A47/A11 Thickthorn Junction

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6.3 Environmental Statement Appendices
Appendix 13.5 – Geomorphology Assessment Report

APFP Regulation 5(2)(a)

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Infrastructure Planning

Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

The A47/A11 Thickthorn Junction Development Consent Order 202[x]

ENVIRONMENTAL STATEMENT APPENDICES
Appendix 13.5 – Geomorphology Assessment Report

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1. Introduction

1.1.1. This report will describe the geomorphological setting of Cantley Stream that may be impacted by the construction of the Proposed Scheme at the A47/A11 Thickthorn Junction. The survey was carried out to assess the current geomorphic setting of the watercourse. The surveys also assessed any impacts due to realignment and other pressures, sediment transport potential and other factors.

1.1.2. The morphological stability is assessed in terms of proposed infrastructure in the vicinity of the watercourse, with construction and operational impacts discussed and mitigation measures proposed, where required.

2. Methods

2.1. Approach

2.1.1. A fluvial audit of the Cantley Stream watercourse was undertaken. This involved both a desktop assessment and a walkover survey, the methods of both are summarised in section 2.3. Guidance on designing the geomorphic walkover survey was taken from the DMRB LA 113 on 'hydromorphological assessment' (Highways England, 2020).

2.2. Desktop review

2.2.1. A desktop review of background and historical information related to the catchment watercourses was undertaken to characterise the geological setting of the catchment.

2.2.2. The following information sources were reviewed as part of the desktop assessment:

- superficial and bedrock geology maps of the catchment area from the British Geological Survey (BGS, 2020)
- historical Ordnance Survey (OS) maps from the National Library of Scotland (NLS, 2020)
- historical air photos and satellite imagery
- Water Framework Directive (WFD) monitoring data for the catchment (Environment Agency, 2020)

2.3. Geomorphic walkover surveys

2.3.1. The walkover surveys were undertaken to ground truth evidence of geomorphic change or instability that may be impacted by the construction of the Proposed Scheme. Dominant geomorphic processes occurring on each river reach were also identified to ensure baseline conditions are adhered to, or improved upon, as far as possible.

2.3.1. The geomorphology competent expert (PhD, MSc, BSc (Hons)) has 12 years of experience in the water sector and has successfully delivered many geomorphological studies and reports, supporting technical assessments for large infrastructure projects.

2.3.2. The walkover surveys were conducted in March 2018 with a further visit in May 2020, with approximately 2.2km of the Cantley Stream surveyed (from Cantley Stream Pond to Intwood Lane – Appendix A). A field tablet computer loaded with ArcGIS Collector was used to record key geomorphic features, processes and anthropogenic pressures whilst walking the length of the river. This approach enabled the production of more accurate mapping of the extent and location of features using the tablet's global positioning system (GPS) receiver. Subsequently, recorded features were automatically uploaded to a geographic information system (GIS) system.

2.3.3. The following information was recorded during the walkover surveys:

- typology of the river and whether this differed from what the predicted natural typology would be (see Table 2-1)
- the stability status of the channel, which characterises the dominant processes occurring within the reach (see Table 2-2 and Table 2-3)
- substrate of the channel
- significant areas of bank erosion or basal scour
- significant areas of deposition
- sources and type of sediment input to the channel (for example landslides, rock fall, bank erosion, tributary streams, poaching)
- anthropogenic pressures on the channel (for example bridges, bank protection, weirs, realignments, invasive species)

Table 2-1 Description of typologies used

Typology	Characteristics
Bedrock	Typically, steep gradient, bed and channel banks show significant areas of obvious bedrock. Cobbles and gravels may exist on the bed also. No floodplain development
Step-pool	Gradient still generally steep, with little floodplain development. Channel has regular or semi-regular well-developed steps, separated typically by pools. Substrate typically composed of large cobbles and boulders, with some gravels.
Plane-bed	A transitionary typology between step-pool and pool-riffle. Typically, moderate gradient, with some floodplain development, but channel often incised below floodplain. Featureless bed often armoured with cobbles. Irregular steps, and irregular bars might be present, as well as a relatively straight planform.
Pool-riffle	Generally shallow gradient, and a relatively wide floodplain. Planform becomes sinuous, with more obvious depositional features such as bars, and more signs of erosion on banks.
Active-meander	Shallow gradient, with a wide floodplain. Extensive depositional and erosional features, and well-developed meanders leading to a sinuous planform.

2.3.4. It is noted that in practice, rivers sometimes go through a transitionary reach between typologies, or can be 'more' one typology than another. In these cases,

it falls to the expert judgment of the geomorphologists surveying the watercourse to understand which typology is more dominant.

2.3.5. A visual assessment of the dominant processes occurring on each reach were classified based on the criteria outlined in Table 2-2. This involved recording observations of erosional or depositional processes occurring within the channel.

2.3.6. Table 2-3 lists the observations and assessments conducted as part of the ST:REAM survey (Sediment Transport: Reach Equilibrium Assessment Method) to determine the stability status.

