Somerset Levels & Moors appraisal package

Project: Somerset Levels & Moors – Modelling/Appraisal
Axe, Brue, Parrett & Tone Dredging Assessment
Client: Environment Agency

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Memorandum on Dredging Assessment for Brue, Axe, Parrett and Tone

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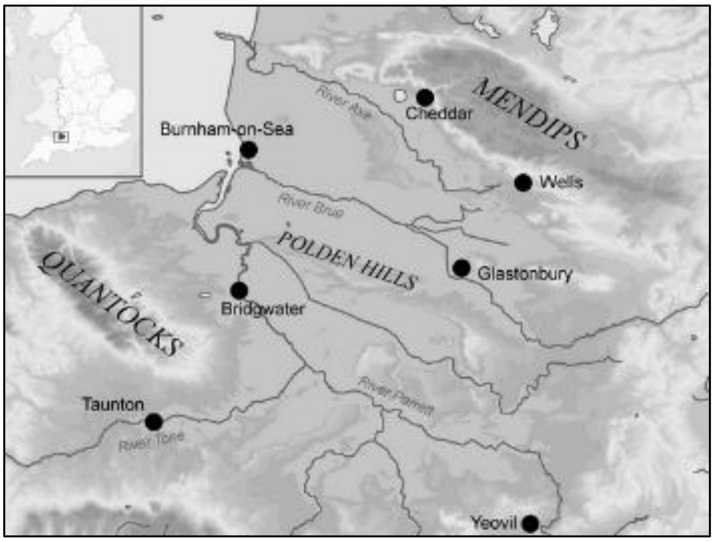
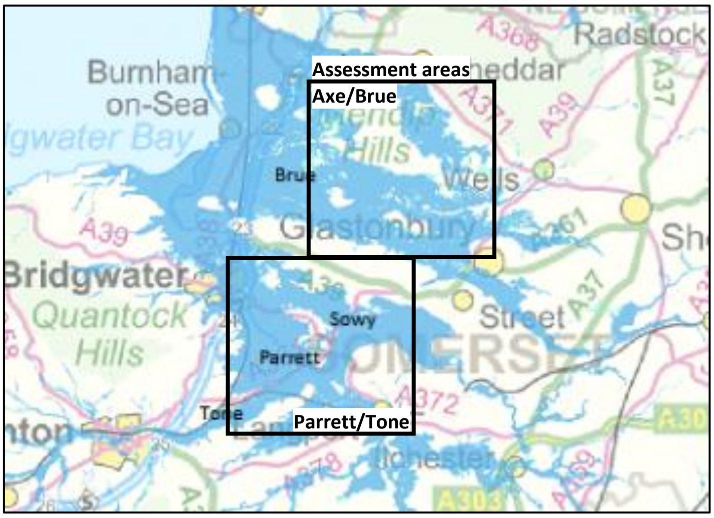


Environment Agency flood map



Review of the effectiveness of further dredging – Axe, Brue, Parrett & Tone

1. Introduction

This memo presents the initial assessment of dredging options for the sites listed below on the Axe, Brue, Parrett and Tone river catchments (see Figures 1.1 and 1.2). The findings provide an evidence base and options matrix for use by the Environment Agency in deciding the effectiveness and prioritisation of further dredging. Assessment of the effectiveness of dredging is one of the key actions of the Somerset Levels and Moors 20-year Flood Action Plan.

<u>Parrett/Tone</u>

• River Parrett	Thorney to Langport	6.2 km
• River Parrett	Langport to Tone confluence	7.8 km
• River Parrett	North Moor to Bridgwater	3.2 km
• River Tone	Ham to Hook Bridge	6.9 km
• River Yeo	Huish Episcopi Pump Station (HEPS) to confluence	1.8 km
• Penzoy River	New Southlake inlet to Kings Sedgemoor Drain	10.4 km

<u>Axe/Brue</u>

• River Axe	Clewer to New Cut	7.7 km
• Cheddar Yeo	Froglands to Axe confluence	8.8 km
• Panborough Drain		6.8 km
• Glastonbury Millstream	Dredging assessed for a 1.8km section	4.3 km

As a desk-based initial assessment it considered engineering feasibility, cost based on working method and silt disposal options, hydraulic impacts in terms of benefits and disbenefits, and environmental constraints. For the Parrett/Tone only a summary is included of the benefits and disbenefits based on the findings of hydraulic assessments reported by Black & Veatch (B&V).

2. Background data

The primary datasets include OS mapping datasets (open data series), LiDAR data at 2m resolution, aerial photographs (25cm resolution) and maximum flood level gauged data. For the Parrett/Tone the hydraulic assessment used the existing model (2014) based on the 2013/14 flood event. For the Axe/Brue the hydraulic assessment used the existing River Axe and Cheddar Yeo design model (2011) and Brue design model (2010) and a standalone model for Panborough Drain was developed.

A high level assessment of potential environmental risks has been undertaken in order to inform initial appraisal and prioritisation of dredging options. The following sources/data informed this environmental assessment:

- Severn River Basin Management Plan (Environment Agency 2009) – water framework directive water body information
- South West River Basin Management Plan (Environment Agency 2009) – water framework directive water body information
- www.environment-agency.gov.uk/wiyby – water framework directive water body information, surface water features
- www.google.co.uk/maps - surface water features, landscape features, roads/paths/tracks
- www.heritagegateway.org.uk – designated heritage features, local heritage features, archaeological findspots
- www.magic.gov.uk – designated and undesignated nature conservation features, designated heritage features, landscape designations, priority habitats, land stewardship
- www.nbn.org.uk – otter, water vole, great crested newt, white-clawed crayfish and depressed river mussel distribution
- www.ordnancesurvey.co.uk – surface water features, landscape features, roads/paths/tracks

For any dredging proposals to be progressed, additional data will be required to adequately describe the baseline condition of the watercourses, to identify data gaps that need further investigation, to determine any potentially significant environmental impacts and to identify appropriate management and mitigation measures to minimise these.

Dredging has the potential for significant adverse environmental effects, and these are considered further in Section 6.

Figure 1.1: Potential reaches for dredging, Axe/Brue

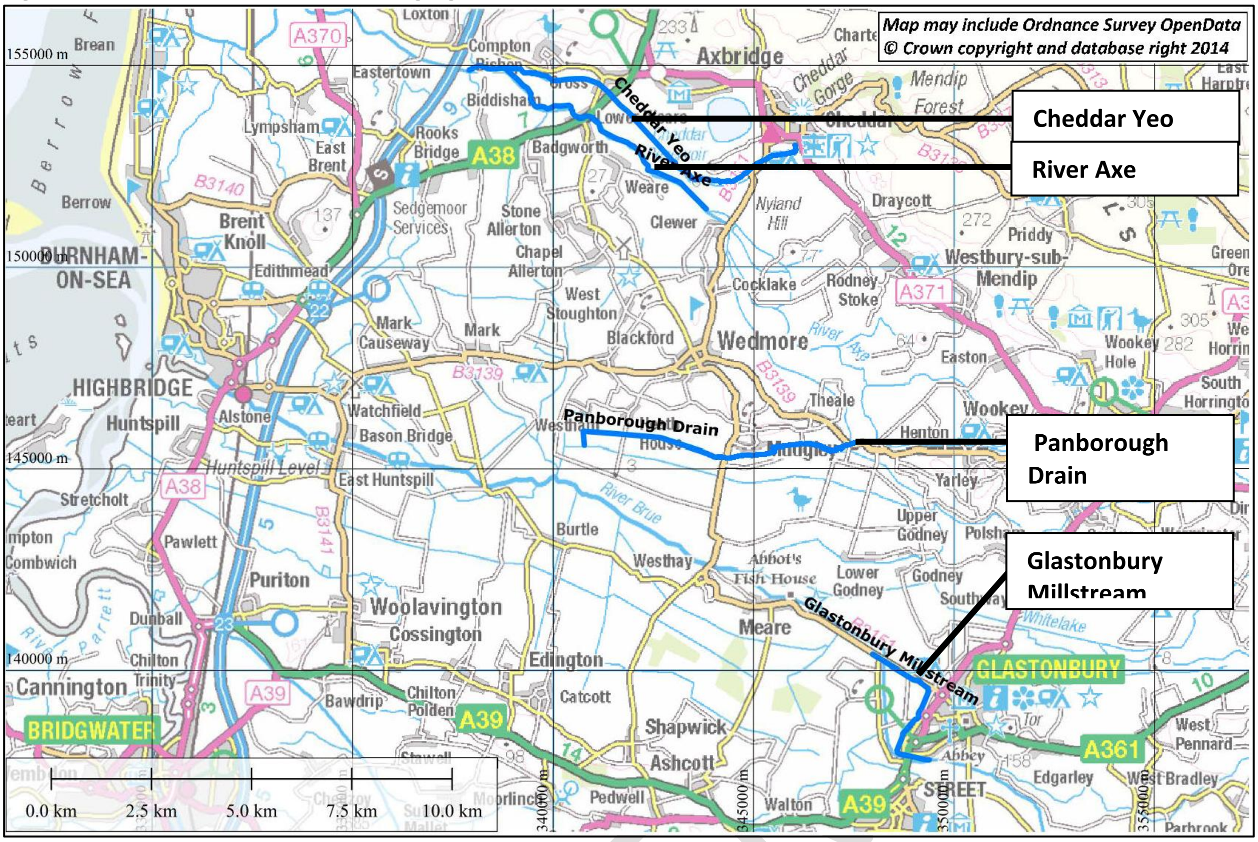
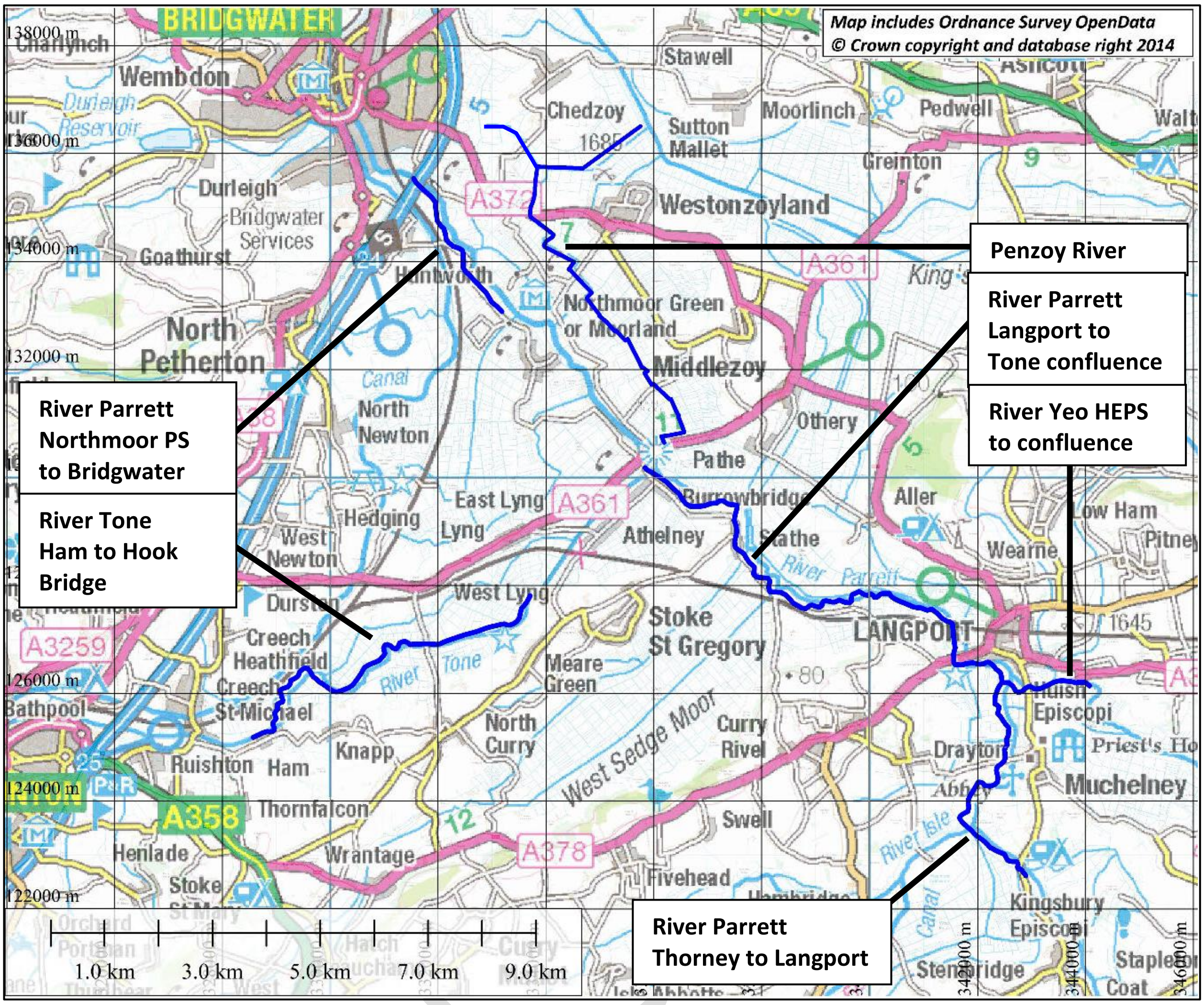


Figure 1.2 Potential reaches for dredging, Parrett/Tone



3. About dredging

Long reach excavator

Dredging can enhance channel capacity by increasing the channel cross section as well as reducing hydraulic roughness. However, in a low gradient system such as the Somerset levels dredging will not necessarily be effective if there is downstream control that limits flow conveyance.

Dredging can restore a channel to a previous condition because the cross sectional area has been reduced by sediment deposition but it can also include additional excavation. However, the overall capacity to pass more flow can also be constrained by factors such as:

- Structures which are constrictions to flow
- Downstream flow capacity including backwater from other channels, pumping or tidal constraints

Dredging may cause unintended consequences including:

- Increasing the flood risk for communities downstream by speeding up the movement of flood water through the river and drainage network.

- Destabilisation of river banks that are very steep in many locations, causing erosion, slip failure and risking damage to infrastructure, with potentially costly repair, e.g. this occurred during previous dredging of the River Parrett opposite Allermoor spillway, necessitating sheet piling repairs.
- Loss of wildlife and habitats within the dredged channel and in riparian reaches with potential for failure to comply with the Water Framework Directive.
- Changes in wetting / flooding of adjacent land and ditch systems.
- Higher velocities resulting in increased movement of sediment downstream which can have implications for reaches both upstream (potential increased scour) and downstream (greater sediment deposition) as well as reduced water quality caused by the increased turbidity – this may not be an issue for the rivers assessed as dredging would not change the velocities very significantly.
- Disturbance and possible mobilisation and increased bioavailability of potentially harmful inorganic and persistent organic substances associated with sediment particles and pore water.
- Where it is not expected that the silt being removed will be contaminated, either chemically or by invasive weed species (including seedbank) excavated material can be spread on the channel banks and immediately adjacent land (in one handling movement) under waste exemption D1, but any suspicion of contamination or intention to spread material more widely will require analysis and appropriate licensing.

To be effective requires regular maintenance dredging. Natural processes seek to create channels appropriate for the dominant flow conditions and which become less efficient for the evacuation of floods.

Various studies suggest dredging can have a significant beneficial impact on flood levels during small and medium floods but not during major floods when overall system capacity is constrained. The duration of flooding can be reduced by enhanced evacuation of water before and after the flood peak. Dredging can also, through the improved channel conveyance enabling better responsiveness, facilitate better regulation of water levels in areas subject to water level management plans.

Dredging may also achieve some environmental benefits including

- Potential to establish a two stage channel which could provide ecological resilience during periods of low flow
- Combining dredging with bank management activities such as clearance of scrub at specific locations where over-shading is known to be having an undesirable effect on habitat quality

Evaluation of the need for dredging should also consider the consequences of it not being carried out. In reaches vulnerable to sediment deposition there is the risk of progressive loss of flow capacity until the channel size matches the relatively small dominant flow. Such reaches are most likely to occur either close to the edges of the Somerset levels where the channels are receiving inflows from steeper ground or close to the sea where tidal inflows can carry sediment laden water. Geology and geomorphology are important with respect to the amount of sediment generated in any particular river system which means that some rivers are more prone to needing dredging than others.

Disposal of dredging material away from site is costly. For cost effectiveness, material can be disposed of at site, e.g. at the back of the river bank. Based on experience from the ongoing Parrett/Tone dredging the circumstances that prevent this include: space constraints (e.g. road or property alongside river), practical limits of the one mechanical movement rule for excavators, presence of invasive species (e.g. cannot place hemlock on arable land) and because the material may be needed elsewhere. This list is not exhaustive, but gives an indication of the potential limitations of disposal at site.

Main rivers are maintained by the Environment Agency, with cutting and removal of vegetation along some channel reaches undertaken once or twice per year in accordance with a published schedule[1]. This also has the beneficial effect of ensuring access for equipment along one or both sides of each channel.

[1] https://www.gov.uk/government/publications/river-and-coastal-maintenance-programme

North Drain and South Drain in the Brue catchment were part of a pilot study into channel dredging.[2] About 70,000m³ of silt was reported have been excavated at a total cost of about £68.000 (tbc). The excavated material was deposited on the channel banks. The study concluded: "Work not economic for flood risk, justified by favourable condition requirement. Benefit to land drainage."

4. Hydraulic assessment

Parrett/Tone hydraulic assessment

The hydraulic assessments of the six dredging sites were undertaken by Black & Veatch. No additional work is undertaken as part of this initial assessment and instead a summary of the Black & Veatch reported findings is included drawn from the following reports:

- TN19 Parrett (Thorney to Langport) Dredging Hydraulic Modelling
- TN21 Parrett (Langport to Tone) Dredging Hydraulic Modelling
- TN20 Parrett (downstream of North Moor) Dredging Hydraulic Modelling
- TN16 Upper Tone Dredging Hydraulic Modelling
- TN22 Yeo (HEPS to Parrett confluence) Dredging Hydraulic Modelling
- TN18 Penzoy Dredging Hydraulic Modelling

The baseline model was calibrated against the winter 2013/14 flood event and includes the following works that are either underway or are scheduled to be completed later this year:

- 8km of dredging on the Tone (from Hook Bridge) and Parrett (from Northmoor Pumping Station)
- bank raising proposed on the Parrett (from Tone to Screech Owl outfall) as part of the Asset Recovery Programme works

The modelling assumes all structures and pumps are operated as described in the Operational Procedures, with no temporary pumps used anywhere in the system. Whilst this does mean the results are not necessarily reflective of what occurred in the 2013/14 flood event it does allow for the direct benefit of the dredging to be assessed. The modelling excludes the planned raising of the Muchelney to Drayton or A372 (Beer Wall) roads.

Axe/Brue hydraulic assessment

In order to provide a rapid initial assessment of the hydraulic impact of dredging in the four channels, existing hydraulic models have been used as far as possible. The two most recent models available for these channels are as follows:

- River Axe and Cheddar Yeo : 'River Yeo and River Axe System Critical Asset Survey', August 2011, B&
- River Brue : 'Brue Model Study', October 2010, Jacobs

The Axe and Yeo model (ISIS 1D/TUFLOW 2D) includes the full extents of the proposed reaches for dredging on these watercourses. The model extends approximately 1.2km (on the Yeo) and 15.3km (on the Axe) above the upstream dredging limit and approximately 0.5km below the downstream dredging limit.

The River Brue (ISIS 1D/TUFLOW 2D) model includes the full extent of the proposed dredging reach for the Glastonbury Mill Stream. The model extends approximately 12.7km upstream of the upstream dredging limit and approximately 23km below the downstream dredging limit.

The Panborough Drain is not represented explicitly in the Brue model. For the purposes of this assessment a simple new stand-alone ISIS 1D model of the Panborough Drain and North Drain has been developed to assess the impact of dredging on drainage of Tealham, Tadham, Aller and Westhay Moor.

2 Environment Agency (2011) Dredging and Pilot Studies Report.

Due to a lack of data the Axe and Yeo model was not fully calibrated under the original modelling project. However the model was verified against four low return period events with satisfactory results. The Brue model was successfully calibrated under the original modelling project against two high flow events. Detailed calibration of the local model of Panborough Drain developed for this assessment is beyond the scope of this study. However, the model results compare favourably with actual water levels recorded for the December 2013 – February 2014 period.

The existing models of the Axe and Yeo and Brue were reviewed in 2014. The reviews recommend improvements to the models. The models will be updated and extended as part of Somerset Levels and Moors Modelling and Appraisal project. However, the performance and extents of the existing models are considered adequate for assessing the relative impacts of changes to channel cross-sections as a result of dredging in order to provide a rapid assessment in advance of the model updating.

As part of the hydraulic assessment a limited channel check survey has been undertaken to identify silt depths at selected locations, to confirm the reliability of the channel cross-sections in the existing models and to confirm the level datum used in the different surveys through reference to structural levels. Additional recent channel surveys of the Panborough Drain and the lower reach of the Glastonbury Mill Stream have been provided by the Environment Agency which include an assessment of silt depths.

Although flooding occurred in some areas of the Axe and Brue catchments during the December 2013 – February 2014 period, it is understood that the severity of the flooding was not as extreme as in the Parrett catchment. For the Axe, Yeo and Glastonbury Mill Stream the impact of dredging has therefore been assessed under the 1 in 100 year design flood as derived under the original model studies.

For the Panborough Drain, in the absence of a detailed hydrological assessment, the impact of dredging has been assessed by considering the drawdown of the Tealham, Tadham, Aller and Westhay Moors via the Panborough Drain, North Drain and North Drain Pump Station following flooding to approximately the level reached in February 2014.

For this initial assessment it is assumed that the channel roughness (represented in the model by Manning's 'n') is not changed by the dredging. This is considered a reasonable assumption, as the main dredging would be within the limits of the channel bed and although initially a lesser roughness may apply for a recently dredged channel and banks it can be expected to quickly 'roughen'. Thus the main hydraulic benefit results from enlarging the waterway cross section.

This is an initial assessment based on readily available data and models for the Axe/Brue. The models used are configured for design flood events, unlike the Parrett/Tone model that is configured only for the 2013/14 flood event. The impacts for a more regular event, for example in terms of land drainage benefits, are also not assessed at this stage. The Axe/Brue models are under development and when updated can be used to confirm the findings reported herein..

5. Cost assessment

Indicative unit costs are derived to support the scheme assessment.

Total unit dredging cost	Rate	Present Value
m^3 of dredging to river bank	£15 /m^3	In addition to capital costs includes
m^3 of dredging, spread to fields	£25 /m^3	maintenance dredging every 5 years

Cost considerations

Dredging costs are subject to a range of factors including:

- Channel width (in particular whether the channel is narrow enough that standard excavators can be used and whether either standard or long reach excavators can work from one bank)
- Ease of access along the side(s) of the channel or other obstacles impeding equipment movement
- Whether the spoil can be deposited close to the channel or has to be moved further away
- Whether the spoil contains any contaminants which would require it to be transported to an approved disposal site
- The hardness of the material (soft silt or consolidated original ground)

- Environmental mitigation requirements (e.g. timing constraints related to fisheries, presence of protected species such as water vole)

Basis for unit dredging cost

Indicative costs advised by EA for dredging with different disposal methods are (selected cost rates applicable to Axe, Brue, Parrett and Tone in bold):

Activities	Cost rates	Total
One mechanical operation	**£5.5/ m^3 dredge to bank** **£3.5/ m^3 haulage**	**£9/ m^3**
More than one mechanical operation	£6.5/ m^3 dredge to tractor & trailer £3.5/ m^3 haulage	£10/ m^3
Direct spread	**£6/ m^3 dredge to tractor and trailer** **£7/ m^3 haulage** **£2/ m^3 disposal to fields**	**£15/ m^3**
Stockpiles in fields	£6/ m^3 dredge to tractor and trailer £7/ m^3 haulage £2/ m^3 disposal to fields £3/ m^3 stockpiling	£18/ m^3
Field spread material	£6/ m^3 dredge to tractor and trailer £7/ m^3 haulage £3/ m^3 stockpiling £7/ m^3 haulage £2/ m^3 disposal to fields	£25/ m^3
Construction material	£6/ m^3 dredge to tractor and trailer £7/ m^3 haulage £3/ m^3 stockpiling	£16/ m^3
Landfill	£50/ m^3 dredge to landfill	£50/ m^3

The above dredging cost rates reflect the contractor's costs only. For each dredging site, quantities of dredging to provide an enhanced waterway cross section are calculated and a total construction cost then estimated based on the cost rates quoted below.

The cost rate build-up is given below. The unit costs of dredging work out at £15 to £25/m^3 of dredging material including contractor's costs, preliminaries and profit, and additions for environmental mitigation, field investigations, design and site supervision. A 30% contingency is assumed, which is below 60% Optimism Bias as cost rates are taken from recent dredging contracts in the project area.

Item	Rate	
- dredging unit cost	£9	/m^3 place to river bank
- dredging unit cost	£15	/m^3 spread to fields
- preliminary items	5	%
- contractor's profit	5	%
- field investigations, incl. sampling/analysis	5	%
- environmental measures, incl. mitigation	5	%
- miscellaneous	5	%
- design/site supervision	10	%
- contingency	30	%

The above excludes land compensation as it is assumed landowners will support dredging without compensation, due to the potential land drainage benefits.

It requires further site specific investigation to determine more reliable cost estimates. For an indicative cost range, lower and upper bound costs are taken as -25% and +50% of the baseline cost derived using the cost rates quoted above. This cost range is included in the feasibility matrix.

A higher cost is applicable for those sites requiring over-water dredging to supplement excavating from the river banks where possible – the sites on the Parrett include Thorney to Langport, Langport to Tone and downstream of North Moor and also the Upper Tone. Dredging quantities are another uncertainty that could lead to changes in the estimated cost. These uncertainties are accounted for in the upper bound cost estimate.

6. Environmental assessment

Overview of approach

High level assessment equivalent to that applied for strategic environmental assessment has been applied to identify environmental baseline features that may be sensitive to dredging activities, with a focus on:

- Sites designated for nature conservation associated with the water courses and/or floodplains including land adjacent to potential dredging sites
- Designated cultural heritage assets associated with rivers and floodplains
- Landscape designations
- Water Framework Directive status and objectives sensitive to dredging. Whilst all water bodies will be sensitive to the potential adverse effects of dredging on their ecological condition (see below), specific consideration is given to those for which hydromorphological mitigation measures are key to ensuring good potential (in order to differentiate levels of risk across sites, where appropriate)
- Other known or anticipated environmental constraints, such as the presence of protected aquatic species, local environmental designations*

*limited to information identified during a high level desk study (incl. NBN Gateway for protected species)

As indicated in Section 1 the aim is to inform feasibility, prioritisation and risk assessment. Further detailed assessment will be required for any dredging activities that are progressed.

Water Framework Directive considerations

There will be significant potential for impacts on the dredged water bodies (and potentially those up- and downstream) which may impact on their ecological condition and Water Framework Directive (WFD) objectives. The following mitigation measures are therefore anticipated as a minimum:

- Dredging must only remove deposited material and not excavate underlying paleo-peat deposits;
- Confirmation of sediment quality (in particular related to heavy metals and hydrocarbons which have been identified in some rivers on the levels) and assessment of the impacts on water quality of disturbing these;
- Specification of sensitive dredging techniques (e.g. maximising works in the dry) at appropriate times of year to minimise effects on water quality and biota;
- Dredging to a depth and cross section that retains a low flow channel;
- Replacement of marginal vegetation.

Any proposed dredging will need to be assessed for compliance with the WFD, examining site proposals individually and in combination, and will need to consider all water bodies within which dredging is proposed as well as upstream and downstream water bodies. If it is concluded that dredging will result in failure of any WFD objective, justification under Article 4.7 would be required; this will need to demonstrate that the public interest out-weighs the impact, that there is no significantly better environmental options, and that all practicable mitigation has been included.

It is expected also that dredging would be delivered alongside a long-term sediment management plan for each catchment, which will address source controls as well as a best practice approach in the channels. Thus the mitigation applied to dredging activities should be compatible with an complementary to the wider catchment initiatives.

Other factors

A number of the rivers screened for future dredging have not been dredged in some time. Desk based analysis suggests that these rivers have a variety of habitats present (riffle pool sequences, etc.) and dredging may create a homogenous system which is likely to vastly reduce biological and geomorphological diversity.

Where dredging has not occurred for some time the river systems will have naturalised somewhat and the ecosystems will be adapted to the current conditions. Undertaking the environmental analysis for these channels will be significantly more complex than for channels which already conform to the managed trapezoidal morphology.

Dredging should need to include measures to conserve, restore and enhance biodiversity where feasible and if habitat improvement works are not possible in situ, funding should be set aside for habitat improvement elsewhere.

Protected species: water voles are likely to be present along all stretches of river within the Somerset Levels and Moors, requiring appropriate management and mitigation during any dredging works.

The above is represented in the estimated dredging costs (5% provision added to construction cost).

7. Dredging assessment: River Parrett, Thorney to Langport

Location

The length of the reach under assessment is 6.2km extending from Thorney Mill downstream to Great Bow Bridge which is about 1km downstream of the confluence with the River Yeo (Figure 7.1, next page).

Current Situation

The channel is embanked along whole length with banks typically 1m to 2m high. Figure 7.2 shows a typical cross section from LiDAR (next page). The typical widths at the water surface are 6 to 9m at water surface upstream of the River Isle confluence, 12 to 15m downstream of Isle confluence and adjacent Midelney pumping station to Westover Bridge and 15 to 20m downstream of that bridge.

Weed cutting is scheduled to be undertaken by the Environment Agency in July / August. Landowners are recommended to keep clear a 7m wide access strip along each bank. Access along each bank is therefore reasonable.

Constraints

Structures: Two road bridge crossings (Thorney and Westover bridges) cross the river within this reach. A railway bridge used to cross this section of river but has been removed.

Access: Access along both banks is generally feasible although houses, gardens and some trees on the left bank over a 0.4km length between Thorney Mill and Thorney Bridge would impede access along that bank. The channel over that reach is relatively narrow and equipment operation from the right bank should be sufficient. Downstream of Thorney Bridge the river passes through open fields as far as Huish Bridge.

Immediately downstream of Huish Bridge there is vegetated area on the left bank and a car park with boat slipway on the right bank. Dredging would need to be undertaken from the right bank with material removed from the site. The next 600m of channel is about 20m wide but has constrained access on the right bank which is a narrow embankment separating the river from the Long Sutton Catchwater drain. There is then a 0.5km length where access is feasible on both banks but the right bank has been recently landscaped as part of a flood protection scheme and there must be some uncertainty about the acceptability of disposing of dredged material on that area.

Working methods: A long reach excavator working from both banks (or one bank where there are access constraints) should be appropriate.

Disposal: It is not expected that the silt being removed will be contaminated. To minimise costs and subject to cooperation from the landowners the excavated material can be deposited or spread on the channel banks and immediately adjacent land (i.e. within reach of a single handling operation) under waste exemption D1 as is believed to have been the historical practice. Deposition beyond this would require proof of benefit, chemical assessment and appropriate licensing.

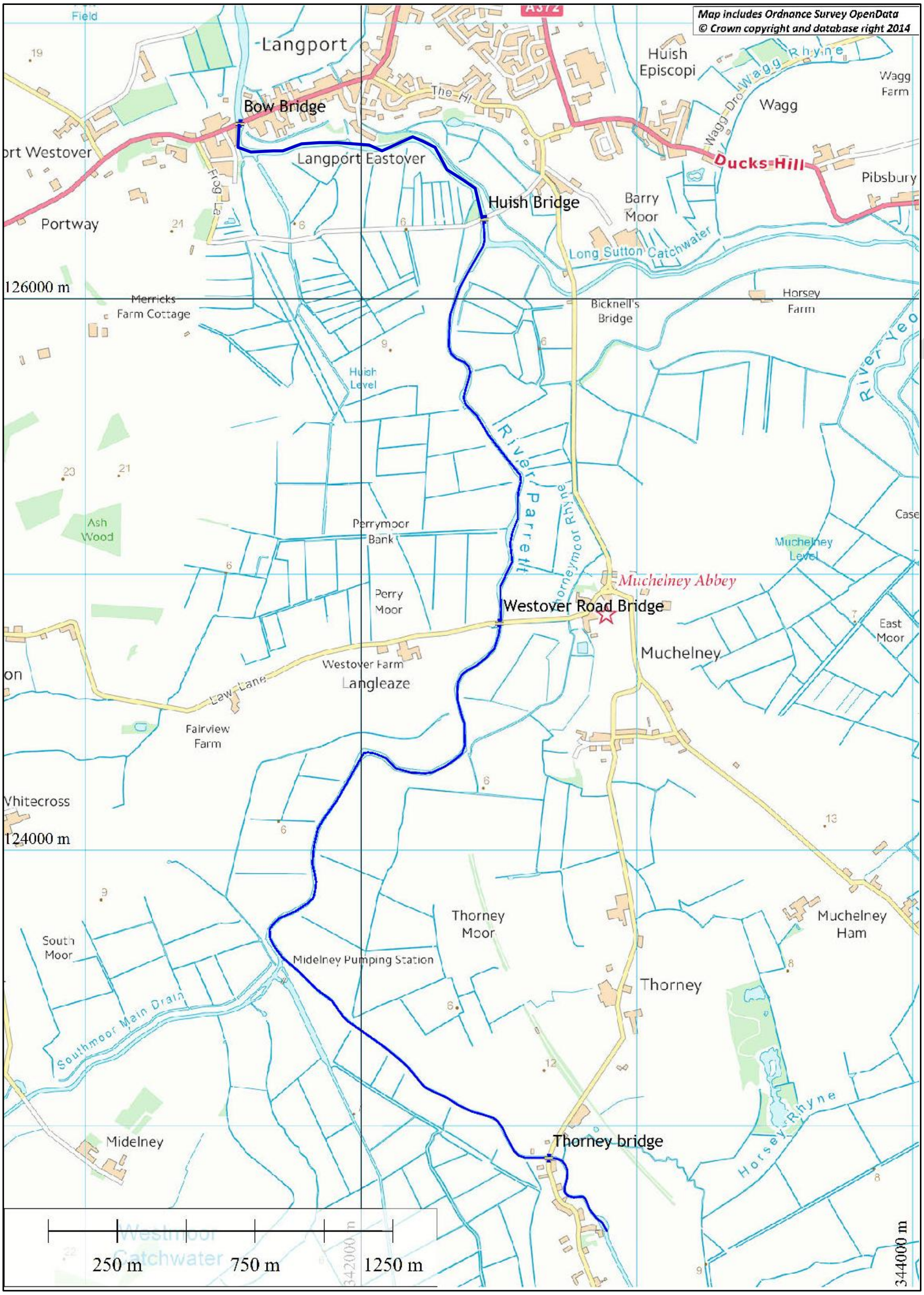
However, there are reaches where this may not be feasible including about 0.5km of recently landscaped area just upstream of Great Bow Bridge. Material arising from over water dredging, at locations where an excavator working from the bank is not feasible, would need to be stockpiled to drain and could then be used to raise low lying land or reinforce the channel banks.

