTM data for the willow carr (refer to Figure 2.1) clearly shows that the upper section of the carr has a slightly more variable and generally higher elevation than the lower section, which is almost flat in many places. It is perhaps these higher, 'drier' areas where some evidence of vegetation change was originally noted.

2.28 The NT report (2009) makes a number of management recommendations and states that 'Restoration of a more natural fluvial system remains highly desirable.' It recognises that a whole catchment approach is needed to address the underlying problems of nutrient enrichment and sediment mobilisation to watercourses acknowledging that an improvement in water retention in the catchment would also contribute to flood risk management. This is also emphasised in the Loe Pool Catchment Management Project 2009 Review (Dinsdale 2009). The NT report highlights the need to achieve the management objectives through:

- Continuing to seek to influence the EA over management of the river and its environs, in particular to restore the river to a more natural course and to facilitate more wetting of the carr (as far as it is compatible with legitimate flood risk management work) as per the recommendations in the Loe Pool management Plan review (Dinsdale 2009).

2.29 A review of the only available water table data, that collected and presented by Collins (1999) and subsequently added to by Barratt (2000) suggests that for the dipwells installed in the upper section of the valley carr at least, groundwater levels drop significantly below 0.1m of the surface for at least three to four months of the monitoring year, despite rainfall and flood water inputs to the system. This is illustrated in Figures 3.3a to 3.4e below. Here, water table conditions in the upper section of the carr are observed as dropping to some 0.3-0.4m below ground level for a several month spell in the monitoring year. The same trend is observed in the dipwells of the lower section of the carr, but the decrease in water table levels is not sufficient to change the habitat conditions needed to sustain wet willow carr woodland and this data, coupled with the inundation maps illustrated in Figures 3.5, provide strong evidence that hydrological conditions in the lower downstream section of the carr remain optimal for the maintenance of a valley carr habitat.

2.30 Thus available data for the site does suggest that the upstream section of the carr is most likely subject to a long-term, drying regime that will probably cause vegetation change if left unchecked.

2.31 It is these areas that should be targeted with the proposed water management options, as presented in Section 4 of this report and illustrated in Appendix 3. These methods will provide a means by which water can be introduced to areas of the carr far more frequently and left to stand and drain, under natural flow, though the carr itself or back into the main river channel.

2.32 Despite the available data only being recorded for a short time period and over one year, it is the only quantitative evidence that interpretations can be based on at this time. Conclusions and recommendations based on this data, therefore, have to be treated with caution and one of the key recommendations from this study is the establishment of a suitable, robust, long-term hydrological monitoring programme for the valley carr. For example, the observed decreasing water table levels, as presented by Collins (1999) and Barratt (2000) are in all likelihood part of a seasonal cycle of water table levels and not part of some long-term, structural trend in drying across the site.

2.33 In the upper reaches of the carr, floodplain topography is more variable, with some areas raised significantly from the main river channel, whilst long sections of the straightened Cober channel have raised berms or levees, produced from the de-silting of the main channel. In many places, these act as a hydrological barrier between the channel and the adjacent floodplain carr, even at bankfull discharge when water should theoretically be spilling out of the channel and onto the floodplain.

2.34 For these reasons, water control management structures are proposed, which may be used to resolve this issue without the need for large-scale, expensive groundworks on site. The design of these features is discussed in more detail in Section 4 and Appendix 3.

Field Survey

2.35 This study has to inform the future management of the Loe Valley Carr. As a result, surveys needed to be comprehensive, accurate and cover both the site and its immediate surroundings in order to be relevant.

2.36 In total, three surveys were undertaken. These included:

- A geomorphological survey and fluvial audit via walkover, including a photographic survey of key locations and features of interest (presented in Appendix 1);

- A walkover hydrological survey including surface hydrology, flow direction, springs and issues etc.(refer to Appendix 1 for photographic record of survey);

- A levelling survey at key locations down the River Cober, which examined the relative elevations between channel depth, water level and the level of standing water in the adjacent valley carr (locations shown in Figure 2.3 and survey details can be found in Appendix 2).

2.37 The field surveys were used to assess the current hydrological and geomorphological state of the river and identify historical fluvial features, as well as those areas where features may be added or else re-instated into the system in order to achieve a more natural flow through the riparian corridor. Several notable features were identified and these will be incorporated into the options for management later in this report.

2.38 A critical element of the field survey was to gain accurate water levels data for key locations downstream of Helston, though the Loe Valley finishing at the Loe Pool. Water levels are critical to understanding the possible effects of any floodplain naturalisation. As no accurate levels data has been supplied for use in the project, local levels were recorded at key locations, allowing the absolute difference in elevation to be calculated between river bed, water level and the level of the floodplain carr at that point. This relatively crude but effective levelling method is illustrated in the photographic survey record and results shown in Appendix 2.

2.39 In terms of water level management and control structures, the understanding of local differences in ground surface elevation in the carr, relative to water level in the River Cober is critical to gain an understanding of how frequently water may be drawn off the river to feed drier areas of the carr, if and when required.

Fluvial Geomorphology and Hydrology

2.40 In terms of geomorphology, there is limited structural diversity of the River Cober throughout the carr. It is almost completely uniform, with a relatively fixed, rectangular river channel of uniform depth between 1.5 and 2m with little in-channel structural diversity. This is almost certainly a result of the schedule of de-silting of the channel, which was implemented after the channel was straightened in the 1940s and has continued up until 2003. Figure 3.6 (Section 3) illustrates relative longitudinal river bed levels and gradients after each notable de-silting programme.

2.41 Few, if any in-channel depositional features are noted, with the exception of one or two areas in the downstream section of the carr, where coarse woody debris has partially blocked the channel and caused flow deflection. In these areas, flow variation has caused some degree of localised bank erosion and a subsequent accumulation of deposited bed load material opposite and slightly downstream of the obstruction.

2.42 In structural diversity terms, these areas represent the only real features of note within the stretch of the Cober, with perhaps the exception of a few bank collapses in the upstream section, where localised erosion protection has been installed by the NT in recent years (refer to photos 61 and 62, Appendix 1).

2.43 There are no notable natural pool riffle sequences. Instead, flow diversity is pretty much restricted to pools and glides, where flow is uniform and consequently channel morphology is similarly uniform.

2.44 The lower section of the Cober has seen less channel modification and so displays some improved structural diversity. This structural diversity has no doubt improved since management became less intensified after 2003.

2.45 Figure 2.3 illustrates locations of notable features relating to geomorphology. The positions were surveyed in the field using GPS and are illustrated in Appendix 1, together with photographs.

2.46 River bed material consists of gravel and smaller fines, whilst river banks are almost uniformly silty loam soils, with localised lenses of finer mine tailings (waste-rock) sediment. No gravel or cobble futures (erosional or depositional) are present in the entire reach and in many places, on the day of survey the river bed was not visible due to the depth of flow encountered.

2.47 Towards the downstream end of the river, where the Cober outlets into Loe Pool, a deltaic deposit has accumulated. Here the river banks gradually decrease in size until the river is almost at the same level as the surrounding floodplain. Surface standing water is far more abundant and floodplain sediments are soft and almost continually saturated or at near saturation condition.

2.48 Due to time and budget constraints, no detailed soils investigations were carried out. However, it is understood that the soil type is classified as Denbigh 1 under the NSRI NATMAP Vector national Soils dataset and that across extensive areas of the carr these soils are overlain by a form of lowland peat, which has accumulated as a result of the carr swamp vegetation.

Levelling Survey - Determining Water Levels in the Cober and Valley Carr

2.49 As discussed, a spot levelling survey was undertaken in order to try to determine, on the day of survey, the absolute difference in height between water level in the River Cober and standing water levels in the adjacent valley carr. This information would help inform the amount of work required to construct flow off-take control structures linking the River Cober and the valley carr as well as determining where preferential flow may occur through the valley carr in a downstream direction.

2.50 Photography has been used to achieve this. The camera was levelled and collimated on a tripod (with spirit levels) and photos taken in the direction of the Cober channel and the adjacent valley carr at the same location. A tape measure was used as a levelling staff and the difference in height (measured from a centre line through the photograph, as in Appendix 2) can be used to determine the absolute difference in height between water level in the River Cober and the standing water level in the carr at that particular time and day.

2.51 The locations at which the levels were taken were chosen for their potential suitability as sites for water level control structures (as proposed in Section 4 and illustrated in Appendix 3). These locations are illustrated in Figure 2.3.

2.52 At the time of survey (20-11-13, 10.00am to 2.00pm), the calculated differences in water levels between the River Cober and the adjacent carr were as follows:

- Section 1 - 0.405m
- Section 2 - 0.025m
- Section 3 - 0.045m
- Section 4 - 0.000m
- Section 5 - 0.040m

2.53 The above levels indicate that at certain locations down the River Cober, a minimal difference in elevation needs to be overcome by the pipe-based water level management/flow control systems implemented for controlling water levels in the valley carr.

2.54 As flow at the time of survey was elevated, but no where near bankfull, the survey results indicate that, in theory it should be possible to keep certain areas of the carr wet almost all year round.

Ecology and Habitats

2.55 A review of the information relating to ecology and habitats shows that there are some useful data relating to the site, but that detailed botanical surveys have not yet been conducted across the site to a standard such as National Vegetation Classification. The National Trust Biosurvey of 2009 contains survey information to JNCC Phase 1 classification level only. In this survey report, the entire area of interest is only sub-classified down to dense scrub and swamp habitats (see Figure 2.4).

2.56 This is somewhat unfortunate as it means that comparing vegetation communities and spatial distribution across the site between years will be problematic. Field observations during this study showed that the vegetation is not uniform across the site and only a more detailed survey would determine current baseline conditions to the appropriate level.

2.57 Section 5 makes recommendations for further, detailed surveys using fixed point quadrats, in order to establish an accurate baseline dataset for the future.

3. DATA ANLAYSIS, INTERPRETATION AND GIS MAPPING

3.1 The aim of the data analysis and interpretation was to build up a pattern of 'behavioural response' for the River Cober and the interactions between rainfall, river levels and the water level of Loe Pool, based on existing evidence. Once established, the hydrological impact on the willow carr habitat has been assessed via GIS-based spatial analysis. Figures 3.1, 3.3 and 3.4 illustrate the time series hydrological datasets that have been identified and examined in detail.

3.2 The data scoping, analysis and interpretation exercise has comprised the following key components:

- Data acquisition, formatting and preparation for use using a variety of software tools;
- Data visualisation by means of time series plots;
- Data analysis - event magnitude and frequency / interactions between Loe Pool and the River Cober;
- Spatial analysis - GIS-based LIDAR topographic analysis in conjunction with hydrometric records; and
- Interpretation of results.

3.3 Each is now briefly discussed.

Data Acquisition and Review

3.4 An early request for data led to the supply of available hydrometric data for a series of stage flow and rainfall stations within the vicinity of the Loe Valley Carr SSSI site. The majority of data were obtained from the local EA office, whilst some additional material was collected from existing reports.

3.5 Datasets were supplied from the EA as raw data outputs in ASCII flat file formats and so required some re-formatting and conversion to be useful for the study. Data consisted largely of two measurement intervals: 1) daily rainfall measurements and 15 minute interval hydrometric data for river stage and flow in the Cober. Where required, flow and stage data were re-sampled in order to make the datasets more manageable for analysis and interpretation. Rainfall intensity data was disregarded as not being of direct use.

3.6 Hydrometric data were processed in a variety of software applications for analysis and interpretation. These included Textpad ASCII text editor, MS Access database, MS Excel Spreadsheet and OTT Hydrometry Hydras 3 Hydrometric data management suite.

3.7 All available data were supplied from the EA, with the exception of flood modelling outputs, which were deemed to be unsuitable for distribution, as they are in draft form and subject to change.

3.8 The following datasets were obtained for the purpose of the study:

- Trenear G.S (SW6750 831043) 15min or daily mean. Level & Flow 1988 - Present
- Boscadjack (SW67445 30749) 15min or daily mean. Level & Flow 1998 - Present

- Loe Pool (SW64642 25590) 15min or daily mean. Level Only 1998 – 2003, & 2006 – Present
- Helston County Bridge (SW65543 27359) 15min or daily mean. Level & Flow July 09 – Present
- Helston Weir (SW65467 27257) 15min or daily mean. Level & Flow 2003 - 2009
- Helston Gauging Stn. (SW65467 27257) 15min or daily mean. Level & Flow 1968 - 1989
- Loe Bar outflow (SW64315 24280) 15 min. Flow Only Oct 2010 – Present
- Wendron WTW (SW 67789 30711) Daily Rainfall 1948 – 2010
- Wendron TBR (SW 67789 30711) Intensity April 09 – present
- Boscadjack (SW 67442 30760) Intensity 1998 – 2010
- RNAS Culdrose Daily Rainfall 1952 – 2010

3.9 After a review of these datasets, a small number of selected series were prepared further for statistical and visual analysis and interpretation. In most cases, 15 minute interval data were re-sampled down to daily means, or in the case of rainfall data series, daily totals. This was undertaken in order to reduce the volume of data being processed and to help clarify the time series responses and patterns, as 15 minute data can often obscure the temporal scale at which the analysis needs to be undertaken. The following processed datasets were examined in more detail:

- Loe Pool (SW64642 25590) daily mean level 2003 to 2006
- Loe Bar outflow (SW64315 24280) daily mean level Oct 2010 – 2013
- Loe Pool daily mean level (combined)
- Helston Weir (SW65467 27257) 15min or daily mean. Level & Flow 2003 - 2009
- Helston Gauging Stn. (SW65467 27257) 15min or daily mean. Level & Flow 1968 - 1989
- Helston gauging station (formerly boating lake and weir) daily mean level (combined)
- Wendron WTW (SW 67789 30711) Daily Rainfall 1948 – 2010
- Wendron TBR (SW 67789 30711) Intensity April 09 – present
- Wendron daily mean rainfall (combined)

3.10 Several of the above datasets were merged into single, continuous datasets as they were reported at essentially the same site, but with different instruments and at different times. The issue of data overlap was an important one as there were periods where no data existed for particular gauges, therefore, the records contain sizable gaps, which make direct comparison and analysis problematic (see Figure 3.1 as an example).

Time Series Analysis of Flow, Stage and Rainfall Regimes

3.11 The two critical datasets were considered to be daily mean water level (mAOD) at Helston gauging station (boating lake) and daily mean water level in Loe Pool. These two datasets represent the closest data describing what is actually happening within the River Cober downstream of Helston (where there is no gauging undertaken at present) and the interaction with water level in the Pool downstream.

3.12 No river stage or flow monitoring instrumentation exists within the SSSI site and this is problematic as it means that data from these adjacent sites has had to be used to infer conditions within the carr at any particular time and flow condition. Although the gradient of the river is shallow, being only an approximate drop of 0.5m in elevation between Zachary's Bridge and the Loe Pool, making inferred judgments justifiable.

3.13 Nevertheless, it is still an issue as the critical requirement of the project is to understand the relationship between higher flows in the River Cober, coupled with the interaction of higher levels of the Loe Pool, which together determine the frequency and intervals of overbank flow and floodplain inundation in the valley carr itself. This is the critical factor when considering the hydrological regime of the carr as it is largely maintained by surface water inundation and pooling of standing surface water in order to maintain continually high water table levels throughout the year.

3.14 Figure 3.1 below illustrates these two critical data series identified for showing the relationship between river levels and water levels in Loe Pool. It is understood that water levels in the River Cober, both within and downstream of Helston, are jointly controlled by river flow off catchment and a 'backing up' or inundation effect, observed when the volume of input waters entering Loe Pool exceed the maximum capacity at which the Loe Bar outfall can evacuate water into the sea. Thus, these two variables combine to affect water levels in the lower valley, and from this, both determine flood risk in lower Helston and the frequency and extent of floodplain carr inundation within the SSSI. This interaction between river and pool is, however a complex one and recent EA correspondence indicates that "the delay to the modelling element of the flood defence review works is related to the complexity associated with the River Cober's interaction with Loe Pool" (EA pers. comm. 2014).

3.15 In Figure 3.1, a dashed line marks the approximate elevation (mAOD) of River Cober as it passes through the middle of the SSSI. Note that bed level gradient is slight and storm events can clearly be seen where elevated pool water levels back water up in the channel into lower Helston.

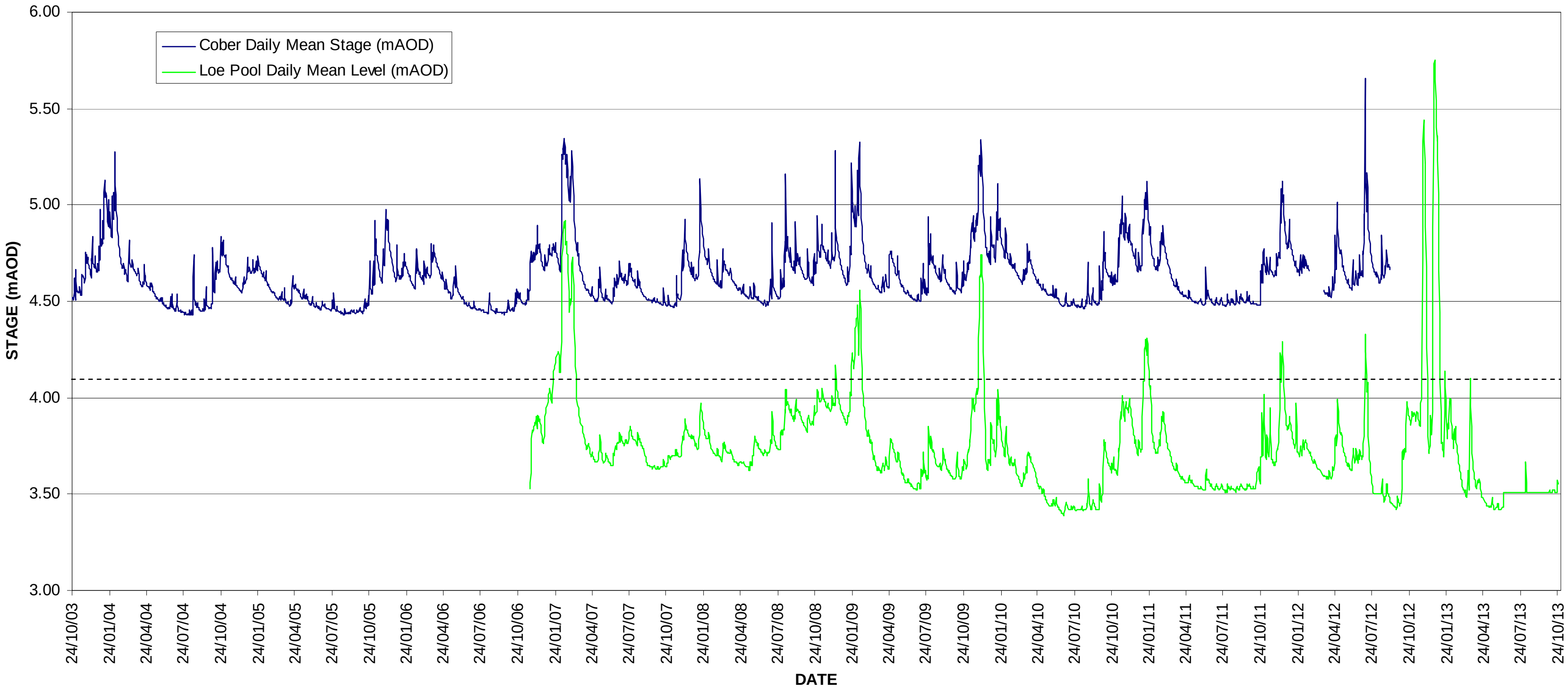


Figure 3.1 Time Series Plot of Daily Mean Water Level at Helston Gauging Station and in Loe Pool, for the Period 24/10/03 to 24/10/13 (dashed line indicates approx. level of carr)

Re-evaluation of Existing Water Table Monitoring Data

3.16 As part of this work programme, floodplain soil water table levels data collected and presented in earlier reports has been included here for examination, in the context of other evidence. The earlier data consists of a limited series of nine datasets in total, each collected over roughly a 15 month period running from August 1998 to November 1999. The data series consist of manual dipwell water table depth measurements, sampled at an approximate temporal frequency of one month. The deployment of these dipwells is illustrated in Figure 3.2 below.

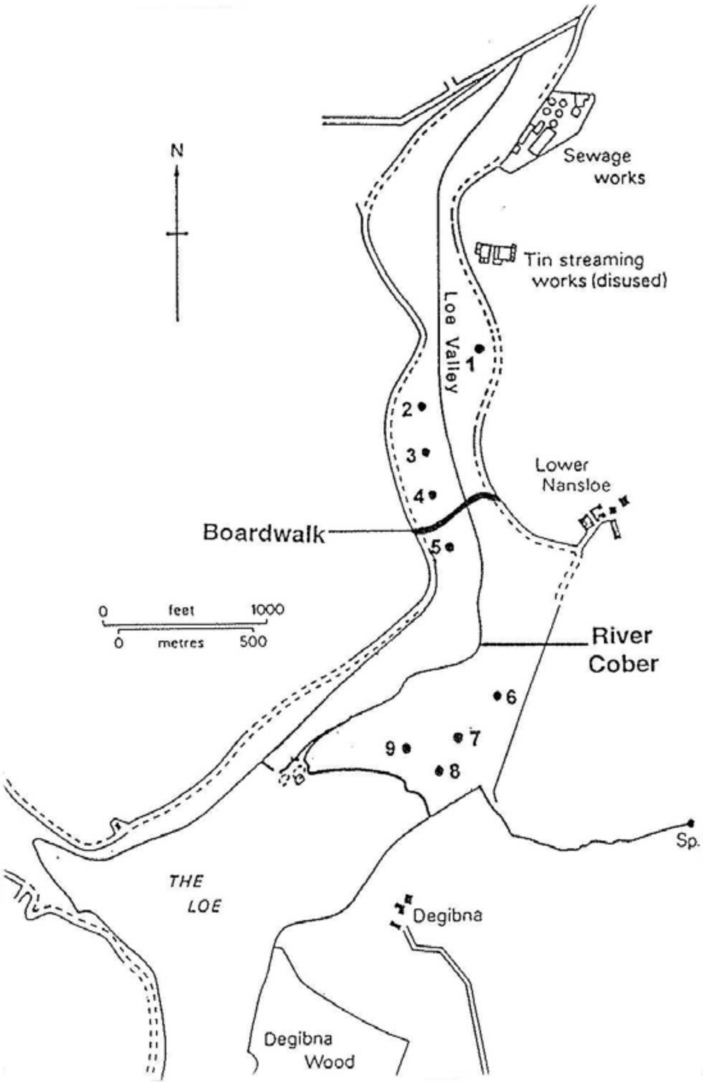


Figure 3.2 Map Indicating the Position of the Nine Water Table Sampling Stations, the River Cober and the Boardwalk within the Loe Pool Wet Woodland (Barratt 2000)

3.17 This data was used in the study by Collins (1999) and later by (Barratt) 2000, in order to assess whether the carr was drying out at an accelerated rate at that time.

3.18 Figures 3.3a to 3.4e below illustrate the water table level, together with daily rainfall totals for each of the dipwell sites; 1 to 4 lying in the upper section of the carr and 5 to 9 in the lower section of the carr.

