Craywatch:

River Cray Restoration Plan

Foots Cray Meadows

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1.0 INTRODUCTION

1.1 Rationale for River Restoration

1.1.1 Freshwater Ecosystems

Across the globe, mismanagement of natural resources, including freshwater, has resulted in significant destruction and loss of natural ecosystems (Lambert, 2003). Freshwater ecosystems are sensitive and subject to stress from anthropogenic activities (Janssen et al, 2005). According to Russo et al. (2012), more than 50% of the world's freshwater ecosystems have been damaged or destroyed.

Freshwater ecosystems provide a wealth of benefits and services to both society and the natural environment ('ecosystem services'). In recent times, studies have been conducted to assess the economic value of freshwater ecosystems due to the importance of the ecological goods and services they provide as fundamental components of catchment systems (Woodward and Wui, 2001). Freshwater ecosystem restoration is a holistic system-based approach to improve the functioning and integrity of the system, thereby improving its ability to provide direct and indirect ecosystem services.

1.1.2 Chalk Streams

Chalk streams are one of the most unique ecosystems in the world. Of around 200 known chalk streams, 85% can be found in South England. Chalk streams are sourced from chalk aquifers and their unique characteristics include clear, mineral-rich waters and clean gravel beds. Chalk streams in good health exhibit high water quality, strong flows, clean gravels and diverse aquatic vegetation, providing a variety of habitat niches ideal for fish and invertebrates.

Despite being a rare habitat, many of the UK's chalk streams are under threat from anthropogenic pressures, including pollution, physical modification and impoundment, invasive non-native species, over-abstraction and climate change. One of the greatest threats to chalk streams is reduced flows driven by the combined effects of over-abstraction and climate change. A range of conservation measures are required in order to protect these distinctive habitats, including restoration projects in areas where this is possible. In urban catchments, opportunities for river restoration are often located where urban rivers flow through parks and open spaces between areas of urban and industrial land use.

1.1.3 Urban Green Spaces

Urban green spaces are a fundamental component of sustainable urban development with space for nature. These green spaces form a key element of green infrastructure networks in urban areas. According to Natural England (2009), green infrastructure is "a network of multi-functional green space… which supports the natural and ecological processes and is integral to the health and quality of life of sustainable communities" Rivers and their banks provide green corridors and landscape permeability for a range of terrestrial and aquatic species within the urban environment, and wetlands are important natural and semi-natural green spaces. A central concept in green infrastructure planning is to incorporate a number of functions into each green space (Natural England, 2009), such as:

- Habitat management;
- Access to nature/interpretation; and
- Flood attenuation and water resource management.

1.1.4 UK Policy Context

The freshwater environment is governed by many policies and guidelines locally, regionally and globally. Within the United Kingdom (UK) freshwater ecosystems are governed by the European Union (EU) Water Framework Directive 2000/60/EC (WFD). The objective of the WFD is to establish an integrated approach for the protection, management and sustainable use of water resources. One of the WFD aims is to prevent further deterioration, protect and enhance the ecological status of aquatic ecosystems and associated wetlands.

1.2 River Cray: Project Background

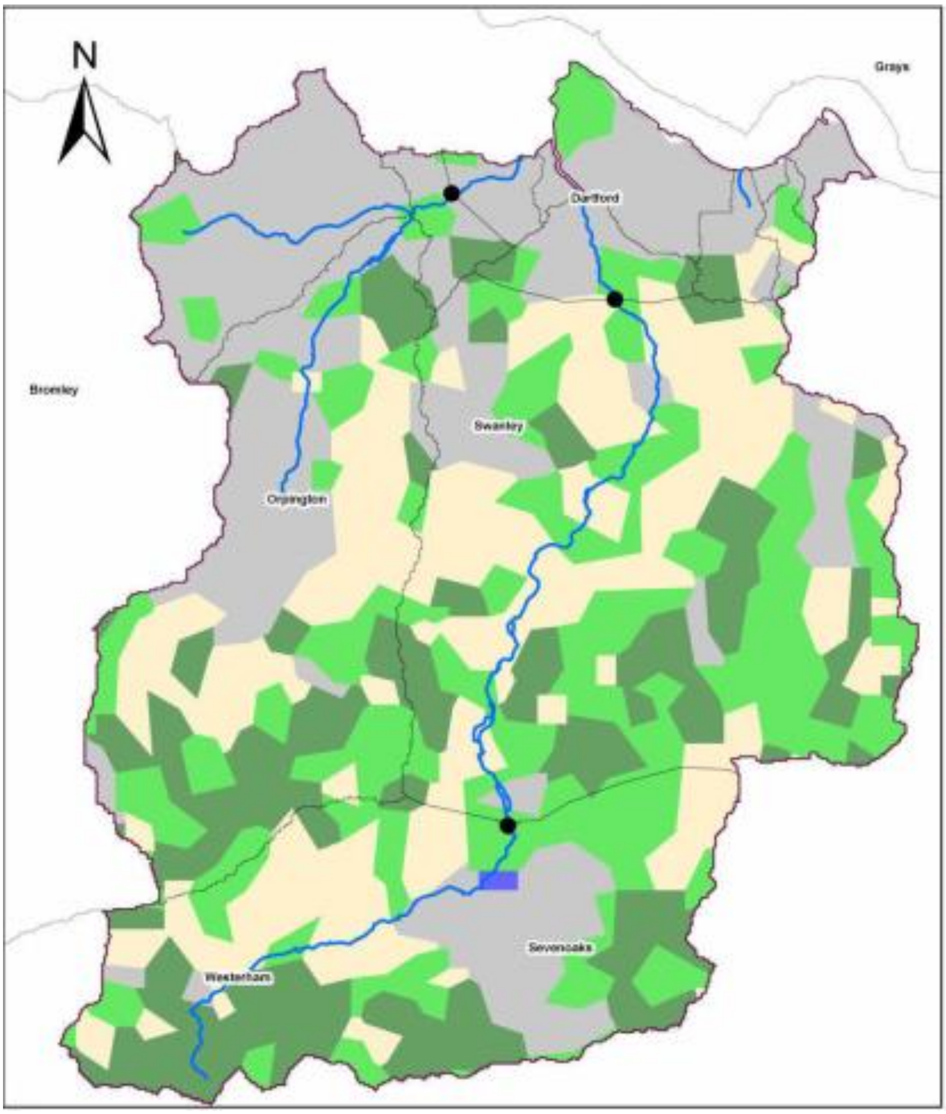

Figure 1, Map showing the River Cray and Darent catchment area (Environment Agency. 2013).