Water Framework Directive: The study reach comprises part of the “Parrett” GB108052015360 water body and all of the “Parrett” GB108052015370 water body. 15370 is heavily modified by flood protection, with two morphological mitigation measures not in place and which could be compromised by dredging (which could further raise and fix banks when dredged material is deposited) as follows:

- Improve floodplain connectivity;
- Set-back embankments.

The 15360 water body is not heavily modified. Both water bodies have Freshwater Fishery Protected Area status, which could constrain timing, extent and methodology of dredging operations.

Figure 7.1 River Parrett, Thorney to Langport



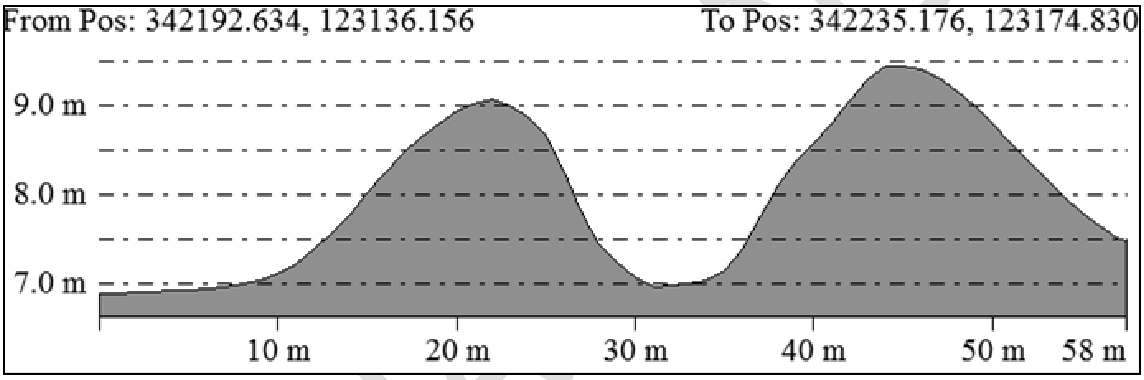
Hydraulic assessment

The Black & Veatch technical note[3]: '…seeks to determine the hydraulic benefits from dredging the River Parrett based on the 2013/2014 flood event and give a qualitative assessment of the likely impacts in other flood events. This will allow an informed decision to be made regarding the requirement for further, more detailed analysis…'. The hydraulic assessment considered two scenarios:

- Scenario 1 – lowering of bed levels by 0.5m along the entire reach.
- Scenario 2 – increased width of the channel between Westover Bridge and Great Bow Bridge achieved by reducing width of berms by a total of 2m.

It is reported that: '…There is minimal change in water levels throughout the event, with the only noticeable change being in very low water levels on the River Parrett at Thorney, and even this will not pass far upstream. Therefore neither dredging scenario is likely to have a significant impact on the frequency of flooding to the area. This shows that flooding in this area is generally controlled by the flow within the moors and the operation of structures rather than the capacity of the channels. Most of the flood water in the moors leaves the River Parrett (or River Isle) upstream of Thorney or comes from the River Yeo. Therefore the main benefit of increasing the capacity of the channels in this area would be to allow earlier pumping. However as this is mainly controlled by flood levels downstream even this is not that significant and … could actually be delayed in certain flood events...'.

Figure 7.2 Cross section from LiDAR



Note: Channel profile not properly shown as LiDAR only approximates the ground surface below water levels.

Cost assessment

For scenario 1 the channel is divided into 3 sections for quantity estimation:

Section	Length	Bed Width	Dredge depth	Dredge Volume
Thorney Mill to Isle	1.7 km	6m	0.5 m	5,100 m³
Isle to Westover Bridge	1.8 km	10m	0.5 m	9,000 m³
Westover Bridge to Great Bow Bridge	2.7 km	15m	0.5 m	20,250 m³
Total	6.2 km			34,350 m³

[3] River Parrett Dredging (Thorney to Langport) – Impacts on flood risk of dredging the River Parrett from Thorney to Langport, Black & Veatch, 20 October 2014

For scenario 2 it is assumed that the channel is an average 3m deep below the berms which indicates $6m^3/m$ run of channel. This represents 37,200 m^3 for 6.2km – it is not clear if this scenario is feasible from Thorney to Great Bow Bridge given how the channel bed width varies (see above). As the quantity of dredging is comparable between Scenarios 1 and 2, only one cost is calculated for Scenario 1.

It is assumed that 80% of dredged material is subject to single handling with material placed on or behind the banks by the excavator and 20% will be double-handled due to greater distance between excavation and disposal points.

On the above basis the estimated costs for modelling Scenario 1 are:

- Full scheme cost estimate of £0.6 million (range: £0.5 to £0.9 million).
- Indicative maintenance dredging cost of £0.2 million is estimated for removal of a third of the original dredging quantity (the actual timing of any maintenance would need to be based on results from monitoring surveys).
- Present Value (PV) cost over 100 years of £1.7 million is estimated based on the initial full dredging cost, with maintenance dredging every 5 years and assuming Treasury Green Book rates (initial 3.5%).

Environmental assessment

There are a number of known and potential local environmental constraints in the vicinity of this reach of the River Parrett. The risk factors are underlined below.

- There are no international or national nature conservation designations; West Moor SSSI (a component site of the Somerset levels and Moors SPA and Ramsar site) lies a short distance off the left bank from Thorney Bridge downstream to the Southmoor Main Drain confluence
- No additional local nature conservation sites
- Otter is known to be present in this reach of the Parrett; the presence of water vole is unconfirmed but should be anticipated; both banks comprise Coastal and Floodplain Grazing Marsh priority habitat throughout, apart from a small area of Traditional Orchard priority habitat on the left bank at Thorney Bridge
- No international cultural heritage assets but two listed buildings directly associated with the river (Thorney Mill and Thorney Mill House at Thorney Bridge) and two in close proximity (The Anchorage and The Old Rising Sun also at Thorney Bridge);
- No local cultural heritage assets or known archaeology associated with the channel or immediately adjacent land; there is a cluster of listed and scheduled features at Muchelney associated with the former abbey, and whilst these are far enough to the east of the Parrett not to be affected by dredging they suggest the potential for archaeology in particular around the nearby river crossing
- No national landscape designations
- Dredging in the lower part of this reach presents a risk of compromising Water Framework Directive hydromorphology objectives for the Parrett heavily modified water body and may be constrained by the Freshwater Fishery Protected Area status that applies through the whole reach from Thorney Bridge up to Langport
- The large majority of the land on either bank is under Stewardship including three fields under High Level Stewardship; those few fields not already under stewardship are within the Somerset Levels and Moors HLS target area

8. Dredging assessment: River Parrett, Langport to Tone confluence

Location

This reach of the River Parrett is about 7.8km long running from Langport to the confluence with the River Tone south of Burrowbridge (Figure 8.1).

Current Situation

Between Langport and Monk's Leaze Clyse the river is typically 20 to 25m wide at the water surface. There is then a gradual narrowing and by Oath footbridge the width is typically 15m. Downstream of Stathe Lock the width becomes even narrower and is typically between 10 and 15m. Figure 8.2 shows a typical cross section from LiDAR (next page).

Constraints

Structures: This reach of the river is crossed by two road bridges (Great Bow Bridge in Langport and Stathe Bridge), a railway bridge (Taunton to Westbury railway) and a footbridge near Oath. The Westover and West Sedgemoor pump stations contribute flow to the river while Monk's Leaze Clyse can take water off the River Parrett into the Sowy River. The right bank of the Parrett downstream of Monk's Leaze Clyse comprises the Allermoor spillway. Prior to construction of the Sowy River in about 1970 this used to discharge water direct to Aller Moor but now spills water into the Sowy River. Beazley's spillway is also on the right bank, further downstream than Allermoor spillway.

Access: Buildings on the right bank for 0.15km downstream of Great Bow Bridge will preclude access on that side. Access along both banks is then generally feasible up to the village of Oath except for a section on the left bank where there is an old navigational lock. The left bank of the river for 0.9km upstream and 1.8km downstream of Oath lock contain intermittent obstructions (buildings, gardens and trees) to dredging work. A public highway between Stathe and Burrowbridge also runs alongside part of the left bank and may preclude machine operation unless the road is closed. The final 0.7km of the left bank upstream of the confluence contains houses and gardens which will prevent access.

Working methods: The typical channel width is around 20m. However, there are substantial sections of the river where access on one back will be severely constrained and dredging would therefore need to be undertaken from the whichever banks are accessible, supplemented by a machine working over water.

Disposal: It is not expected that the silt being removed will be contaminated. To minimise costs and subject to cooperation from the landowners the excavated material can be deposited or spread on the channel banks and immediately adjacent land (i.e. within reach of a single handling operation) under waste exemption D1 as is believed to have been the historical practice. Deposition beyond this would require proof of benefit, chemical assessment and appropriate licensing.

However, there are reaches where this may not be feasible including: (i) area just upstream of Great Bow Bridge and (ii) the Aller Moor spillway. Material arising from over water dredging, at locations where an excavator working from the bank is not feasible, would need to be stockpiled to drain and could then be used to raise low lying land or reinforce the channel banks.

Figure 8.1 River Parrett, Langport to Tone Confluence

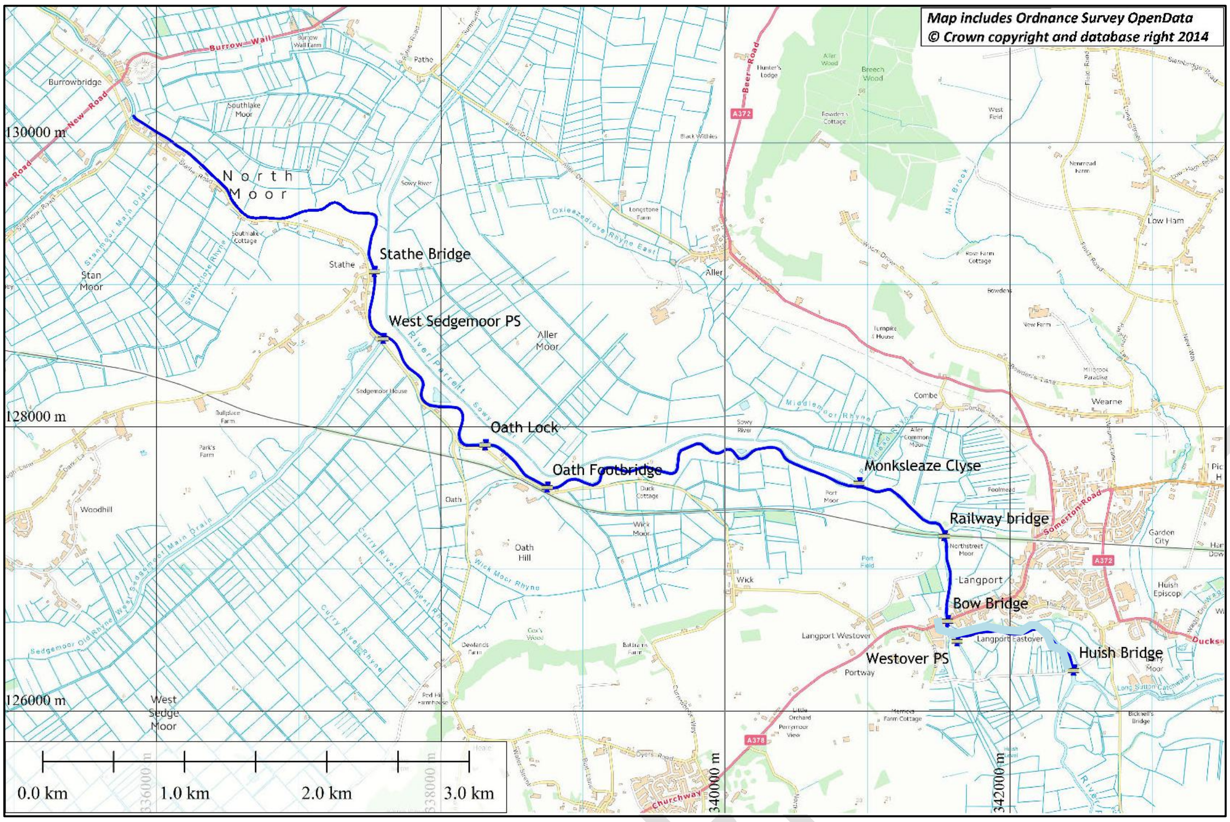
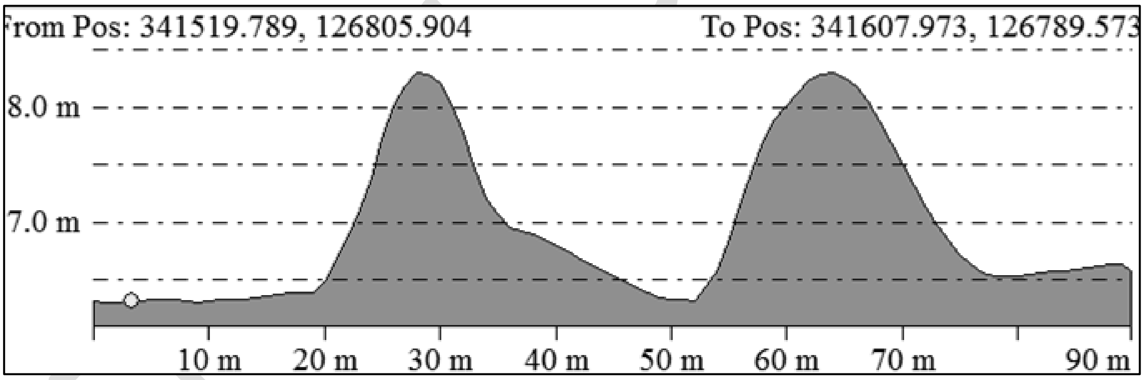
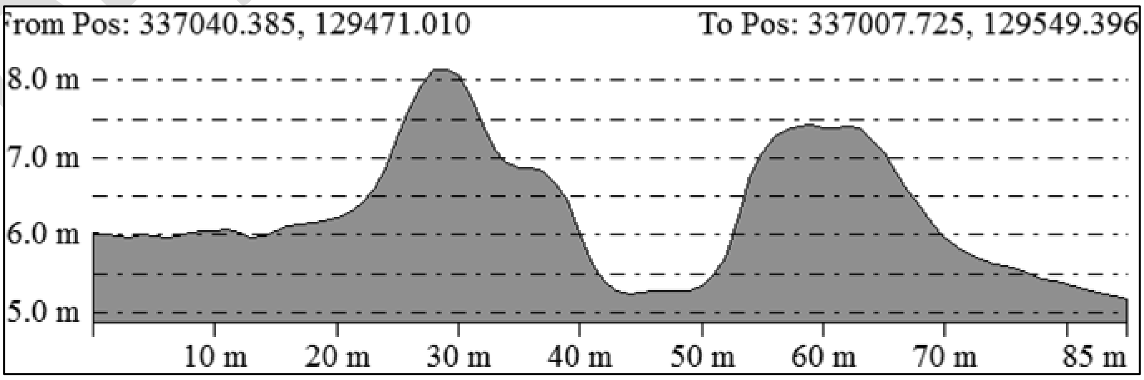


Figure 8.2 Cross sections from LiDAR

(a) Section just downstream of Langport



(b) Section downstream of Stathe



Note: Channel profile not properly shown as LiDAR only approximates the ground surface below water levels.

Water Framework Directive: The study reach encompasses the entirety of the "Parrett" GB108052015470 river water body. This is heavily modified by land drainage, with a number of morphological mitigation measures not in place some of which could be compromised by dredging (which could further raise and fix banks when dredged material is deposited) as follows:

- Sediment management strategies (develop and revise);
- Improve floodplain connectivity;
- Set-back embankments;
- Increase in-channel morphological diversity.

The water body also has Freshwater Fishery Protected Area status, which could constrain timing, extent and methodology of dredging operations.

The study reach extends downstream into the "Parrett" GB540805210900 transitional water body. This is heavily modified by flood protection, with a number of morphological mitigation measures not in place some of which could be compromised by dredging (and any associated bank raising / fixing) as follows:

- Manage disturbance;
- Site selection (dredged material disposal) (e.g. avoid sensitive sites);
- Sediment management;
- Preserve and where possible enhance ecological value of marginal aquatic habitat, banks and riparian zone;
- Managed realignment of flood defence.

The water body also has Freshwater Fishery Protected Area status, which could constrain timing, extent and methodology of dredging operations. Screening assessment would be required in relation to Natura 2000 Protected Area status / European designated nature conservation sites.

The Southlake Moor SSSI designation (and associated SPA, Ramsar and NNR designations) on the right bank from Stathe to Burrowbridge introduces a number of probable constraints including:

(i) Requirement for Habitats Regulations Assessment (HRA) in respect of the SPA and Ramsar site, and possible restriction on working months for dredging (to avoid wintering bird season).

(ii) A need to also demonstrate through HRA that dredging will not lower water levels in the adjacent Ramsar site to the detriment of its qualifying features.

(iii) Restrictions on the placing of dredged material anywhere on the bank within this reach. Close consultation with Natural England will be essential, and any land drainage or dredging deposition affecting this reach will require their consent.

Hydraulic assessment

The Black & Veatch technical note[4]: '…seeks to determine the hydraulic benefits from dredging the River Parrett based on the 2013/2014 flood event and give a qualitative assessment of the likely impacts in other flood events. This will allow an informed decision to be made regarding the requirement for further, more detailed analysis…'. The hydraulic assessment considered two scenarios:

- Scenario 1 – increased width of channel between Great Bow Bridge and Aller Moor spillway, achieved by reducing width of berms by a total of 2m.
- Scenario 2 – increased width of channel between Aller Moor spillway and River Tone confluence achieved by reducing width of berms by a total of 4m.

The results reported by Black & Veatch are summarised below in terms of dredging benefits/disbenefits:

- Water levels reduce in-channel between Thorney Bridge and the Parrett/Tone confluence and in the Moors upstream of Great Bow Bridge, i.e. Wet Moor, West Moor, Muchelney Level, Thorney Moor and Huish Level – the maximum decrease varies between 20 and 40mm.
- No change to the number of properties flooded.
- Scenario 1: no impact at Curry and North Moors and 10mm increase in peak flood levels in Aller and Kings Sedge Moors.
- Scenario 2:
  - flood duration reduces by 2 days for properties and infrastructure (greatest impact at Westover Estate), mainly due to less floodwater spilling over Allermoor spillway
  - 30-80mm decrease in Aller and King Sedge Moors respectively
  - flows and 20-300mm water levels increase downstream in Curry and North Moors respectively
  - flood duration increases by 16 and 3 days in North and Curry Moors respectively
  - generally more benefit upstream of Great Bow Bridge, but this makes flooding worse at North and Curry Moors due to less floodwater spilling over the Aller Moor spillway
  - negative impacts could potentially be offset by dredging downstream of North Moor or by other means

Cost assessment

For the purposes of this estimate the Aller Moor spillway is assumed to be 0.4km downstream of Monk's Leaze Clyse, i.e. about 1.9km downstream of Great Bow Bridge. The section of channel downstream of Great Bow Bridge covered by Scenario 1 is about 1.9 km long with a typical depth below the berm of 4m. The excavation volume is therefore about 15,200 m^3. The section of channel covered by Scenario 2 is about 6.9 km long with a typical depth below the berm of 4.5m. The excavation volume is therefore about 124,200 m^3.

It is assumed that 80% of dredged material is subject to single handling with material placed on or behind the banks by the excavator and 20% will be double-handled due to greater distance between excavation and disposal points.

On the above basis the estimated cost for modelling Scenario 1 are:

- Full scheme cost estimate of £2.1 million (range: £1.6 to £3.1 million).
- Indicative maintenance dredging cost of £0.7 million is estimated for removal of a third of the original dredging quantity (the actual timing of any maintenance would need to be based on results from monitoring surveys).
- Present Value (PV) cost over 100 years of £6.0 million is estimated based on the initial full dredging cost, with maintenance dredging every 5 years and assuming Treasury Green Book rates (initial 3.5%).

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[4] River Parrett Dredging (Langport to Tone confluence) – Impacts on flood risk of dredging the River Parrett from Langport to the confluence with the River Tone, Black & Veatch, 20 October 2014

Environmental assessment

There are significant environmental constraints along part of this reach of the River Parrett principally associated with nature conservation designations in the lower section. The risk factors are underlined below.

- From Stathe to Burrowbridge the Parrett's right bank is within the Somerset Levels and Moors SPA and Ramsar site, Southlake Moor SSSI and the Somerset Levels NNR, which all share a boundary here; (the left bank is largely constrained by the road and development).
- The Parrett also skirts the Somerset Levels and Moors SPA and Ramsar site and West Sedgemoor SSSI around Oath but is separated from these sites by the road.
- From east of Oath as far as Stathe the Parrett is within the West Sedgemoor RSPB reserve.
- Otter is known to be present throughout this reach of the Parrett, and water vole has also been recorded; apart from the peri-urban areas at Langport Eastover-Westover, Stathe and Burrowbridge both banks comprise Coastal and Floodplain Grazing Marsh priority habitat.
- No international cultural heritage assets, but two listed buildings directly associated with the river (two sections of Great Bow Bridge at Langport).
- Three "withy boilers" (one listed) in close proximity to the river (at Oath and Burrowbridge), and the Parrett-Tone confluence notable for the historic navigation on the Tone.
- No national landscape designations.
- Dredging presents a risk of compromising Water Framework Directive hydromorphology objectives for the Parrett river and transitional water bodies and may be constrained by the Freshwater Fishery Protected Area status that applies through the whole reach Burrowbridge up to Huish Bridge at Langport.
- Limited extents of land on each bank are under Stewardship including 14 fields on the left bank (mostly around Langport) and 7 on the right bank (at Langport but more significantly a reach under High Level Stewardship from Stathe to Burrowbridge); those areas not already under stewardship are within the Somerset Levels and Moors HLS target area (apart from Oath to Stathe).

The SSSI designation relates to extensive grazing marsh and ditch systems. Unit 44 alongside the Parrett is in favourable condition, but the ditches within it (unit 46) are unfavourable no change and impacted by high phosphate

In the short-term dredging might exacerbate high phosphate by encouraging its release from sediment, but this could be mitigated by undertaking works in winter months. There could be some longer term benefit by removing the sediment that constitutes a phosphate sink (which could help improve SSSI condition if combined with controls on remaining phosphate inputs).

9. Dredging assessment: River Parrett, North Moor to Bridgwater

Location

The reach under consideration is 3.15km and extends along the River Parrett from Northmoor pump station to the M5 motorway bridge (Figure 9.1, next page).

Current Situation

The river is embanked although the bank height slightly reduces towards the downstream as the prevailing ground level rises. Figure 9.2 shows a typical cross section from LiDAR (next page).

The channel is tidal along the whole section and therefore subject to cyclic fluctuations in water level, flow and velocities. The bed level progressively drops towards the downstream from about 2m AOD near Northmoor pump station to 1m AOD at the M5 bridge.

Constraints

Structures: No bridges or other structures of note occur along this section of the River Parrett.

Access: A road runs along the left bank for about 1.7km downstream of the pump station and there is a farm access track running along about 0.75km of the right bank. There is also an access road to commercial premises close to the right bank near the end of the reach. Access for dredging for more than half the length of this section is therefore subject to road closures or other temporary arrangements. Subject to this constraint and a few houses and farm buildings near the channel banks it should be possible to operate equipment on both banks.

Working methods: Long reach excavators working on each bank should be capable of channel widening. However, over-water dredging is assumed to be required for any bed deepening.

Disposal: It is not expected that the silt being removed will be contaminated. To minimise costs and subject to cooperation from the landowners the excavated material can be deposited or spread on the channel banks and immediately adjacent land (i.e. within reach of a single handling operation) under waste exemption D1 as is believed to have been the historical practice. Deposition beyond this would require proof of benefit, chemical assessment and appropriate licensing.

Material arising from over water dredging, at locations where an excavator working from the bank is not feasible, would need to be stockpiled to drain and could then be used to raise low lying land or reinforce the channel banks.

Water Framework Directive: The study reach comprises part of the “Parrett” GB540805210900 transitional water body. This is heavily modified by flood protection, with a number of morphological mitigation measures not in place some of which could be compromised by dredging (and associated bank raising / fixing) as follows:

- Manage disturbance;
- Site selection (dredged material disposal) (e.g. avoid sensitive sites);
- Sediment management;
- Preserve and where possible enhance ecological value of marginal aquatic habitat, banks and riparian zone;
- Managed realignment of flood defence.

The water body also has Freshwater Fishery Protected Area status, which could constrain timing, extent and methodology of dredging operations. Screening assessment would be required in relation to Natura 2000 Protected Area status / European designated nature conservation sites.

Figure 9.1 River Parrett, North Moor to Bridgwater

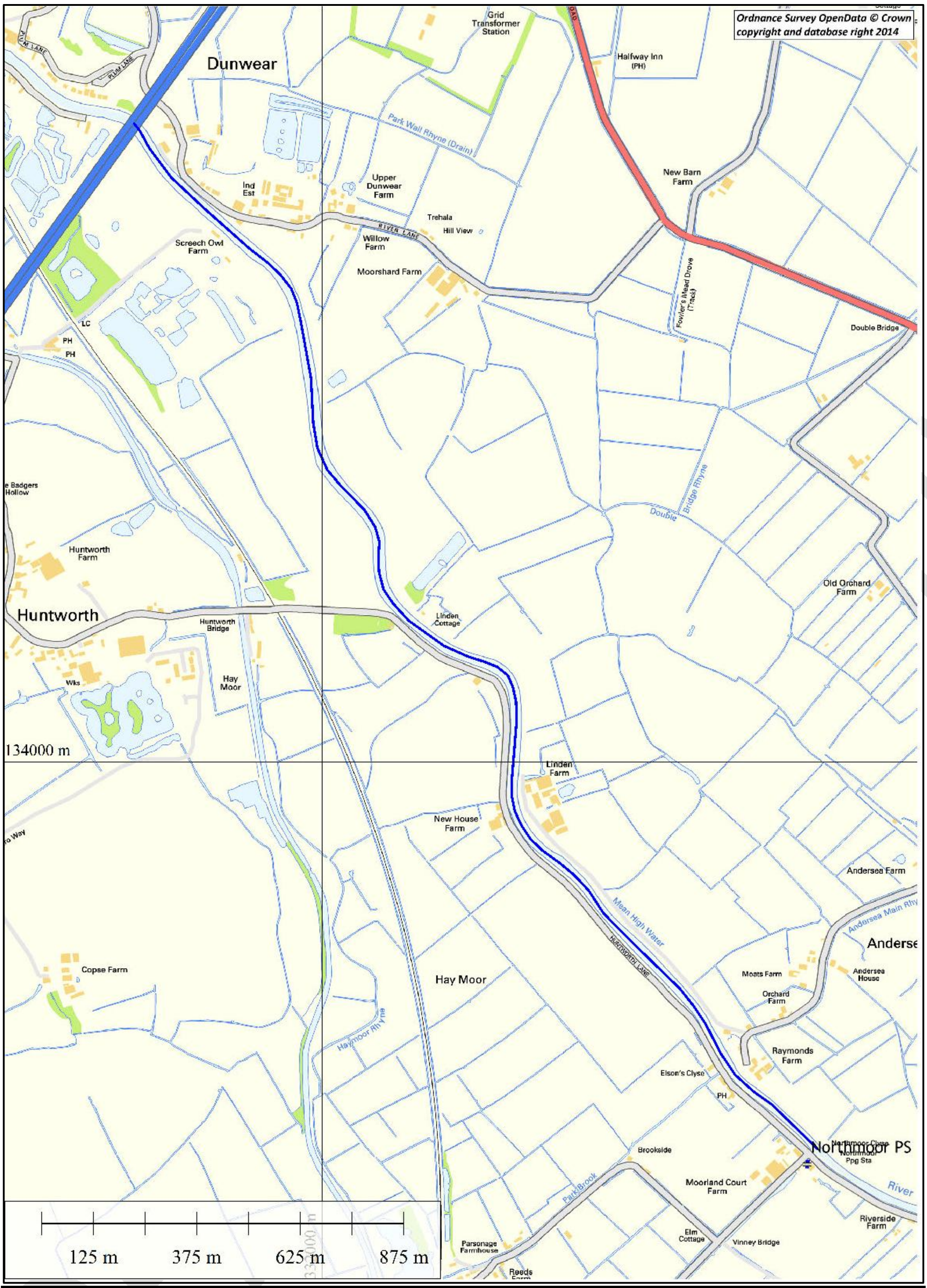
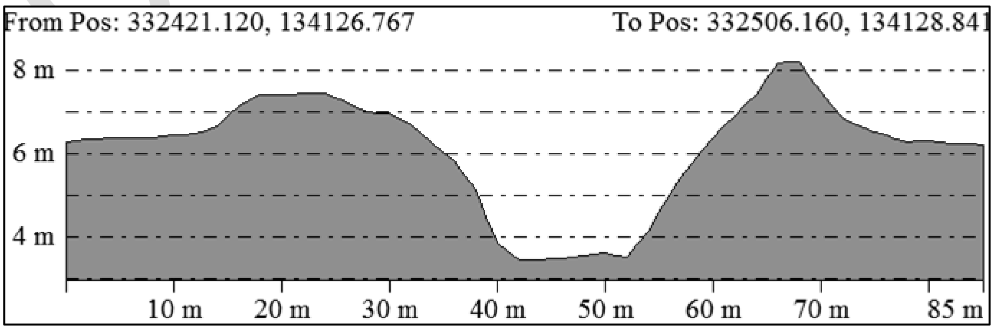


Figure 9.2 Cross section from LiDAR



Note: Channel profile not properly shown as LiDAR only approximates the ground surface below water levels.

Hydraulic assessment

The Black & Veatch technical note[5]: '…seeks to determine the hydraulic benefits from dredging the River Parrett based on the 2013/2014 flood event and give a qualitative assessment of the likely impacts in other flood events. This will allow an informed decision to be made regarding the requirement for further, more detailed analysis…'. The hydraulic assessment considered two scenarios:

- Scenario 1: increased width of channel achieved by reducing width of berms by a total of 2m.
- Scenario 2: increased width of channel achieved by reducing width of berms by a total of 4m.

The results reported by Black & Veatch are summarised below in terms of dredging benefits/disbenefits:

- Fluvial peak water levels reduce in the moors around the Parrett/Tone confluence, with the most significant impact in North Moor (260mm) and a lesser impact in Curry, Aller and Kings Sedge Moors.
- Property flooding reduces with the only significant impact in North Moor where potentially, compared against the baseline, 10 to 20 properties no longer flood internally (both scenarios) and for 25 to 35 properties, the flood duration is reduced by up to 20 days.
- Flood duration reduces in the moors upstream of Langport, although no impact on peak levels, due to less overtopping of Allermoor spillway allowing upstream pumping to commence earlier.
- Tide peaks in the Parrett upstream of Northmoor reduce but with an increase in tide peaks between North Moor and the M5 Motorway Bridge (20-50mm) and no change in tide peaks at Bridgwater.
- Frequency of flooding of all the key moors downstream of Langport could decrease, with the impact likely to be most significant in Salt and North Moors due to the reduced overtopping from Curry Moor. No impact to the moors upstream of Langport, but there may be small reductions in flood durations across all events.
- For more frequent flood events the flooding reduces in Salt and North Moors but with minimal (if any) impact on the number of affected properties, as these are only at risk in more extreme floods. Duration of road flooding also reduces as road flooding occurs early in a flood event.
- Potential to re-silt the quickest out of any of the Parrett and Tone catchment reaches being currently assessed (by Black & Veatch). There may be value in extending any further analysis downstream through Bridgwater

Cost assessment

The channel progressively deepens downstream with a depth below berm level of about 6m at the upstream end of this reach and about 7m at the downstream end. An average depth below berm level of 6.5m is assumed. The total length of channel is about 3.15 km. Scenario 1 channel widening represents a volume of about 41,000 m^3 and Scenario 2 widening is 82,000 m^3.

