Hornsea Project Four: Environmental Statement (ES)

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Volume A6, Annex 2.1: Geomorphological Baseline Survey Report

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Glossary

Term	Definition
Berm	A low-lying strip of land beside a watercourse. The berm area is a natural extension of the main river channel and can carry water when flows in the watercourse are high.
Channel	A natural, or constructed, passageway or depression of perceptible linear extent containing continuously or periodically flowing water and sediment, or a connecting link between two bodies of water.
Commitment	A term used interchangeably with mitigation and enhancement measures. Commitments are Embedded Mitigation Measures. The purpose of Commitments is to reduce and/or eliminate Likely Significant Effects (LSEs), in EIA terms. Primary (Design) or Tertiary (Inherent) are both embedded within the assessment at the relevant point in the EIA (e.g. at Scoping, Preliminary Environmental Information Report (PEIR) or ES). Secondary commitments are incorporated to reduce LSE to environmentally acceptable levels following initial assessment i.e. so that residual effects are acceptable.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for one or more Nationally Significant Infrastructure Projects (NSIP).
Energy balancing infrastructure (EBI)	The onshore substation includes energy balancing Infrastructure. These provide valuable services to the electrical grid, such as storing energy to meet periods of peak demand and improving overall reliability.
Erosion	Erosion is the process of detachment and transport of soil particles by the erosive agents of raindrop impact and surface runoff from rainfall.
Export cable corridor (ECC)	The specific corridor of seabed (seaward of Mean High Water Springs (MHWS)) and land (landward of MHWS) from the Hornsea Project Four array

Term	Definition
	area to the Creyke Beck National Grid substation, within which the export cables will be located.
Floodplain	A strip of relatively flat land bordering a watercourse, built of sediment carried by the stream and dropped in slackwater beyond the influence of the swift current of the channel. The level of the flood plain is generally about the stage of the mean annual flood, and therefore one and only one floodplain level can occur in a limited reach of bottomland.
Fluvial	From the Latin word, *fluvius*, for river, refers to streams. Included are stream processes (fluvial processes), fluvial landforms, such as fluvial islands and bars, and biota living in and near stream channels. Common usage is often extended by geomorphologists to hydrologic processes on hillslopes.
Geomorphology	Study of landforms including, in recent times, investigations into the processes that cause and alter the landforms.
High Voltage Alternating Current (HVAC)	High voltage alternating current is the bulk transmission of electricity by alternating current (AC), whereby the flow of electric charge periodically reverses direction.
High Voltage Direct Current (HVDC)	High voltage direct current is the bulk transmission of electricity by direct current (DC), whereby the flow of electric charge is in one direction.
Hornsea Project Four Offshore Wind Farm	The term covers all elements of the project (i.e. both the offshore and onshore). Hornsea Four infrastructure will include offshore generating stations (wind turbines), electrical export cables to landfall, and connection to the electricity transmission network. Hereafter referred to as Hornsea Four.
Landfall	The generic term applied to the entire landfall area between Mean Low Water Spring (MLWS) tide and the Transition Joint Bay (TJB) inclusive of all construction works, including the offshore and onshore ECC, intertidal working area and landfall compound. Where the offshore cables come ashore east of Fraisthorpe.
Main River	Main Rivers are usually large rivers or streams that are designated under the Water Resources Act (1991) and are shown on the statutory Main River Map. They are managed by the Environment Agency, who carry out construction, maintenance and improvement works to manage flood risk.
National Grid Electricity Transmission (NGET) substation	The grid connection location for Hornsea Four at Creyke Beck.
Onshore substation (OnSS)	Comprises a compound containing the electrical components for transforming the power supplied from Hornsea Project Four to 400 kV and to adjust the power quality and power factor, as required to meet the UK Grid Code for supply to the National Grid. If a HVDC system is used the OnSS will also house equipment to convert the power from HVDC to HVAC.
Order Limits	The limits within which Hornsea Project Four (the 'authorised project') may be carried out.
Ordinary Watercourse	Ordinary watercourses are watercourses that are not designated as Main Rivers under the Water Resources Act (1991). Responsibility for their maintenance with regards to flood risk lies with the Lead Local Flood

Term	Definition
	Authority, or an Internal Drainage Board for some watercourses within an Internal Drainage District.
Orsted Hornsea Project Four Ltd.	The Applicant for the proposed Hornsea Project Four Offshore Wind Farm Development Consent Order (DCO).
Planning Inspectorate (PINS)	The agency responsible for operating the planning process for Nationally Significant Infrastructure Projects (NSIPs).
Planform	The planform evolution of meandering rivers occurs as a result of mutual adjustments between meandering form and processes.
Riparian	The area of land alongside a river, often planted with trees.
Sinuosity	Sinuosity, as applied to stream-channel pattern, is a non-dimensional ratio of the length of the channel thalweg to the length of the stream valley, measured between the same points.
Silt	As fluvial sediment, silt is sediment defined to be of particle diameter between 0.002 and 0.062 mm. Some systems define the lower size limit to be 0.004 mm.
Study area	A defined length/area of river for the geomorphological walkover survey along each of the watercourses identified for the project.
Sedimentation (Siltation)	The process by which sediment is mechanically deposited from suspension within a fluid, generally water, or ice, thereby accumulating as layers of sediment that are segregated owing to differences in size, shape, and composition of the sediment particles.
Scour	Removal of sediment such as sand and gravel.
Substrate	Sediment material that rests at the bottom of a river.
Thalweg	A line connecting the lowest points of successive cross-sections along the course of a valley or river.
Water Framework Directive	Directive of the European Parliament and of the Council 2000/60/EC establishing a framework for community action in the field of water policy (generally known as the Water Framework Directive (WFD).
Wetland	Wetland is a bottomland or low-lying area, including ephemeral-lake floors, at which water either is shallowly ponded on the surface or has a persistent (weeks or longer) near-surface condition of ground-water saturation adequate to support hydrophytic vegetation.

