REPORT

Restoration of Long and Round Ponds (Phase I): Options Appraisal Study

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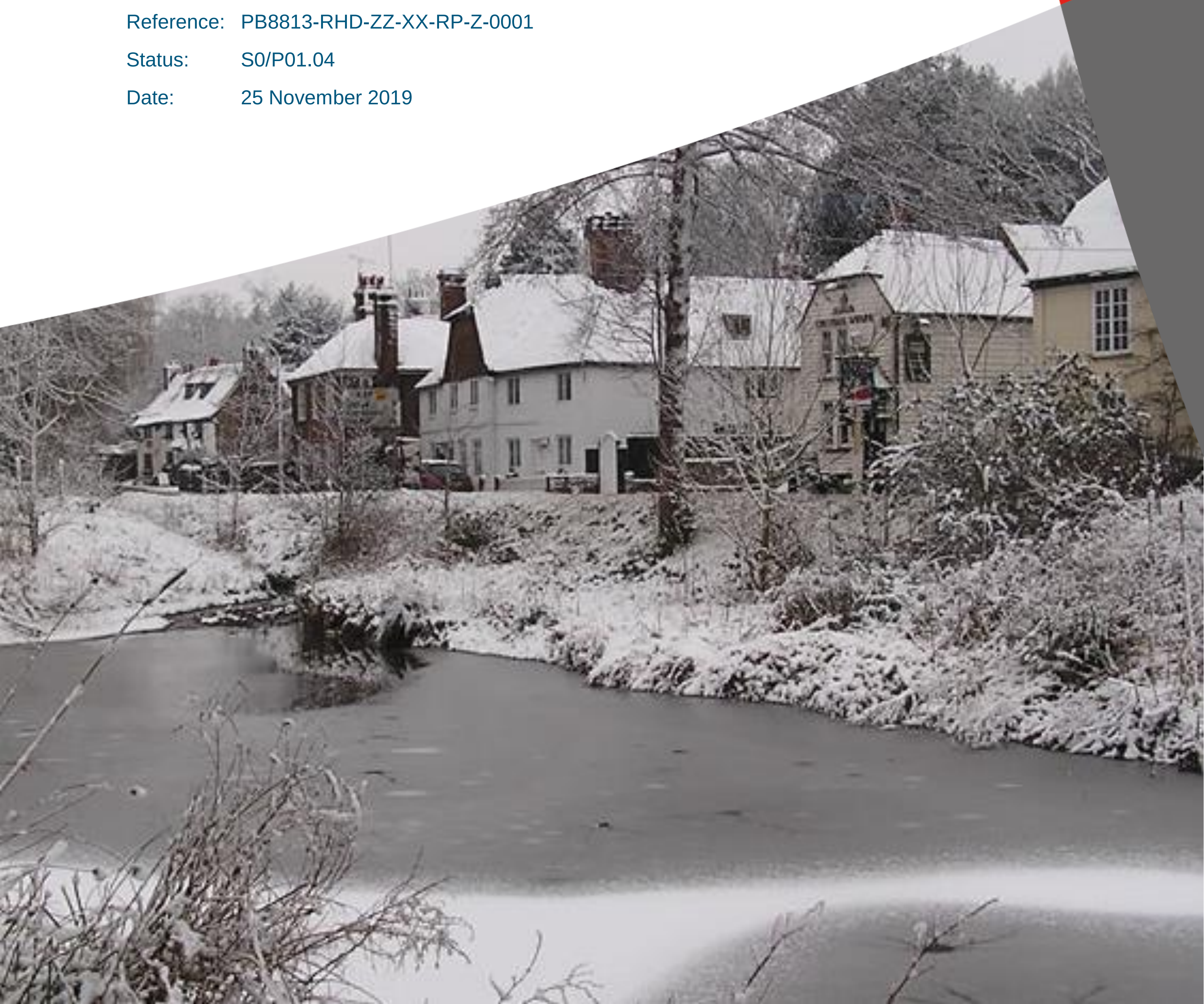

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Executive Summary

Royal HaskoningDHV have been commissioned by Kent County Council (KCC) and the Darent Valley Landscape Partnership Scheme (DVLPS) to undertake an Options Appraisal Study for the long term management of the Long and Round Ponds in Westerham. This would aim to restore the ponds to good condition and enhance the wellbeing and community benefits the ponds can provide for the town of Westerham. The key aims of the options appraisal are to identify sustainable and low maintenance solutions which would ecologically restore the ponds while also providing potential flood risk benefits to the local community as part of the wider Natural Flood Management (NFM) scheme. The options appraisal forms Phase I of the project.

Based on the outcomes of this report, the most appropriate habitat restoration solutions to directly achieve the key considerations of the project is the removal of sediment from the Long and Round Ponds through either wet or dry dredging, with dry dredging the recommend technique via partial or complete draw down of the ponds. This technique will allow for precise control and greater scope for achieving the required profiles for the ponds, restricted and controlled working, establishment of greater diversity of local terrestrial and aquatic flora and fauna, and allows the creation of micro-habitats in the lake bed through targeted re-profiling (during sediment removal) to further promote habitat diversity in the Long and Round Ponds. However, dredging should be undertaken in combination with the installation of sediment traps, attenuation features and other NFM measures to help control sediment input from the catchment and ensure the long term success of restoring the ponds without the need for future maintenance.

Acknowledgements

Royal HaskoningDHV would like to thank all members of the team for producing this feasibility report in particular Mary Tate of Darent Valley Landscape Partnership Scheme, and local residents (Friends of Long Pond) who have provided their time and support on this exciting project. We look forward to seeing the potential habitat restoration measures identified in this report for the Long and Round Ponds to help improve the ecological condition of the ponds for the whole community to enjoy.

Source: http://www.visitwesterham.org.uk

Source: http://www.visitwesterham.org.uk

1 Introduction

1.1 Background

1.1.1 The Darent Valley Landscape Partnership Scheme (DVLPS) is a large-scale partnership, working to conserve and enhance the distinctive Darent Valley landscape and reconnect people to it. At the heart of the scheme is the valley's historical connection with the Victorian artist, Samuel Palmer, who lived in Shoreham and called the valley his 'earthly paradise'. Through its partnership approach DVLPS is delivering over forty integrated cultural and art, access, heritage and biodiversity projects within communities, towns and villages throughout the scheme area between Dartford and Westerham in west Kent. DVLPS is led by the Kent Downs Area of Outstanding Natural Beauty (AONB) Unit and hosted by Kent County Council.

1.1.2 The long-term management of the Long and Round Ponds located in the town of Westerham forms Phase One of a three phase project as part of the DVLPS vision for the Darent Valley. The ponds once formed part of a historic working mill on the site and are two of several mill ponds along the length of the River Darent. They are particularly valued by the local residents for their historical and amenity value.

1.1.3 The Westerham Long Pond is leased from the Squerryes Estate, which is located to the south, by Westerham Town Council. Prior to 2000, Long Pond had become almost completely silted up, with just a meandering channel remaining. The pond was de-silted in 2000 as part of the town's millennium celebrations, and again in 2005. However, the pond has gradually refilled with silt. This process of siltation is anecdotally reported to have escalated since 2000 in comparison to previous years. The Long and Round Ponds are part of a wider scheme to instate a number of Natural Flood Management (NFM) measures, which are being funded by both Heritage Lottery and Interreg projects along the length of the River Darent to reduce flooding and runoff events. A number of stakeholders are involved including the Environment Agency, South East Rivers Trust, Local Authorities and the local community, including the Friends of Long Pond (FOLP).

1.1.4 The Water Framework Directive (WFD) requires all EU Member States to protect and, where possible, enhance the condition of all bodies of water. Under the requirements of the WFD, water bodies such as the River Darent must reach Good Ecological Status (GES) by 2021 (or, in cases where there are significant pressures to address, 2027). The Long and Round Ponds are in line features which form part of the Upper Darent WFD water body, which does not currently meet the WFD targets and is classified with a "Poor" ecological status. The Environment Agency are obliged to ensure that the required WFD objectives are achieved in the future.

1.2 Aim and Scope of Project

1.2.1 Royal HaskoningDHV have been commissioned by Kent County Council (KCC) / DVLPS to undertake an Options Appraisal Study for the long term management of the Long and Round Ponds. This would aim to restore the ponds to GES and enhance the wellbeing and community benefits the ponds can provide for the town of Westerham. Key aims of the options appraisal are to identify sustainable and low maintenance solutions which would ecologically restore the ponds while also providing potential flood risk benefits to the community of Westerham as part of the NFM scheme. The options appraisal forms Phase I of the project.

1.2.2 A summary of the key scope of works and approach for this project is provided below:

- **Stage 1 – Long and Round Ponds Site Meeting:** a site meeting was held at the site of the Long and Round Ponds on the 7th of October 2019 attended by the project team. This included representatives of Royal HaskoningDHV, the DVLPS Countryside Manager, and a member of the FOLP who is also a local resident of Westerham. It provided an opportunity to gain background information and clarify the project objectives, whilst also undertaking a site walkover to assist in characterising the existing environment.
- **Stage 2 – Desk Based Assessment:** describing the physical and ecological characteristics of the ponds and the features they support, to provide specific background information to inform the other sections of this report.
- **Stage 3 – Silt Analysis:** following the site meeting, samples were obtained from the ponds and subjected to analysis by ALS Laboratories.
- **Stage 4 – Options, Appraisal and Capital Costs:** building on the stages above, a range of techniques available for improving both water quality and ecological improvements in the ponds were identified (in particular those associated with sediment removal); and appraised, in order to identify the most viable habitat restoration solutions for the ponds. A range of the NFM techniques were also identified in order to compliment the habitat restoration solutions for the ponds.
- **Stage 5 – Sediment Re-use or Disposal and Flood Storage Capacity:** for the most viable habitat restoration solutions for the ponds, further details on the potential disposal routes for the removed sediment based upon the outcomes of the silt analysis were identified.
- **Stage 6 – Recommendations:** for habitat restoration solutions for the Long and Round Ponds based upon the overall outcomes of this Phase I project.
- **Stage 7 – Next steps and challenges**, including required permissions for implementing Phase II of the project – Design and Construction.
- **Stage 8 – Management Programme and Enhancements:** a long term restoration management programme was developed for the ponds taking into consideration the outcomes of this Phase I project; current management plans; and, long term cost implications of managing the most viable (recommended) restoration solutions. In addition, ecological and landscape enhancements associated with the Long and Round Ponds are also discussed.

1.3 Key Guidance and Legislation

1.3.1 Key guidance documents used in this report include:

- Review of Lake Restoration Techniques and Costs (Royal Haskoning, 2003)
- Guide to Lake Protection Management (Freshwater Society, 2004)
- The Lake and Reservoir Restoration Guidance Manual (1988) (http://www.wwwalker.net/pdf/lake_reserv_guidance_manual.pdf
- UK Lake Restoration (https://www.ceh.ac.uk/our-science/projects/uk-lake-restoration)
- Lake Restoration Methods and Feasibility of Water Quality Management in lake of the Woods (Energy and Natural resources, 1982)
- Common Standards Monitoring Guidance (JNCC, 2016) (https://hub.jncc.gov.uk/assets/1b15dd18-48e3-4479-a168-79789216bc3d)
- Vegetation communities of British lakes: a revised classification (JNCC, 2006)
- Flood Risk (https://www.gov.uk/guidance/flood-risk-and-coastal-change)
- Waste management (https://www.gov.uk/topic/environmental-management/waste)
- Definition of Waste: Development Industry Code of Practice (CL:AIRE, 2011)
- Guidance on Applying the Waste Hierarchy (Department for Environment, Food and Rural Affairs (Defra), 2011) (https://www.gov.uk/government/publications)

1.3.2 Key legislation documents taken into consideration in this report include:

- EU Directives
  - Water Framework Directive (2000/60/EC)
  - European Union (EU) Eel Regulation (1100/2007/EC)
  - EU Waste Framework Directive (2008/98/EC)
- UK Acts of Parliament
  - Environmental Protection Act 1990
  - Water Resources Act 1991
  - Reservoirs Act 1975
  - Land Drainage Act 1991 (c.59) section 61 A-D
  - Part 7 (Fisheries), Chapter 3 (Migratory and freshwater fish) of the Marine and Coastal Access Act 2009 (c.51) (The Marine Act)
- UK Regulations and Directions
  - The Water Environment (Water Framework Directive) (England and Wales) Regulations 2003
  - Environmental Permitting (England and Wales) Regulations 2010
  - The Waste (England and Wales) Regulations 2011
  - The Hazardous Waste (England and Wales) Regulations 2005
  - The Water Environment (Water Framework Directive) (England and Wales) (Amendment) Regulations 2015
  - The Water Framework Directive (Standards and Classification) Directions 2015
  - The Eels (England and Wales) Regulations 2009

1.3.3 Key Policy and Action Plans

- Biodiversity 2020: A strategy for England's wildlife and ecosystem services (2011)
- The Eels (England and Wales) Regulations 2009
- 'A Green Future: Our 25 Year Plan to Improve the Environment' (2018)

2 Desk Based Assessment

2.1 Introduction

2.1.1 This section of the report introduces the Long and Round Ponds in the context of the Phase I Options Appraisal Study, and focuses on describing the physical and ecological characteristics of the ponds and the features they support. This will provide specific background information to inform the other sections of this report.

2.2 Methodology

2.2.1 A review and validation of existing surveys; data; and, reports were conducted to inform the subsequent stages and overall outcomes of this project, including baseline information on the following:

- The geographical and hydrological setting of the ponds, including the riverine habitats both upstream and downstream based on the site visit, data and reports.
- Environmental constraints, including fluvial processes and sources of silt based on the site visit, data and reports.
- Review of current management practices and what has been implemented to date both at the catchment and local scale.
- Summary of lake restoration techniques and NFM measures.

2.2.2 The following key reports, data and information were reviewed:

- Photos relating to Moorhouse Sandpits from 2003.
- Flooding and Siltation on the Upper Darent at Westerham – compiled by Stuart Merrylees, Hon. Sec. of the FOLP (2019).
- Sources of Silt and Sand in Long Pond and Round Pond Westerham (DVLPS (2015).
- Westerham Long Pond: Review of De-Silting Problems (2008) – written by Stuart Merrylees, Hon. Sec. of the FOLP.
- Assessing the potential application of Natural Flood Management (NFM) techniques in the Upper River Darent Catchment, Kent – South East Rivers Trust (SERT) (2015).
- Biodiversity data from the Kent and Medway Biodiversity Records Centre.

2.2.3 Key sources of publicly available data and analysis used to inform this report included:

- MAGIC (Natural Environment GIS) (https://magic.defra.gov.uk/)
- Historic England (https://historicengland.org.uk/)
- Environment Agency WFD Catchment Data Explorer (https://environment.data.gov.uk/catchment-planning/)
- Kent County Council interactive mapping (https://webapps.kent.gov.uk/KCC.ExploreKent.Web.Sites.Public/Default.aspx)

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2.3 Assessment

Location

2.3.1 The Long and Round Ponds are located on the southwestern side of Westerham, directly to the south of the A25 which runs through the village, between the Goodley Stock Road to the west and Mill Lane to the east (**Figure 2.1**). The land and ponds are owned by the Squerryes Estate, with the main house Squerryes Court located just 250 m to the south. It is leased from the Squerryes Estate by Westerham Town Council and is now managed by the FOLP who are a volunteer group.

Figure 2.1 The Long and Round Ponds

Source: https://www.bnhs.co.uk

History and Cultural Heritage

2.3.2 The River Darent rises to the west of Westerham and flows eastwards, parallel with the A25. The Long and Round Ponds were man-made and were created for water storage, through modifying the Cross Dyke (see **Figure 2.1**), to feed the Darenth Mill at the east end of the town and included a number of sluices which have since been removed. **Figure 2.2** below shows the Long and Round ponds on a historical map from 1896.

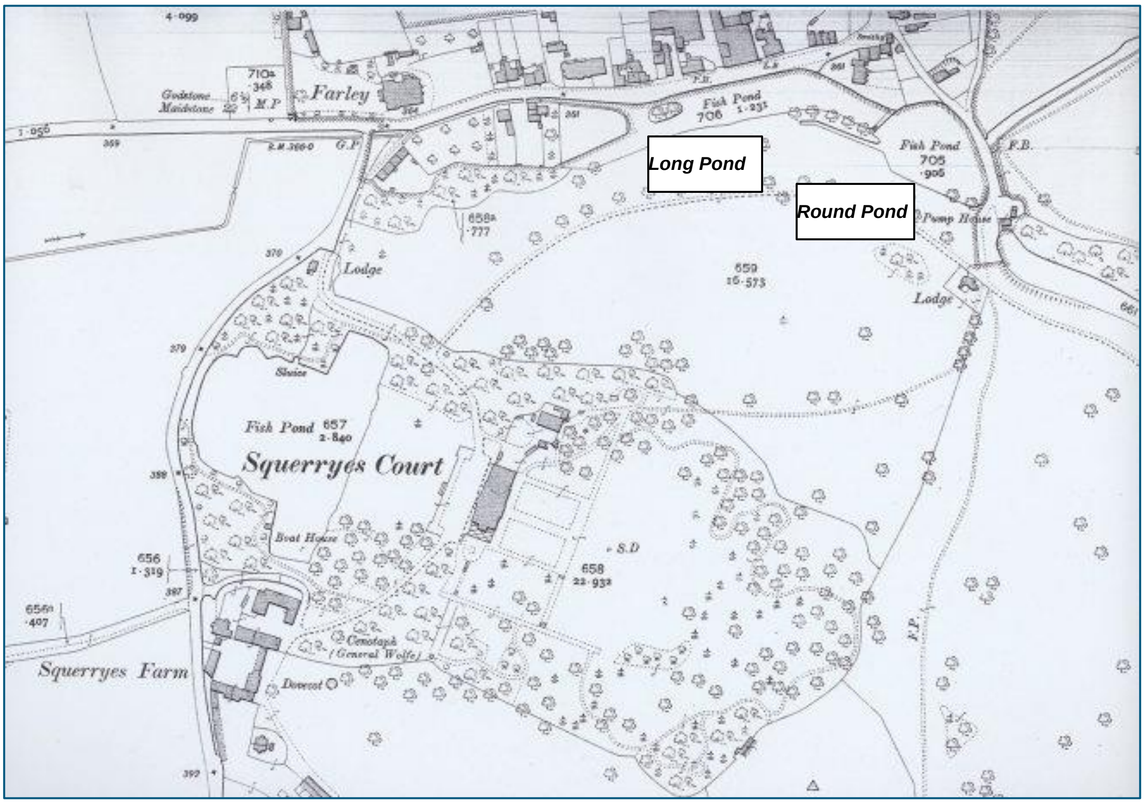

Figure 2.2 Historical map from 1896 including Squerryes Court with the Long and Round Ponds visible at the top labelled 'Fish Pond'. Source: https://www.westerhamheritage.org.uk/content/catalogue_item/map-of-long-pond-including-squerryes-court-2 [Accessed 25/10/19]

2.3.3 According to an information sign at the entrance to the Long Pond, it was originally known as Squerryes Green, but the local tenants relinquished their rights to the Lord of Squerryes Estate in 1775. At this time, it is probable that a pond of some sort existed due to reports of a 'scold' called Hannah Saxby being sentenced to be ducked in 'Westerham Water'. The pond was then dug to its current dimensions in the middle of the 19th century to then silt up during the Second World War. Its local importance is signified by the fundraising effort which led to its desilting and management in 2000.