Table 2-2 Criteria for classification of dominant processes

Stability status	Characteristics
Erosional source	No evidence of deposition, only erosion.
Erosional exchange	Erosion dominant, but some small-scale depositional features present.
Balance exchange	Evidence of both deposition and erosion are both present on the reach.
Balance transport	Limited evidence of either deposition or erosion observed (generally bedrock channels or heavily modified channels have this classification)
Depositional exchange	Depositional features dominant, but some evidence of erosion observed.
Depositional sink	Only depositional features present (typically approaching lakes or confluences)

Table 2-3 Field observations indicating erosion or depositional dominant channels (Parker et al., 2015)

Dominant process	Indicators
Erosion	Terraces Old channels in floodplain Undermined structures Exposed tree roots Tree collapse (both banks) Trees leaning towards channel (both banks) Drowned trees in channel Narrow/deep channel Bank failures (both banks) Thick gravel exposure in the banks overlain by fines Armoured compacted bed
Deposition	Buried structures Buried soil horizons Many uncompacted ‘over loose’ bars Eroding banks at shallows Contracting bridge openings Deep, fine sediment overlying coarse particles in bed/banks Many unvegetated bars

3. Geomorphology surveys

3.1. Introduction

3.1.1. The following section describes the geomorphology survey undertaken noting the geomorphological conditions and any modifications to the channel which may impact on the geomorphic stability.

3.2. Overview of chalk stream geomorphology

3.2.1. It is estimated that of a recognised 210 ‘true’ chalk streams on Earth, 160 of them are in England (Berrie, 1992). This makes them exceedingly rare and sensitive habitats. The River Yare and its tributaries (including the Cantley Stream) are included in this short list, and thus have special geomorphological properties to be considered as part of the construction and operation of the Proposed Scheme.

3.2.2. The geomorphology of chalk streams, due to their relative rarity, have not had a significant volume of research conducted on them compared to other forms of watercourse. However, it is generally understood that flow in chalk streams is primarily fed by groundwater sources, which creates a relatively persistent flow with large, high-energy floods a rarity. As such, chalk streams have a limited ability to migrate across their floodplain. They generally have gravel beds and are considered sensitive to changes in siltation.

3.3. Cantley Stream

3.3.1. Cantley Stream originates approximately 3km south west of the A47/A11 Thickthorn Junction and flows generally eastward towards the western boundary of Norwich where it joins Intwood Stream, a tributary of the River Yare. It is approximately 5.5 km in length, flowing mainly through agricultural land, except for a small area of woodland south of Cringleford.

3.3.2. The stream appears to have undergone significant historic realignment prior to 1881, likely for the purposes of improving agricultural drainage and creating straight field boundaries. This is an assumption based on the appearance and location of the majority of the stream due to its planform. Historic Ordnance Survey maps dating back to 1881 were reviewed, however no major planform adjustments were observed. Some minor adjustments and culverting of the channel due to road construction can be observed by comparing historic maps with recent aerial imagery of the site.

3.4. Water Framework Directive (WFD) Classification

3.4.1. The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 requires that all groundwater and surface waterbodies achieve 'good' ecological status (or 'good' ecological potential for a heavily modified water body). This classification requirement is expected to continue beyond the United Kingdom leaving the EU. To achieve 'good' status overall, a water body must achieve good status in all the River Basin Management Plan (RBMP) assessment criteria (biological, hydro-morphological, physio-chemical and chemical quality), therefore, a deterioration in one of these criteria may result in the water body failing to meet the WFD objectives.

3.4.2. The Cantley Stream, being classified as an ordinary watercourse, is not a WFD water body in its own right. However, its ecological and chemical status will have an impact on the Intwood Stream WFD water body (GB105034051240) catchment status of which Cantley Stream is a part.

3.4.3. Based on the 2019 status, the current Anglian RBMP, as shown by the Environment Agency's Catchment Data Explorer website (Environment Agency, 2020) indicates that the Intwood Stream WFD water body overall classification is 'moderate'. The Intwood Stream is a heavily modified water body, with the WFD water body ecological potential being limited to 'moderate' by the physico-chemical quality elements ('moderate' potential for phosphate). The chemical status is classified as a 'fail', due to the presence of a priority hazardous substance, namely, polybrominated diphenyl ethers.

3.4.4. Table 3-1 below lists the reasons for the Intwood Stream not achieving 'good' overall status.

Table 3-1 Intwood Stream WFD water body (WBID: GB105034051240) Reasons for Not Achieving Good Status (Environment Agency, 2020)

Reason Type	Significant Water Management Issues (SWMI)	SWMI Certainty	Activity	Activity Certainty	Category	Category Certainty	Business Sector	Classification Element
RNAG	Point source	Confirmed	Sewage discharge (continuous)	Confirmed	Water Industry	Confirmed	Not applicable	Phosphate
RNAG	Diffuse source	Probable	Poor soil management	Probable	Agriculture and rural land management	Probable	Agriculture – Arable	Phosphate