Acronyms

Acronym	Definition
DCO	Development Consent Order
EBI	Energy Balancing Infrastructure
OnSS	Onshore Substation
PEIR	Preliminary Environmental Information Report
PRoW	Public Right of Way
WFD	Water Framework Directive

Units

Unit	Definition
km	kilometres
m	Metre

1 Introduction

1.1.1.1 Orsted Hornsea Project Four Limited (the 'Applicant') is proposing to develop the Hornsea Project Four offshore wind farm (hereafter 'Hornsea Four'). Hornsea Four will be located approximately 69 km offshore the East Riding of Yorkshire in the Southern North Sea and will be the fourth project to be developed in the former Hornsea Zone. Hornsea Four will include both offshore and onshore infrastructure including an offshore generating station (wind farm), export cables to landfall, and on to an onshore substation (OnSS) with energy balancing infrastructure (EBI), and connection to the electricity transmission network.

1.1.1.2 Royal HaskoningDHV was commissioned to undertake a geomorphological baseline survey of the major watercourses proposed to be crossed by Hornsea Four. The baseline survey involved a walkover of ten key watercourses to establish and characterise the baseline conditions at those sites.

1.2 Aims

1.2.1.1 The aim of the geomorphological walkover survey was to characterise the geomorphological baseline conditions of the major watercourses that are proposed to be crossed by Hornsea Four.

1.2.1.2 Characterising the geomorphology of watercourses provides baseline information on their physical form and the processes (such as sediment transport and deposition) that may influence this form. This baseline information has been used to determine how the watercourses are likely to respond to the construction, operation and decommissioning of Hornsea Four. This baseline environment will then be used to inform the detailed design, construction and monitoring phases of Hornsea Four, to ensure the geomorphological and ecological integrity of these watercourses is maintained.

1.2.1.3 The purpose of this report is to present the baseline characteristics of the surveyed watercourses, and to provide an overall understanding of their existing condition against which potential impacts can be assessed. The baseline information gathered during this geomorphological walkover survey has been used to inform the assessments presented in **Volume A3, Chapter 2: Hydrology and Flood Risk**; and **Annex 2.3: Water Framework Directive Compliance Assessment**.

2 Methodology

2.1.1.1 This section presents the study areas and methodology used to undertake the field survey.

2.2 Study Area

2.2.1.1 Ten major watercourses which are proposed to be crossed by Hornsea Four were identified for the targeted geomorphological walkover survey, as set out in **Paragraph 2.2.1.3** and shown in **Figure 1**. The watercourses considered to be major are 'Main Rivers' and/or river water bodies identified under the Water Framework Directive (WFD) in the Humber River Basin Management Plan. By proxy, the catchments for these watercourses are also

proposed to contain elements of Hornsea Four, which means that there is potential for these watercourses to be affected either directly or indirectly during the construction, operation and decommissioning.

2.2.1.2 The identified Hornsea Four geomorphological baseline study area included the total length and area of each of the ten watercourses within the Hornsea Four pre-Development Consent Order (DCO) boundary (submitted at Preliminary Environmental Information Report (PEIR) (Orsted 2019)), as the area most likely to be affected by project activities such as temporary access crossings, and ground disturbance.

2.2.1.3 An additional 200 m upstream and downstream of the Hornsea Four pre-DCO boundary (submitted at PEIR) was also identified for survey. This additional area was surveyed to provide context of the wider geomorphology of the watercourse and to allow potential upstream and downstream effects to be considered and evaluated. For further details on any material changes between the Hornsea Four pre-DCO boundary and the Hornsea Four Order Limits see **Section 2.4**.

2.2.1.4 The ten watercourses identified for survey are listed below and are provided on **Figure 1**:

- Gransmoor Drain;
- Barmston Sea Drain;
- Foston Beck (also known as Lowthorpe Beck or Kelk Beck);
- White Dike;
- Driffield Navigation Canal;
- West Beck;
- Scurf Dike;
- Watton Beck;
- Bryan Mills Beck; and
- Scorborough Beck.