2.3.4 The parkland of Squerryes Court lies directly adjacent to the Long and Round Ponds and includes fields to the west and north of the site. This is designated as a Registered Park and Garden, the outline of which is shown in **Figure 2.3** below.

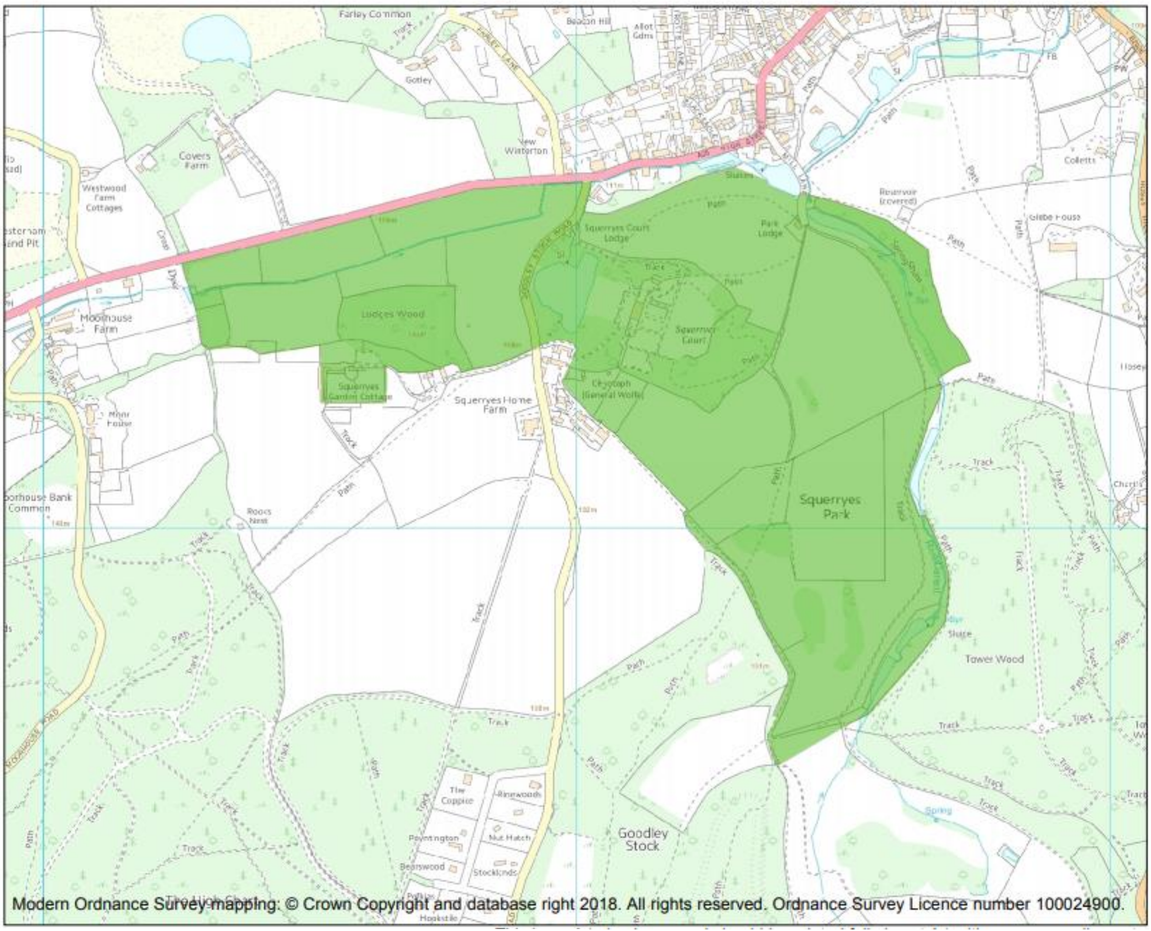

Figure 2.3 Squerryes Court Registered Park and Garden

2.3.5 The registered park area covers 69 ha, of which 60 ha comprises parkland and woodland which lies on the north and east-facing slopes of a greensand ridge. The northern edge abuts the A25 main road, and the site is bisected by the Goodley Stock Road which runs north to south through the middle of the designated area.

2.3.6 Westerham itself is a conservation area covering 36 ha designated in 1973. It includes the historic town centre and Squerryes Court, and therefore also covers the Long and Round Ponds.

Land Use and Recreation

2.3.7 The fields to the south of the Long Pond are largely grassland which have been used as grazing pasture. There is a further pond in the grounds of Squerryes Court which can be seen on the map in **Figure 2.3.**

2.3.8 The Long Pond is owned by the Squerryes Estate and is leased by Westerham Town Council who allow public access. In 2007, the Long Pond was used by the Royal National Lifeboat Institution (RNLI) to hold a fair to raise money for lifeboats, during which the ducking of Hannah Saxby was re-enacted.

2.3.9 There are no public rights of way directly adjacent to the ponds, but the Greensand Way passes directly to the east. This is a long-distance path which follows a ridge of greensand rock across Surrey and Kent.

Hydrogeology and Hydrological Connectivity (including Flood Risk)

2.3.10 The River Darent is a distinctive chalk river which flows for 34 km from the Lower Greensand hills through the North Downs to reach a confluence with the Thames. It supports a diverse ecology associated with this chalk habitat and has a high conservation value. It also has a long history of modification to sustain human activity.

2.3.11 The 100 km^2 Upper Darent catchment is underlain by permeable chalk, mudstone sandstone and therefore some streamflow to these areas are via a slow responding baseflow with losses to the aquifer below. At Westerham the catchment is underlain by:

- The Lower Greensand Group (sandstone and mudstone);
- Gault and Upper Greensand Formation (Mudstone, Sandstone and Limestone) to the north; and
- Wealden Group (Sandstone and Siltstone) to the south.

2.3.12 Further to the north is a strip of Grey Chalk Subgroup followed by a significant area of the White chalk Subgroup. The aquifer found directly below Westerham is classified as a major principal aquifer with intermediate vulnerability. Principal aquifers are those that have a high intergranular and/or fracture permeability and therefore provide a high level of water storage. Intermediate vulnerability indicates an area that offers some groundwater protection perhaps characterised by low leaching soils.

2.3.13 According to the *Initial Hydrological Assessment* (JBA Consulting, 2019), the 13 km^2 catchment at Westerham is the smallest on the River Darent and has a flashy response to rainfall. In addition, the River Darent includes several potential 'pinch points' in southwest Westerham (SERT, 2015) including at the culvert beneath the Goodley Stock Road, and at the entrance to the Long Pond, and the entrance to the Round Pond.

2.3.14 The Long and Round Ponds are in-line with the River Darent and therefore have only one major input at the western end and output at the eastern end. **There are also drains which divert water from the A25 into the ponds and contribute silt, sediment and water**. The spillway and flood relief channel in the field to the south also takes excess water in periods of high flow.

2.3.15 Upstream of the Upper River Darent is the Cross Dyke which is an ordinary watercourse. This flows through fields to the south of the A25 and meets the River Darent at the Goodley Stock Road via a culvert beneath the road. The narrow diameter of this culvert causes water to accumulate in the field directly to the west of the Goodley Stock Road and restricts the rate at which it enters the main river. The Cross Dyke has been artificially modified and flows in a 'dog leg' around the perimeter of the field rather than at the lowest point of the valley.

2.3.16 There is a stream which takes water from the Squerryes Court Pond down the hill, passing to the west of Squerryes Park Cottages, and joining the River Darent. From this point, the River Darent flows easterly adjacent to the A25 and is channelised, as visible in **Figure 2.4** prior to flowing into the Long Pond after Pitt's Car Park.

Figure 2.4 River Darent between the A25 road and cottages

2.3.17 **There is a flood relief channel which was constructed by the Environment Agency following floods in 2004. This flows from the Goodley Stock Road, where it takes water from the Squerryes Court Pond to join the Round Pond, bypassing the Long Pond to the south.** The Long Pond is a widening of the river channel, which narrows again to then widen to form the Round Pond. This then joins the Spring Shaw stream via a sluice at the eastern edge of the Round Pond to continue downstream as the River Darent.

2.3.18 **Figure 2.5**, provides a summary of the hydrological connectivity of the Long and Round Pounds, along with location of the water control structures (sluices).

Figure 2.5 Long and Round Pond Hydrological Connectivity

Source: https://osmaps.ordnancesurvey.co.uk/51.26263,0.06965,17

2.3.19 Data from the Environment Agency's Flood Map for Planning service is shown in **Figure 2.6** below. The dark blue Flood Zone 3 refers to land which has a 1 in 100 or greater annual probability of river flooding; the lighter blue Flood Zone 2 refers to land having between a 1 in 100 and 1 in 1,000 annual probability of river flooding. This shows that the River Darent has a 1 in 100 or greater annual probability of flooding directly adjacent to the river; an area that incorporates several residential properties and sections of the A25 where it flows through Westerham. The field south of the Long Pond within the Squerryes Estate is also subject to flooding. As such, **Figure 2.6** provides a useful tool to identify flood risk constraints associated with areas of potential storage of sediment removed from the ponds (further detailed in **Section 4** and **Section 6**).

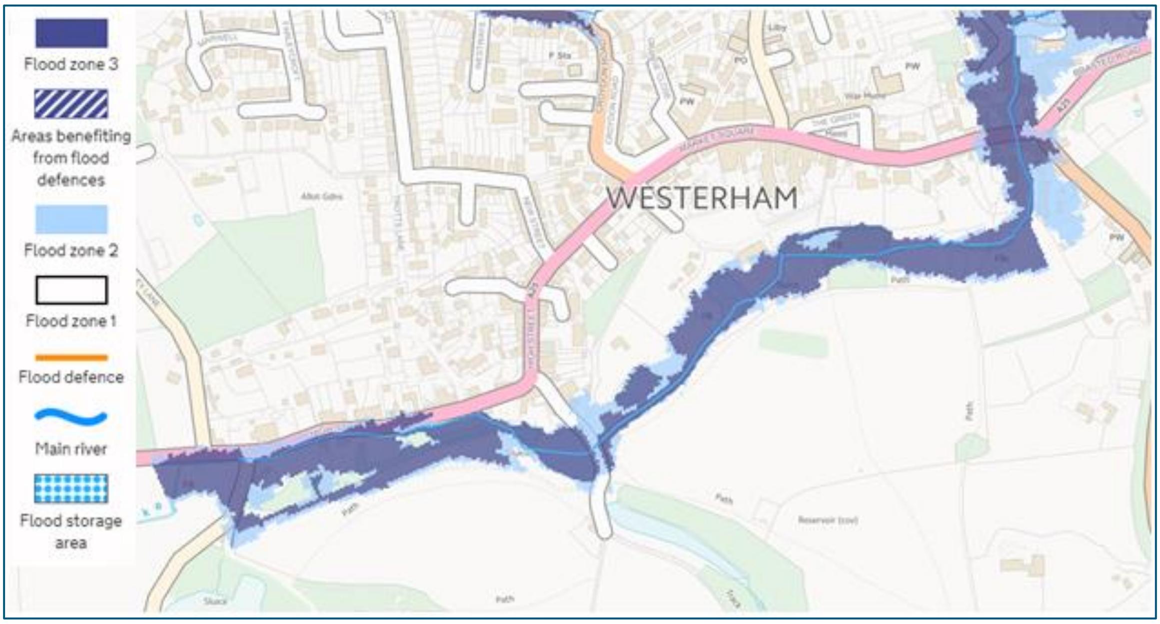

Figure 2.6 Environment Agency Flood Risk Mapping at Westerham. Source: flood-map-for-planning.service.gov.uk [Accessed 28/10/2019]

Sources of Sediment

2.3.20 Approximately 1.5 km upstream of the Long Pond, to the west of Westerham, there is the entrance to an active sand pit: **Moorhouse Sandpits**. Although the active sandpit itself is 2.4 km west of the Long Pond, access from the A25 is gained by the entrance just to the west of the Grasshopper Inn. A report by DVLPS (2015) entitled "Sources of Silt and Sand in Long Pond Westerham" includes photographs showing sand at the entrance to the Moorhouse Sandpits in 2015 following rainfall.

2.3.21 This is purported to originate from the tyres of lorries where they turn in and out of the site, to then be washed into the stream at Moorhouse Farm Bridge and then feed into the River Darent. This issue has been reduced through discussions with the owners of the Moorhouse Sandpits, leading them to clear a settling lagoon north of the Grasshopper Inn, reducing the volume of sand escaping. This is shown in **Figure 2.7**.

2.3.22 **Road drainage** is also identified as a potential source of siltation and pollution to the River Darent in the report Flooding and Siltation on the Upper Darent at Westerham (Merrylees, 2019). Blockages have occurred along the A25 in previous years which have led to rain water and silt running down the road which then drains into the Long Pond. KCC have now installed pipes which drain into the River Darent, and a dropped kerb was installed alongside some of these drains opposite Farley Lane.

Figure 2.7 Sand trap lagoon at Moorlands

2.3.23 **Arable land** occurs to the south of the River Darent, and run-off occurs down the Goodley Stock Road and from Squerryes Home Farm. This run-off may contain sediment and silt, particularly from the arable fields directly to the west of the Goodley Stock Road at Squerryes Court Farm. This arable land is likely to be the greatest source of sediment, although a greater area of the catchment of the Upper River Darent comprises woodland and grassland.

2.3.24 Of the three potential sources of sediment in the catchment, it is likely that catchment run-off from arable land is likely to be the greatest source due to its greater proportion of area within the catchment. Road drainage and the Moorhouse Sandpits contribute additional sediment in the vicinity of the ponds.

Ecology

Designated Sites, Flora and Fauna

2.3.25 A desk study was requested from Kent and Medway Biological Records Centre by DVLPS including information on protected species and statutory and non-statutory designated sites within a 3 km radius surrounding the Long and Round Ponds. This returned information which is summarised below. Only protected areas within a 1 km radius were considered for the purpose of this report as there is little mechanism for impact further than this, unless the sites are hydrologically connected, due to the nature of any works that may take place.

Non-statutory designated sites

2.3.26 Westerham lies within the Kent Downs AONB designated for, among other qualities, its biodiverse chalk grassland and its water and wetland habitats including chalk streams, ponds and marshes. It is also a heavily wooded rural and farmed landscape which has a strong cultural and historical heritage, embodied by the Long and Round Ponds.

2.3.27 Westerham Mines Site of Special Scientific Interest (SSSI) is located approximately 900 m southeast of the Long and Round Ponds. This is a series of abandoned ragstone mines, located chiefly in woodland, which are designated due to their use by a variety of hibernating bats including:

- Whiskered bat *Myotis mystacinus*;
- Brandt's bat *Myotis brandti*;
- Daubenton's bat *Myotis daubentoni*;
- Natterer's bat *Myotis nattereri;* and
- Brown long-eared bat *Plecotus auritus*.

2.3.28 The heathland in this area also supports a rich heathland breeding bird community including nightjar *Caprimulgus europaeus*.

2.3.29 Approximately 1 km to the north, Westerham Woods SSSI is designated as a rare example of ancient woodland on Gault Clay in Kent with rich ground flora and breeding bird community.

Non-statutory designated sites

2.3.30 Two local wildlife sites (LWS) also lie approximately 750 – 900 m to the southeast – Crockhamhill Common and Hosey Common, with Farley Common LWS located approximately 400 m to the northwest.

2.3.31 These are part of a group of eight LWS which are collectively known as the Sevenoaks Greensand Commons which are under the management of Kent Wildlife Trust. Crockhamhill Common is designated as an acidic and neutral woodland with heathy areas, while Hosey Common is designated as ancient woodland with an area of acid grassland. Farley Common is designated for its acid grassland and fringing oak woodland.

Habitats

2.3.32 An area of ancient woodland lies directly adjacent to the southeast of the Long and Round Ponds, bordered by plantation woodland on the site of ancient woodland.

Protected Species

2.3.33 A number of protected plant species have been recorded within the 3 km search area including:

- Common spotted-orchid *Dactylorhiza fuchsii*;
- Bluebell *Hyacinthoides non-scripta* – protected under the Wildlife and Countryside Act Schedule 8 (1981) is widely recorded across the area; and
- Sowbread *Cyclamen hederifolium.*

2.3.34 Protected animal species recorded in the Biodiversity Records Centre information includes the white-clawed freshwater crayfish *Austropotamobius pallipes*. However, during the site visit of the 7th October 2019, an invasive signal crayfish *Pacifastacus leniusculus* was observed in the Round Pond; the presence of which would strongly indicate that the native white-clawed crayfish is not present at this location.

2.3.35 Great crested newts *Triturus cristatus* have been observed in the locality of Westerham and are protected under the Wildlife and Countryside Act (WACA) Schedule 5 (1981). There are many records of reptiles including grass snakes *Natrix helvetic*a, adders *Vipera berus*, common lizards *Zootoca vivipara* and slow worms *Anguis fragilis* all of which are also protected by the WACA Schedule 5 (1981).

2.3.36 Protected mammal species including the West European hedgehog *Erinaceus europaeus*, hazel dormouse *Muscardinus avellanareus*, badgers *Meles meles* and the following species of bats have all been observed within a 3 km radius of the Long and Round Ponds:

- Brandt's Bat *Myotis brandtii*;
- Daubenton's Bat;
- Whiskered Bat;
- Natterer's Bat;
- Noctule Bat *Nyctalus noctula*;
- Common Pipistrelle *Pipistrellus pipistrellus*;
- Brown long-eared bat.

Ecological Survey

2.3.37 In September 2019, an ecological survey was carried out by Bramley Associates (2019), with a particular focus on native white-clawed crayfish and other protected species. The findings of this survey are summarised below.

2.3.38 It was noted that the River Darent in this area historically has records of holding the non-native signal crayfish just downstream of the pond. The surveyors used standard techniques of manual searching and hand-netting to search for crayfish, and simultaneously carried out an ecological walkover survey. During the survey, signal crayfish were found up and downstream of the Long Pond in the River Darent. It is therefore considered that due to the prevalence of the non-native signal crayfish, which out-compete the native white-clawed crayfish, it is unlikely that any works could impact upon native white-clawed crayfish populations.

2.3.39 The Long Pond was observed to have a dense native riparian habitat dominated by bulrushes, sedge and alder. The Spring Shaw which flows into the River Darent from the south was observed to contain brown trout *Salmo trutta* which is a priority species under the UK Post-2010 Biodiversity Framework. Other fish species include 3-spined stickleback *Gasterosteus aculeatus*, stone loach *Barbatula barbatula* and possibly European eel *Anguilla anguilla,* based on data the Environment Agency National Fish Populations Database (NFPD) 2019.