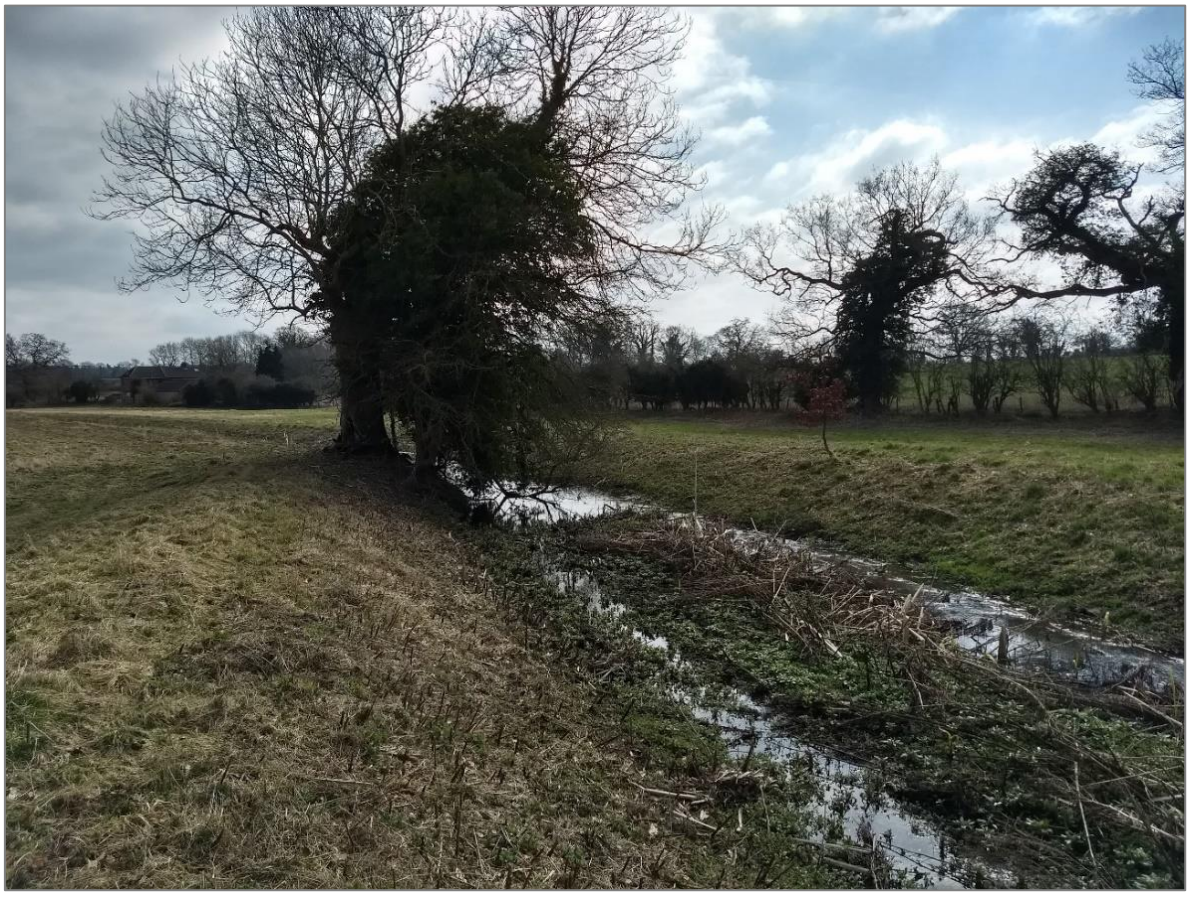
3.4.5. With respect to the Proposed Scheme, it can be seen that the existing WFD status is unaffected by any recorded instances of pollution from transportation infrastructure sources and the reasons for not achieving good status are due to

poor soil management and sewage discharge. Transportation is not considered a pressure on the Intwood Stream WFD.