500000

520000

460000

440000

N

GRID NORTH

Gransmoor Drain

Barmston Sea Drain

Foston Beck

White Dike

Driffield Canal

River Hull

Scurf Dike

Watton Beck

Bryan Mills Beck

Scorborough Beck

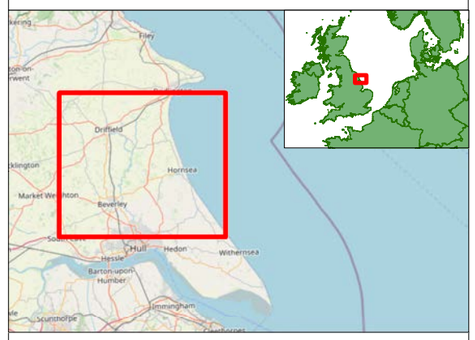
Date: 14/06/2021 Author: 303273 Name: HOW04RH0082_GEO_WalkoverSurveyStudyArea

Hornsea Four

Figure 1
Geomorphological Walkover Survey Study Area

Order Limits

Geomorphological Survey Locations



Coordinate system: British National Grid

Scale@A3: 1:130,000

0 1.5 3 6 Kilometres

0 0.75 1.5 3 Miles

REV	REMARK	DATE
	First Issue for PEIR	02/07/2019
A	Updated following PEIR consultations, for DCO	14/06/2021

Title: Geomorphological Walkover Survey Study Area
Document no: HOW04RH0082
Created by: AZ
Checked by: EH
Approved by: CS

Royal HaskoningDHV

Ørsted

2.3 Field Survey

2.3.1.1 The geomorphological walkover survey was undertaken in March 2019 using best-practice guidance for geomorphological characterisation and monitoring, including:

- Environment Agency (2007) – Geomorphological Monitoring Guidelines for River Restoration Schemes; and
- River Restoration Centre (2011) – Practical River Restoration Appraisal Guidance for Monitoring Options.

2.3.1.2 Following this best-practice guidance, a visual inspection was undertaken along the study area for each watercourse. The main characteristics of each watercourse were recorded from the bank top using ESRI Collector for ArcGIS software and all photographs taken with an iPhone 7 12 megapixel camera (ƒ/1.8 aperture 6-element lens). The following parameters were recorded in order to characterise the baseline geomorphology of each watercourse:

- Flow conditions - including dominant flow types and the degree of variability within each reach;
- Channel form - including planform, width and depth variation, bank form and condition, substrate types, and the type and presence of bed forms, such as pools, riffles and bars;
- Floodplain characteristics - including connectivity to the river channel and the structure of the riparian zone; and
- Evidence of channel modification -including enlargement and re-sectioning, artificial bank protection, embankments and in-channel structures.

2.3.1.3 The resulting data (see **Section 3**) on geomorphological conditions can subsequently be interpreted to provide insight into the dominant geomorphological processes operating in each reach (e.g. erosion, sediment transport, or deposition) and infer how each watercourse is likely to respond to the potential effects from Hornsea Four.

2.4 Survey limitations

2.4.1.1 The survey was undertaken in March 2019. The findings of the walkover survey were not limited by vegetation growth, turbidity or high flows, and as such the visibility of the bed and banks of each watercourse was sufficient for their overall geomorphological characteristics to be described.

2.4.1.2 Access to parts of Gransmoor Drain and Bryan Mills Beck was restricted at the time of the survey. It was possible to access a large proportion of each reach and adjacent areas upstream and downstream. Field observations were further validated against aerial photography of inaccessible parts of each reach. These restrictions are therefore not considered to have limited the geomorphological characterisation of these water bodies.

2.4.1.3 The walkover survey that was undertaken in March 2019 to classify the baseline geomorphology of the main rivers along the proposed onshore ECC covered the pre-DCO

boundary (submitted at PEIR). The Hornsea Four Order Limits has since been refined and updated. As a result, the section of the Driffield Canal (ref ECC.1.19, detailed in **Volume A1, Chapter 3: Site Selection and Consideration of Alternatives**) which had previously fallen within the Hornsea Four geomorphological survey area now only lies partially within the Hornsea Four Order Limits (see inset in **Figure 1**). However, the reach of the Driffield Canal which was surveyed in March 2019 and still partially covers the Hornsea Four Order Limits in this location, was found to support very uniform geomorphology and flow conditions. Given the artificial nature of the watercourse, the area surveyed within the Hornsea Four Order Limits it is considered to be representative of the geomorphological characteristics of the wider canal. All other watercourse crossing locations are unaffected by the refined Hornsea Four Order Limits.

3 Results

3.1 Gransmoor Drain

3.1.1.1 The details of the watercourse are presented in **Table 1** and the results of the walkover survey are presented in **Table 2**. It should be noted that it was not possible to walk along the entire study area at this location because access to parts of the watercourse study area were restricted at the time of the survey. However, it was possible to access a large proportion of the study area and therefore this restriction did not prevent the geomorphological characterisation of this water body. For further details on survey limitations see **Section 2.4**.

Table 1: Details of Gransmoor Drain.

WFD Water Body	Gransmoor Drain
Water Body ID	GB104026066630
Watercourse Type	Ordinary Watercourse
Grid Reference	TA1476558967

Table 2: Geomorphological Walkover of Gransmoor Drain.

Parameter	Details
Overview	Gransmoor Drain consists of a uniform incised channel that has been artificially straightened and incised adjacent to arable farmland (**Plate 1**). 