2.3.40 No signs of water vole *Arvicola amphibius* or otter *Lutra lutra* were observed during the survey, although signs of badgers *Meles meles* were observed and several of the trees surrounding the Long and Round Pond were considered to show good bat roost potential. The area surrounding the ponds also shows potential to provide reptile basking, foraging and hibernation habitat. Therefore, in any proposed scheme of works, protected species will require consideration and potential mitigation to avoid adverse impacts.

Water Framework Directive

2.3.41 The Water Framework Directive (WFD) (Council Directive 2000/60/EC establishing a framework for community action in the field of water policy) was adopted by the European Commission (EC) in December 2000. The WFD requires that all European Union (EU) Member States must prevent deterioration to, and protect and enhance the status of, aquatic ecosystems. This means that Member States must ensure that new schemes do not adversely impact upon the status of aquatic ecosystems, and that historical modifications that are already impacting it need to be addressed.

2.3.42 The Long and Round Ponds are in-line with what is marked on the Environment Agency's Main River Map, as the River Darent which flows east from the Goodley Stock Road. Main Rivers are usually larger rivers and streams that are important from a conveyance and flood risk perspective, and are shown on the Environment Agency's Main River Map. The Environment Agency carries out maintenance, improvement or construction work on Main Rivers to manage flood risk. Other rivers are called 'ordinary watercourses'. Lead local flood authorities (and, where appropriate, internal drainage boards) carry out flood risk management work on ordinary watercourses.

2.3.43 Contrary to the Main River Map; mapping by the Ordnance Survey and the Environment Agency's Catchment Data Explorer (Environment Agency, 2019) indicates that the River Darent flows from the south to then turn east at Mill Lane directly downstream of the Round Pond. **Therefore, according to this mapping, the Long and Round Ponds are in line with the Cross Dyke**. However, regardless, the Long and Round Ponds are either directly upstream of, or in-line with the River Darent and therefore any effects on the Long and Round Ponds have the potential to affect the water body itself.

2.3.44 The River Darent is known as the Upper Darent from Crockhamhill Common, where it flows south, then east through Westerham. It then meanders east to pass north of Sevenoaks to cross the M25 west of Willowbrook where it becomes the Middle and Lower Darent. The WFD classification information for the Upper Darent, which is not designated artificial or heavily modified, is summarised **in Table 2-1** below.

2.3.45 According to the Environment Agency's Catchment Data Explorer there are several reasons why the overall waterbody classification in 2016 was 'Poor'. These include groundwater abstraction by the water industry which impacted upon macrophytes and phytobenthos and physical modifications which have created barriers to fish migration and have caused ecological discontinuity. In addition, **poor soil management and grazing livestock within the catchment** have caused a deterioration in water quality through diffuse pollution. The flow has also been impacted by groundwater abstraction.

Table 2-1 WFD Cycle 2 Classifications for the Upper Darent surface water body (GB106040024221)

Classification Item	2013	2014	2015	2016
Overall water body	Moderate	Moderate	Poor	Poor
Ecological	Moderate	Moderate	Poor	Poor
Biological quality elements	Moderate	Moderate	Poor	Poor
Macrophytes and phytobenthos combined	-	Moderate	Poor	Poor
Fish	Moderate	Moderate	Moderate	Moderate
Invertebrates	-	High	High	High
Hydromorphological Supporting Elements	Supports good	Supports good	Supports good	Supports good
Hydrological Regime	Does not support good	Does not support good	Does not support good	Does not support good
Morphology	Supports good	Supports good	Supports good	Supports good
Physico-chemical quality elements	-	-	Good	Good
Ammonia (phys-chem)	-	-	High	High
Dissolved oxygen	-	-	High	High
pH	-	-	High	High
Phosphate	-	-	Good	Good
Temperature	-	-	High	High
Specific pollutants	Moderate	Moderate	High	High
Triclosan	High	High	-	-
Manganese	-	-	-	High
Copper	Moderate	Moderate	High	High
Iron	-	-	-	High
Zinc	High	High	High	High
Chemical	Good	Good	Good	Good
Priority substances	Good	Good	Good	Good
Lead and its compounds	Good	Good	Good	Good
Nickel and its compounds	Good	Good	Good	Good
Priority hazardous substances	Good	Good	Good	Good

Classification Item	2013	2014	2015	2016
Cadmium and its compounds	Good	Good	Good	Good
Di(2-ethylhexyl)phthalate (priority hazardous	Good	Good	-	-
Nonylphenol	Good	Good	-	-
Tributyltin compounds	Good	Good	-	-

2.4 Historical and Current Management

Darent Catchment

2.4.1 Historical management of the River Darent as a whole has led to the over widening and deepening of the channel and the loss of chalk stream characteristics (Environment Agency, 2014). In particular its use to power water mills required the flow to be diverted down artificial channels leaving low flows in the natural channel.

2.4.2 In addition, structures such as weirs and sluices have been introduced which inhibit fish passage. Low energy conditions caused by low flows and impoundment have **encouraged sedimentation on the bed of the channel**, causing concretion of the gravels and reducing spawning opportunities for fish. In the past decade, there has been increasing recognition that NFM may provide more cost-effective management techniques.

Long and Round Ponds

2.4.3 According to the report Flooding and Siltation on the Upper Darent at Westerham (Merrylees, 2019), major flood events in the 1960s led to culverts being installed below Vicarage Hill (A25). In the 1980s, following further flood events, a weir was replaced at Mill Lane to handle waters from the Round Pond and the Long Pond, and the Round Pond was desilted.

2.4.4 The Long Pond was desilted in 2000 as part of the town of Westerham's Millennium project, but then required further desilting in 2005 as the ponds silted up more quickly than anticipated. This is despite discussions being held with the owners of Moorhouse Sandpits which led to the clearance of an old settling lagoon. This helped to reduce the amount of sediment escaping from the operation of the sandpits. **However, siltation still occurred again resulting in the need for a more long term sustainable solution**.

2.4.5 In 2004, the Environment Agency created a spillway with a flood relief channel in the fields immediately to the south of the Long Pond due to flood events upstream (see **Figure 2.5**). There were then further flood events in the winter of 2013/2014 which led Kent County Council (KCC) to commission a study from the South East Rivers Trust: Assessing the potential application of NFM techniques in the Upper River Darent Catchment, Kent (South East Rivers Trust) due to the clear need for better strategies for managing flood risk. This report identifies Westerham as a potential location for NFM measures which could be incorporated into, and work in tandem with, the restoration of the Long and Round Ponds. **Suggested measures include offline attenuation ponds upstream of the existing online ponds which would help to trap and hold silt and in turn reduce the potential for sediment accumulation to occur in the Long and Round Ponds**.

3 Site Visit and Sediment Analysis

3.1 Introduction

3.1.1 A site visit was carried out on the 7th October 2019 to hold a start-up project meeting and also to carry out a site walkover and sediment sampling. The potential constraints and opportunities associated with possible management solutions were considered; in particular the removal and disposal of pond sediments, existing structures, flood management schemes and the hydrological connections between the ponds, river and floodplain.

3.2 Methodology

3.2.1 The walkover included the following key tasks:

- Survey of stream habitats both upstream and downstream of the ponds to assess the likely impacts of any proposed restoration solution on the River Darent.
- Identification of the main sources of silt entering the ponds.

3.2.2 Three sediment (silt) samples were collected from each of the ponds at locations around the perimeter of the pond shown on **Figure 3.1** for laboratory analysis for a range of determinands (listed in full in **Appendix I and II**) including:

- Physico-chemical properties such as pH, nitrite soluble as nitrogen, and exchangeable ammonia as nitrogen;
- Heavy metals such as cadmium, chromium, arsenic, zinc, mercury, lead, phosphorous and copper;
- Polycyclic aromatic hydrocarbons such as phenanthrene, anthracene and pyrene (among others); and
- Contaminants associated with pesticide and fungicide use such as 2,4,5-Trichlorophenol (2,4,5-T), Bentazone, and diclofop.

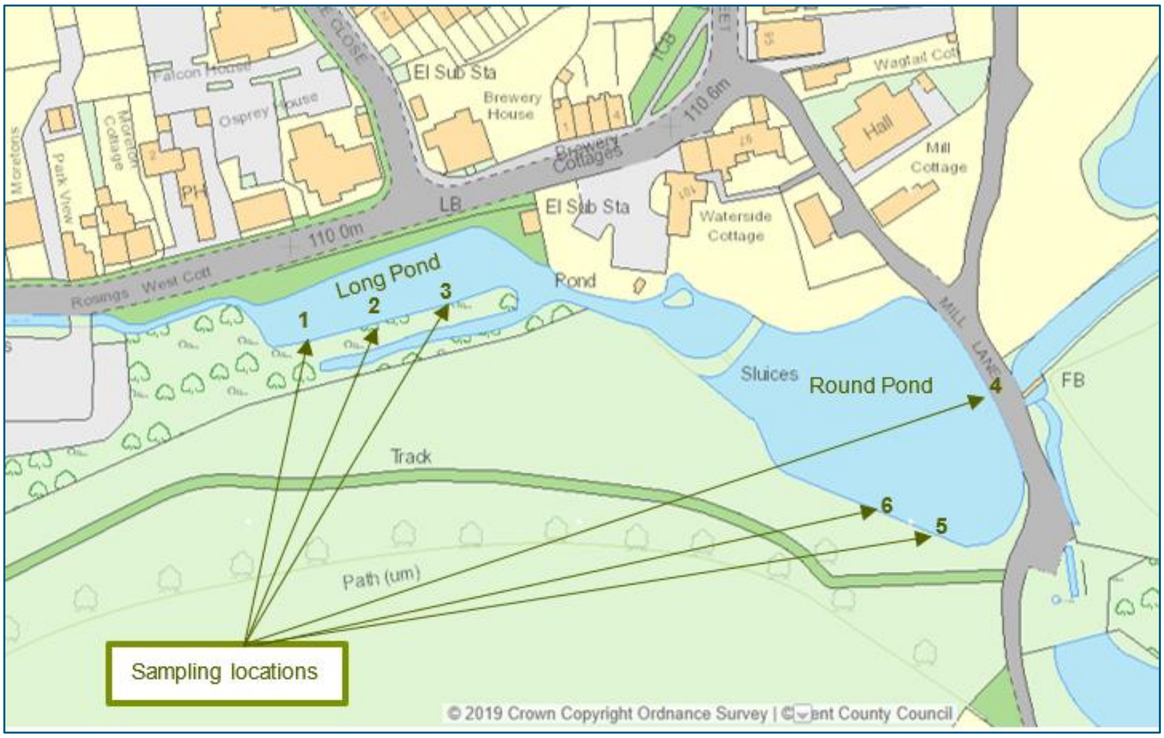

Figure 3.1 Sediment sampling locations 1 to 6

3.2.3 These samples were taken by wading safely into the ponds to knee height and collecting sediments to place into collection jars and boxes provided by ALS Laboratories (https://www.als-testing.co.uk/). Rubber gloves were worn whilst collecting samples to avoid contamination of the samples.

3.2.4 The collected sediment samples were sent to ALS Laboratories for analysis, the result of which was then evaluated for the options of re-use (within the site area) or disposal (off-site) based on relevant guidance, including CL:AIRE Definition of Waste Industry Code of Practice and Environment Agency Technical Guidance WM2 - Interpretation of the definition and classification of hazardous waste (3rd Edition, August 2013).

3.2.5 The results of the laboratory analysis have been screened against **Generic Assessment Criteria (GAC) for a public open space (Park) end use and soil organic matter content (SOM) of 1%** to determine if the sediment could represent a potential unacceptable risk to current and future site users. This criteria is used as there are no suitable sediment quality guidelines in the UK, and the potential end uses of the sediment for deposition make the public open space (Park) GAC the most suitable alternative. It should be noted the assessment is based on long term risks and has been undertaken on samples recovered from the area of the specified proposed works only.

3.2.6 The GAC utilised in the assessment were collated from the LQM/CIEH S4ULs (2015) and EIC/AGS/CL:AIRE GACs (2010) Soil Generic Assessment Criteria for Human Health Risk Assessment (CL:AIRE, 2010). Where appropriate, reference has also been made to the provisional Category 4 Screening Levels (pC4SL) published by Defra in 2014. Where no published criterion has been identified, assessment criteria have been derived by Royal HaskoningDHV using the deterministic CLEA v1.06 model, or, in the case of lead, using the US Environmental Protection Agency IEUBK and Adult Lead models. The assessment is considered to represent a conservative approach.

3.2.7 This method of silt analysis allowed the DVLPS immediate access to the results and enabled the project team to highlight any constraints on the selection of the proposed restoration solutions for the ponds straightaway.

3.3 Results

3.3.1 The results and assessment are presented in **Appendix I and II** and summarised below:

- The majority of the determinands were recorded at concentrations exceeding the laboratory limit of detection (LOD).
- Those that did exceed the LOD were mainly metals and include arsenic, boron, copper, iron, lead, nickel, phosphorous, tin, zinc, magnesium and potassium.
- Polycyclic Aromatic Hydrocarbons (PAHs) were also recorded at concentrations exceeding the LOD.
- No determinands were recorded at concentrations exceeding the GAC for a public open space end use.

3.3.2 Although majority of the determinands were recorded at concentrations exceeding the laboratory limit of detection, no samples exceeded the GAC for a public open space end use and SOM content of 1% (please **Appendix I** for results). **Based on the results it is not anticipated that the sediment at the site would represent an unacceptable risk to current or future users**.

3.3.3 If the dredged sediments are to be placed next to the pond, the Environment Agency's D1 waste exemption should apply. The exemption allows 50 cubic metres of dredged material to be deposited for each metre length of land, on the condition that the material is placed next to the water it was dredged from (the dredging must be removed from the waterway and deposited mechanically in one operation). If other options of disposal are considered, such as storage of sediments on nearby fields, a waste permit might apply.

4 Pond Restoration Options

4.1 Introduction

4.1.1 This section of the report discusses the potential options available for pond restoration which are applicable to the Long and Round Ponds and the specific issues that occur for this project, including options that could be integrated into the wider management of the Upper Darent catchment. NFM opportunities are also discussed in more detail to provide context to the restoration options.

4.2 Natural Flood Management

4.2.1 NFM focusses on using softer techniques which alter, restore or use landscape features and natural processes to reduce flood risk. This is in contrast to previously favoured 'hard-engineering' options which are increasingly unsustainable, require expensive ongoing maintenance and are not conducive to a biodiverse ecosystem.

4.2.2 The principal on which NFM operates is the slowing down of water which passes through the catchment. This then spreads the peak flow rate more evenly over a greater time period, reducing the maximum flood water height. NFM techniques are designed to work by one or a combination of the following mechanisms (Parliamentary Office of Science and Technology (POST), 2011):

- Storing water in the catchment, either in existing or newly created catchment features;
- Increasing soil infiltration;
- Slowing the transit of water through the catchment by increasing resistance to flow or increasing channel length; or
- Reducing flow connectivity.

4.2.3 The slowing down of water reduces the amount of sediment it can hold and certain NFM measures can cause more sediment to be deposited on the floodplain and limit sediment ingress into watercourses. In this way, the restoration of the Long and Round Ponds can be integrated into NFM measures within the Upper Darent catchment, by using techniques that slow the flow of water into the Upper Darent and encourage sediment deposition upstream.

4.3 NFM Measures

4.3.1 A brief summary of NFM techniques is provided in **Table 4-1** and **Figure 4.1** below.

Table 4-1 Summary of NFM Measures. Information from Environment Agency (2017)

NFM Technique	Summary	How it works
River Restoration	Involves techniques such as reintroducing meanders to rivers and restoring physical processes.	Making a river more sinuous can reduce water velocities and attenuate flow by slowing and storing floodwaters thereby reducing flood peaks.
Floodplain Restoration	Restoring hydrological connectivity between the river and its floodplain encouraging more regular inundation and flood water storage.	Decreases the magnitude of the flood peak and reduces downstream depths.
Leaky Barriers	Usually formed of wood and can either occur naturally or are installed across watercourses and floodplains.	Intercept the flow of water in a river and help to restore river-floodplain connectivity therefore reducing flood peaks, slow water velocities and store water on the floodplain.
Offline Storage Areas	Areas of floodplain (adapted with a containment bund, inlet, outlet and spillway) to store and then release flood waters in a controlled manner.	Provide temporary flood storage which can reduce peak flow. However, limited evidence of performance in extreme flood events.
Catchment Woodland	Catchment woodland can intercept, slow, store and filter water	Woodland can help to reduce flood peaks and flood flows from 3 to 70% and also flood frequency.
Cross-slope Woodland	Woodland that is planted across a hill slope in a catchment.	Intercepts the flow of water as it runs down the hill reducing rapid runoff and encouraging infiltration and storage of water in the soil. Absence of measured data at the catchment level, however is known to provide ecosystem services.
Floodplain Woodland	Woodland planted on the floodplain.	Can slow floodwaters and increase water depth on the floodplain reducing flood peaks and delaying the peak timing. This can desynchronise flood peak and reduce peak height.
Riparian Woodland	Woodland planted on land immediately adjoining a watercourse.	Can slow flood flows and help to reduce sediment delivery to the watercourse and reduce bankside erosion.
Soil and Land Management	Sustainable measures of management such as	These work by reducing peak flow and slowing and storing surface water runoff

NFM Technique	Summary	How it works
	conservation tillage, early sowing of winter crops and cover crops, stoking density, vegetation cover, hedges and buffer strips.	and encouraging infiltration. They can also reduce sediment runoff, reducing siltation and diffuse pollution.
Headwater Management	Headwater drainage management can involve managing flow paths in the field, from tracks, paths and roads.	These normally operate best as a cluster of management techniques which work to delay and intercept flow and reduce peak flow locally. Caution is required when using in-channel barriers that they do not dislodge and cause blockages further downstream.
Runoff Management	Runoff pathway management can include the introduction of ponds, swales and sediment traps which normally operate best as a cluster of features.	These measures intercept, slow and filter surface water runoff to reduce peak flow locally. They can also retain sediment and pollutants and can play an important part in the carbon cycle.