3.5. Geomorphological walkover

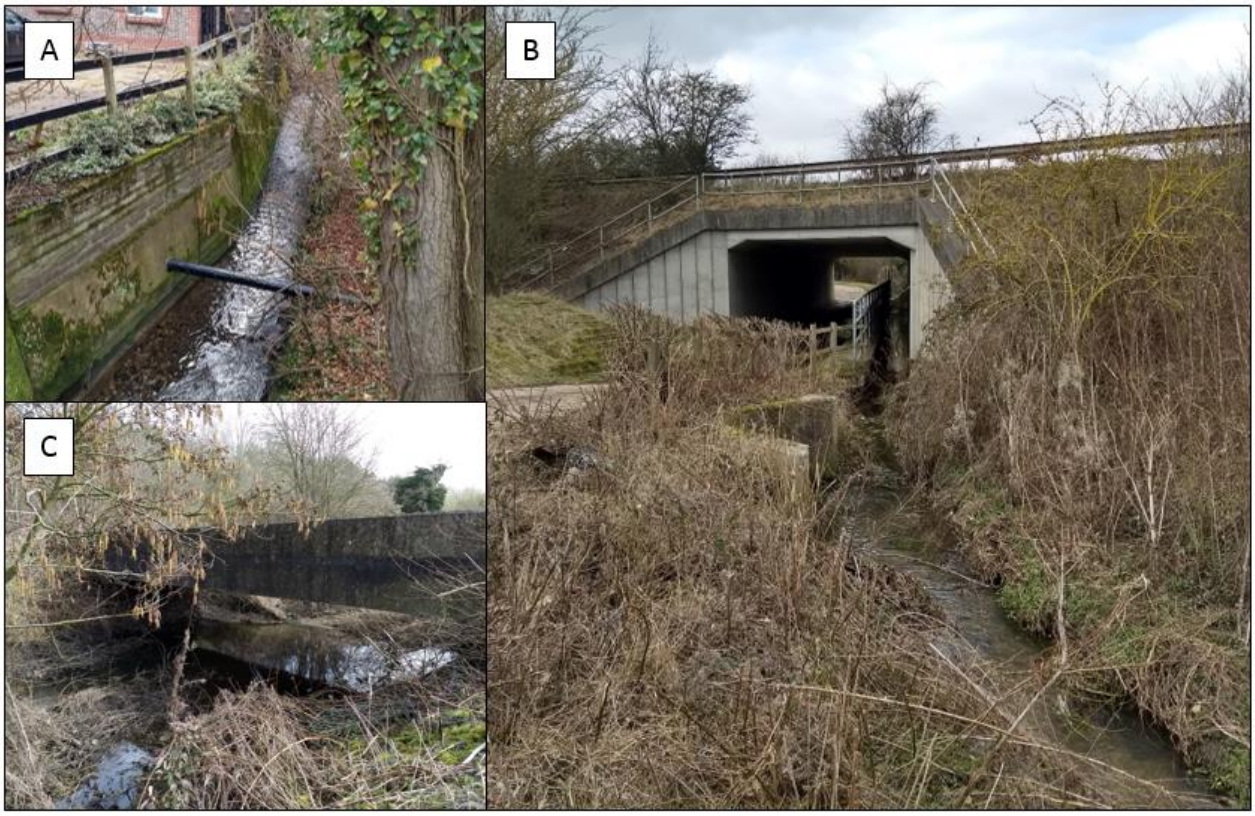
3.5.1. This section describes the conditions found on the geomorphological walkover surveys undertaken in March 2018 and May 2020. A walkover survey map is presented in Appendix A.

3.5.2. The channel has been modified along most of its length, with very few natural chalk stream features evident. As well as realignment, the channel appears to have been over-widened and over-deepened in many sections, particularly between the A11 and Cantley Lane South. This has resulted in the deposition of large muddy bars in the channel (Caption 3.1). Embankments have also been constructed along the tops of the banks on this section of the reach.



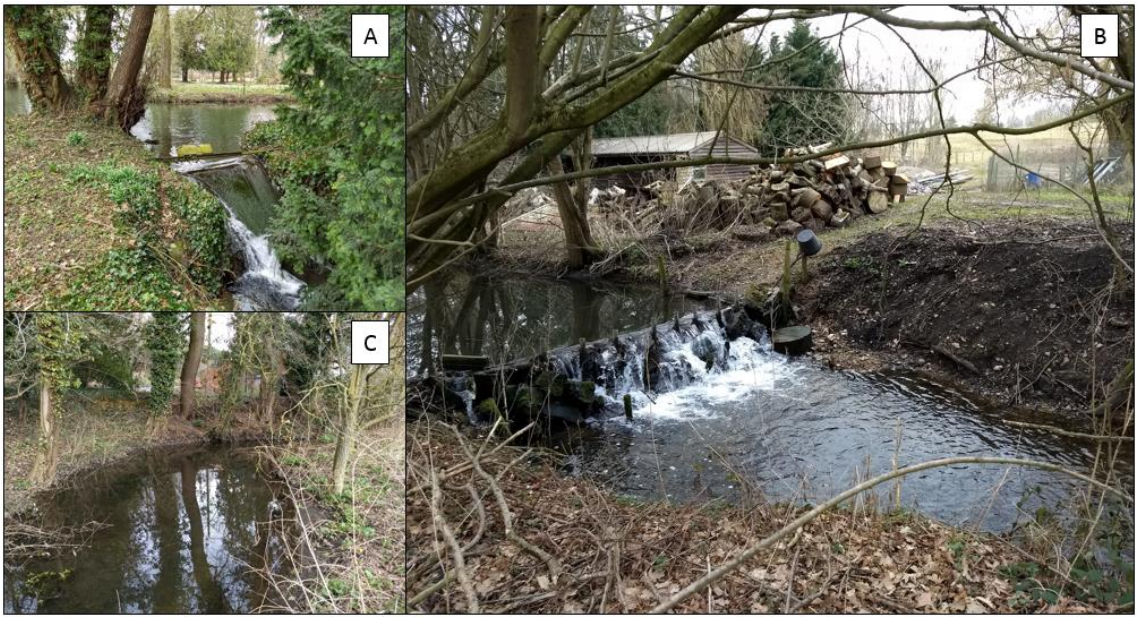
Caption 3.1 Typical view of Cantley Lane Stream (upstream of Cantley Lane), looking downstream.

3.5.3. Cantley Stream has been culverted at four road crossings (the A11, the A47, Cantley Lane South and Intwood Road). Additionally, there are three footbridge crossings on the reach (Caption 3.2).