Parameter	Details
	Plate 1: Gransmoor Drain.
Channel Form	The channel has a straight planform. The banks are relatively steep, approximately 1 m – 2 m high, stable and well vegetated in places. Although large sections of bare banks are a feature throughout the study area. The channel is approximately 7 m – 10 m wide at the bank top; and 5 m wide at the bank base, displaying a typical U shape uniform channel (Plate 1). The substrate is dominated by sands and silts and appears to be a typical sediment deposition zone, with slow flows, low gradients and low velocities contributing to the settling out of fine sediments/silts.
Substrate Conditions	The substrate is dominated by silts. Although a proportion is likely to be derived from exposed banks during higher-energy flows, the majority of the fine sediment load is likely to be sourced from the agricultural catchment upstream.
Flow Conditions	The wide, straight uniform channel of Gransmoor Drain is characterised by low energy glide flows, with limited flow diversity or in channel features observed.
Floodplain Characteristics	Floodplain connectivity is likely to be constrained at lower flows due to the deeply incised nature of the channel.
In-channel / Riparian Vegetation	The banks and margins are well vegetated in places with rushes (*Juncaceae spp.*), sedges (*Cyperaceae spp.*) and reeds (*Phragmites spp.*). Some in-channel aquatic vegetation growth was also recorded in the silt substrate.
Modifications / Structures	The channel is deeply incised and is likely to have been historically re-sectioned and enlarged for land drainage purposes.

3.2 Barmston Sea Drain

3.2.1.1 The details of the water body are presented in Table 3 and the results of the walkover survey are presented in Table 4.

Table 3: Details of Barmston Sea Drain.

WFD Water Body	Barmston Sea Drain / Skipsea Drain to Confluence
Water Body ID	GB104026077770
Watercourse Type	Ordinary Watercourse
Grid Reference	TA131568

Table 4: Geomorphological Walkover of Barmston Sea Drain.

Parameter	Details
Overview	The Barmston Sea Drain is approximately 15 km in length with a predominately straight planform. The channel displays very limited flow and geomorphological diversity, although large wetland features are evident on the floodplain directly north of the drain (Plate 2). However, overall the Barmston Sea Drain within the study area is typical of a large modified drainage system, with a uniform channel shape and incised as a result of historical re-sectioning and enlargement for land drainage purposes (Plate 2).  **Plate 2: Barmston Sea Drain.**
Channel Form	The channel has a straight planform. The banks are relatively steep, approximately 1 m – 2 m high, stable and well vegetated in places throughout the study area. The channel is approximately 7 m – 10 m wide at the bank top; and 7 m wide at the bank base, displaying a typical U-shape style channel (Plate 2). The substrate is dominated by sands and silts and appears to be a typical sediment deposition zone with slow flows, low gradients and low velocities contributing to the settling out of fine sediments/silts.
Substrate Conditions	As stated above, the substrate is dominated by silts. Some local erosion of banks was evident alongside field drainage pipes and overland flow, all of which appear to contribute to local siltation of the channel bed within the study area (Plate 3). However, the dominant source of fine sediments appears to be associated with upstream land management practices.  **Plate 3: Discharge from field drain into Barmston Sea Drain.**

Parameter	Details
Flow (Habitat) Conditions	The wide, straight uniform channel is characterised by low energy glide flows, which were observed throughout the study area, with limited flow diversity or in-channel features.
Floodplain Characteristics	Large floodplain wetland systems (Plate 2 and Plate 4) suggest that there is a good degree of floodplain connectivity in parts of the study area.  Plate 4: Wetland on the floodplain of the Barmston Sea Drain.
In-channel / Riparian Vegetation	The banks and margins are well vegetated with rushes, sedges and reeds. There is some in-channel aquatic vegetation, although the vegetation is heavily silted (Plate 3).
Modifications / Structures	The channel is deeply incised and is likely to have been historically re-sectioned and enlarged for land drainage purposes.

3.3 Foston Beck

3.3.1.1 The characteristics of Foston Beck (also known as Lowthorpe Beck or Kelk Beck) are described in Table 5 and the results of the walkover survey are presented in Table 6.

Table 5: Details of Foston Beck.

WFD Water Body	Lowthorpe/Kelk/Foston Beck from Source to Frodingham Beck
Water Body ID	GB104026067101
Watercourse Type	Main River
Grid Reference	TA092551

Table 6: Geomorphological Walkover Survey Foston Beck.