1.2.1 River Cray Catchment and Setting

The River Cray is a chalk stream located in south-east London, with a sub-catchment covering a total of 124km^2. The River Cray rises from springs in Orpington and flows for 14km, through urban and suburban areas including Bexley and Crayford, as well as a number of green spaces including Ruxley Gravel Pits Site of Special Scientific Interest (SSSI) and Foots Cray Meadows before joining the River Darent and entering the Thames as a tributary at Crayford Ness, east of Erith (Darent Catchment Partnership. 2018). The River Shuttle joins the River Cray as a tributary in Bexley, upstream of Hall Place.

The River Cray lies within the Darent and Cray and catchment, which falls within The Greater Thames River Basin. As an urban river, the River Cray is subject to relatively high levels of stress, and has been physically modified by anthropogenic activities over the years. Key issues that affect the River Cray are water quality and water quantity. Water quality is impacted by pollution through urban misconnections, leading to sewage input, road runoff, and physical pollution including litter and fly-tipping. Abstractions take place on the River Cray as the aquifers that provide river flow are used to provide drinking water for South East England. The coupled effect of climate change and over abstraction has led to low flows affecting the River Cray. River flow is also degraded through a series of impoundments, caused by physical modifications including weirs, bridges and historic mills, of which there were once 14 along the length of the river. These engineered features interrupt the natural flow patterns of the river, negatively impacting longitudinal connectivity. These impoundments cause reduced water quality and obstruct fish passage, negatively impacting fish populations by reducing the quality and quantity of suitable breeding habitat and impeding upstream migration to reach what habitat may be available.

The Darent and Cray Catchment Partnership vision is “for the Darent and Cray to be a clean healthy river system with a sustainable flow which supports a diversity of wildlife by 2027.” The Action Plan for the catchment targets key issues to be addressed in order to achieve this. In the Cray catchment, The Environment Agency’s WFD Ecological and Chemical classification for 2016 assesses three water bodies: the Upper Cray, Lower Cray, and Shuttle. One water body (Upper Cray) has an ecological status or potential of Moderate and two water bodies (Lower Cray and Shuttle) have an ecological status of poor. All 3 water bodies have a chemical status of good (Environment Agency. 2019). The area of the River Cray addressed in this restoration plan lies within the Upper Cray boundary for WFD classification.

The Bexley Biodiversity Action Plan (2011) sets out those habitats and species that London Borough of Bexley has adopted as key priorities in terms of biodiversity action. These include rivers and streams, and parks and open spaces. London Borough of Bexley has fourteen designated strategic green wildlife corridors within the borough, including the River Cray Valley corridor.

1.2.2 River Cray Restoration: Project Overview

The river restoration work proposed in this plan falls within the Craywatch project, funded by Enovert Community Trust and the London Borough of Bexley. The project aims to:

- Improve the River Cray's potential to support biodiversity through physical restoration work to the river at Foots Cray Meadows; and
- Increase the River Cray's value as a natural amenity by offering opportunities for the local community to learn about and interact with the river through volunteering and citizen science.

Restoration works will be delivered in part through volunteer events open to the local community. Through citizen science including Modular River Survey (MoRPh), trained volunteers will assist Thames21 in gathering morphological baseline and monitoring data for the restoration works. The community engagement activities and citizen science will offer local participants the opportunity to increase their understanding of chalk stream ecology, river physical processes, and foster a sense of stewardship towards the river and surrounding spaces.

1.2.3 Site Description: Foots Cray Meadows

Foots Cray Meadows is located in the London Borough of Bexley, to the east of Sidcup and between the residential areas of Foots Cray to the south and North Cray to the north-east. At 100 hectares in size, Foots Cray Meadows is the largest open space in the London Borough of Bexley. The park is a well-used amenity open space within the borough, popular with walkers, families, dog walkers and wildlife-watchers. Five Arches Bridge and lake at the heart of the park are a particular hotspot for visitors.

Foots Cray Meadows and the River Cray are both designated as an Area of Metropolitan Importance for Nature Conservation (AMINC), a non-statutory designation applied to sites with importance for biodiversity at the regional (Greater London) level. Foots Cray Meadows is also a Local Nature Reserve. The site is one of four Local Nature Reserves within the borough of Bexley, a statutory designation applied at local authority level. As well as the River Cray chalk stream ecosystem, other habitats within the site include ancient woodland, neutral grassland, species-rich wet grassland, wildflower meadows, ponds and amenity grassland.

Foots Cray Meadows is currently a public park, however it was originally a country seat dating back to Elizabethan times. Five Arches Bridge was built in the late 18^{th} century as part of a landscaping scheme designed by Lancelot 'Capability' Brown, and is a Grade II listed historical structure (Historic England. 2020).