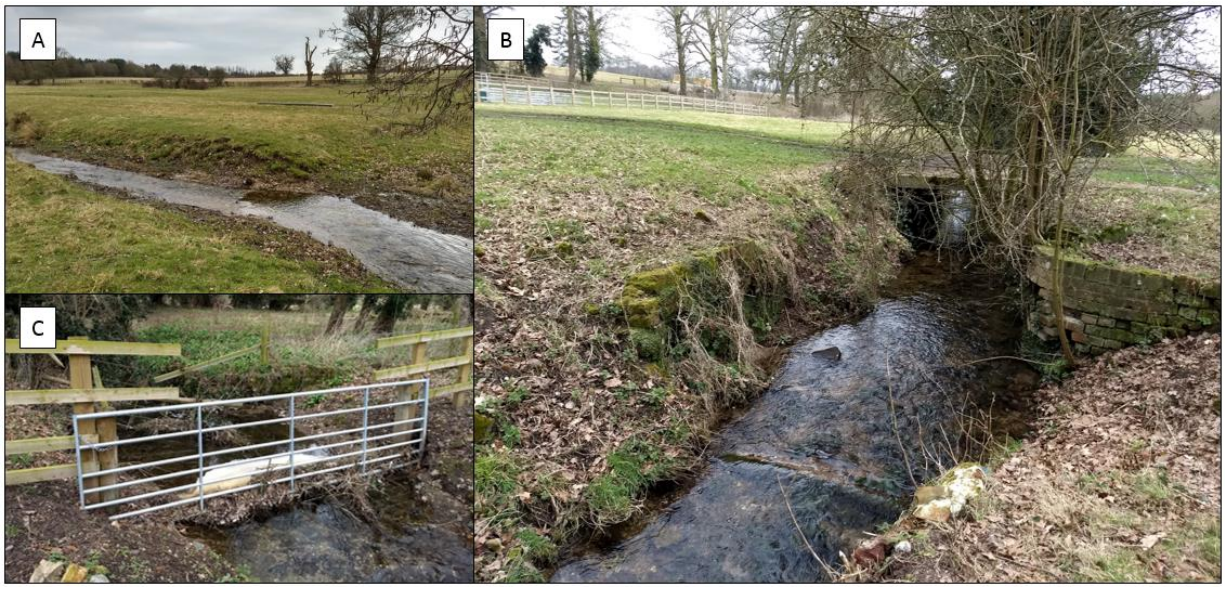
Caption 3.2 Photos of bridge crossings on the surveyed reach of Cantley Stream (A) Photo taken from the Intwood Road bridge, looking upstream; (B) the A11 crossing; (C) Foot bridge approximately 20 m east of the A11.

3.5.4. Two weirs and one partial-blockage of large woody debris, acting in a similar manner to a weir, are present on the surveyed reach which have impounded water forming in-line ponds (Caption 3.3, photo C). Of the two weirs one forms the upstream boundary of the reach (Caption 3.3, photo A), and the other is located just upstream of where the channel aligns with the northern edge of the railway (Caption 3.3, photo B). The large woody debris acting as a weir is located immediately to the east of Cantley Lane South.



Caption 3.3 Photos of weirs on the surveyed reach of Cantley Stream. (A) Shows the man-made upstream weir (Cantley Stream Pond); (B) Shows a man-made weir upstream of the A47 culvert, (C) Shows water ponding behind the naturally formed weir just east of Cantley Lane South.

3.5.5. Other morphological pressures on the channel include occasional bank protection. The most extensive area of bank protection is located downstream of Cantley Stream Pond and is composed of brick walls lining both banks (Caption 3.4, photo B). The brick walls are collapsing in places, adding brick debris to the channel. Downstream of this area, two gates cross the channel which have caused a build-up of debris behind them. Upstream of the A11, there is minor bank erosion on the right bank (looking downstream) as a result of livestock poaching, which may be a source of fine sediments entering the channel. Other than this, there was only minor area of bank erosion observed along the surveyed reach and a small section of bedrock is exposed in the lower left bank (looking downstream), upstream of the A11, displaying evidence of basal scour.



Caption 3.4 Photos of additional morphological pressures on the surveyed reach of Cantley Stream. (A) Bank erosion due to poaching by sheep on the right bank; (B) Collapsing brick wall bank protection downstream of the Cantley Stream Pond; (C) Partial blockage of the channel due to debris build up behind a gate crossing the channel.

3.5.6. A further site visit to Cantley Stream was undertaken in May 2020 to determine if any significant changes to the original geomorphological walkover survey had occurred. No specific concerns were observed, nor any significant changes from the original survey observed. As the May 2020 survey was undertaken in spring as opposed to winter (March 2018) during the first survey, the channel was observed to be significantly more vegetated than the 2018 survey. Near uniform siltation of the channel bed was observed where the channel bed could be seen through vegetation, with few gravel deposits that would typically be expected in a chalk stream.

3.6. Discussion

3.6.1. Cantley Stream shows few features typical of a chalk stream, being heavily modified and channelised. As such, there is opportunity for stream improvements to be made.

3.6.2. Near-continuous silt-covered bed and few gravel beds were observed throughout the survey, with little evidence of conveyance between these reaches. This is likely due to the majority of the discharge in a chalk stream being derived from groundwater. As a consequence, transport of silts and sediments by fluvial processes is relatively weak, a product of relatively low stream power due to the groundwater-fed discharge. Stream power is a measure of the energy expenditure per unit area of river bed, and channels with low stream power do not transport sediment effectively.