Parameter	Details
Overview	The Foston Beck is chalk river approximately 13 km in length with a predominately straight planform. The channel displays limited flow and geomorphological diversity, although in places

Parameter	Details
	a two-stage channel is a feature (Plate 5). However, overall Foston Beck within the study area is typical of a large modified drainage system, with a uniform channel shape and bounded by embankments (Plate 5).  **Plate 5: Foston Beck.**
Channel Form	The channel has a straight planform. The banks are relatively steep, approximately 1 m high, stable and well vegetated in places throughout the study area. The channel is approximately 7 m – 10 m wide at the bank top; and 7 m wide at the bank base, displaying a two-stage channel in places, with a low flow channel and aligned with flood embankments (Plate 5). The substrate is dominated by sands and silts, resultant of a typical sediment deposition zone, with slow flows, low gradients and low velocities contributing to the settling out of fine sediments / silts. Limited exposures of the natural course substrates that would typically be expected in a chalk river were observed in this reach.
Substrate Conditions	Temporary and semi-permanent fine channel deposits are present within the study area, as well as coarse deposits. Fine sediment deposits are mainly in the form of toe accumulation interspersed between marginal vegetation, with berm establishment in places. However, the channel is dominated by a silty flat bed, which may be the reason for the lack of aquatic vegetation within the study area. ·There is extensive fluvial erosion (toe scour) in places, although there was no evidence of geotechnical bank failure present during the time of the survey. There was also evidence of field drain outfalls and eroded access banks adjacent to arable land (Plate 6).

Parameter	Details
	 **Plate 6: Sources of sediment to Foston Beck.**
Flow Conditions	The wide, straight channel is characterised by low energy glide flows, which were observed throughout the study area, with some flow diversity and in-channel features.
Floodplain Characteristics	Foston Beck does appear to be constrained within the flood embankments. As such, limited floodplain connectivity along the beck was observed throughout the study area.
In-channel / Riparian Vegetation	The banks and margins are well vegetated with rushes, sedges and reeds. In places emergent aquatic vegetation in the channel was noted, although obscured by silt deposition (**Plate 7**). The submerged vegetation cover varies from 5% to 40% throughout the study area.  **Plate 7: In-channel vegetation growth in Foston Beck.**

Parameter	Details
Modifications / Structures	The Foston Beck is aligned with a flood embankment along both channel banks of the beck. It is predominantly straight and is likely to have been historically re-sectioned and enlarged for land drainage purposes.

3.4 White Dike

3.4.1.1 The details of the water body are summarised in Table 7 and the results of the walkover survey are presented in Table 8.

Table 7: Details of White Dike.

WFD Water Body	Lowthorpe/Kelk/Foston Becks from Source to Frodingham Beck
Water Body ID	GB104026067101
Watercourse Type	Ordinary Watercourse
Grid Reference	TA087550

Table 8: Geomorphological Walkover Survey of White Dike.

Parameter	Details
Overview	White Dike within the study area is a uniform, incised channel that has been artificially straightened and aligned with flood embankments adjacent to arable farm land (Plate 8). The channel is dominated by glide flows and silt deposition. No major sediment sources were noted, although drainage outfalls from the adjacent fields were noted, with possible local bank scour from bridge abutments. The dominant source of fine sediments appears to be associated with upstream land management.  **Plate 8: White Dike.**
Channel Form	The channel has a straight planform and uniform morphology with a flat bed. The banks are relatively steep, approximately 1 m high, stable and well vegetated in places throughout the study area. The channel is approximately 7 m – 10 m wide at the bank top; and 6 m wide at the bank base. Both banks are aligned with flood embankments (Plate 8). The channel within the study area appears to be of a typical sediment deposition zone, with slow flows, low gradients and low velocities contributing to the settling out of fine sediments / silts along a flat bed with limited geomorphological complexity (Plate 9).

Parameter	Details
	 **Plate 9: Silt deposition and field drain outfall in White Dike.**
Substrate Conditions	The substrate is dominated by sands and silts, although silts / fine sediments are the main substrate material overlying the sands. No major sediment sources were noted, although outfalls from the adjacent fields were noted, with possible local bank scour from bridge abutments. The dominant source of fine sediments appears to be associated with upstream land management.
Flow Conditions	The wide, straight uniform channel is characterised by low energy glide flows, which were observed throughout the study area, with limited flow diversity or in-channel features.
Floodplain Characteristics	White Dike appears constrained within the flood embankments and as such, a limited floodplain area was observed throughout the study area.
In-channel / Riparian Vegetation	The banks and margins are well vegetated with rushes, sedges and reeds. There was some in-channel aquatic vegetation, although heavily silted (Plate 8).
Modifications / Structures	White Dike is lined with a flood embankment along both channel banks of the beck. It is predominantly straight and is likely to have been historically re-sectioned and enlarged for land drainage purposes.

3.5 Driffield Navigation Canal

3.5.1.1 The details of the water body are summarised in Table 9 and the results of the walkover survey are presented in Table 10.

Table 9: Details of the Driffield Navigation.

WFD Water Body	Driffield Navigation
Water Body ID	GB70410028
Watercourse Type	Main River
Grid Reference	TA075539

Table 10: Geomorphological Walkover Survey of Driffield Navigation.

Parameter	Details
Overview	The Driffield Navigation Canal is approximately 8 km in length with a predominately straight planform. Within the study area, the canal has uniform flow, medium gradient, gravelly bed with localised silt with bank material predominantly fine grained. The bed is dominated by sandy clay with a large proportion of silt in places. Both banks generally have vegetated graded profiles aligned with flood embankments, with a public right of way (PRoW) (and access track) following the left bank of the canal (**Plate 10**). The Driffield Navigation Canal within the study area is popular for recreational fishing, with some minor bank protection works evident in the study area.  **Plate 10: Driffield Navigation.**
Channel Form	The channel has a largely straight planform. The fine-grained banks are relatively steep, approximately 1 m – 2 m high, stable and well vegetated in places throughout the study area. The channel is approximately 10 m – 12 m wide at the bank top; and 7 m wide at the bank base, displaying a wide and deep channel profile (**Plate 11**).