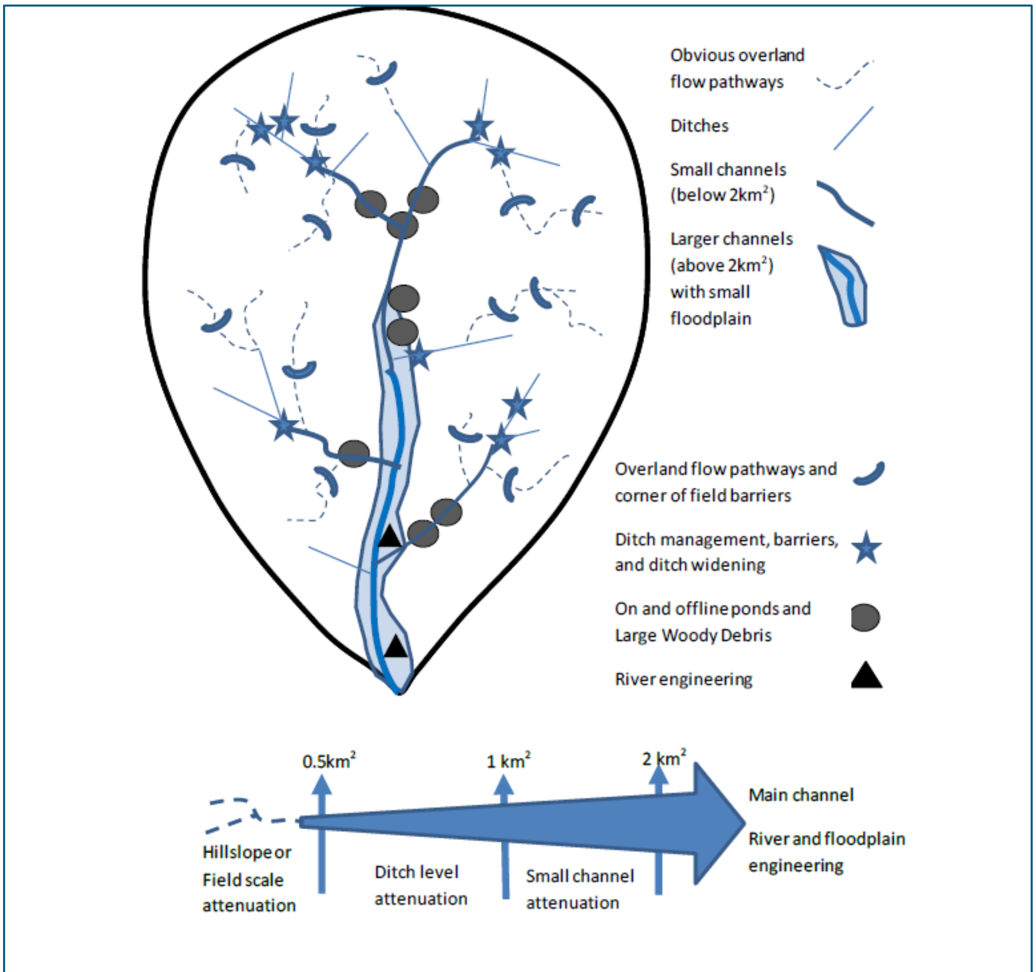

Figure 4.1 NFM at the Catchment Scale

Source: Quinn et al. (2013)

4.3.2 However, despite the growing interest in NFM techniques, there is a lack of long term monitoring data available; especially over several flooding events. Therefore, the application of these measures requires careful consideration. **It is likely, however, that there are significant positive impacts of implementing NFM to reduce runoff and slowing flood flows**.

4.4 Restoration Options

Option 1: Do nothing

4.4.1 If no work is carried out on the Long and Round Ponds, it is likely that the process of siltation will continue as it has in the past, as discussed above, and the Long and Round Ponds will become infilled with silt over the medium to long term. The river is likely to maintain a channel through the ponds, however.

Impacts

4.4.2 As this option requires no invasive works, such as groundworks or excavation, there is minimal direct environmental impact. However, an indirect impact will be the alteration of the habitat over time from the existing habitat of the ponds, to a wetland, and then a river channel. However, the river would be returning to a more natural state, and this could be considered a beneficial impact and considered favourable from a WFD perspective.

Option 2: Sediment removal (dredging) of the Long and Round Ponds

4.4.3 Sediment removal involves the partial or complete removal of unconsolidated sediment from the bed of a lake or pond, most commonly by dredging. Techniques used for dredging originate from those used for harbours and ports which have been scaled back for use in lakes and reservoirs; however, the Long and Round Ponds are small in size. **Dredging can accomplish several goals: removal of toxic sediments, increase water depths, reduce sediment re-suspension, nutrient removal, and contour alteration for habitat improvements**. Therefore, taking this into account, a high-level assessment of different dredging techniques has been carried out below, with particular reference to potentially wet or dry dredging of the Long and Round Ponds.

Wet dredging

4.4.4 Mechanical dredgers: These use grab buckets that are clam-like in design. The bucket is lowered into the sediment and closed, then extracted and deposited elsewhere. These dredgers can be operated from the edge of the pond/lake and in confined areas and have been used in previous desilting operations at the Long Pond; as such, a similar approach would be adopted for this phase of the project. However, this dredging technique can lead to high levels of turbidity and can experience inefficiencies in the dropping, lifting, uneven lake/pond bed contour; and unloading process.

4.4.5 Hydraulic dredgers: These are usually made up of a cutterhead, which is the piece of equipment that carries out the excavation by loosening the sediment, with a hydraulic suction pipe through which the sediments are pumped (**Figure 4.2**). The sediments are then pumped through the suction pipe and disposed on the lakeside or into barges. Pneumatic dredgers use a similar technique, but use hydrostatic pressure to force the sediment into the suction head.

4.4.6 Other types of wet dredging equipment and techniques commonly used for the removal of sediments in lakes/ponds or restoration which could be adopted for this project include:

- Dragline dredgers: Track-mounted crawler cranes that remove sediments through dragging a bucket across the lake bed.
- Suction dredging: A floating platform with an engine that powers a suction pump (**Figure 4.2**). Removed sediments which have been vacuumed, pass along tubes or pipes directly leading to an adjacent disposal site, often a field of low ecological quality or geotextile bags.

Dry dredging

4.4.7 Alternative techniques to wet dredging for removing sediment from the Long and Round Ponds is dry bed excavation, which involves the complete or partial; draw-down of a lake prior to removal of the sediment (also known as dry dredging) through the use of land based plant such as bulldozers or long arm excavators (**Figure 4.2**). This technique typically involves diverting water or draining sections of lake. Sheet piling or cofferdams are commonly used to contain the area and temporarily reroute the water's flow. Surface water is then pumped from the area and ground water flow can be controlled. In some areas, such as wetlands or small lakes, it is possible to excavate "in the dry" without redirecting water. Waterbodies can also naturally be drier during summer months.

4.4.8 The main advantages of dry dredging are that it allows precise control to be achieved for a particular lake/pond profile which achieves both the desired restoration vision and minimises excess sediment removal and capital costs.

Deposition of sediment

4.4.9 Dredged sediment must be disposed of in a way which does not risk it re-entering the watercourse from which it has been removed. In addition, the condition and composition of the sediment must be taken into consideration when determining a suitable location for deposition in order to avoid impacts associated with excess nutrient load or contaminants which may be present within the sediment. The results of the sediment analysis in **Section 3** will inform the suitability of these options, further expanded upon in **Section 6**.

Figure 4.2 Key Wet and Dry dredging techniques applicable for the Long and Round Ponds

4.4.10 Proposed disposal can be carried out for the removal of sediment from the Long and Round Ponds by:

- Collecting the removed sediment from the ponds in geotextile bags, which allow the water to soak away (dewater), and then spreading the dried sediment in a suitable location, such as the field south of the ponds associated with Squerryes Estate or landscaping within the site area of the ponds. However, this method is reliant on the sediment being suitable for use in an agricultural setting (see **Section 6**).
- A common method is to create sediment lagoons within a raised bund in a nearby flat location and to run the sediment slurry through a pipe. The water drains away, and the sediment is able to settle out. The design of the drainage pattern within the lagoon system will minimise the length of the path taken by the water and hence, maximise the retention of suspended solids; or
- If the sediment is contaminated, it must be treated as contaminated waste, and therefore disposed of appropriately.

4.4.11 **Figure 4.3**, illustrates the concept of dry dredging the Long and Round Ponds, based on the potential removal of sediment and storage in an adjacent field, further detailed in **Section 6** of this report.

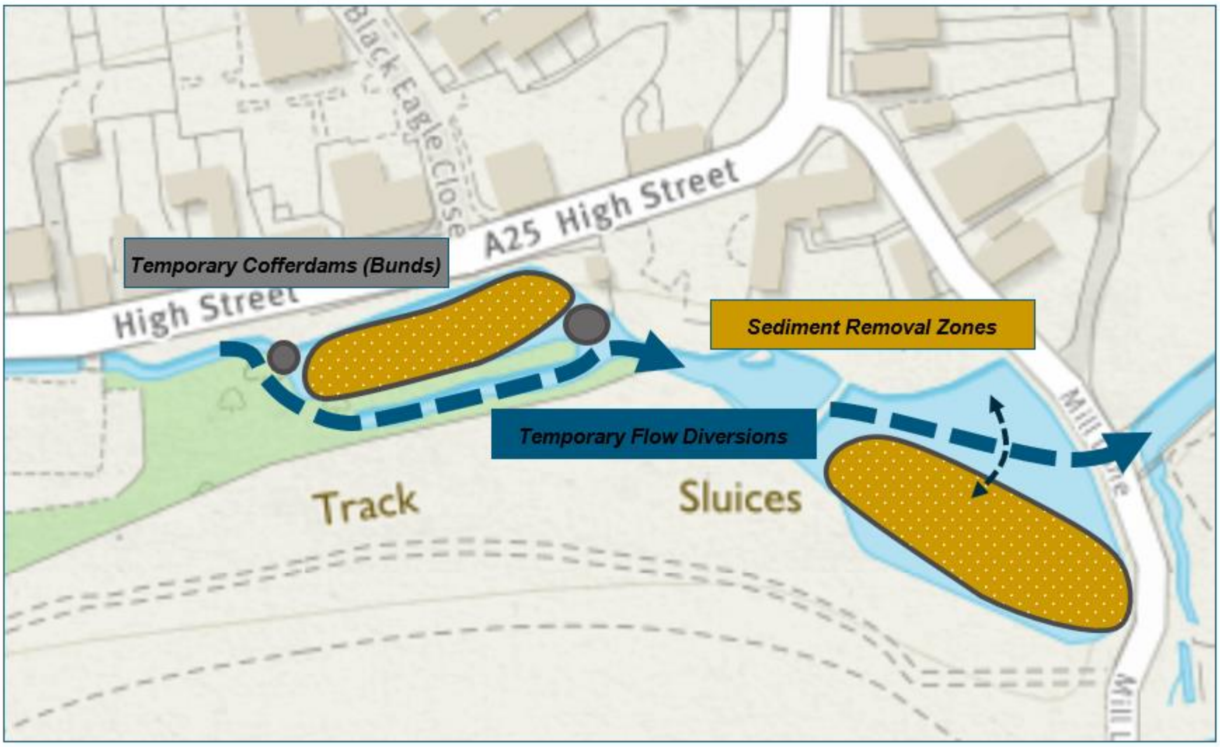

Figure 4.3 Dry Dredging of the Long and Round Ponds

Restoration post-dredging

4.4.12 Following the dredging process, the Long and Round Ponds would be restored through a process of landscaping and planting of riparian vegetation; perhaps in consultation with a suitably qualified ecologist. This would aim to minimise erosion and maximise sediment retention in the banks of the ponds using native species and local species.

Impacts

4.4.13 Dredging through either wet or dry techniques, would be invasive to the Long and Round Ponds themselves, and may cause impacts upon the bank habitat due to operation of machinery, which could lead to loss of habitat within the ponds and consequent displacement of species. In addition, there is potential for contamination and increased sediment mobilisation to occur during construction works, either through the use of machinery or by release of contaminants already contained within the sediment. This could potentially affect the River Darent downstream of the ponds.

4.4.14 The potential impacts above are predicted to be only short-term until the dredging operations have been completed; and can be minimised through best practise mitigation, including the implementation of an Environmental Action Plan (EAP).

4.4.15 The overall dredging works have the potential to accomplish several goals for the ponds, including the removal of toxic/organic sediments, increase water depths, reduce sediment re-suspension, nutrient removal, and contour alteration for habitat improvements, for example new microhabitats through re-profiling. In the short term it may solve the issue of sedimentation in the ponds; in the long term, however, the source of sediment and the conditions for its deposition will remain the same and the process will begin again with the associated concerns from local residents and potential requirement for a repeat of the dredging in the near future.

4.4.16 This option would require consideration of WFD compliance, protected species, and may require a fish rescue prior to works beginning. **However, this option could provide considerable habitat and ecological improvements to the Long and Round Ponds**.

Option 3: Take the Long Pond offline

4.4.17 The River Darent could be diverted down the pre-existing flood relief channel directly south of the Long Pond (see **Figure 4.4**, purple dash line) which would take the Long Pond offline and isolate it from the source of the sediment. This could be achieved by constructing an earth embankment (bund) across the western inlet to the Long Pond, excavating between the drainage channel and the pond to allow the river to bypass the pond, and carrying out some clearance works within the drainage channel itself. The river channel would then be reconnected upstream of the Round Pond (purple dash line, **Figure 4.4**) and the Long Pond would be taken completely offline. Alternatively, a flow control structure could be installed which would allow some water to enter the ponds if groundwater and rainfall is insufficient to replenish them.

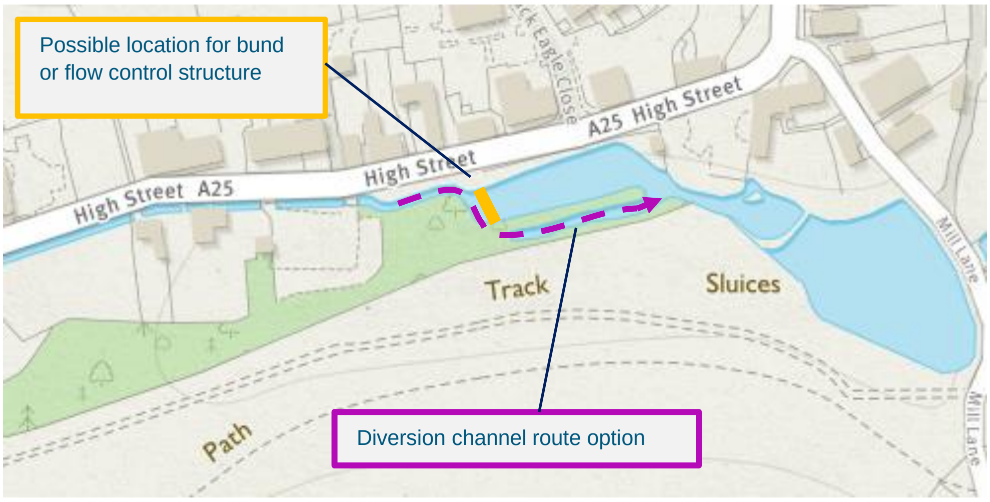

Figure 4.4 Diversion channel route options for making Long Pond offline *Source: https://osmaps.ordnancesurvey.co.uk*

Impacts

4.4.18 In the short term, the construction of an earth embankment or flow control structure and diversion of the channel at the entrance to the Long Pond will require significant groundworks in close proximity to, and within, the river channel. This could create a temporary influx of sediment with the potential to smother aquatic flora and fauna, with the additional potential for pollutants related to construction machinery to enter the water. However, these potential impacts are predicted to be only short-term, local, and minimised through best practise mitigation, including the implementation of an Environmental Action Plan (EAP) and good practice measures for undertaking construction near water.

4.4.19 In the long term, if the pond is taken completely offline using an earth bund, although this option is low maintenance and therefore non-invasive once operational, the pond habitat would alter as it would be isolated and no longer receiving an influx of water. This may mean that the pond becomes more seasonal and dries up in the summer with a resultant change in vegetation. As the nature of the pond would be changing with this option, it may no longer fulfil its cultural heritage and community value, particularly if it were to dry up in the summer. In addition, it would no longer provide any floodwater attenuation value that it currently has; although this could be supplemented by NFM measures, such as those detailed in **Table 4.1**.

4.4.20 If a flow control structure is implemented, it would allow the Long Pond to retain its current habitat but may require a greater operational maintenance requirement to operate the flow control structure. In addition, this option may require an impoundment license from the Environment Agency.

4.4.21 It is also likely that taking the Long Pond offline will cause siltation to occur in the Round Pond as it will then become the first point where the river channel widens and flow slows, as the Long Pond currently is, therefore causing sediment and silt to be deposited here instead. This may therefore still require ongoing desilting, unless catchment scale sediment management is implemented.

4.4.22 Further consideration of this option would require a WFD Compliance Assessment as part of a Flood Risk Activity Permit (FRAP) as works are taking place within an Environment Agency Main River; protected species; and fish rescue considerations. **However, this option will provide considerable habitat and ecological improvements to the Long and Round Ponds**.

Option 4: Install a sediment trap upstream

4.4.23 Sediment traps can take many forms (Scottish Environmental Protection Agency (SEPA), 2015) but normally comprise an excavation on a surface water runoff pathway. Water enters the excavation, is retained there allowing sediment to settle out before it is discharged; controlling its release to the river network. They are one of a suite of measures known as rural sustainable drainage systems (rural SuDS).

4.4.24 They are best targeted to overland flow pathways of small catchments allowing them to make a meaningful reduction in sediment. The larger the surface area of the feature, the greater its sediment removal potential. They can be created by excavating an area and installing an outlet pipe or overspill outlet or creating an earth bund and are particularly useful in sloping areas where runoff will exit a field at a particular point in a valley bottom. The can also be an area of widened channel with a wide, low weir across it. Maintenance will include periodic removal of accumulated sediment and occasional cutback of vegetation on the bunds, or within the trap itself.

4.4.25 However, in order to impact on the sediment load reaching the Long and Round Ponds, it may be necessary to install more than one sediment trap, with the required land-take to accommodate this, to ensure sufficient sediment is trapped to impact on the siltation rate of the ponds. This will require a greater maintenance commitment.

4.4.26 A sediment trap could also comprise the construction of a ditch within the river channel itself where it enters the Long Pond. However, this is likely to only intercept the larger, heavier material such as coarse sand and gravel leaving the silt in suspension to settle within the ponds. It would also require regular maintenance and, due to the location and setting of the ponds with the A25 on its northern edge and mature trees and residential properties surrounding it, this would be difficult to carry out.

Impacts

4.4.27 This option requires minor earthworks which may, in the short term, be destructive to the river habitat, especially if the sediment trap is placed at the entrance to the Long Pond. Although these potential impacts are predicted to be only short-term; local, and minimised through best practise mitigation, including the implementation of an EAP. However, once constructed this may create the potential for new habitat creation upstream. A reduction in sediment inputs to the Cross Dyke will help to reduce the sediment load entering the Long and Round Ponds.

4.4.28 Ongoing maintenance may require additional permitting; although would contribute to improving GES for the River Darent.

Option 5: Create runoff attenuation features

4.4.29 Runoff attenuation features (RAF) incorporate two of the measures outlined in **Table 4-1**: creation of offline storage areas; and runoff management. The report produced by SERT, (2015) discussing NFM measures for the Upper Darent catchment, considers that this is a suitable option, particularly for Westerham upstream of the Long Pond to reduce flood risk and considers this in some detail.

4.4.30 To the west of the Goodley Stock Road, where the watercourse is known as the Cross Dyke, it is clear from historical mapping that it has been artificially modified. The map shown in **Figure 4.5** shows the Cross Dyke where it makes a 'dog-leg' shape opposite Springfield, but also shows an alternative swale which the river was known to take through the field directly to the west of Springfield south of the A25. The SERT's report also notes that the river channel is now at an elevated level to the south and not in the valley bottom where it would naturally flow. According to local residents, and as evidenced by photos in the report by Merrylees (2019), the flow returned to this swale during the flood event of June 2016.