4. Impacts of the Proposed Scheme

4.1.1. The major infrastructure planned that may impact the geomorphological status of the Cantley Stream are the proposed Cantley Stream underpass extension, Cantley Stream realignment and Cantley Lane South culvert. General arrangement drawings of the structures can be found in the General Arrangement Plans **(TR010037/APP/2.2)** and a complete description of the Proposed Scheme can be found in Environmental Statement (ES) Chapter 2 The proposed scheme **(TR010037/APP/6.1)**.

Cantley Stream underpass extension

4.1.2. An existing underpass carrying the A11 over Cantley Stream would need to be extended to accommodate a widened carriageway where the A11 - A47 link road diverges from the A11 eastbound carriageway. The A11 slip road underpass extension is proposed with a headroom of 2.85m over the private farm access track to match headroom to the existing structure. The extension is approximately 13m in length and retains the existing clear span width of 5m. The upstream wingwalls of the existing Cantley Stream underpass would be demolished as part of the construction.

Cantley Stream realignment

4.1.3. The proposed construction new of the Cantley Lane link road would require the existing Cantley Stream to be realigned by approximately 390m. The adjacent access track would also be diverted.

4.1.4. The proposed construction of the A11 Cantley Stream underpass requires a watercourse realignment immediately upstream of the A11, associated with the slip road extension and realignment of the farm access track. The approximate length of the realignment is 13m.

Cantley Lane South culvert

4.1.5. As part of the realignment of Cantley Lane South with the proposed Cantley Lane link road, a new culvert would be required to carry the diverted Cantley Stream beneath the existing Cantley Lane South carriageway. The size of the proposed culvert is approximately 2.35m high by 6m wide and is 40m in length. The existing Cantley Lane South culvert is approximately 10m in length.

Outfalls

4.1.6. Seven new outfall structures would discharge surface water runoff from the highway and natural catchment drainage into Cantley Stream. These are located:

- Upstream of A11 Cantley Lane underpass discharging to the south bank of Cantley Stream from proposed highway drainage catchment A
- Upstream of A11 Cantley Lane underpass discharging to the north bank of Cantley Stream from proposed natural catchment drainage catchment A and detention basin (Basin 1)
- Two outfalls upstream of Cantley Lane South culvert discharging to the north bank of Cantley Stream from proposed natural catchment drainage catchment B
- Two outfalls downstream of Cantley Lane South culvert discharging to the north and south bank of Cantley Stream from proposed highway drainage catchment E and E2
- Upstream of Cringleford Railway Bridge discharging to the north bank of Cantley Stream via Basin 2 from proposed highway drainage catchment F2

4.1.7. The location of the outfalls is shown in Appendix B and Appendix E of ES Appendix 13.2 (Drainage strategy) **(TR010037/APP/6.3)**.

4.2. Construction impacts

4.2.1. The construction of the proposed outfalls, Cantley Stream underpass extension, Cantley Lane South culvert and the Cantley Stream realignment would require temporary construction works adjacent to and within the channel. The underpass extension would require temporary diversion of Cantley Stream. These activities have the potential to mobilise sediment and contaminants.

4.2.2. The primary impacts of construction on the geomorphological features of Cantley Stream would be on channel stability and sedimentation. The main areas in which channel stability may be impacted are the realignment, the culvert extension under the A11 Cantley Stream underpass and the new culvert under Cantley Lane South. These will involve significant interventions within the channel and thus has the potential to destabilise and collapse channel banks as well as release significant volumes of silt downstream.

4.2.3. As stated above, evidence suggests that Cantley Lane appears to have limited capacity for sediment conveyance. Therefore, any increase in sedimentation caused by construction activities would have a disproportionately significant impact on the channel due to the greater residence time in a particular channel reach. This has the potential to limit sediment transport if the culvert and underpass structures aren't designed to conserve the conveyance capacity of the existing river.

4.3. Operational impacts

4.3.1. The realignment of Cantley Stream for approximately 390m would result in the loss or deterioration of channel and riparian habitat and the reduction of morphological complexity of Cantley Stream. This would lead to degradation of the stream habitat and supporting ecological features (including water vole).

4.3.2. The proposed outfalls, extension of the A11 Cantley Stream underpass and the Cantley Lane South culvert would result in the loss of existing riparian zone and channel bed. There is approximately an additional 15m of culverting at the underpass and an additional 30m associated the realigned (and replaced) Cantley Lane South culvert.

4.3.3. The proposed culverts on Cantley Stream are unlikely to have any significant impact on sediment transport in the watercourse, provided that there is no change in conveyance capacity for any sediment that is transported by the stream. The base of the culvert may decrease channel roughness and may increase velocities and thus sediment transport rates in the local reach, which has the potential to impact the geomorphic stability of the watercourse over the longer term.

4.3.4. A key operational impact on the geomorphological features of the watercourses from the Proposed Scheme is sedimentation. Increases in hard standing areas due to the presence of the road surface and associated infrastructure has the potential to increase surface water runoff, and with it, increased sediment being washed into Cantley Stream. This coupled with the associated increase in traffic volumes will result in an increase in pollutant loads, including sediment, in highway runoff being discharged into Cantley Stream.