Parameter	Details
	 **Plate 11: Wide and deep channel of the Driffield Canal.**
Substrate Conditions	The substrate is dominated sandy clay with a large proportion of silt in places; and appears to be a typical sediment deposition zone, with slow flows, low gradients and low velocities contributing to the settling out of fine sediments / silts. The majority of channel-edge deposits are formed by toe accumulation, interspersed between trapping by marginal vegetation. There are a large number of temporary fine channel deposits. Some fluvial erosion (toe scour) on both banks throughout the study area was evident along with field drains and access tracks providing a sediment source to the watercourse (Plate 12).  **Plate 12: Sources of sediment to the Driffield Canal.**
Flow Conditions	The wide, straight channel is characterised by low energy glide flows, which were observed throughout the study area, with limited flow diversity or in-channel features.
Floodplain Characteristics	The Driffield Navigation Canal does appear constrained within the flood embankments. As such limited floodplain connectivity along the beck was observed throughout the study area. Parts of the floodplain are tilled to within metres of the watercourse.

Parameter	Details
In-channel / Riparian Vegetation	The banks and margins are well vegetated with rushes, sedges and reeds. In places emergent aquatic vegetation in the channel was noted, although obscured by silt deposition (Plate 13).  **Plate 13: Marginal vegetation growth within the Driffield Canal.**
Modifications / Structures	The Driffield Navigation is lined with a flood embankment along both channel banks, predominantly straight and with an enlarged channel. Local bank protection and boat moorings are present (Plate 14).  **Plate 14: Structures on the banks of the Driffield Navigation*.** **(note the tilled land adjacent to the bank)*

3.6 West Beck

3.6.1.1 The details of the water body are summarised in Table 11 and the results of the walkover survey are given in Table 12.

Table 11: Water body details for West Beck.

WFD Water Body	West Beck Lower to River Hull
Water Body ID	GB104026067040
Watercourse Type	Main River
Grid Reference	TA0649452895

Table 12: Geomorphological Walkover Survey of West Beck.

Parameter	Details
Overview	West Beck within the study area is predominantly meandering and has been historically over-deepened and over-widened for navigation purposes. As a result, the river is very deep, with steep banks and uniform flow conditions (Plate 15). The channel is largely bordered by flood embankments. Large parts of the banks are exposed, although there is localised tree and good wet woodland and backwaters (Plate 16). Cleaves Weir is located upstream of the study area.

Plate 15: West Beck.

Plate 16: Wet woodland and backwater on West Beck.

Parameter	Details
Channel Form	Within the study area, West Beck is very deep with steep banks and uniform flow conditions (Plate 15). The channel is approximately 15 m wide at the bank top; and 8 m wide at the bank base with a good degree of geomorphological complexity in places, in particular, adjacent to the farm building. The study area is surrounded by arable farming, with flood embankments lining the river (Plate 15).
Substrate Conditions	Within the study area, the West Beck Lower has a medium gradient and a silty bed with occasional fine and coarse gravel. ·Bank material is fine grained, dominated by sandy gravelly clay with localised silt. Both banks display a predominantly vegetated graded profile and as stated aligned with flood embankments.
Flow Conditions	The West Beck study area is characterised by uniform laminar flow, contributing to the settling of fine silts on the bed and overall depositional nature of the study area (Plate 17). Only minor sediment sources were noted along the study area (e.g. bank erosion), suggesting that the majority of the sediment load is derived from the upstream catchment.  **Plate 17: Fine Sedimentation on the bed of West Beck.**
Floodplain Characteristics	Within the study area, the river is constrained within the flood embankments. As such, limited floodplain connectivity along the river was observed throughout the study area.
In-channel / Riparian Vegetation	The banks and margins are well vegetated with rushes, sedges and reeds. In places emergent aquatic vegetation in the channel was noted, although obscured by silt deposition (Plate 17).
Modifications / Structures	There is no bank protection within the study area, although the river is lined with flood embankments. Upstream of the study area is Cleaves Weir (potentially in place as a fish passage barrier).

3.7 Scurf Dike

3.7.1.1 The details of the water body are presented in Table 13, and the results of the walkover survey are presented in Table 14.

Table 13: Water Body Details for Scurf Dike.

WFD Water Body	Scurf Dike
Water Body ID	GB104026067010
Watercourse Type	Main River
Grid Reference	TA0504550736

Table 14: Geomorphological Walkover Survey of Scurf Dike.