2.0 METHODOLOGY

2.1 Desktop Survey

A desktop analysis of the study site (the River Cray within Foots Cray Meadows) was undertaken to identify the freshwater ecosystems onsite and their geographical topology. The geographical study was undertaken using a Geographical Information System (GIS). The historical aerial imagery was also reviewed to determine what the benchmark/reference state of the river system from a geomorphological perspective, prior to transformation and local urban development. The desktop analysis further served to inform the overall river restoration planning process, with the objectives being to:

- Identify potential restoration intervention locations for implementation;
- Preliminarily evaluate the study site based on:
  - Topography (Lidar);
  - Area;
  - Level of transformation;
  - Visible problem/impact areas;
  - The potential risk to urban infrastructure.
- Prioritise areas/features within the study site that warrant restoration.

2.2 Site Visits

Numerous site visits were conducted to verify the extent of freshwater ecosystems within the study site and assess the current level of ecological integrity and ecosystem services provided by the river and wetland habitats. Observation points (points of interest/waypoints) were recorded using a Global Positioning System (GPS)3. The subsequent information was used to inform the production of a GIS spatial coverage of observation points. Observation points may include, but are not limited to:

- Non-native invasive plant infestations;
- Possible restoration intervention locations;
- Possible surface water management interventions;
- Impact/problem points;
- Different vegetation communities;
- Areas of untransformed habitat; and
- River MoRPh Survey.

2.3 Restoration Process

The planning process for river restoration involves a number of different organisations and stakeholders. The process of restoration planning, design and implementation includes the following steps:

- Desktop analysis: GIS-based data collection;
- Site visit: Assessment of the current state of the habitat within the study site and identification of restoration intervention types and locations;

- Design and reporting: Compiling restoration strategy based on the findings of the data collected; designing technical specifications and methodology for implementation and monitoring;
- Stakeholder consultation: Discussions and site visits with local stakeholders, including the catchment partnership, Environment Agency, landowners and local Friends and volunteer groups.
- Environmental authorisation: Gain environmental authorization from the relevant competent authority;
- Implementation: Carry out the restoration plan in accordance with stipulated conditions from the authorities; and
- Monitoring and evaluation: Undertake relevant monitoring activities as specified in the restoration plan. Types of monitoring can include fixed point photography, water quality monitoring, and physical habitat assessments.

3.0 STUDY RESULTS

3.1 Site Assessment

Figure 2, Map of Foots Cray Meadows (Friends of Foots Cray Meadows. 2010).

The study site consists of managed grassland, woodland and riverine habitats. The River Cray is subject to many urban pressures, including: physical modifications, low flows and abstraction, and point and diffuse source pollution. Low flows, poaching and urban encroachment have had negative geomorphological impacts on the river channel, leading to an over widened channel with slow flows and little geomorphic diversity. Five Arches Bridge impounds the River Cray preventing the build-up of sediment to narrow the river channel. There are currently no known invasive species which would affect the restoration designs (such as Japanese knotweed, *Fallopia japonica*) in the restoration area.

Geomorphic diversity is present in some areas, with upstream of Five Arches Bridge having clean gravels, in-channel berms and benches and large wood. Natural large wood in the river channel has successfully led to the formation of a mid-channel gravel bars, as shown in Figure 3. As the Cray moves downstream the channel bed becomes less diverse and is covered by a fine layer of silt, with no clean gravel pools or bars. Five Arches Bridge acts as a dam, impeding river flow and sediment transportation, contributing to the lack of diversity downstream. The River Cray has natural channel banks with surrounding bank top vegetation. While the channel banks are natural, they are heavily impacted by poaching as this is a heavily used public site for dog walkers. This has led to an increase in erosion in many areas of the channel banks, as shown in Figure 4. Previous river restoration to create vegetated channel bars have been only partially successful, as shown in Figure 5 and 6. This is likely due to a lack of sediment as the river is impounded by Five Arches Bridge and a lack of light due to extensive bank top trees.

Figure 3, Photographs of geomorphic features upstream of Five Arches Bridge.

Figure 4, Evidence of poaching of the river banks.

River restoration will focus downstream of Five Arches Bridge, building upon pre-existing restoration works that have taken place. It has been determined that restoration interventions will have the greatest impact in this area.

Figure 5, Photographs showing constructed berms as part of river restoration which have successfully vegetated.

Figure 6, Photographs showing previous constructed berms as part of river restoration which have not fully vegetated.

3.2 Supporting Information for Restoration Design

3.2.1 Public Amenity and Engagement

Foots Cray Meadows is the largest open space in the London Borough of Bexley. This makes it a popular recreational open space for visitors, particularly in the summer months, and it is a heavily used dog walking site throughout the year. The Cray Riverway and London Loop walking routes also follow the route of the river through Foots Cray Meadows. As a result of this the River Cray has been very heavily poached, particularly by dogs entering the river, as seen in Figure 3. Ongoing public use of the site for recreational purposes must be considered when designing river restoration scheme.

3.2.2 Historical Context

Five Arches Bridge is a Grade II-listed historical structure (Historic England. 2020). This structure acts as a dam impeding river flows and trapping sediment and silt. Despite these geomorphic impacts on the river, the bridge is not included the restoration works proposed within this plan due to the bridge's protected heritage status. If opportunities to address these issues arise in future then these works will be subject to a separate assessment and restoration plan.