Figure 4.5 Historical mapping from between 1871 and 1890 showing the 'dog-leg' in the Cross Dyke and swale through the middle of the field to the west of the Goodley Stock Road. Source: Kent County Council, Available online: https://webapps.kent.gov.uk/KCC.KLIS.Web.Sites.Public/ViewMap.aspx [Accessed 1511/2019]

Offline ponds

4.4.31 Therefore, both the SERT report and Merrylees (2019) consider that a series of offline ponds (in which three are proposed), could be created at points along this swale using soil bunds, working with its natural tendency to flood between the A25 and the river channel. During high flows, flow deflectors or spill points would guide waters, via the most tortuous route possible, into the low area where water would accumulate behind the first soil bund, then the second and third. Water is released slowly back into the watercourse via an outlet point once the flood peak has passed. This has been proven in Welton and Quinn (2011) to remove sediment from the flow.

4.4.32 As well as providing flood water retention benefits, as described in the SERT report (2015), these ponds are likely to capture sediments which are principally carried by flows during and after rainfall events. According to rough calculations as mentioned in Merrylees (2019), an area of around 150m^2 would be required with a minimum depth of 1 m to trap the size of sand and silt particles required and the potential maximum storage capacity of the three offline ponds in the locations proposed by the SERT report (2015) of approximately 2,906m^3.

4.4.33 Therefore, these ponds have the potential to reduce downstream sediment transfer and slow the rate of accumulation in the Long and Round Ponds. Once sediment has accumulated within the ponds, it could then be spread across pastureland in adjacent fields, subject to waste regulations and appropriate permitting. In addition, the westerly roadside bank of the Goodley Stock Road could be raised to help prevent water from reaching the road where it becomes a further flood hazard, and also provide additional sediment accumulation capacity.

Small wetlands

4.4.34 A key natural technique in the removal of excessive sediments directly entering a lake or pond, which can be considered as a type of runoff attenuation feature include the establishment of small wetlands (< 350m^2) which are predominately unlined ponds constructed along run-off pathways. These wetlands, often constructed from common reed (*Phragmites australis*), slow the connection between the sediment source and the water bodies and provide more opportunity for sediment and nutrients to settle out or be taken up by aquatic organisms before the water source enters a particular water body (Royal Haskoning, 2003).

4.4.35 The creation of these could be carried out in similar locations as identified for the offline ponds, by diverting the Cross Dyke and allowing it to create a wetland habitat west of the Goodley Stock Road. However, this would be a permanent, rather than transient, feature and may therefore be less favourable to the landowner. In addition, as this is located in the upper reaches of the catchment it may not be a suitable location for wetland habitat.

Impacts

4.4.36 An important consideration is the impact to fish in creating an offline pond. If flow is diverted artificially during times of high flow, there must be a route created to allow aquatic fauna to re-enter the river so that they don’t remain trapped in the pond (Welton and Quinn, 2011).

4.4.37 Maintenance will involve the emptying of the ponds of sediment and represents a long term commitment to maintenance which may not be desirable. However, benefits can be seen in the potential for creation of new habitat in both methods as the level of flow in and out of the ponds can be controlled or altered. Landowners may see benefit from sediment being captured that would otherwise be washed off the field.

Option 6: Other potential NFM measures

4.4.38 Other NFM measures (**Table 4-1**) which may be applicable include river restoration techniques such as reintroducing meanders into the Cross Dyke upstream of the Goodley Stock Road, planting of riparian woodland in order to encourage sediment retention upstream and the installation of leaky barriers. Leaky barriers could potentially be used in the creation of attenuation ponds in combination with **Option 5** and would significantly slow the water velocity and may act to trap sediment as well.

4.4.39 A more catchment wide approach in the effective removal of excessive nutrients, sediments or pollutants is the establishment of upstream buffer strips. A buffer strip is an area of land adjacent to a watercourse that is left un-cropped in order to intercept surface drainage and to minimise soil erosion.

4.4.40 Buffer strips can effectively reduce the amount of sediment and pollutants carried by run-off to water bodies including lakes/ponds by slowing down overland surface flows, disconnecting surface flow pathways and encouraging sediment to settle out. Buffer strips can be comprised of a mixture of natural plants, including grasses, shrubs and trees, and therefore can also provide valuable habitats for invertebrates, mammals and birds (Royal Haskoning, 2003).

Impacts

4.4.41 These measures are more holistic in approach and can largely be built from local materials. They may also provide damp areas for wildlife, if appropriate. However, they do require input when in use to release the water via an outlet pipe or sluice gate and must be emptied to ensure they can continue to fill during rainfall events.

Management of catchment sediment supply

4.4.42 In order to tackle the root cause of the sedimentation in the Long Pond, wider-ranging sediment management techniques should be considered across the Squerryes sub-catchment alongside all the options listed above to reduce the sediment load of the Cross Dyke and River Darent. This will help to reduce the amount of silt and sediment reaching the Long Pond and therefore help to reduce accumulation rates. Sources of sediment identified within the catchment and potential management options are listed in **Table 4-2** below. Some sediment management measures, particularly with regard to agricultural land, is best practice. However, there is a need to work with landowners in helping them to reduce sediment supply, retain nutrients and protect soil. Resources exist including the Sediment Matters Handbook (Environment Agency, 2011) and Safeguarding our Soils (Defra, 2009) in order to help landowners to carry out sediment management.

Table 4-2 Sources of sediment and potential management measures

Source of sediment	Potential management option
Moorhouse Sand Pits	Ensure the continued management of the settling lagoon that is already in existence just north of the Grasshopper Pub. This could be done under agreement with the Moorhouse Sand Pits who would be responsible for the management.
Road drainage from A25	Drainage interceptors and/or combined with SUDs, which has been successfully implemented for Stover Lake in Devon. https://www.devon.gov.uk/stovercountrypark/sustainable-drainage-system/construction
Agricultural land; particularly arable which has unvegetated soil, or gateways and tracks that experience high rates of erosion. Slopes are a significant factor with a greater risk of soil erosion associated with a steeper downward slope.	Planting of trees and hedgerows in collaboration with local farmers at sites of high output from arable fields could be considered to intercept silt. This could be combined with sediment traps, which use soil bunds or the excavation of a small area with a pipe or overspill installed, to intercept sediment. Bunds are particularly useful in sloping fields.

Figure 4.6 Example Road Drainage Interceptors and SUDs – Stover Lake, Devon

5 Options Appraisal and Capital Costs

5.1 Introduction

5.1.1 This section of the report aims to carry out an appraisal of the options discussed in **Section 4** and determine their feasibility and suitability for application at the Long and Round Ponds as well as providing a high level estimated capital cost and brief environmental assessment. Key considerations discussed in the start-up meeting are as follows:

- Restoration should aim to maintain the Long and Round Ponds as ponds, and not allow them to silt up further, or to simply become river channel.
- The chosen option should ideally integrate into catchment-wide NFM measures and help to reduce the risk of flooding in Westerham.
- Future management of the ponds should be low-maintenance to avoid the need to further expenditure of time and money.
- The restoration and management should be as low cost as possible whilst still being effective.
- Community engagement/use should be enhanced where possible.

5.2 Appraisal

5.2.1 An appraisal is provided of each option in **Table 5-1** taking into account the high level impact assessments provided in **Section 4.4**. Capital costs of the options are also included based upon costs estimates from similar projects undertaken by Royal HaskoningDHV. **These costs would need to be considered in greater detail when deciding which option to take forward.**

5.2.2 It is considered that catchment management measures to reduce sediment supply will need to be implemented in some form, whichever option is selected. Therefore, these are not included in the appraisal table below, but are assumed to be necessary and therefore not required to be assessed.

Table 5-1 Options appraisal

Option		Feasibility	Environmental Considerations	Technical Considerations	Potential Cost	Suitability
1	**Do nothing**	Very high as requires no design and construction.	• There would be no invasive works required with this option, and therefore no direct environmental impacts. • However, the pond habitats that currently exists would eventually disappear. • No direct long term ecological and/or community benefits.	The Long Pond would continue to experience sedimentation, likely becoming wetland and then eventually part of the river channel. This would not necessarily be a bad ecological change, just a change in habitat, although potential for ongoing maintenance.	**Short-term** Cost: No cost. **Long-term** cost: No cost	This option does not deliver the aims of the scheme in maintaining the Long Pond as a pond for its community and heritage value. **Therefore, this option has low suitability**.
2	**Sediment removal (dry or wet dredging)**	High feasibility, as has been proven to work due to dredging being carried out for the Long Pond previously. Most freshwater contractors undertake this type of sediment of removal, with dry dredging being preferred over wet dredging due to more precise habitat restoration profiling of lakes and ponds.	• Has the potential to contribute to improving the ecological status of the River Darent, Long and Round Ponds. • Potential to re-establish a greater diversity of submerged and floating aquatic plants through seeding of the pond bed prior to refilling. This may include the use of traditional plastic mesh baskets, fabric planting bags, pre-planted coir pallets or directly planting into the natural pond bed. • Potential to create micro-habitats in the lake bed through re-profiling (during sediment removal) to further	• Sediment removal via wet or dry dredging of the Long and Round Ponds would potentially require an on-going programme of works in order to contribute to restoring the ecological condition of the ponds i.e. not a self-sustaining option. • Option is reliant on disposal or re-use of dredged material which will need to comply with all relevant waste management regulations. • Will require a site/field to temporary store the material for dewatering (up to 8 weeks), prior to spreading the material if suitable.	**Short-term cost**: Medium to high costs for construction and design **(£80,000 - £120,000)** (not including moving of sediments off site (once dewatered) greater than 1.5 km, if required).	This option will provide considerable habitat and ecological improvements to the Long and Round Ponds, although should be used in combination with other suitable measures that limit sediment inputs to the River Darent. **Therefore, assigned overall medium suitability if used alone, and high if used in combination (e.g. Options 4, 5 & 6)**.

Option	Feasibility	Environmental Considerations	Technical Considerations	Potential Cost	Suitability
		promote aquatic diversity in the ponds. • Increased water depths and volume of water held within the ponds. • Potential to support local agricultural community through re-use of dredged material as organic fertiliser or landscaping material. • Option is reliant on disposal or re-use of dredged material which will need to comply with all relevant waste management regulations. • Temporary loss of pond habitat and displacement of wildlife. • Temporary minor disturbance during dredging (visual, noise, dust, and obstructions). Although these potential impacts are predicted to be only short-term; local, and minimised through best practise mitigation, including the implementation of an EAP. • The potential trapping of fish must be considered.	• Previous dredging has required extensive recovery work and time. • Potential for planning, depending on sediment disposal route (e.g. temporary or permeant change of land use); permits and consents.	**Long term costs**: dependent on use of sediment management/NFM measures, would be relatively low. However, if not in place, continued sediment removal would be required over the 10 year period. Estimated cost £50,000 over the 10 years not including moving of sediments off site (once dewatered) greater than 1.5 km, if required.	

Option		Feasibility	Environmental Considerations	Technical Considerations	Potential Cost	Suitability
3	**Take Long Pond offline**	High feasibility as will require modifications to divert the channel, although channels already in existence. Little extra land-take required and no long term maintenance commitments for the Long and Round Ponds.	• Has the potential to contribute to improving the ecological status of the River Darent and Round Ponds. • In the long term, although this option is low maintenance and therefore non-invasive; once operational, the pond habitat would alter as it would be isolated and no longer receiving an influx of water and sediment. This would not necessarily be a bad ecological change, just a change in habitat. • Potential dredging of the Round Pond would still be required (Option 2 incorporated). • Temporary minor disturbance (visual, noise, dust, and obstructions), in particular dredging can be quite messy. Although these potential impacts are predicted to be only short-term; local, and minimised through best practise mitigation, including the implementation of an EAP. • The potential trapping of fish must be considered.	• Potential knock-on effects of siltation in the Round Pond; and continued maintenance (as stated will required dredging, as taking the Long Pond offline does not totally assist in restoring the Round Pond). • Will cause long term change in the Long Pond habitat, may cause it to dry up at times, therefore not maintain/restoring the pond in its current state and connection with the local community and FOLP. • Not a self-sustaining option; and would should be used in combination with other suitable measures that limit sediment inputs to the River Darent. • Permits and consents for works, for example FRAP.	**Short-term costs**: design and construction medium costs - **£60,000 - £100,000** Does not include dredging of the Round Pond, or the Long Pond if required. **Long term costs**: ongoing potential dredging requirement in the Round Pond if sedimentation occurs downstream once Long Pond offline. £50,000 over the 10 years not including moving of sediments off site (once dewatered) greater than 1.5 km, if required.	**Low suitability,** as likely to not meet the local community aim of maintaining the pond, as historic pond habitat. Round Pond siltation moves the problem rather than offering a solution, with continued maintenance required for the Round Pond. Not a self-sustaining option; and would need to be used in combination with other suitable measures that limit sediment inputs to the River Darent.

Option		Feasibility	Environmental Considerations	Technical Considerations	Potential Cost	Suitability
4	**Install sediment trap(s)**	Medium feasibility, as selection of a suitable site requires further consideration and landowner permission. Long term maintenance requirements, although construction is straightforward.	• Has the potential to contribute to improving the ecological status of the River Darent and Round Ponds. • May create the potential for new habitat creation upstream and could benefit agricultural outputs in the long term by reducing run-off from fields and allowing nutrients to be retained in the soil system • Some ground works are required, but mostly in agricultural fields with little ecological value.	• Requires a commitment to maintenance (emptying, vegetation clearance and checking) of the sediment trap. • Potential need for landowner discussion and recompense. • Does not address the whole habitat restoration of the Long and Round Ponds, which would still require immediate restoration actions.	**Short term costs**: Medium costs for design and construction. **£40,000 - £80,000** for one trap dependent on type of trap. £10,000 approx. for design and remainder for construction. **Long term costs**: approximately £4,000 per year per trap (including permitting, management, waste management and maintenance work).	**Medium suitability**; offers a sustainable solution to preventing sediment reaching the Long and Round Pond. However, may need to be used in combination with other measures in a catchment-wide approach to be truly effective, along with direct restoration measures for the Long and Round Ponds.
5	**Create runoff attenuation features**	Low to Medium feasibility, as further modelling and consideration of location of the ponds needs to be undertaken as well as agreeing with landowners.	• Has the potential to contribute to improving the ecological status of the River Darent and Round Ponds. • Potential positive impact with creation of new habitat in the catchment.	• Requires permission from landowner to create ponds. • Long term maintenance. • Modelling needed to determine appropriate size. • Does not address the whole habitat restoration of the Long and Round Ponds, which would	**Short term costs**: Medium costs for design and construction. **£40,000 - £80,000** for one feature, dependent on location and size.	Provides a sustainable, ecologically friendly way of reducing sediment inputs into the Long Pond alongside potential benefits of habitat creation. Provides most likely way to maintain ponds as they currently are whilst reducing risk of future siltation. However, may

Option		Feasibility	Environmental Considerations	Technical Considerations	Potential Cost	Suitability
			• Groundworks required which may cause destruction of habitat. • The potential trapping of fish must be considered.	still require immediate restoration actions.	**Long term costs**: approximately £4,000 per year per feature (including permitting, management, waste management and maintenance work).	need to be used in combination with other measures in a catchment-wide approach to be truly effective, along with direct restoration measures for the Long and Round Ponds. **Therefore, assigned overall medium suitability if used alone; and high if used in combination (e.g. Option 2).**
6	**Other NFM measures**	Medium-High feasibility as reasonably low-input and using natural materials.	• Will improve riparian and catchment habitat with minimal intervention.	• Will need to be used in tandem with another method in order to be effective. • Requires land-take which will need landowner approval.	**Short term costs**: Low to medium costs for design and construction **£20,000 - £60,000 –** dependent on type of features chosen and requirement for planning/permitting etc. **Long term costs**: £500 - £1000 per year for maintenance.	**Medium – high suitability** if used in combination with other measures (e.g. Option 2). Will contribute to sediment retention and therefore help in achieving long term sustainable aims of the restoration.

5.3 Summary

5.3.1 Based on **Table 5.1** and **Section 4.4**, the most appropriate habitat restoration solutions to directly achieve the key considerations of the project, as outlined in **Section 5.1** above, is the removal of sediment in the Long and Round Ponds through either wet or dry dredging (**Option 2**), with dry dredging the recommend technique via partial or complete draw down of the ponds. This technique will provide an immediate change and allow for precise control and greater scope for achieving the required profiles for the ponds. It also allows restricted and controlled working, establishment of greater diversity of local terrestrial and aquatic flora and fauna and the creation of micro-habitats in the lake bed through detailed re-profiling (during sediment removal) to further promote aquatic diversity in the Long and Round Ponds. However, dredging (**Option 2**) should be undertaken in combination with other options as part of a combined scheme such as installation of a sediment trap, attenuation features and NFM measures (**Options 4, 5 & 6**) to reduce sediment influx to the Pond and ensure that dredging is not required as frequently as it previously has been.

Figure 5.1 Pictures showing examples of methods used in different Options

6 Sediment Re-use or Disposal and Flood Storage Capacity

6.1 Introduction

6.1.1 This section of the report briefly highlights the potential options available for the removed sediment from the Long and Round Ponds based upon the collected sediment samples which were sent to ALS Laboratories for contamination testing and evaluated for the options of re-use (within the site area) or disposal (off-site) (see **Section 3**).

6.2 Waste Classification of Sediment

6.2.1 Based on the outcomes of **Section 3** regarding the waste classification of the sampled sediments for the Long and Round Ponds, the results of the laboratory analysis have concluded that pond sediments do not cause concern to human health, as they do not exceed the GAC; and can be used for such purposes as landscaping and spreading on fields for non-agricultural purposes. However, a Materials Management Plan (and potential for leachate testing) should be developed for the sediment removal implementation phase of the project.

6.3 Sediment Re-Use and Disposal Options

6.3.1 If taken forward, the sediment removed from the Long and Round Ponds through dry dredging could be stored on nearby fields, such as the field directly to the south which is owned by Squerryes Estate. This field could be used for temporary storage for dewatering purposes, with the potential for permanent storage through spreading of the dredged material over the surface of the field. The process of using the field for dewatering is detailed below and conceptually presented in **Figure 7.1**:

- Prior to using the field, a review of ecological and archaeological constraints would be undertaken to ensure such environmental receptors will not be impacted upon by the storage and dewatering of the dredged material.
- Agreement with the landowner would be required.
- A large sheet(s) of fine woven mesh (0.025 mm to 0.5 mm) will be placed down on the field and left in place for one week to enable any reptiles to escape from the field to nearby habitats.
- The sediment from the ponds once removed by a long reach excavator and placed in a tractor/trailer (**estimated volume of 3,000 m^3 based on 0.5 m silt depth**), will be transported on each occasion to the potential field and placed on the fine woven mesh. Once adequate sediment has been placed (potentially the whole dredged sediment), the fine woven mesh will be folded over the sediment and secured to the ground to allow for dewatering (drying out of the material).
- The secured fine woven mesh layer will allow dewatering, while ensuring minimal release of fine sediments back into nearby watercourses during potential flood events. It is predicted that the height of the folded woven mesh would be 500 mm, and as such will not cause a visual disturbance to the public.