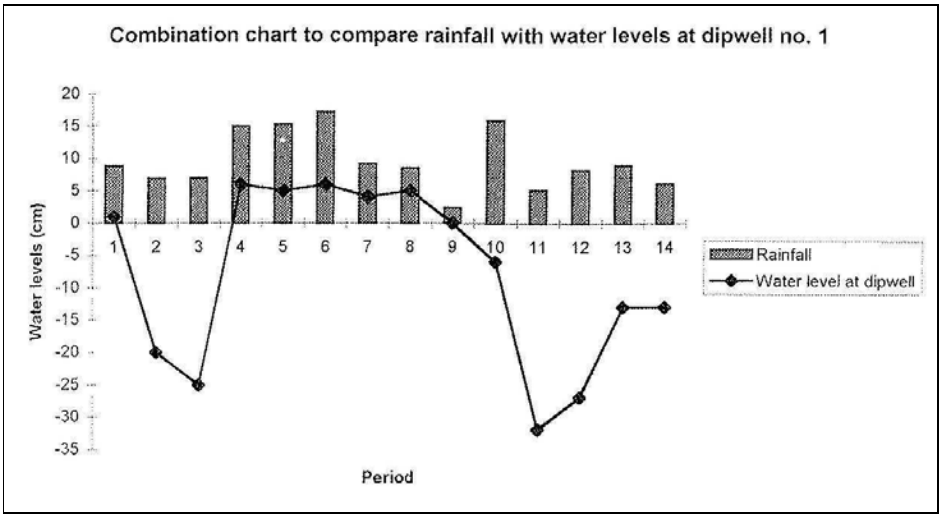


Figure 3.3a Dipwell 1, Upper Carr Area

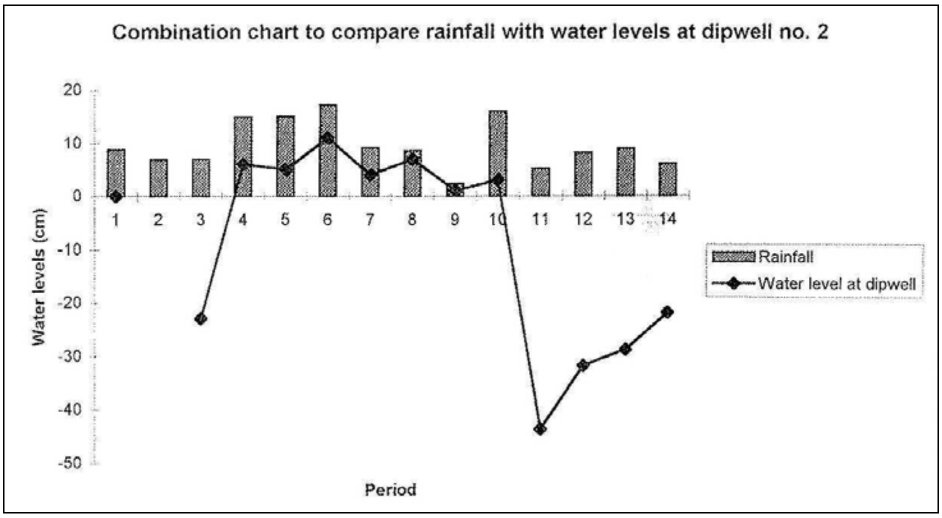


Figure 3.3b Dipwell 2, Upper Carr Area

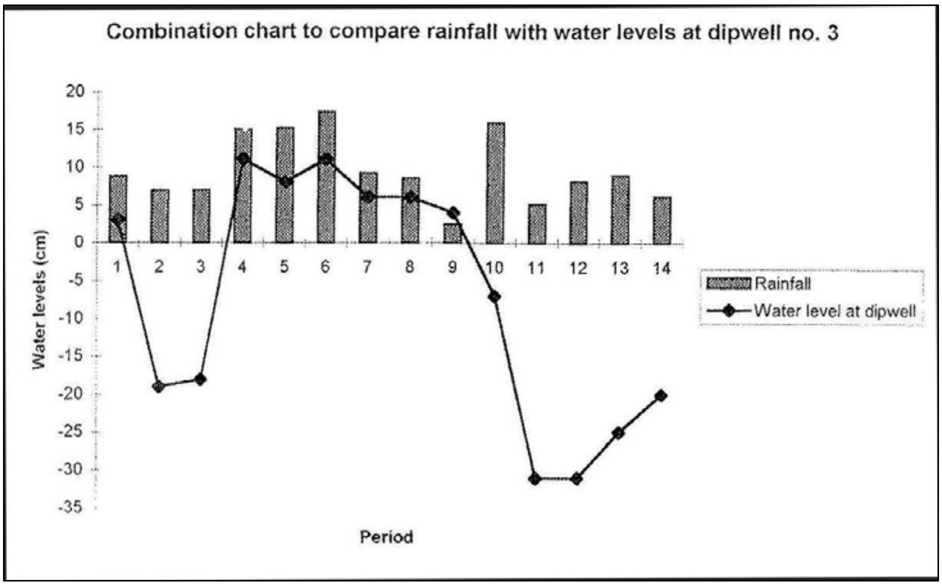


Figure 3.3c Dipwell 3, Upper Carr Area

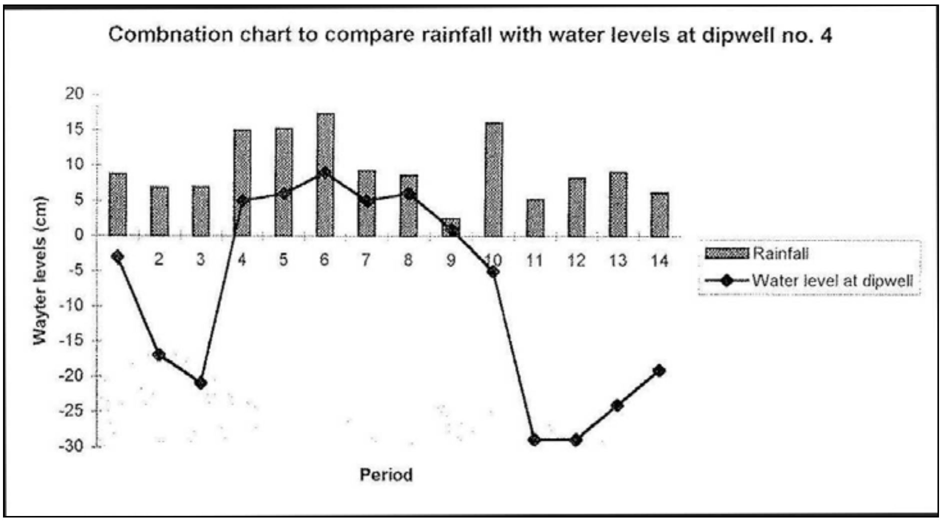


Figure 3.3d Dipwell 4, Upper Carr Area

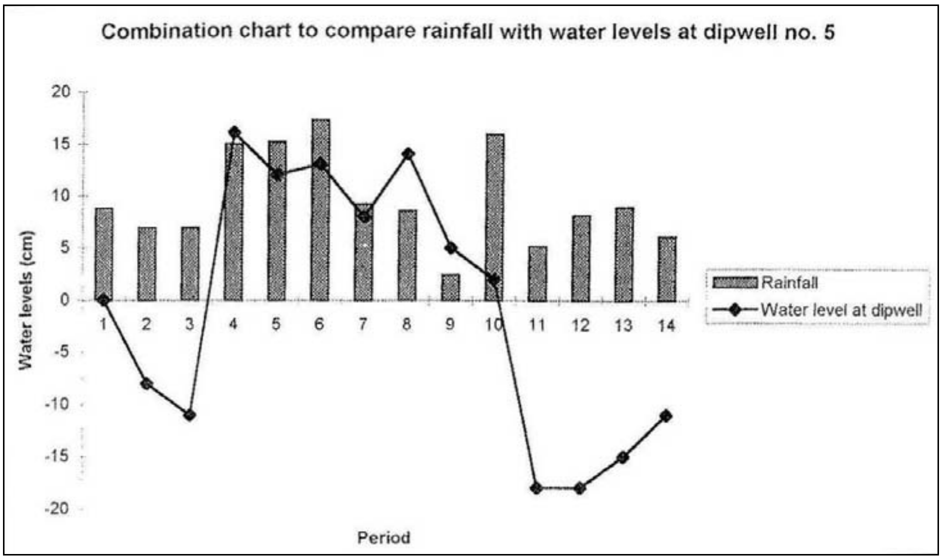


Figure 3.4a Dipwell 5, Lower Carr Area

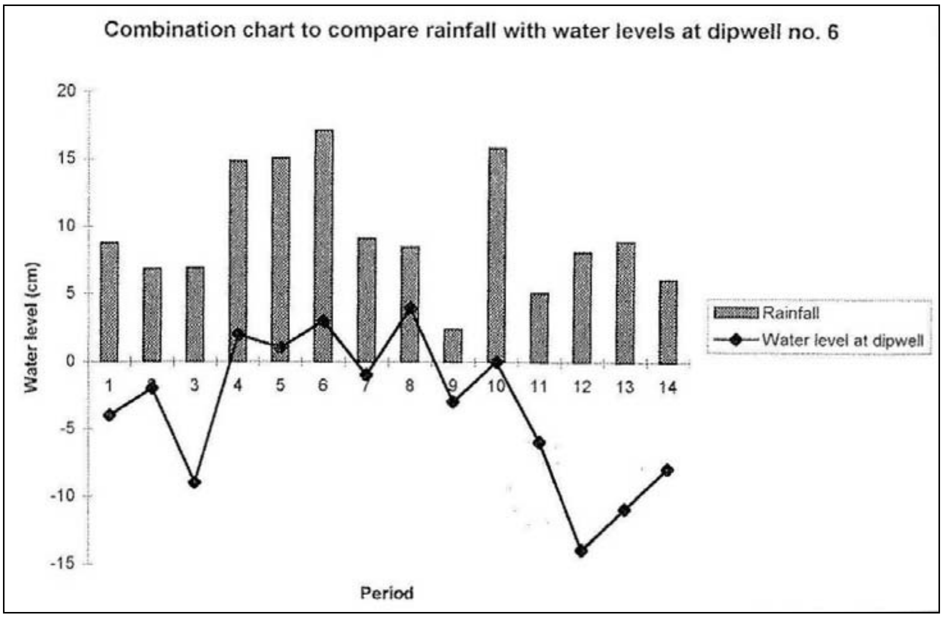


Figure 3.4b Dipwell 6, Lower Carr Area

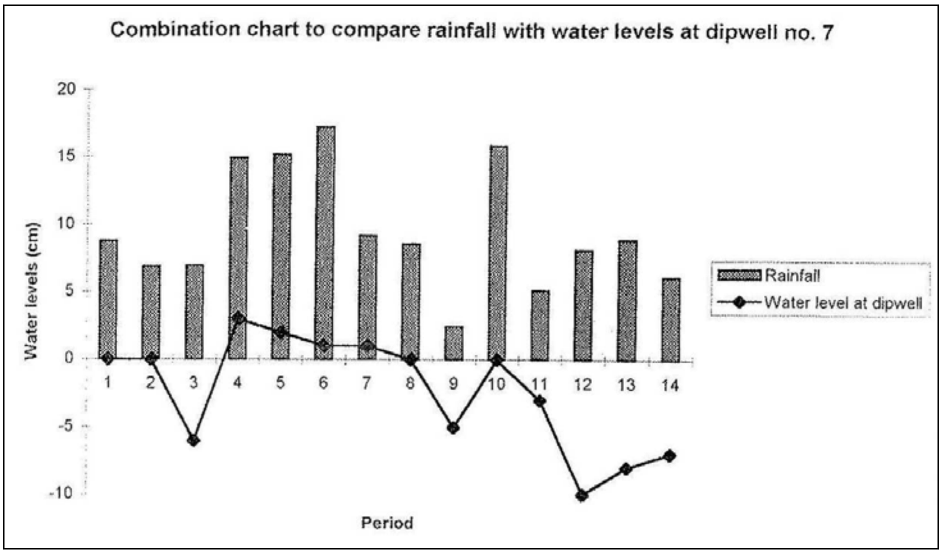


Figure 3.4c Dipwell 7, Lower Carr Area

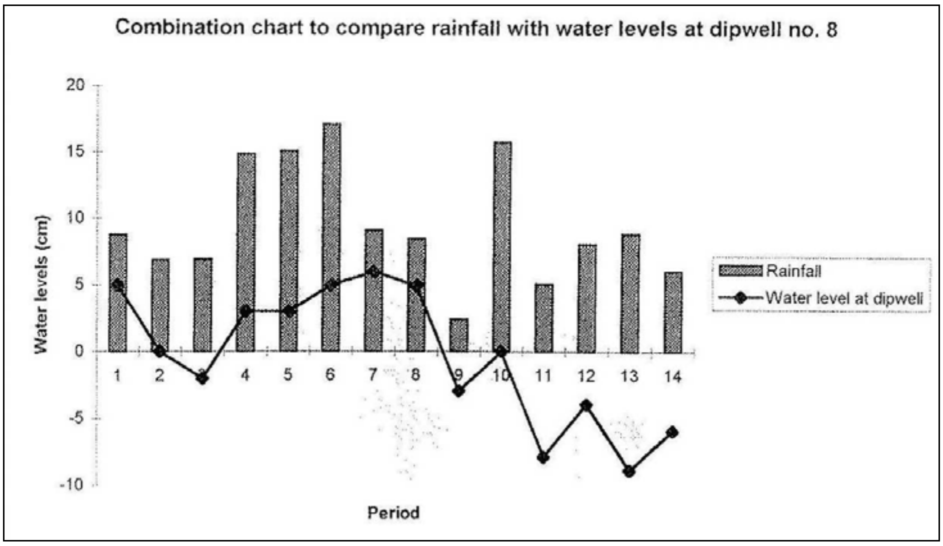


Figure 3.4d Dipwell 8, Lower Carr Area

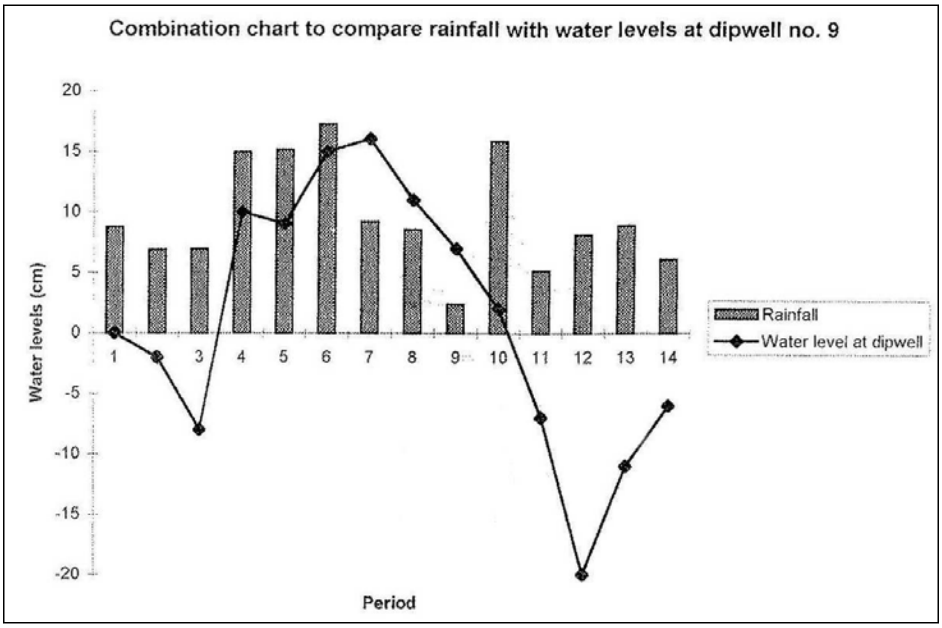


Figure 3.4e Dipwell 9, Lower Carr Area

3.19 The monthly, approximate sampling regime, coupled with the manual sampling technique used and the monitoring period of only 15 months, means that the data do not match current British Standards for quality control and the short span of data renders it unsuitable for assessing evidence for long term, temporal hydrological trends.

3.20 However, at this time, it is the only known data relating to floodplain soil water table levels within the valley carr site and so nevertheless form an important data resource for this project, despite the obvious restrictions in it and its lack of robustness for rigorous study.

3.21 The results of the water table monitoring programme are discussed in Section 4, within the context of other evidence collected reviewed and analysed as part of this study.

Derivation of Local Bed, Bank, and other Topographic Levels and Longitudinal River Gradient

3.22 Little, if any detailed topographic data is available for the site, meaning that equating actual flow depths (stage) to bank top levels at any particular point is not possible. The LIDAR topography data, as shown in Figure 1.2 goes some way to resolving this issue and gives reasonably accurate indications of where bank and floodplain topography varies locally, but provides no useful data describing the River Cober channel; its shape, depth and accurate form.

3.23 Having said this, the LIDAR DTM data is extremely useful in that it does provide an indication of suitable locations for installing flow take off structures, i.e. at stretches of river channel where river bank top is relatively low compared to flow depth.

3.24 The LIDAR DTM also highlights those areas of floodplain that are lower lying and so will remain inundated for longer periods, as well as performing as potential flow pathways through the floodplain carr itself.

3.25 None of the hydrometric datasets supplied by the EA contained information regarding local topographic levels at each gauging station. A request has been made to determine whether this information exists and is held by the EA, but at the present time, all data analysis and interpretation is based on levels data collected in the field by PAA survey team during the period of fieldwork covering the 19th and 20th of November 2013.

3.26 Stage and flow have been determined and assessed at the exact time intervals at which measurements of bank height and flow depth in channel were taken as part of the levelling survey. This data has been used to calculate a single, representative datum from which all stage/flow analysis and assessments of potential floodplain inundation are based.

3.27 A review of existing reports suggests that the drop in longitudinal gradient in the bed of the River Cober between Zachary's Bridge (upstream of the site) at Helston, and the point at which the Cober currently enters the Loe Pool is approximately 0.5 to 0.75m. This level drop occurs over a horizontal distance of approximately 1200m. In the absence of a detailed bed gradient survey, it is assumed that the bed level gradient of the River Cober as it passes through the carr is constant and so a mean gradient can be calculated, together with an approximate absolute levels at various points of interest though the site. These calculated levels can be validated against the LIDAR DTM topographic data which, in general should only be up to 0.15m in absolute difference from the calculated levels.

3.28 Based on the bed level surveys presented in the River Cober Maintenance Plan (2007) and illustrated in Figure 3.6 it is fair to assume that midway through the willow carr, the bed level is some 0.25m below that measured at Zachary’s Bridge. In the surveys shown, the bed level is precisely 3.0m AOD in 2003 at 600m downstream of Zaccharys Bridge, a position in proximity to the access gate which marks the boundary between maintained and low maintenance NT land.

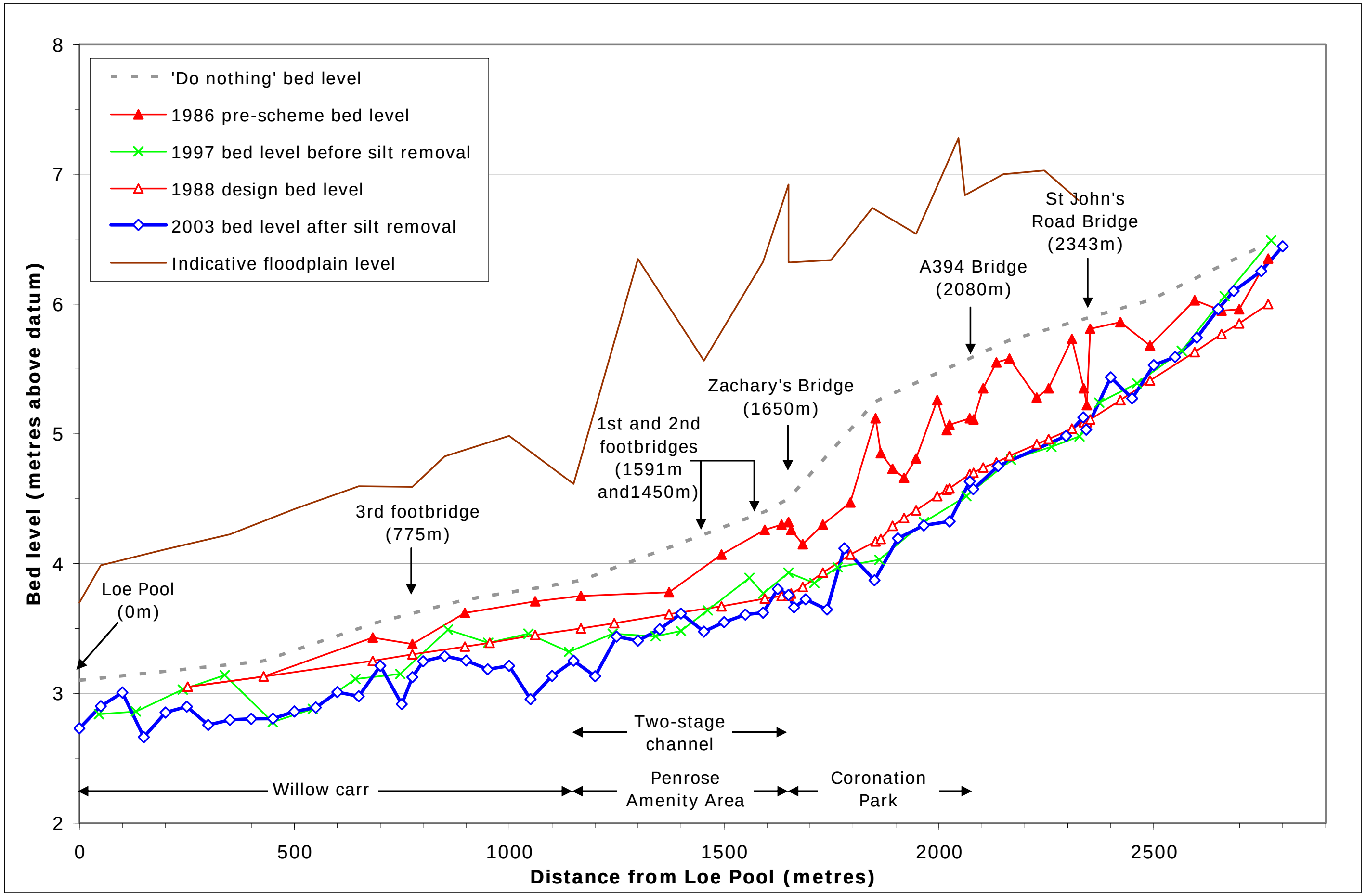


Figure 3.6 Longitudinal Bed Level Surveys of the River Cober, including Predicted Bed Levels under Different Maintenance Regimes (EA 2007)

3.29 Of course, the levels used here and the subsequent floodplain inundation analysis based on this are subject to change due to external factors, especially channel maintenance by the EA on the River Cober. This stretch of channel is known to have had a long history of modification, including straightening and de-silting works. At the present time, the channel has not been de-silted since 2003 (EA 2007), and so bed levels are almost certainly increasing over time due to sediment accretion. If this 'do nothing' maintenance programme continues, overbank spilling of channel flow will inevitably become more frequent due to the shallower channel geometry, with all other channel dimensions remaining fixed. However, if the de-silting maintenance regime was to re-commence, then frequency of floodplain inundation will almost certainly decrease once again due to the increased channel capacity and depth of flow in channel, relative to the adjacent floodplain areas.

3.30 As the future maintenance regime of this stretch of the River Cober is under review and not yet determined, it is impossible to say which may be the outcome. In either case, the potential hydrological implications of this type of channel maintenance work needs to be considered, especially in respect to the hydrological regime required in order to maintain the valley carr habitat.

3.31 Interestingly, pre-scheme bed levels were notably higher than present bed levels suggesting that potential flood risk would have been notably higher in the period up to maintenance in 1986. It would be useful to investigate historical data to determine whether the frequency and severity of flooding in the area was indeed higher at this time.

Flood Risk Modelling

3.32 The Loe Valley Carr SSSI has a hydrological regime that is relatively uncommon in the UK. Loe Bar forms a hydrological barrier to the natural ria, (flooded coastal valley). Historically, water would have percolated through the shingle and sand bar, but recent mining activity has meant that the shingle bar has become 'blinded', thus not allowing water to pass though at sufficient rate and so requires an underground outfall tunnel through which to drain into the sea. These unusual characteristics mean that the valley is particularly prone to flooding through the combined effects of high river flows and water 'backing up' the valley due to increasing water levels in Loe Pool.

3.33 This interaction is responsible for current and historical flooding in the lower parts of Helston and is the subject of current, ongoing modelling and consultation, by a number of groups, including Black and Veatch. As such, this aspect of the project is not reported in any detail here. What is acknowledged though, is the current consensus, based on evidence from previous studies (EA 2007, Dinsdale 2009) and current work being undertaken by Black and Veatch on behalf of the EA suggest that the scale and scope of proposed management changes to the River Cober through Loe Valley Carr SSSI will have negligible effects on upstream flood risk in Helston itself. This is of key importance since it removes one of the key constraints to scheme development.

3.34 Evidence presented later shows, unsurprisingly, that while surface inundation by water back up from Loe Pool only extends so far up through the valley carr SSSI, water in the river channel itself does back up a considerable distance upstream from the site.

3.35 At the present time, the Flood Defence Strategy for Helston is under review and open for further development. The implications of this are discussed in more detail in Section 6.

Topographic Analysis using GIS

3.36 High resolution LIDAR digital terrain model data were obtained for the entire study area from the Environment Agency (South West) free of charge, for use in the study. The data consists of a raster grid layer of cells, each with a measured elevation above Ordnance Datum. The grid has a fixed, ground resolution of 0.5m and is quoted to 0.15m in vertical accuracy.

3.37 The level of vertical accuracy quoted is an issue in a hydrological study of a site such as this, as the bed level gradient of the River Cober is extremely shallow, only decreasing some 0.5m or so over many hundreds of meters. The net result is that although very useful, the LIDAR data can not be used for levelling purposes. Furthermore, as discussed earlier, LIDAR DTM data is particularly poor at picking out surface features such as river channels, especially when the feature is relatively small. The LIDAR remote sensing technique returns no measurements for areas of open water and so the water level in the River Cober, together with the river bed itself are not represented accurately at all in the dataset.

3.38 After reviewing the available time series stage and levels data for the River Cober and Loe Pool, a series of reference water level heights were identified and used to model and visualise surface water inundation extent and depth across the carr SSSI under a range of different storm/runoff conditions. The reference levels used ranged from 4.0m to 5.0m in 0.25m intervals. An additional level of 5.5m was also used in order to represent flow and levels in the most extreme recent storm event, that of Christmas 2012, where emergency pumping was implemented at Loe Bar by the EA in order to reduce flooding upstream in the Cober catchment. The results of the inundation modelling are presented in Figure 3.5.

3.39 A constant raster grid was calculated for each of the reference water levels. The actual topographic elevation for the carr site was then subtracted from the reference level, to give a calculated water depth for each cell in the grid. Where surface topography is lower than the reference value, standing water would pond up to a calculated depth. Conversely, where surface topography is greater than reference depth, a negative cell value is returned.

3.40 A second analysis was then undertaken in order to remove all of the negative values from each output grid. The resulting surface water inundation maps are illustrated in Figures 3.5a to 3.5f, for each reference water level respectively and the results are discussed in Section 4.