3.2.3 Flood Risk

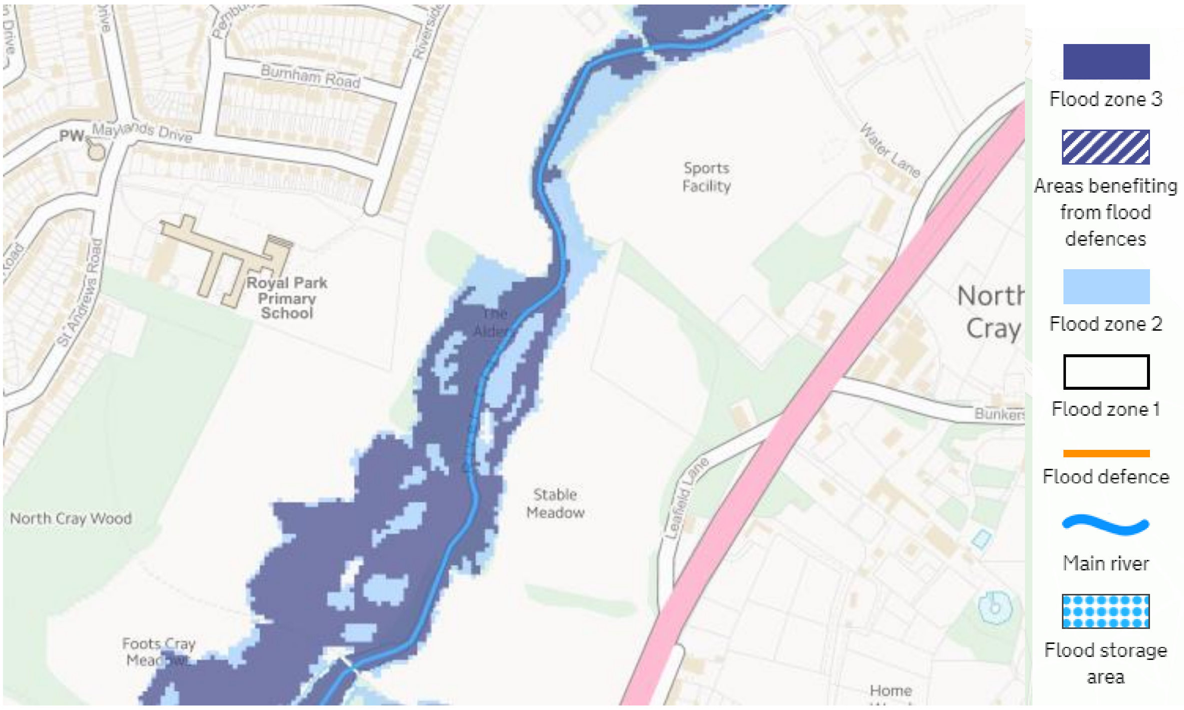

Figure 7, Environment Agency flood risk maps, showing the different flood zones of the River Cray in Foots Cray Meadows (Environment Agency. 2020).

The River Cray at Foots Cray Meadows does not present a flood risk to any commercial, public or residential dwelling, as shown in Figure 7. As the Cray flows through this open space it has a wide floodplain. There is therefore no concern that restoration interventions may increase flood risk.

4.0 RESTORATION STRATEGY

4.1 Aims and Objectives

Aim: The aim of this project is to restore a functioning and resilient chalk stream ecosystem.

Objectives:

- To create more diverse geomorphic chalk stream features, increasing flow variation and clean gravels.
- To mitigate against low flows, increasing sinuosity and flow rates.
- Create new chalk stream habitats and increase the variation of habitats.

4.2 Restoration Interventions

4.2.1 Vegetation Management

The clearance of bank side vegetation will increase light penetration, therefore encouraging further in-channel and bank vegetation establishment. This will be achieved through clearing scrub and small trees to increase light penetration to the River Cray.

4.2.2 Large Wood

Large wood is used to create a series of geomorphic features and increase the complexity of river channels. This is achieved by adding a significant element of hydraulic roughness, changing river flow and channel depth (Pilotto *et al.* 2014). This increase in hydraulic roughness retards flows around deflectors, increasing storage of sediment and organic matter, and the flow is increased and concentrated in the remaining channel (Pilotto *et al*. 2014).). Morphological changes induced by large wood include changes in channel width and depth due to the accumulation, scouring and sorting of sediment, forming in channel geomorphological features (Gurnell *et al.* 2005; Pilotto, et al. 2014).

The increase in the complexity of river morphology creates a diverse range of microhabitats (Harvey et al. 2017; Wondzell and Bisson, 2003) highly benefiting aquatic organisms and biodiversity (Pilotto et al. 2014), as channel morphology has the second greatest impact on fluvial ecology after water quality (Hendry *et al.* 2010). Large wood provides habitats, shelter and nutrients for many aquatic and terrestrial flora and fauna (Gurnell *et al.* 2005). The subsequent sorting of sediment allows patches of clean gravels develop, which serves as spawning grounds for many species of fish (Sussex Wildlife Trust, 2016). The increase in flow diversity allows for the establishment of in channel vegetation (Pilotto *et al.* 2018). These habitats can act as refuge for macrophytes and fish during high flow events (Pilotto *et al.* 2018).