Parameter	Details
Overview	Scurf Dike within the study area is a uniform incised channel that has been artificially straightened and is lined with flood embankments (Plate 18). The channel is dominated by glide flows and silt deposition. No sediment sources were noted along the study area suggesting a dominant source of fine sediments is associated with land and catchment management.  **Plate 18: Scurf Dike.**
Channel Form	The channel has a straight planform and uniform channel with a flat bed. The banks are relatively steep, approximately 0.7 m high, stable and well vegetated in places throughout the study area. The channel is approximately 7 m – 10 m wide at the bank top, and 6 m wide at the bank base. Both banks are aligned with flood embankments (Plate 18 and Plate 19). The channel within the study area appears to be of a typical sediment deposition zone, with slow

Parameter	Details
	flows, low gradients and low velocities contributing to the settling out of fine sediments / silts along a flat bed, with limited geomorphological complexity (Plate 19).  Plate 19: Fine siltation on the bed of Scurf Dike.
Substrate Conditions	The substrate is dominated by sands and silts. Although silts / fine sediments are the main substrate material overlying the sands, the water was generally clear at the time of the walkover survey, despite this high silt content. No sediment sources were noted along the study area, suggesting a dominant source of fine sediments is associated with land and catchment management.
Flow Conditions	The wide, straight uniform channel is characterised by low energy glide flows, which were observed throughout the study area, with limited flow diversity or in channel features.
Floodplain Characteristics	Scurf Dike appears to be constrained within the flood embankments and as such, limited floodplain connectivity along the beck was observed throughout the study area.
In-channel / Riparian Vegetation	The banks and margins are well vegetated with rushes, sedges and reeds (Plate 20).

Parameter	Details
	 Plate 20: Marginal vegetation growth within Scurf Dike.
Modifications / Structures	The Scurf Dike is lined with a flood embankment along both channel banks of the beck. The Scurf Dike is predominantly straight and is likely to have been historically re-sectioned and enlarged for land drainage purposes.

3.8 Watton Beck

3.8.1.1 The details of the water body are summarised in Table 15 and the results of the walkover survey are presented in Table 16.

Table 15: Water body details for Watton Beck.

WFD Water Body	Watton Beck
Water Body ID	GB104026066980
Watercourse Type	Main River
Grid Reference	TA0184249746

Table 16: Geomorphological Walkover Survey of Watton Beck.

Parameter	Details
Overview	The Watton Beck is approximately 11 km in length with a predominately straight planform. The channel displays limited flow and geomorphological diversity, although in places a two-stage channel is a feature of the Watton Beck (Plate 21). However, overall the Watton Beck within the study area is typical of a modified drainage system, with uniform channel shape and aligned with embankments (Plate 21).

Parameter	Details
	 **Plate 21: Watton Beck.**
Channel Form	The channel has a straight planform and the banks are relatively steep at approximately 1 m high. They are stable and well vegetated in places throughout the study area. The channel is approximately 7 m – 10 m wide at the bank top, and 5 m wide at the bank base, displaying a two-stage channel in places with a low flow channel and aligned with embankments (**Plate 21** and **Plate 22**). The substrate is dominated by sands and silts and appears to be of a typical sediment deposition zone, with slow flows, low gradients and low velocities contributing to the settling out of fine sediments/silts.  **Plate 22: Low flow channel in Watton Beck.**
Substrate Conditions	As stated above, the substrate is dominated by sands and silts. The overall quality of water reflects the high silt content influencing turbidity levels. No sediment sources were noted along the study area, suggesting a dominant source of fine sediments is associated with land and catchment management.

Parameter	Details
Flow Conditions	The wide, straight channel is characterised by low energy glide flows, which were observed throughout the study area, with limited flow diversity or in-channel features.
Floodplain Characteristics	The Watton Beck appears constrained within the flood embankments and as such, limited floodplain connectivity along the beck was observed throughout the study area.
In-channel / Riparian Vegetation	The banks and margins are well vegetated with rushes, sedges and reeds; and in places emergent aquatic vegetation in the channel was noted, although obscured by silt deposition.
Modifications / Structures	The Watton Beck is lined by a flood embankment along both channel banks of the beck. The Watton Beck is predominantly straight and is likely to have been historically re-sectioned and enlarged for land drainage purposes.

3.9 Bryan Mills Beck

3.9.1.1 The details of the water body are summarised in Table 17 and the results of the walkover survey are presented in Table 18. It should be noted that it was not possible to walk along the entire study area at this location because access to parts of the study area was restricted at the time of the survey. However, it was possible to access a large proportion of the study area and therefore this restriction did not prevent the geomorphological characterisation of this water body. For further details on survey limitations see Section 2.4.

Table 17: Water Body details for Bryan Mills Beck.

WFD Water Body	Bryan Mills Beck Source to Bryan Mills Farm
Water Body ID	GB104026066960
Watercourse Type	Ordinary Watercourse
Grid Reference	TA1476558967

Table 18: Geomorphological Walkover Survey of Bryan Mills Beck.