6.3.2 The sediment removal phase would be carried out between June and August (summer), and the dewatering phase, via runoff or infiltration into the ground, would be expected to take up to six weeks, at which point the now dry material could be either spread on the field (subject to further testing), used for landscaping within the area surrounding the Long and Round Ponds, or moved from the site (for example to another nearby field). If the dredged material is moved, this should be kept to a maximum of 1.5km, if possible, to keep costs low.

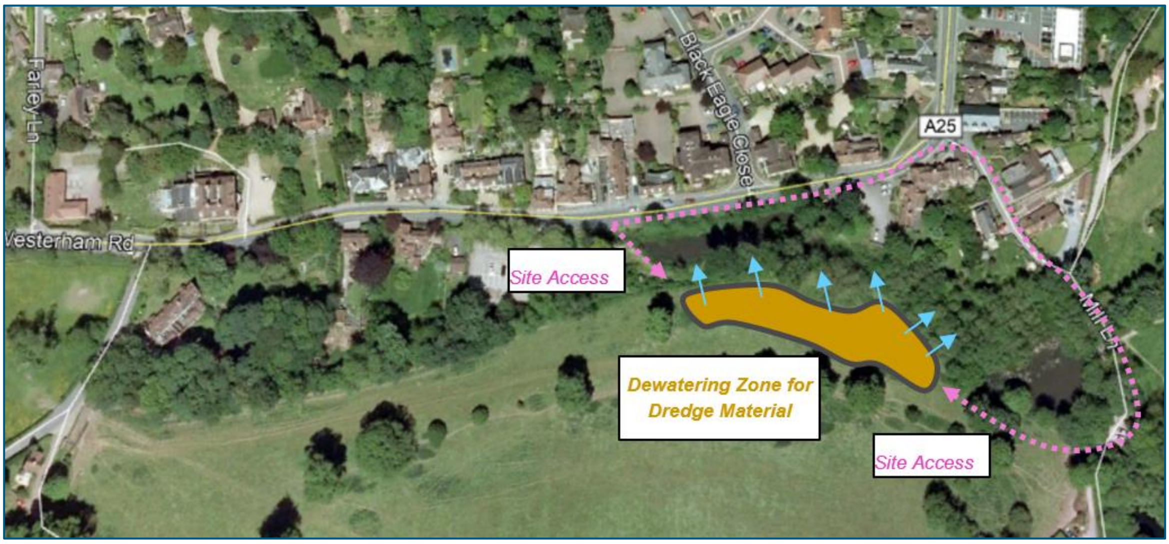

Figure 6.1 Potential temporary and long term sediment storage field for dewatering and spreading of dredge material

6.4 Flood Storage Capacity

6.4.1 Of the identified habitat restoration solutions for the Long and Round Ponds, Option 2 (removal of sediments through dredging) has a greater benefit regarding flood storage capacity and reducing flood risk (when combined with NFM measures). This is because the potential for the removal of sediment to increase the storage capacity of the ponds in comparison to the other options of do nothing or making the Long Pond offline, which will not increase the storage capacity of the ponds.

6.4.2 Please note a review of the Reservoirs Act 1975 should be undertaken to ensure the restored ponds fall under 10,000 m^3 in capacity, which may require the interpretation of LiDAR data of the site, i.e. need to ensure the volume of water in the restored ponds is in keeping with the current Reservoirs Act 1975.

7 Conclusion

7.1 Introduction

7.1.1 This section of the report provides a brief overview of the recommended habitat restoration solutions for the Long and Round Ponds, including a long-term restoration management plan or programme taking into consideration the outcomes of this feasibility study and other relevant management plans. Complimentary enhancements are suggested associated with the habitat restoration solutions; along with the next steps required to successfully implement Phase II of the project – Design and Construction.

7.2 Recommendations

7.2.1 Based on the outcomes of this report, the most appropriate habitat restoration solutions to directly achieve the key considerations of the project, in particular the long term vision of the community, is the removal of sediment in the Long and Round Ponds through either **wet or dry dredging (Option 2)**, with dry dredging the recommend technique via partial or complete draw down of the ponds. However, the main issue requiring a resolution to enable the long term, sustainable restoration of the Long and Round Ponds is the influx of sediment and silt into the Upper River Darent at Westerham.

7.2.2 Therefore, if **Option 2** is taken forward to Phase II, the management of sediment from the contributing catchment through best practice measures is paramount to the success of this habitat restoration option. This must consider all sources of sediment in the Squerryes sub-catchment, along with potential options to incorporate **sediment traps, attenuation features and other NFM measures** (**Options 4, 5 & 6**). It is further recommended that such additional measures be implemented first, prior to the primary habitat restoration solution of **Option 2**.

7.2.3 **Figure 7.1** provides a conceptual summary of the recommended habitat restoration solutions for the Long and Round Ponds.

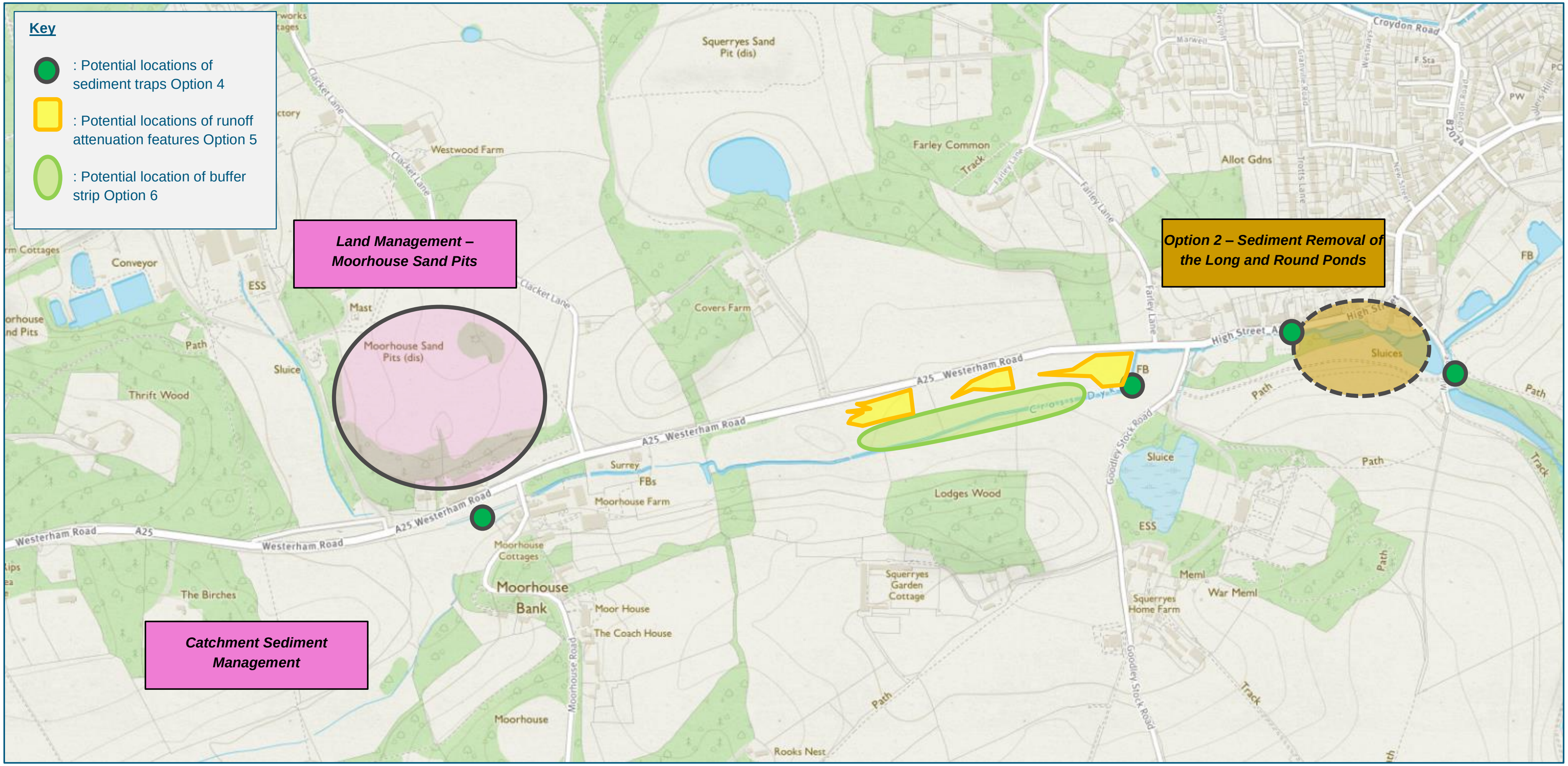

Figure 7.1 Conceptual summary of the recommended habitat restoration solutions for the Long and Round Ponds

7.3 Next Steps and Challenges

7.3.1 To enable the successful implementation of the above recommend habitat restoration solutions for the Long and Round Ponds, the following key actions will require consideration prior to the commencement of the works:

- Bathymetry survey of the Long and Round Ponds, to determine the specific amount of the sediment to be removed, in combination with an invasive survey of sediment depths to work out the thickness of sediment accumulation.
- Topographic survey of the Long and Round Pond site, to support the design of the proposed habitat restoration works.
- Detailed engineering survey of assets, to support the design of the proposed habitat restoration works.
- Sediment modelling in the Squerryes sub-catchment to ascertain the sources and quantity of sediment entering the Cross Dyke and Long Pond.
- Further sediment sampling to ensure sediment is consistent throughout the Long and Round Ponds.
- Protected and invasive species surveys for example great crested newts (GCN), reptiles, bats and ground-nesting birds. A fish survey will also be required.
- Consultation with the Local Planning Authority regarding the requirements of planning (also see below); and agreement on the preferred (recommended) habitat restoration solutions.
- EIA screening letter to the Local Planning Authority, to determine if the proposed restoration works will require an EIA under the Town and County Planning Act; or a non-statuary EIA can be produced to support any Environment Agency/IDB Permits.
- Low Risk Environmental Report and appendices, including WFD, EAP and Materials Management Plan to support the above EIA requirements.
- A detailed method statement; outline and detailed design for the recommend habitat restoration solutions, for example **Option 2 dry dredging**; **and associated complimentary NFM measures**. This would also require, a utilities search; Flood Risk Assessment (FRA); consultation with Reservoir Panel Engineer; and high level hydraulic modelling, to support the detail design.
- Finalise disposal route for dredged material well in advance of the commencement of works, if Option 2 taken forward. This should include landownership consultation.

7.4 Long Term Restoration Programme and Enhancements

7.4.1 Based on the above, the following stages should thus be implemented:

Phase II – 2020

- Agreement of the recommend habitat restoration solutions for Long and Round Ponds;
- Consultation and agreement on catchment sediment management processes to be implemented;

- Further details on the complimentary NFM habitat restoration solutions, such as sediment traps, buffer strips and land management which should be implemented prior to the main restoration solution for the ponds, for example dredging; and
- Landowner consultation on the above to gain support.

Phase III – 2020

- Topographic and ecological/fish surveys.
- Engineering and utilities surveys.
- Further sediment sampling.
- Detail design of NFM measures; and primary habitat restoration measure for the Long and Round Ponds, for example Option 2, dry dredging and disposal criteria.
- Funding applications for the below phases of work.

Phase IV – 2021

- Consents and permits.
- Finalisation of designs.
- Planning application, if required.

Phased V – 2022

- Tender contracts for construction.
- Construction – July to August 2022.

7.4.2 Potential enhancements within the Long and Round Pond sites to compliment this project include the following:

- **Community seating.**
- **Dedicated walk boards (paths).**
- **Community information boards.**
- **Tree management.**
- **Better lighting.**
- **Bird and bat boxes.**
- **Community (school) water quality monitoring initiatives.**

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Appendices

Appendix I –
ALS Sediment Sample Results

Acronyms

Adaptation – Adjustment (of habitats or species) to environmental conditions.

Anaerobic Bacteria – Bacteria that thrive in an environment of low or no dissolved oxygen.

Anoxic – The absence of oxygen.

Benthivore/ous – Term to describe fish that eat invertebrates and plants that occur in the sediment.

Bathometry – The measurement of the depths of oceans, seas, or other large bodies of water including lakes.

CL:AIRE – Definition of Waste Industry - Code of Practice.

Diffuse pollution – Sediment or contaminants originating from a variety of small-scale locations.

Epilimnion – The upper water layer.

Eutrophication – The enrichment of water bodies by nutrients, primarily nitrogen and phosphorus.

Hypolimnion – The lower water layer, extending from the sediment to the base of the thermocline (the point of greatest temperature gradient in the water column).

Littoral zone – Shallow edge waters.

Macrophytes – Large vascular aquatic plants. They may be attached to sediments, being emergent or submerging of free-floating in form.

Metalimnion – The zone intermediate between the epliminion and the hypolimnion. This is also referred to the thermocline.

Oligotrophication – The status of water bodies characterised by low nutrient concentrations and low plant growth.

Phytoplankton – Microscopic algae that generally float in the water.

Sediment – The accumulation of abiotic and biotic materials on the beds of water bodies.

SPRHOST – Measure of the percentage of rainfall running off the site.

SSSI – Site of Special Scientific Interest.

Water Framework Directive (WFD) – EU legislation that integrates water management through river basin planning.

Watercourse – Is any flowing body of water. These include rivers, streams, anabranches, and so forth.

Glossary

Acronym	Definition
AONB	Area of Outstanding Natural Beauty
DVLPS	Darent Valley Landscape Partnership Scheme
EU	European Union
FOLP	Friends of the Long Pond
FRAP	Flood Risk Activities Permit
GAC	Generic Assessment Criteria
GEP	Good Ecological Potential
GES	Good Ecological Status
KCC	Kent County Council
LOD	Limit of Detection
LWS	Local Wildlife Site
NFM	Natural Flood Management
PAH	Polyaromatic Hydrocarbons
POST	Parliamentary Office of Science and Technology
RAF	Runoff Attenuation Features
RNLI	Royal National Lifeboat Institution
SDC	Sevenoaks District Council
SEPA	Scottish Environmental Protection Agency
SERT	South East Rivers Trust
SOM	Soil Organic Matter
SuDS	Sustainable Drainage System
SSSI	Site of Special Scientific Interest
WACA	Wildlife and Countryside Act
WFD	Water Framework Directive

Royal HaskoningDHV

Darent Valley Partnership

Kent Downs Area of Outstanding Natural Beauty

Interreg 2 Seas Mers Zeeën TRIPLE C European Regional Development Fund

With its headquarters in Amersfoort, The Netherlands, Royal HaskoningDHV is an independent, international project management, engineering and consultancy service provider. Ranking globally in the top 10 of independently owned, nonlisted companies and top 40 overall, the Company's 6,000 staff provide services across the world from more than 100 offices in over 35 countries.

Our connections

Innovation is a collaborative process, which is why Royal HaskoningDHV works in association with clients, project partners, universities, government agencies, NGOs and many other organisations to develop and introduce new ways of living and working to enhance society together, now and in the future.

Memberships

Royal HaskoningDHV is a member of the recognised engineering and environmental bodies in those countries where it has a permanent office base.

All Royal HaskoningDHV consultants, architects and engineers are members of their individual branch organisations in their various countries.

Integrity

Royal HaskoningDHV is the first and only engineering consultancy with ETHIC Intelligence anti-corruption certificate since 2010.

ETHIC Intelligence CERTIFICATE ANTI-CORRUPTION COMPLIANCE SYSTEM

royalhaskoningdhv.com

Appendix I: ALS Sediment Sample Results

Unit 7-8 Hawarden Business Park
Manor Road (off Manor Lane)
Hawarden
Deeside
CH5 3US
Tel: (01244) 528700
Fax: (01244) 528701
email: hawardencustomerservices@alsglobal.com
Website: www.alsenvironmental.co.uk

Royal Haskoning
Burns House
Harland road
Haywards Heath
RH16 1PG

Attention: Kitty Taylor

CERTIFICATE OF ANALYSIS

Date of report Generation:	18 November 2019
Customer:	Royal Haskoning
Sample Delivery Group (SDG):	191101-118
Your Reference:	Not Specified
Location:	Not Specified
Report No:	530091

This report has been revised and directly supersedes 529164 in its entirety.

We received 6 samples on Monday October 21, 2019 and 6 of these samples were scheduled for analysis which was completed on Monday November 18, 2019. Accredited laboratory tests are defined within the report, but opinions, interpretations and on-site data expressed herein are outside the scope of ISO 17025 accreditation.

Should this report require incorporation into client reports, it must be used in its entirety and not simply with the data sections alone.

Chemical testing (unless subcontracted) performed at ALS Life Sciences Ltd Hawarden (Method codes TM) or ALS Life Sciences Ltd Aberdeen (Method codes S).

All sample data is provided by the customer. The reported results relate to the sample supplied, and on the basis that this data is correct.
Incorrect sampling dates and/or sample information will affect the validity of results.
The customer is not permitted to reproduce this report except in full without the approval of the laboratory.

Approved By:

Sonia McWhan
Operations Manager

Received Sample Overview

Lab Sample No(s)	Customer Sample Ref.	AGS Ref.	Depth (m)	Sampled Date
21065801	1			
21065804	2			
21065805	3			
21065806	4			
21065807	5			
21065808	6			

Maximum Sample/Coolbox Temperature (°C) : **10.6**

ISO5667-3 Water quality - Sampling - Part3 -
During Transportation samples shall be stored in a cooling device capable of maintaining a temperature of (5±3)°C.

ALS have data which show that a cool box with 4 frozen icepacks is capable of maintaining pre-chilled samples at a temperature of (5±3)°C for a period of up to 24hrs.

Only received samples which have had analysis scheduled will be shown on the following pages.