4. RESULTS

Assessment of Hydrological Regime for the Valley Carr

4.1 The analysis of the LIDAR DTM data reveals several important points about the morphologic structure of the floodplain. These are:

- That topography is extremely flat with little variation, except for a few small areas or patches. The reason for the existence of these is unknown.
- A relict, former channel is very clearly identifiable at the upper section of the site and could be used for floodplain enhancement, but at considerable capital cost.
- Raised berms or levees are visible down the entire length of both banks of the River Cober. These are probably a result of both natural and anthropogenic factors including the preferential deposition of sediment as water overbanks on to the floodplain in high flows, coupled with the in-situ deposition of river bed material after de-silting works in the channel.
- The LIDAR DTM is of sufficient detail to pick out notable raised pathways through the carr, some of which are affecting natural lateral surface water flow though the carr.
- The LIDAR DTM data is of insufficient detail to characterise the dimensions and morphology of the River Cober main channel. This meant that the determination of local levels has had to be achieved by field survey, rather than GIS-based data extraction.
- The LIDAR DTM is of sufficient detail and resolution to allow a scenario-based inundation modelling exercise, as outlined in Section 3 above, which has examined the flood inundation effect of flows and pool water levels across a range of storm event conditions and the hydrological effect of these inundations in the context of the carr vegetation. The results of these are now presented.

Current Frequency and Magnitude of Willow Carr Inundation

4.2 Figures 3.5a to 3.5f show the results of the GIS-based topographic and hydrological analysis, which has been devised to investigate and predict the extent and depth of flood water inundation across Loe Pool and upstream into the River Cober and its riparian floodplain under a range of different flow/water levels during storm events. The magnitude of each storm event has been determined via a threshold frequency analysis of the time series stage and pool level data supplied by the EA for the project and illustrated here in Figure 3.1 and summarised in Table 4.1.

4.3 The time series data presented in Figure 3.1 was analysed using a basic frequency threshold method in order to identify the frequency and magnitude of inundation during the period for which data has been collected. The magnitude of any storm event, represented in recorded water level in Loe Pool, is set against the number of times in which that flow/level condition occurred.

4.4 Figure 3.1 illustrates the available hydrometric stage and rainfall data for the River Cober at Helston. Loe Pool Water level is also included here in order to allow the determination of the relationship between water level in the river and the pool and the interaction between the two. Loe Pool daily mean level is illustrated in Figure 3.1.

4.5 This interaction is critical in terms of carr hydrology as it is the primary mechanism by which the carr is inundated with water and hence maintained as a habitat.

Table 4.1 Number of Carr Inundation Events, November 2006 to December 2013 (water level measured at Loe Pool boat house and Loe Bar outfall)

Recorded Water Level in Loe Pool	Number of Events (Nov 2006 - Dec 2013)
4.00m AOD +	21
4.25m AOD +	8
4.50m AOD +	5
4.75m AOD +	4
5.00m AOD +	2
5.50m AOD +	1*

* Exceptional event of Christmas 2012, which led to flooding in Helston and emergency pumping at Loe bar

4.6 The magnitude and frequency of these events compares to earlier data for the period 1998 to 2003, as shown in the Loe Pool Catchment Management Project (Dinsdale 2009), in that the patterns of magnitude/frequency of event are consistent between the two periods.

4.7 Examining each of the inundation maps in turn, observations can be summarised as follows.

4.8 A water level of 4.0m in Loe Pool represents an elevated condition, compared to the normal range of water level in the pool at or near baseflow conditions. Figure 3.5a shows the inundation effect observed in the carr woodland at this water level. As can be seen, inundation is restricted to the lowest 500m of the carr, with minimal depths of standing water in most places (0 to 1.28m maximum). From a review of the existing hydrometric data supplied by the EA and illustrated in Figure 3.1, this level of water in the pool was observed 21 times over the period November 2006 to December 2013, giving an event return period (frequency of occurrence) of roughly 1 in 0.3 year (3 times annually).

4.9 It is interesting to note that a water level of 4.0mAOD in Loe Pool only leads to minimal inundation of the willow carr, as illustrated in Figure 3.5a. This is perhaps surprising as anecdotal evidence obtained from discussions with local visitors and land managers tends to suggest that inundation occurs more frequently than this. Having said this, it is the case that once the carr inundates, it takes a number of days to dry out once more and it might be this factor that leads to the perception that the site is flooded or waterlogged for lengthy periods each year.

4.10 Increasing the water level to 4.25m in Loe Pool (as shown in Figure 3.5b) represents a more significant storm event compared to the normal range of water level in the pool at or near baseflow conditions. Figure 3.5b shows the corresponding increased surface water inundation effect observed in the carr woodland at this water level. As can be seen, the spatial extent of inundation is greatly increased with standing water extending some 930m upstream of the River Cober confluence with Loe pool. Here, standing water depths range from zero to 1.53m. Thus, a relatively small increase in water level in Loe pool has a very significant impact on the extent of inundation in the willow carr and this is a result of the very low topographic gradient observed throughout the valley carr area, which at the most is probably below 0.5m in total. This water level was observed 8 times in the period for which data is available, giving a return period for this magnitude of event of approximately 1 in 1 year.

4.11 At a water level of 4.50m AOD (Figure 3.5c), the extent of surface water inundation barely increases throughout the carr, with only water depth appearing to significantly increase to a maximum depth of 1.78m in some places. Again, this is dictated by the micro-topography of the floodplain and carr itself. In total, 5 events were observed during the period November 2006 to December 2013, giving a return period of approximately 1 in 1.5 years.

4.12 Increasing again, a water level depth of 4.75m in Loe Pool represents a very significant storm event, with only four such magnitude events observed during the period for which data is available between November 2006 and December 2013. At this depth, again, there is a negligible increase in the spatial extent of inundation, but depth of standing surface water increases markedly to 2.03m maximum, with the entire carr being submerged under 0.5m of water or more. The return period for this magnitude of flow/inundation event is approximately 1 in 1.75 years. Figure 3.5d illustrates the extent and depth of surface water inundation at this magnitude of event.

4.13 At more extreme levels of inundation, from 5.0m and upwards (Figures 3.5e and 3.5f respectively), standing water extends right through the entire valley carr, to some 500m below Zachary's Bridge and extending 1200m through the SSSI. Only the more pronounced topography of the upper reaches, (formed primarily by the dredging from the 1988 two stage channel and the former municipal refuse tip) prevent inundation extending further upstream towards Helston. A pool water level of 5.0m has been observed only twice between November 2006 and December 2013, giving an event return period of 1 in 3.5 years.

4.14 The maximum event magnitude recorded during the available data period was 5.5m and occurred on or near to Christmas Day 2012. This event was so severe that the EA had to install emergency pumps at Loe Bar in order to evacuate additional water from the pool into the sea (Cameron *pers. comm.)* It is also the case that the EA had made preparations for emergency pumping on two previous occasions within the two previous years (Cameron *pers. comm.).* Figure 3.5f illustrates the inundation extent of this magnitude of event on the carr, with water levels averaging 2.0m or so across large areas of the carr woodland. A single event of this magnitude was observed during the period for which data is available, making it approximately a 1 in 7 year return period.

4.15 As can be seen from the figures, the issue of an accelerated drying out of the carr, should there be one, will be particularly prevalent in the upper reaches of the valley carr, where the floodplain is slightly more raised and narrower. It is these zones that would benefit most from artificially maintained standing water.

Floodplain Soil Water Regime

4.16 Based on the GIS-based floodplain inundation modelling, coupled with the existing water table data published by Barratt (2000) and included here in Figures 3.3 and 3.4 above, it can be concluded that the upper area of the carr woodland is indeed generally drier than the lower section of the carr for up to three to four months in summer. Crucially, water table levels drop below those required to sustain carr vegetation and so it is possible, that over time, changes in vegetation may be sustained under current conditions. A combination of general river bed level, coupled with the local topographic variation in the floodplain itself means that this drying effect is more pronounced further upstream towards Helston and it is these areas, which will require some form of assisted re-wetting or surface water level control, either by diversion of water from the main River Cober channel, or by the introduction of surface water on site from other external sources.

4.17 The study shows that in the lower carr, the seasonal pattern in soil water regime observed over the study period mirrors that of the water table levels as recorded in the dipwells in the upper section (wells 1 to 4) is the same, but much less pronounced in severity i.e. depth variability. Across dipwells 5 to 9, water table depth decreases to 0.1m, and 0.2m in the driest periods of the year, but only for short time periods (refer to Figures 3.3a to 3.3d respectively). This observation, combined with the increased frequency of inundation from Loe Pool strongly suggests that the majority of this section of the site can and will sustain a natural willow carr habitat into the future and so requires no direct intervention at this time.

4.18 As Figures 3.4a to 3.4e and Figure 2.2 show, however, there are areas of the lower floodplain, where topography dictates that surface inundation is not guaranteed at lower, less extreme storm conditions and drawing water off the River Cober main channel is not possible. In particular, an area south of Nansloe Farm is fairly extensive in size and may be liable to drying as well. In this area, natural surface water is introduced to the site via a stream, which runs down slope from the Caudrose catchment and through Nansloe Farm itself. It is entirely feasible to bypass a proportion of this flow and to use it in order to maintain the carr vegetation in these areas. Similarly, other streams feed into the carr at different locations and from upslope of the SSSI. Each of these can potentially act as a source of water to feed into the carr and maintain favourable hydrological conditions, though it is recommended that water quality assessments be undertaken before opting to use these external water sources and diverting flow from them across large areas of the floodplain valley carr.

4.19 The proposed we-wetting scheme for this area of floodplain is illustrated indicatively in Figure 6.1 (a and b), where a network of open feeder ditches for the bypass and re-distribution of flow are marked as solid black lines.

Evidence of Temporal Trends

4.20 As stated above, there appears to be evidence from both the GIS-based topographic analysis and the earlier groundwater study to suggest that that the upper section of the carr, in places, may be experiencing a long-term drying trend that is more accelerated than would be observed under natural terrestrialisation.

4.21 This statement is delivered with a note of caution, however, since the time series data only cover 15 months duration and, from experience elsewhere, PAA note that real, long-term, directional (monotonic) trends in hydrology tend to be determined only when sufficient data allows this. In a study of this type, a minimum of 4 years worth of data would be required in order to make any firm judgements as to whether there are real trends and what direction and magnitude those trends take.

4.22 Section 6 makes key recommendations regarding the commissioning of a suitable hydrometric monitoring scheme for the valley carr site. A relatively modest capital outlay should ensure that high quality data is collected for key locations over a long period of time, thus ensuring that future trends can be detected and quantified very easily.

4.23 A much clearer understanding of the hydrological behaviour and response of the Loe Valley Carr woodland and the floodplain on which it stands has been achieved by review of existing data and field surveys. based on this improved understanding and the key findings, a series of options for management have been formulated, many of which could be applied in isolation, or else in conjunction in order to achieve the desired results. These are presented in Section 5.

5. OPTIONS FOR MANAGEMENT

5.1 Based on the key findings presented above, a series of management options are now detailed. The options proposed fall into two principal groups: options for managing hydrology, principally for managing surface water availability and extent on the floodplain area year round, and those for enabling river channel habitat enhancement. All are interlinked though, to a certain extent. Appendix 3 contains a technical summary of each of the options for management presented here.

Hydrological Management

5.2 Our proposed scheme consists of several management techniques, which can be used together or in isolation, in order to increase the frequency of floodplain inundation throughout the willow carr area, as well as increasing the residence time of standing water in the floodplain. In turn this should give rise to an increase in general water table levels across the willow carr, so arresting or else restricting any accelerated drying that may be occurring across the site.

5.3 The scheme relies on improving hydraulic connectivity between the floodplain areas in which the willow carr lies, with the incised, straightened River Cober. This can be done in a relatively straightforward manner by the following methods, which may be used in conjunction, or alone:

- Installation of flow conduits (underground pipes or open culverts, page 1, Appendix 3), at strategic locations, connecting the River Cober river bank with areas of carr lying at the same or lower, local topographic level;

- Introduction of water from higher land adjacent to the valley carr site via a series of culverts, pipes or small aqueducts into areas of carr lying at higher local topographic level (page 9, Appendix 3);

- Removal of potential floodplain flow restrictions caused by raised gravel pathways in key areas and replacing them with boardwalk sections (refer to pages 10 and 11, Appendix 3);

- Installation of floodplain flow control structures at the locations where raised footpaths are breached, in order to allow control of water movement downstream through the floodplain at those times of year where standing water needs to be maintained on the floodplain for longer (page 2, Appendix 3).

5.4 All four options presume subsequent throughflow of water downstream within the willow carr floodplain area itself, once the increased volumes of water are directed into the willow carr areas where required.

5.5 These simple, effective water level management techniques are summarised in more detail in Appendix 3, whilst Figure 6.1 illustrates some of the preferable locations for installation. These were derived after careful consideration of bank topography and local floodplain topographic configuration, based on field survey and the GIS-based analysis of the LIDAR digital terrain model.

5.6 By capturing more river flow under a wider range of flow conditions, the proposed scheme effectively enhances flood storage of the willow carr area and thus will prevent some of the accumulation of flow in Loe Pool, where such episodes can be problematic and lead to a risk of exacerbated flooding upstream.

5.7 Principally, the management techniques proposed for achieving improved hydrological coupling between main river channel and valley floodplain are:

- Open water level control structures
- Buried water level control structures
- Levee management
- Bank scalloping
- Berm creation
- Coarse woody debris management in and adjacent to river channel
- Raising river bed level
- Change in design for replacement footbridges

5.8 Once surface water is introduced into the floodplain more frequently, water can be controlled in the carr itself by the following methods:

- Use of drop boards to trap and pond water in low lying areas;
- Selective removal of raised gravel paths and hard standing to promote lateral and downstream flow though the carr; and
- Raised boardwalk sections to allow public access whilst maintaining hydrological connectivity.

5.9 Appendix 3 presents these various options for management, in the form of a technical handbook or reference manual. With the exception of changes to footbridge design, all methods presented are relatively simple and inexpensive to implement.

5.10 Re-designed footbridges, with wider spans between stone/concrete abutments, would allow elevated flow to pass more freely down the Cober main channel. As flow constricts around features, it increases in depth as the water piles up on itself. This effect alone can caused flooding and so careful consideration should be given, where possible to replacing foot bridges, should the need arise, with more flood-sensitive structures.

5.11 Figure 6.1 shows the approximate location of water level control structures, which could be used to re-connect river to floodplain. These locations are approximate and in some instances figurative. The exact location of such structures would need to be determined via detailed levelling surveys down the River Cober, as the LIDAR DTM data, although detailed, is not of sufficient resolution to identify optimal locations for installation. The field survey target notes (points of interest), illustrated in Figure 2.3 show the exact locations of several suitable sites which were identified in the field as having minimal difference between baseflow in the channel and standing water in the adjacent carr. At the time of field survey (20-11-13, 10.00am to 2.00pm), the calculated differences in water levels between the River Cober and the adjacent carr were as presented in Section 2 (2.46).

5.12 The above levels, as illustrated in Figure 2.3, indicate that a minimal difference in elevation needs to be overcome by a pipe or culvert-based water level management/flow control system at locations Section 2 to Section 5 inclusive.

5.13 As flow at the time of survey was elevated, but nowhere near bank flow, the survey results indicate that, in theory it should be possible to keep certain areas of the carr wet almost all year round.

5.14 The creation and/or installation of other management structures, such as river channel enhancements is very much open to discussion, but similarly, areas of lower bank topography, relative to river channel and floodplain level, should again be chosen to minimise the ground works required and to utilise local topography, as much as possible to aid water flow and surface inundation.

5.15 Appendix 3 contains detailed, illustrated descriptions of each proposed management option.

Habitat Management

5.16 In terms of habitat management, an assisted natural recovery approach is favoured and has already been recommended in previous studies (e.g. Dinsdale 2009). Here, habitats are essentially left to their own devices, with minimal intervention, in order to develop and sustain optimal habitat conditions. The critical requirement for the Loe Valley Carr is the maintenance of a stable, specific soil water table regime, that is essential to the willow carr vegetation.

5.17 Principally, the main methods for sensitive, sustainable habitat management include:

- Hydrological management as above to preserve habitat stability;
- Access restriction to promote growth and re-growth of vegetation and a diversification of vegetation community types;
- Continuance of minimal maintenance schedule for vegetation clearance;
- Systematic monitoring for the introduction of non-native invasive species, both aquatic and terrestrial;
- With the exception of amenity features such as pathways where vegetation management is a requirement to keep pathways open, the carr woodland should be left relatively undisturbed with no or minimal intervention; and
- Optional management for removal of invasive species, such as Himalayan balsam, Japanese knotweed and parrot's feather (see Section 6).

Access Management

5.18 Loe Valley Carr SSSI and the Loe Pool provide key ecosystem services to the local area, including biodiversity, habitat value, species conservation and water quality services, as well as key services for the local population in terms of access, recreation and amenity. All are seen as critical to the sustainability of the site and its role in the wider landscape and so all require careful consideration in terms of long-term, sustainable management and, where possible, enhancement.

5.19 On review, it is recommended that public access should neither be increased nor restricted. Access should remain the same, though with the modifications to the structure of each footpath at the key locations duly noted. In this way, a balance is achieved that satisfies several key, ongoing requirements;

5.20 Continued maintenance of current public access and amenity value;

5.21 Continued restricted access in the most sensitive areas of the carr woodland, including the lower section, downstream of the National Trust access gate and across large area of the upper carr which are inaccessible due to deep standing water, rough terrain and the hazard of fallen trees and course woody debris accumulation;

- Localised access restriction for erosion reduction purposes due to strategic vegetation planting and management;
- Encourage vegetation build up in both accessible and non-accessible areas of the site;
- Manage current footpaths to reduce sediment and nutrient inputs into the carr from localised, external sources; and.
- Installation of information boards to keep the general public informed of developments on site and to encourage access along favoured routes.

5.22 Figure 6.2 illustrates the current site access and limited proposed changes to rights of way.

Other Management Considerations

5.23 A key assumption being made for the purpose of this study is that the outfall infrastructure and drainage capacity at the Loe Bar outfall remains unchanged. However, as has been shown in recent years, the capacity of the current outfall is inadequate for very high flows and high pool water levels experienced during extreme storm events and very prolonged wet periods.

5.24 It is recognised that future management options do include changes to the outfall and drainage capacity at Loe Bar (EA, pers. comm. 2014). Should any future flood risk assessment and mitigation strategies implemented opt to increase the capacity of the outfall, or else add an additional outfall (such as proposed in the Helston Cober Appraisal - Long List of Options report; Black and Veatch 2013) then this will affect water levels within the pool and upstream into the woodland carr.

5.25 Careful consideration would be required in order to design a structure that has the capacity to drain the pool and so reduce flood risk in Helston, but also allow a range of flows and levels to naturally occur, in order to provide a suitable hydrological regime and to wet the valley carr sufficiently each year. A secondary outfall could easily be designed in such a way as to be sympathetic to improved or enhanced management of the Loe Valley carr for biodiversity and flood risk benefits, so fulfilling all principal requirements.

5.26 In terms of nutrient budgets, it is accepted that introducing more water to the valley carr system will have a positive impact on pollution loading within Loe Pool, as more nutrients will be absorbed and 'locked' up in the floodplain soils. Work has also been undertaken to reduce phosphate loading from the Helston sewage treatment works and this has had a considerable impact on water quality. In addition to this, sustainable drainage systems (SuDS) could be employed at key locations in order to:

- Reduce the quantity of nutrients enriching the pool; and

- Help maintain stable flow levels and flow control.

5.27 In particular, runoff from the roads in and around Helston, agricultural runoff from fields immediately adjacent to the carr and the sewage runoff from NRAS Culdrose could be treated via this method, which would also serve to regulate water flow onto the carr, especially in extreme (high or low) flow conditions.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 The hydrological investigation reported here has proved extremely useful in that it has highlighted the key issues which influence the long-term sustainability of the Loe Valley Carr habitat, whilst highlighting the issues concerning the implications to current and future flood risk management and the ongoing, water level and water quality management of Loe Pool. A series of key recommendations have been developed from the findings and are now summarised.

Recommendations for Monitoring

6.2 The quantitative evidence on which many of the key interpretations and conclusions made in this report are based is limited and in many cases, not robust enough. It is imperative that a proper, long-term programme of river stage (level) be implemented at one key location on the River Cober, within the SSSI. This could consist of a single river stage measurement instrument at some point midway through the SSSI. A suitable location at or near the footbridge and NT access gate to the lower section of the site would be useful. High resolution stage data should be collected at 15 minute intervals and measured locally and to Ordnance Datum. Data should be downloaded every three to six months and stored securely.

6.3 It is also critical that long term, high resolution monitoring of water table levels, at a minimum of three key locations (possibly more) within the valley carr woodland itself should be established and maintained over a several year period in order to allow seasonality to be factored out and to give an accurate picture of water table behaviour across the site. This would consist of a series of steel dipwell tubes with lockable, tamper-proof lids, each containing a groundwater pressure transducer with inbuilt data logger. Water table level should be measured locally and to Ordnance Datum. Again, data needs to be collected at regular intervals and a suitable schedule of maintenance and checking adopted. It is also recognised that the proposed monitoring programme will need to be installed and configured in order to take account of any works associated with the new flood defence scheme, in whatever way it is implemented.

6.4 A list of equipment suppliers is provided in Appendix 4, together with costs for illustrative purposes. It is recommended that any installation and commissioning of monitoring equipment is undertaken by suitably qualified and experienced technicians.

6.5 From experience in similar monitoring projects, it is strongly recommended that time series stage and water table level should be collected for a minimum period of four years or more, before appropriate statistical tests may determine real, temporal trends in hydrological behaviour, such as decreasing water table levels or changes in inundation frequency, depth and flow. These key variables are seasonal in nature and 'event' affected, thereby producing noisy, variable data which can be difficult to interpret with certainty. This issue is only resolved by the collection of a sufficient period of data to allow robust statistical testing for underlying trends.

6.6 Regular longitudinal bed level surveys of the River Cober from Helston to Loe Pool are recommended in order to monitor the geomorphological effects of any new management regime implemented and the possible impacts on local flow levels, frequency of floodplain inundation and subsequently carr hydrology.

6.7 A programme of continued, regular re-survey of vegetation types and habitat are required in order to ensure that the vegetation communities of the willow carr remain stable, or are in fact transitioning into drier woodland vegetation communities. Survey to NVC level will allow this to be assessed over time.

Recommendations for Hydrological Management

6.8 The report concludes that, based on the available evidence to date, there is a risk that the upper sections of the carr are drying out over time. With this in mind, simple, cost-effective methods for water level control have been proposed, which will increase the availability of water for surface flooding and inundation in this critical upper section of the valley carr. These water control structures will be comparatively simple to install using the minimal capital outlay and equipment requirement.

6.9 The valley carr site may only need a limited number of the water level control structures (perhaps four or five), as illustrated in Appendix 3, placed at strategic locations throughout the site, in order to be effective. These structures will allow increased inundation of the valley carr at sub-bankfull flow conditions, thereby increasing the frequency with which water is introduced to the floodplain from the river. Furthermore, the control structures can also be used in reverse, if required, in order to allow flow to drain from sections of heavily inundated floodplain.

6.10 It is understood that the lower section of the carr will remain in a stable state under the observed current hydrological regime and so minimal water level management should be required across this area.

6.11 In conjunction with artificial water level control structures, it is recommended that the schedule of 'do nothing' or minimal maintenance and removal of vegetation and cessation of channel de-silting should be continued indefinitely in order to allow bed levels to accrete over time, thereby reducing channel storage capacity and allowing more frequent over bank flow into the carr. Hydrometric monitoring should ensure that any potential implications to flood risk upstream are fully understood.

6.12 As proposed in Section 5 and illustrated in Appendix 3, other recommendations include the restoration of natural patterns of surface flow pathways within the carr itself by selectively removing raised gravel hard standing, which has been used for path ways in recent years. These removed restored sections will re-wet and should be bridged with raised wooden boardwalks in order to allow natural flow patterns to develop whilst also maintaining public access.

6.13 Whilst continued public access is recommended for the site as a whole, access could be restricted in key areas in order to promote vegetation re-growth and, for example, the re-establishment of trees adjacent to the channel. This would lead to biodiversity benefits as well as structural diversity within and adjacent to the River Cober, as the vegetation acts as flow deflectors and will promote lateral channel migration and the development of a more natural, sinuous channel over time.

6.14 Combining the recommendations above will lead to a better understanding of the long-term hydrology of the site and promote biodiversity enhancements. Improved understanding will also lead to better and more appropriate decision making in the future.

Recommendations for Vegetation Management

6.15 The NT Conservation Evaluation (2009) identifies the Loe Valley carr as National Vegetation Classification type W2: *Salix-cinerea-Betula pubescens-Phramites austalis* woodland, most likely the *Alnus glutinos-Filpedula* sub-community. A number of the more frequent plants are listed including meadow sweet (*Filipendula ulmaria*), common reed (*Phragmites autralis),* reed canary-grass (*Phalaris arundinacea*), water mint (*Mentha aquaitca*), gypsywort (*Lycopus europaeus*) and common marsh bedstraw (*Galium palustra*). The publication Water Level

Requirements of Selected Plants and Animals (English Nature 1997) provides the dry/wetness range of some of the wetland plants and each plant can tolerate both drier (water table below the surface) and wetter (water depth above the ground surface) conditions. Although the floodplain surface is relatively flat there are variations in micro-topography and a range of conditions exist that provide the habitat requirements and mosaic of habitats for all these wetland species. It is proposed that the water table should be managed using the methods presented above, to achieve a maximum depth of water of 10cm above ground and a water table depth of 10cm below the surface during drier periods. This range would be suitable for all the plant species listed and matches the tolerance range of grey willow (*Salix cinerea oleifolia*), which is the dominant tree species.