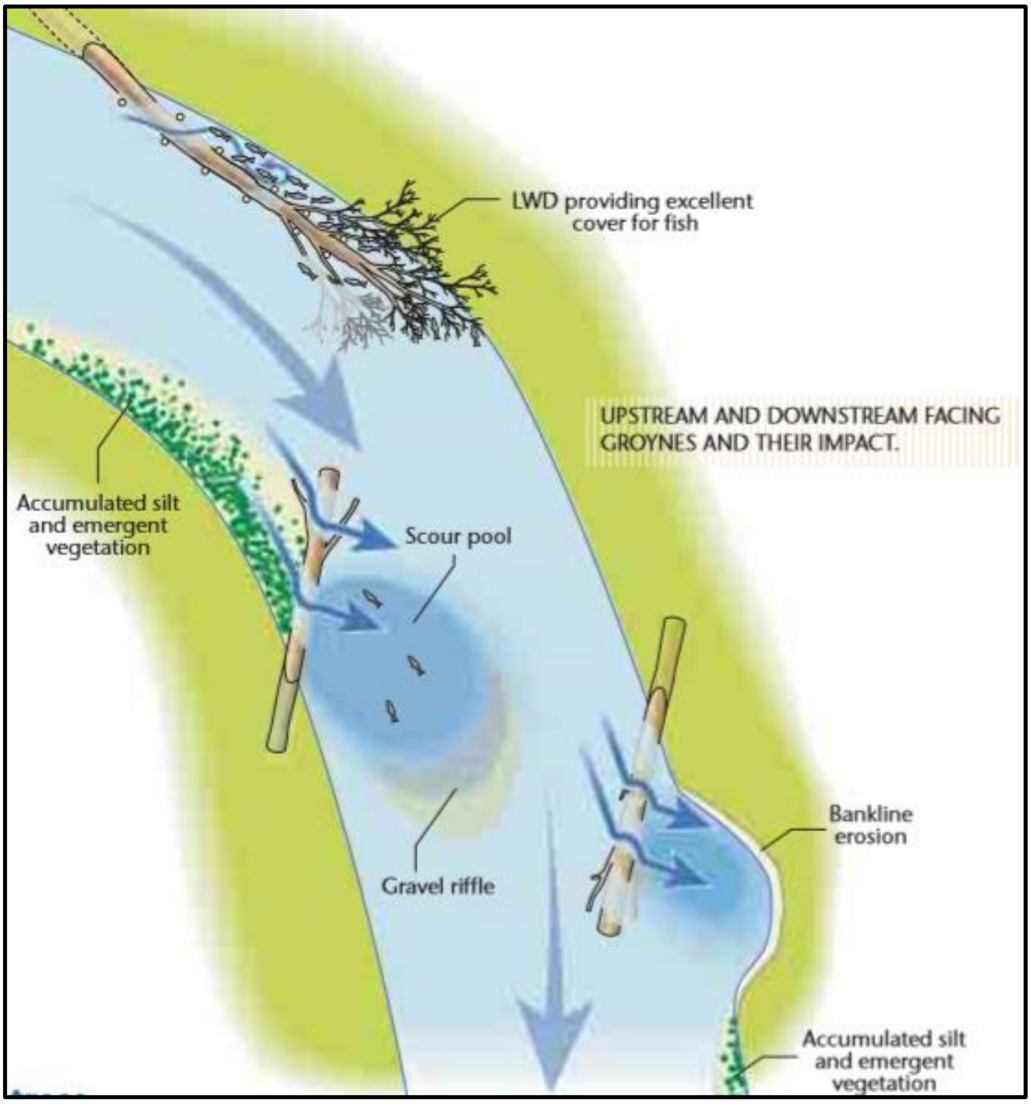

Figure 8, Diagram of Large Wood deflectors and their effect on geomorphology. Riffles, pools and sediment accumulation are highlighted (Wild Trout Trust. 2019).

4.2.2.1 Large Wood Berms

Unvegetated berms will be filled with large wood sourced from bank top vegetation. This is to increase roughness, retarding flows and increasing sediment deposition.

Through filling these unvegetated berms with large wood, hydraulic roughness is increased retarding flows, therefore increasing sediment deposition. The increase in sediment deposition coupled with increase in light penetration through clearing bank top vegetation clearance means there is an increased potential for bank top vegetation to establish.

4.2.2.2 Large Wood Deflectors

Large wood will be installed facing downstream upstream and downstream in all restoration reaches. In some locations small trees will be hinged into the channel bank. Trees to be hinged have be chosen based on location, size and species. Bexley tree officers have been consulted in the selection of trees to be hinged. Hinging trees means that they remain attached to the channel bank. This makes them more secure making it less likely they will be moved downstream during high flow events. In the short term hinge trees can continue to grow.

Large wood will be fixed directly into the channel where suitable bank top trees are not available to hinge. These will be installed facing downstream and upstream, depending on their location. Large wood will be installed out of the channel bank and out of large wood berms. In locations where erosion is present large wood will be installed parallel to the channel banks upstream and downstream of large wood deflectors to protect channel banks from erosion and to encourage sediment deposition. Deflectors will also be installed out of berms, to encourage scour, increasing pools and clean gravel.

In a wider section of the river identified as suitable (see Section 4.3) it is proposed that large wood will be installed into the centre of the river channel as an island. Large wood will be placed parallel on the adjacent channel banks to protect banks from erosion.

4.2.3 Additional Considerations

Any in-channel modifications may result in changes to the river's flow, channel profile and course. The restoration interventions proposed in this plan aim to cause positive changes and increase the river's overall health. The plan takes into consideration the river's setting in a historic public park with multiple uses. Interventions have been designed to avoid significant changes to the river's course through bank erosion, whilst ensuring that all in-channel large wood is securely fixed to avoid potential impacts of this becoming dislodged and travelling downstream.

Through extending the natural features already present sinuosity is increased, which may cause changes in erosion and depositional patterns. Through installing large wood upstream of berms channel banks are protected from any subsequent erosion. Several small trees from bank top will be installed in the channel. These will be staked in place to prevent trees becoming dislodged during high flow events.

All large wood will be securely staked in place and fixed together using wire. This prevents it from becoming dislodged and damaging downstream structures. Large wood deflectors will cover 40-60% of the channel bank, 2m is the smallest pinch that will be installed. The above designs are indicative drawings, the location of large wood installations may vary by up to 10m. Suitable bank top trees to be hinged have been identified. However these are an indication of the size of tree, spacing of tree and direction of trees that will be hinged. In reality the exact tree to be hinged may vary, and the direction of hinge may vary. Currently 16 appropriate trees have been identified, however where appropriate some designed large wood deflectors may be replaced with hinged trees where the appropriate trees are available.