Validated

CERTIFICATE OF ANALYSIS

SDG:	191101-118	**Client Reference:**	Not Specified	**Report Number:**	530091
Location:	Not Specified	**Order Number:**	PB9630-101-100	**Superseded Report:**	529164

Results Legend

- **X** Test
- **N** No Determination Possible

Sample Types -

- S - Soil/Solid
- UNS - Unspecified Solid
- GW - Ground Water
- SW - Surface Water
- LE - Land Leachate
- PL - Prepared Leachate
- PR - Process Water
- SA - Saline Water
- TE - Trade Effluent
- TS - Treated Sewage
- US - Untreated Sewage
- RE - Recreational Water
- DW - Drinking Water Non-regulatory
- UNL - Unspecified Liquid
- SL - Sludge
- G - Gas
- OTH - Other

Lab Sample No(s)			21065801	21065804	21065805	21065806	21065807	21065808
Customer Sample Reference			1	2	3	4	5	6
AGS Reference								
Depth (m)								
Container			250g Amber Jar (ALE210)	250g Amber Jar (ALE210)	250g Amber Jar (ALE210)	250g Amber Jar (ALE210)	250g Amber Jar (ALE210)	250g Amber Jar (ALE210)
Sample Type			S	S	S	S	S	S
Acid herbicides*	All	NDPs: 0 Tests: 6	X	X	X	X	X	X
Alkali Metals by iCap-OES (Soil)	All	NDPs: 0 Tests: 6	X	X	X	X	X	X
Ammonium Soil by Titration	All	NDPs: 0 Tests: 6	X	X	X	X	X	X
Loss on Ignition in soils	All	NDPs: 0 Tests: 6	X	X	X	X	X	X
Metals in solid samples by OES	All	NDPs: 0 Tests: 6	X	X	X	X	X	X
NO3, NO2 and TON by KONE (s)	All	NDPs: 0 Tests: 6	X	X	X	X	X	X
PAH by GCMS	All	NDPs: 0 Tests: 6	X	X	X	X	X	X
pH	All	NDPs: 0 Tests: 6	X	X	X	X	X	X
Phenols Spec MS (S)	All	NDPs: 0 Tests: 6	X	X	X	X	X	X
Sample description	All	NDPs: 0 Tests: 6	X	X	X	X	X	X

Sample Descriptions

Grain Sizes

very fine	<0.063mm	fine	0.063mm - 0.1mm	medium	0.1mm - 2mm	coarse	2mm - 10mm	very coarse	>10mm

Lab Sample No(s)	Customer Sample Ref.	Depth (m)	Colour	Description	Inclusions	Inclusions 2
21065801	1		Dark Brown	N/A	Vegetation	None
21065804	2		Dark Brown	N/A	Vegetation	None
21065805	3		Dark Brown	N/A	Vegetation	Oil/Petroleum
21065806	4		Dark Brown	Sand	Stones	Vegetation
21065807	5		Dark Brown	Sand	Stones	Vegetation
21065808	6		Dark Brown	Silty Clay Loam	Stones	None

These descriptions are only intended to act as a cross check if sample identities are questioned, and to provide a log of sample matrices with respect to MCERTS validation. They are not intended as full geological descriptions.

We are accredited to MCERTS for sand, clay and loam/topsoil, or any of these materials - whether these are derived from naturally ocurring soil profiles, or from fill/made ground, as long as these materials constitute the major part of the sample.

Other coarse granular materials such as concrete, gravel and brick are not accredited if they comprise the major part of the sample.

Validated

CERTIFICATE OF ANALYSIS

SDG:	191101-118	Client Reference:	Not Specified	Report Number:	530091
Location:	Not Specified	Order Number:	PB9630-101-100	Superseded Report:	529164

Results Legend

#	ISO17025 accredited.
M	mCERTS accredited.
aq	Aqueous / settled sample.
diss.filt	Dissolved / filtered sample.
tot.unfilt	Total / unfiltered sample.
*	Subcontracted - refer to subcontractor report for accreditation status.
**	% recovery of the surrogate standard to check the efficiency of the method. The results of individual compounds within samples aren't corrected for the recovery
(F)	Trigger breach confirmed
1-3+§@	Sample deviation (see appendix)

Customer Sample Ref.			1	2	3	4	5	6
Depth (m)			.	.	.	.	.	.
Sample Type			Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)
Date Sampled			-	-	-	-	-	-
Sample Time			.	.	.	.	.	.
Date Received			21/10/2019	21/10/2019	21/10/2019	21/10/2019	21/10/2019	21/10/2019
SDG Ref			191101-118	191101-118	191101-118	191101-118	191101-118	191101-118
Lab Sample No.(s)			21065801	21065804	21065805	21065806	21065807	21065808
AGS Reference								
Component	**LOD/Units**	**Method**						
Moisture Content Ratio (% of as received sample)	%	PM024	81 §	85 §	88 §	80 §	50 §	71 §
2,4,5-Trichlorophenol (2,4,5-T)*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
2,4,5-TP (Fenoprop)*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
2,4-D*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
2,4-DB*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
2,4-Dichloroprop (2,4 DP)*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
4-Chlorophenoxyacetic acid (4-CPA)*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
Acifluorfen*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
Bentazone*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
Bromoxynil*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
Dicamba*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
Diclofop*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
Dinoseb*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
DNOC*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
Fluroxypyr*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
Ioxynil*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
2-methyl-4-Chlorophenoxyacetic acid (MCPA)*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
4-(4-Chloro-o-tolyloxy) butyric acid (MCPB)*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
Mecoprop (MCPP)*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
Propoxycarbazone-sodium*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
Triclopyr*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
Triclosan*	<0.01 mg/kg	SUB	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §	<0.01 §
Loss on ignition	<0.7 %	TM018	23 §	28.2 §	35.9 §	28.2 §	5.99 §	18.7 §
Exchangeable Ammonia as N	<12 mg/kg	TM024	<12 §	<12 §	<12 §	62.4 §	<12 §	<12 §
pH	1 pH Units	TM133	6.61 §	6.57 §	5.78 §	6.01 §	6.77 §	6.42 §
Arsenic	<0.6 mg/kg	TM181	12.2 §	12.7 §	16.8 §	10.4 §	5.45 §	10.5 §
Boron	<0.7 mg/kg	TM181	53.9 §	109 §	91.4 §	2690 §	20.1 §	324 §
Cadmium	<0.02 mg/kg	TM181	0.59 §	20 §	1.7 §	0.935 §	0.351 §	0.874 §
Chromium	<0.9 mg/kg	TM181	36.9 §	46 §	39.6 §	71.6 §	20.7 §	49.3 §
Copper	<1.4 mg/kg	TM181	62.3 §	103 §	80.3 §	72.8 §	17.2 §	66.7 §
Iron	<1000 mg/kg	TM181	22800 §	23000 §	21500 §	21700 §	15700 §	23000 §
Lead	<0.7 mg/kg	TM181	78.4 §	226 §	83.5 §	95.9 §	60.3 §	95.1 §
Mercury	<0.14 mg/kg	TM181	<0.14 §	2.12 §	<0.14 §	<0.14 §	<0.14 §	<0.14 §

Results Legend		
#	ISO17025 accredited.	
M	mCERTS accredited.	
aq	Aqueous / settled sample.	
diss.filt	Dissolved / filtered sample.	
tot.unfilt	Total / unfiltered sample.	
*	Subcontracted - refer to subcontractor report for accreditation status.	
**	% recovery of the surrogate standard to check the efficiency of the method. The results of individual compounds within samples aren't corrected for the recovery	
(F)	Trigger breach confirmed	
1-3+§@	Sample deviation (see appendix)	

Component	LOD/Units	Method	1	2	3	4	5	6
Customer Sample Ref.			1	2	3	4	5	6
Depth (m)			.	.	.	.	.	.
Sample Type			Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)
Date Sampled			-	-	-	-	-	-
Sample Time			.	.	.	.	.	.
Date Received			21/10/2019	21/10/2019	21/10/2019	21/10/2019	21/10/2019	21/10/2019
SDG Ref			191101-118	191101-118	191101-118	191101-118	191101-118	191101-118
Lab Sample No.(s)			21065801	21065804	21065805	21065806	21065807	21065808
AGS Reference								
Nickel	<0.2 mg/kg	TM181	35.3 §	32.2 §	40.9 §	38.1 §	22.5 §	38.5 §
Phosphorus	<1 mg/kg	TM181	1480 §	1220 §	1360 §	1380 §	517 §	832 §
Selenium	<1 mg/kg	TM181	<1 §	1.38 §	1.96 §	1.3 §	<1 §	1.66 §
Tin	<0.24 mg/kg	TM181	7.43 §	33.8 §	9.12 §	8.35 §	12.5 §	8.14 §
Zinc	<1.9 mg/kg	TM181	322 §	1240 §	385 §	864 §	73.3 §	366 §
Magnesium	<8 mg/kg	TM224	2620 §	2520 §	2990 §	2750 §	1720 §	2910 §
Potassium	<16 mg/kg	TM224	2560 §	4470 §	2910 §	4380 §	2270 §	3440 §
Total Oxidised Nitrogen as N, 2:1 water soluble	<0.226 mg/kg	TM243	0.744 §	2.04 §	1.29 §	0.519 §	0.305 §	<0.226 §
Nitrate as N, 2:1 water soluble	<0.226 mg/kg	TM243	0.333 §	0.928 §	0.607 §	0.234 §	<0.226 §	<0.226 §
Nitrite (soluble) as N	<0.03 mg/kg	TM243	0.0785 §	0.187 §	0.0736 §	0.0523 §	0.0491 §	0.0359 §

CERTIFICATE OF ANALYSIS

SDG:	191101-118	**Client Reference:**	Not Specified	**Report Number:**	530091
Location:	Not Specified	**Order Number:**	PB9630-101-100	**Superseded Report:**	529164

PAH by GCMS

Results Legend

#	ISO17025 accredited.
M	mCERTS accredited.
aq	Aqueous / settled sample.
diss.filt	Dissolved / filtered sample.
tot.unfilt	Total / unfiltered sample.
*	Subcontracted - refer to subcontractor report for accreditation status.
**	% recovery of the surrogate standard to check the efficiency of the method. The results of individual compounds within samples aren't corrected for the recovery
(F)	Trigger breach confirmed
1-3+§@	Sample deviation (see appendix)

Customer Sample Ref.			1	2	3	4	5	6
Depth (m)			.	.	.	.	.	.
Sample Type			Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)
Date Sampled			-	-	-	-	-	-
Sample Time			.	.	.	.	.	.
Date Received			21/10/2019	21/10/2019	21/10/2019	21/10/2019	21/10/2019	21/10/2019
SDG Ref			191101-118	191101-118	191101-118	191101-118	191101-118	191101-118
Lab Sample No.(s)			21065801	21065804	21065805	21065806	21065807	21065808
AGS Reference								
Component	**LOD/Units**	**Method**						
Naphthalene-d8 % recovery**	%	TM218	86.9 §	88.2 §	86.1 §	86.6 §	92.1 §	94.2 §
Acenaphthene-d10 % recovery**	%	TM218	86.8 §	88.2 §	87 §	83.2 §	88.9 §	91.8 §
Phenanthrene-d10 % recovery**	%	TM218	91.2 §	88.1 §	86.1 §	81.4 §	84.6 §	85.6 §
Chrysene-d12 % recovery**	%	TM218	83.5 §	81.7 §	78.9 §	77.2 §	76.1 §	77.5 §
Perylene-d12 % recovery**	%	TM218	84 §	79.1 §	75.4 §	74.6 §	80.6 §	83.1 §
Naphthalene	<9 µg/kg	TM218	<45 §	<45 §	<45 §	<45 §	<45 §	<90 §
Acenaphthylene	<12 µg/kg	TM218	483 §	<60 §	<60 §	335 §	<60 §	<120 §
Acenaphthene	<8 µg/kg	TM218	<40 §	<40 §	<40 §	<40 §	<40 §	<80 §
Fluorene	<10 µg/kg	TM218	<50 §	<50 §	<50 §	<50 §	<50 §	<100 §
Phenanthrene	<15 µg/kg	TM218	2150 §	1600 §	1800 §	1070 §	163 §	1180 §
Anthracene	<16 µg/kg	TM218	638 §	544 §	680 §	447 §	<80 §	<160 §
Fluoranthene	<17 µg/kg	TM218	8320 §	6850 §	7660 §	4730 §	597 §	4450 §
Pyrene	<15 µg/kg	TM218	7480 §	6220 §	6970 §	4160 §	529 §	4040 §
Benz(a)anthracene	<14 µg/kg	TM218	3950 §	3360 §	3710 §	2410 §	296 §	2330 §
Chrysene	<10 µg/kg	TM218	3660 §	3690 §	4070 §	2580 §	271 §	2310 §
Benzo(b)fluoranthene	<15 µg/kg	TM218	5640 §	6100 §	6730 §	4240 §	534 §	4360 §
Benzo(k)fluoranthene	<14 µg/kg	TM218	2150 §	2020 §	2210 §	1450 §	210 §	1640 §
Benzo(a)pyrene	<15 µg/kg	TM218	5200 §	3890 §	4360 §	2640 §	360 §	3200 §
Indeno(1,2,3-cd)pyrene	<18 µg/kg	TM218	3580 §	3810 §	3830 §	2540 §	252 §	2180 §
Dibenzo(a,h)anthracene	<23 µg/kg	TM218	784 §	<115 §	<115 §	<115 §	<115 §	<230 §
Benzo(g,h,i)perylene	<24 µg/kg	TM218	4290 §	3410 §	3480 §	2320 §	341 §	2900 §
PAH, Total Detected USEPA 16	<118 µg/kg	TM218	48300 §	41500 §	45500 §	28900 §	3550 §	28600 §

Validated

CERTIFICATE OF ANALYSIS

SDG:	191101-118	**Client Reference:**	Not Specified	**Report Number:**	530091
Location:	Not Specified	**Order Number:**	PB9630-101-100	**Superseded Report:**	529164

Phenols Spec MS (S)

Results Legend

#	ISO17025 accredited.
M	mCERTS accredited.
aq	Aqueous / settled sample.
diss.filt	Dissolved / filtered sample.
tot.unfilt	Total / unfiltered sample.
*	Subcontracted - refer to subcontractor report for accreditation status.
**	% recovery of the surrogate standard to check the efficiency of the method. The results of individual compounds within samples aren't corrected for the recovery
(F)	Trigger breach confirmed
1-3♦§@	Sample deviation (see appendix)

		Customer Sample Ref.	1	2	3	4	5	6
		Depth (m)	.	.	.	.	.	.
		Sample Type	Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)	Unspecified Solid (UNS)
		Date Sampled	-	-	-	-	-	-
		Sample Time	.	.	.	.	.	.
		Date Received	21/10/2019	21/10/2019	21/10/2019	21/10/2019	21/10/2019	21/10/2019
		SDG Ref	191101-118	191101-118	191101-118	191101-118	191101-118	191101-118
		Lab Sample No.(s)	21065801	21065804	21065805	21065806	21065807	21065808
		AGS Reference						
Component	**LOD/Units**	**Method**						
4-Nitrophenol	<1 µg/kg	TM072	<1 §	<1 §	<1 §	<1 §	<1 §	<1 §
2,4,6-Trichlorophenol	<1 µg/kg	TM072	<1 §	<1 §	<1 §	<1 §	<1 §	<1 §
2-Nitrophenol	<1 µg/kg	TM072	<1 §	<1 §	<1 §	<1 §	<1 §	<1 §
2,4-Dichlorophenol	<1 µg/kg	TM072	<1 §	<1 §	<1 §	<1 §	<1 §	<1 §
Pentachlorophenol	<1 µg/kg	TM072	<1 §	<1 §	<1 §	<1 §	<1 §	<1 §
Phenol	<1 µg/kg	TM072	<1 §	<1 §	<2 §	<2 §	<1 §	<1 §
4-Chloro-3-methylphenol	<1 µg/kg	TM072	<1 §	<1 §	<1 §	<1 §	<1 §	<1 §
2,4-Dimethylphenol	<1 µg/kg	TM072	<1 §	<1 §	<1 §	<1 §	<1 §	<1 §
2-Chlorophenol	<1 µg/kg	TM072	<1 §	<1 §	<1 §	<1 §	<1 §	<1 §
Sum of Detected Phenols	<9 µg/kg	TM072	<9 §	<9 §	<10 §	<10 §	<9 §	<9 §

Table of Results - Appendix

Method No	Reference	Description
PM024	Modified BS 1377	Soil preparation including homogenisation, moisture screens of soils for Asbestos Containing Material
SUB		Subcontracted Test
TM018	BS 1377: Part 3 1990	Determination of Loss on Ignition
TM024	Method 4500A & B, AWWA/APHA, 20th Ed., 1999	Determination of Exchangeable Ammonium and Ammoniacal Nitrogen as N by titration on solids
TM072	Modified: US EPA Method 8141A	Determination of Phenols by GC-MS
TM133	BS 1377: Part 3 1990;BS 6068-2.5	Determination of pH in Soil and Water using the GLpH pH Meter
TM181	US EPA Method 6010B	Determination of Routine Metals in Soil by iCap 6500 Duo ICP-OES
TM218	Shaker extraction - EPA method 3546.	The determination of PAH in soil samples by GC-MS
TM224	US EPA Method 6010B	Determination of Alkaline Metals by iCap 6500 Duo ICP-OES
TM243		Mixed Anions In Soils By Kone

NA = not applicable.

Chemical testing (unless subcontracted) performed at ALS Life Sciences Ltd Hawarden (Method codes TM) or ALS Life Sciences Ltd Aberdeen (Method codes S).

Test Completion Dates

Lab Sample No(s)	21065801	21065804	21065805	21065806	21065807	21065808
Customer Sample Ref.	1	2	3	4	5	6
AGS Ref.						
Depth						
Type	Unspecified So	Unspecified So	Unspecified So	Unspecified So	Unspecified So	Unspecified So
Acid herbicides*	18-Nov-2019	18-Nov-2019	18-Nov-2019	18-Nov-2019	18-Nov-2019	18-Nov-2019
Alkali Metals by iCap-OES (Soil)	07-Nov-2019	07-Nov-2019	07-Nov-2019	07-Nov-2019	07-Nov-2019	07-Nov-2019
Ammonium Soil by Titration	07-Nov-2019	07-Nov-2019	07-Nov-2019	07-Nov-2019	07-Nov-2019	07-Nov-2019
Loss on Ignition in soils	07-Nov-2019	07-Nov-2019	08-Nov-2019	07-Nov-2019	07-Nov-2019	07-Nov-2019
Metals in solid samples by OES	08-Nov-2019	08-Nov-2019	08-Nov-2019	08-Nov-2019	07-Nov-2019	08-Nov-2019
NO3, NO2 and TON by KONE (s)	08-Nov-2019	08-Nov-2019	08-Nov-2019	08-Nov-2019	08-Nov-2019	08-Nov-2019
PAH by GCMS	08-Nov-2019	08-Nov-2019	08-Nov-2019	08-Nov-2019	07-Nov-2019	07-Nov-2019
pH	07-Nov-2019	07-Nov-2019	07-Nov-2019	07-Nov-2019	07-Nov-2019	07-Nov-2019
Phenols Spec MS (S)	11-Nov-2019	11-Nov-2019	11-Nov-2019	11-Nov-2019	11-Nov-2019	11-Nov-2019
Sample description	02-Nov-2019	02-Nov-2019	02-Nov-2019	02-Nov-2019	02-Nov-2019	02-Nov-2019

CERTIFICATE OF ANALYSIS

Work Order	: **PR19C0558**	Issue Date	: 18-Nov-2019
Customer	: **ALS Life Sciences Ltd**	Laboratory	: ALS Czech Republic, s.r.o.
Contact	: Reporting	Contact	: Client Service
Address	: Unit 7-8 Hawarden Business Park Manor Road, Hawarden CH5 3US Deeside United Kingdom	Address	: Na Harfe 336/9 Prague 9 - Vysocany 190 00 Czech Republic
E-mail	: euhdnsubconresults@ALSGlobal.com	E-mail	: customer.support@alsglobal.com
Telephone	: ----	Telephone	: +420 226 226 228
Project	: 191101-118	Page	: 1 of 3
Order number	: 191101-118	Date Samples Received	: 08-Nov-2019
		Quote number	: PR2018ALSAL-GB0004 (CZ-256-18-0022)
Site	: ----	Date of test	: 09-Nov-2019 - 18-Nov-2019
Sampled by	: CLIENT	QC Level	: ALS CR Standard Quality Control Schedule

General Comments

This report shall not be reproduced except in full, without prior written approval from the laboratory.