6.16 It is recommended that the woodland is generally unmanaged or at least that only discreet intervention is carried out. Invasive action (e.g. large tree removal that can change the light and moisture conditions) has the potential to damage plants and alter the site hydrology. Standing and fallen deadwood should remain to support invertebrates, damselflies and dragonflies, lichens, mosses, bryophytes, fungi and other saproxylics. If left the wet woodland will perpetuate itself through natural regeneration, progressing through stages of senescence and regrowth.

6.17 It is appropriate, however, to remove non-native species. A number of invasive species are present including Japanese knotweed (*Fallopia japonica*) and Himalayan balsam (*Impatiens glandulifera*) that have spread along the margins of the River Cober and to Loe Pool. This issue has been known about for some time and some control and eradication work has been undertaken in the past (e.g. Dinsdale 2000 and 2003) and Kerrier District Council and the NT currently have ongoing eradication programmes. Nevertheless, small patches of knotweed and more extensive sections of balsam were observed as part of this survey. Other species of concern include parrot's feather (*Myriophyllum aquaticum*) that has been recorded in the amenity area ponds. The prevention of the spread of invasive species to Loe Pool is very important and Coronation Lake has been identified as is a possible provenance for algal propagules. In 2007 and 2008 (Dinsdale 2009) there were blooms of water net (*Hydrodictyon reticulatum*) and Nuttall's waterweed (*Elodea nuttallii*) was recorded in Loe Pool in 1999 increasing in abundance until 2006 and crashing in 2007 (Dinsdale 2007 and 2008). Systematic monitoring is required for all non-native invasive species and of all Schedule 9 species such as floating pennywort (*Hydrocotyle ranunculoides*), water fern (*Azolla filiculoides*) and Australian swamp stonecrop (*Crassula helmsii*). There has been a history of algal blooms in Loe pool in the recent past, though these are now much reduced with more limited extent appearing in hot summers only. It is thought that this reduction is related to reduction in nutrient enrichments to the pool following upgrading of Helston Sewage Works and changes to agricultural practices in the catchment (J Lister, pers. comm. 2014).

Implications to Flood Risk Management

6.18 One of the principal findings of this study is that water level depth in the River Cober, the principal cause of flood risk in lower Helston, is directly controlled by the interaction of flow off the Cober catchment, combined with the obstruction of flow at Loe Bar. These principal factors combine to cause elevated water levels in Loe Valley and hence a well-observed 'backing up effect', which can affect river levels well upstream into Helston, due to the very low longitudinal bed gradient of the river channel. In short, flow simply has nowhere to go.

6.19 With an unlimited flood defence budget, it would make sense to resolve the flood risk problem at the downstream end of the catchment, by installing a second, higher capacity outfall through Loe Bar to the sea. However, with limited, more realistic budgets, other solutions frequently have to be found. Although not part of the scope of this study, an increasing number of recent flood defence and mitigation projects have taken the upstream approach, as discussed in Section 1, where catchment management is changed in order to reduce flood risk downstream. Again, at the present time, this is not a feasible option for the Cober catchment at the present and so a balance has to be achieved. Mathematical modelling of the causes of flooding at Helston is not reported here, only that the geography of the carr has minimal impact on flood risk in Helston. With this in mind, it is expected that works to re-naturalise and re-wet the Loe Valley carr SSSI will have minimal effects on flood risk and may even bring some benefits under certain conditions, where flow is dissipated across the floodplain, albeit temporarily, increasing flood storage.

6.20 As stated in Section 3, at present, the Helston Flood Defence Strategy is under review. This process has recently been reported on in the form of the Environment Agency Helston (Cober) Appraisal - Long List of Options (prepared by Black and Veatch, 2013). It is also understood that Black and Veatch, on behalf of the Environment Agency are still undertaking flood risk modelling work on the system.

6.21 Within the appraisal document, a list of 16 options are proposed, which could potentially improve on or else mitigate against flood risk. Many of the management options proposed here are complimentary with those proposed in the appraisal.

6.22 It is widely appreciated though, that there needs to be a synergy between the requirements for flood risk management and hydrological/habitat management in Loe Valley Carr. Going forward, this will only be achieved by regular consultation, review and agreement between the EA and the NT.

6.23 There is thus a timely opportunity to allow the findings of this study to feed into the review process and allow enhancements and modifications of the new defence strategy (and vice-versa) that meet a range of multi-objective requirements, principally flood risk mitigation, enhanced biodiversity and landscape, enhanced amenity value and improved water quality. In this respect, it is considered that the range of management options proposed here for the Loe Valley Carr SSSI not only present no additional flood risk to Helston, but actually represent a 'win-win' situation to all stakeholder groups concerned.

6.24 Again, recent consultation with the EA stresses that further discussion regarding the maintenance regime for this section of the Cober is required. This has been identified as an important element of the Helston Flood Defence Strategy and an agreed and adopted Maintenance Plan is an objective for the flood defence review project. Continued consultation between the EA and the NT is, therefore, essential.

6.25 The EA stress that "..the scope of proposed work included in this study reinforces the need for all parties to have seen and gained acceptance of Black and Veatch's modelling outputs. Further information relating to constraints associated with the Helston Flood Defence Strategy are required to inform this (NT) study..." The EA have, therefore, committed to make available the final hydrological modelling outputs, but the timing of the release of this information is a critical factor in informing both studies and this needs to be appreciated by both organisations going forward.

Is Re-Naturalisation Achievable?

6.26 This study has demonstrated that a range of relatively inexpensive measures could be employed in order to promote a re-naturalisation of the River Cober downstream of Helston and the valley carr habitat in which it sits. Furthermore, this re-naturalisation should be achievable with minimal impact on upstream flood risk and allow continued or even enhanced public access and amenity.

6.27 By utilising existing topography, structural changes to the river banks and the carr itself should allow increased frequency of inundation across significant areas of the carr and in particular, the potentially drier upstream section of the habitat, which is at most risk from accelerated drying.

6.28 Once introduced to the floodplain, simple structures and measures can be employed in order to increase the residence time of standing water, and so maintain optimal habitat conditions in terms of soil moisture and water table levels. Taken together, these simple measures thus serve to re-connect the river channel with its floodplain. In addition, if the River Cober is allowed to accumulate bed sediment naturally, the depth of the channel should decreased over time and re-naturalise, leading to increased frequency of over bank flow and by default, a more naturally functioning fluvial system.

6.29 The obvious spin-off benefits are enhanced biodiversity and the continued sustainability of this nationally important habitat, whilst the floodplain can also act as a scrubbing system, in which nutrients are fixed and removed from streamflow and/or inundation, thus improving the water quality of Loe Pool.

6.30 In terms of capital outlay, expensive management options have been avoided in favour of simpler, more cost-effective and economically sustainable options. Furthermore, the physical size and spatial extent and location of these management structures means that increases to floodplain 'roughness'; a key factor in considering flood risk, will be kept to an absolute minimum.

6.31 The type of management proposed here is scalable, in that a small scale implementation need only be tried in order to prove its effectiveness, without the need for significant capital outlay at the start. A 'try it and see' approach is ideal in order to determine those techniques which are effective and those which may be less effective or not suitable for the site. Similarly the amount of works required may be very small, presenting "big and quick wins" from the outset, with a minimal capital outlay.

6.32 The obvious, multiple benefits that will accrue from the proposed scheme mean that it is ultimately within all parties interests to implement further monitoring and enhanced management of this important site.

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FIGURES

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Buxton, Derbyshire, SK17 6SN.
Telephone 01298 27086

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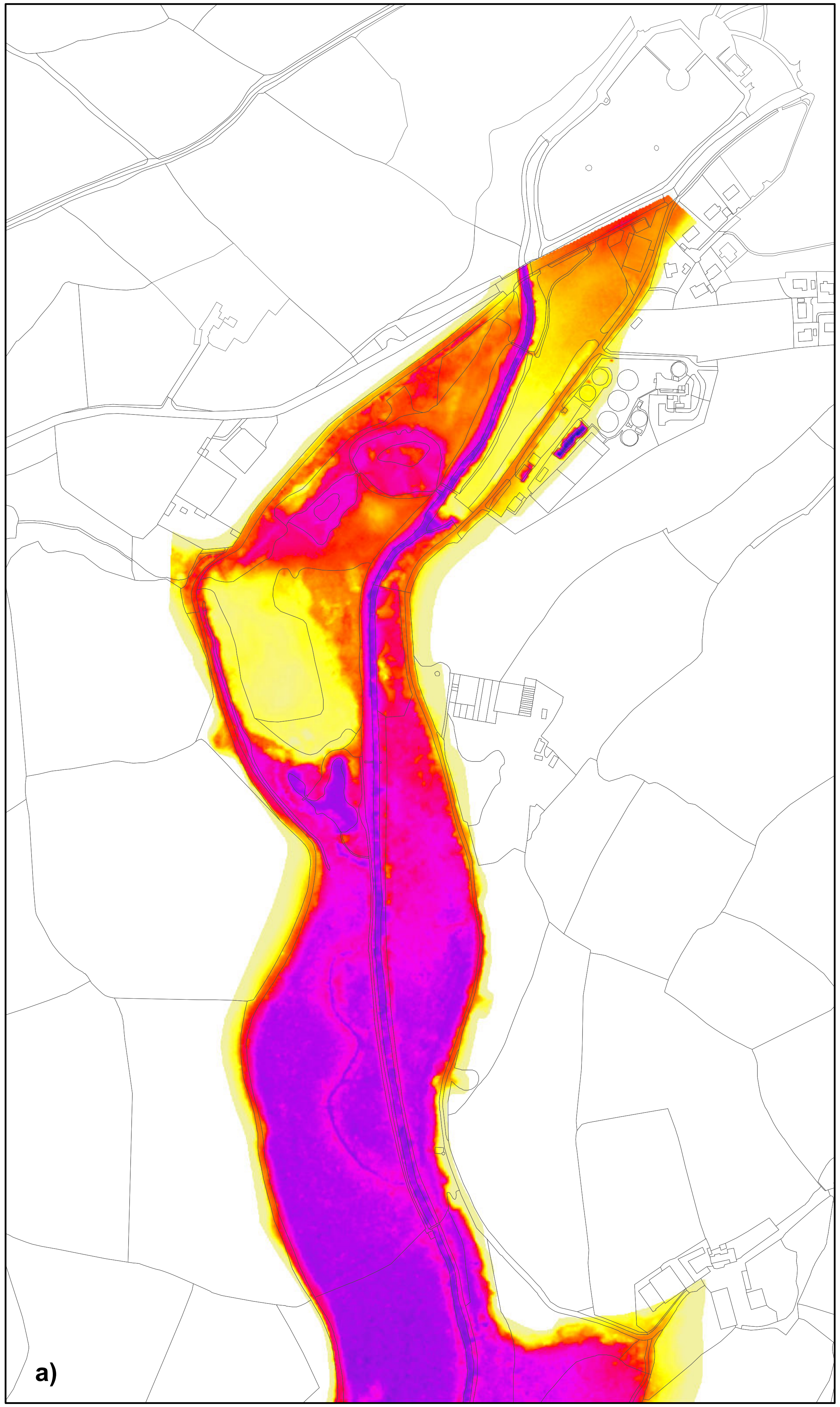
British National Grid
Projection: Transverse Mercator
False Easting: 400000.000000
False Northing: -100000.000000
Central Meridian: -2.000000
Scale Factor: 0.999601
Latitude Of Origin: 49.000000

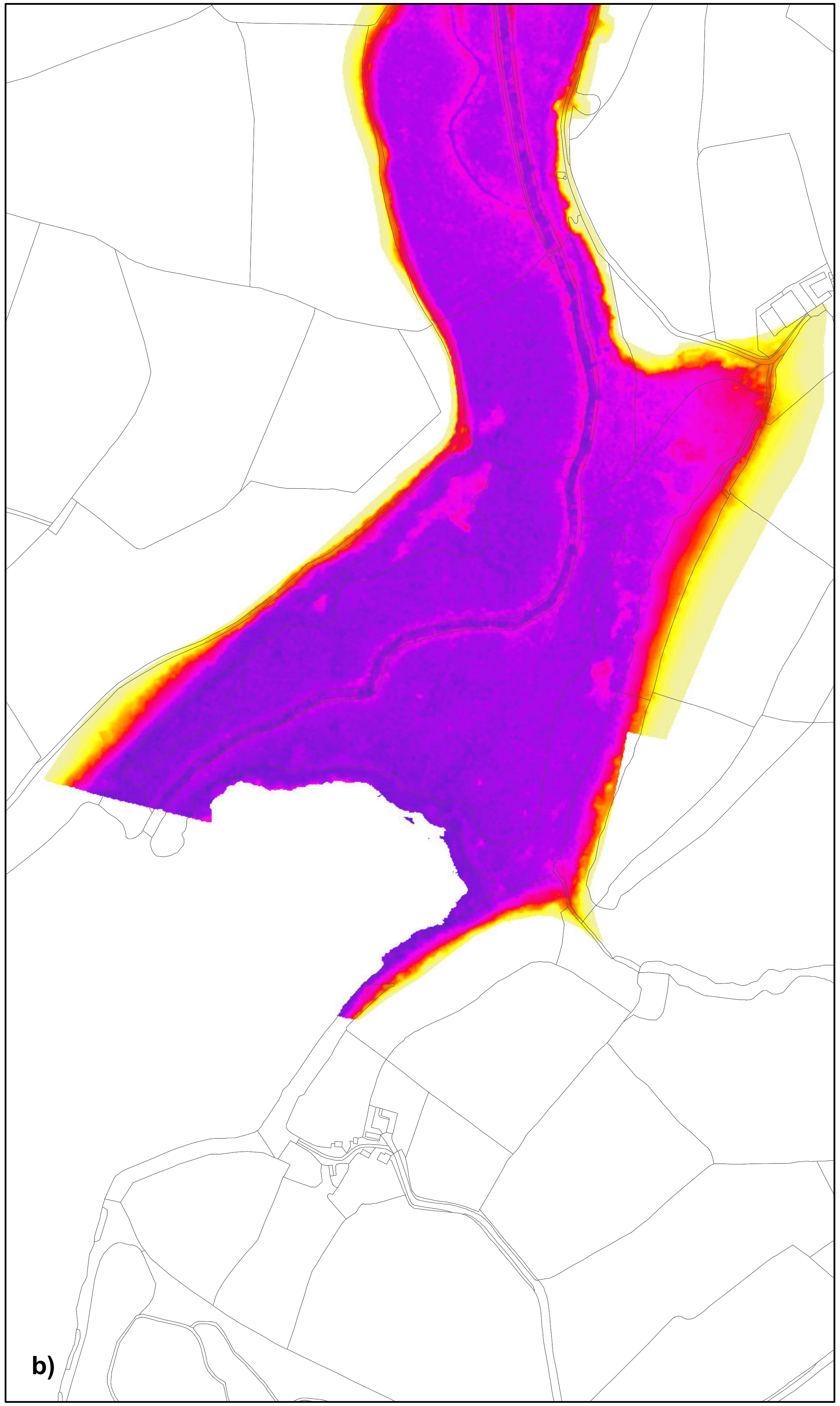
ISO A3

0 125 250 500 Meters

Title: **OVERVIEW OF LOE POOL AND VALLEY CARR SSSI**	Discipline: Hydrology
	Scale: 1:15,000 — Drawing No.: Figure 1.1
	Drawn By: GCH — Originator: GCH — Date: 29/01/2014
Project Name: Hydrological Study - Loe Valley Carr SSSI	PAA Ref.: — Revision: A



a)



b)

Legend

Elevation (mAOD)

High : 13.04

Low : 2.72

N

British National Grid
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False Northing: -100000.000000
Central Meridian: -2.000000
Scale Factor: 0.999601
Latitude Of Origin: 49.000000

ISO A3

0 50 100 Meters

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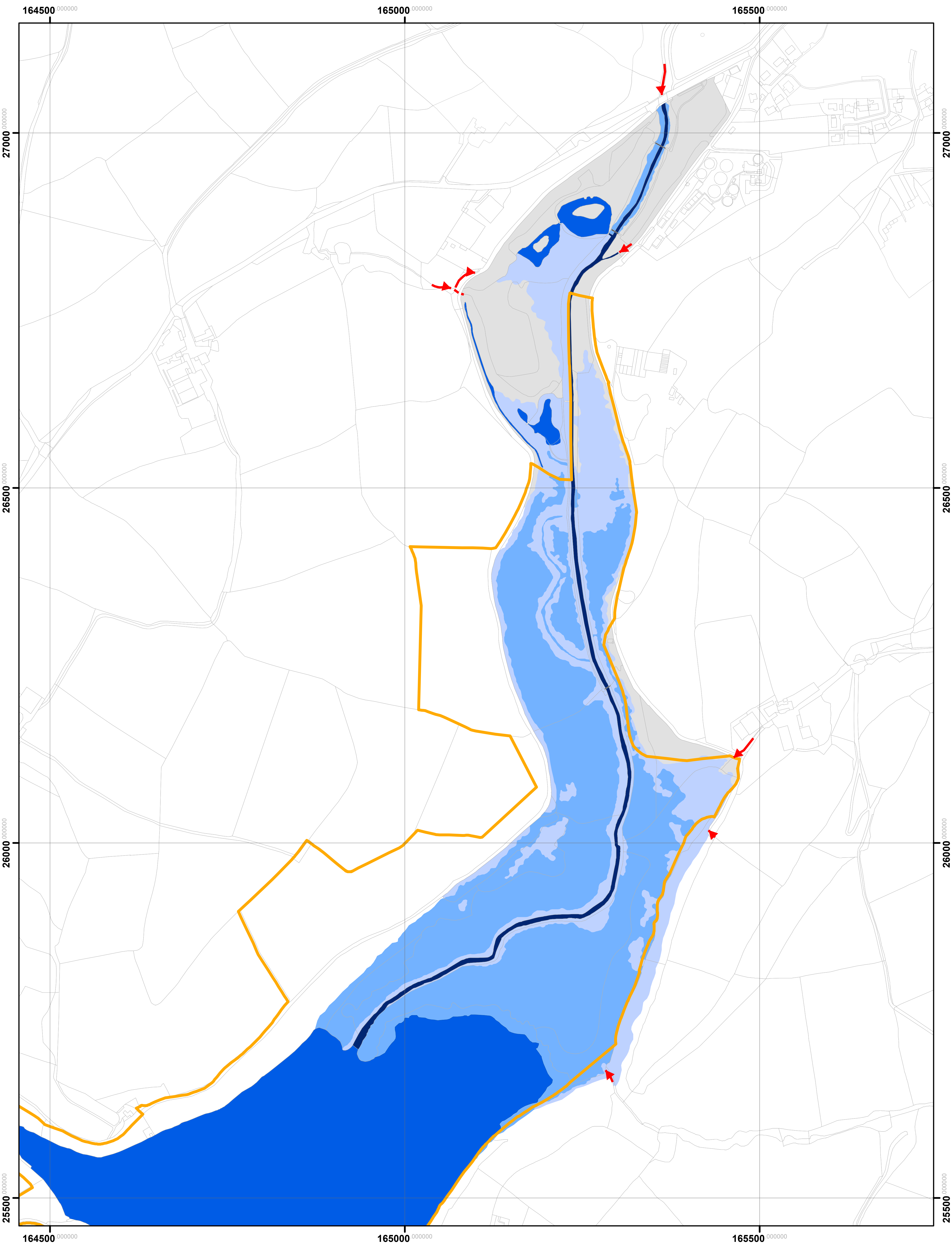
Telephone 01298 27086

Project Name	Loe Valley Carr SSSI Hydrological Investigation
Discipline	Hydrology
Title:	FLOODPLAIN TOPOGRAPHY FROM 0.5m RESOLUTION LIDAR DTM DATA
Scale: 1:4,500	Drawing No. Figure 2.1
Drawn By: GCH	Originator: GCH
Date: 29/01/2014	
PAA Ref.	Revision: 1.0



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False Northing: -100000.000000
Central Meridian: -2.000000
Scale Factor: 0.999601
Latitude Of Origin: 49.000000

ISO A3

0 50 100 Meters

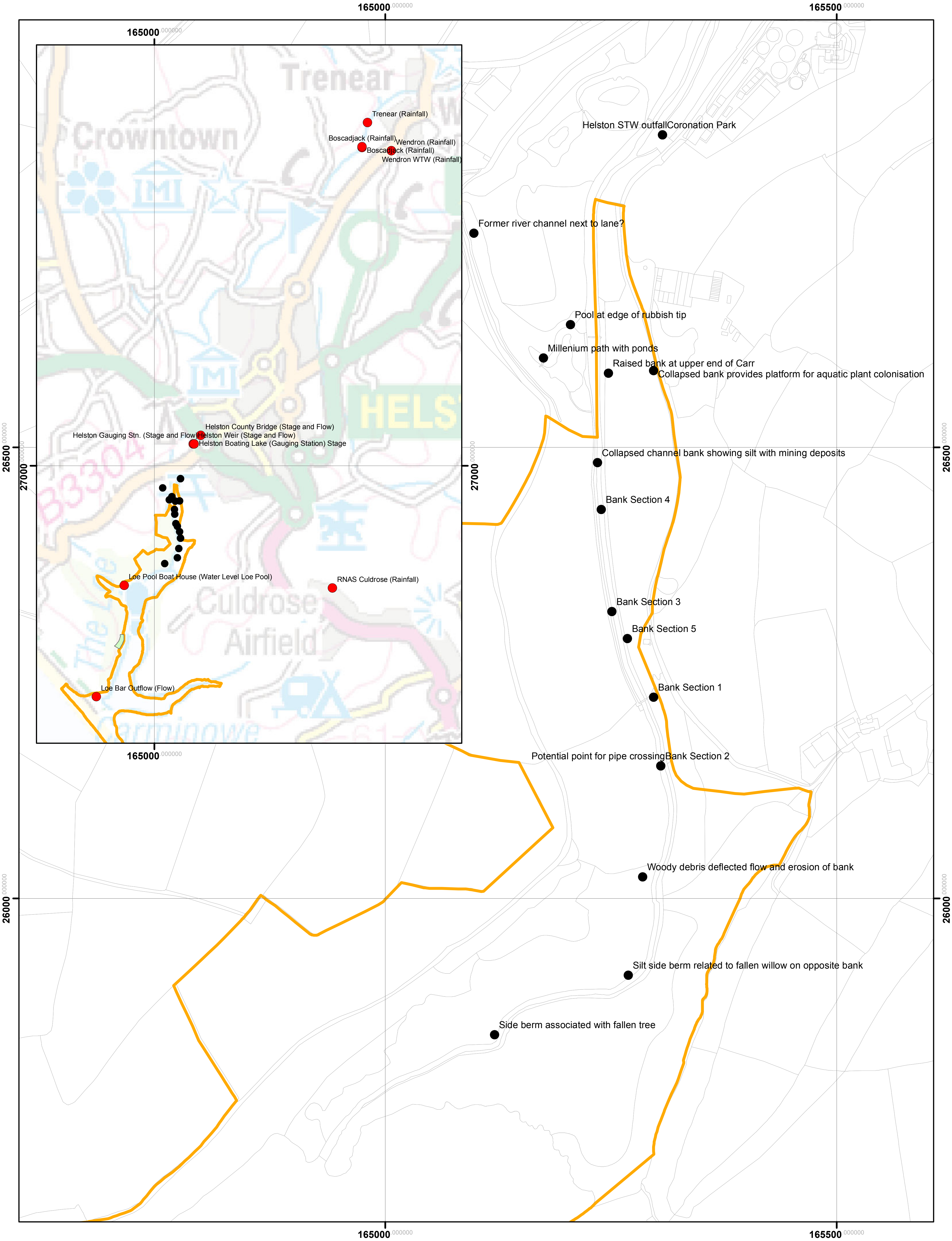
Legend

Carr hydrological units

Description

- Elevated land - water control not feasible
- Raised areas - water level control problematic
- Low lying areas - water level control possible or not required
- Standing water
- River Cober
- Structure
- Major sources of flow (excluding R. Cober)

Title: SURFACE HYDROLOGY	Discipline: Hydrology
	Scale: 1:15,000
	Drawing No.: Figure 2.2
	Drawn By: GCH
	Originator: GCH
	Date: 29/01/2014
Project Name: Hydrological Study - Loe Valley Carr SSSI	PAA Ref.:
	Revision: A