It is assumed that 80% of dredged material is subject to single handling with material placed on or behind the banks by the excavator and 20% will be double-handled due to greater distance between excavation and disposal points. The estimated base unit costs are increased by 20% to allow for dredging in tidal water.

On the above basis the estimated cost for modelling Scenario 1 are:

- Full scheme cost estimate of £0.85 million (range: £0.65 to £1.25 million).
- Indicative maintenance dredging cost of £0.28 million is estimated for removal of a third of the original dredging quantity (the actual timing of any maintenance would need to be based on results from monitoring surveys).
- Present Value (PV) cost over 100 years of £2.4 million is estimated based on the initial full dredging cost, with maintenance dredging every 5 years and assuming Treasury Green Book rates (initial 3.5%).

5 River Parrett Dredging (Downstream of North Moor) – Impacts on flood risk of dredging the River Parrett from North Moor pumping station to the M5 motorway bridge, Black & Veatch, 20 October 2014

The estimated cost for modelling Scenario 2 are:

- Full scheme cost estimate of £1.65 million (range: £1.25 to £2.5 million).
- Indicative maintenance dredging cost of £0.55 million is estimated for removal of a third of the original dredging quantity (the actual timing of any maintenance would need to be based on results from monitoring surveys).
- Present Value (PV) cost over 100 years of £4.7 million is estimated based on the initial full dredging cost, with maintenance dredging every 5 years and assuming Treasury Green Book rates (initial 3.5%).

Environmental assessment

There are a number of known and potential local environmental constraints in the vicinity of this reach of the River Parrett. Recognising that there is some potential to extend dredging through Bridgwater, the reach from the M5 to just downstream of the town centre is also considered here. The risk factors are underlined below.

- There are no international or national nature conservation designations.
- Screech Owl Local Nature Reserve lies on the left bank just upstream of the M5, and comprises of a wetland mosaic in flooded former clay pits.
- Otter and water vole are reported at Screech Owl LNR; otter is expected and water vole should be anticipated in the Parrett here and more widely; upstream of the M5 most of the right bank and intermittent reaches of the left bank comprise Coastal and Floodplain Grazing Marsh priority habitat.
- There are no international cultural heritage assets upstream or downstream of the M5; there is only one listed building (Linden Farmhouse) near the river channel upstream of the M5 but numerous listed buildings in Bridgwater town centre.
- No local cultural heritage assets or known archaeology is reported associated with the channel or immediately adjacent land upstream of the M5; Bridgwater town centre has numerous records.
- No national landscape designations.
- Dredging presents a risk of compromising Water Framework Directive hydromorphology objectives for the Parrett transitional water body and may be constrained by the water body's Freshwater Fishery Protected Area status.
- Upstream of the M5 a small part of the left bank (one field) and a larger extent of the right bank (8 fields) are under Stewardship and most of the rest is within the Somerset Levels and Moors HLS target area.

10. Dredging assessment: River Tone, Ham to Hook Bridge

Location

The length of this reach of the River Tone is about 6.85 km (Figure 10.1, next page).

Current Situation

The channel is subject to tidal influence as far upstream as the New Bridge sluices and is embanked with the bank heights progressively increasing downstream. The river is typically 15 to 20m wide at the water surface at the upstream end but reducing to 10 to 15m downstream of New Bridge. Access along both sides of the river is generally good. Figure 10.2 shows a typical cross section from LiDAR (next page).

Constraints

Structures: This reach of river is crossed by four bridges: Coalharbour Bridge at the upstream end, Knapp Bridge, New Bridge (which also has sluices) and Hook Bridge at the downstream end.

Access: A domestic garden with trees along the river bank will preclude access along the first 0.15km of the left bank of the reach. There is also no defined access along the river bank adjacent to New Bridge House in the centre of this reach of river. Other than at these constraints the river passes through farmland with open access along each bank.

Working methods: Where accessible and technically feasible the dredging would be undertaken by long reach excavators working from each bank. However, deepening of the bed in the centre of the river would have to be carried out over water.

Disposal: It is not expected that the silt being removed will be contaminated. To minimise costs and subject to cooperation from the landowners the excavated material can be deposited or spread on the channel banks and immediately adjacent land (i.e. within reach of a single handling operation) under waste exemption D1 as is believed to have been the historical practice. Deposition beyond this would require proof of benefit, chemical assessment and appropriate licensing.

Material arising from over water dredging, at locations where an excavator working from the bank is not feasible, would need to be stockpiled to drain and could then be used to raise low lying land or reinforce the channel banks.

Water Framework Directive: The study reach comprises part of the "Tone DS Taunton" water body (GB108052015482). This is heavily modified by flood protection but its hydromorphological conditions supports good potential (although one mitigation measure is indicated on http://www.environment-agency.gov.uk/wiyby and should be investigated further). The water body has Freshwater Fishery Protected Area status, which could constrain timing, extent and methodology of dredging operations.

The lower part of the study reach extends into the "Parrett" GB540805210900 transitional water body. This is heavily modified by flood protection, with a number of morphological mitigation measures not in place some of which could be compromised by dredging (and any associated bank raising / fixing) as follows:

- Manage disturbance;
- Site selection (dredged material disposal) (e.g. avoid sensitive sites);
- Sediment management;
- Preserve and where possible enhance ecological value of marginal aquatic habitat, banks and riparian zone;
- Managed realignment of flood defence.

The water body also has Freshwater Fishery Protected Area status, which could constrain timing, extent and methodology of dredging operations. Screening assessment would be required in relation to Natura 2000 Protected Area status / European designated nature conservation sites.

Figure 10.1 River Tone, Ham to Hook Bridge

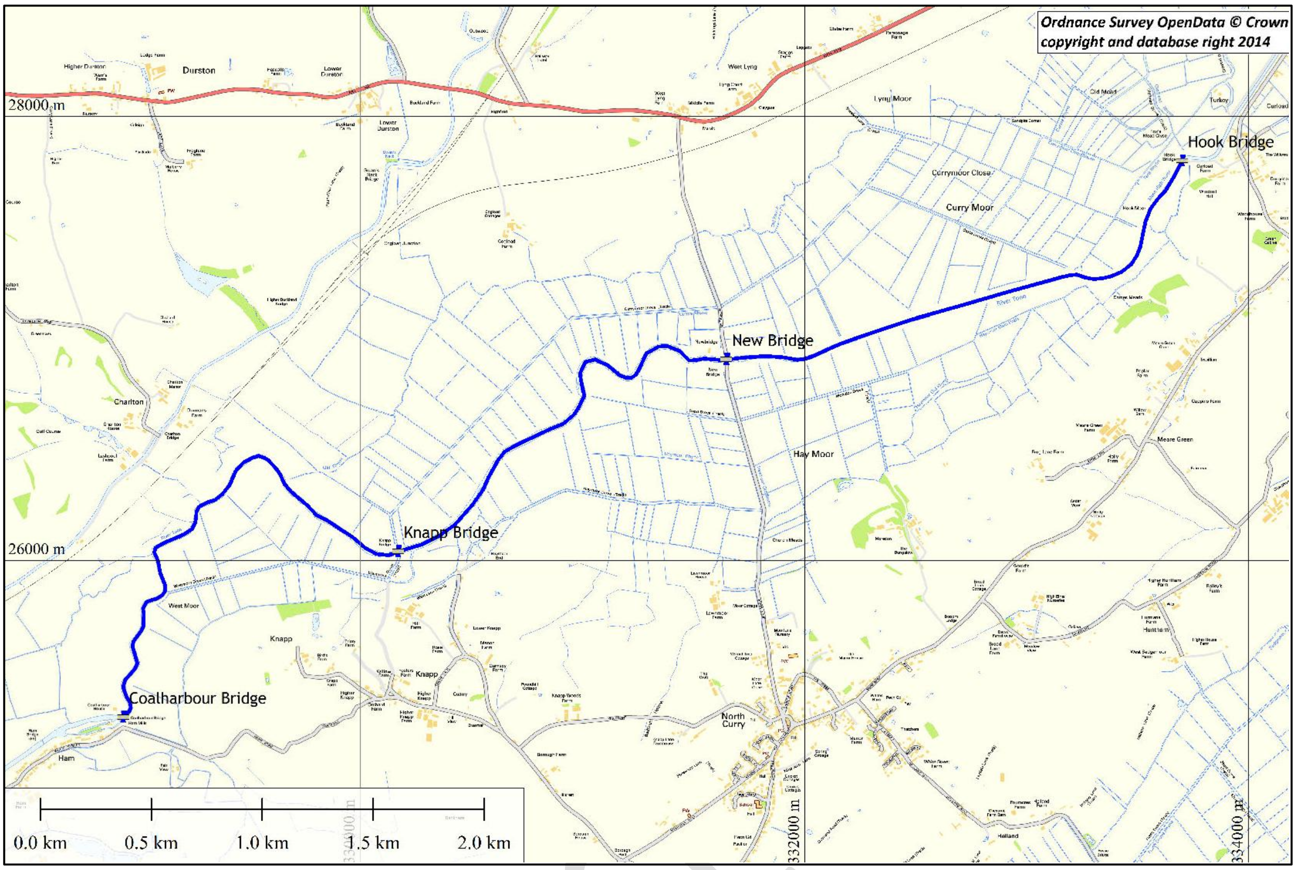
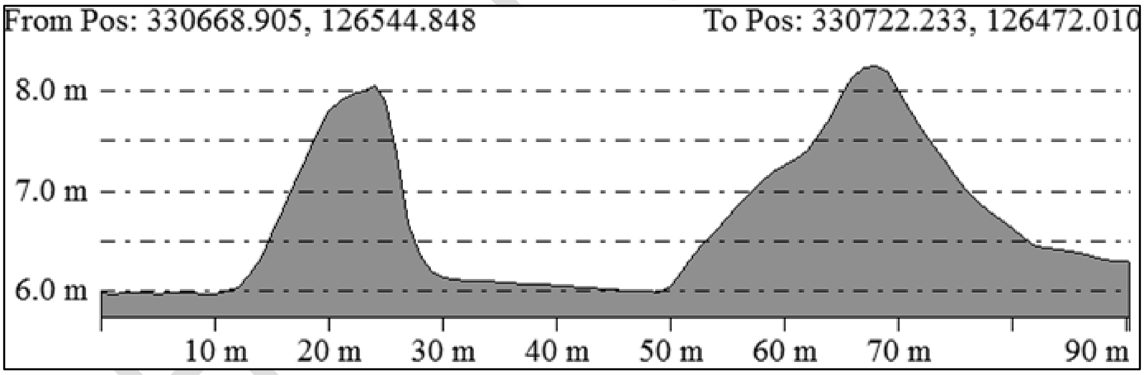


Figure 10.2 Cross section from LiDAR
taken between the Knapp and New bridges



Note: Channel profile not properly shown as LiDAR only
approximates the ground surface below water levels.

The SSSI designations (and associated SPA and Ramsar designations) introduce a number of probable constraints including:

(i) Requirement for Habitats Regulations Assessment (HRA) in respect of the SPA and Ramsar site, and possible restriction on working months for dredging (to avoid wintering bird season).

(ii) A need to also demonstrate through HRA that dredging will not lower water levels in the adjacent Ramsar site to the detriment of its qualifying features.

(iii) Limitations on dredging within the river which is a component unit of the SSSI.

(iv) Restrictions on the placing of dredged material anywhere on the banks which are all within the SSSI.

Close consultation with Natural England will be essential, and any dredging activities will require their consent. Any activities would need to be compatible with the Curry Moor Water Level Management Plan which is required to achieve favourable status in the SSSI.

Hydraulic assessment

The Black & Veatch technical note[6]: '…seeks to determine the hydraulic benefits from dredging the River Tone based on the 2013/2014 flood event and give a qualitative assessment of the likely impacts in other flood events. This will allow an informed decision to be made regarding the requirement for further, more detailed analysis.…'. The hydraulic assessment considered two scenarios:

- Scenario 1 – application of Tone Valley Scheme design profiles between Ham Weir and Hook Bridge.
- Scenario 2 – increased capacity of the channel between Knapp Bridge and Hook Bridge achieved through lowering the bed level by 0.5m and increasing the channel width by reducing the width of the berms by a total of 4m.

The results reported by Black & Veatch are summarised below in terms of dredging benefits/disbenefits:

- In-channel water levels reduce between Ham Weir and Hook Bridge, reducing the flow and water levels in West Curry, Curry, Hay and West Moors as well as Salt and North Moors due to the reduced volume of water passing from Curry Moor over Athelney Spillway and through Lyng Cutting.
- Duration of pumping reduces in North and Salt Moors by almost three days, and to a lesser degree in Curry and Hay Moors.
- Flooding to properties, infrastructure and land reduces in North and Salt Moors though only minimal impact. Potentially two properties no longer flood internally for Scenario 2 and the flood duration reduces for the remaining properties only by 1-2 days.
- Flood duration reduces for the A361 and several fields by 1-2 days (estimate only),. In all other locations the flood duration shows little change.
- Flood frequency and duration decreases for all the moors in the area (i.e. West Curry, Curry, West, Hay, North and Salt Moors) due to the reduced bank overtopping along the River Tone.
- Potential to offset impacts if banks raised at the western ends of Curry and Hay Moors, particularly in-channel along the River Tone but unlikely to fully offset for West Moor.

Cost assessment

Scenario 1 is estimated to require about 20m³ per metre of excavation, half of which is assumed to be 'hard' material (based on Figure 1, Technical Note, Black & Veatch). Scenario 2 is estimated to require about 35m³ per metre of excavation, half of which is assumed to be 'hard' material (based on Figure 2, Technical Note, Black & Veatch). This material formed in the berms is assumed to be the build-up of material since the Tone Valley scheme.

[6] River Tone Dredging upstream of Hook Bridge – Impacts on flood risk of dredging the River Tone upstream of Hook Bridge, Black & Veatch, 30 September 2014

Scenario 1 channel widening represents a volume of about 137,000 m^3 and Scenario 2 about 240,000 m^3.

It is assumed that 80% of dredged material is subject to single handling with material placed on or behind the banks by the excavator and 20% will be double-handled due to greater distance between excavation and disposal points.

On the above basis the estimated cost for modelling Scenario 1 are:

- Full scheme cost estimate of £2.3 million (range: £1.7 to £3.5 million).
- Indicative maintenance dredging cost of £0.77 million is estimated for removal of a third of the original dredging quantity (the actual timing of any maintenance would need to be based on results from monitoring surveys).
- Present Value (PV) cost over 100 years of £6.6 million is estimated based on the initial full dredging cost, with maintenance dredging every 5 years and assuming Treasury Green Book rates (initial 3.5%).

The estimated cost for modelling Scenario 2 are:

- Full scheme cost estimate of £4.0 million (range: £3.0 to £6.0 million).
- Indicative maintenance dredging cost of £1.35million is estimated for removal of a third of the original dredging quantity (the actual timing of any maintenance would need to be based on results from monitoring surveys).
- Present Value (PV) cost over 100 years of £11.5 million is estimated based on the initial full dredging cost, with maintenance dredging every 5 years and assuming Treasury Green Book rates (initial 3.5%).

Environmental assessment

There are significant environmental constraints in the vicinity of this reach of the River Tone principally associated with nature conservation designations. The risk factors are underlined below.

- Both banks throughout this reach are within the Somerset Levels and Moors SPA and Ramsar site and the Curry and Hay Moors SSSI.
- No additional local nature conservation sites.
- Otter is known to be present in this reach of the Tone; the presence of water vole is unconfirmed but should be anticipated; the entire left bank and almost the entire right bank comprise Coastal and Floodplain Grazing Marsh priority habitat; the small remaining part of the right bank is Traditional Orchard priority habitat.
- No international cultural heritage assets but three listed buildings directly associated with the river (Ham Wharf House and Ham Mills at Ham, Knapp Bridge) and three in close proximity (Coldharbour and Greenlands Old Ham Wharf Farm at Ham and Newbridge [house] at New Bridge).
- No local cultural heritage assets or known archaeology associated with the channel or immediately adjacent land (except at the known listed sites).
- No national landscape designations.
- Dredging in the lower part of this reach presents a risk of compromising Water Framework Directive hydromorphology objectives for the Parrett transitional water and may be constrained by the Freshwater Fishery Protected Area status that applies through the whole reach from Hook Bridge up to Ham.
- The majority of the land on either bank is under Stewardship including several fields under High Level Stewardship; this is particularly the case on the right bank (approximately 30 of 35 fields under stewardship, compared to approximately 27 of 40 on the left bank); those areas not already under stewardship are within the Somerset Levels and Moors HLS target area.

The SSSI designation relates to coastal grazing marsh with the significant interests associated with the network of ditches and rhynes, the annual winter flooding of grassland and the value of the grassland for breeding waders and other birds. The Tone from Ham to Hook Bridge is associated with the following units (from upstream to downstream):

- Left bank - units 81, 82, 84, 86, 87 all unfavourable declining, with factors including poor water quality (high phosphate) in ditches and lack of safe bird roosts due to water level management.
- Right bank – units 100, 98, 97, 93 all as above.
- River itself - unit 101 also unfavourable recovering (with high phosphate again a factor).

In the short-term dredging might exacerbate high phosphate by encouraging its release from sediment, but this could be mitigated by undertaking works in winter months. There could be some longer term benefit by removing the sediment that constitutes a phosphate sink (which could help improve SSSI condition if combined with controls on remaining phosphate inputs).

11. Dredging assessment: River Yeo, Huish Episcopi pumping station to Parrett confluence

Location

This reach of the River Yeo extends 1.8km from the Huish Episcopi pumping station to the confluence with the River Parrett (Figure 11.1, next page).

Current Situation

The channel width is typically 8m to 12m at the water surface although it widens to about 20m immediately upstream of the confluence with the River Parrett. The channel is predominantly embanked on the left side only with the natural ground level on the right side of the channel being at about bank top level. The Long Sutton Catchwater drainage channel runs within this higher ground at usually 20 m to 60m away although there is one section where it is closer. Figure 11.2 shows a typical cross section from LiDAR (next page).

Constraints

Structures: This reach of river is crossed by three bridges: Pibsbury Bridge near the upstream end carries the access road to the pump station and Bicknell's bridge crosses the river about 400m upstream of the confluence. A pipe bridge also crosses the river immediately upstream of Bicknell's Bridge. There is also a drainage siphon under the river about 150m downstream of Bicknell's bridge.

Access: The first section of about 150m upstream of Pibsbury Bridge has large trees on the left bank. These may be a constraint on equipment operation on that side of the river. About 450m downstream of this bridge the Long Sutton Catchwater drain converges on to the right bank of the River Yeo and then runs approximately parallel leaving a bank top separation varying between about 15m and 30m for about 350m when the intervening bank width reduces to about 4m. There is a widening of this intervening bank in the vicinity of Bicknell's Bridge but it then narrows again. Apart from the house adjacent to Bicknell's Bridge there is clear access on the left bank downstream from Pibsbury Bridge up to the end of the reach.

Working methods: Given the constraints to working from both banks, use of a very long reach excavator working from the left bank (right bank upstream of Pibsbury Bridge) may be appropriate. Care must be given to avoiding damage to the drainage siphon under the river downstream of Bicknell's Bridge.

Disposal: It is not expected that the silt being removed will be contaminated. To minimise costs and subject to cooperation from the landowners the excavated material can be deposited or spread on the channel banks and immediately adjacent land (i.e. within reach of a single handling operation) under waste exemption D1 as is believed to have been the historical practice. Deposition beyond this would require proof of benefit, chemical assessment and appropriate licensing.

Water Framework Directive: The study reach comprises part of the "Yeo DS Over Compton" water body (GB108052015682). This is heavily modified by flood protection but whilst its morphological mitigation measures assessment supports moderate (rather than good) potential no mitigation measures are identified in the RBMP (although one is indicated on http://www.environment-agency.gov.uk/wiyby and should be investigated further). The water body has Freshwater Fishery Protected Area status, which could constrain timing, extent and methodology of dredging operations.

Figure 11.1 River Yeo, Huish Episcopi pumping station to Parrett confluence

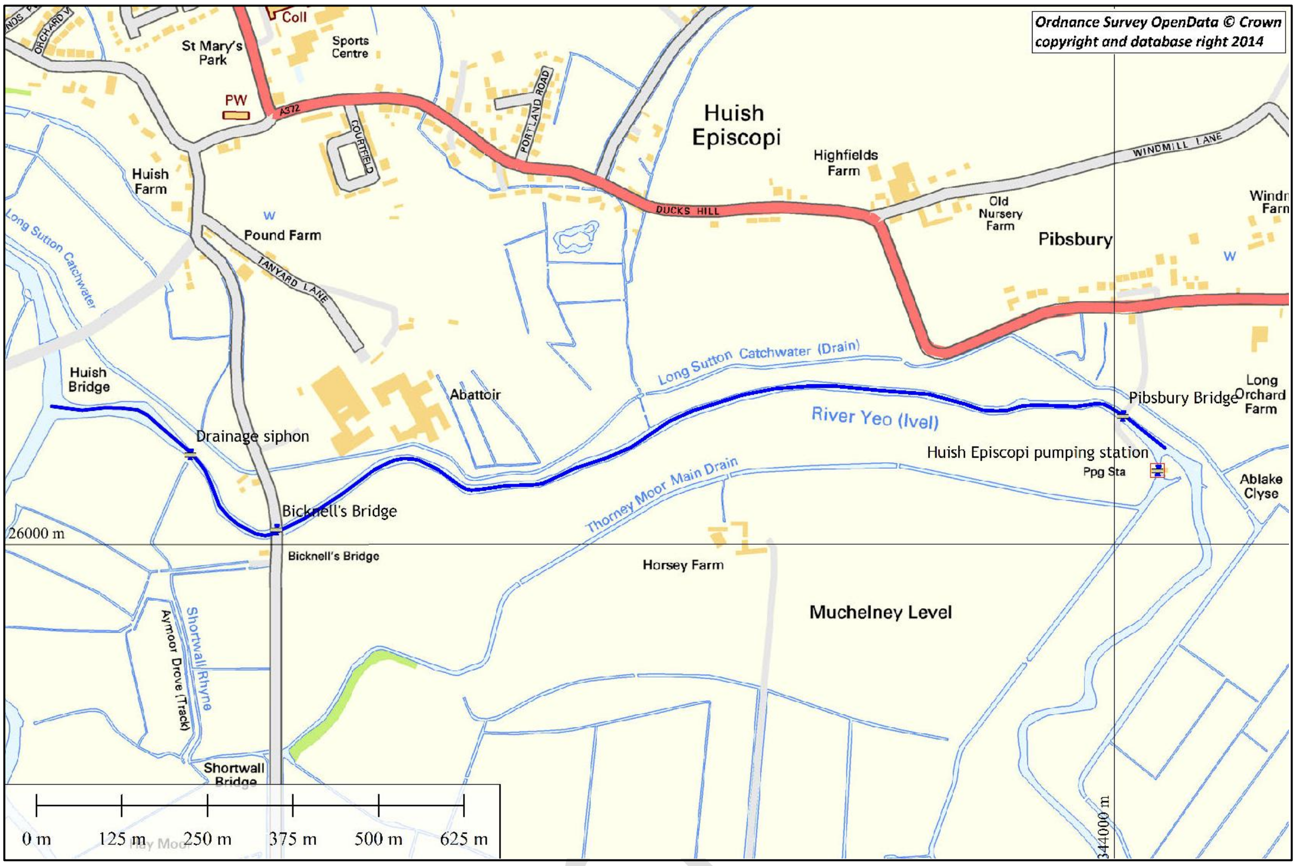
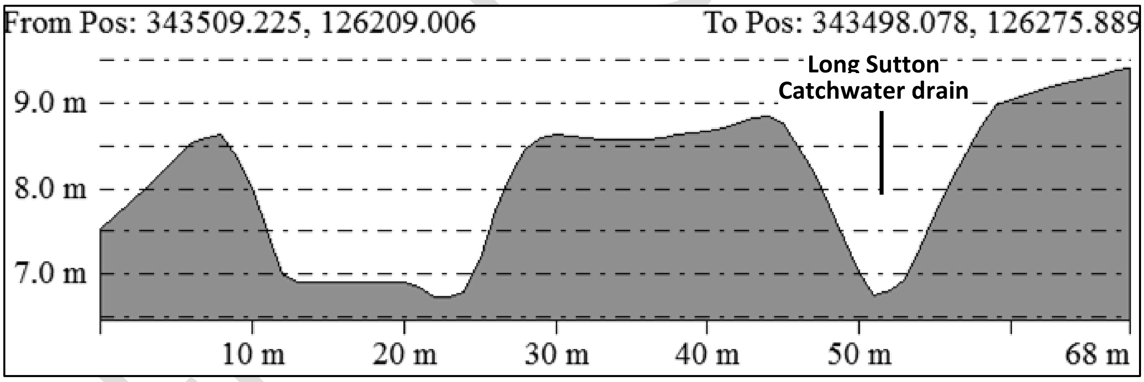


Figure 11.2 Cross section from LiDAR



Note: Channel profile not properly shown as LiDAR only approximates the ground surface below water levels.

Hydraulic assessment

The Black & Veatch technical note[7]: '… seeks to determine the hydraulic benefits from dredging the River Yeo based on the 2013/2014 flood event and give a qualitative assessment of the likely impacts in other flood events. This will allow an informed decision to be made regarding the requirement for further, more detailed analysis …'. The hydraulic benefits were assessed for this in combination with the Thorney to Langport and Langport to Allermoor spillway dredge.

The results reported by Black & Veatch are summarised below in terms of dredging benefits/disbenefits:

- Water levels in-channel reduce between HEPS and Yeo/Parrett confluence (in River Yeo) and between Thorney Bridge and Parrett/Tone confluence and in the moors upstream of Great Bow Bridge (i.e. Wet and West Moors, Muchelney Level, Thorney Moor and Huish Level), with decreases of only 40-140mm.
- Small increase in flows passing downstream with 10mm increase in water levels in the moors downstream of Great Bow Bridge (i.e. Aller, Kings Sedge and North Moors) for scenario 2.
- No change to the number of properties flooded but flood duration at Westover Trading Estate reduces by 2.5 and 5.3 days and the Langport to Muchelney Road by 16 or 20 hours, and Thorney properties by 18 or 24 hours for scenarios 1 and 2 respectively.
- No change in flood duration in the moors upstream of Great Bow Bridge and in the downstream moors a minor increase in duration of flooding by 3 to 9 hours.
- Water level increases at the downstream moors could possibly be mitigated, e.g. by dredging elsewhere.

Cost assessment

The modelling report assumes a lowering of the river bed by 0.5m along the reach of river under consideration. The length of the reach is 1.8km and the average excavation width is estimated to be 10m. The volume of material to be excavated is therefore about 9,000 m³.

Access for dredging is generally adequate although there are a few sections with trees or bushes along the channel banks. There is also a section of about 0.2km where the right bank is relatively narrow with the Long Sutton Catchwater drain running close to the river.

It is assumed that 80% of dredged material is subject to single handling with material placed on or behind the banks by the excavator and 20% will be double-handled due to greater distance between excavation and disposal points. Additional care would also be required when working in the vicinity of the drainage siphon downstream of Bicknell's bridge.

On the above basis the estimated cost for modelling Scenario 1 are:

- Full scheme cost estimate of £0.15 million (range: £0.1 to £0.25 million).
- Indicative maintenance dredging cost of £0.05 million is estimated for removal of a third of the original dredging quantity (the actual timing of any maintenance would need to be based on results from monitoring surveys).
- Present Value (PV) cost over 100 years of £0.45 million is estimated based on the initial full dredging cost, with maintenance dredging every 5 years and assuming Treasury Green Book rates (initial 3.5%).

As the hydraulic benefits were assessed in combination with the Thorney to Langport and Langport to Allermoor spillway dredge, the costs do not reflect the benefits that would be achieved by just the HEPS to Parrett confluence dredge.

7 Penzoy and Chedzoy channels Dredging – Impacts on flood risk of dredging the Penzoy and Chedzoy systems, Black & Veatch, 20 October 2014

Environmental assessment

There are relatively few environmental constraints in the vicinity of this reach of the River Yeo (Ivel). The risk factors are underlined below.

- There are no international or national nature conservation designations; West Moor SSSI (a component site of the Somerset levels and Moors SPA and Ramsar site) lies a short distance upstream (eastwards) of the upper extent of the potential dredging.
- No local nature conservation sites.
- Otter is likely to be present in this reach of the River Yeo (Ivel); the presence of water vole is unconfirmed but should be anticipated; both banks comprise Coastal and Floodplain Grazing Marsh priority habitat apart from very small areas towards the upstream end of this reach.
- No international or national cultural heritage assets.
- No local cultural heritage assets or known archaeology associated with the channel or immediately adjacent land.
- No national landscape designations.
- Dredging presents a risk of compromising Water Framework Directive objectives related to Freshwater Fishery Protected Area status.
- The left bank is under Stewardship upstream of Bicknell Bridge but not downstream and the right bank is not under Stewardship (but is partly within the Somerset Levels and Moors HLS target area).

12. Dredging assessment: Penzoy River, New Southlake inlet to Kings Sedgemoor Drain

Location

The section of Penzoy system under consideration for dredging is about 10.4km long running from Burrow Wall to its downstream confluence with the Chedzoy New Cut and the Chedzoy New Cut from Portwall Drove to the outfall into the Kings Sedgemoor Drain at Chedzoy Flap (Figure 12.1, next page). Upstream of Burrow Wall in flood conditions levels are controlled by the volume of storage available rather than the conveyance of the channel through Southlake.

The river comprises various channels with different local names: Hitching's Rhyne at the upstream, Andersea Main Rhyne in the central section, then Horsey Main Drain and finally Chedzoy New Cut.

Current Situation

The channel is about 3 to 4m water surface width in the upstream section gradually increasing to about 10m from about mid point up to the Chedzoy New Cut which is slightly narrower with about 8 to 9m water surface width. The Penzoy is a drainage channel and operates with the water surface below ground level. It is not significantly embanked. Figure 12.2 shows a typical cross section from LiDAR (next page).

Constraints

Structures: The channel is crossed by about 24 structures comprising 2 road bridges, 6 farm access bridges (thought to be clear spans across the channel), 14 culverts (assumed to be pipes) and 2 footbridges. The culverts occur in the smaller, upstream, part of the channel. The culverts have submerged flow under normal operation and may need to be supplemented or replaced in order to pass significantly larger flows.

Access: The channel mainly passes through open farmland and access to both sides of the channel is generally available. There are trees on the right bank of the channel where it runs adjacent to Lake Wall.

Working methods: The limited width of the upstream half of the channel places it within reach of a normal excavator working from both sides. The downstream, wider, sections would require use of a longer reach machine.

Disposal: It is not expected that the silt being removed will be contaminated. To minimise costs and subject to cooperation from the landowners the excavated material can be deposited or spread on the channel banks and immediately adjacent land (i.e. within reach of a single handling operation) under waste exemption D1 as is believed to have been the historical practice. Deposition beyond this would require proof or benefit, chemical assessment and appropriate licensing.

Water Framework Directive: The study reach comprises part of one of the channels on the "Kings Sedgemoor Drain" water body (GB108052021400). This is an artificial water body, for land drainage, and its morphological mitigation measures assessment supports moderate (rather than good) potential. The only measure not in place as identified in the RBMP (although two measures are indicated by http://www.environment-agency.gov.uk/wiyby and should be investigated further) relates to fish passage at pumping and not be compromised by dredging. The water body has Freshwater Fishery Protected Area status, which could constrain timing, extent and methodology of dredging operations.

The Southlake Moor SSSI designation (and associated SPA, Ramsar and NNR designations) to the south of Burrow Wall (the A361) near Burrowbridge, plus the Langmead and Weston Level SSSI designation to the east of Andersea, introduce a number of probable constraints including:

(i) Requirement for Habitats Regulations Assessment (HRA) in respect of the SPA and Ramsar site, and possible restriction on working months for dredging (to avoid wintering bird season).

(ii) A need to also demonstrate through HRA that dredging will not lower water levels in the adjacent Ramsar site to the detriment of its qualifying features.

(iii) Restrictions on the placing of dredged material anywhere on the bank within this reach. Close consultation with Natural England will be essential, and any land drainage or dredging deposition affecting this reach will require their consent.