4.3 Restoration Design Overview

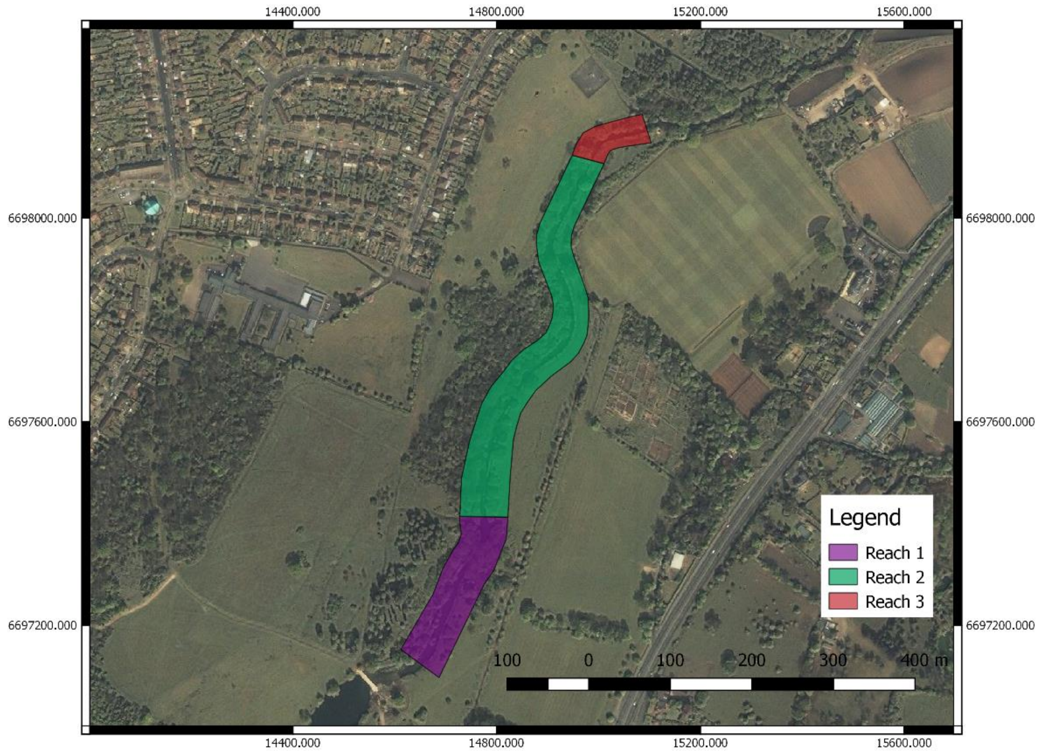

Figure 9, Map of restoration area, highlighting restoration reaches.

The restoration area covers an 850m length of the River Cray through Foots Cray Meadows, downstream of Five Arches Bridge. For the purpose of this river restoration this stretch has been divided into 3 reaches, as shown in Figure 9. The River Reaches have been subdivided in this manner due to the density of bank top vegetation, public access and previous restoration that has taken place.

4.3.1 Reach 1

Figure 10, Photographs of Reach 1 showing an over-widened channel with little geomorphic diversity.

While much of this reach is over-widened with little geomorphic diversity, there are some stretches more geomorphic variation. For example downstream of Five Arches Bridge reedbed has developed naturally which pinches the River Cray. This creates faster flows and clean gravels.

There is a large ford in this reach with dog and public access to the river at both banks, as shown in Figure 11. In this area, in-channel wood will not be installed, allowing this section to continue to be used by members of the public and dogs.

Figure 11, Showing ford in Reach 1, a popular recreation site for dogs and families.

4.3.1.1 Restoration Intervention

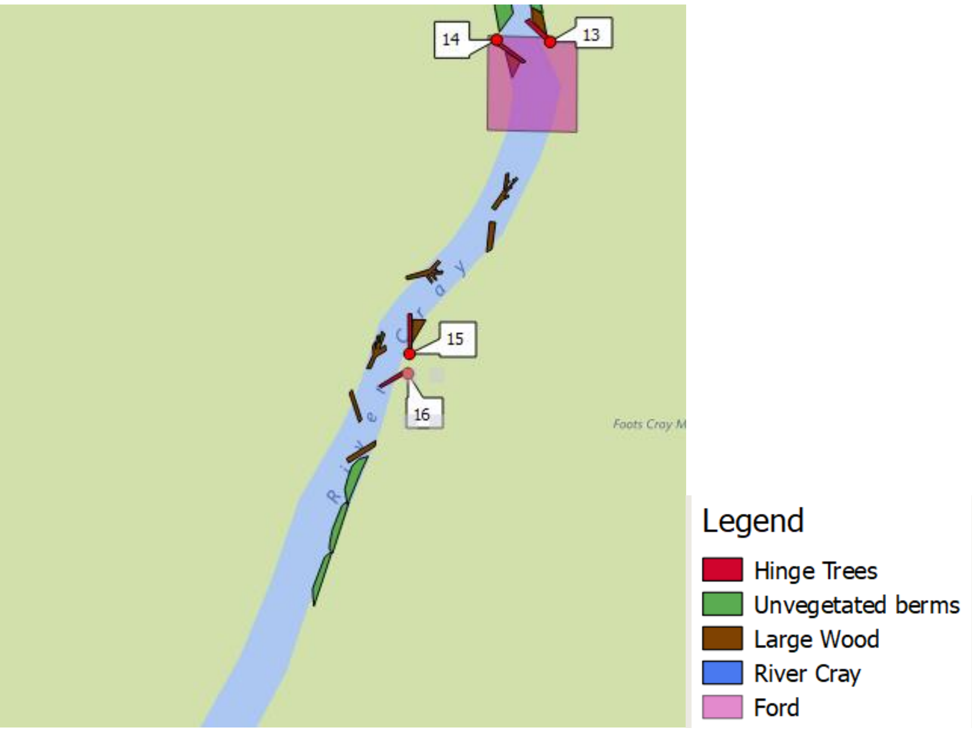

Figure 12, Map showing restoration interventions in Reach 1

Figure 12 shows the river restoration interventions that will be used in Reach 1. No restoration will take place at the ford in this reach, allowing this are to continue to be used by dogs and families for recreation. In this reach trees will be hinged, the exact location and direction that trees will be hinged will vary by 10 meters. Large wood deflectors will also be installed in the river channel in this reach.