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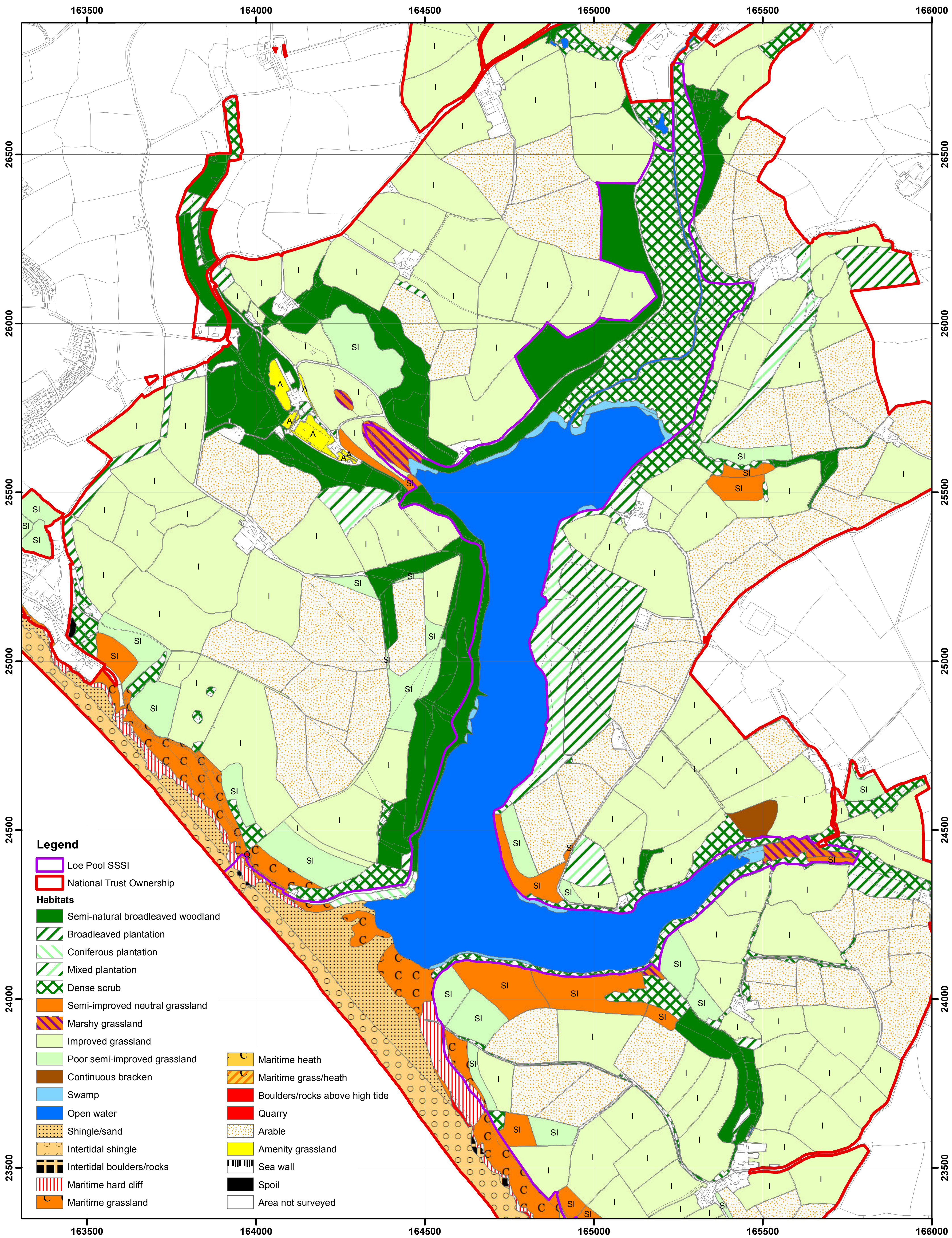
False Northing: -100000.000000
Central Meridian: -2.000000
Scale Factor: 0.999601
Latitude Of Origin: 49.000000

ISO A3

0 50 100 Meters

Title: **SITE SURVEY AND EXISTING MONITORING STATIONS**	Discipline: Hydrology		
	Scale: 1:15,000	Drawing No.: Figure 2.3	
	Drawn By: GCH	Originator: GCH	Date: 29/01/2014
Project Name: Hydrological Study - Loe Valley Carr SSSI	PAA Ref.:	Revision: A	



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False Easting: 400000.000000
False Northing: -100000.000000
Central Meridian: -2.000000
Scale Factor: 0.999601
Latitude Of Origin: 49.000000

N

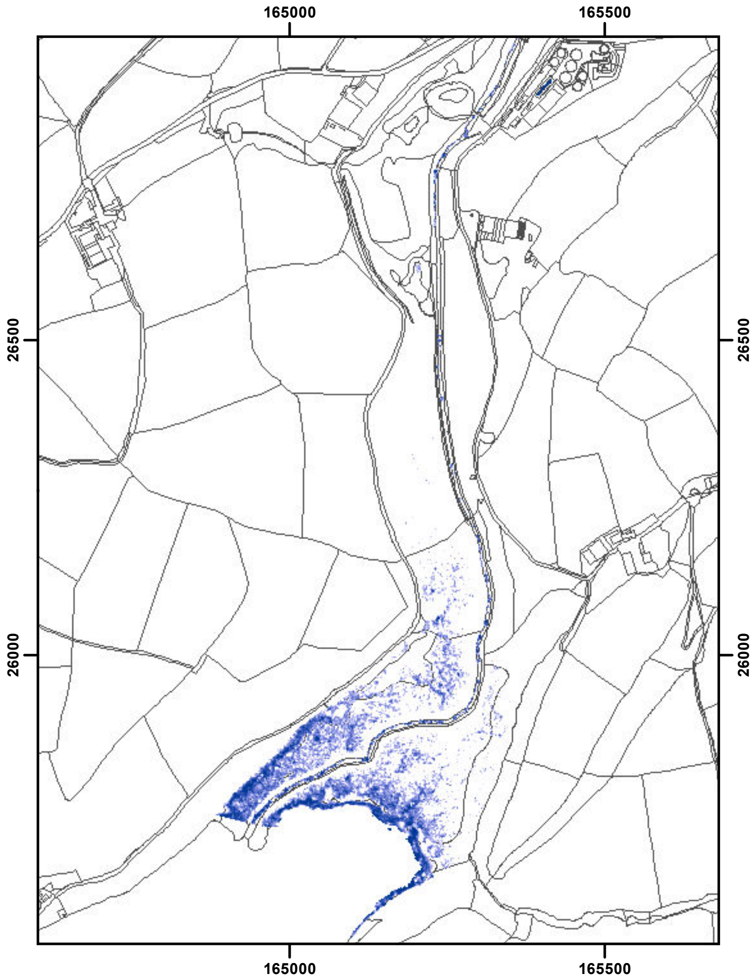
ISO A3

0 100 200 300 Metres

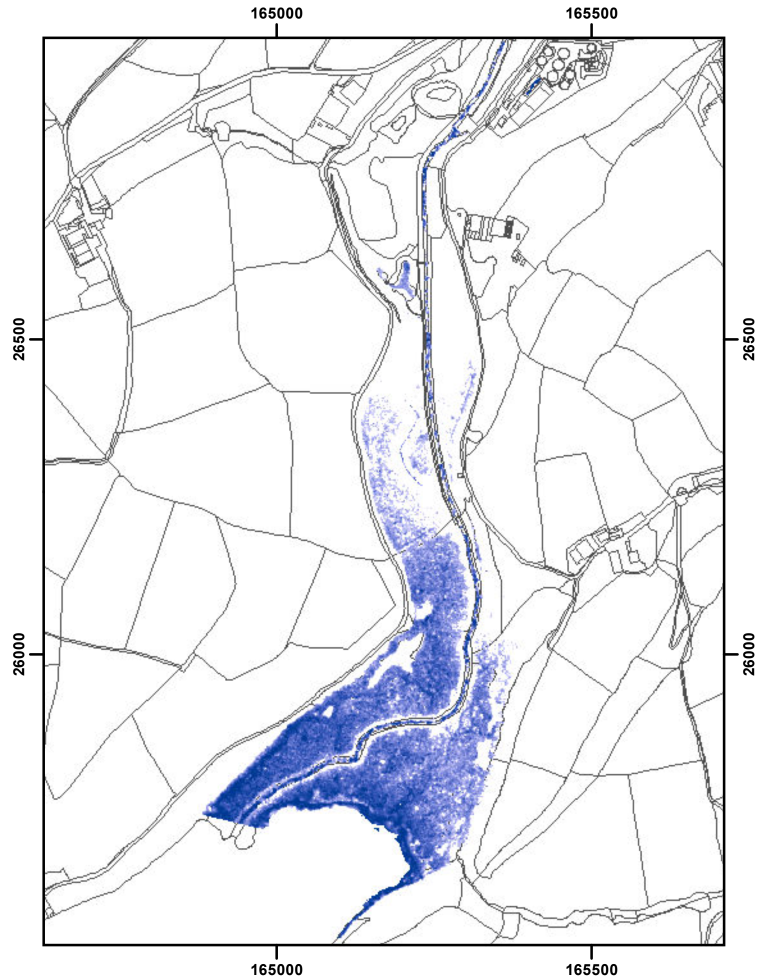
Title: **LOE POOL AND VALLEY CARR SSSI: HABITATS AND ECOLOGY**

Project Name: Hydrological Study - Loe Valley Carr SSSI

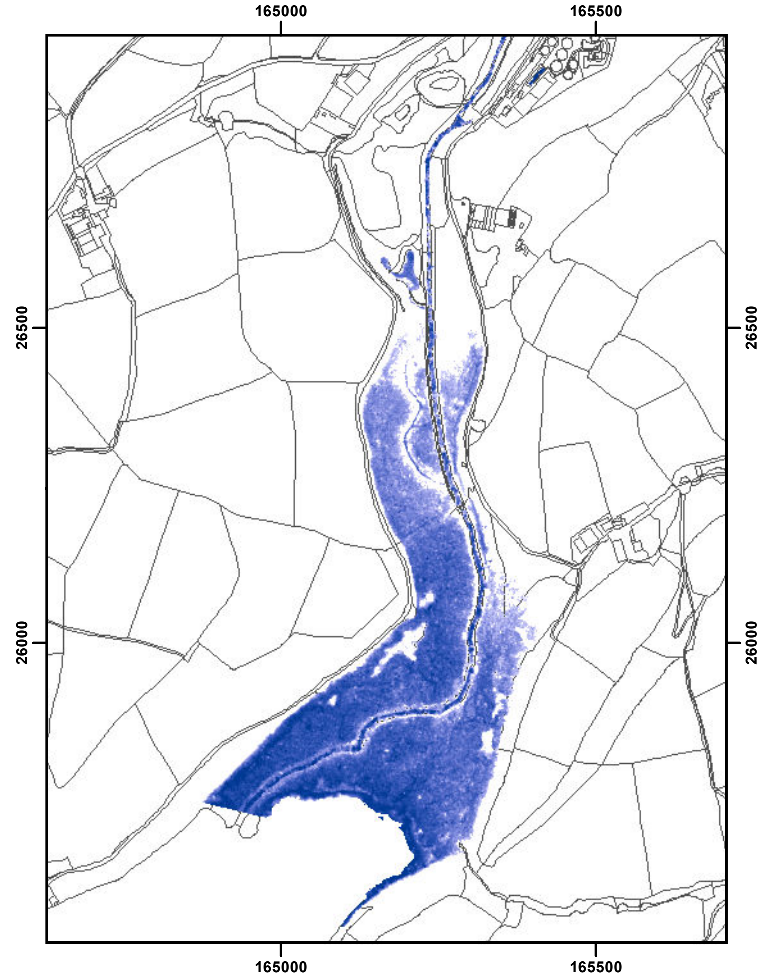
Discipline: Hydrology		
Scale: 1:15,000	Drawing No.: Figure 2.4	
Drawn By: GCH	Originator: GCH	Date: 29/01/2014
PAA Ref.:	Revision: A	



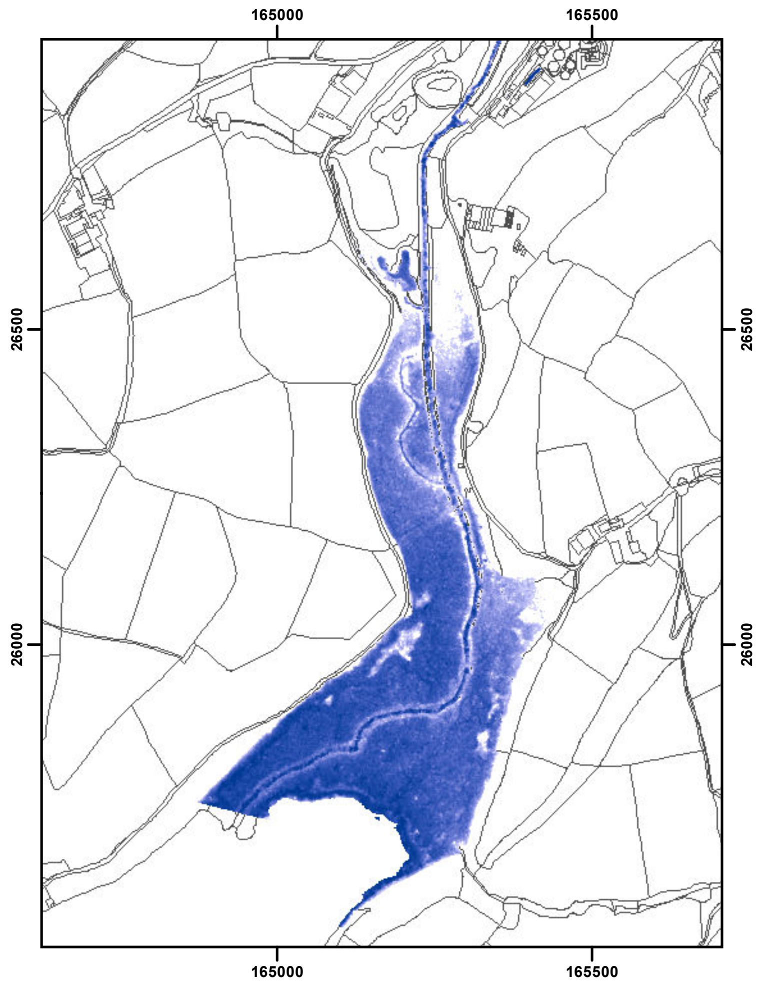
Loe Pool water depth 4.00m



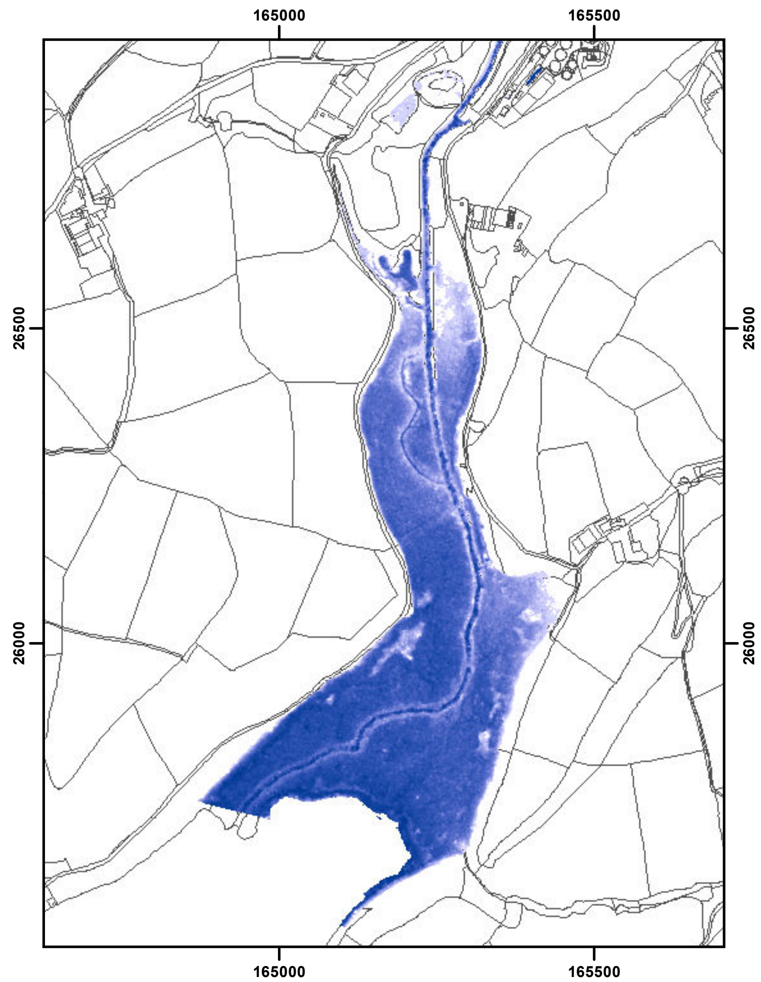
Loe Pool water depth 4.25m



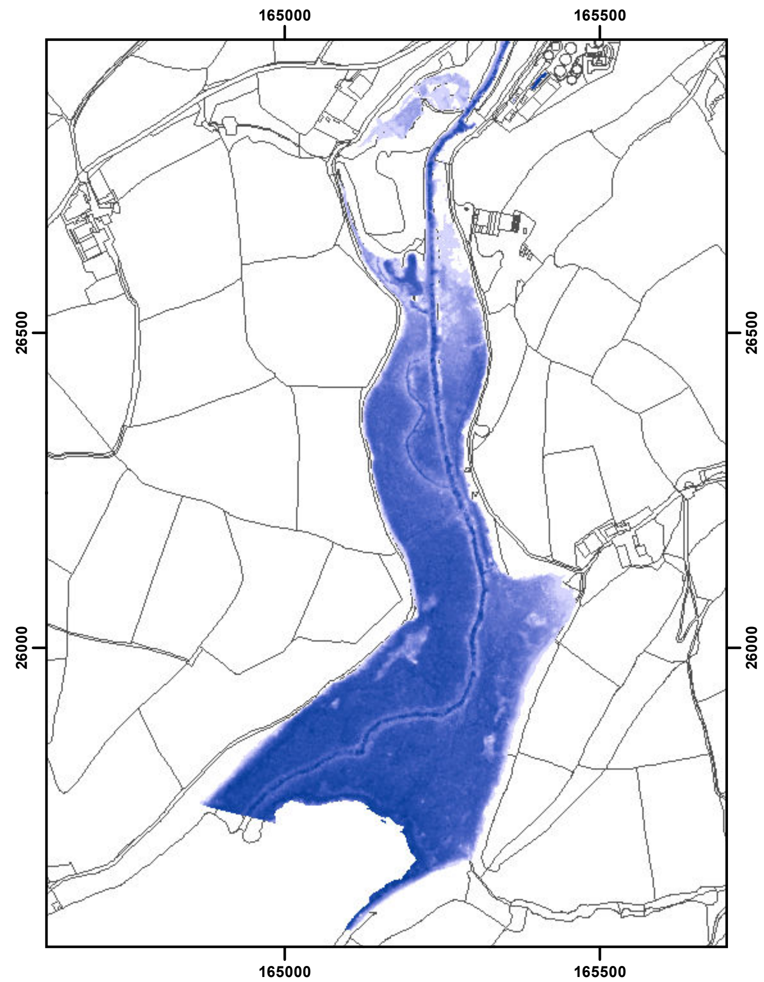
Loe Pool water depth 4.50m



Loe Pool water depth 4.75m



Loe Pool water depth 5.00m



Loe Pool water depth 5.50m (one event, December 2012)

Legend

Water Depth (m)

High : 3.0

Low : 0

N

British National Grid
Projection: Transverse Mercator
False Easting: 400000.000000
False Northing: -100000.000000
Central Meridian: -2.000000
Scale Factor: 0.999601
Latitude Of Origin: 49.000000

ISO A3

0 125 250 Meters

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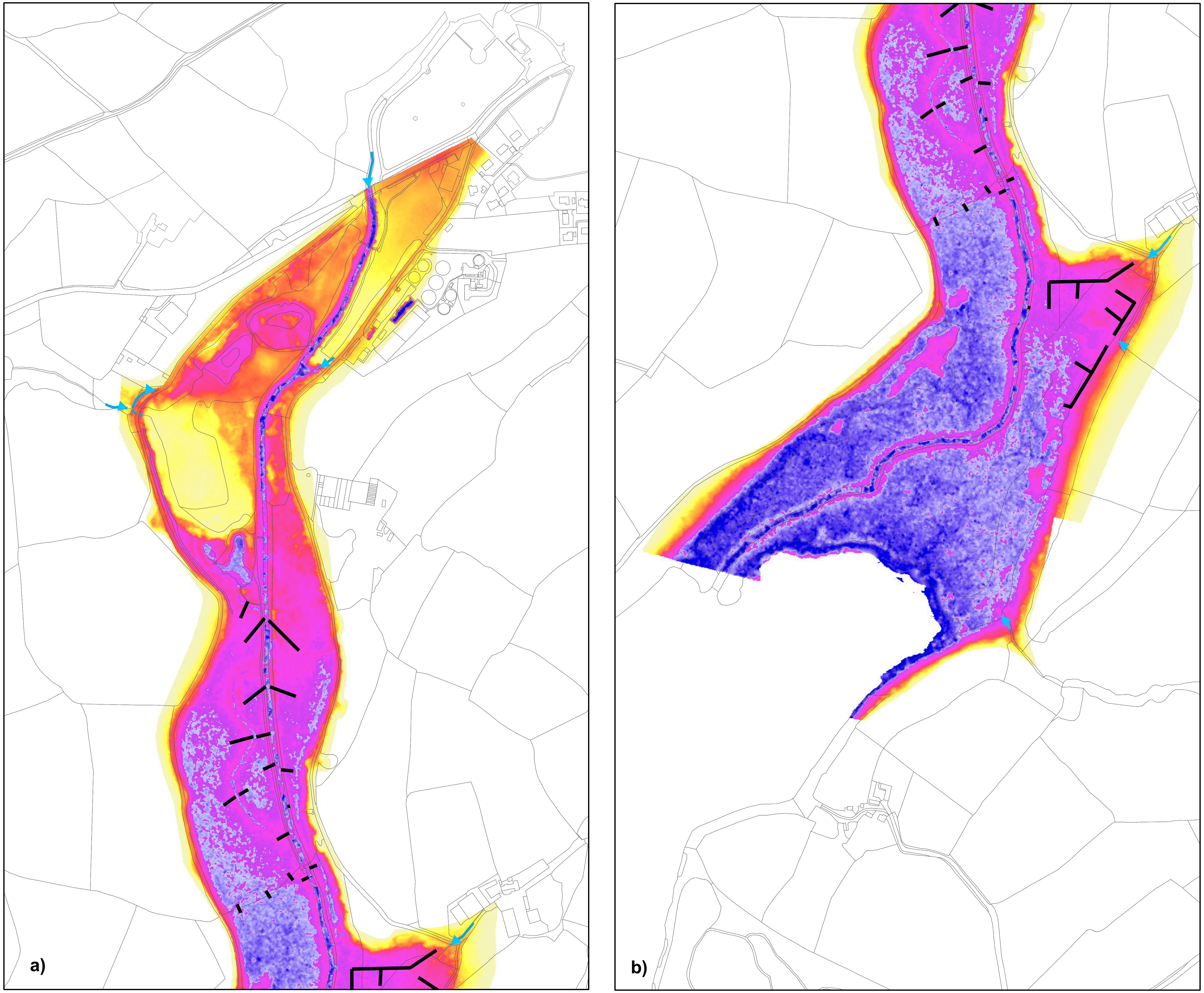
Project Name: Loe Valley Carr SSSI Hydrological Investigation

Discipline: Hydrology

Title:

FLOODPLAIN INUNDATION EXTENT AND DEPTH AT VARIOUS LOE POOL WATER LEVELS (FLOODS)

Scale	1:500,000	Drawing No.	Figure 3.5
Drawn By	GCH	Originator	GCH
Date	29/01/2014		
PAA Ref.		Revision	1.0



Legend

- Major sources of additional flow
- Water level management structures

4.25m AOD Inundation
High : 1.53
Low : 0

N

British National Grid
Projection: Transverse Mercator
False Easting: 400000.000000
False Northing: -100000.000000
Central Meridian: -2.000000
Scale Factor: 0.999601
Latitude Of Origin: 49.000000