Figure 12.1 Penzoy River, New Southlake inlet to Kings Sedgemoor Drain

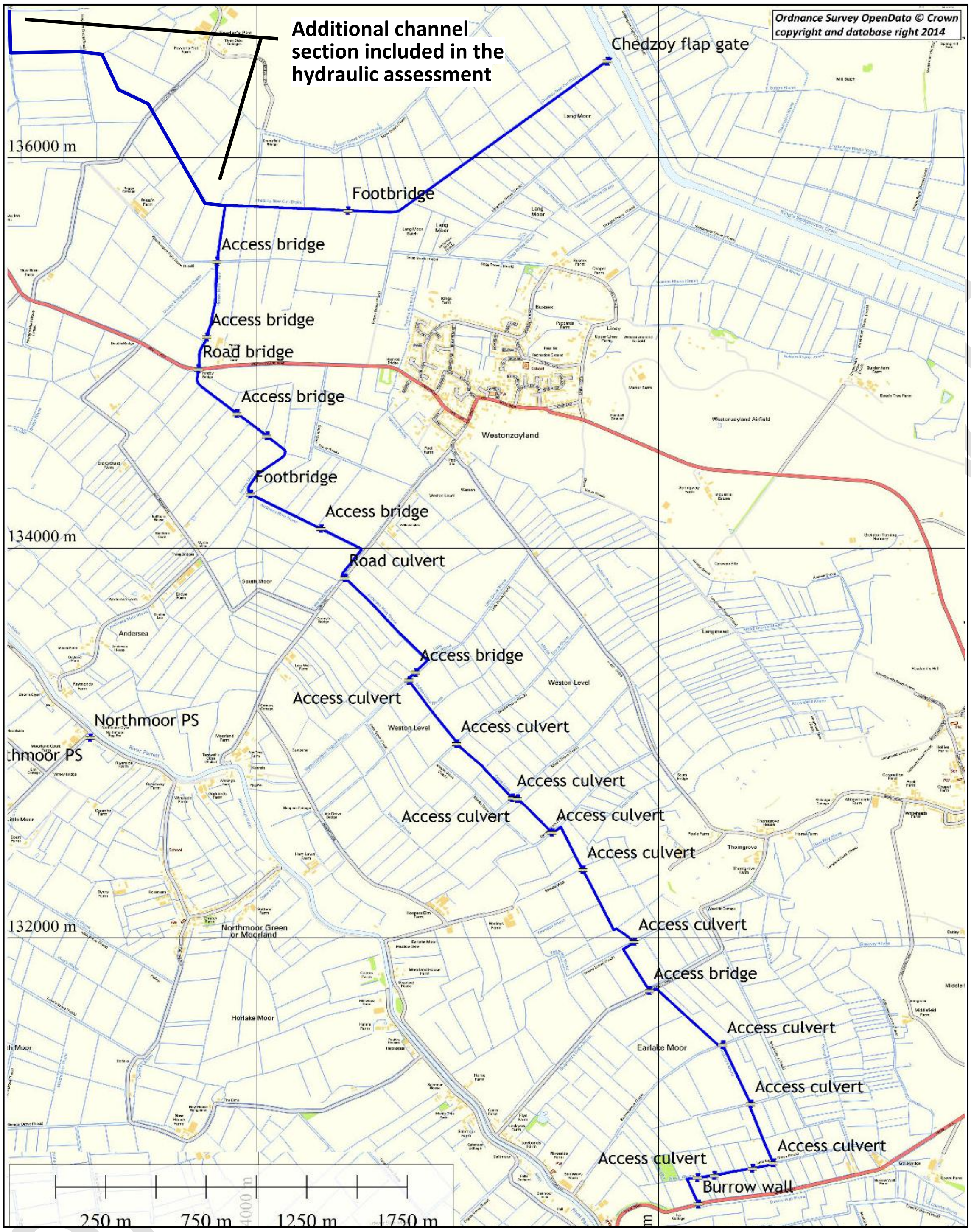
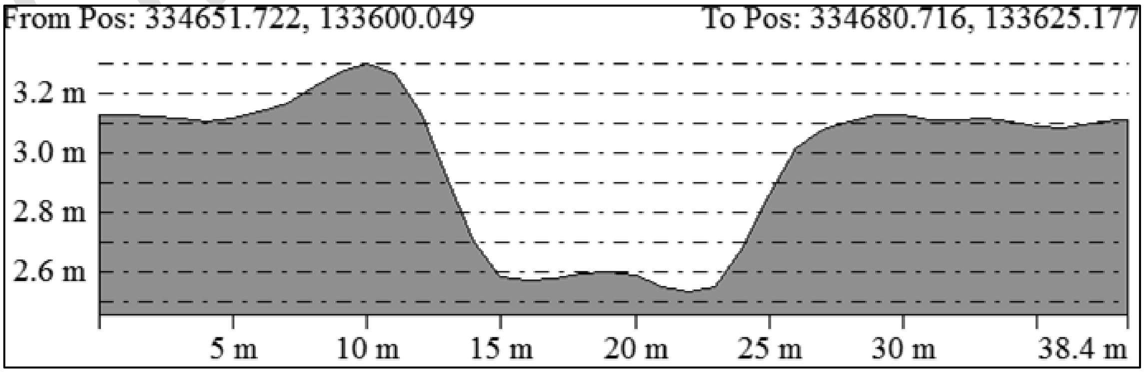


Figure 12.2 Cross section from LiDAR



Note: Channel profile not properly shown as LiDAR only approximates the ground surface below water levels.

Hydraulic assessment

The Black & Veatch technical note[8]: '…seeks to determine the hydraulic benefits from dredging based on the 2013/2014 flood event and give a qualitative assessment of the likely impacts in other flood events. This will allow an informed decision to be made regarding the requirement for further, more detailed analysis …'. The hydraulic assessment considered two scenarios:

- Scenario 1: increase capacity by removing the silt identified in the 2011 channel survey.
- Scenario 2: increase the channel size where it is currently smaller than the 1970s design proposal for the Penzoy and Chedzoy systems.

The results reported by Black & Veatch are summarised below in terms of dredging benefits/disbenefits:

- Scenario 1: no change in the peak water levels upstream of the Lake Wall, but the peak levels both in-channel and in the moors downstream of the Lake Wall reduce by no more than 10mm.
- Scenario 2: reduces the in-channel and moors water levels in the area by about 10mm except no change in the Southlake and Weston Level.
- Flood frequency and duration: impacts only for more frequent flood events with river levels just above bankfull, generally only after heavy localised rainfall rather than overtopping from the other watercourses.
- Frequency of flooding: reduces during more frequent flood events in the adjoining fields due to both the increased channel capacity and the improved conveyance to Westonzoyland pump station, though impact unlikely to benefit the flooding of properties or major roads.
- Condition of Southlake under Burrow Wall to the Penzoy River: flow heavily restricted by the inlet structure to the culvert and if improved in combination with dredging on the Penzoy and Chedzoy systems there may be minor benefit in larger flood events to the depth and flood duration on Southlake and possibly the Sowy River moors. Alternatively, flow restriction from Southlake could be considered a benefit if it reduces downstream flood levels by limiting flows into the Penzoy River.
- Dredging may also benefit water level management during low flows.

Cost assessment

The modelling report does not identify the locations where Scenario 2 is applicable and the cost estimate is therefore only presented for Scenario 1 which assumes 0.6m excavation of the bed for a bed width averaging 4m for the upstream half of the channel and 0.5m excavation over 6m width for the downstream half of the channel.

The relatively small size of the channel makes the work suitable for normal excavators and lower unit costs can be expected than for work using long reach machines. It is assumed that excavated material can be spread nearby.

The estimated quantity of dredging is 28,000 m^3 In addition to the dredging cost, provision should be made to enlarge pipe culverts so they are capable of passing additional flow. At £10k per culvert this would add £140k to the cost.

It is assumed that 80% of dredged material is subject to single handling with material placed on or behind the banks by the excavator and 20% will be double-handled due to greater distance between excavation and disposal points.

8 Penzoy and Chedzoy channels Dredging – Impacts on flood risk of dredging the Penzoy and Chedzoy systems, Black & Veatch, 17 October 2014

On the above basis the estimated cost for modelling Scenario 1 are:

- Full scheme cost estimate of £0.38 million (range: £0.28 to £0.56 million).
- Indicative maintenance dredging cost of £0.13 million is estimated for removal of a third of the original dredging quantity (the actual timing of any maintenance would need to be based on results from monitoring surveys).
- Present Value (PV) cost over 100 years of £1.1 million is estimated based on the initial full dredging cost, with maintenance dredging every 5 years and assuming Treasury Green Book rates (initial 3.5%).

Environmental assessment

There are significant environmental constraints along this drain network associated with nature conservation designations, in particular. The risk factors are underlined below.

- South of the A361 (Burrow Wall) near Burrowbridge, Burrow Wall Rhyne parallel to the road delimits the northern edge of the Somerset Levels and Moors SPA and Ramsar site, Southlake Moor SSSI and the Somerset Levels NNR, which all share a boundary here; the feeder drains are fully within the designated area; to the east of Andersea the drain network passes through the heart of Langmead and Weston Level SSSI.
- No additional local nature conservation sites.
- Otter is known to be present in the area around Burrow Bridge and generally between the Parrett and King's Sedgemoor Drain so should be anticipated, and water vole is expected (recorded around the upstream end of the Chedzoy New Cut); the entire channel apart from the upstream end of the Chedzoy New Cut (which is partly in priority habitat and partly not) is located within areas of Coastal and Floodplain Grazing Marsh priority habitat on both banks, except one small area of Lowland Meadows priority habitat.
- No international cultural heritage assets but at Burrowbridge the channel passes alongside Burrow Mump Scheduled Monument and Former Allermoor Pumping Station and Allermoor Cottage listed building. The Chedzoy New Cut approaching King's Sedgemoor Drain passes through the site of the Battle of Sedgemoor.
- Local cultural heritage assets are possible, with finds near the channels around Burrowbridge including Roman coins and an Anglo-Saxon causeway.
- No national landscape designations.
- Dredging presents a risk of compromising Water Framework Directive objectives related to Freshwater Fishery Protected Area status.
- Land under Stewardship varies from south to north: south of the A361 at Burrowbridge about 70% of adjoining land is under Stewardship (10% Higher Level); from the A361 to Shepherds Drove about 60% (0% Higher Level); from Shepherds Drove to Lake Wall about 80% (5% Higher Level); from Lake Wall to A372 Westonzoyland Road about 60% (30% Higher Level); and north of the A372 about 60% (0% Higher Level).

The Southlake Moor SSSI designation relates to extensive grazing marsh and ditch systems. Unit 44 alongside the ditches is in favourable condition, but the ditches within it (unit 46) are unfavourable no change and impacted by high phosphate. The Langmead and Weston level SSSI is also designated for its grazing marsh and ditch systems and the invertebrate community found in the ditches are of particular interest. The units alongside which the ditch passes (terrestrial units 46, 47, 48) or is connected (water unit 49) are all unfavourable due variously to waterlogging, poor water quality and over-shading of ditches by scrub. Dredging (if permitted by Natural England) could potentially be combined with scrub clearance and management here to provide benefit to the SSSI.

13. Dredging assessment: River Axe, Clewer to New Cut

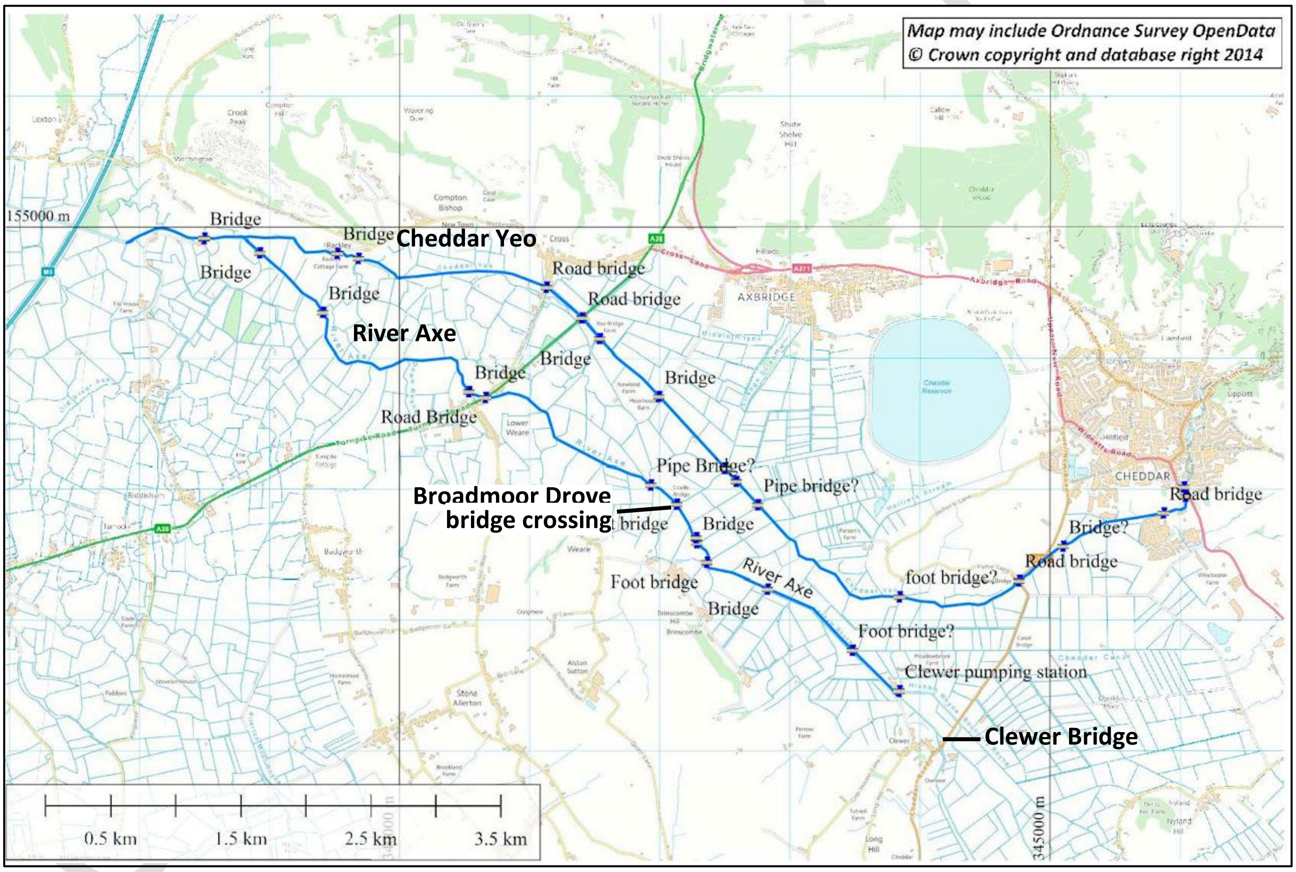
Location

The proposed reach for dredging is about 7.7km long (Figure 13.1). The reach starts at the outfall of the Clewer pump station and ends about 950m downstream of the confluence with the Cheddar Yeo. The channel mainly passes through fields with a width typically 9m to 10m at the normal water surface. This reach of the River Axe is relatively remote from the hills and the sediment load should be low.

The Clewer pump station is located at the end of the Hixham Rhyne at the point that it joins the River Axe and serves a total catchment area of 34.5 km². The station provides winter drainage for this land of which 6.6 km² is prone to flooding. The area is primarily agricultural land with a few isolated farms. The area served by the station includes Cheddar Moor, Draycott Moor, Monk Moor, Stoke Moor, Westbury Moor, Knowle Moor and part of Wedmore Moor (located on the opposite bank of the River Axe).

The catchment of the pump station extends to the Mendip Hills and is likely to receive sediment-laden runoff during heavy rainfall events. Much of this sediment is likely to settle out in the smaller channels but some may pass through the pump station into the River Axe.

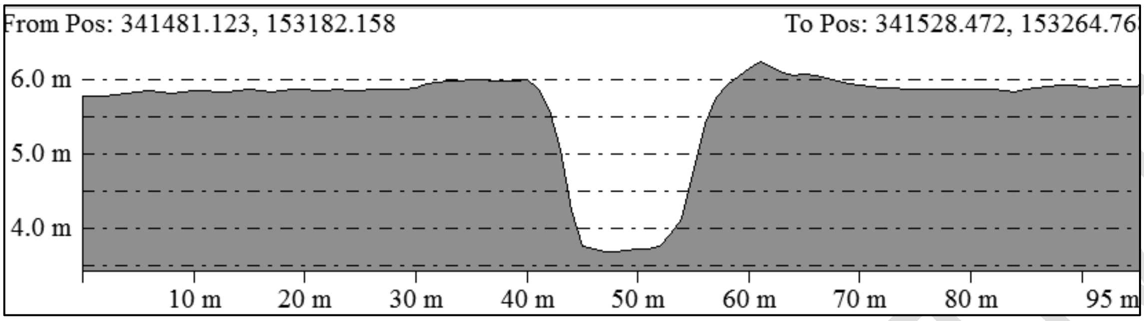
Figure 13.1 River Axe and Cheddar Yeo location of potential dredging



Current Situation

The River Axe channel banks are generally slightly raised above the surrounding ground level, probably as a result of previous dredgings disposal. A typical cross section is shown below (Figure 13.2). A track runs along south side but access interrupted by drainage channels on north side.

Figure 13.2 River Axe typical channel cross section



Note: Channel profile not properly shown as LiDAR only
approximates the ground surface below water levels.

The channel has not been dredged recently and appears on the aerial photography (Figure 13.3) to be in moderately good condition except for the section immediately downstream of the Cheddar Yeo confluence. However, the channel sides are poached at several locations by livestock using channel for drinking water. Bank material at these locations will have tended to slip into the bed and reduce the channel capacity.

Figure 13.3 River Axe, downstream of Cheddar Yeo Confluence

© Bluesky International Ltd/Getmapping PLC

Constraints

Structures: There are 10 bridges identified of various sizes crossing this reach of the river. There is also a pumping station for water abstraction at Brinscombe about 2km downstream of the Clewer pumping station which is used as a supplementary water source for the Cheddar reservoir.

Access: There is access along each side of the channel subject to crossing of lateral drainage channels and there are a few locations with trees on the channel banks.

Working methods: The channel width (typically 10m to 12m at the water surface) means that dredging could generally be undertaken by a long reach excavator working from one bank. An exception to this may be the degraded channel downstream of the Cheddar Yeo confluence.

Disposal: It is not expected that the silt being removed will be contaminated. To minimise costs and subject to cooperation from the landowners the excavated material can be deposited or spread on the channel banks and immediately adjacent land (i.e. within reach of a single handling operation) under waste exemption D1 as is believed to have been the historical practice. Deposition beyond this would require proof of benefit, chemical assessment and appropriate licensing.

Water Framework Directive: The study reach comprises parts of two water bodies within the Axe (GB109052021520 “R Axe - source to conf Stubbingham Rhyne” and GB109052021570 “R Axe-Stubbingham Rhyne to conf Brean Cross Sluice”). Water body 1520 is heavily modified by land drainage but there are no associated mitigation measures which could be compromised by dredging. Water body 1570 is not heavily modified. Both water bodies have Freshwater Fishery Protected Area status, which could constrain timing, extent and methodology of dredging operations.

Hydraulic assessment

Summary of check survey: The table below summarises the structural levels surveyed in September 2014 and the levels in the original Axe and Yeo model survey. The difference in levels is 20-30mm which is acceptable for the purposes of the assessment and confirms a common datum level.

Location	Model level (mAOD)	Survey level (mAOD)
Clewer bridge soffit	6.40	6.37
A38 road bridge soffit	6.03	6.01

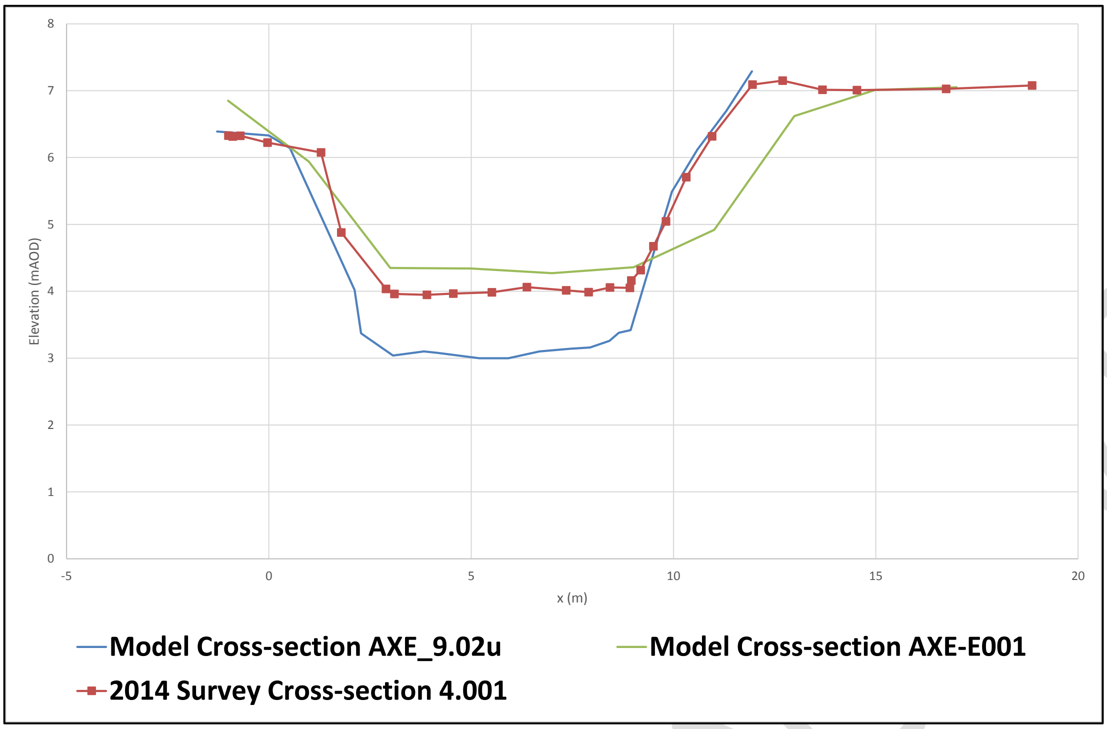
The check survey channel cross-sections are generally very similar to the cross-sections in the model as illustrated below (Figure 7.4). The surveyed bed level upstream of Clewer Bridge is approximately 1m higher than the model cross-section at this location. However, the surveyed bed level is consistent with the model bed levels downstream of the bridge. This apparent ‘step’ in bed level was identified as part of the model review and occurs at the point where two different surveys were used for the reach upstream and downstream of the bridge.

The check survey suggests that the model bed levels downstream of the bridge are reliable and similar to the bed level upstream of the bridge. On this basis the discrepancy is most likely in the model bed levels upstream of the bridge and limited to one or two cross-sections. This issue will be further investigated as part of the model updating process. The area is approximately 700m upstream of the proposed dredging reach and the discrepancy in bed levels does not appear to significantly affect the hydraulic profile along this reach (see below). On this basis the model is considered adequate for initial assessment of the effect of dredging.

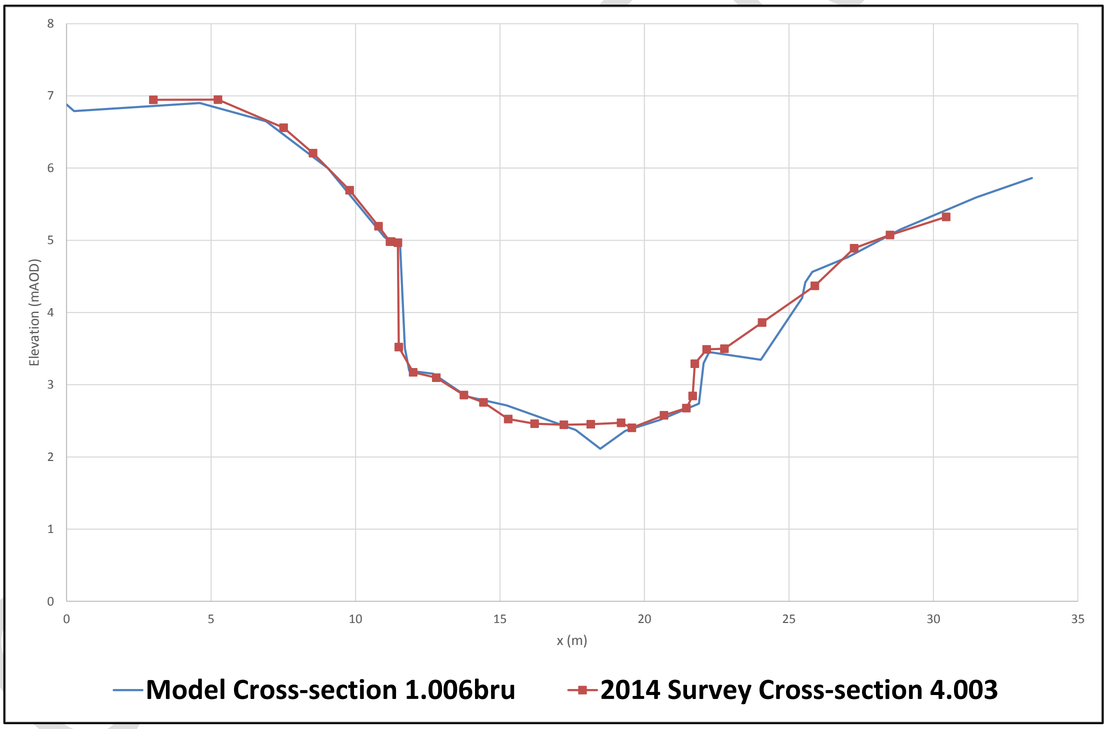
Similarly, the model survey cross-sections show a step down in bed level of approximately 1m in the vicinity of the Broadmoor Drove bridge crossing upstream of Brinscombe Farm. Check survey cross-sections further upstream and downstream of this location are consistent with the model cross-sections. It is possible that the step is due to an error in the original survey. However, at high flow the variations in bed level do not appear to significantly affect the hydraulic profile (see Figure 13.4).

Silt was observed at only two of the five surveyed cross-sections – at the A38 road bridge and approximately 300m downstream – as shown below (Figure 13.5). In each case the silt depth is generally less than 200mm. It is not possible to determine the silt depths at the time of the original survey used in the model, as for reach downstream of Clewer there are only bathymetry survey data available.

Figure 13.4 Model cross section versus survey cross section

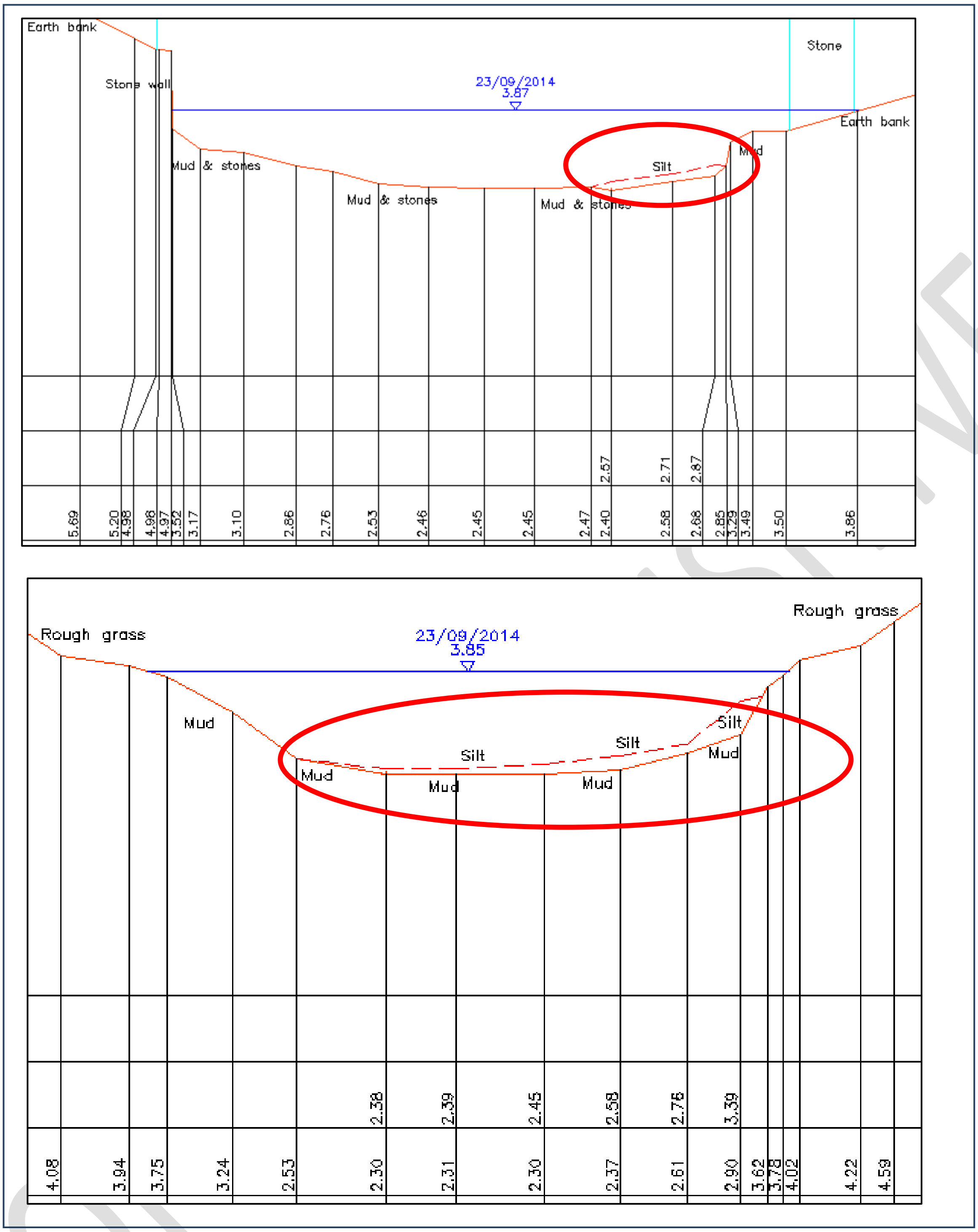


a) Upstream of Clewer Bridge



b) Upstream of A38 bridge

Figure 13.5 Surveyed cross sections

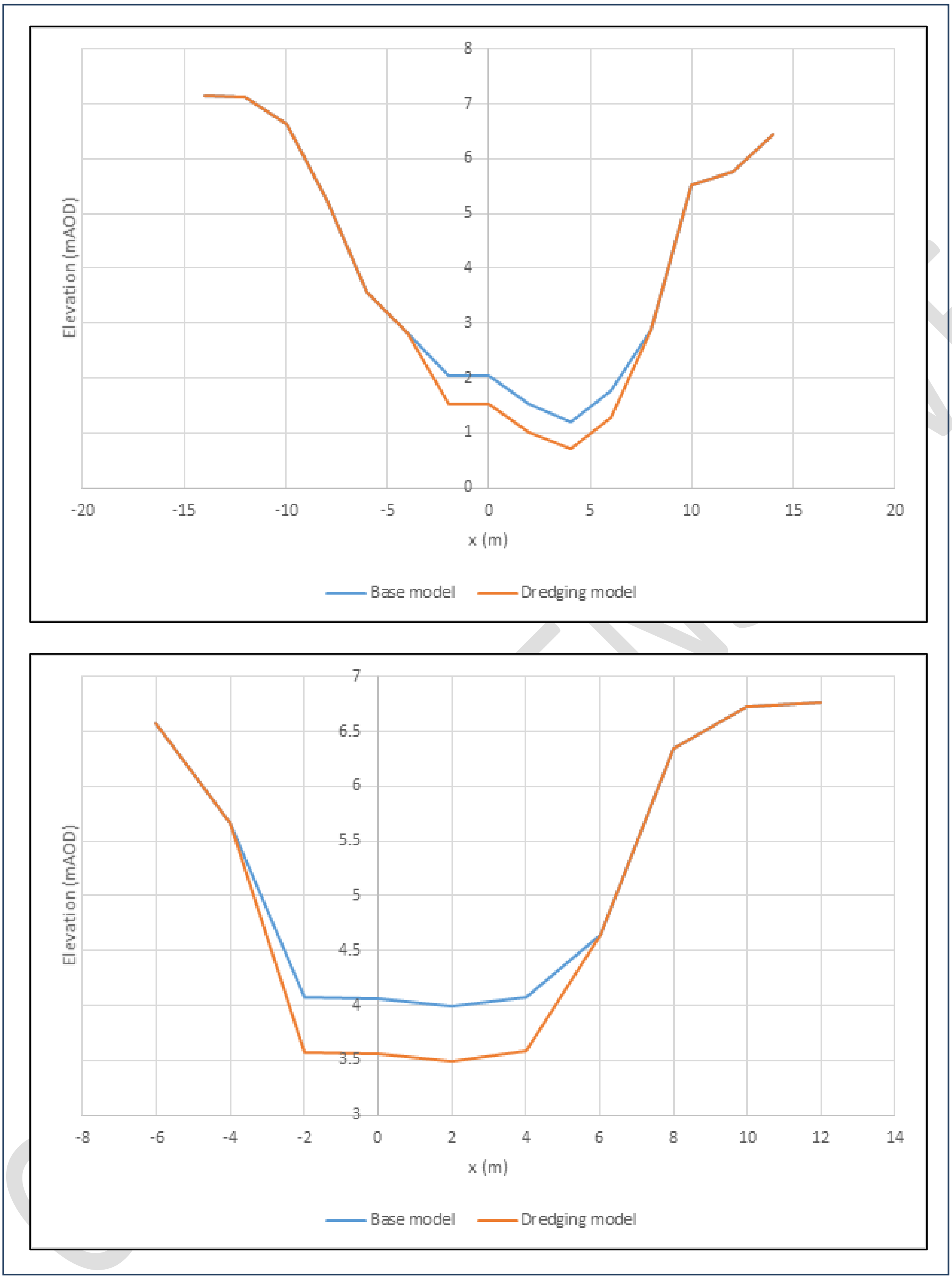


Hydraulic assessment – model simulations

In order to provide a first assessment of the impact of dredging and in the absence of a detailed silt survey of the entire reach, a nominal 0.5m reduction in bed levels has been applied to all the model cross-sections within the dredging reach as illustrated below (Figure 13.6). Given the results of the limited check survey this is likely to represent an upper bound estimate of the dredging depth.