4.3.2 Reach 2


Figure 13, Photographs of Reach 2. These show unvegetated berms and tall bank top vegetation.

Public access to this reach is more limited, meaning the bank top is more densely vegetated. These bank top trees provide large amounts of shading in the summer, hindering the establishment of in-channel vegetation. As a result previous restoration interventions in this reach have been unable to fully vegetate.

4.3.2.1 Restoration Intervention

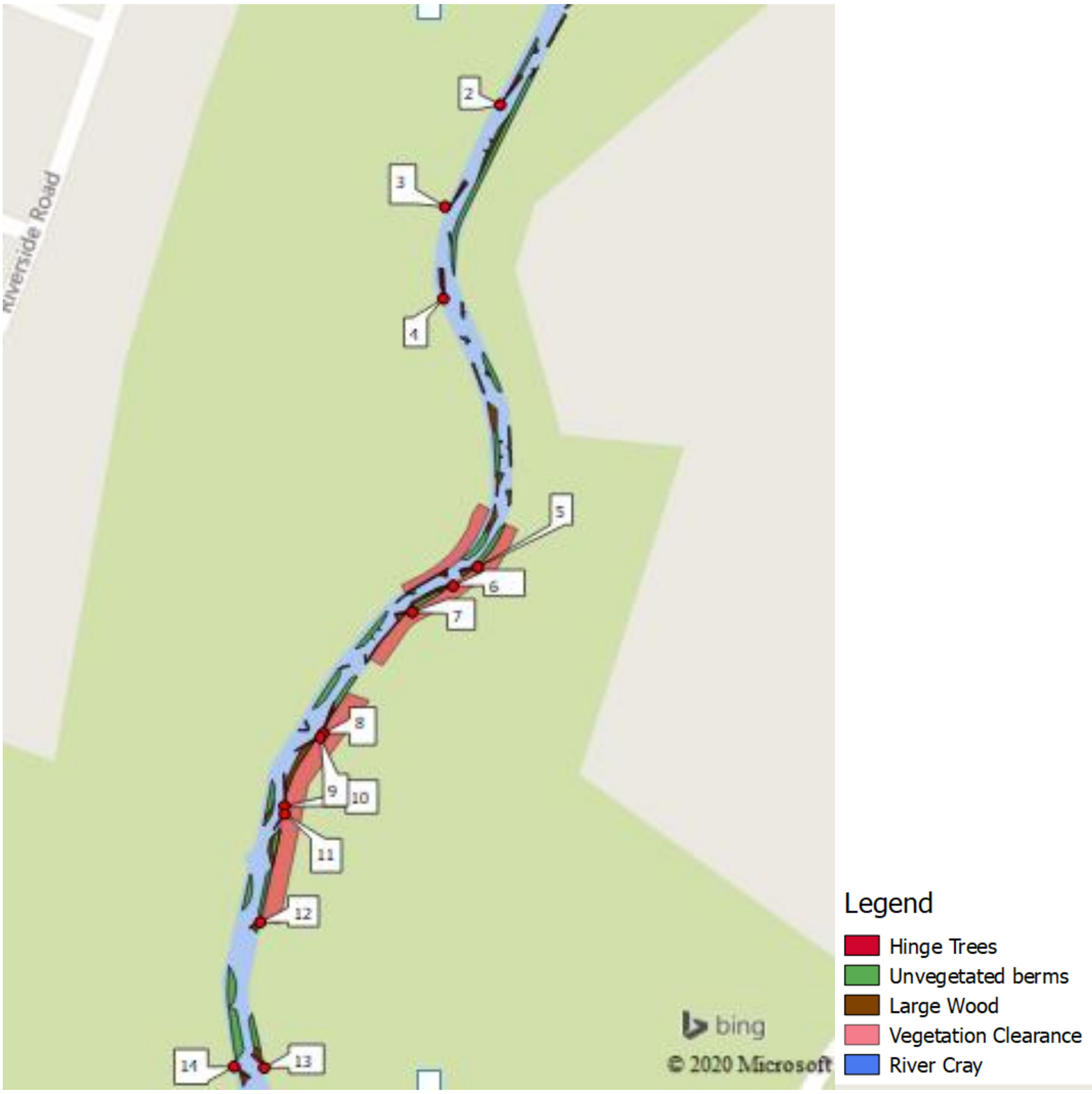

Figure 14, Map showing restoration interventions for Reach 2.

Restoration interventions in Reach 2 are shown in Figure 14, this shows the location of trees to be hinged. The increase in bank top vegetation means there are more suitable trees to hinge in this reach. Large wood deflectors will be installed in areas where appropriate trees to hinge are not present.

Vegetation clearance of bankside saplings, smaller trees and scrub will take place in this reach to increase light penetration. Cleared vegetation will be used to infill unvegetated berms, increasing hydraulic roughness and sediment deposition, allowing marginal vegetation to establish.

4.3.3 Reach 3


Figure 15, Photographs of Reach 3 showing little geomorphic diversity and tall bank top vegetation. Shows some previously installed berms in this reach to have successfully vegetated.

There is limited public access to this reach of the River Cray, it is therefore the least impacted by poaching. This reach has less tall bankside vegetation, allowing more light to reach the channel. This has allowed more in-channel vegetation to establish. There is evidence of bank erosion in this reach as shown in Figure 16.

Figure 16, Evidence of bank erosion in Reach 3.