ISO A3

0 50 100 Meters

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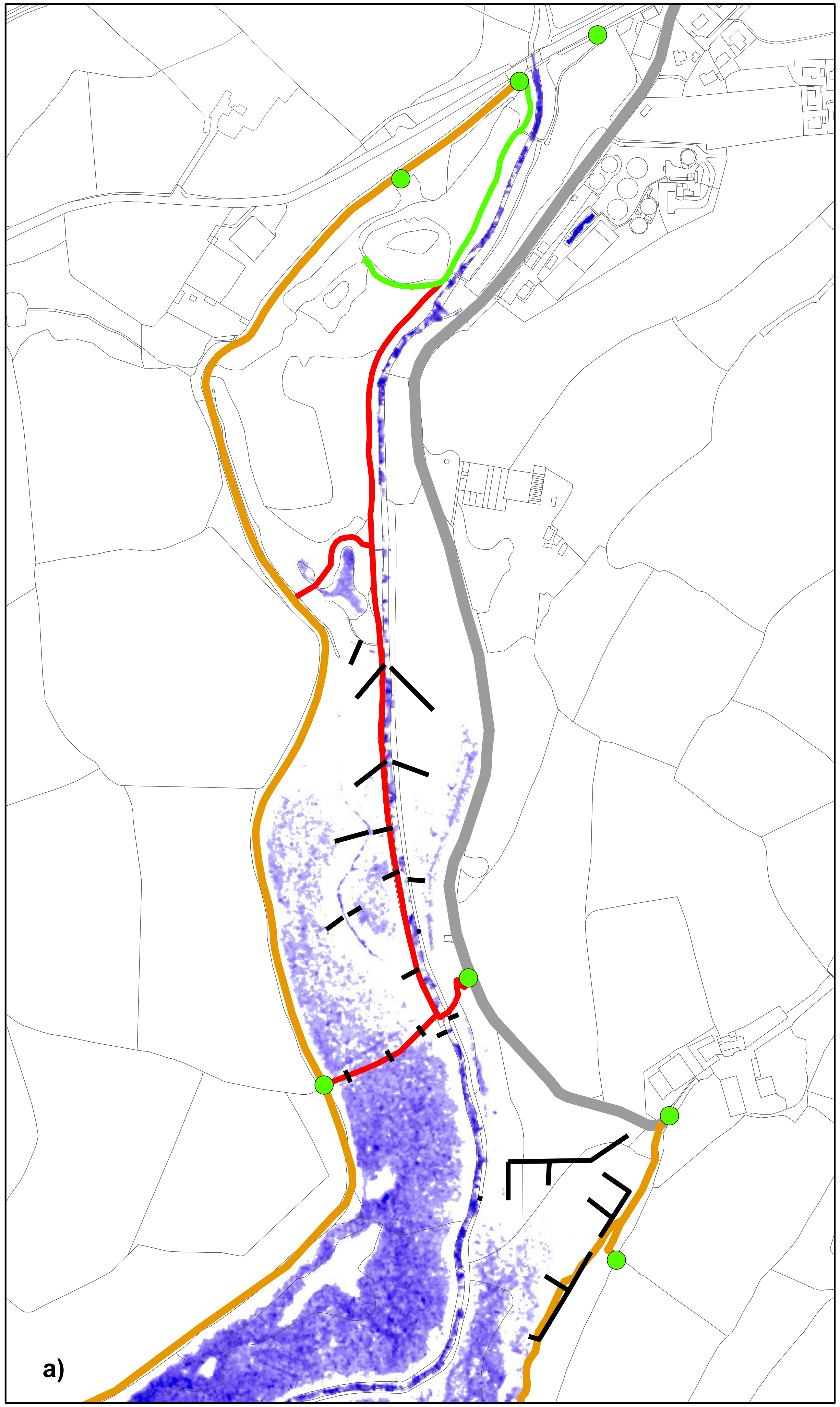
Project Name: Loe Valley Carr SSSI Hydrological Investigation

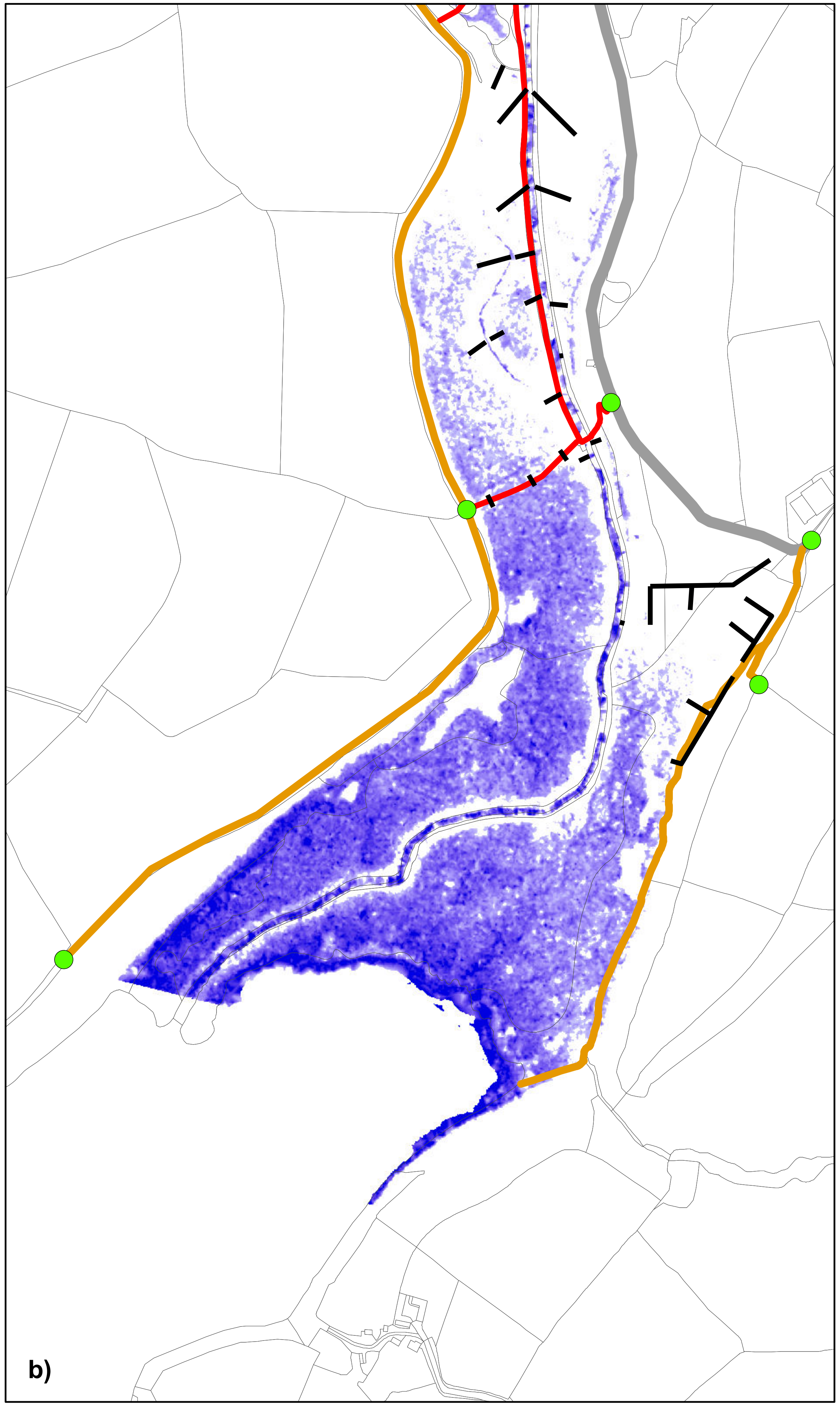
Discipline: Hydrology

Title:

INDICATIVE LOCATION OF POSSIBLE FLOW AND WATER LEVEL CONTROL STRUCTURES

Scale	1:12,000	Drawing No.	Figure 6.1
Drawn By: GCH	Originator: GCH	Date	29/01/2014
PAA Ref.		Revision	1.0





Legend

- Public access points

Paths tracks and walkways

- Bridleway
- Footpath to be retained and modified
- Footpath to be retained unmodified
- Tarmaced lane
- Water level management structures

N

British National Grid
Projection: Transverse Mercator
False Easting: 400000.000000
False Northing: -100000.000000
Central Meridian: -2.000000
Scale Factor: 0.999601
Latitude Of Origin: 49.000000

ISO A3

0 50 100 Meters

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Project Name	Loe Valley Carr SSSI Hydrological Investigation
Discipline	Hydrology
Title:	CURRENT AND PROPOSED SITE MANAGEMENT AND PUBLIC ACCESS

Scale	1:4,500	Drawing No.	Figure 6.2
Drawn By GCH	Originator GCH	Date	29/01/2014
PAA Ref.		Revision	1.0

APPENDICES

APPENDIX 1

Field Notes and Photographic Survey

APPENDIX 1

FIELD NOTES (19-11-2013, 20-11-2013)

River Cober in Helston (St Johns Close area)

River Cober in Helston (St Johns Close area) - Stage meter right bank looking downstream

River Cober in Helston (LiDL Store) - Stage meter and urban runoff outfall, left bank looking downstream

River Cober in Helston - Zacharys Bridge, left bank looking downstream

River Cober immediately downstream of Zacharys Bridge – Two-stage flood channel constructed in 1988 as part of Helston flood defence works

River Cober downstream of Zacharys Bridge - Two stage flood channel constructed in 1988 as part of Helston flood defence works

Photo 77 - Very significantly raised bank on left bank of River Cober, looking across to the stretch of two-stage channel (1988 flood defence works). Carr behind bank reasonably wet though little standing water (November). Extremely dense vegetation. Pipe installation not recommended due to unsuitable topography, levels and access issues.

Photo 61 - Collapsed silt bank with mining sediment deposits

Photo 62 - Collapsed silt bank with mining sediment deposits

Photo 63 - Water drains out of the carr into the river (site where in-filled, former river channel exits the carr)

Photo 64 - Water drains out of the carr into the river (where infilled, former channel exits the carr)

Photo 65 - Pool at edge of rubbish tip (SW65205,26636)

Photo 66 - Pool at edge of rubbish tip (SW65205,26636)

Photo 67 - Small tributary stream running in opposite direction to River Cober, towards Helston

Photo 68 - Old river channel? Next to lane. (SW65098,26737)

Photo 70 - Quarry

Photos 71, 72, 73 - Millennium path with ponds and channels (SW65175,26599)

Tributary feeding into the carr at Nansloe Farm (Location B)

High coarse sediment load at tributary feeding into the carr at the lower end near Loe pool reedbeds (Location A)

Loe Pool (Location C)

EA Outfall from Loe Pool into sea (Location N)

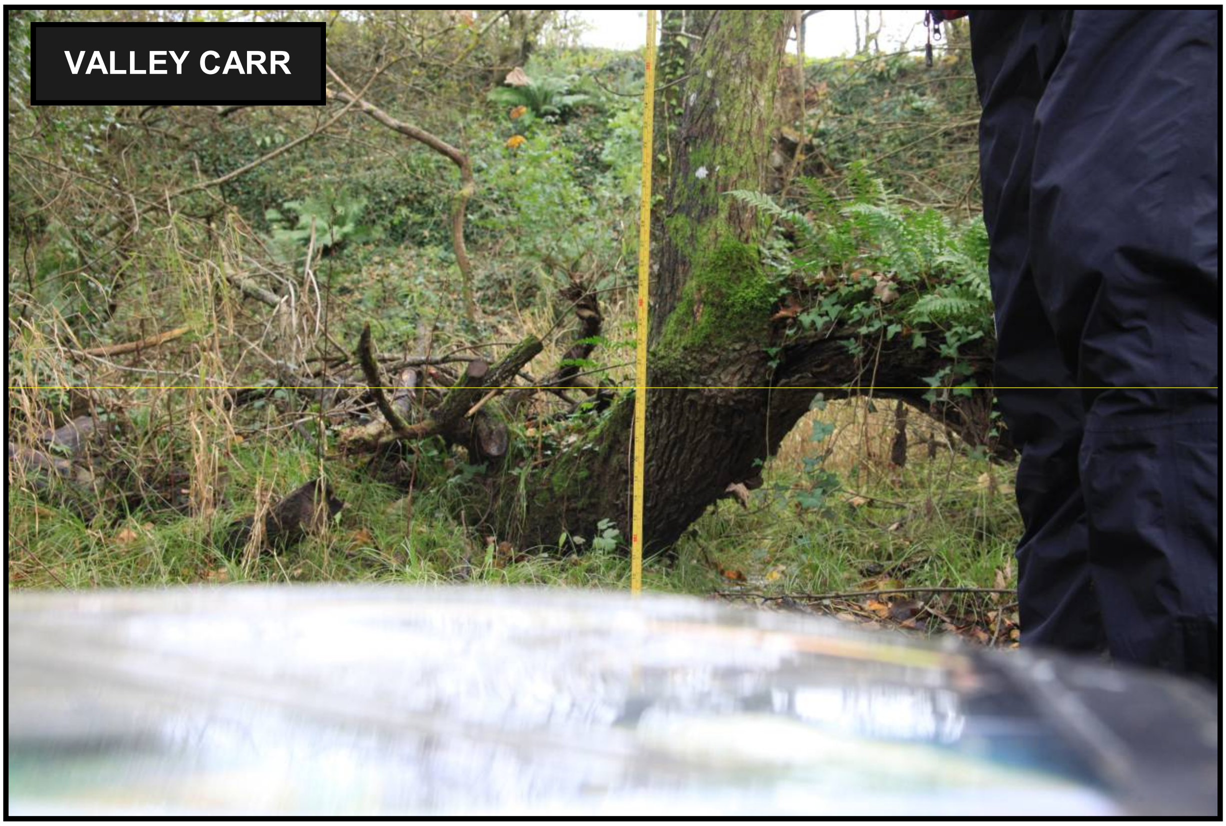
APPENDIX 2

Levels Survey – River Cober 20-11-13

LOE VALLEY CARR HYDROLOGICAL STUDY
APPENDIX 2 - LEVELS SURVEY

Penny Anderson Associates Ltd
Consultant Ecologists

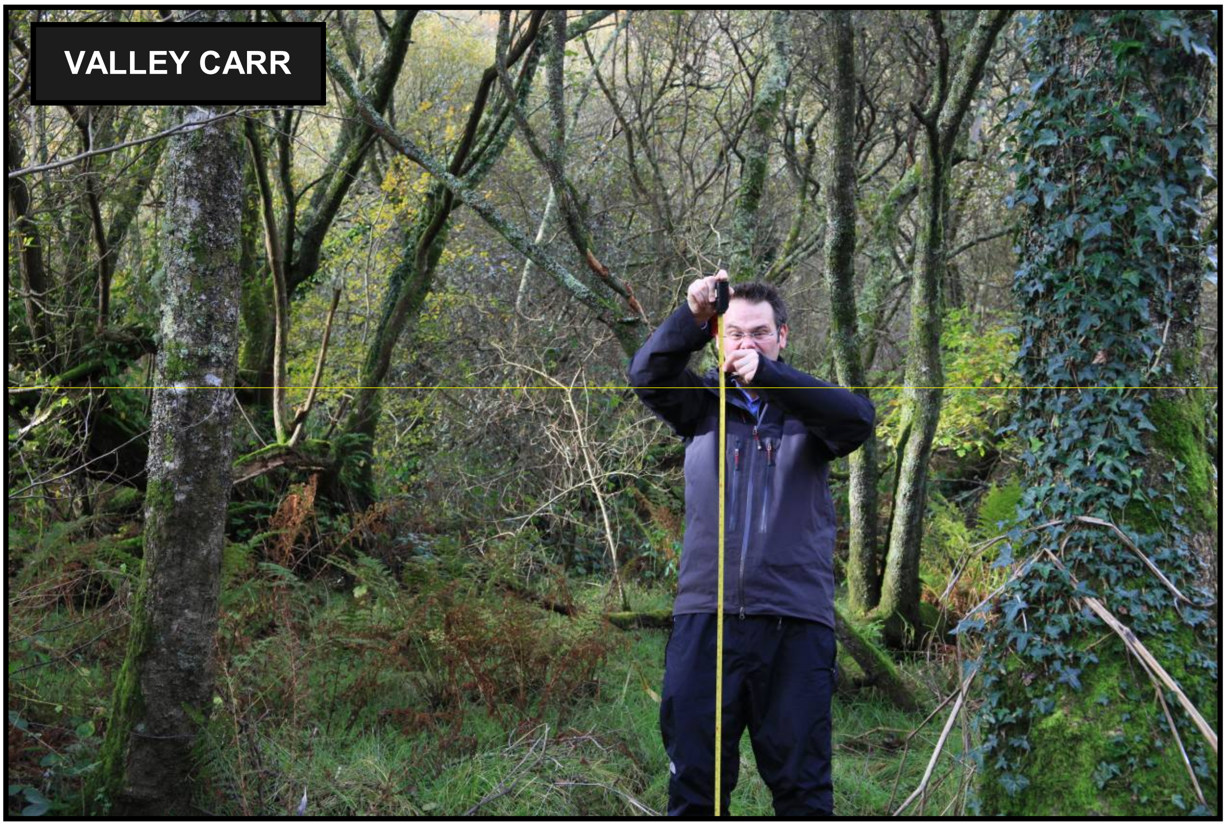
Section No.	1	**Date**	20/11/2013
Surveyor	GH & GJH	**Time**	10.40
Grid Reference	SW 65297,26223	**Water Level**	1.5m (approx)
Notes	Left bank looking downstream, just DS of NT gate and pathway. Photos 51 (river) and 52 (carr).		



LOE VALLEY CARR HYDROLOGICAL STUDY
APPENDIX 2 - LEVELS SURVEY

Penny Anderson Associates Ltd
CONSULTANT ECOLOGISTS

Section No.	2	**Date**	20/11/2013
Surveyor	GH & GJH	**Time**	11.00
Grid Reference	SW 65305, 26147	**Water Level**	1.5m (approx)
Notes	Right bank looking DS. South of NT gate. Photos 53,54 and 55		



LOE VALLEY CARR HYDROLOGICAL STUDY
APPENDIX 2 - LEVELS SURVEY

Penny Anderson Associates Ltd
Consultant Ecologists

Section No.	3	**Date**	20/11/2013
Surveyor	GH & GJH	**Time**	11.25
Grid Reference	SW 65251, 26318	**Water Level**	1.25-1.5m (approx)
Notes	Right bank, looking downstream. North of NT gate by public ROW. Photos 56 (river) and 57/58 (carr).		

RIVER COBER

VALLEY CARR

LOE VALLEY CARR HYDROLOGICAL STUDY
APPENDIX 2 - LEVELS SURVEY

Penny Anderson Associates Ltd
Consultant Ecologists

Section No.	4	**Date**	20/11/2013
Surveyor	GH & GJH	**Time**	12.00
Grid Reference	SW 65239, 26431	**Water Level**	1.5m (approx)
Notes	Right bank looking DS, North of NT gate by public ROW. Photos 59 (river) and 60 (carr).		

LOE VALLEY CARR HYDROLOGICAL STUDY
APPENDIX 2 - LEVELS SURVEY

Section No.	5	**Date**	20/11/2013
Surveyor	GH & GJH	**Time**	12.50
Grid Reference	SW 65268, 26288	**Water Level**	1.5m (approx)
Notes	Left bank looking DS, North of NT gate by public ROW. Photos 59 (river) and 60 (carr). Access into Carr extremely difficult due to dense vegetation and surface water-logging.		

RIVER COBER

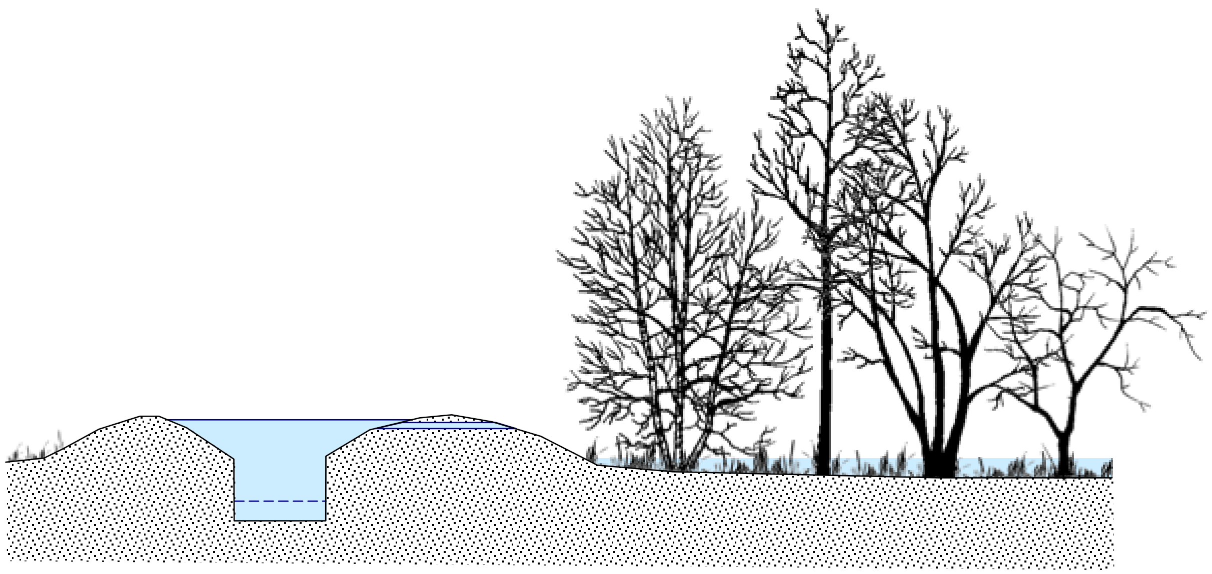
VALLEY CARR

APPENDIX 3

Options for Management – Technical Summary

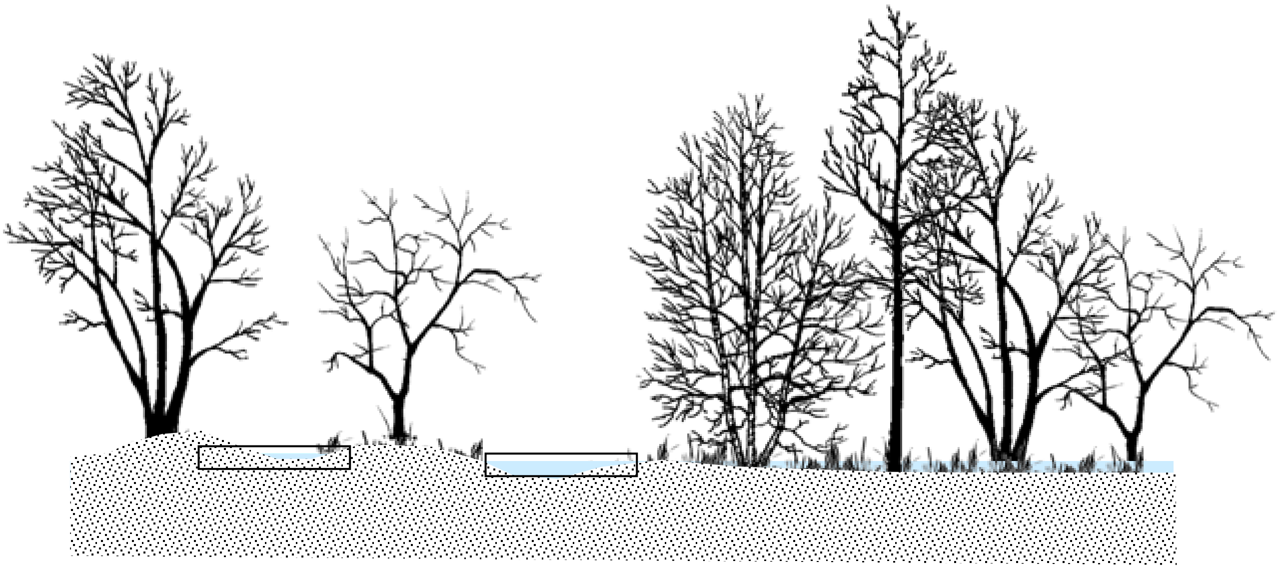
APPENDIX 3
OPTIONS FOR MANAGEMENT: TECHNICAL SUMMARY

Technique:	Loe Valley Carr - Water Level Management Structures



Objective	To mange the supply of water to the floodplain valley carr in order to maintain optimal soil water table levels for the continued sustenance of the willow carr wet woodland habitat. Water taken off the main river channel of the Cober via flow bypass structures which operate at river levels slightly below bankfull conditions. Subject to levels surveys.
Where used	Loe Valley Carr SSSI – upper, drier section of the carr
Method	Structures can be closed (i.e. buried pipes) or open (sunk conduit sections), with flow controls at each end, which may consist of lockable caps (pipes) or mini drop board weirs (open conduit sections). Pipes installed and buried at suitable locations. Conduit sunk into river bank / levees at suitable locations. Careful siting required and subject to detailed local levels survey. Suitable / appropriate river bank erosion protection may be required.
Consult	Environment Agency and National Trust – relevant contacts. Ensure that siting and number of water level management structures is compatible with existing and future maintenance plans for the River Cober.
Further management	Minimal, but periodic checks to ensure that structures remain clear of debris and water levels are managed as required, throughout the year.
Equipment	Small excavator, ground works tools, plastic pipe or concrete open conduit products
Flood Risk	None / Beneficial- May decrease flood risk for certain periods during storm events by increasing floodplain storage of water

Technique:	Loe Valley Carr - Water Level Management Structures



Objective	To mange the supply of water to the floodplain valley carr in order to maintain optimal soil water table levels for the continued sustenance of the willow carr wet woodland habitat. Water is retained for longer time periods on drier areas of the carr by low, removable drop board weir structures located in conjunction with other flow control structures or areas of lower topography, such as relict channels
Where used	Loe Valley Carr SSSI – upper, drier section of the carr
Method	Structures can be closed (i.e. board(s) in place to prevent flow) or open (boards removed to surface flow), in order to cause surface ponding in key locations and increase periods of at or near surface soil saturation. Board control structures sited at suitable locations, such as breaches in raised gravel pathways. Careful siting required and subject to detailed local levels survey.
Consult	Environment Agency and National Trust – relevant contacts. Ensure that siting and number of water level management structures is compatible with existing and future maintenance plans for the River Cober.
Further management	Ongoing management and maintenance required for water level management, throughout the year. Generally, boards left in place during summer (drier) months and removed during winter (wetter) months. Ensure that structures remain clear of debris and water levels are throughout the year.
Equipment	Small excavator, ground works tools, treated timber for installation in waterlogged conditions
Flood Risk	None / Beneficial – May decrease flood risk for certain periods during storm events by increasing floodplain storage of water