The existing Axe and Yeo model has been run for the 1 in 100 year design event (this model is based on a storm duration of 50.75 hours) derived under the original model study, 'with' and 'without' dredging. The 'with' dredging simulation includes the effect of dredging in the Cheddar Yeo channel. The modelling of dredging indicates only limited benefit in terms of flood risk. As most of the flooding derives from the Axe not Cheddar Yeo, a standalone Axe dredging scenario was not examined i.e. the results would be similar.

Figure 13.6 Model cross sections – base / dredging cross sections



Hydraulic assessment – results

As illustrated in the long section below (Figure 13.7, next page), the effect of dredging is to reduce the model 1 in 100 year maximum water levels in the river channel by up to 45mm in the reach upstream of Lower Weare. Downstream of Lower Weare the maximum water levels are increased by up to 170mm at the M5 crossing. The impact in lesser events is not assessed at this stage.

The increase in water level in the downstream reach is a result of increased flow in the river channel entering the un-dredged reach downstream. The peak flow in the Axe upstream of the confluence with the Cheddar Yeo increases by approximately 10% from $16.8m^3/s$ to $18.4m^3/s$ as illustrated in the plot below. Due to the very shallow gradient of the channel (approximately 1 in 4,000) the backwater from the un-dredged reach extends around 4km upstream.

The effect on the maximum extent of flooding is illustrated in the plan below (Figure 13.8).

Hydraulic assessment – benefits/disbenefits

The differences in flood extent are minimal. The modelling of a dredging scenario indicates no overall change in flood mechanism in terms of the overtopping into the floodplain along the dredging area and similarly no overall change in overtopping downstream. The impacts on flood extent, duration, flooding to properties, infrastructure and agricultural land are minimal. This is evident from the very small changes in floodplain extent shown below.

Benefits:

- Some properties and minor roads/lanes upstream of Clewer at risk in a 100-year design flood and dredging would result in a small reduction in maximum level of 30mm or less, and duration.

Disbenefits:

- Some properties at the downstream end of the dredging reach (Biddisham/Crab Hole) at risk in a 100-year design flood where flood level/duration would be increased up to about 150mm and potentially also further downstream (beyond M5) as a result of increased peak flow but model used ends at M5.

Figure 13.8 Modelled effect of dredging – flood extent mapping

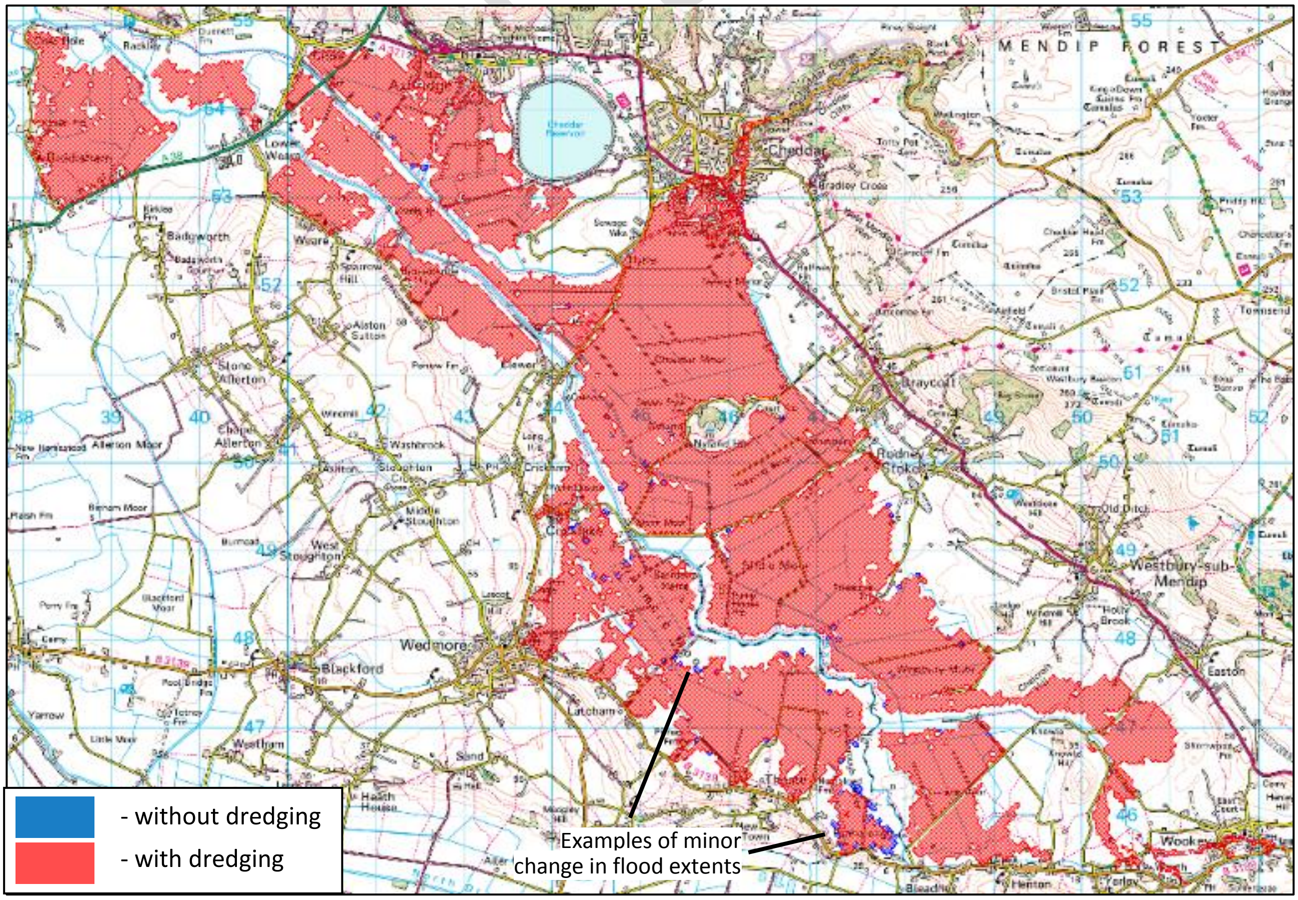
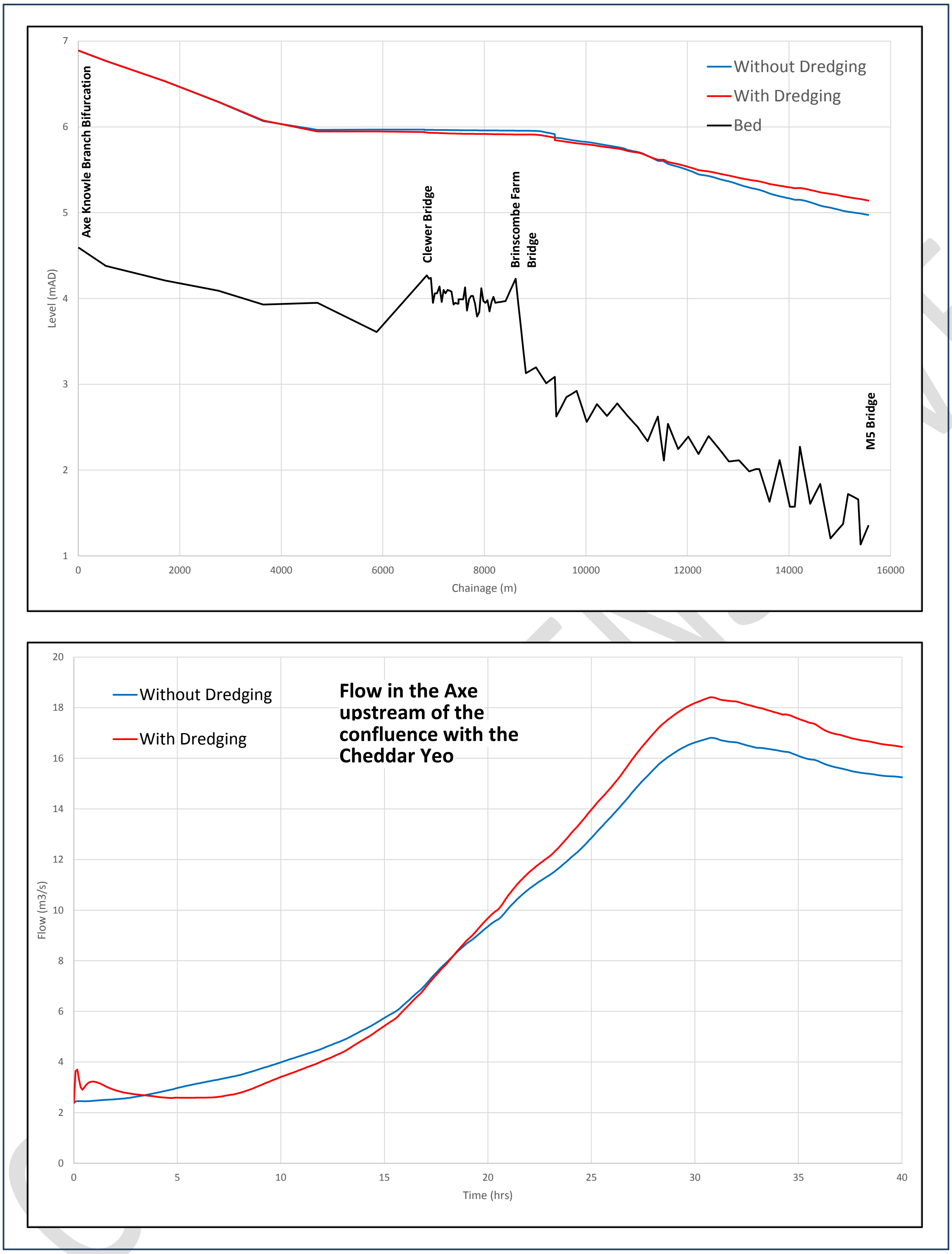


Figure 13.7 Modelled effect of dredging – long section and flow-time plot



Cost assessment

The total quantity of dredging is estimated at 30,000 m^3 for a nominal 0.5m dredge of channel bed along the entire length. This quantity is indicative and the actual degree of any dredging will be confirmed based on channel survey data. Modelling tested the 0.5m depth of dredging and based on surveyed silt depths for the other Axe/Brue channels this is considered a conservative estimate.

It is assumed that 80% of dredged material is subject to single handling with material placed on or behind the banks by the excavator and 20% will be double-handled due to greater distance between excavation and disposal points.

On the above basis the estimated costs are:

- Full scheme cost estimate of £0.5 million (range: £0.4 to £0.8 million).
- Indicative maintenance dredging cost of £0.17 million is estimated for removal of a third of the original dredging quantity (the actual timing of any maintenance would need to be based on results from monitoring surveys).
- Present Value (PV) cost over 100 years of £1.45 million is estimated based on the initial full dredging cost, with maintenance dredging every 5 years and assuming Treasury Green Book rates (initial 3.5%).

The cost assumptions include:

- Material being excavated will be recent ‘soft’ sediment.
- Most of the channel is accessible from both banks but it should be possible to undertake much of the dredging using a long reach excavator operating on one bank. It is not expected that the silt will contain any contamination (although this would need to be confirmed) and it is assumed that most of the dredged material can be disposed of on the backs of the existing banks but some may be spread on nearby fields.
- Limited amount of additional handling where dredging around structures or under bridges
- No specific environmental mitigation requirements, e.g. timing constraints related to fisheries, presence of protected species such as water vole.

Environmental assessment

There are no significant environmental constraints in the vicinity of this reach of the River Axe, although water vole, otter and Freshwater Fishery status could constrain dredging operations. The risk factors are underlined below.

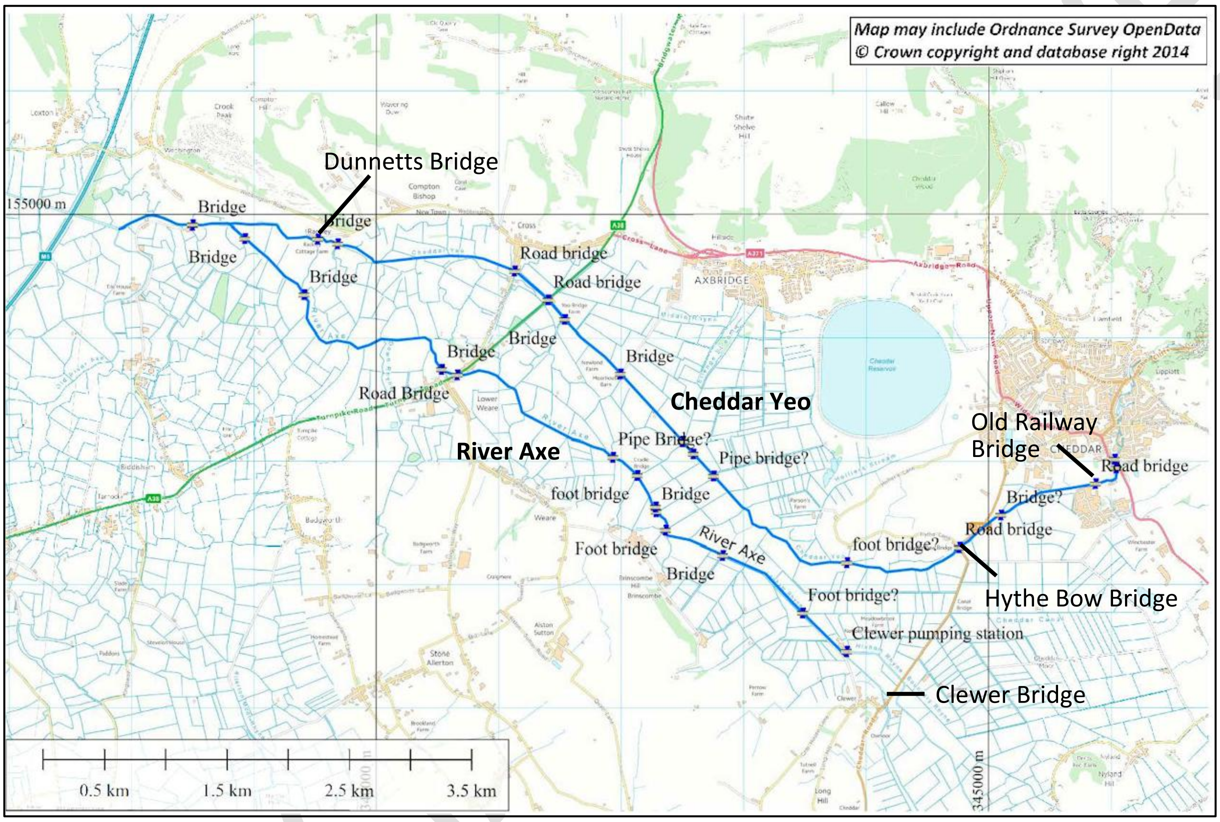
- No international or national nature conservation sites
- No local nature conservation sites
- The presence of otter and water vole is probable
- No international or national cultural heritage assets
- No local cultural heritage assets; archaeology record closely associated with the river at Lower Weare
- No national landscape designations
- Dredging presents a risk of compromising Water Framework Directive objectives for Freshwater Fishery Protected Area status
- Large extents of the land on either bank (especially the right bank) are under Entry Level Stewardship; those areas not already under stewardship are within the Somerset Levels and Moors HLS target area.

14. Dredging assessment: Cheddar Yeo, Froglands to Axe confluence

Location

The Cheddar Yeo runs slightly north of the River Axe (Figure 14.1). The proposed reach for study is about 8.8km long downstream from the town of Cheddar. The channel width, at water level, is about 5m at the upstream end and 13m downstream of the confluence with the Axe. The channel mainly passes through fields. The proximity of this reach of channel to the Mendip Hills indicates the high probability of significant sediment loads during heavy rainfall with likelihood of deposition where the channel slope and flow velocity reduces.

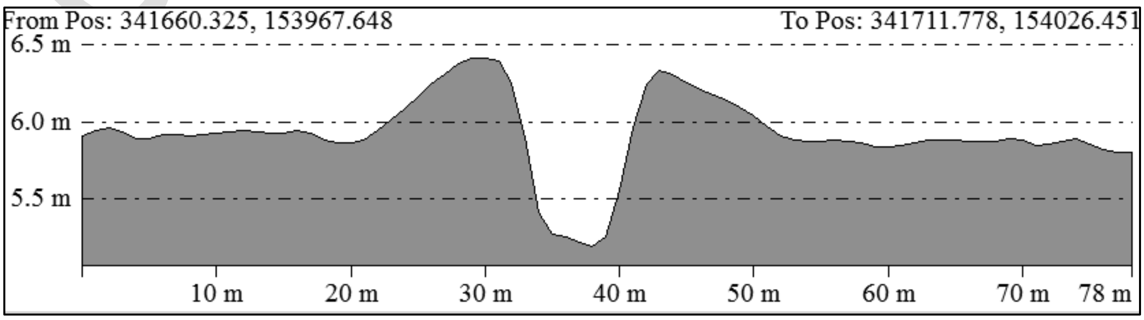
Figure 14.1 River Axe and Cheddar Yeo location of potential dredging



Current Situation

The banks of the channel stand above the flood plain (Figure 14.2) which may reflect a much greater extent of channel maintenance compared to the River Axe and is probably the consequence of the higher sediment loads transported off the Mendip Hills by the steeper upper section of the river. This sediment is then deposited where the channel slope and velocity reduce.

Figure 14.2 Cheddar Yeo typical channel cross section



Note: Channel profile not properly shown as LiDAR only
approximates the ground surface below water levels.

From the 2010 aerial photography below (Figure 14.3) it appears that the channel is partly overgrown with vegetation and is suggestive of shallow water depth (although the photography could have been taken just before the routine weed cutting).

Given the history of lead mining in the Mendip Hills it is possible that the sediment, particularly in the section between Cheddar and the A38, contains traces of this metal which may affect disposal options for dredged material although it is probable that the channel banks along this reach also contain similar proportions of lead.

Figure 14.3 Cheddar Yeo: channel condition about 2.5km downstream of Cheddar confluence

<u>Constraints</u>

Structures: There are about 15 bridges of varying size and importance crossing the river. Many are footbridges or for farm access although a pipe bridge carries the water main running from the Brinscombe pumping station on the River Axe to the Cheddar reservoir.

Access bridge

Access: Most of the channel flows through farmland and access for dredging equipment will be reasonably easy although there may be some difficulties on the outskirts of Cheddar town where the channel is partly overgrown by trees.

Disposal: To minimise costs and subject to cooperation from the landowners the excavated material can be deposited or spread on the channel banks and immediately adjacent land (i.e. within reach of a single handling operation) under waste exemption D1 as is believed to have been the historical practice. Deposition beyond this would require proof or benefit, chemical assessment and appropriate licensing.

However, as noted above, there is the risk of lead (and other contaminants) in the sediment in the upstream half of the channel which may necessitate specific analysis and risk assessment (both toxicological and ecotoxicological) to confirm the acceptability of this. Given that the potential source of any contamination is discontinued and dispersed, the risk of dredged material being classified as "hazardous waste" and therefore requiring disposal is low. Historical data may exist to support this assessment. Any deposition beyond the immediate bankside would require proof of benefit, chemical assessment and appropriate licensing.

Working methods: Dredging of the upstream part of the channel can be undertaken by a long reach excavator working from one bank but equipment on both banks may be required further downstream where the channel widens.

Water Framework Directive: The study reach comprises all of the Cheddar Yeo water body (GB109052021540 "R Cheddar Yeo - source to conf Stubbingham Rhyne") and downstream of Brinscombe is classified as part of Axe water body (GB109052021570" R Axe-Stubbingham Rhyne to conf Brean Cross Sluice"). Water body 1540 is heavily modified by flood protection and dredging could compromise some of the measures needed to achieve good potential as follows:

- Retain marginal aquatic and riparian habitats (channel alteration) (in place)
- Improve floodplain connectivity (not in place)
- Increase in-channel morphological diversity (not in place)

Water body 1570 is not heavily modified. Both water bodies have Freshwater Fishery Protected Area status, which could constrain timing, extent and methodology of dredging operations.

Hydraulic assessment

Summary of check survey: The table below summarises the structural levels surveyed in September 2014 and the levels in the original Axe and Yeo model survey. The difference in levels is 10-30mm which is acceptable for the purposes of the assessment and confirms a common datum level.

Location	Model level (mAOD)	Survey level (mAOD)
B3151 Hythe Bow Bridge soffit	7.04	7.01
A38 road bridge soffit	6.09	6.10

The check survey channel cross-sections are generally very similar to the cross-sections in the model as illustrated below (Figure 14.4). The original survey used in the model dates from 2002, though the surveys were primarily done in 2007 (bathymetry) and 2010 (standard survey of Yeo and Axe). The comparisons below therefore reflect fairly recent survey, well within 10 years.

Silt was observed at only one of the five surveyed cross-sections – adjacent to Cheddar Business Park (Figure 14.5). The silt depth is typically 200-250mm.

Hydraulic assessment – model simulations

In order to provide a first assessment of the impact of dredging and in the absence of a detailed silt survey of the entire reach, a nominal 0.5m reduction in bed levels has been applied to all the model cross-sections within the dredging reach as illustrated below (Figure 14.6). Given the results of the limited check survey this is likely to represent an upper bound estimate of the dredging depth.

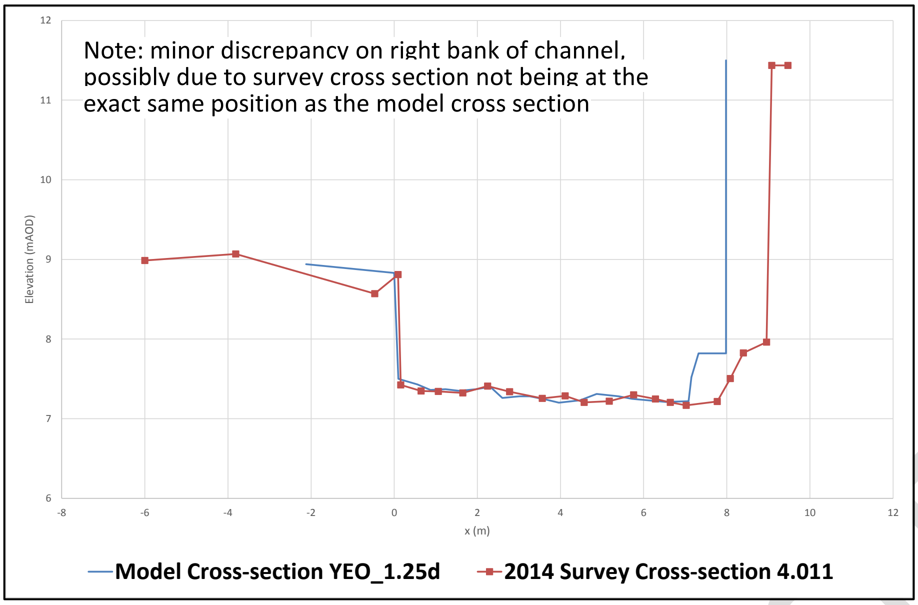
The existing Axe and Yeo model has been run for the 1 in 100 year design event (this model is based on a storm duration of 50.75 hours) derived under the original model study, 'with' and 'without' dredging. The 'with' dredging simulation includes the effect of dredging in the Axe channel.

Hydraulic assessment – results

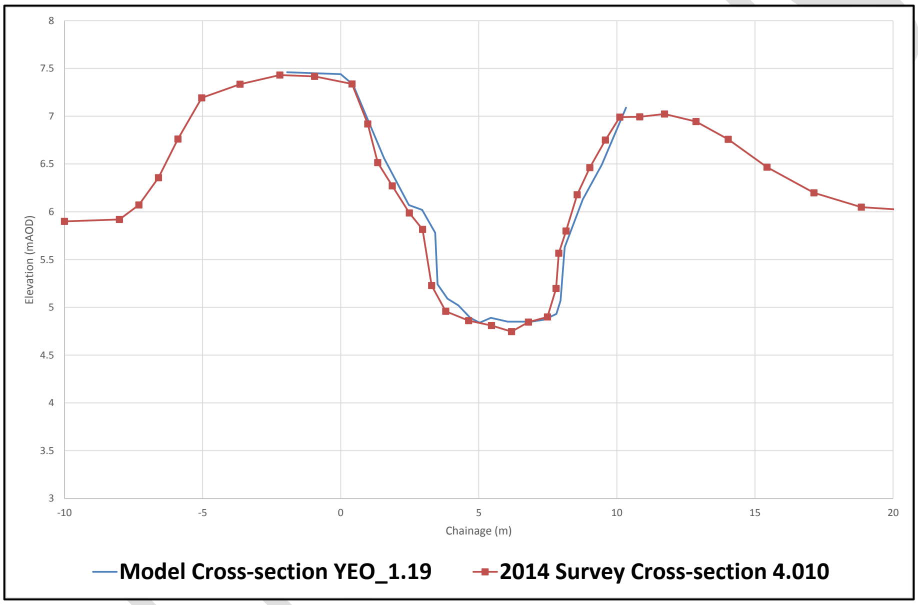
As illustrated in the long section below (Figure 14.7), the effect of dredging is to reduce the model 1 in 100 year maximum water levels in the reach between the old railway bridge and Hythe Bow Bridge, though not all along this length and in places any difference is minimal. The maximum reduction in level is approximately 130mm immediately downstream of the old railway bridge in Cheddar.

At Hythe Bow Bridge there is no difference in level. Immediately upstream of the railway bridge the maximum level is increased by approximately 70mm due to increased flow over the old rock weir which has been retained at the same crest level. Between Hythe Bow Bridge and Dunnetts Bridge the change in maximum water level due to dredging varies in the range between +20mm and -20mm. Downstream of Dunnetts Bridge the maximum levels with dredging are increased by up to approximately 130mm at the confluence with the Axe.

Figure 14.4 Model cross section versus survey cross section

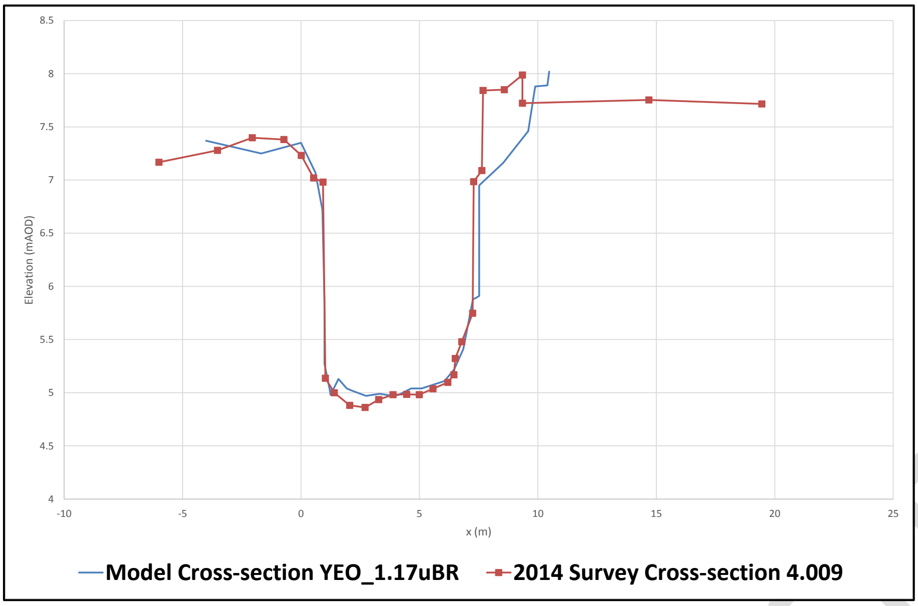


a) Downstream of A371 bridge

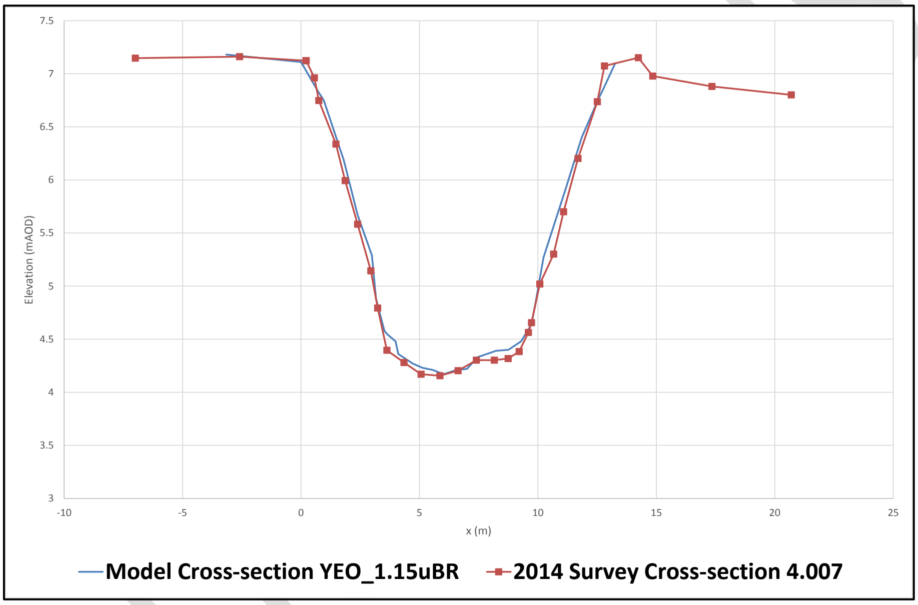


b) Adjacent Cheddar Business Park

Figure 14.4 Model cross section versus survey cross section (continued)