Parameter	Details
Overview	Bryan Mills Beck displays a sinuous planform, although incised adjacent to arable farming in places (Plate 23).  **Plate 23: Bryan Mills Beck.**
Channel Form	The channel has a sinuous planform and although similar to Gransmoor Drain, the beck is deeply incised, with a 2 m - 3 m bank base, 5 m bank top and steep well vegetated banks up to 2 m in places (Plate 23). The beck does display a variety of in-channel features, such as riffles, bars with variety of geomorphological processes occurring such as deposition and erosion.
Sediment	Substrate is dominated by silts, with a dominant source of fine sediments which appears to be associated with land and catchment management along with exposed banks (as can be observed in Plate 23).
Flow (Habitat) Conditions	The Bryan Mills Beck displays a variety of flow habitats, such as deep riffles and glides.
Floodplain Characteristics	It appears connectivity with the floodplain is constrained within the deep incised channels.
In-channel / Riparian Vegetation	The banks and margins are well vegetated in places with rushes, sedges and reed; and some in-channel aquatic vegetation, although these were heavily silted.
Modifications / Structures	For both sites, the channels are deeply incised in places and are likely to have been historically enlarged (although a degree of natural recovery is apparent).

3.10 Scorborough Beck

3.10.1.1 The details of the water body are summarised in Table 19 and the results of the walkover survey are presented in Table 20.

Table 19: Water body details for Scorborough Beck.

WFD Water Body	Scorborough Beck
Water Body ID	GB104026066901
Watercourse Type	Ordinary Watercourse
Grid Reference	TA1476558967

Table 20: Geomorphological walkover of Scorborough Beck.

Parameter	Details
Overview	Scorborough Beck is a chalk river approximately 8 km in length with a straight to moderately sinuous planform. The channel displays flow and geomorphological diversity in places. In particular, through Bealey's Plantation and Lakes Wood which encompass the study area. Springs are a dominant feature in Bealey's Plantation and Lakes Wood which contribute to the crystal-clear waters flowing through the study area (Plate 24).  **Plate 24: Scorborough Beck.**

Parameter	Details
Channel Form	The channel has a straight to moderately sinuous planform. The banks are relatively shallow, approximately 0.5 m to 1 m high, stable and well vegetated in places throughout the study area. The channel is approximately 5 m to 7 m wide at the bank top, and 3 m to 5 m wide at the bank base, displaying diversity in the channel width-depth ratio of the Scorborough Beck. The substrate is dominated by sands, gravels and organic matter with only localised deposits of silts noted at low flow velocity zones, such as the channel margins and in the lee of emergent aquatic vegetation. This was predominately associated with tree roots undercutting the banks, and local bank erosion during high flows (Plate 25).

Plate 25: Localised bank erosion on Scorborough Beck.

The Scorborough Beck within the study area is influenced by a north-south running field drain, which is narrow and well vegetated in places, with steep, uniform banks and overall trapezoidal shape. The drain contained water at the time of the fluvial walkover, although does not appear to support regular flows (Plate 26)

Plate 26: Field drain connected to Scorborough Beck.

Parameter	Details
Substrate Conditions	As stated above, the substrate is dominated by sands, gravels and organic matter. The clear water reflects the spring fed Scorborough Beck within the study area and the low sediment yield from the surrounding catchment.
Flow Conditions	Flows are dominated by low energy glides and riffles, providing good flow diversity along the Scorborough Beck within the study area (Plate 27).  Plate 27: Evidence of flow diversity within Scorborough Beck.
Floodplain Characteristics	The floodplain on both banks are associated with Bealey's Plantation and Lakes Wood and arable agriculture, with the Scorborough Beck generally not constrained with good floodplain connectivity.
In-channel / Riparian Vegetation	The banks are well vegetated with riparian trees, with fringes of healthy emergent aquatic vegetation in the channel. Wet woodland is also a feature as part of Bealey's Plantation and Lakes Wood.
Modifications / Structures	The study area does contain structures in the form of PRoW foot bridges; vehicle access bridge supports; and discharge (field) pipes. Although no direct evidence of channel modification was noted during the fluvial walkover.

4 Summary

4.1 Main survey findings

4.1.1.1 The geomorphological walkover survey has demonstrated that watercourses in the study area predominantly consist of lowland, low gradient channels that have been extensively modified in the past (largely for land drainage or navigation purposes). As a result, these watercourses have straightened planforms with re-sectioned and enlarged channels that support limited geomorphological diversity and largely uniform flow conditions. These channels are frequently deeply incised, and their large capacity and low energy are

combined with high sediment loadings from contributing catchments, therefore encouraging fine sedimentation on the bed.

4.1.1.2 Several of the watercourses, principally those in the upper River Hull catchment (including Foston Beck, White Dike and West Beck) are chalk rivers. Although these watercourses have also been extensively modified and do not necessarily display typical chalk river characteristics in their respective study areas summarised in this report.

4.1.1.3 The results of the walkover survey have been used to inform the baseline assessment presented in **Volume A3, Chapter 2: Hydrology and Flood Risk**. The results have also been used as the basis of the assessment of potential project impacts on the geomorphology and physical habitat condition of surface waters presented in **Volume A3, Chapter 2: Hydrology and Flood Risk**; and the assessment of potential impacts on the hydromorphological quality elements supported by river water bodies presented in **Annex 2.3: Water Framework Directive Compliance Assessment**. Further discussion regarding the outcomes of this survey and the implications for the project are provided in these reports.

5 References

Environment Agency (2007) Geomorphological Monitoring Guidelines for River Restoration Schemes. Available online: https://www.therrc.co.uk/MOT/References/EA_Geomorphological_monitoring_guidelines.pdf (Accessed 5 May 2019).

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