Technique:	River Cober – Raising River Bed Levels

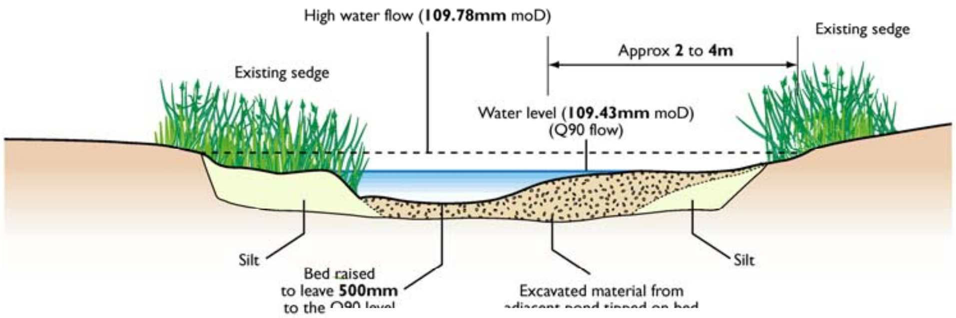


Figure 5.5.2
SECTION A THROUGH RAISED BED AND MARGINAL SHOAL

These techniques are developed to suit site

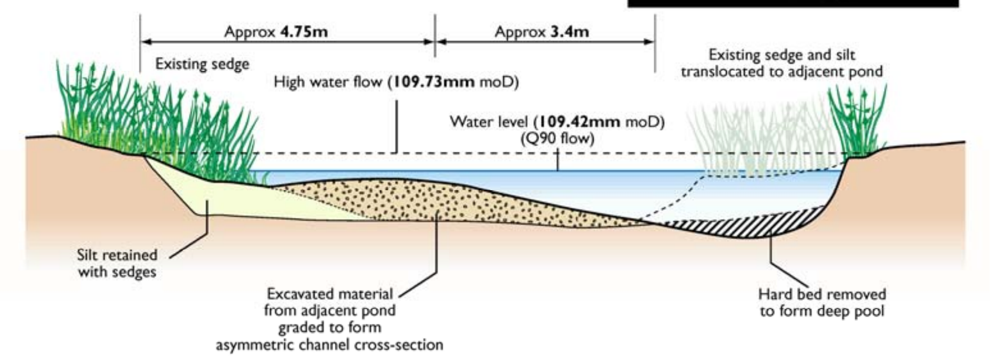
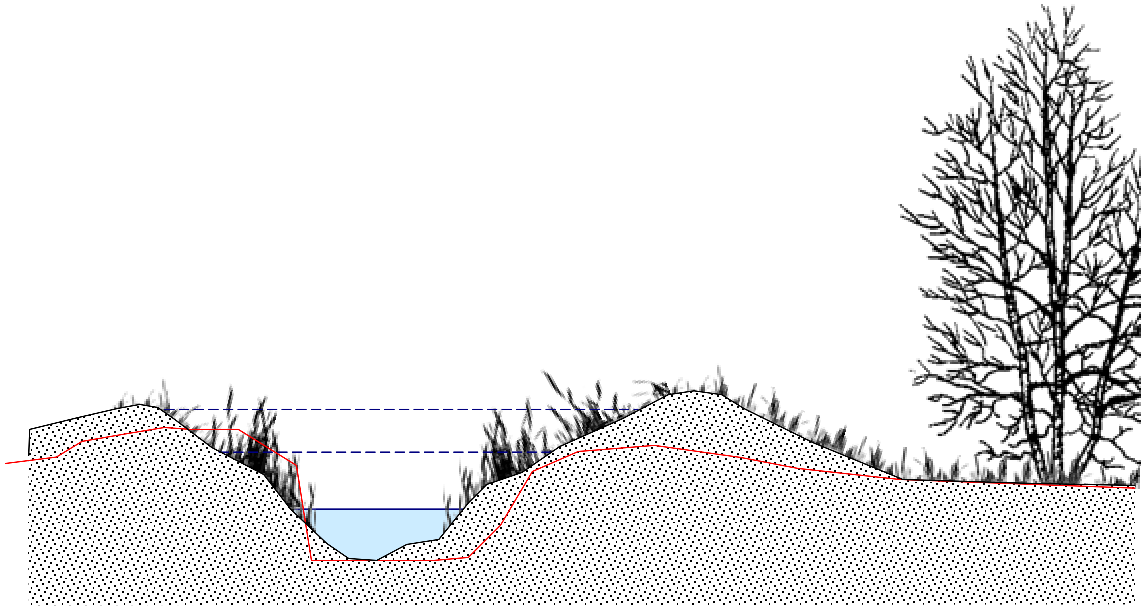


Figure 5.5.3
SECTION B THROUGH RAISED BED AND NEW POOL

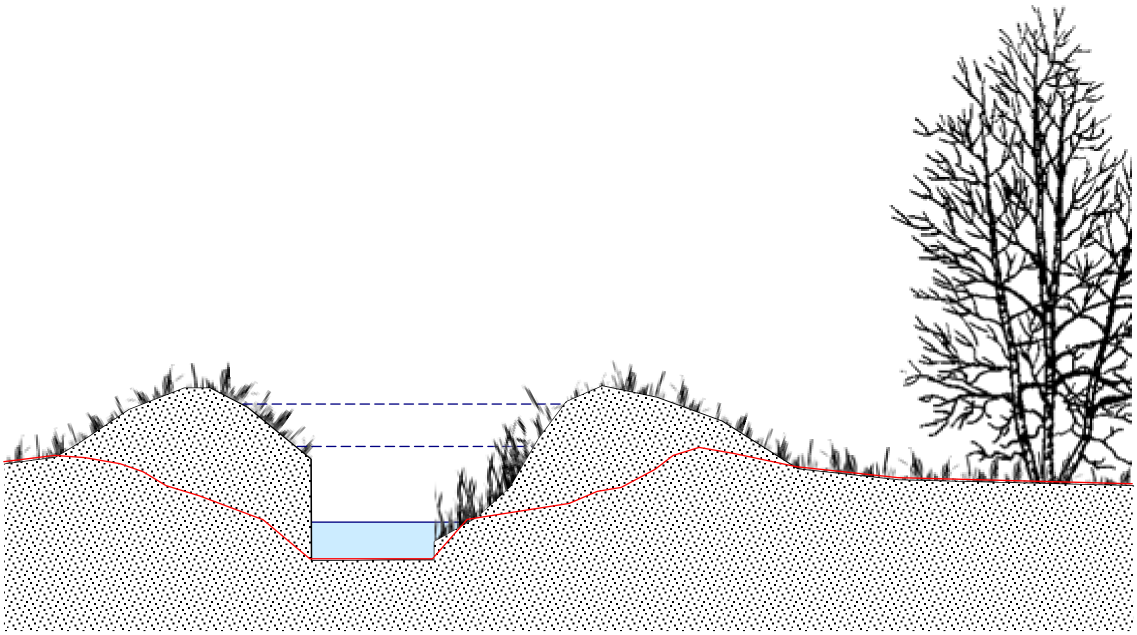
Objective	Restoration of the River Cober to a more natural cross section form via the cessation of channel de-silting, thereby allowing the river bed to accrete naturally to a more natural state. Where appropriate bed material may be sculptured to encourage more structural diversity and mimic more natural fluvial geomorphological processes and forms
Where used	River Cober main channel, through Loe Valley Carr SSSI, downstream of 1988 two-stage flood alleviation channel
Method	Minimal direct intervention required as river bed should naturally accrete, providing there are no channel de-silting works undertaken. In time, as bed accretes and channel depth decreases, structural variation may be added by means of a 360 excavator.
Consult	De-silting and channel cross sectional changes will lead to a reduction in flow capacity in the main river. This may have possible flood risk implications and so consultation with the EA is required.
Further management	Minimal, but periodic checks to ensure that rates of accumulation are sustainable
Equipment	None initially. A 360 excavator may be required for later works
Flood Risk	Possibility of slight increased flood risk as river bed accretes' over time and channel decreases capacity. Consideration for hydrological modelling.

Technique:	River Cober - Levee Re-profiling for Re-wetting



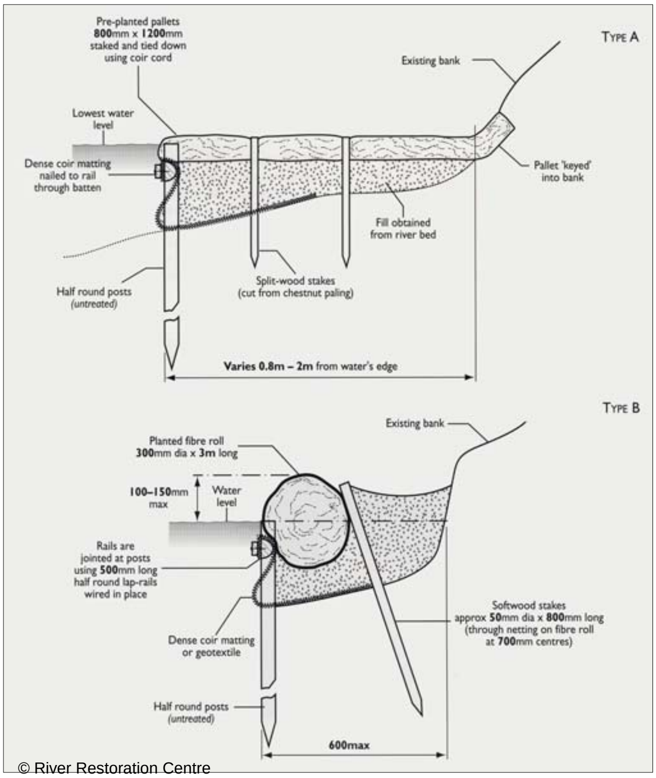
Objective	To encourage more frequent overbank flow above, at or just below bankfull discharge conditions.
Where used	River Cober main channel through Loe Valley Carr SSSI
Method	River banks and levees are re-profiled from the current configuration (see cross section above) to new cross sectional form (denoted by solid red line). Vegetation management, including reduction in tree clearance will introduce barriers to flow, causing water levels to increase locally, where re-profiling has taken place, streamflow will spill more frequently into areas of the floodplain carr.
Consult	Should have positive effects in terms of increased floodplain storage of flood waters, but EA consultation is recommended.
Further management	None
Equipment	360 excavator. Material will need to be removed from site.
Flood Risk	None / Beneficial – May decrease flood risk for certain periods during storm events by increasing floodplain storage of water and encouraging over bank flow

Technique:	River Cober - Bank Scalloping



Objective	To encourage more frequent overbank flow above, at or just below bankfull discharge conditions.
Where used	River Cober main channel through Loe Valley Carr SSSI
Method	River banks and levees are periodically re-profiled from the current configuration (see cross section above) to new a new 'scalloped' cross sectional form (denoted by solid red line). Vegetation management, including reduction in tree clearance will introduce barriers to flow, causing water levels to increase locally, where re-profiling has taken place, streamflow will spill more frequently into areas of the floodplain carr.
Consult	Should have positive effects in terms of increased floodplain storage of flood waters, but EA consultation is recommended.
Further management	None
Equipment	360 excavator. Material will need to be removed from site.
Flood Risk	Positive benefits to flood risk by increasing channel storage capacity

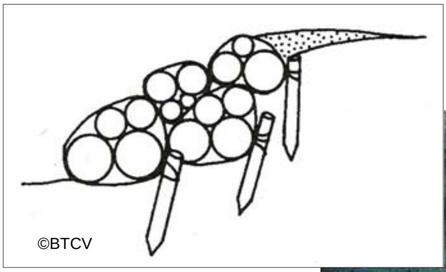
Technique:	River Cober - Berm Creation



Newly created berm | willow / hazel spiling to retain stability of bank | bank cut in sub-soil with appropriate seed mix

Objective	Maintain the drainage function of the river channel while supporting wetland plants such as sedges and reeds. In flood conditions, water can still use the whole channel width.
Task Description	A narrow submerged ledge is created or retained at the bank toe, just at/or below normal water level. Work can be conducted from one bank with minimal in-channel disturbance.
Suitable For	River Cober main channel through SSSI
Wildlife Benefits	Plant variety is improved. Direct benefits also occur for bird and invertebrates that feed and breed in waterside reed habitats. Shelter and food is provided to fish and other organisms living in the water.
Technical Details	The technique can be used to narrow channels and create meanders without changing the capacity of watercourse. Sub-soil from other tasks can be utilised for the berm (top soil is not suitable because of it's nutrients and seeds). Alternatively, coir can be used in flashy rivers where unconsolidated sediments may be washed away. These can be pre-planted with native marsh species or allowed to colonise naturally.
On-going Management	Once habitats have become established, vegetation management may not be necessary at all or should be minimised and conducted outside the bird breeding season (March to August inclusive). Cutting may help to maintain flood capacity of channel.
Consider	Breeding birds may use bank habitats, and are protected March-August inclusive. Fish may use in-channel habitats such as gravel, especially during the October-June period. Seek advice from Natural England and Environment Agency in advance of installation.
Flood Risk	May slightly decrease channel storage capacity and alter flow characteristics during storm events. Modelling may determine effect, but overall, likely to be negligible on R. Cober

Technique:	River Cober - Coarse Woody Debris Management



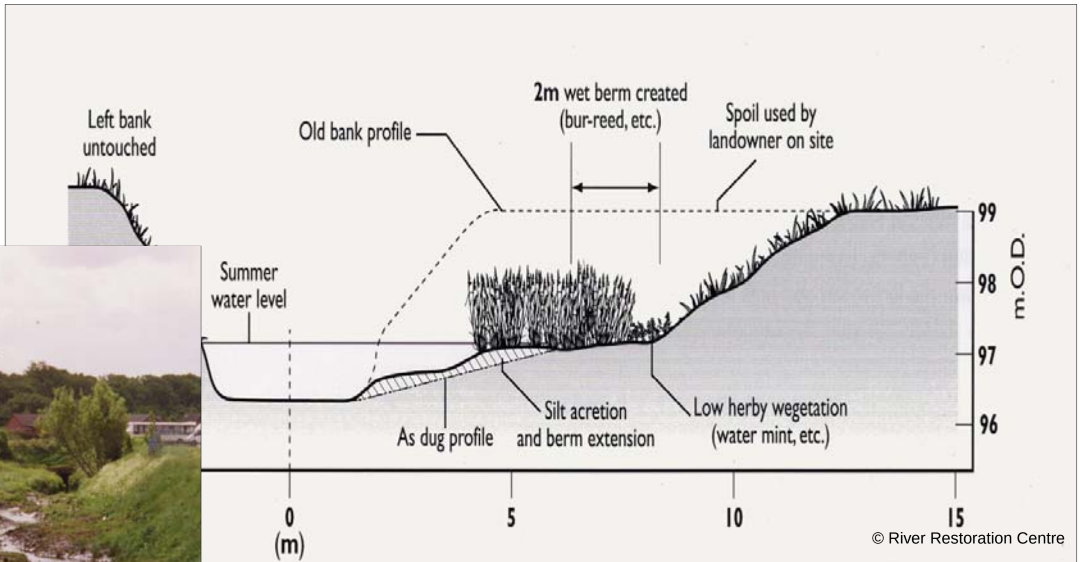
Revetment made from reclaimed logs wired together – a potential use for fallen timber removed from the channel.

Dead wood provides valuable habitats for insects, fungi, birds and a range of other wildlife.

A fallen tree in a river channel can be a potential flood risk when water levels rise, but also creates flow diversity and through this, channel structural diversity.

Objective	Fallen trees and timber in rivers <u>can</u> cause flood risk, so may need removal. In other situations, they may have no effect. Standing and fallen dead wood in and by rivers provides vital wildlife habitats. In rivers, habitat and channel structural diversity can be greatly enhanced by dead wood.
Where used	Suitable for several stretches of the River Cober main channel, especially where trees grow up to and adjacent to main channel
Method	Fallen trees removed from the channel should be retained in the vicinity of the river to provide wildlife habitats. They can be staked or tied securely at the river margin, as in the drawing above. This method can also provide protection against erosion. Where wood must be removed from the channel, timber should be placed on the bank (away from where it could be washed back in by floods), where it will decay and provide wildlife opportunities. Standing deadwood should be retained upright where possible (as long as there is no public risk).
Consult	If tree has obvious holes that could be used by bats, consult with Natural England. Always work outside the March-August period to protect birds from illegal disturbance whilst breeding.
Further management	Minimal, but periodic checks to ensure that in-channel wood remains securely attached, are advised.
Equipment	Specialist contractors or suitably trained NT personnel. Chainsaw and personal protective equipment. Machinery to lift timber from stream
Flood Risk	May increase water levels locally for certain periods during storm events by increasing floodplain roughness and flow deflection / obstruction. Modelling recommended

Technique: **River Cober - Enhancing Straightened River Channel**



Left: a re-meandered channel within existing flood embankments. Willow scrub is allowed to grow on one bank to give some but not excessive shading.

Objective

Increase habitat diversity in straightened river channels whilst slowing down flood water without compromising flood capacity.

Task Description

Berms on alternate banks are used to create meanders and vegetated ledges which benefit wildlife and fish. These also act to slow the water and reduce erosion.

Situation

Method is suitable for watercourses which have been straightened. River Cober downstream of Helston has been re-aligned, speeding water through the valley carr. Faster water has greater erosive power and can cause significant damage to flood defences, property and the landscape.

On-going Management

Vegetation which develops may require management through mowing or grazing - keep to a minimum, and consider management on alternate banks each year.

Wildlife Benefits

Once installed, there is potential for wetland plants to grow, and these create a variety of habitats for birds and insects. Fish also benefit from increased shelter, reduced silt from erosion and more feeding opportunities.

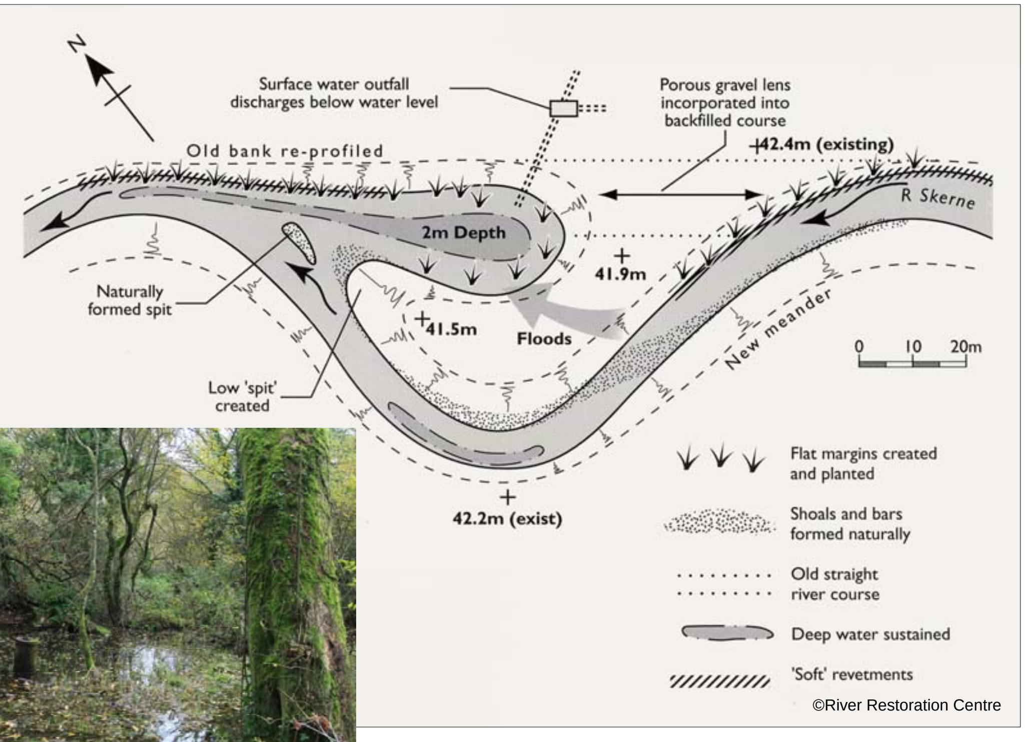
Consider

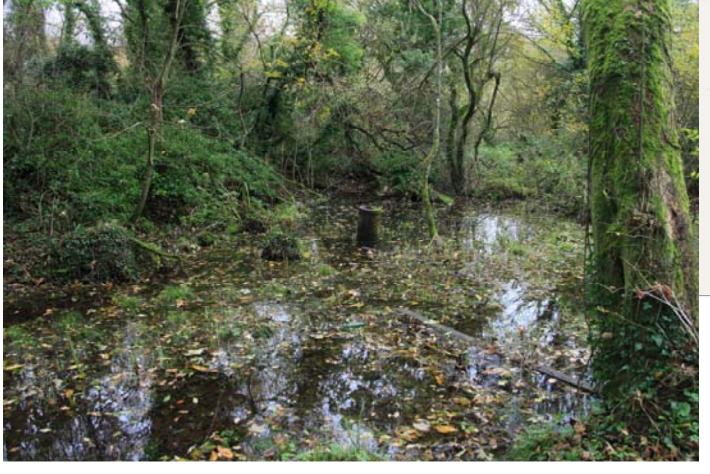
If work to bank is proposed between March and August, breeding birds may be present, and Natural England should be consulted. All in-channel works require the agreement of the Environment Agency in advance.

Flood Risk

None

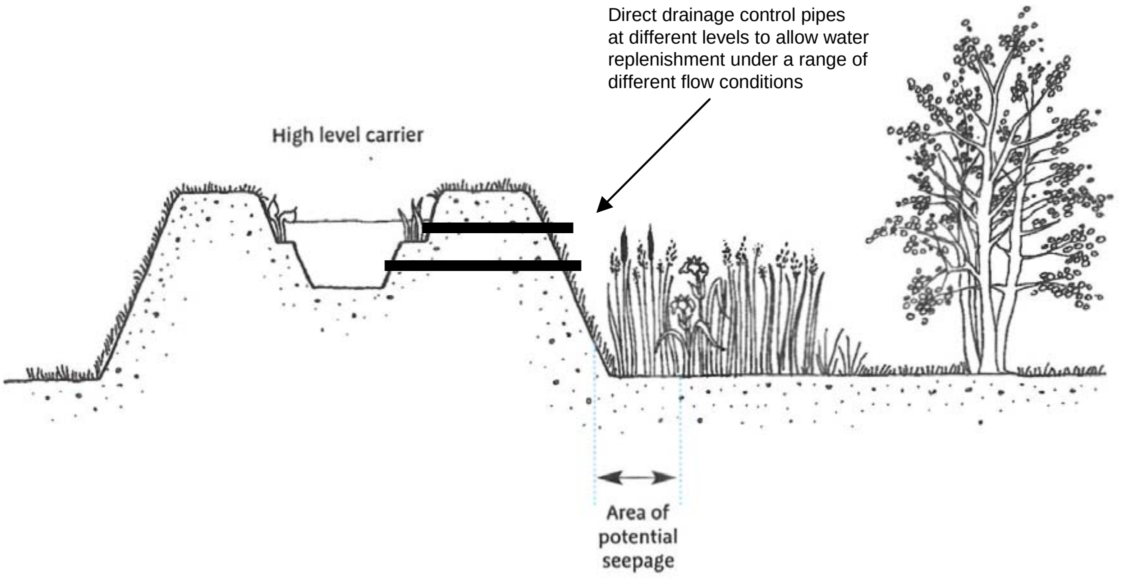
Technique:	River Cober - Backwater Creation Using Old Channel





Objective	To create flow diversity to benefit wildlife without impeding channel. Old channel through the carr can be partially re-used to provide refuges for fish and other organisms during high flow conditions.
Task Description	Backwaters with reduced flow velocities are created through re-connection of old channels to the river (at the downstream end) or constructed anew. In-channel wildlife and fish habitat can be retained without affecting the drainage capacity of the watercourse. Backwaters should connect in a downstream direction. Can be combined with outfall treatment reedbeds or other features. Backwaters can be planted with vegetation obtained from works (e.g. dredging) elsewhere on the river, taking care to ensure invasive weeds such as Japanese knotweed are not introduced. Best installed during low flows.
Situation	All channel sizes can benefit from backwaters. On the River Cober at Loe valley car, SSSI the former channel is still present in the floodplain of the middle reaches, making ideal opportunities for such habitat enhancements.
On-going Management	Minimum management is required, once the backwater has been installed, although occasional vegetation clearance may be necessary to maintain open water.
Consult	Environment Agency, Blach and Veatch, Landowner permission and consultation regarding the extent and scope of works.
Flood Risk	None – May increase flood storage during certain periods during storm events by increasing floodplain storage of water

Technique:	Valley Carr – Re-wetting Raised, Drier Areas



Objective	To maintain water table levels throughout the year in drier areas of the Valley Carr SSSI by the introduction of water from upslope external sources feeding in to the valley carr system.
Task Description	Surface water is drawn off feeder streams and diverted into drier areas of the carr down slope. Flow may need to be transferred to drier areas via cut or raised channels (as above), depending on local topography. Local topography to be utilised to avoid expensive ground works, where possible.
Situation	Drier areas of carr adjacent to feeder streams where slope can be used to divert flow (e.g. Nansloe Farm area)
On-going Management	Ensure that feeder ditches are maintained and cleared of debris on a regular (annual?) basis.
Consult	None required. Liaison with landowners if water is ‘captured’ from drains and land not under National trust ownership.
Flood Risk	None

Technique:	Valley Carr - Removal of Raised Footpaths

Objective	Raised gravel paths currently act as an obstruction to natural flow. The current path layout (Figure 6.2) shows that flow is restricted on both sides of the floodplain. Re-instatement of lateral floodplain surface water flow through the woodland can be archived easily by punching holes through these pathways and bridging them with raised boardwalks
Where used	Suitable locations on principal pathways crossing the woodland carr (see Figure 6.2)
Method	Gravel pathways removed at suitable locations by hand, or a small mini-excavator, where access allows. Material moved off site or re-distributed onto other retained sections of raised pathways. Gravel removed to natural soil surface level. Standing water allowed to accumulate once more and encourage vegetation re-growth.
Consult	Consultation with any agency should not be required.
Further management	Minimal, but periodic checks to ensure that breaches are maintained may be advised
Equipment	Manual ground works tools or mini-excavator
Flood Risk	None

Technique:	Valley Carr - Raised Boardwalks to Allow Floodplain Flow

Objective	Fallen trees and timber in rivers <u>can</u> cause flood risk, so may need removal. In other situations, they may have no effect. Standing and fallen dead wood in and by rivers provides vital wildlife habitats. In rivers, habitat diversity can be greatly enhanced by dead wood.
Where used	Suitable locations on principal pathways crossing the woodland carr (see Figure 6.2)
Method	Construct main boardwalk sections off site, or use appropriate supplier. Install posts onto which the boardwalk is attached using standard methods. Ensure that the length of boardwalk required is kept to a minimum and that the boardwalk is never raised to a level in order to cause significant obstruction to floodplain flow in extremely high flow (storm) conditions.
Consult	Consultation with the Environment Agency may be required if the floodplain boardwalk sections are of significant length or elevation above the natural level of the floodplain. Both conditions should be avoided.
Further management	Minimal, but periodic checks to ensure that integrity of boardwalk remains and no risk to public safety are advised.
Equipment	Chainsaw and personal protective equipment. Machinery to lift and install wood structures
Flood Risk	Minimal obstruction to flow across floodplain as structures installed to allow floodplain flow of water in downstream or upstream (inundation) directions

Technique:	**Water Level Monitoring – River Cober**

Objective	Monitor river water level (stage) in the River Cober as it passes through Loe Valley Carr SSSI. Characterise levels, variation and response of flow to rainfall and inundation by fluvial overbank flow and / or upstream inundation. Acquire reliable, long-term quantitative data on flow levels: a critical requirement of the future management plan.
Where used	Suitable location on the River Cober, between existing upstream and downstream gauges
Method	Chose suitable location for equipment installation. Stone bridge abutments are ideal. Install stilling well tube using drill, resin steel bolts and brackets as above. Install pressure level sensor in well, with lockable, protective well cap. Data telemetry option can be used to transmit data out from the installation, minimising ongoing field administration. Well top cap is surveyed in to Ordnance Survey Datum in ensure reliable levels data are obtained.
Consult	Installation and commissioning to be undertaken by specialist equipment supplier / consultancy.
Further management	Periodic data downloading is required, possibly on a 3 month or 6 month schedule. Data can also be collected automatically via radio telemetry, though at additional cost.
Equipment	Steel protective stilling well, mounting brackets and supports, pressure transducer device with associated data cable and data management software.