c) Upstream Hythe Bow Bridge



d) Upstream of A38 bridge

Figure 14.5 Surveyed cross section, adjacent to Cheddar Business Park

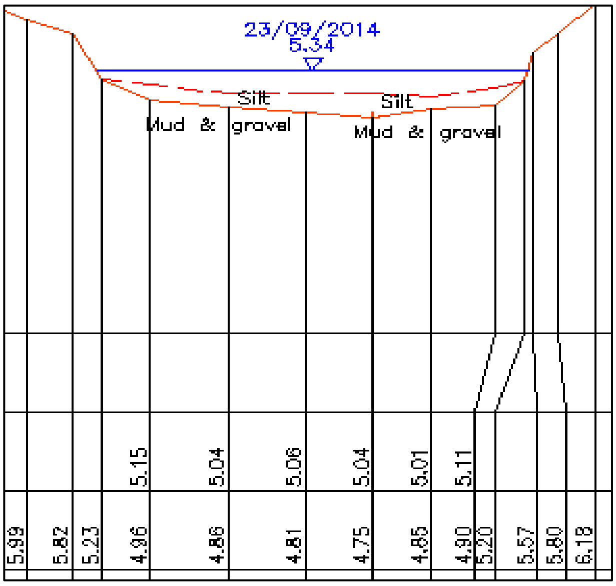


Figure 14.6 Model cross sections – base / dredging cross sections

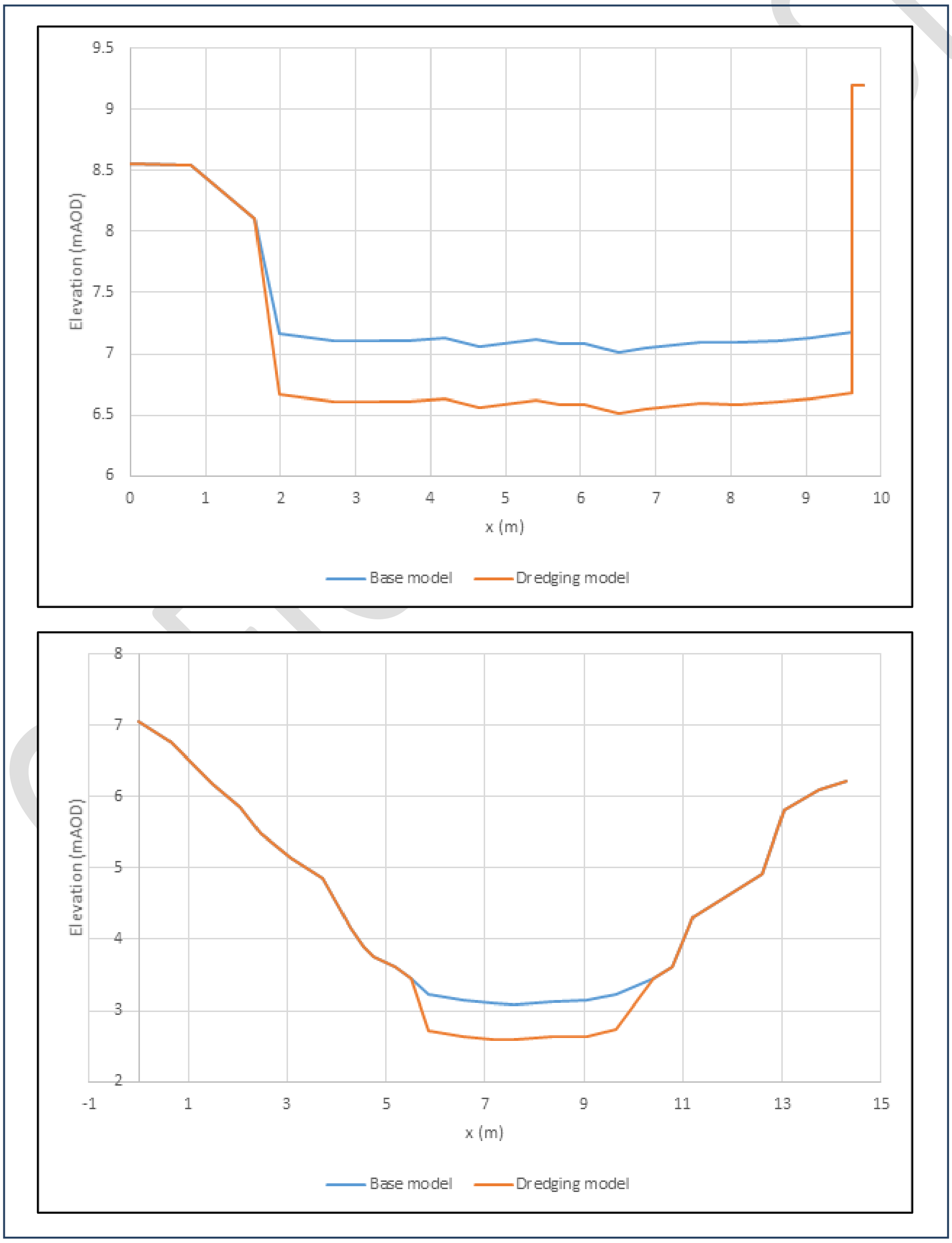
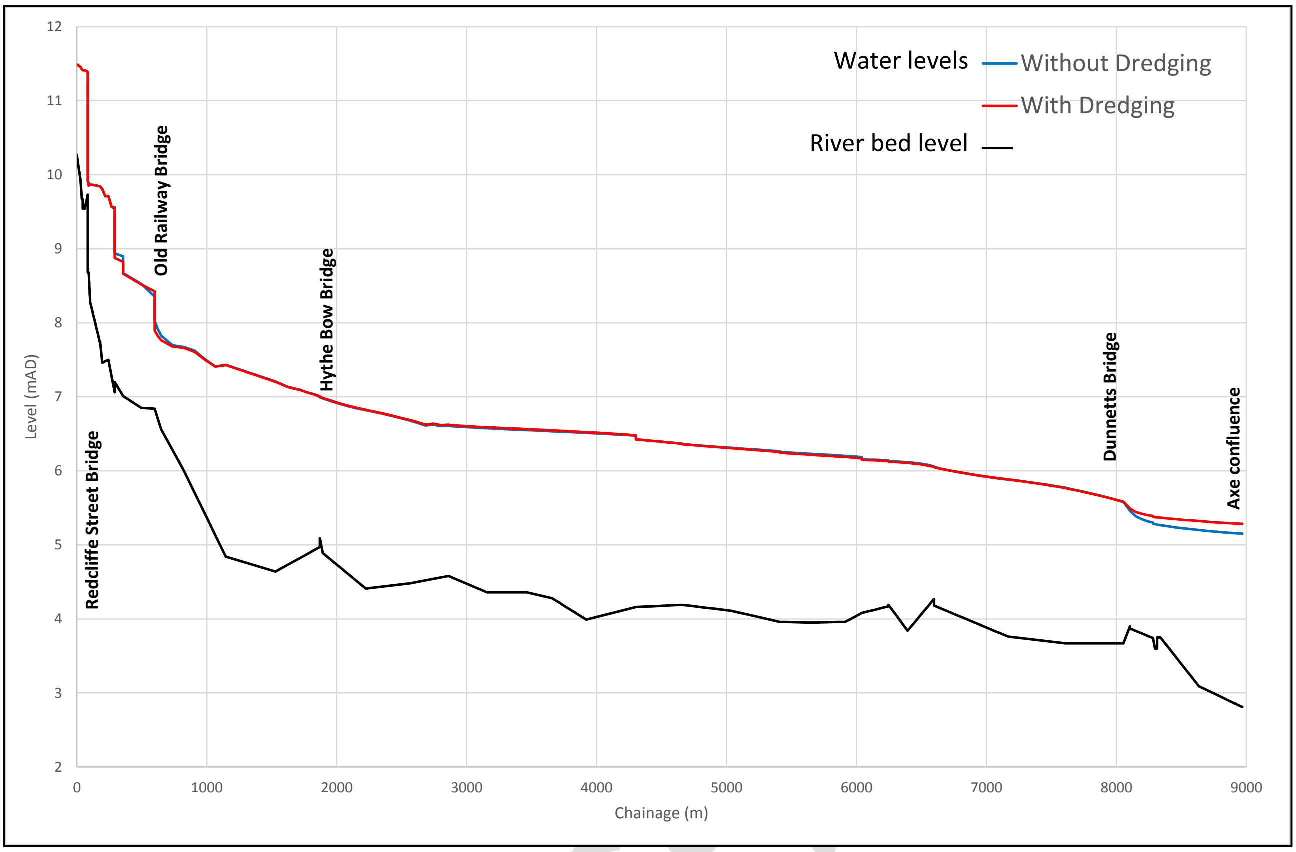


Figure 14.7 Modelled effect of dredging – long section plot



The increase in water levels is a result of increased flow in the river channel. As illustrated in the plots below, the peak flow in the Yeo channel upstream of the old railway bridge increases by approximately 10% from 10.9m^3/s to 12.0m^3/s and the peak flow in the channel upstream of the confluence with the Axe increases by approximately 21% from 6.5m^3/s to 7.9m^3/s.

The effect on the maximum extent of flooding is illustrated in the plan below (Figure 14.9). The differences in flood extent are minimal.

Hydraulic assessment – benefits/disbenefits

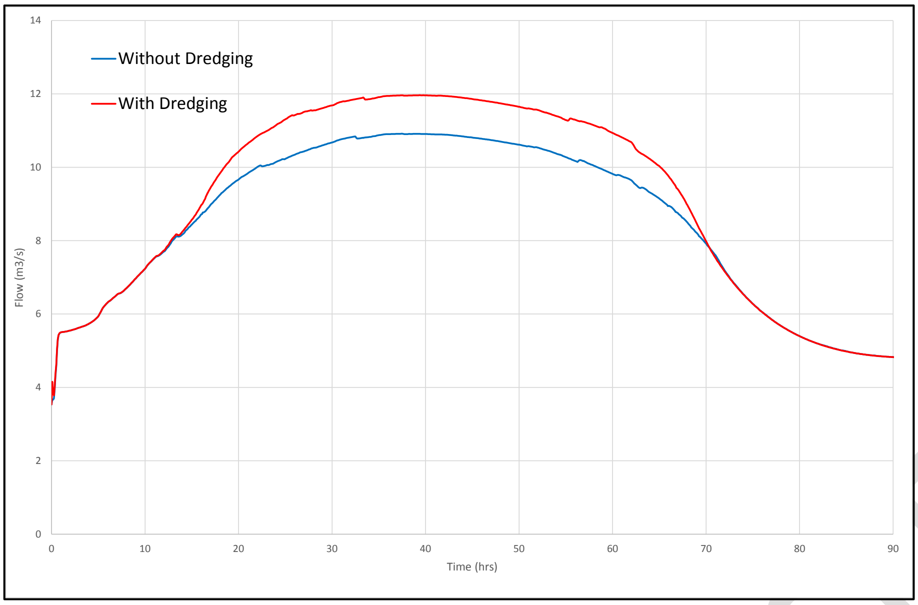
Benefits:

- Some property at risk in 100-year design flood just downstream of Cheddar, between B3151 and A371, e.g. Cheddar Business Park. Dredging would reduce peak level by up to 130mm.

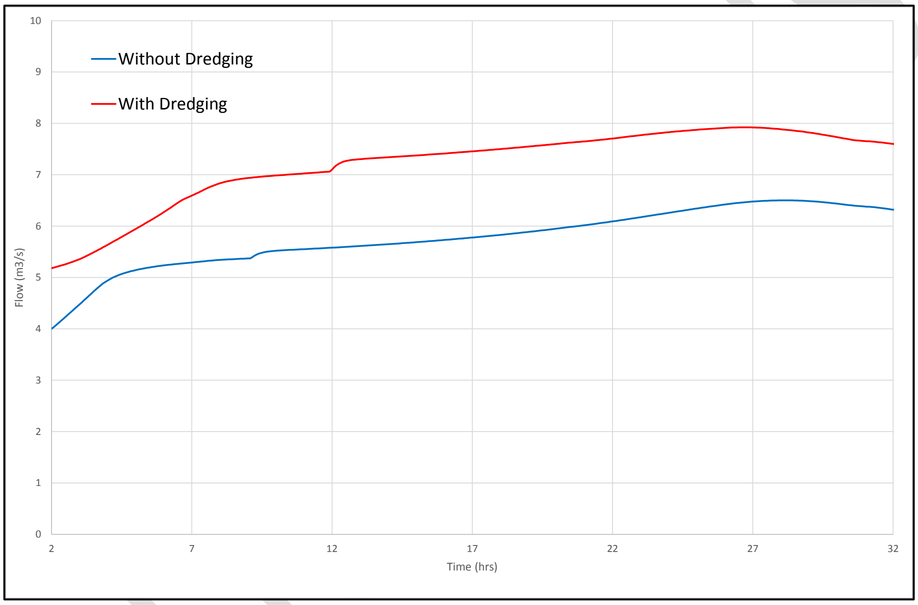
Disbenefits – similar to Axe (Clewer to New Cut) but less impact if Yeo dredged alone:

- Some properties at the downstream end of the dredging reach (Biddisham/Crab Hole) at risk in a 100-year design flood where flood level/duration would be increased up to about 150mm and potentially also further downstream (beyond M5) as a result of increased peak flow but model used ends at M5.

Figure 14.8 Modelled effect of dredging – flow-time plots downstream

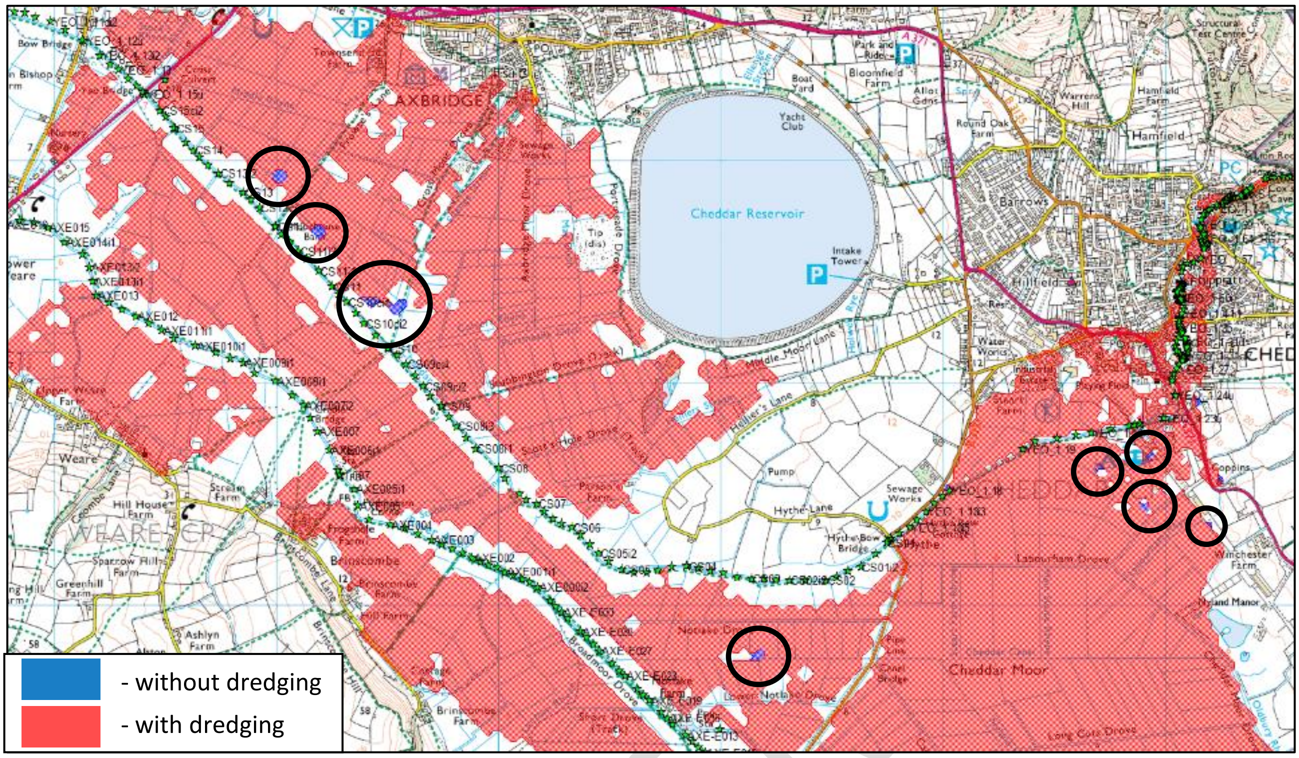


a) Yeo channel upstream of the old railway bridge



b) Yeo channel upstream of Axe confluence

Figure 14.9 Modelled effect of dredging – – flood extent mapping
(the very minor differences in floodplain extents are circled)



<u>Cost assessment</u>

The total quantity of dredging is estimated at 17,000 m^3. This quantity is indicative and the actual degree of any dredging will be confirmed based on channel survey data. Modelling tested the 0.5m depth of dredging and based on surveyed silt depths for the other Axe/Brue channels this is considered a conservative estimate.

It is assumed that 80% of dredged material is subject to single handling with material placed on or behind the banks by the excavator and 20% will be double-handled due to greater distance between excavation and disposal points.

On the above basis the estimated costs are:

- Full scheme cost estimate of £0.3 million (range: £0.2 to £0.45 million).
- Indicative maintenance dredging cost of £0.1 million is estimated for removal of a third of the original dredging quantity (the actual timing of any maintenance would need to be based on results from monitoring surveys).
- Present Value (PV) cost over 100 years of £0.82 million is estimated based on the initial full dredging cost, with maintenance dredging every 5 years and assuming Treasury Green Book rates (initial 3.5%).

The cost assumptions include:

- Material being excavated will be recent 'soft' sediment.
- Most of the channel is accessible from both banks but it should be possible to undertake much of the dredging using a long reach excavator operating on one bank. It is not expected that the silt will contain any contamination (although this would need to be confirmed) and it is assumed that most of the dredged material can be disposed of on the backs of the existing banks but some may be spread on nearby fields.
- Limited amount of additional handling where dredging around structures or under bridges
- No specific environmental mitigation requirements, e.g. timing constraints related to fisheries, presence of protected species such as water vole.

Sampling and analysis of sediments (and historic bankside deposits) for lead would be required. If the tests identify material that is unsuitable for local disposal according to current regulations then there will be substantial additional costs in disposal.

Environmental assessment

There are no significant environmental constraints in the vicinity of this reach of the Cheddar Yeo, although water vole, (otter) and Freshwater Fishery Protected Area status could constrain dredging operations. The risk factors are underlined below.

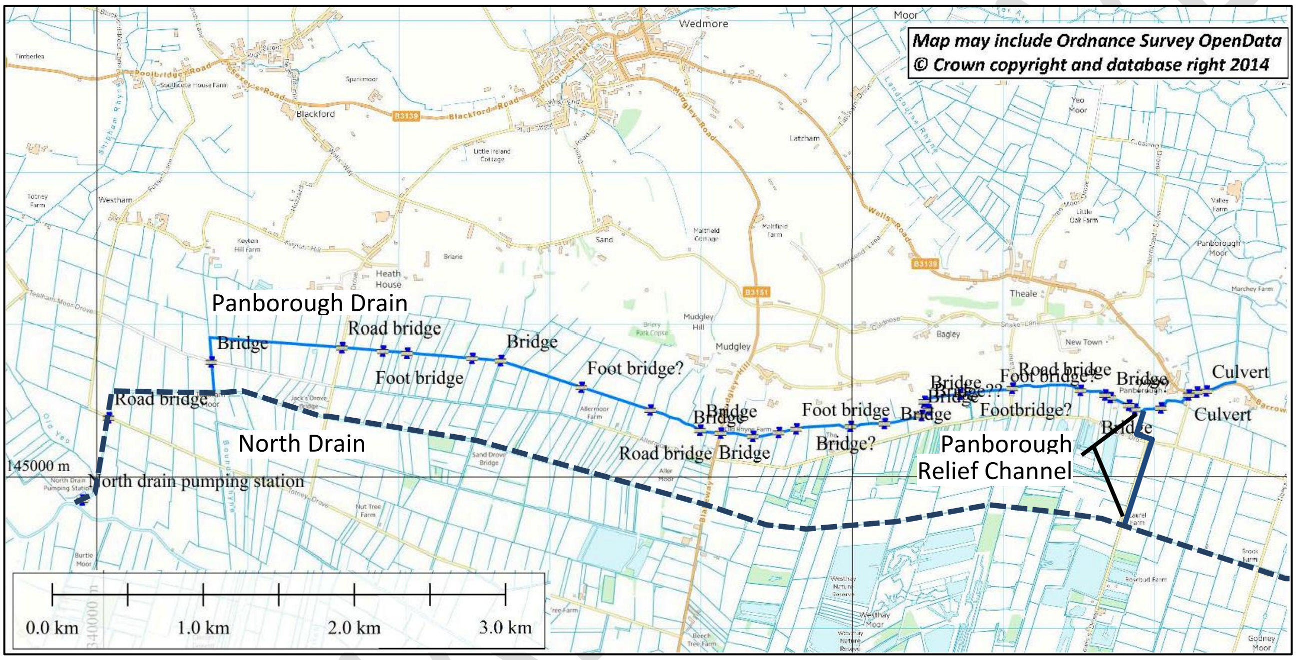
- No international or national nature conservation sites
- No local nature conservation sites
- The presence of water vole is probable (and otter possible)
- No international or national cultural heritage assets which are likely to constrain dredging. In Cheddar a Scheduled Monument extends to the right bank in the playing fields of The Kings of Wessex School and the adjacent caravan and camping site (dredging disposal would never be an option here). A Scheduled Monument (duck decoy) on the right-hand floodplain at Parson's Farm will locally constrain dredging application to land.
- No local cultural heritage assets; archaeology record closely associated with the river at Rackley
- No national landscape designations; the river approaches the Mendip Hills AONB but is far enough distant to have no constraints on the dredging proposals
- Dredging presents a risk of compromising Water Framework Directive objectives for water bodies, including hydromorphology and Freshwater Fishery Protected Area status
- The majority of the land on either bank is under Entry Level Stewardship; those areas not already under stewardship are within the Somerset Levels and Moors HLS target area

15. Dredging assessment: Brue – Panborough Drain

Location

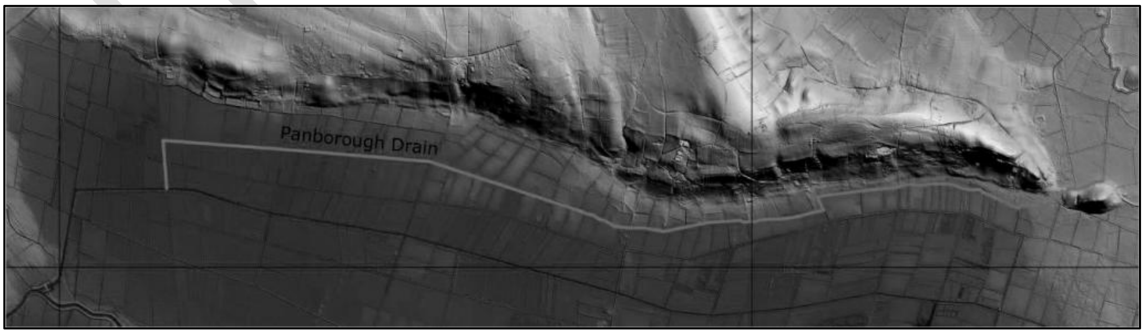
Panborough Drain lies about 2.5km south of the village of Wedmore and runs, mainly east-west, for about 7.5km from Panborough hill to its confluence with North Drain (Figure 15.1). North Drain, which runs east – west about 500m south of Panborough Drain discharges via the North Drain Pump Station constructed in 1958 into the River Brue about 1.5km downstream of the confluence between the two drains. The drain is in or adjacent to the Westhay Moor SSSI and Tealham & Tadham Moors SSSI. A watercourse called the Panborough Relief Channel connects the upstream part of the Panborough Drain to the North Drain.

Figure 15.1 Panborough Drain



The main catchment for the Panborough Drain is the high ground to the north (Figure 15.2). Runoff from this area is likely to carry significant sediment load during heavy rainfall. Some of this is likely to enter the channel and will be deposited when the flow velocity reduces.

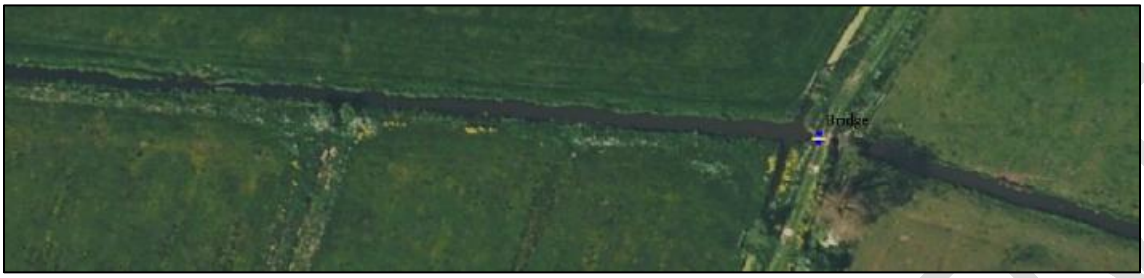
Figure 15.2 Panborough Drain topography



Current Situation

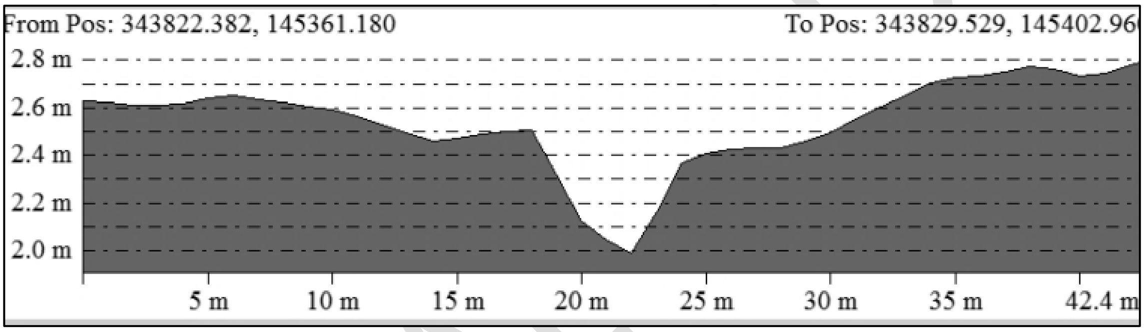
Drainage in the area has been progressively improved over many years with the construction of the North Drain pumping station in 1958 enabling a significant improvement in water level management. Panborough Drain is in moderately good condition with some narrowing in places. Weed cutting is undertaken by the Environment Agency.

Figure 15.3 Panborough Drain – aerial photography



The channel mainly passes through fields and is about 1m wide at the water surface at its upstream end increasing to 3m at the downstream end.

Figure 15.4 Panborough Drain – typical channel cross section midway along channel



Note: Channel profile not properly shown as LiDAR only approximates the ground surface below water levels.

Responsibility for the operation and maintenance is undertaken by the Environment Agency in close coordination with the Axe Brue Drainage Board. Water levels are controlled by a weir near the upstream end while the Panborough Boards mid way along the channel are used to maintain a summer water level (1.98m) but are open during the winter. The drain is covered by the North Drain Water Level Management Plan (WLMP) intended to ensure that the interest features of the SSSIs are supported, which was approved by the Lower Brue and Upper Brue Drainage Boards in April 2010[9].

Constraints

Structures: There are nearly 30 bridges and culverts along the channel. Most are for farm access or are footbridges but five are road crossings. Each should be checked to ensure that it does not constitute a constriction to the flow if the channel is improved. Manual dredging may be required in or adjacent to these structures.

The Panborough relief channel weir accommodates penning boards to alter the level of the weir.

Access: The WLMP Table 1 (maintenance schedule) notes that there is poor access along the right bank of the channel. However, it is implied that access along the left bank is satisfactory. Regular access is currently undertaken for weed cutting. .

[9] http://www.somersetdrainageboards.gov.uk/media/North-Drain-WLMP-Brue-Approved-Apr-10.pdf

Working methods: The size of channel places it in the working range of normal excavators operating from one bank. It is expected that, subject to the agreement of the landowners, the dredged material can be disposed of along the channel bank. This is understood to have been the arrangement for dredging of the nearby North Drain.

Environmental: The SSSI designations (and associated SPA and Ramsar designations) introduce a number of probable constraints including:

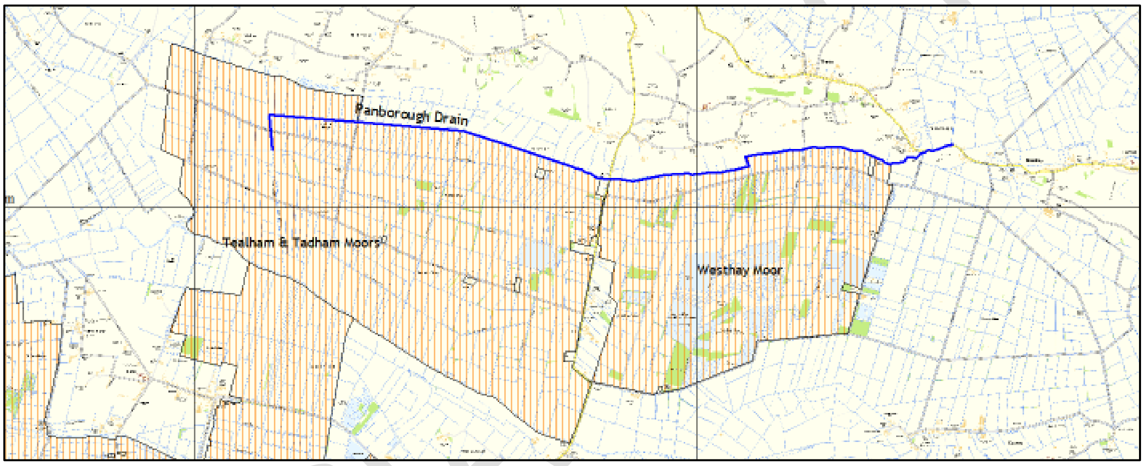
(i) requirement for Habitats Regulations Assessment (HRA) in respect of the SPA and Ramsar site, and possible restriction on working months for dredging (to avoid wintering bird season);

(ii) a need to also demonstrate through HRA that dredging will not lower water levels in the adjacent Ramsar site to the detriment of its qualifying invertebrate species;

(iii) restrictions on the placing of dredged material anywhere on the left bank or on either bank in the downstream few hundred metres (i.e. within the SSSIs).

Close consultation with Natural England would be essential, and any land drainage or dredging deposition affecting the SSSIs will require their consent. Any activities would need to be compatible with the WLMP which is required to achieve favourable status.

Figure 15.5 Panborough Drain – SSSIs in vicinity of Panborough Drain



Water Framework Directive: The study reach comprises a tributary in the "North Drain" water body catchment (GB108052021200) which is an artificial water body. Dredging would need to be aligned with the measures needed to achieve good potential as follows:

- Appropriate techniques to align and attenuate flow to limit detrimental effects of drainage features (not in place)
- Appropriate water level management strategies, including timing and volume of water moved (not in place)

However, there are unlikely to be significant conflicts. The water body also has Freshwater Fishery Protected Area status, which could constrain timing, extent and methodology of dredging operations.

<u>Hydraulic assessment</u>

Summary of survey: A channel cross-section survey of the Panborough Drain was undertaken by the Environment Agency in March 2014 and provided for use in this assessment. The survey indicates a total silt volume of approximately 28,000m^3 along the 6.8km length of channel.

The main function of the Panborough Drain is to collect water from the Tealham, Tadham, Aller and Westhay Moors via direct overland flow and from an extensive network of field drains. Water from Panborough Drain is discharged to the North Drain. North Drain collects water from the Tadham and Westhay Moors to the south of Panborough Drain. Water from the North Drain is discharged to the River Brue via a gravity sluice and the North Drain pump station when the water level in the Brue is higher than the drain level.

Water enters the moors via controlled flow from the River Sheppey, direct runoff from the local catchment and uncontrolled overflow from the River Brue. The total volume of water stored up to a level of 2.5mAOD (typical flood level during the period December 2013 to February 2014) is approximately 3.5Mm^3 for the moors drained by Panborough Drain.

The additional volume that would be provided by dredging the Panborough Drain represents less than 1% of the total storage volume, i.e. any impact in terms of enhanced flood storage would be minimal. Most of the silt volume lies below the normal winter penning level and would therefore not be available for flood storage. Therefore dredging the drain will not provide any benefit in terms of the maximum flood level and extent.

During and after a flood, drainage of these moors is principally via the North Drain pump station since the water level in the Brue precludes gravity drainage. In order to assess the impact of dredging on the drainage of the moors following a flood event a simple 1D ISIS model has been developed. The model includes the entire surveyed reach of the Panborough Drain and an extract of the North Drain channel from the main Brue model as far upstream as Lewis Drove weir. Upstream of this point the ground and channel levels rise above typical flood level.

The model includes the flood storage volume of the moors and the overbank flow routes from the moors into the drains. A detailed representation of the field drain network into the main drains is beyond the scope of this rapid initial assessment.

Two versions of the model have been prepared – 'without' dredging, using the top of silt levels from the 2014 survey and 'with' dredging, using the 'hard bed' levels (i.e. assuming all silt is removed). The models have been used to simulate the drawdown of the moors from an initial flood level of 2.5mAOD. This corresponds to the level on 16 February 2014 at the start of the recession of the winter flood period. This approach based on observed data is adopted as there is no pre-existing model for Panborough Drain (and therefore no 100-year simulation). The model includes a simplified representation of the operation of the North Drain pump station. The pumps are controlled according to water level in the North Drain and the Brue.

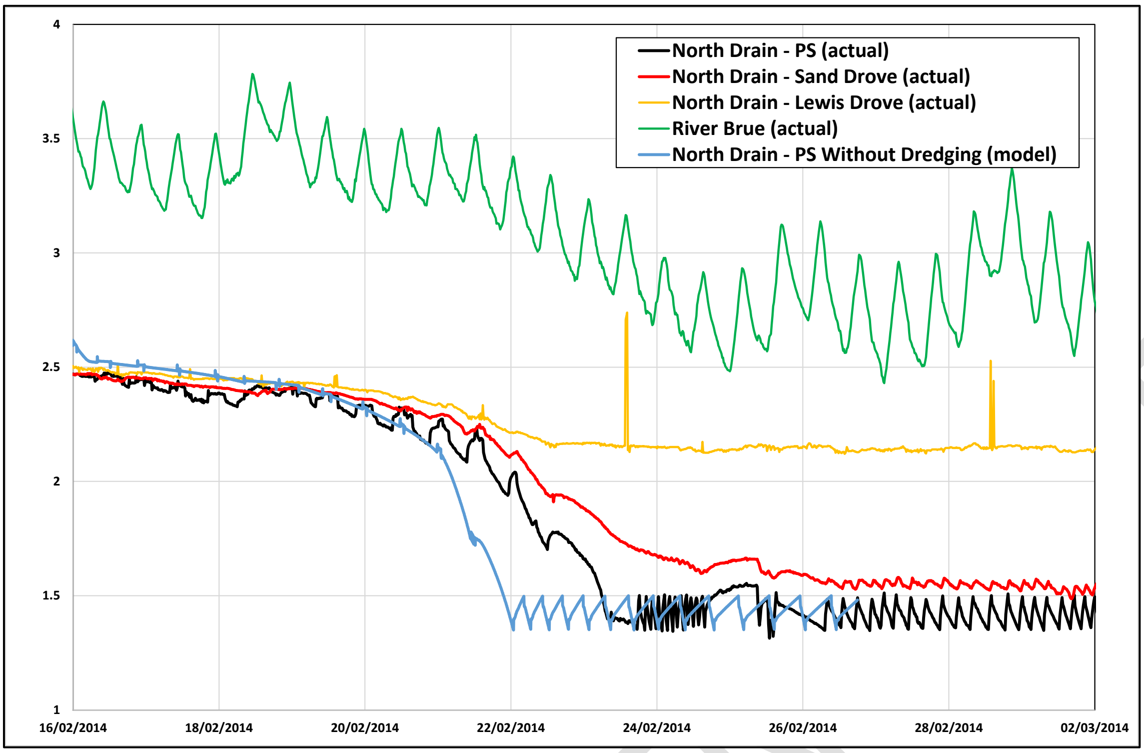
The charts below (Figures 15.6 and 15.7) show the actual and model water levels in the North Drain for the two model scenarios. In both scenarios, 'without' and 'with' dredging, the model water level drawdown is similar to the actual profile. The time to reach the penning level at the pump station is approximately 6 days in the model simulations, compared to 7 days in the actual event.

The difference in timing is probably largely due to additional inflow to the drains from the field drain network once the water level in the moors is below bank top level and which is not included in the model. However, the results suggest that there is little benefit in dredging in terms of water level control at the pump station.