4.3.5. The underpass under the A11 is to be extended by approximately 15m from its current length, which may impact the ability for the channel to migrate. However, the Cantley Stream is heavily modified, therefore, has little ability in itself to migrate naturally, therefore this impact is judged to be negligible.

4.3.6. Seven proposed outfalls would discharge natural catchment and highway drainage from the Proposed Scheme with the potential to cause erosion within Cantley Stream. The outfall structure itself, if not set back into the river bank, can create localised turbulent flows which could lead to erosion of the bed and bank. In turn this can lead to channel instability and structural damage leading to increased sedimentation downstream.

5. Mitigation during construction and operation

5.1.1. Consultation with the Environment Agency and Norfolk County Council (the Lead Local Flood Authority) was undertaken to discuss the Proposed Scheme's impacts and mitigation requirements.

5.1.2. As there are construction activities planned within and adjacent to Cantley Stream, approval must be sought for an ordinary watercourse consent from Norfolk County Council before any construction works is undertaken.

5.2. Construction

5.2.1. For no deterioration in river water quality, aquatic ecology, and hence the WFD status of the river, robust silt management during construction and operation of the Proposed Scheme is required. Due to the low conveyance of silt in channel, any additional load of silt will likely have a local but particularly detrimental effect on a reach. Sediment must be controlled as close to the source as possible, and sediment traps shall be installed alongside new temporary or permanent drainage measures. These shall be maintained with regular inspection and cleaning.

5.2.2. The realignment of Cantley Stream and the construction of the proposed outfalls, culvert and underpass extension shall be constructed at the first phases of the phased construction plan. The new river channel and Cantley Lane South culvert shall be constructed off-line and shall be designed to minimise impacts on sediment entrainment. In-river sediment controls (for example, straw matting) during the connection of the stream diversion with the existing stream shall be used. Reconnection of the new alignment with the existing stream shall be undertaken during low flows to minimise sediment transport.

5.3. Operation

5.3.1. With regards to geomorphology, the Environment Agency were concerned that realignment of the channel may lead to a loss in stream length and a change in stream gradient. Being a chalk stream, Sweco proposed restoring the planform and cross section of the watercourse to a more natural chalk stream environment, with a depth and width ratio of at least 1:10 and a more 'box' like cross section. The Environment Agency were broadly supportive of this endeavour.

5.3.2. However, subsequent ecological surveys found that the presence of water voles in the watercourse would limit the ability for the channel to be restored to a more natural chalk stream environment. This is because water voles need a minimum water depth of 30 cm to provide suitable habitat. Investigations using hydraulic

modelling found that this was not achievable during mean flow conditions, were the channel to be modified to resemble a natural chalk stream.

5.3.3. As a compromise, soft-engineered pool and riffle bedforms must be included in the realigned channel to allow more geomorphic diversity. This would also ensure that water voles had water depths (in the pools) suitable for their habitat during periods of low flow. Further details of the hydraulic assessment can be found in Annex B of Flood risk assessment (ES Appendix 13.1) (**TR010037/APP/6.3**).

5.3.4. Together with the soft-engineered pool and riffle bedforms within the proposed channel realignment, improvements in the riparian environment through riparian planting along Cantley Stream, in the realigned reach and upstream and downstream shall provide mitigation for the loss or deterioration of riparian banks due to additional culverting. In addition, where the realigned stream meets the existing stream to the east of Cantley Lane South, a section of the existing stream, approximately 38m in length, must be restored to provide backwater habitat for water vole and other species. The location of water vole habitat creation and riparian planting can be seen in the Environmental Masterplan (**TR010037/APP/6.8**).

5.3.5. Further opportunities to improve the geomorphic complexity of Cantley Stream within the DCO boundary are limited due to the presence of water vole and / or because the reach is to be utilised as an area for translocating existing water vole from the existing reach to be realigned, for example, the reach downstream of Cantley Lane South.

5.3.6. The design of the realigned channel would be undertaken at detailed design stage in consultation with the Environment Agency, Norfolk County Council and other stakeholders.

5.3.7. To minimise geomorphological impacts on the Cantley Stream, the culvert and underpass design must maintain existing flow and sediment conveyance. The new culvert planned under Cantley Lane South must be of sufficient size (6m width by 2.35m high) and capacity to cause no impedance to sediment transport downstream. The extension of the A11 Cantley Stream underpass must maintain existing underpass dimensions.

5.3.8. The installation of a natural channel bed within the Cantley Lane South culvert shall minimise the impact on channel connectivity including the aquatic ecology. A sediment bed depth of 750mm has been assumed in the proposed design. The sediment bed at the base of the A11 Cantley Stream underpass extension shall be maintained as per the existing underpass.

5.3.9. An assessment of pollution impacts from routine runoff to surface waters was undertaken using Highways England Water Risk Assessment Tool (HEWRAT). This assessment establishes potential impacts of pollutants (including sediment) in routine highway runoff for the Proposed Scheme upon Cantley Stream and the requirement for mitigation measures to adequately reduce the risk.