4.3.3.1 Restoration Intervention

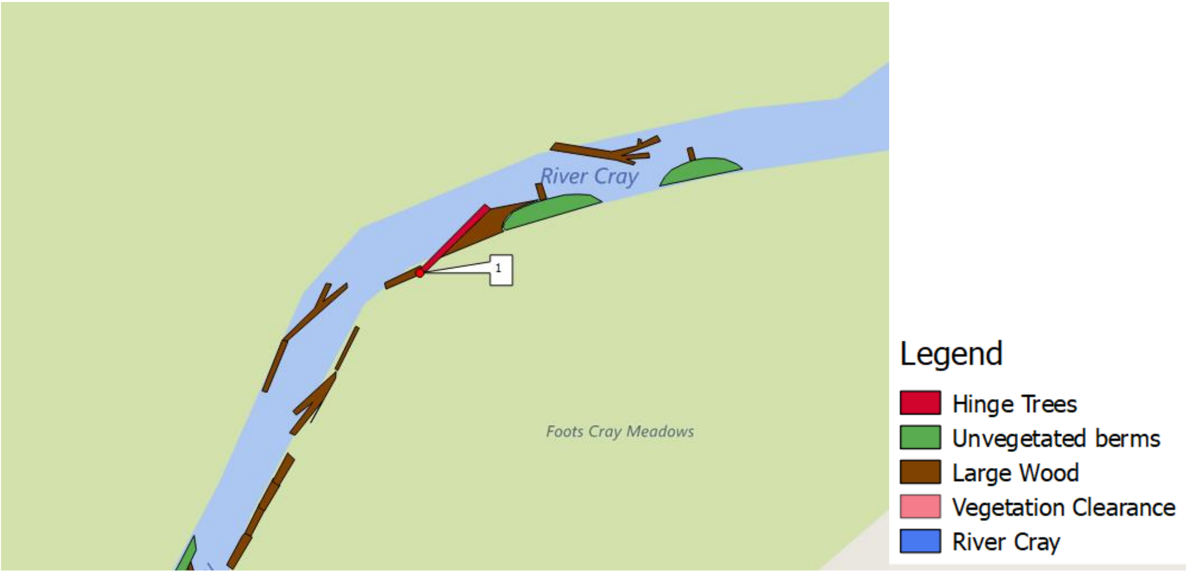

Figure 17, Map of restoration interventions in Reach 3.

Figure 17, shows restoration interventions that will be used in Reach 3. Fewer trees will be hinged due to the limited number of suitable bank top trees. Less bank top vegetation clearance is required in this reach due to fewer bank top trees. Evidence of some bank erosion is present, in this area large wood will be placed parallel to the channel bank to protect from further erosion. Berms that have been unable to vegetate will be filled with large wood and extended further out into the channel.

4.4 Community Involvement

The Craywatch project focuses on engaging the local communities with the River Cray. Volunteers will be invited to participate in the restoration works via event days led by Thames21, to install large wood in the river channel and clear bank top vegetation. All tree hinging will be completed by a contractor, as this activity requires suitably qualified and experienced personnel.

5.0 MONITORING

Monitoring is vital in river restoration to establish which objectives have been achieved and which have not been as successful. This informs future restoration work as well as reassuring local communities and stakeholders of the positive impact this work is having.

Temporal assessments will take place for the evaluation of effectiveness. Before restoration and in monthly intervals volunteer lead monitoring of river geomorphology and water quality will take place. This information will be used to compare the effectiveness of different techniques and inform future restoration designs.

5.1 MoRPh Survey

MoRPh survey will be used to assess the impact restoration has on the physical habitat and geomorphological features. MoRPh surveys will be used to evaluate the success or shortcomings of this restoration work. These will be completed regularly by volunteers, producing data, while engaging and educating the community.

5.2 Riverfly Monitoring Initiative (RMI)

RMI surveys will be completed monthly by volunteers at fixed locations. RMI not only indicates ecosystem health by the number and variety of invertebrates present, but also water quality. This will be completed pre and post restoration.

6.0 REFERENCES

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APPENDIX 1: BANK TOP TREES TO BE HINGED

Right bank/left bank identified according to perspective of observer facing downstream.

Number	Photograph	Upstream/ Downstream	Species (if known)	GPS	Right/ Left Bank
1		Upstream	-	TQ4850872549	Right
2		Upstream	-	TQ4845072471	Left

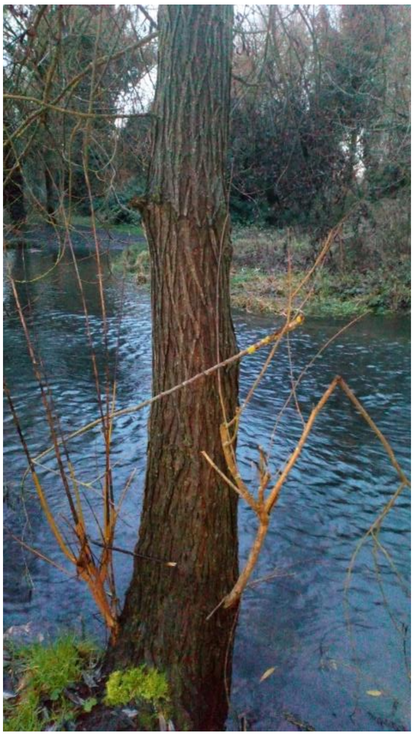
3		Upstream	-	TQ4843672446	Left
4		Upstream	-	TQ4843972401	Left

5		Downstream	Ash	TQ4844872290	Right
6		Upstream	Ash	TQ4843872282	Right

7		Upstream	Ash	TQ4842672276	Right
8		Upstream	Ash	TQ4838872225	Right

9		Upstream or Downstream	Ash	TQ4838472225	Right
10		Upstream/ Downstream	-	TQ4837372185	Right

11		Upstream/ Downstream	-	TQ4837772185	Right
12		Downstream	Ash	TQ4836772145	Right

13 & 14		Upstream Downstream	- -	TQ4836672103	Right Left
15		Upstream	-	TQ4833972009	Right
16		Upstream/ Downstream	-	TQ4833371990	Right