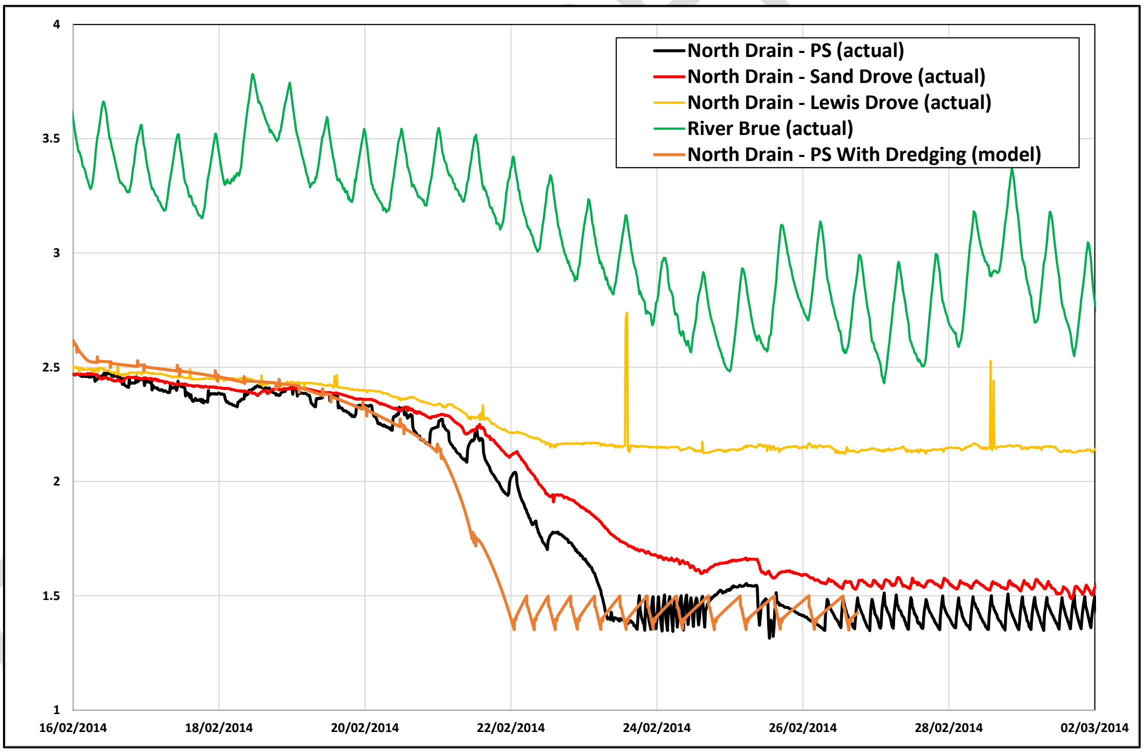
The long section plot below (Figure 15.7) shows the water surface profile along the Panborough Drain once the penning level is reached at the pump station. The model assumes a nominal flow of 0.1m^3/s along the drain at the end of the drawdown.

The results show a reduction in water level of up 0.45m at the upstream end of the drain as a result of dredging. This will enable a more rapid drawdown of the remaining volume of water in the field drain network to penning level. However, without more detailed modelling of the drainage network it is not possible to quantify this impact.

Figure 15.6 Panborough Drain – Long section plots, without / with dredging scenarios

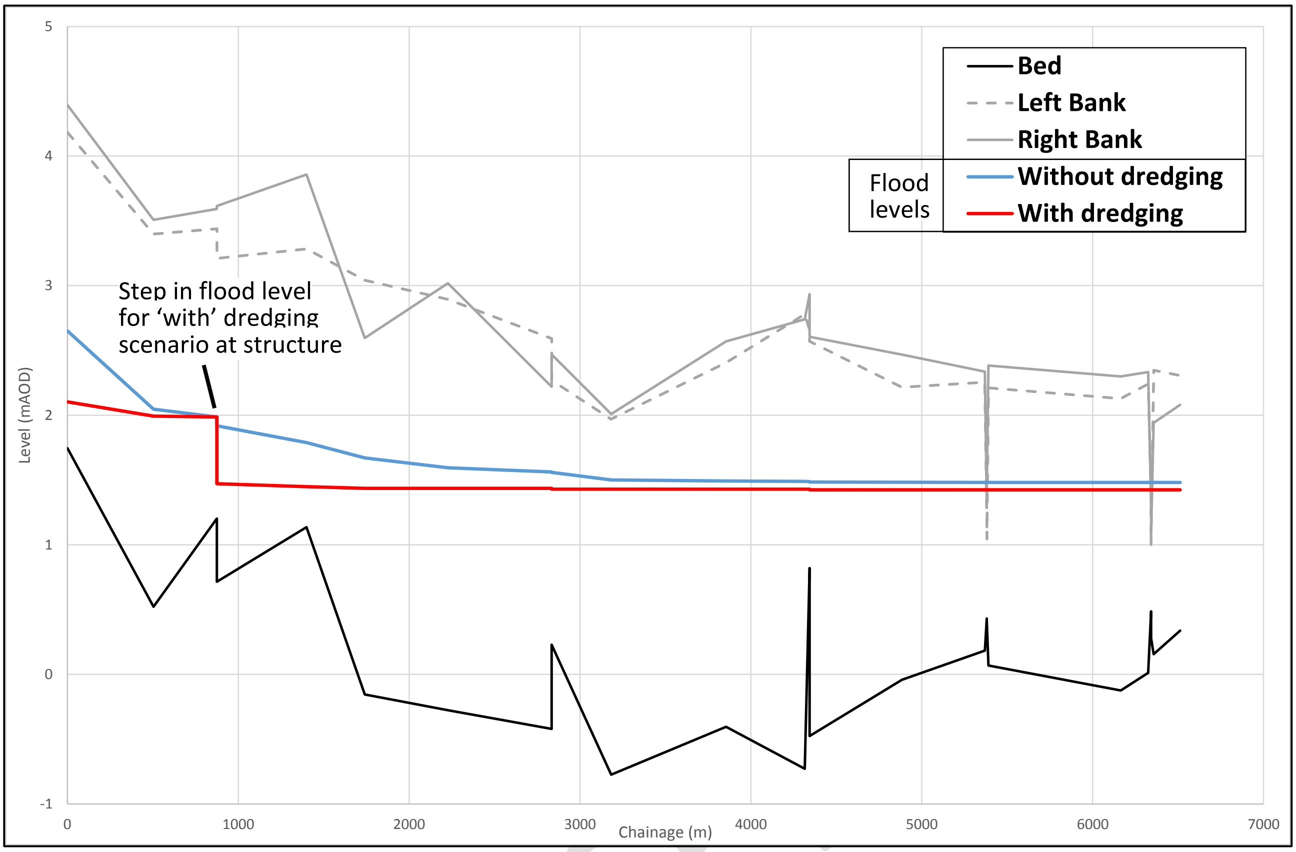


a) Without dredging scenario



b) With dredging scenario

Figure 15.7 Panborough Drain – long section plot, penning level at pump station



Hydraulic assessment – benefits/disbenefits

Benefits:

- Better water level management in the moors and field drainage rather than property/infrastructure.
- Panborough to Mudgley (approx.): Faster drainage of low level flood water following flood event and improved control of penning level
- Possibly improves operation of North Drain Pump Station by allowing more continuous operation of pumps (more efficient) due to better conveyance down the Drain at the tail end of a flood (so potentially less start/stop).These are really related to better water level management in the moors and field drainage rather than property/infrastructure, e.g. Panborough to Mudgley (approx.): Faster drainage of low level flood water following flood event and improved control of penning level.

Disbenefits:

- None identified.

Cost assessment

The total quantity of dredging is estimated at 28,000 m^3. It is assumed that 80% of dredged material is subject to single handling with material placed on or behind the banks by the excavator and 20% will be double-handled due to greater distance between excavation and disposal points.

On the above basis the estimated costs are:

- Full scheme cost estimate of £0.48 million (range: £0.35 to £0.7 million).
- Indicative maintenance dredging cost of £0.24 million is estimated for removal of a half of the original dredging quantity (the actual timing of any maintenance would need to be based on results from monitoring surveys).
- Present Value (PV) cost over 100 years of £1.8 million is estimated based on the initial full dredging cost, with maintenance dredging every 5 years and assuming Treasury Green Book rates (initial 3.5%).

The cost assumptions include:

- Material being excavated will be recent 'soft' sediment and free of contamination.
- The drain width is within the reach of medium reach excavators which will be more productive than the specialist long reach machines and a third reduction in unit costs is assumed.
- Most of the channel is accessible from both banks but it should be possible to undertake much of the dredging using a medium reach excavator operating on one bank and it is assumed that the dredged material will be suitable for deposition on or behind the channel banks or spread on adjacent fields.
- Limited amount of additional handling where dredging around structures or under bridges
- No specific environmental mitigation requirements, e.g. timing constraints related to fisheries, presence of protected species such as water vole.

Environmental assessment

There are significant environmental constraints in the vicinity of this reach of the Panborough Drain principally associated with nature conservation designations. The risk factors are underlined below.

- Westhay Moor SSSI and Tealham and Tadham Moors SSSI are both component sites within the Somerset Levels and Moors SPA and Somerset Levels and Moors Ramsar site; the left bank of Panborough Drain is within SSSI throughout, and both banks plus the drain itself in its western extent.
- Somerset Levels NNR and Westhay Moor NNR are within a few hundred metres but highly unlikely to be affected
- No additional local nature conservation sites
- Otter is known to be widespread in the adjacent SSSIs and is probable in Panborough Drain; the presence of water vole is unconfirmed but should be anticipated; the SSSIs occupying the left bank comprise Coastal and Floodplain Grazing Marsh priority habitat
- No international or national cultural heritage assets
- No local cultural heritage assets; previous archaeology record associated with the channel
- No national landscape designations, but the proximity of the NNRs should be noted
- Dredging presents a risk of compromising Water Framework Directive objectives for water bodies, including hydromorphology and Freshwater Fishery Protected Area status
- The majority of the land on either bank is under Entry Level Stewardship with some additional fields under High Level Stewardship; those areas not already under stewardship are within the Somerset Levels and Moors HLS target area

The entire length being considered for dredging is within the impact risk zone of the SSSIs. These are mixed wetlands incorporating former raised bog areas, with the water table high throughout the year with regular and extensive winter flooding. Aquatic and bankside plant and invertebrate communities associated with ditch habitats are nationally outstanding. Numerous breeding bird species include grassland ground nesting species. Open water and grassland attract wintering waterfowl, and specific non-breeding waterfowl species are the SPA qualifying features.

The Panborough Drain is associated with the following units (from east to west):

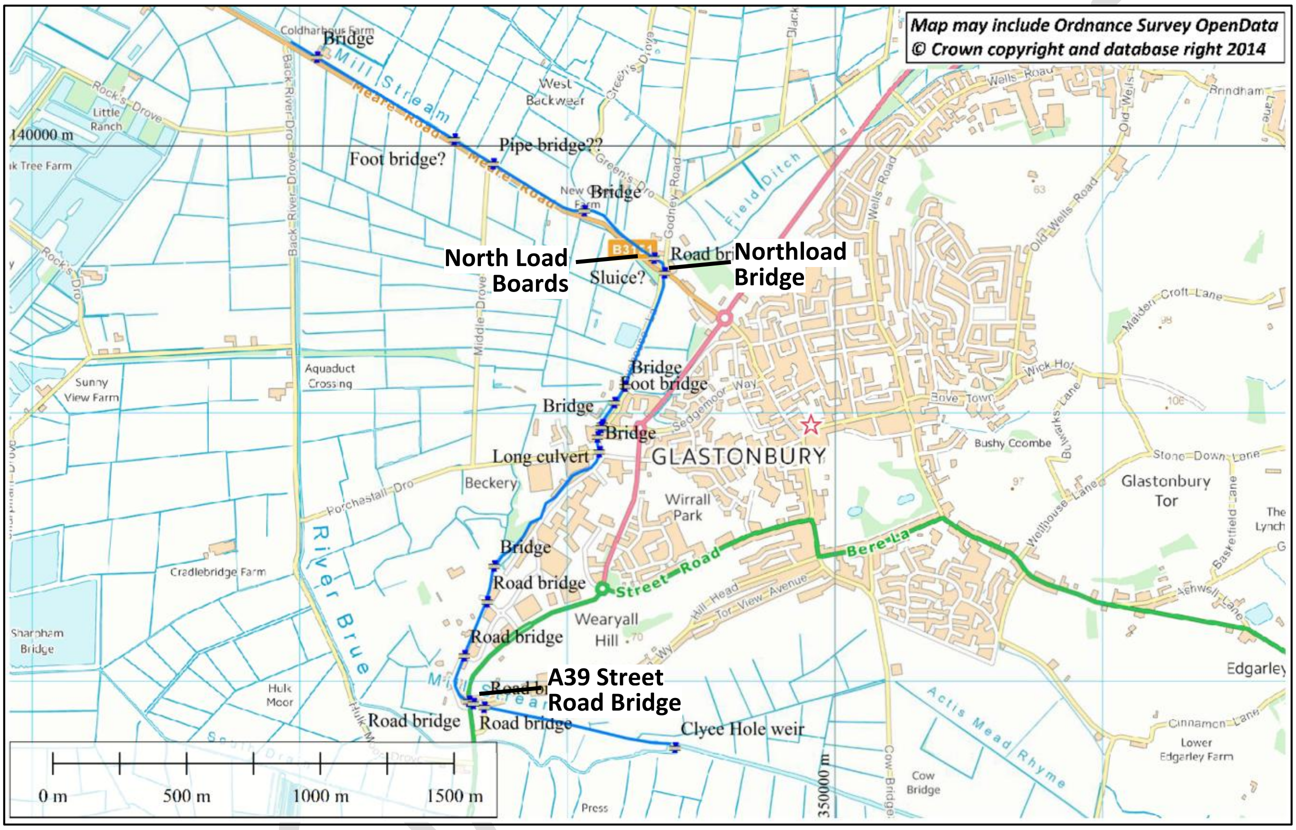
- Westhay Moor SSSI unit 88, unfavourable due to poor water quality in ditches, low water levels and excess growth of rush (amongst other factors)
- Westhay Moor SSSI unit 87, unfavourable due to poor water quality in ditches
- Tealham and Tadham Moors SSSI unit 121,unfavourable recovering with WLMP and water quality measures in place (amongst other factors)
- Tealham and Tadham Moors SSSI unit 120, unfavourable recovering as above
- Tealham and Tadham Moors SSSI unit 114, favourable
- Tealham and Tadham Moors SSSI unit 113, unfavourable recovering as above (121)
- Tealham and Tadham Moors SSSI unit 109, unfavourable recovering as above (121)

16. Dredging assessment: Glastonbury Millstream

Location

The Glastonbury Millstream is a branch of the River Brue and runs around the west side of Glastonbury (Figure 16.1). The overall length of this reach of channel is about 4.3km of which about 2km on the periphery of the town is engineered channel between walls. It is believed that the millstream was originally constructed in the 12th century by Glastonbury Abbey to supply a water mill[10].

Figure 16.1 Glastonbury Millstream



The River Brue starts to steepen about 2km upstream of Clyce Hole weir so the incoming sediment loads long the river may be significant and would be consistent with the build-up of sediment immediately upstream of the Clyce Hole weir. In addition, the inflows to the Millstream from the relatively steep local catchment are likely to carry sediment. The result is deposition of sediment in the flatter sections of the channel which will need to be periodically removed to maintain capacity.

Current Situation

The Glastonbury Millstream starts at the Clyce Hole (also spelt Clyse Hole) weir on the River Brue and comprises three main sections:

- An entry throttle structure leading to about 750m of earthen channel running westwards across sloping terrain from Clyce Hole weir to the edge of Glastonbury town (Figure 16.2)
- About 1.9km of channel running northwards along the western side of the town comprising a mixture of walled channel, bridges, culverts (the longest about 70m) and earth channel
- About 1.6km of earthen channel running north-westwards.

[10] http://somersetrivers.org/index.php?module=Content&func=view&pid=102

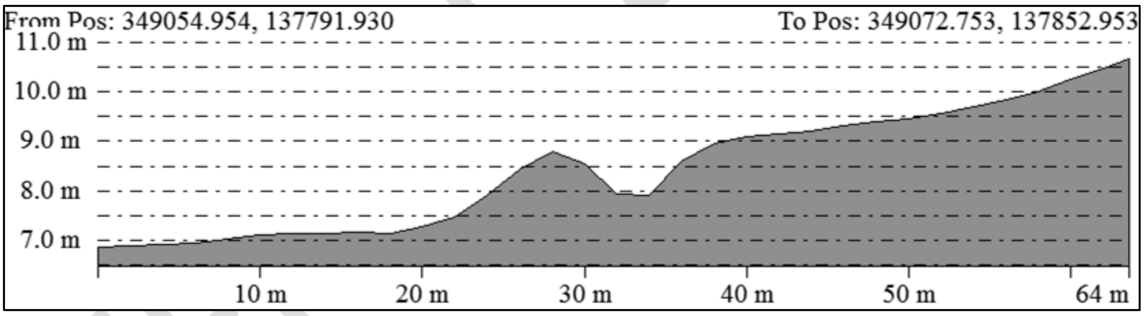
Figure 16.2 Glastonbury Millstream at Clyce Hole Weir

The focus of this dredging study is on the upstream and downstream sections rather than the intervening engineered channel section. During summer the channel conveys water which is diverted by a sluice structure (North Load Boards) to help manage water levels for farmland north of Glastonbury. The channel also receives discharges from a sewage treatment works.

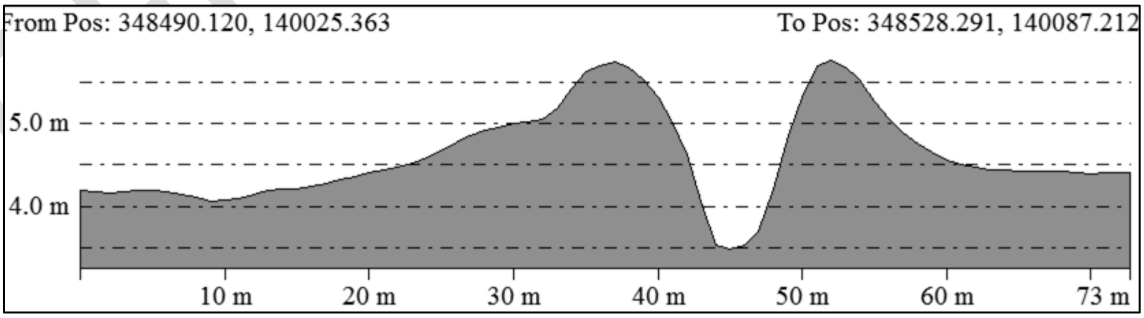
The millstream and adjacent River Brue are located midway in the Brue catchment and are therefore vulnerable to flooding caused by heavy summer rainfall[11] as well as prolonged moderate winter rainfall.

There is a distinct contrast between the geometry of the upstream and downstream sections of channel. The former is located on a distinct cross slope while the latter is embanked above flat terrain.

Figure 16.3 Glastonbury Millstream – indicative cross sections



(a) indicative cross section of upstream section of channel



(b) indicative cross section of downstream section of channel

11 http://www.westerndailypress.co.uk/Flood-warning-remains-place-heavy-showers/story-16531500-detail/story.html

Constraints

Structures: There are 18 bridges and culverts identified that cross the channel. Most of these are on the central section of channel where dredging is not expected to be undertaken.

Access: Access is available along the left bank of the upstream section of channel and on the right bank of the downstream section (a road is on the left bank of this section).

Disposal: It is not expected that the silt being removed will be contaminated. To minimise costs and subject to cooperation from the landowners the excavated material can be deposited or spread on the channel banks and immediately adjacent land (i.e. within reach of a single handling operation) under waste exemption D1 as is believed to have been the historical practice. Deposition beyond this would require proof or benefit, chemical assessment and appropriate licensing.. It is recommended that material excavated from the upstream section of channel is deposited on the left (downslope) side to avoid the risk of the material being washed back into the waterway.

Buried services: It is understood that an asbestos cement water main runs alongside the right (northern) bank of the downstream section of channel and there is the risk that deposited dredged material could damage the pipe. Possible restrictions on the deposition of material will have to be clarified with the pipe's owners. It is also possible that the dredged material may contain contaminants arising from the discharge from the sewage treatment works further upstream.

Working methods: The millstream channel is about 3m wide and within the capability of normal excavators working from one bank.

Environmental: Dredging should be sufficiently removed from sensitive urban receptors to have only a low risk of disturbing local communities, but in some locations (e.g. to south of The Roman Way at Northover) this may need to be addressed through sensitive operational implementation.

Water Framework Directive: The study reach comprises part of the "Brue" water body (GB108052021190) which is an artificial water body. Dredging presents a low risk of compromising one of the mitigation measures needed to ensure good potential: Improve floodplain connectivity (in place). The water body also has Freshwater Fishery Protected Area status, which could constrain timing, extent and methodology of dredging operations.

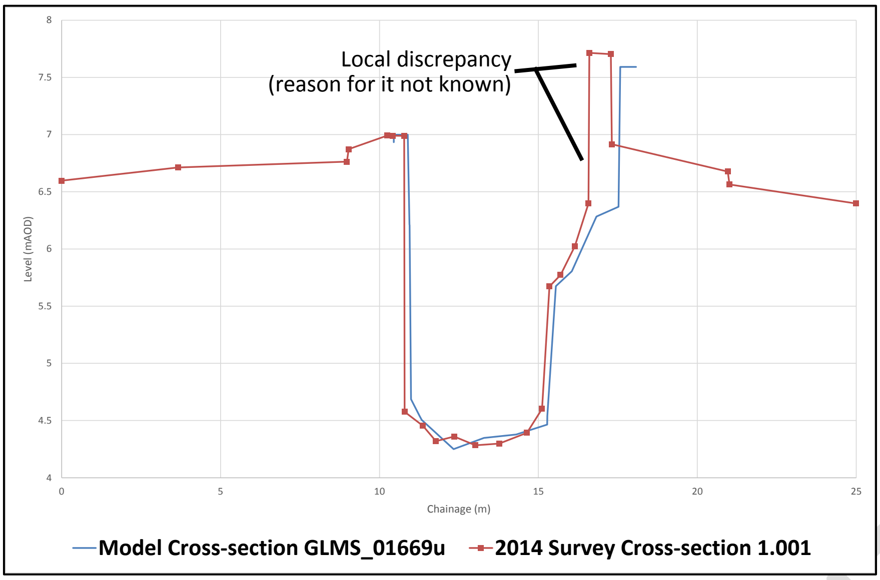
Hydraulic assessment

Summary of check survey: The table below summarises the structural levels surveyed in September 2014 and the levels in the original Axe and Yeo model survey. The differences in level are within +/-20mm which is acceptable for the purposes of the assessment and confirms a common datum level.

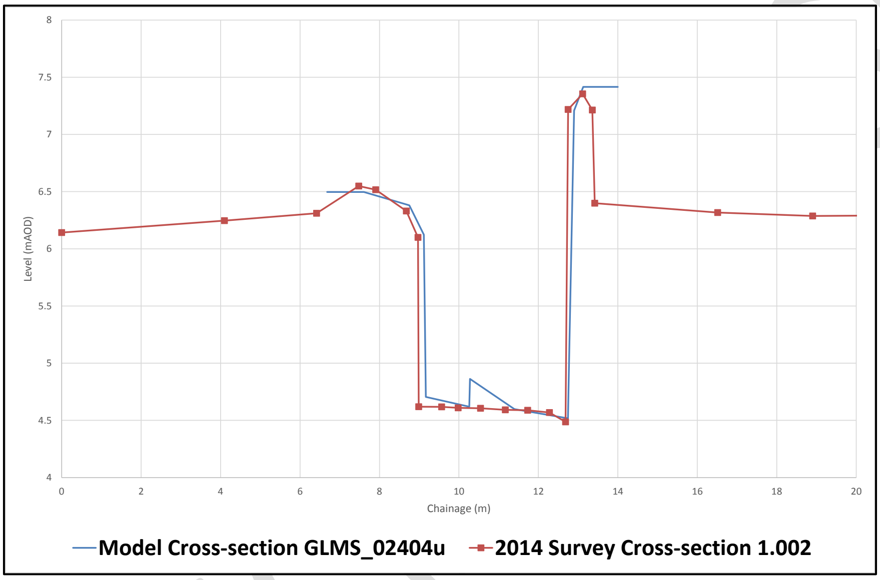
Location	Model level (mAOD)	Survey level (mAOD)
Northload Bridge soffit	6.46	6.47
Porchestall Drove Bridge left bank stone wall top	6.12	6.10
Beckery Old Road Bridge soffit	8.05	8.03

The check survey channel cross-sections are generally very similar to the cross-sections in the model as illustrated below (Figure 16.4).

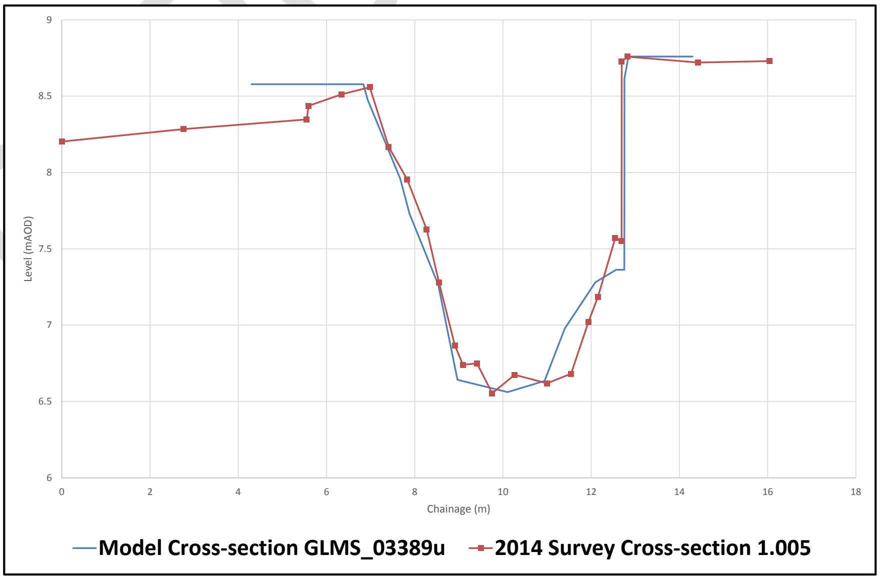
Figure 16.4 Glastonbury Millstream – survey channel cross-sections versus model sections



a) Upstream Northload bridge



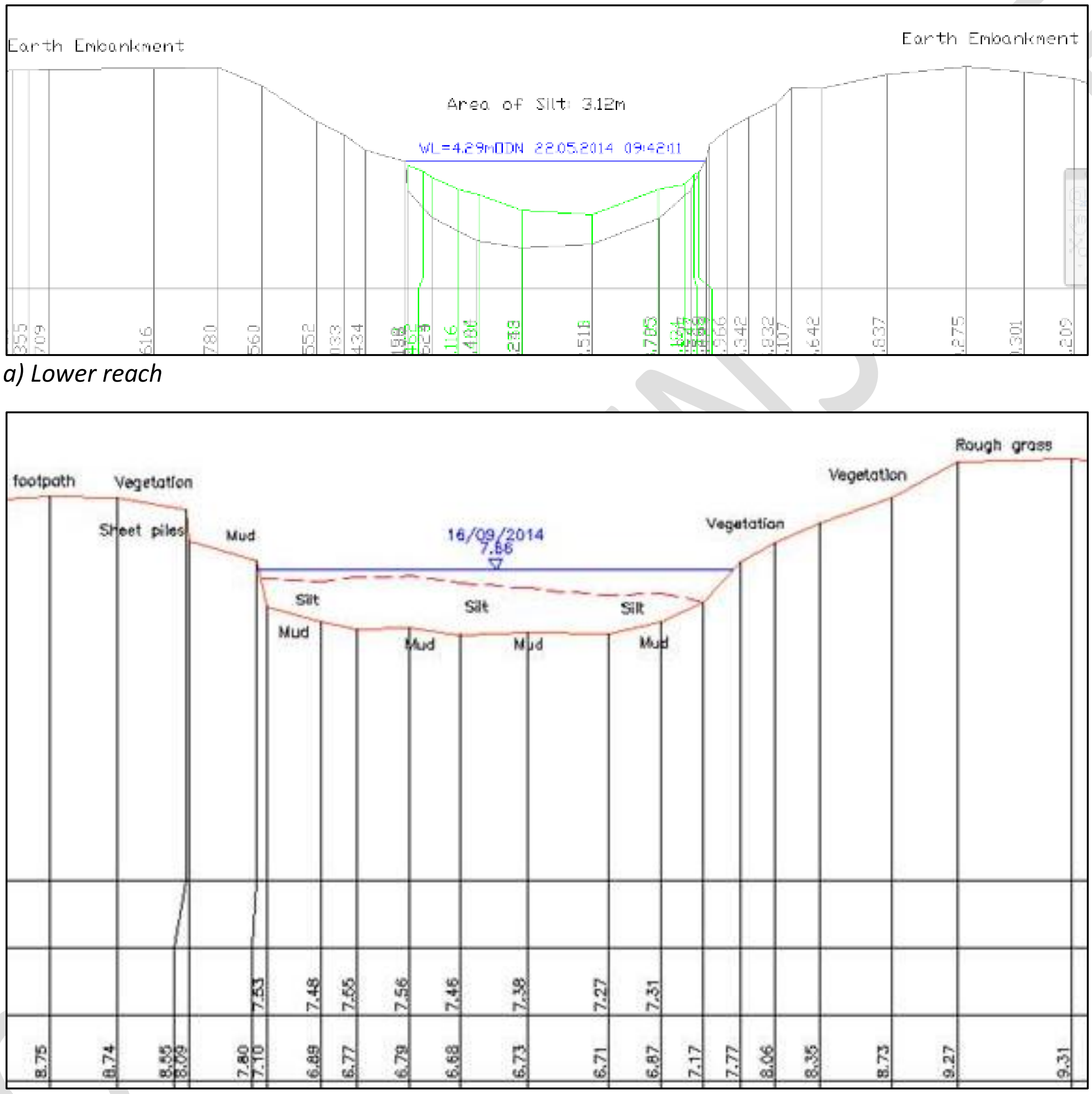
b) Upstream Porchestall Drove bridge



c) Upstream Beckery Old Road Bridge

No significant silt was observed at any of the six surveyed cross-sections within the middle reach of the Glastonbury Mill Stream (between the A39 Street Road Bridge and Northload Bridge). The 2014 Environment Agency survey of the lower reach (Northload Bridge to the Brue confluence) indicates average silt depths of 0.5m to 0.8m – see example cross-section below. The check surveys (Figure 16.5) undertaken upstream and downstream of Clyce Hole at the entrance to the stream indicates average silt depths of around 0.4m downstream of the 'throttle' at the entrance to the stream and around 0.6m upstream of the throttle – see example cross-section below.

Figure 16.5 Glastonbury Millstream – survey cross sections



a) Lower reach

b) Clyce Hole - upstream of throttle

Hydraulic assessment – model simulations

In order to provide a first assessment of the impact of dredging the existing Brue model has been run for the 1 in 100 year design simulation (storm event duration – 45 hours) derived under the original model study, 'with' and 'without' dredging. The 'without' dredging simulation assumes the silt bed profiles from the 2014 surveys in the Clyce Hole area and in the downstream reach. The 'with' dredging simulation assumes removal of silt to the 'hard bed' levels identified in the surveys.

Hydraulic assessment – results

As illustrated in the long section below (Figure 16.6), the effect of dredging in this flow scenario is limited. Maximum model levels at the upstream end of the stream are reduced by around 20mm. Maximum levels in the middle reach are increased by up to 30mm and maximum levels in the lower reach differ by less than 10mm.

The increase in levels in the middle reach is a result of an increase in flow into the stream as a result of dredging. The peak flow into the stream is increased by around 6% from 1.7m^3/s to 1.8m^3/s (Figure 16.7).

The effect on the maximum extent of flooding is illustrated in the plan below (Figure 16.8). The differences in flood extent are minimal, though the overall effect is to marginally reduce flood risk.