5.3.10. The routine runoff assessment shows that there is a negligible impact following dilution in the channel for both soluble and sediment-bound pollutants when the additional measures from the drainage design have been included. Water quality treatment measures include filter drains and detention basins or swales; all three of these measures facilitate sediment removal with treatment efficiencies of 60%, 50% and 80% respectively (DMRB CG501; Highways England, 2020). The output from the runoff and spillage assessments can be found in ES Appendix 13.4 (Water quality assessment) **(TR010037/APP/6.3)** and the proposed drainage design can be found in ES Appendix 13.2 (Drainage Strategy) **(TR010037/APP/6.3)**.

5.3.11. Design of the outfalls has not been undertaken at preliminary design. Outfall design shall ensure the outfall structure is set back from the channel bank and bed to minimise the impact on flow and sediment conveyance. The outfall must not be placed at location that is geomorphologically active (erosion, deposition or channel migration). Scour protection must be incorporated into the design to ensure no bank or bed erosion results from the discharge to the watercourse. Outfall design shall comply with the guidance set out in CIRIA's Culvert, screen and outfall manual (Benn. J. *et al*., 2019).

6. Conclusion

6.1.1. Cantley Stream is a minor watercourse, heavily modified throughout its length of approximately 3km until it flows, via Intwood Stream, into the River Yare.

6.1.2. The watercourse has no WFD status in its own right, however it is a tributary of the Intwood Stream, a heavily modified water body that has a WFD status of 'moderate' with an objective to remain at 'moderate' ecological potential. This is primarily due to sewage discharge and poor land management practices within the catchment.

6.1.3. Chalk stream dynamics provide poor conveyance for sediments within the channel, with evidence of siltation continuously through the heavily-modified trapezoidal channel with seemingly poor conveyance.

6.1.4. The Proposed Scheme would realign approximately 390m of the watercourse to create space for the proposed Cantley Lane link road to be constructed to the north. A new culvert would convey Cantley Stream under Cantley Lane South. The culvert under the A11 would also be extended upstream by approximately 15m with a minor watercourse diversion of similar length.

6.1.5. Construction impacts upon the channel would be primarily due to increased siltation of the channel as a result of watercourse realignment and increased hardstanding and reduced permeability working areas during construction activities. The potential impact on the watercourse would be exacerbated by the relative inefficiency of the watercourse's ability to discharge sediment and hence any impacts would result in a disproportionately significant impact on the channel due to the greater residence time in a particular channel reach.

6.1.6. Key operational impacts would be sedimentation from highway drainage, potential erosion and sedimentation impacts from the proposed outfall discharge, impacts on flow and sediment conveyance from the inclusion of a new culvert under Cantley Lane South and Cantley Stream realignment, the extension of the A11 Cantley Stream underpass and the new outfalls. There is a loss of riparian and channel bed from the additional culverting.

6.1.7. Mitigation should include robust silt measures during both construction and operation, to ensure no additional siltation occurs within the channel. Realignment should ensure that no channel length is lost, and geomorphic bedforms are introduced to improve geomorphic diversity of the channel as well as ensuring the water vole populations have sufficient depths of water in which to live. The new culvert, underpass extension and proposed outfalls should maintain sediment and flow conveyance. Erosion protection measures on the discharge from outfalls should be included to mitigate against additional

sediment entrainment. Riparian planting along Cantley Stream and creation of a backwater channel from the existing stream shall provide mitigation for the loss or deterioration of riparian banks and channel bed due to additional culverting.

6.1.8. Should infrastructure be required in channel, it is recommended to carry out hydraulic modelling to specifically determine the shear stress present on the channel banks and the proposed infrastructure. This will allow structures to be designed to withstand expected hydraulic loading from the flow of water. This would also give an understanding on the likely changes to flow regimes any infrastructure may cause, which could have an impact on erosion rates of the channel.

7. References

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Appendix A. Walkover survey map

Narrow, overgrown channel with trapezoidal cross section.

Reach is trapezoidal, with significant siltation of bed. Both banks have embankments. Some minor, infrequent erosion at base of banks.

Reach is trapezoidal, with significant siltation of bed, albeit slightly more sinuous than upstream. Both banks have embankments. Some bedform diversity.

Plane Riffle

Culvert under A11 lined entirely with concrete, no natural features.

Culvert under Cantley Lane South currently split into two sections. No impedance of sediments observed, although channel narrows.

Canley Stream Pond, no specific sediment impedance observed, although pond will act as a sediment sink. Appears maintained by landowner.

N

0 75 150 225 300 Metres

LEGEND

- DCO Boundary
- Typology
- Bank Erosion
- Weir
- Bridge
- Existing realignment
- Grey Bank Protection
- Embankment
- Culvert

REFERENCE MAP

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REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	16/03/2021	First edition	JP	JB	FG

DESIGNER: SWECO

CONTRACTOR: GallifordTry

CLIENT: highways england

PROJECT TITLE: A47/A11 THICKTHORN JUNCTION

PROJECT STAGE: PCF STAGE 3

DRAWING TITLE: WALKOVER SURVEY MAP

SUITABILITY: FOR INFORMATION

SHEET SIZE	SCALE	STATUS
A3	1:7,649	S2

DRAWING NUMBER: HE551492-GTY-EGN-000-DR-LX-30001