Technique:	**Water Level Monitoring – Floodplain Valley Carr**

Objective	Monitor groundwater and surface standing water levels within Loe Valley Carr. Characterise levels, variation and response of water table levels to rainfall and inundation by fluvial overbank flow and / or upstream inundation. Acquire reliable, long-term quantitative data on water table levels
Where used	A minimum of three key locations within the Loe Valley Carr SSSI – sites to be agreed in consultation with the national Trust
Method	Plastic piping is used to manufacture dipwells off site. Dipwells are installed using a steel augur, D-shaped Russian corer or may be manually driven into the ground if soil conditions permit. Groundwater pressure level sensors installed in each tube and calibrated. Elevation of dipwell cap/top surveyed in to Ordnance Datum to give reliable depth measurements.
Consult	Installation and commissioning to be undertaken by specialist equipment supplier / consultancy.
Further management	Periodic data downloading is required, possibly on a 3 month or 6 month schedule. Data can also be collected automatically via radio telemetry, though at additional cost.
Equipment	Steel protective stilling well, mounting brackets and supports, ground / surface water pressure transducer device with associated data cable and data management software.

APPENDIX 4

List of Equipment, Costs and Suppliers

APPENDIX 4

LIST OF EQUIPMENT, COSTS AND SUPPLIERS

Indicative Equipment and Installation Costs

Water table measurement - Pressure level sensor device, such as OTT Orpheus Mini, complete with installation in steel well tube at appropriate locations across the site:

groundwater sensor	£950.00
Well tube	£150.00
Installation and commissioning:	£250.00 (based on a rate of £500.00 per day)
MINIMUM TOTAL PER UNIT:	**£1,350.00**

Stream Stage measurement - Pressure level sensor device, such as OTT PLS, complete with installation in steel stilling well at appropriate location in the River Cober channel:

PLS Sensor	£1,100.00
Well tube (plus fixings)	£200.00
Installation and commissioning:	£250.00 (based on a rate of £500.00 per day)
TOTAL PER UNIT:	**£1,550.00**

Data management software:	£500.00 - £3,000.00
Rugged field notebook PC[1]	£1,500.00

[1] Optional

Suppliers

OTT Hydrometry UK

Unit 2 Magnet Business Park
14 High Hazels Road
Barlborough
Chesterfield
Derbyshire
S43 4UZ

Tel: 01246 573480

Email: sales@ott-hydrometry.co.uk

Web: http://www.ott.com/web/ott_uk.nsf/id/pa_companyuk.html

Xylem Analytics UK Limited

2 Focal Point
Lacerta Court
Works Road
Letchworth, Hertfordshire
SG6 1FJ
United Kingdom

Tel: 01462-673581

Email: adminuk@xyleminc.com

Web: http://www.xylemanalytics.co.uk/index.php

RSHydro

RS Hydro
Leask House
Hanbury Road
Stoke Prior
Bromsgrove
B60 4JZ

Tel: 01527 882060

Email: info@rshydro.co.uk

Web: http://www.rshydro.co.uk/

Hydro-Logic Services

Hydro-Logic Services LLP
Suite 3
Swallow Court
Devonshire Gate
Tiverton
Devon

EX167EJ

Tel: 01884 841473

Email: enquiries@hydro-logic.co.uk

Web: http://www.hydro-logic.co.uk/HL/index.php

APPENDIX 5

Summary of EA Maintenance Schedule (2007)

River Cober maintenance schedule reviewed
(OPS DEL instruction register: OD 0009)

This is an interim maintenance regime until the Helston flood scheme review is completed and if required we may revert to our original regime, after giving notice to NT / EN.

Date reviewed: 14th March 2006

Present: David Harker (EA – ASM TL), Joe Parish (EA – ASM), Martin Rule (EA – FRB), Alistair Cameron (NT), Andrew McDouall (EN).

Area of review: Downstream B3304 Porthleven road bridge from first footbridge (where Kerrier want to establish a Nature Reserve) through the Loe Valley to Loe Pool.

Area 1: From small footbridge and weir (NGR: SW6529326854) to bottom footbridge at gate (NGR: SW6528026216).

Right bank – Cut with machine **once a year in September**. Allow the odd grass tuft to break away forming islands in isolation, but not to encourage any accumulations due to capacity reduction.

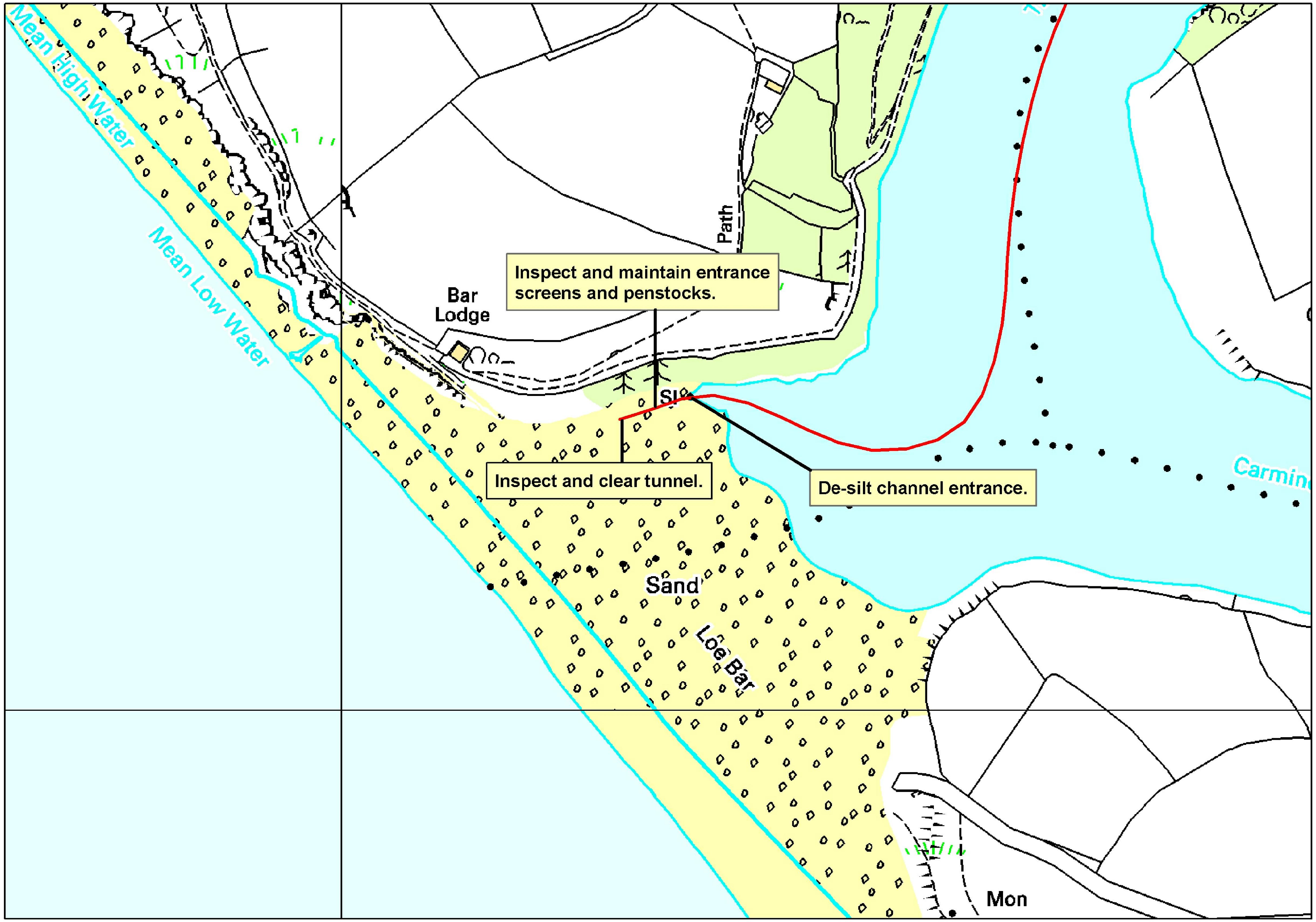
Left bank – To be cut every other year, ensuring woody vegetation is not allowed to establish. Cut out woody vegetation as needed i.e. do not allow thick gorse to encroach toward watercourse.

Area 2: From bottom footbridge (NGR: SW6528026216)– Loe Pool (NGR: SW6491925723)

Right bank – No cutting of non-woody vegetation. Woody vegetation to be cut back to enable vehicular access to where Cober meets Loe Pool. Only woody vegetation to be prevented from establishing. NT to discourage public access by reducing gate size.

Left bank – No maintenance required.

Channel – Fallen trees to be assessed individually with NT and studies to be done to calculate impact trees have on sedimentation of upstream channel.

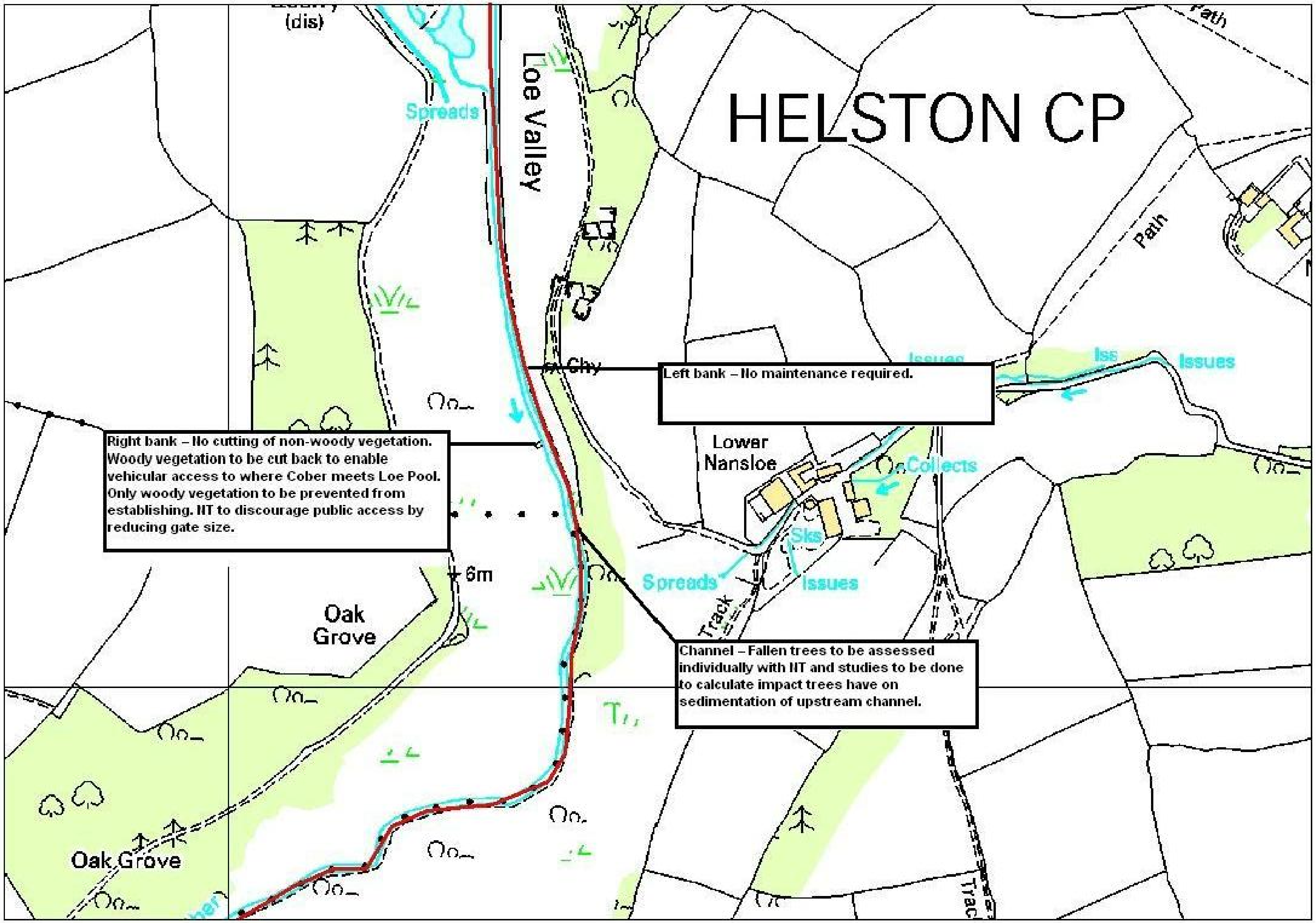


Field Delivery are to clear all debris and obstructions from the channel, including overhanging vegetation in the sections of river channel indicated in red.

Mowing - M1, ME1
Weedcutting - W2,W8
Tree and Bush Management - B3, BE1
Desilting- D1

Environment Agency
UNIT 26, PENNYGILLAM INDUSTRIAL ESTATE, LAUNCESTON

Job RIVER COBER FLOOD RISK MANAGEMENT MAINTENANCE	**Title** RIVER COBER FR13S020 MAINTENANCE PLAN MAP 1 OF4	This map is reproduced from Ordnance Survey material with the permission of Ordnance Survey on behalf of the Controller of Her Majesty's Stationery Office © Crown copyright Unauthorised reproduction infringes Crown copyright and may lead to prosecution or civil proceedings. The Environment Agency 100026380 2010.	Date FEBRUARY 2010 Scale DO NOT SCALE Drawn KJB Checked KJB	Job No EGM10.3.1 Drawing No RIVER COBER - PLAN 1 OF 4



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Mowing - M1, ME1
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Environment Agency

UNIT 26, PENNYGILLAM INDUSTRIAL ESTATE, LAUNCESTON

Job	RIVER COBER FLOOD RISK MANAGEMENT MAINTENANCE	Date: FEBRUARY 2010	Job No: EGM10.3.1
Title	RIVER COBER FR13S020 MAINTENANCE PLAN MAP 2 OF 4	Scale: DO NOT SCALE	Drawing No: RIVER COBER - PLAN 1 OF 4
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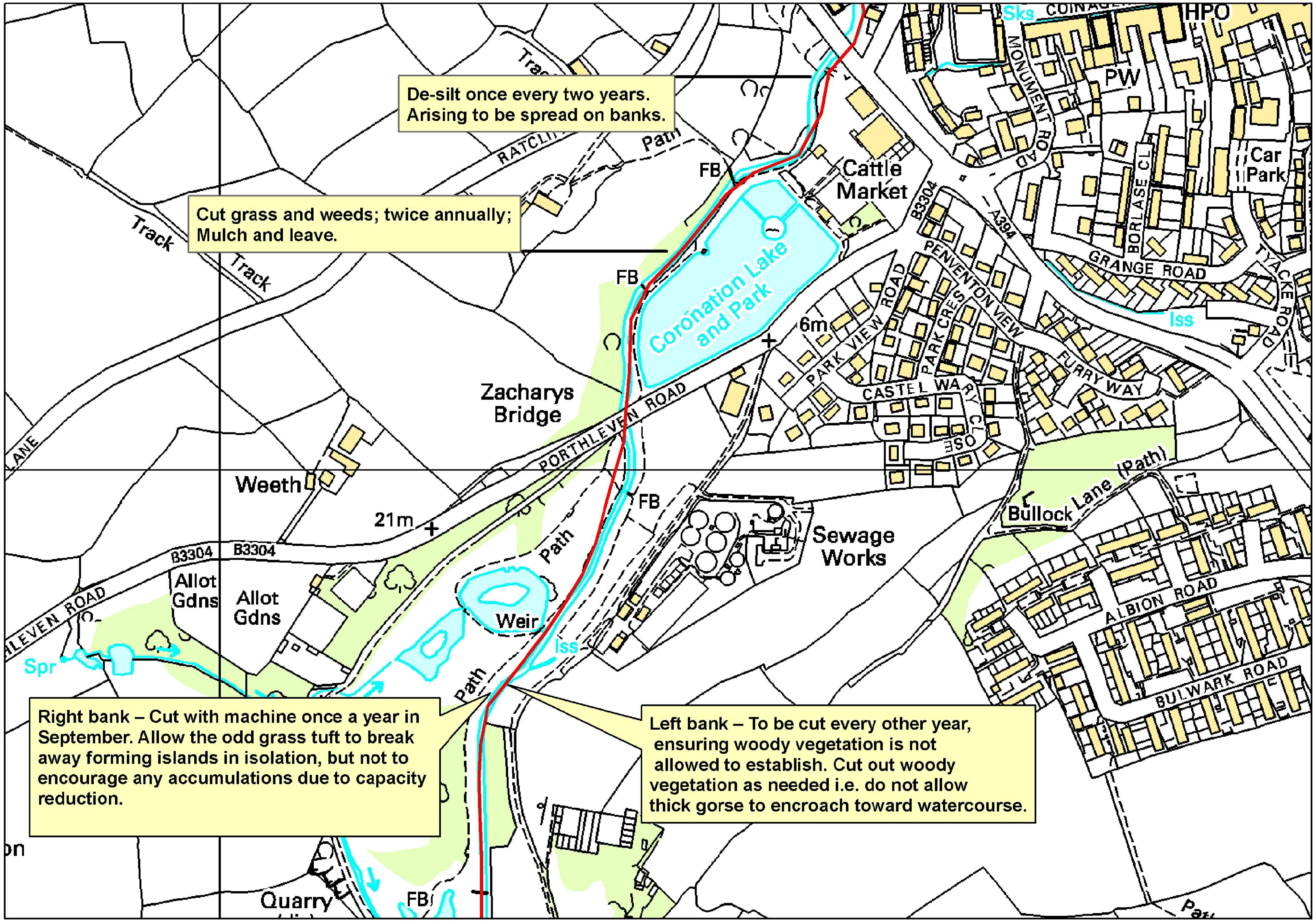

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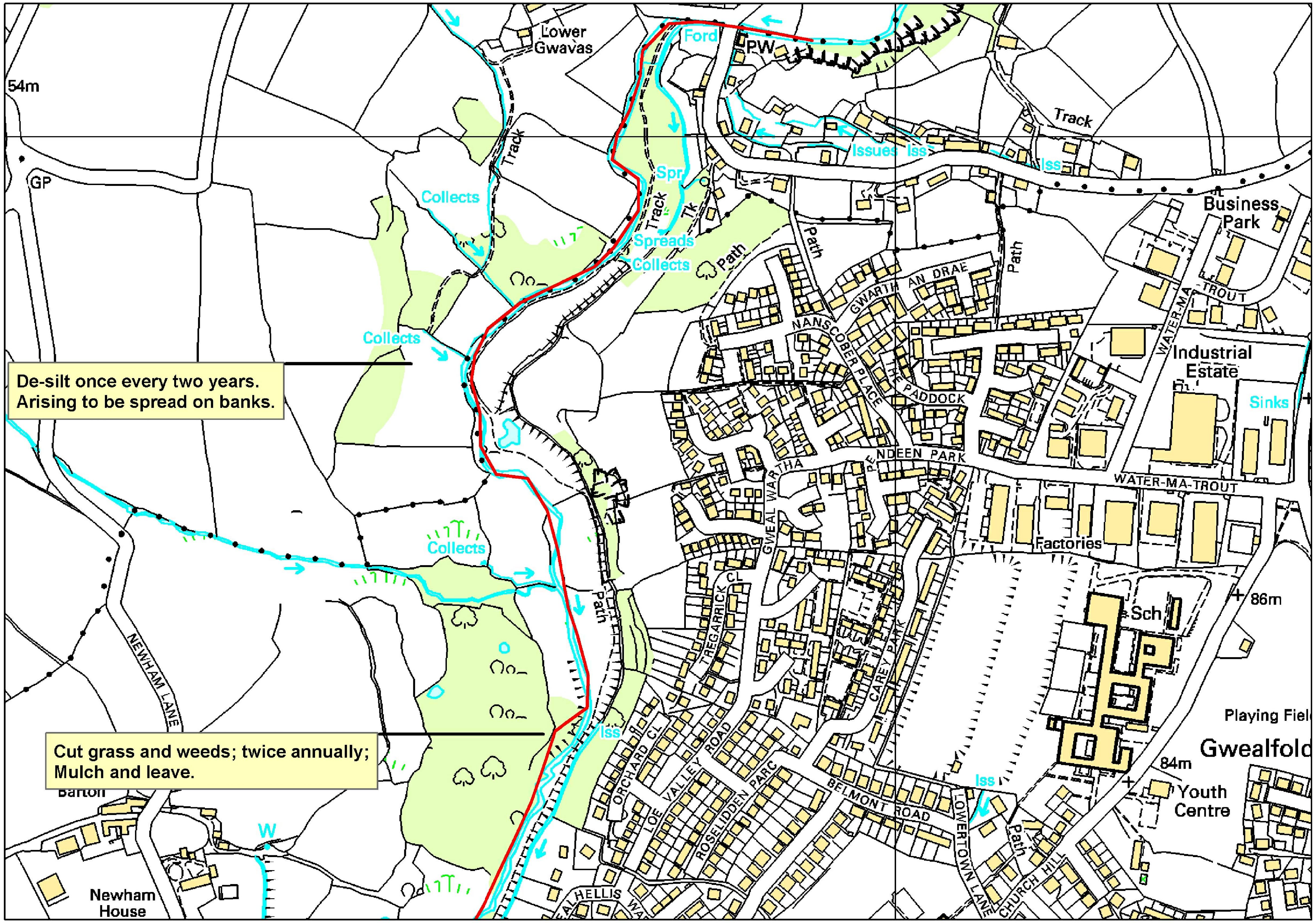
Mowing - M1, ME1
Weedcutting - W2,W8
Tree and Bush Management - B3, BE1
Desilting- D1

Environment Agency
UNIT 26, PENNYGILLAM INDUSTRIAL ESTATE, LAUNCESTON

Job	RIVER COBER FLOOD RISK MANAGEMENT MAINTENANCE	Title	RIVER COBER FR13S020 MAINTENANCE PLAN MAP 3 OF 4

Date: FEBRUARY 2010	Job No: EGM10.3.1
Scale: DO NOT SCALE	
Drawn: KJB	Drawing No: RIVER COBER - PLAN 3 OF 4
Checked: KJB	



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Mowing - M1, ME1
Weedcutting - W2,W8
Tree and Bush Management - B3, BE1
Desilting- D1

Environment Agency
UNIT 26, PENNYGILLAM INDUSTRIAL ESTATE, LAUNCESTON

Job	RIVER COBER FLOOD RISK MANAGEMENT MAINTENANCE	**Title**	RIVER COBER FR13S020 MAINTENANCE PLAN MAP 4 OF 4

Date: FEBRUARY 2010	Job No: EGM10.3.1
Scale: DO NOT SCALE	Drawing No: RIVER COBER - PLAN 4 OF 4
Drawn: KJB	
Checked: KJB	

Penny Anderson Associates Ltd
CONSULTANT ECOLOGISTS

Park Lea, 60 Park Road, Buxton, Derbyshire SK17 6SN