Figure 16.6 Modelled effect of dredging – long section

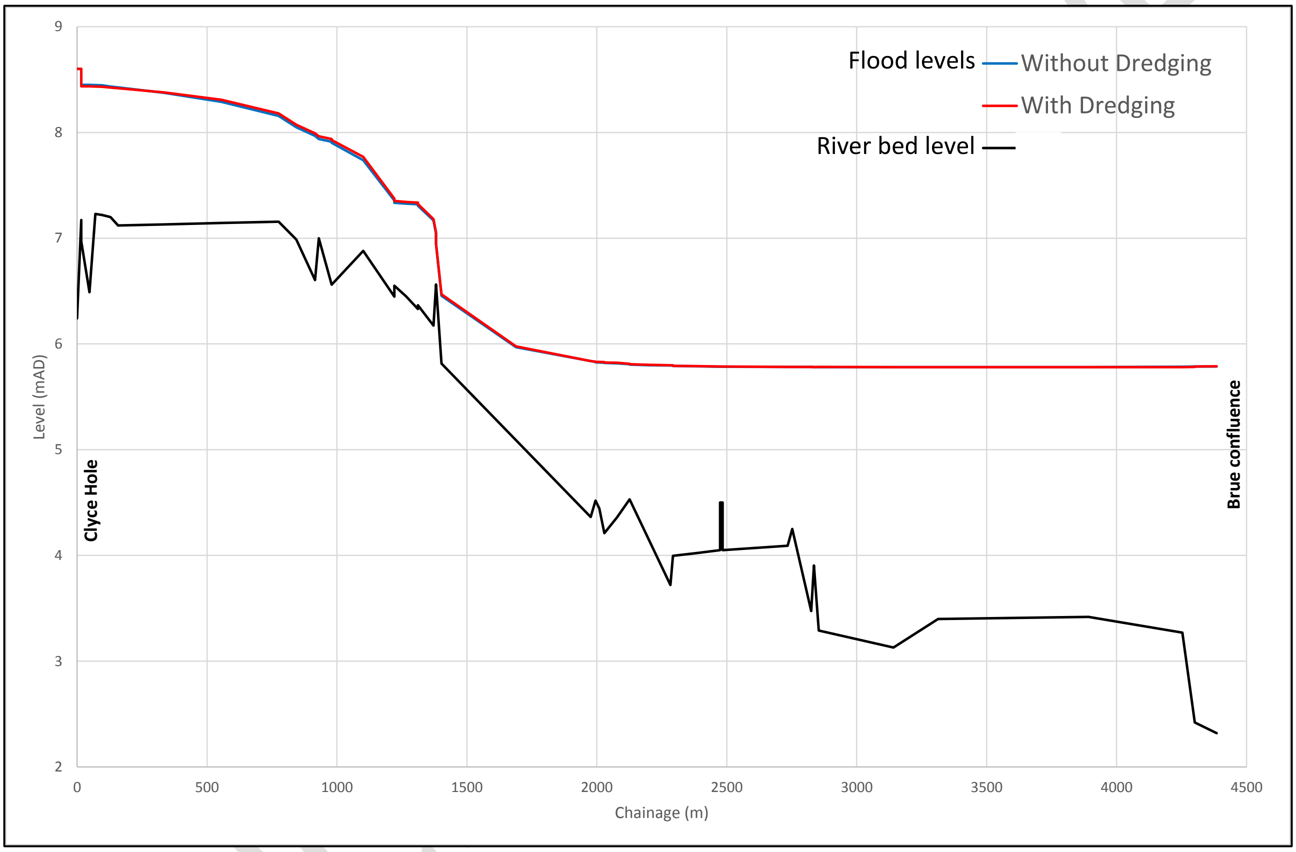
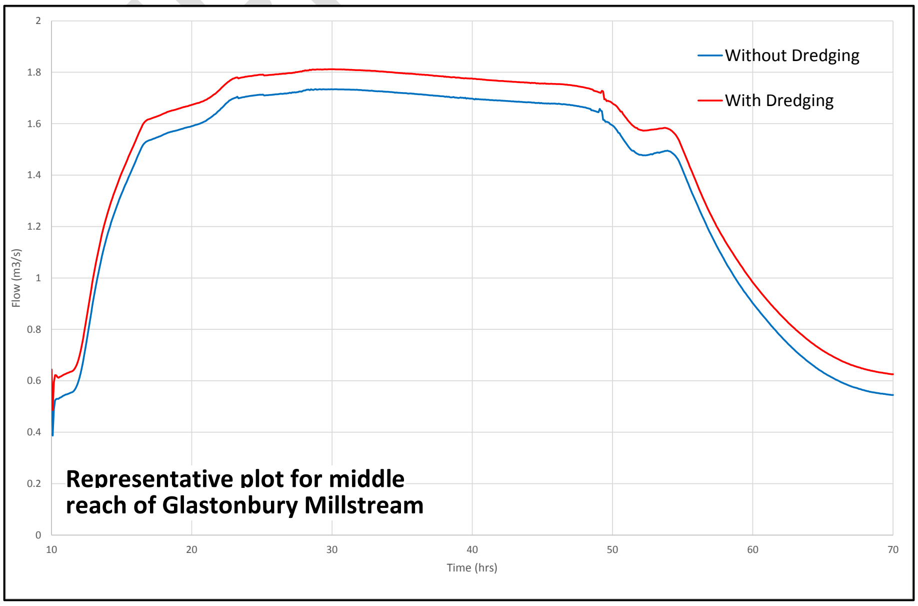


Figure 16.7 Modelled effect of dredging – flow-time plot



Hydraulic assessment – benefits/disbenefits

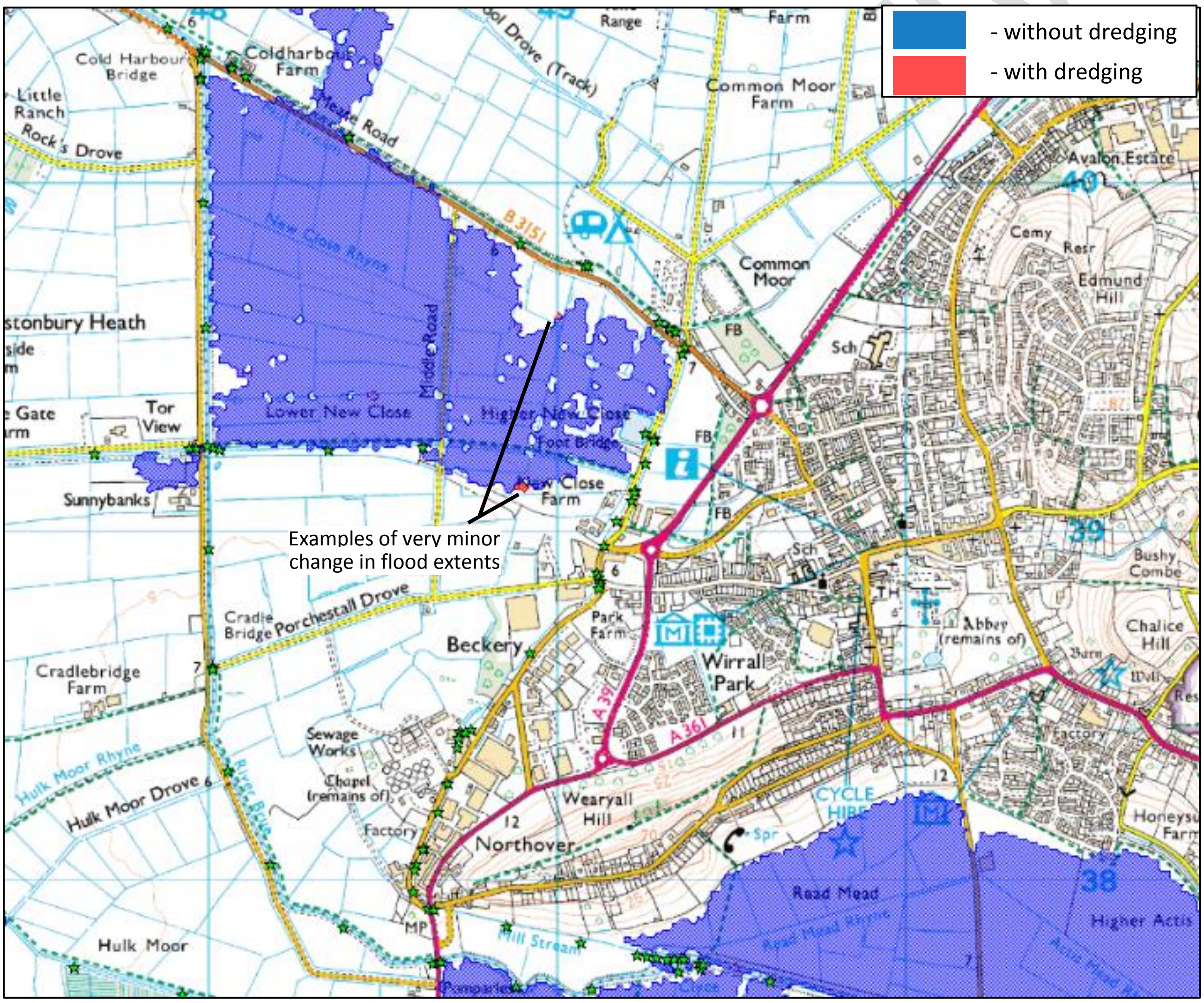
Benefits:

- Potentially improved water quality/less impact of STW effluent through higher low flows – non-flood related, residents may benefit (odour/environment) and may be a factor for further redevelopment of derelict sites along the Glastonbury Millstream.

Disbenefits:

- Increase in river level up to ~30mm for 100-year design flood so increase in potential flood risk, though model not predicting property/infrastructures flooding from Glastonbury Millstream for this event.
- Higher water level in Glastonbury Millstream potentially impacting on ability of STW to discharge peak effluent flows during wet weather – impact of say ~30mm rise in stream level may not be a problem.

Figure 16.8 Modelled effect of dredging – flood extent mapping



Cost assessment

The total quantity of dredging is estimated at 3,500 m^3. It is assumed that 80% of dredged material is subject to single handling with material placed on or behind the banks by the excavator and 20% will be double-handled due to greater distance between excavation and disposal points.

On the above basis the estimated costs are:

- Full scheme cost estimate of £0.06 million (range: £0.05 to £0.09 million).
- Indicative maintenance dredging cost of £0.03 million is estimated for removal of a half of the original dredging quantity (the actual timing of any maintenance would need to be based on results from monitoring surveys).
- Present Value (PV) cost over 100 years of £0.23 million is estimated based on the initial full dredging cost, with maintenance dredging every 5 years and assuming Treasury Green Book rates (initial 3.5%).

The cost assumptions include:

- Material being excavated will be recent 'soft' sediment and free of contamination.
- The drain width is within the reach of medium reach excavators which will be more productive than the specialist long reach machines. As quantities are small, no reduction in unit costs is assumed.
- Most of the channel is accessible from both banks but it should be possible to undertake much of the dredging using a medium reach excavator operating on one bank and it is assumed that the dredged material will be suitable for deposition on or behind the channel banks or spread on adjacent fields.
- Extra care will be required when working close to the asbestos cement water main.
- Dredging of the Brue immediately upstream of Clyce Hole weir will probably require work from both banks.
- Limited amount of additional handling where dredging around structures or under bridges
- No specific environmental mitigation requirements, e.g. timing constraints related to fisheries, presence of protected species such as water vole.

Environmental assessment

There are no significant environmental constraints in the vicinity of this reach of the Glastonbury Millstream, although otter and Freshwater Fishery status could constrain dredging operations. The risk factors are underlined below.

- No international or national nature conservation sites
- No local nature conservation sites
- <u>The presence of otter is probable; the presence of water vole is unconfirmed but should be anticipated; the upstream and downstream extents are both largely coincident with Coastal and Floodplain Grazing Marsh priority habitat</u>
- No international cultural heritage assets; closely associated with one Grade II Listed building (3 Mill Lane) with a second (former tannery) at a culverted reach, both in Northover but within the central channel reach not to be dredged
- No local cultural heritage assets; potential archaeology associated with managed channel in historic settlement area
- No national landscape designations
- <u>Dredging presents a risk of compromising Water Framework Directive objectives related to Freshwater Fishery Protected Area status</u>
- Adjacent agricultural land is not under Environmental Stewardship but is within the Somerset Levels and Moors HLS target area

17. Options Matrix

The feasibility matrix presents the overall findings of the assessment work and is summarised below in a series of tables – cost assessment, hydraulic assessment and environmental assessment. A summary of the options matrix is presented below assuming the following prioritisation criteria:

Scale: - small up to 50,000m^3 dredging → medium <100,000m^3 → large >100,000m^3
Cost: - low up to £0.5 million → medium <£1.5 million → high >£1.5 million
Disbenefits: - low risk <5cm flood level increase → medium <30cm → high >30cm
Environmental: - low risk, e.g. minimal dredging, no designations → medium → high risk
Effectiveness: - prioritisation assessed in terms of '13/14 flood event for the Parrett/Tone and 100 year flood event for the Brue/Axe.

The ranking order is indicative only and based on a reduction of flood risk to properties. Prioritisation should also be considered alongside other interventions, such as ring bank defences that provide the greatest benefit to people and communities.

Options Matrix – Summary (1 of 2)

Site	Scale	cost	Flood risk benefits		Water level management benefits	Negative flood risk impacts	Environment.	Effectiveness
			Properties	Duration				
Parrett: North Moor PS to M5 bridge 3.2km)	small/med	med/high	up to 20 properties	Reduced duration of up to 20 days for 25 -35 properties	Reduced duration of floods - may reduce agricultural damages (particularly applies to spring/summer floods in this area as experienced in 2012)Maintenance dredging will enable compliance with WLMP/Favourable Condition status to achieve required seasonal levels.	low/medium	medium	1
Tone: Ham to Hook Bridge (6.9km)	large	high	fewer than 5 properties	Reduced duration of up to 2 days in some moors, properties and A361	Reduced duration of floods - may reduce agricultural damages (particularly applies to spring/summer floods as experienced in 2012) Maintenance dredging will enable compliance with WLMP/Favourable Condition status to achieve required seasonal levels.	low	low	2
Parrett: Langport to Tone confluence (7.8km)	large	high	no change	Reduced duration up to 2 days at Westover Trading Estate and Thorney properties	Reduced duration of flooding in some moors - may reduce agricultural damages. Maintenance dredging will enable compliance with WLMP/Favourable Condition status to achieve required seasonal levels.	medium	medium	3
Glastonbury Millstream (4.3km)	small	low	no change	No reduction to duration of property flooding	Potential benefits for improved summer water supply/drainage to adjacent agricultural land. Funded by IDB precept.	low	low	4
Parrett: Thorney to Langport (6.2km)	small	medium	no change	Reduction in duration up to 2-4 hours for properties at Westover Trading Estate	Increased capacity of channels may allow earlier pumping. Maintenance dredging will enable compliance with WLMP/Favourable Condition status to achieve required seasonal levels.	low	low	5
Yeo: HEPS to Parrett confluence (1.8km) (NB not standalone option - tested with Thorney to Langport & Langport to Tone sites)	small	low	no change	Reduced duration up to 5 days at Westover Trading Estate and up to 1 day for Thorney properties	Minimal impact. Maintenance dredging will enable compliance with WLMP/Favourable Condition status to achieve required seasonal levels.	low	low	6

Options Matrix – Summary (2 of 2)

Site	Scale	cost	Flood risk benefits		Water level management benefits	Negative flood risk impacts	Environment.	Effectiveness
			Properties	Duration				
Axe: Clewer to New Cut (7.7km)	small	low/med	no change	Minor reduction in duration of flooding between Crickham to Lower Weare and some properties and roads u/s Clewer	Minimal benefit – increased conveyance at lower levels may aid drawdown in advance of flood event	medium	low	7
Penzoy: Burrow Wall to Chedzoy Flap (10.4km)	small	low	no change	Reduced duration for adjoining fields only in more frequent events	Reduction in moors water levels. Maintenance dredging will enable compliance with WLMP/Favourable Condition status to achieve required seasonal levels. Improved discharge may result in more storage capacity available when high-level carriers overtop during flood event.	low	low	8
Cheddar Yeo: Froglands to Axe confluence (8.8km)	small	low	no change	No reduction to duration of property flooding	Minimal impact	medium	medium	9
Panborough Drain (6.8km)	small	low/med	no change	No reduction to duration of property flooding	Faster drainage of low level flood water following flood event - possibly resulting in reduced duration of flooding to moors	low	medium	10

A. Options Matrix – Cost assessment

Option	Cost estimate* (cost range -25%, +50%)	Maintenance estimate	Cost as Present Value, over 100 years
River Parrett: Thorney to Langport, 6.2km	£0.6m (range: £0.5m-£0.9m) 35,000 m^3 £97/m or £17/m^3	£0.2m every 5 years 12,000 m^3 (one third of original dredging)	PVc £1.7m
River Parrett: Langport to Tone confluence, 7.8km	£2.2m (range: £1.6m-£3.1m) 124,000 m^3 £256/m or £18/m^3	£0.7m every 5 years 41,500 m^3 (one third of original dredging)	PVc £6.0m
River Parrett: North Moor PS to M5 bridge, 3.2km	Scenario 1 £0.85m(range: £0.65m-£1.25m) 41,000 m^3 £265/m or £21/m^3 Scenario 2 £1.65m (range:£1.25m-£2.5m) 82,000 m^3 £515/m or £20/m^3	Scenario 1 £0.28m every 5 years 14,000 m^3 (one third of original dredging) Scenario 2 £0.55m every 5 years 28,000 m^3 (one third of original dredging)	Scenario 1 PVc £2.4m Scenario 2 PVc £4.7m
River Tone: Ham to Hook Bridge, 6.9km	Scenario 1 £2.3m (range: £1.7m-£3.5m) 137,000 m^3 £333/m or £18/m^3 Scenario 2 £4.0m (range: £3.0m-£6.0m) 240,000 m^3 £580/m or £17/m^3	Scenario 1 £0.77m every 5 years 45,000 m^3 (third of original dredging) Scenario 2 £1.35m every 5 years 80,000 m^3 (one third of original dredging)	Scenario 1 PVc £6.6m Scenario 2 PVc £11.5m
River Yeo: HEPS to Parrett confluence, 1.8km	£0.15m (range £0.1m-£0.25m) 9,000 m^3 £89/m or £18/m^3	£0.05m every 5 years 3,000 m^3 (third of original dredging)	PVc £0.45m
Penzoy system: Burrow Wall to Chedzoy Flap, 10.4km	£0.38m (range:£0.28m-£0.56m) 28,000 m^3 £37/m or £14/m^3	£0.13m every 5 years 8,000 m^3 (third of original dredging)	PVc £1.1m
River Axe: Clewer to New Cut, 7.7km	£0.5m (range: £0.4m-£0.8m) 30,000 m^3 £65/m or £17/m^3	£0.17m every 5 years 10,000 m^3 (third of original dredging)	PVc £1.45m
Axe: Cheddar Yeo, Froglands to Axe confluence, 8.8km	£0.3m (range: £0.2m-£0.45m) 17,000 m^3 £34/m or £17/m^3	£0.1m every 5 years 6,000 m^3 (third of original dredging)	PVc £0.82m
Brue: Panborough Drain, 6.8km	£0.48m (range:£0.35m-£0.7m) 28,000 m^3 £71/m or £17/m^3	£0.24m every 5 years 14,000 m^3 (half of original dredging)	PVc £1.8
Brue: Glastonbury Millstream, 4.3km (only 1.8km dredging)	£0.06m (range:£0.05m-£0.09m) 3,500 m^3 £33/m or £17/m^3	£0.03m every 5 years 1,750 m^3 (half of original dredging)	PVc £0.23k

*full scheme cost (incl. contractor's cost, preliminaries, design and site supervision, contingency)

B. Options Matrix – Hydraulic assessment (Parrett/Tone)

Option	Hydraulic benefits		Hydraulic disbenefits		Potential to combine with other options
	Location	Degree of benefit	Location	Degree of disbenefit	
River Parrett: Thorney to Langport, 6.2km **Ref: B&V technical note, TN19 Parrett (Thorney to Langport) Dredging Hydraulic Modelling**	Lower flood levels (only 50mm max): • Thorney Bridge to Parrett confluence • Moors: Midelney/West Moor, Thorney Moor, Perry Moor, Mulcheney Level • Westover trading estate Reduced duration of flooding (2-4 hours): • Properties • Langport to Muchelney Road	√ √ √ √ √	Increase in flows downstream: • Great Bow bridge to Allermoor spillway (+10mm)	X	Potential to combine with other Parrett dredging to: • increase overall evacuation of flood flows out to sea. • limit any disbenefits of increasing flows downstream by dredging isolated reaches.
River Parrett: Langport to Tone confluence, 7.8km **Ref: B&V technical note, TN21 Parrett (Langport to Tone) Dredging Hydraulic Modelling**	Lower flood levels (20-40mm max): • Thorney Bridge to Parrett confluence • Moors: Wet Moor, West Moor, Mulcheney Level, Thorney Moor, Huish Level Reduced duration of flooding (2 days, Scenario 2): • Properties nr Sowy/KSD (less Allermoor spill flows) • Langport to Muchelney Road	√ √ √√ √√	Increase in flows downstream: • Curry Moor (+20mm) • North Moor (+300mm)	XX XXX	As above
River Parrett: North Moor PS to M5 bridge, 3.2km **Ref: B&V technical note, TN20 Parrett (downstream of North Moor) Dredging Hydraulic Modelling**	Lower flood levels: • North Moor (260mm) • North Moor area (stops flooding in 10-20 properties) • Other moors: Curry, Aller and King Sedge Moors Reduced duration of flooding (2 days, Scenario 2): • North Moor area (20 days, 25-35 properties) • Properties nr Sowy/KSD (less Allermoor spill flows)	√√√ √ √√√ √√	Increase in tide peaks: • North Moor and M5 bridge (+20-50mm)	XX	As above
River Tone: Ham to Hook Bridge, 6.9km **Ref: B&V technical note, TN16 Upper Tone Dredging Hydraulic Modelling**	Lower flood levels: • In-channel Ham Weir to Hook Bridge (up to 20mm for Scenario 1 and 100mm for Scenario 2) • Moors: West Curry, Curry, Hay and West Moors (up to 30mm for Scenario 1 and 50mm for Scenario 2) • North Moor area (stops flooding in 2 properties) Reduced duration of flooding • Most significant in West Curry Moor and West Moor	√ √ √√ √	None reported		Combines with downstream dredging on Tone and Parrett

B. Options Matrix – Hydraulic assessment (Parrett/Tone)

Option	Hydraulic benefits		Hydraulic disbenefits		Potential to combine with other options
	Location	Degree of benefit	Location	Degree of disbenefit	
River Yeo: HEPS to Parrett confluence, 1.8km **Ref: B&V technical note, TN22 Yeo (HEPS to Parrett confluence) Dredging Hydraulic Modelling**	Lower flood levels (up to 100mm for Scenario 1 and 140mm for Scenario 2): • In-channel HEPS to Yeo/Parrett confluence • Moors: Wet Moor, West Moor, Mulcheney Level, Thorney Moor and Huish Level Reduced duration of flooding • Westover trading estate, Langport (2 to 5 days) • Thorney properties (<1 day) • Langport to Muchelney Road (<1 day)	 √ √ √√ √ √	Minor increase in flood duration: • Moors downstream	 X	Links to Parrett dredging – see comment above on potential to combine with other Parrett dredging.
Penzoy system: Burrow Wall to Chedzoy Flap, 10.4km **Ref: B&V technical note, TN18 Penzoy Dredging Hydraulic Modelling**	Lower flood levels: • Moors downstream of Lake Wall (10mm) Reduced duration of flooding • Adjoining fields, only for frequent flood events from local heavy rainfall (not for repeat of '13/14 flood).	 √ √	None reported		Potential to combine with Sowy/KSD enhanced capacity improvements. Potential to improve flow from Southlake under Burrow Wall to Penzoy River as inlet structure to culvert is heavily restricted – requires improvement in combination with dredging.

B. Options Matrix – Hydraulic assessment (Axe)

Option	Hydraulic benefits		Hydraulic disbenefits		Potential to combine with other options
	Location	Degree of benefit	Location	Degree of disbenefit	
River Axe: Clewer to New Cut, 7.7km	1) Crickham to Lower Weare (approx.): reduction in river water levels (up to approx. 45mm for 100 year flood) and duration of flood levels 2) Clewer Pump Station : increase in duration of operation due to reduction in time river level over pump cut threshold (e.g. approx. increase of 12 hours pump No. 2 operation in 1 in 100 year/2 day event) 3) Some properties and minor roads/lanes upstream of Clewer at risk in a 100-year design flood and dredging would result in a small reduction in maximum level of 30mm or less, and duration.	√ √√	1) Downstream of Lower Weare (approx.): increase in river water levels (up to approx. 170mm for 100 year flood) and flows (approx. 10% for 100 year flood) 2) Some properties at the downstream end of the dredging reach (Biddisham/Crab Hole) at risk in a 100-year design flood where flood level/duration increased up to ~150mm and potentially further downstream (beyond M5) as a result of increased peak flow (but model ends at M5).	XX	Combining with Cheddar Yeo tends to increase disbenefits
River Axe: Cheddar Yeo, Froglands to Axe confluence, 8.8km	1) Cheddar old railway bridge to Hythe Bow Bridge: reduction in river water levels (up to approx. 130mm for 100 year flood) and duration of flood levels. 2) Some property at risk in 100-year design flood just downstream of Cheddar, between B3151 and A371, e.g. Cheddar Business Park (dredging would reduce peak level by up to 130mm).	√√	1) Downstream of Dunnetts Bridge (approx.): increase in river water levels (up to approx. 130mm for 100 year flood). 2) Similar to Axe (Clewer to New Cut) but less impact if Yeo dredged alone: Some properties at the downstream end of the dredging reach (Biddisham/Crab Hole) at risk in a 100-year design flood where flood level/duration increased up to ~150mm and potentially further downstream (beyond M5) as a result of increased peak flow (but model ends at M5)	XX	Combining with Axe tends to increase disbenefits

B. Options Matrix – Hydraulic assessment (Brue)

Option	Hydraulic benefits		Hydraulic disbenefits		Potential to combine with other options
	Location	Degree of benefit	Location	Degree of disbenefit	
Brue: Panborough Drain, 6.8km	1) Better water level management in the moors and field drainage rather than property/infrastructure. 2) Panborough to Mudgley (approx.): Faster drainage of low level flood water following flood event and improved control of penning level 3) Potential for greater transfer of flow from Axe and increased operational flexibility 4) Possibly improves operation of North Drain Pump Station by allowing more continuous operation of pumps (more efficient) due to better conveyance down the Drain at the tail end of a flood (so potentially less start/stop).	√√ √	No significant disbenefits identified		Potential to combine with improvements to Axe-Brue transfer via Panborough Gap Allows benefits of North Drain dredging to be extended along Panborough Drain
Brue: Glastonbury Millstream, 4.3km (1.8km dredging)	1) Downstream of inlet 'throttle' at Clyce Hole to A39 bridge (approx.) : reduction in river water levels (up to approx. 20mm for 100 year flood) 2) Entire length: increased flow into stream from the Brue during low flow periods, increased dilution of STW effluent, improved water quality– non-flood related, residents may benefit (odour/environment) and may be a factor for further redevelopment of derelict sites along the Glastonbury Millstream. 3) Northload sluice: increased flow available for diversion	√ √√ √√	1) A39 bridge to Dyehouse Lane bridge (approx.): increase in river water levels (up to approx. 30mm for 100 year flood). 2) Model not predicting property/infrastructures flooding from Glastonbury Millstream for this event. 3) Higher water level in potentially impacting on ability of STW to discharge peak effluent flows during wet weather – impact of ~30mm rise in level may not be a problem.	X	Potential to combine increased low flow with channel improvements/ restoration and future redevelopment of stream corridor Combining dredging with an improved control structure (sluice gate) to manage flow into GMS – open up during low flow, close during flood flow

C. Options Matrix – Environmental assessment (Parrett/Tone)

River Parrett: Thorney to Langport, Huish Bridge (6.2km) - lower environmental risk
River Parrett: Langport (Huish Bridge) to Tone confluence (7.7km) - higher environmental risk
River Parrett: North Moor to Bridgwater (3.2km) - lower environmental risk
River Tone: Ham to Hook Bridge (6.9km) - higher environmental risk
River Yeo: Huish Episcopi PS to confluence (1.8km) - lower environmental risk
Penzoy River: New Southlake inlet to Kings Sedgemoor Drain (10.4km) - higher environmental risk

Option	Constraints/challenges				Other benefits	
	Sustainability	Environmental	Material disposal	Access	Environmental	Socio-economic
River Parrett: Thorney to Langport, 6.2km	Energy cost for routine dredging	• Freshwater Fishery protected area status • Otter present and water vole anticipated • Potential archaeology associated with historic river crossing near Muchelney • Risk of compromising WFD hydromorphology	Widely constrained: • Most adjacent land is under Environmental Stewardship • Both banks entirely UK priority habitat	No issues	-	-
River Parrett: Langport to Tone confluence 7.8km	Energy cost for routine dredging	• Freshwater Fishery protected area status • Otter present and water vole probable • HRA required & possible seasonal constraints on dredging operations alongside SPA at Stathe to Burrowbridge Need to demonstrate no effects on water levels in adjacent SPA/Ramsar site (additional water level structure(s) may be required) • Potential archaeology at Oath, Burrowbridge), and the Parrett-Tone confluence • Risk of compromising WFD hydromorphology	Constrained at least locally: • Some adjacent land under Environmental Stewardship • Both banks mostly UK priority habitat • RSPB reserve West Sedgemoor	No issues	Dredging might remove sediment acting as one source of phosphate, with benefit to Southlake Moor SSSI	Possibility of agricultural enrichment where not in conflict with Stewardship or priority habitat
River Parrett: North Moor PS to M5 bridge 3.2km	Energy cost for routine dredging	• Freshwater Fishery protected area status • Otter present and water vole probable • Risk of compromising WFD hydromorphology	Constrained at least locally: • Some adjacent land under Environmental Stewardship • Both banks mostly UK priority habitat • LNR on left bank	No issues (unless extended into Bridg-water)	-	Possibility of agricultural enrichment where not in conflict with Stewardship or priority habitat

Option	Constraints/challenges				Other benefits	
	Sustainability	Environmental	Material disposal	Access	Environmental	Socio-economic
River Tone: Ham to Hook Bridge 6.9km	Energy cost for routine dredging	• Freshwater Fishery protected area status • Otter present and water vole anticipated • HRA required & possible seasonal constraints on dredging operations along entire reach Need to demonstrate no effects on water levels in SPA/Ramsar site (additional water level structure(s) may be required) • Risk of compromising WFD hydromorphology	Widely constrained: • Most adjacent land is under Environmental Stewardship • Both banks mostly UK priority habitat	No issues	• Improved ability to drain land may benefit Curry and Hay Moors SSSI bird roosts • Dredging might remove sediment acting as one source of phosphate, with benefit to Hay Moors SSSI	-
River Yeo: HEPS to Parrett confluence 1.8km	Energy cost for routine dredging	Freshwater Fishery protected area status; Otter probable and water vole anticipated	Constrained at least locally: • Some adjacent land under Environmental Stewardship • Both banks entirely UK priority habitat	No issues	-	Possibility of agricultural enrichment where not in conflict with Stewardship or priority habitat
Penzoy system: Burrow Wall to Chedzoy Flap, 10.4km	Energy cost for routine dredging	• Freshwater Fishery protected area status • Otter present and water vole probable; • HRA required & possible seasonal constraints on dredging operations in SPA near Burrowbridge Need to demonstrate no effects on water levels in SPA/Ramsar site (additional water level structure(s) may be required) • Potential archaeology associated with SM and surrounding area at Burrowbridge and battle site surrounding Chedzoy New Cut	Widely constrained: • Much adjacent land is under Environmental Stewardship • Both banks mostly UK priority habitat • Adjacent SM at Burrowbridge	No issues	• Improved ability to drain land may benefit Longmead and Weston Levels SSSI by reducing waterlogging • dredging could be combined with scrub clearance to reduce shading impact • Dredging might remove sediment acting as one source of phosphate, with benefit to Southlake Moor SSSI	-

C. Options Matrix – Environmental assessment (Axe/Brue)

River Axe: Clewer to New Cut, 8km - lowest environmental risk
Axe: Cheddar Yeo, Froglands to Axe confluence, 9km - Intermediate environmental risk
Brue: Panborough Drain, 4km - highest environmental risk
Brue: Glastonbury Millstream, 4.3km (1.8km dredging) - lowest environmental risk

Option	Constraints/challenges				Other benefits	
	Sustainability	**Environmental**	**Material disposal**	**Access**	**Environmental**	**Socio-economic**
River Axe: Clewer to New Cut, 7.7km	Energy cost for routine dredging	Freshwater Fishery protected area status Water vole & otter probable	Unconstrained	No issues	Opportunity to stop bank poaching/ erosion	Possibility of agricultural enrichment (but may conflict with Stewardship)
Axe: Cheddar Yeo, Froglands to Axe confluence, 8.8km	Energy cost for routine dredging	Freshwater Fishery protected area status Water vole & otter probable; Risk of compromising WFD for *R Cheddar Yeo - source to conf Stubbingham Rhyne*	Potential for heavy metal contamination which presents a risk (low) of constraining this; Locally constrained at Parson's Farm (Scheduled Monument)	No issues	-	Possibility of agricultural enrichment (but may conflict with Stewardship)
Brue: Panborough Drain, 6.8km	Energy cost for routine dredging	Freshwater Fishery protected area status Otter probable and water vole anticipated HRA required & possible seasonal constraints on dredging operations alongside SPA Need to demonstrate no effects on water levels in adjacent SPA/Ramsar site (additional water level structure(s) may be required	Locally constrained at some fields (Higher Level Stewardship) to north; Constrained on c90% of south bank and 15% of north bank due to SSSI designations	No issues	Improved ability to drain land may benefit SSSI Water Level Management Plan	Possibility of agricultural enrichment (but may conflict with Stewardship)
Brue: Glastonbury Millstream, 4.3km (1.8km dredging)	Energy cost for routine dredging	Freshwater Fishery protected area status Otter probable and water vole anticipated	Reasonably unconstrained	No issues	-	Possibility of agricultural enrichment