The laboratory declares that the test results relate only to the listed samples. If the section "Sampled by" of the Certificate of analysis states: "Sampled by Customer" then the results relate to the sample as received.

Responsible for accuracy

Testing Laboratory No. 1163
Accredited by CAI according to
CSN EN ISO/IEC 17025:2018

Signatories	*Position*
Zdeněk Jirák	Environmental Business Unit Manager

L 1163

Analytical Results

Sub-Matrix: **SOIL**			Client sample ID	21069097		21069325		21069502	
			Laboratory sample ID	PR19C0558-001		PR19C0558-002		PR19C0558-003	
			Client sampling date / time	[09-Nov-2019]		[09-Nov-2019]		[09-Nov-2019]	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	**21.2**	± 6.1%	**21.9**	± 6.1%	**14.0**	± 6.2%
Pesticides									
2.4.5-T	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
2.4.5-TP	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
2.4-D	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
2.4-DB	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
2.4-DP (isomers)	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
4-CPP	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Bentazone	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Dinoseb	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Fluroxypyr	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
MCPA	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
MCPB	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
MCPP (isomers)	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Acifluorfen	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Bromoxynil	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
DNOC	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Dicamba	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Diclofop	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Ioxynil	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Propoxycarbazone-sodium	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Triclopyr	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Triclosan	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----

Sub-Matrix: **SOIL**			Client sample ID	21069962		21070029		21070161	
			Laboratory sample ID	PR19C0558-004		PR19C0558-005		PR19C0558-006	
			Client sampling date / time	[09-Nov-2019]		[09-Nov-2019]		[09-Nov-2019]	
Parameter	Method	LOR	Unit	Result	MU	Result	MU	Result	MU
Physical Parameters									
Dry matter @ 105°C	S-DRY-GRCI	0.10	%	**18.5**	± 6.2%	**56.5**	± 6.0%	**28.9**	± 6.1%
Pesticides									
2.4.5-T	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
2.4.5-TP	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
2.4-D	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
2.4-DB	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
2.4-DP (isomers)	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
4-CPP	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Bentazone	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Dinoseb	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Fluroxypyr	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
MCPA	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
MCPB	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
MCPP (isomers)	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Acifluorfen	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Bromoxynil	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
DNOC	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Dicamba	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Diclofop	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Ioxynil	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Propoxycarbazone-sodium	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Triclopyr	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----
Triclosan	S-PESLMSA1	0.0100	mg/kg DW	<0.0100	----	<0.0100	----	<0.0100	----

If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, delivery date in brackets without a time component will be displayed instead. Measurement uncertainty is expressed as expanded measurement uncertainty with coverage factor k = 2, representing 95% confidence level.

Key: LOR = Limit of reporting; MU = Measurement Uncertainty. The MU does not include sampling uncertainty.

The end of result part of the certificate of analysis

Brief Method Summaries

Analytical Methods	*Method Descriptions*
Location of test performance: Na Harfe 336/9 Prague 9 - Vysocany Czech Republic 190 00	
S-DRY-GRCI	CZ_SOP_D06_01_045 (CSN ISO 11465, CSN EN 12880, CSN EN 14346), CZ_SOP_D06_07_046 (CSN ISO 11465, CSN EN 12880, CSN EN 14346, CSN 46 5735) Determination of dry matter by gravimetry and determination of moisture by calculation from measured values.
S-PESLMSA1	CZ_SOP_D06_03_182.B (CSN EN 15637, US EPA 1694) Determination of acidic herbicides and drug residues by liquid chromatography method with MS/MS detection.

A `*` symbol preceding any method indicates laboratory or subcontractor non-accredited test. In the case when a procedure belonging to an accredited method was used for non-accredited matrix, would apply that the reported results are non-accredited. Please refer to General Comment section on front page for information. If the report contains subcontracted analysis, those are made in a subcontracted laboratory outside the laboratories ALS Czech Republic, s.r.o.

The calculation methods of summation parameters are available on request in the client service.

Appendix

General

1. Results are expressed on a dry weight basis (dried at 35ºC) for all soil analyses except for the following: NRA and CEN Leach tests, flash point LOI, pH, ammonium as NH4 by the BRE method, VOC TICs and SVOC TICs.

2. If sufficient sample is received a sub sample will be retained free of charge for 30 days after analysis is completed (e-mailed) for all sample types unless the sample is destroyed on testing. The prepared soil sub sample that is analysed for asbestos will be retained for a period of 6 months after the analysis date. All bulk samples will be retained for a period of 6 months after the analysis date. All samples received and not scheduled will be disposed of one month after the date of receipt unless we are instructed to the contrary. Once the initial period has expired, a storage charge will be applied for each month or part thereof until the client cancels the request for sample storage. ALS reserve the right to charge for samples received and stored but not analysed.

3. With respect to turnaround, we will always endeavour to meet client requirements wherever possible, but turnaround times cannot be absolutely guaranteed due to so many variables beyond our control.

4. We take responsibility for any test performed by sub-contractors (marked with an asterisk). We endeavour to use UKAS/MCERTS Accredited Laboratories, who either complete a quality questionnaire or are audited by ourselves. For some determinands there are no UKAS/MCERTS Accredited Laboratories, in this instance a laboratory with a known track record will be utilised.

5. If no separate volatile sample is supplied by the client, or if a headspace or sediment is present in the volatile sample, the integrity of the data may be compromised. This will be flagged up as an invalid VOC on the test schedule and the result marked as deviating on the test certificate.

6. NDP - No determination possible due to insufficient/unsuitable sample.

7. Results relate only to the items tested.

8. LoDs (Limit of Detection) for wet tests reported on a dry weight basis are not corrected for moisture content.

9. **Surrogate recoveries** - Surrogates are added to your sample to monitor recovery of the test requested. A % recovery is reported, results are not corrected for the recovery measured. Typical recoveries for organics tests are 70-130%. Recoveries in soils are affected by organic rich or clay rich matrices. Waters can be affected by remediation fluids or high amounts of sediment. Test results are only ever reported if all of the associated quality checks pass; it is assumed that all recoveries outside of the values above are due to matrix affect.

10. Stones/debris are not routinely removed. We always endeavour to take a representative sub sample from the received sample.

11. In certain circumstances the method detection limit may be elevated due to the sample being outside the calibration range. Other factors that may contribute to this include possible interferences. In both cases the sample would be diluted which would cause the method detection limit to be raised.

12. Mercury results quoted on soils will not include volatile mercury as the analysis is performed on a dried and crushed sample.

13. For leachate preparations other than Zero Headspace Extraction (ZHE) volatile loss may occur.

14. For the BSEN 12457-3 two batch process to allow the cumulative release to be calculated, the volume of the leachate produced is measured and filtered for all tests. We therefore cannot carry out any unfiltered analysis. The tests affected include volatiles GCFID/GCMS and all subcontracted analysis.

15. Analysis and identification of specific compounds using GCFID is by retention time only, and we routinely calibrate and quantify for benzene, toluene, ethylbenzenes and xylenes (BTEX). For total volatiles in the C5-C12 range, the total area of the chromatogram is integrated and expressed as ug/kg or ug/l. Although this analysis is commonly used for the quantification of gasoline range organics (GRO), the system will also detect other compounds such as chlorinated solvents, and this may lead to a falsely high result with respect to hydrocarbons only. It is not possible to specifically identify these non-hydrocarbons, as standards are not routinely run for any other compounds, and for more definitive identification, volatiles by GCMS should be utilised.

16. We are accredited to MCERTS for sand, clay and loam/topsoil, or any of these materials - whether these are derived from naturally occurring soil profiles, or from fill/made ground, as long as these materials constitute the major part of the sample. Other coarse granular material such as concrete, gravel and brick are not accredited if they comprise the major part of the sample.

17. **Tentatively Identified Compounds (TICs)** are non-target peaks in VOC and SVOC analysis. All non-target peaks detected with a concentration above the LoD are subjected to a mass spectral library search. Non-target peaks with a library search confidence of >75% are reported based on the best mass spectral library match. When a non-target peak with a library search confidence of <75% is detected it is reported as "mixed hydrocarbons". Non-target compounds identified from the scan data are semi-quantified relative to one of the deuterated internal standards, under the same chromatographic conditions as the target compounds. This result is reported as a semi-quantitative value and reported as Tentatively Identified Compounds (TICs). TICs are outside the scope of UKAS accreditation and are not moisture corrected.

18. **Sample Deviations**

If a sample is classed as deviated then the associated results may be compromised.

1	**Container with Headspace provided for volatiles analysis**
2	**Incorrect container received**
3	**Deviation from method**
§	**Sampled on date not provided**
♦	**Sample holding time exceeded in laboratory**
@	**Sample holding time exceeded due to late arrival of instructions or samples**

19. **Asbestos**

When requested, the individual sub sample scheduled will be analysed in house for the presence of asbestos fibres and asbestos containing material by our documented in house method TM048 based on HSG 248 (2005), which is accredited to ISO17025. If a specific asbestos fibre type is not found this will be reported as "Not detected". If no asbestos fibre types are found all will be reported as "Not detected" and the sub sample analysed deemed to be clear of asbestos. If an asbestos fibre type is found it will be reported as detected (for each fibre type found). Testing can be carried out on asbestos positive samples, but, due to Health and Safety considerations, may be replaced by alternative tests or reported as No Determination Possible (NDP). The quantity of

Identification of Asbestos in Bulk Materials & Soils

The results for identification of asbestos in bulk materials are obtained from supplied bulk materials which have been examined to determine the presence of asbestos fibres using ALS (Hawarden) in-house method of transmitted/polarised light microscopy and central stop dispersion staining, based on HSG 248 (2005).

The results for identification of asbestos in soils are obtained from a homogenised sub sample which has been examined to determine the presence of asbestos fibres using ALS (Hawarden) in-house method of transmitted/polarised light microscopy and central stop dispersion staining, based on HSG 248 (2005).

Asbestos Type	Common Name
Chrysotile	White Asbestos
Amosite	Brown Asbestos
Crocidolite	Blue Asbestos
Fibrous Actinolite	-
Fibrous Anthophyllite	-
Fibrous Tremolite	-

Visual Estimation Of Fibre Content

Estimation of fibre content is not permitted as part of our UKAS accredited test other than: - Trace - Where only one or two asbestos fibres were identified.

Respirable Fibres

Respirable fibres are defined as fibres of <3 µm diameter, longer than 5 µm and with aspect ratios of at least 3:1 that can be inhaled into the lower regions of the lung and are generally acknowledged to be most important predictor of hazard and risk for cancers of the lung.
Standing Committee of Analysts, *The Quantification of Asbestos in Soil (2107).*

Further guidance on typical asbestos fibre content of manufactured products can be found in HSG 264.

The identification of asbestos containing materials and soils falls within our schedule of tests for which we hold UKAS accreditation, however opinions, interpretations and all other information contained in the report are outside the scope of UKAS accreditation.

Royal HaskoningDHV

Appendix II: Human Health Risk Assessment

Sample Date:	Oct-19	LAB ID Number CL/:				21065801	21065804	21065805	21065806	21065807	21065808
		Client Sample Description:		SOM 1%		1	2	3	4	5	6
Determinand	Method Codes:	Units:	LOD	POS (Park)	Mean						
Soil Colour		-	-	-	-	Dark brown	Dark brown	Dark brown	Dark brown	Dark brown	Dark brown
Other Material		-	-	-	-	Vegetation	Vegetation	Vegetation, Oil/ petroleum	Stones, vegetation	Stones, vegetation	Stones
Soil Texture		-	-	-	-	N/A	N/A	N/A	Sand,	Sand	Silty clay loam
Moisture Content Ratio (% of as received sample)	PM024	%	-	-	75.83	81	85	88	80	50	71
Loss on ignition	TM018	%	<0.7	-	23.33	23	28.2	35.9	28.2	5.99	18.7
Exchangeable Ammonia as N	TM024	mg/kg	<12	-	20.40	<12	<12	<12	62.4	<12	<12
pH	TM133	pH units	1	-	6.36	6.61	6.57	5.78	6.01	6.77	6.42
Arsenic	TM181	mg/kg	<0.6	170.00	11.34	12.2	12.7	16.8	10.4	5.45	10.5
Boron	TM181	mg/kg	<0.7	46000.00	548.07	53.9	109	91.4	2690	20.1	324
Cadmium	TM181	mg/kg	<0.02	555.00	4.08	0.59	20	1.7	0.935	0.351	0.874
Chromium	TM181	mg/kg	<0.9	33000/ 220	44.02	36.9	46	39.6	71.6	20.7	49.3
Copper	TM181	mg/kg	<1.4	44000.00	67.05	62.3	103	80.3	72.8	17.2	66.7
Iron	TM181	mg/kg	<1000	-	21283.33	22800	23000	21500	21700	15700	23000
Lead	TM181	mg/kg	<0.7	580.00	106.53	78.4	226	83.5	95.9	60.3	95.1
Mercury	TM181	mg/kg	<0.14	30/240	0.47	<0.14	2.12	<0.14	<0.14	<0.14	<0.14
Nickel	TM181	mg/kg	<0.2	800.00	34.58	35.3	32.2	40.9	38.1	22.5	38.5
Phosphorus	TM181	mg/kg	<1	-	1131.50	1480	1220	1360	1380	517	832
Selenium	TM181	mg/kg	<1	1800	1.38	<1	1.38	1.96	1.3	<1	1.66
Tin	TM181	mg/kg	<0.24	-	13.22	7.43	33.8	9.12	8.35	12.5	8.14
Zinc	TM181	mg/kg	<1.9	170000	541.72	322	1240	385	864	73.3	366
Magnesium	TM224	mg/kg	<8	-	2585.00	2620	2520	2990	2750	1720	2910
Potassium	TM224	mg/kg	<16	-	3338.33	2560.00	4470.0	2910	4380	2270	3440.00
Total Oxidised Nitrogen as N, 2:1 water soluble	TM243	mg/kg	<0.226	-	0.85	0.744	2.04	1.29	0.519	0.305	<0.226
Nitrate as N, 2:1 water	TM243	mg/kg	<0.226	-	0.43	0.333	0.928	0.607	0.234	<0.226	<0.226
Nitrite (soluble) as N	TM243	mg/kg	<0.03	-	0.08	0.079	0.187	0.074	0.052	0.049	0.036
Naphthalene-d8 % recovery**	TM218	%	-	-	89.02	86.9	88.2	86.1	86.6	92.1	94.2
Acenaphthene-d10 % recovery**	TM218	%	-	-	87.65	86.8	88.2	87	83.2	88.9	91.8

Phenanthrene-d10 % recovery**	TM218	%	-	-	86.17	91.2	88.1	86.1	81.4	84.6	85.6
Chrysene-d12 % recovery**	TM218	%	-	-	79.15	83.5	81.7	78.9	77.2	76.1	77.5
Perylene-d12 % recovery**	TM218	%	-	-	79.47	84	79.1	75.4	74.6	80.6	83.1
Naphthalene	TM218	µg/kg	<9	1200000	52.50	<45	<45	<45	<45	<45	<90
Acenaphthylene	TM218	µg/kg	<12	2.90E+07	75.00	483	<60	<60	335	<60	<120
Acenaphthene	TM218	µg/kg	<8	29000000	46.67	<40	<40	<40	<40	<40	<80
Fluorene	TM218	µg/kg	<10	20000000	58.33	<50	<50	<50	<50	<50	<100
Phenanthrene	TM218	µg/kg	<15	6200000	1327.17	2150	1600	1800	1070	163	1180
Anthracene	TM218	µg/kg	<16	1.50E+08	424.83	638	544	680	447	<80	<160
Fluoranthene	TM218	µg/kg	<17	6300000	5434.50	8320	6850	7660	4730	597	4450
Pyrene	TM218	µg/kg	<15	15000000	4899.83	7480	6220	6970	4160	529	4040
Benz(a)anthracene	TM218	µg/kg	<14	49000	2676.00	3950	3360	3710	2410	296	2330
Chrysene	TM218	µg/kg	<10	93000	2763.50	3660	3690	4070	2580	271	2310
Benzo(b)fluoranthene	TM218	µg/kg	<15	13000	4600.67	5640	6100	6730	4240	534	4360
Benzo(k)fluoranthene	TM218	µg/kg	<14	370000	1613.33	2150	2020	2210	1450	210	1640
Benzo(a)pyrene	TM218	µg/kg	<15	11000	3275.00	5200	3890	4360	2640	360	3200
Indeno(1,2,3-cd)pyrene	TM218	µg/kg	<18	150000	2698.67	3580	3810	3830	2540	252	2180
Dibenzo(a,h)anthracene	TM218	µg/kg	<23	1100	245.67	784	<115	<115	<115	<115	<230
Benzo(g,h,i)perylene	TM218	µg/kg	<24	1400000	2790.17	4290	3410	3480	2320	341	2900
PAH, Total Detected	TM218	µg/kg	<118	-	32725.00	48300	41500	45500	28900	3550	28600
4-Nitrophenol	TM072	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1
2,4,6-Trichlorophenol	TM072	µg/kg	<1	1100000	<1	<1	<1	<1	<1	<1	<1
2-Nitrophenol	TM072	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1
2,4-Dichlorophenol	TM072	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1
Pentachlorophenol	TM072	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1
Phenol	TM072	µg/kg	<1	440000	<1	<1	<1	<1	<1	<1	<1
4-Chloro-3-methylphenol	TM072	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1
2,4-Dimethylphenol	TM072	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1
2-Chlorophenol	TM072	µg/kg	<1	-	<1	<1	<1	<1	<1	<1	<1
Sum of Detected Phenols	TM072	µg/kg	<1	-	9.33	<9	<9	<10	<10	<9	<9
2,4,5-Trichlorophenol (2,4,5-T)	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,4,5-TP (Fenoprop)	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,4-D	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,4-DB	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,4-Dichloroprop (2,4 DP)	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

4-Chlorophenoxy acetic acid (4-CPA)	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Acifluorfen	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bentazone	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bromoxynil	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dicamba	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Diclofop	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dinoseb	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
DNOC	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluroxypyr	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ioxynil	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2-methyl-4-Chlorophenoxy acetic acid (MCPA)*	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4-(4-Chloro-o-tolyloxy) butyric acid (MCPB)	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mecoprop (MCPP)*	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Propoxycarbazone-sodium	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Triclopyr	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Triclosan	SUB	mg/kg	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

(red)	Exceeds GAC limit
(blue)	Under limit of detection where LoD is below GAC