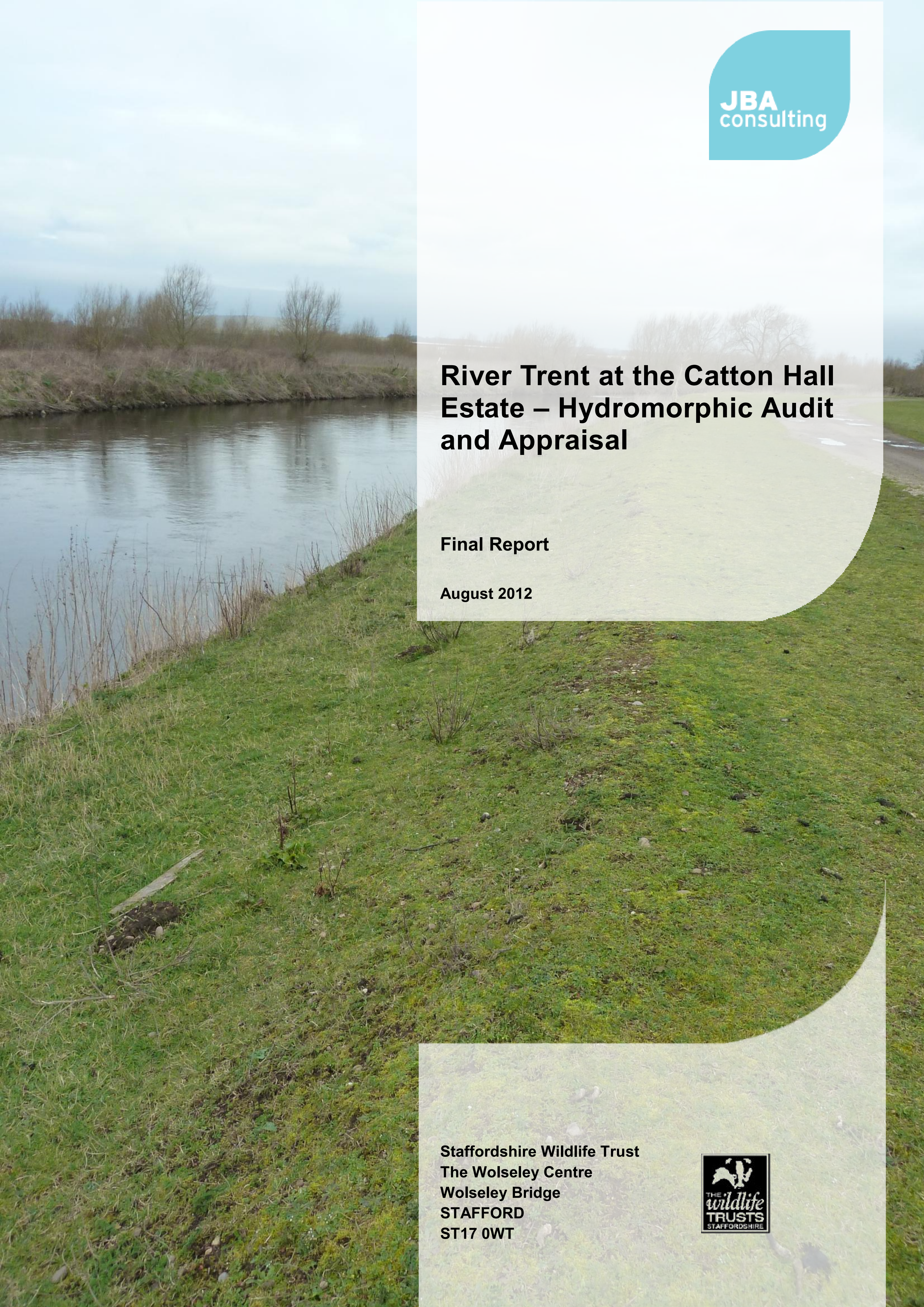

River Trent at the Catton Hall Estate – Hydromorphic Audit and Appraisal

Final Report

August 2012

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Revision History

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Draft Report v2.0	Breach analysis detail Further detail added to conclusion	Julie Wozniczka
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Contract

This report describes work commissioned by the Staffordshire Wildlife Trust, by email dated 13 February 2012. The Staffordshire Wildlife Trust's representative for the contract was Julie Wozniczka. Seb Bentley, Matthew Hemsworth and George Heritage of JBA Consulting carried out this work.

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Purpose

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Executive Summary

This report describes the hydromorphic audit results, options appraisal and hydraulic modelling undertaken to determine the most suitable option for the restoration works along a section of the River Trent at Catton Hall Estate. The principle aims of the study are driven by Water Framework Directive Measures, seeking opportunities to improve the hydromorphological and ecological status of this reach.

The River Trent local to the study reach is designated as a Heavily Modified Waterbody. At present, the Water Framework Directive (WFD) defines the overall river status as Poor Potential, but with a target of reaching Good Ecological Potential by 2027. An opportunity exists to improve the morphological and ecological status/potential by restoring the reach of the Trent at Catton Hall.

Several restoration activities have been identified including planting of the riparian margin, stone pitching (rip rap) removal from bank toe, chute channel restoration and embankment removal. Chute channel restoration will make way for increased diversity whilst decreasing outer bank erosive pressures in a number of locations. The removal of and regrading of river banks will also reduce some erosive pressures and will allow the channel to reconnect with its floodplain and the introduction of island features in shallower areas (based on upstream analogues) will also be of benefit. Further measures such as the introduction of large woody debris will give rise to increased channel ecological diversity.

Hydraulic modelling was undertaken in Hec-Ras and ISIS to simulate the existing and proposed flow regimes. Velocities, sheer stresses and water levels were compared to ensure channel stability is maintained and flood risk is not increased.

The proposed options will increase hydromorphic diversity along the reach and will create new habitats and dramatically improve the connectivity between the river and its floodplain. The proposed river reach will also create a more diverse, albeit low energy, set of hydraulic habitats.

In the longer term other schemes could be introduced in the reaches up and downstream of the Catton Hall reach, potentially using similar methods and options (following further investigation and analysis) to those identified in this study.

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Abbreviations

ISIS	Hydrology and hydraulic modelling software
JBA	JBA Consulting
PPS25	Planning Policy Statement 25
QMED	Median Annual Flood (with return period 2 years)
Q95	Flow exceeded 95% of the time
WFD	Water Framework Directive

1 Introduction and Background

1.1 Background to the study

JBA Consulting were commissioned by the Staffordshire Wildlife Trust in February 2012 to undertake a geomorphological audit and options appraisal for the proposed restoration of a section of the River Trent at Catton Hall Estate. The principle aims of the study are driven by Water Framework Directive Measures, seeking opportunities to improve the hydromorphological and ecological status of this reach. This report describes the hydromorphic audit results, options appraisal and limited hydraulic modelling undertaken to determine the most suitable option for the restoration works.

The River Trent local to the study reach is designated as a Heavily Modified Waterbody. At present, the Water Framework Directive (WFD) defines the overall river status as Poor Potential, but with a target of reaching Good Ecological Potential by 2027. An opportunity exists to improve the morphological and ecological status/potential by restoring the reach of the Trent at Catton Hall.

Restoration needs to be mindful of impacts locally, and upstream and downstream of Catton Estate. In particular, the risk of breaching the left bank (facing downstream) into the gravel pit lakes owned by Hansons needs to be assessed alongside the restoration proposals.

This report details the current hydromorphic state of the River Trent at Catton Estate and audits the character of the channel, allowing prediction to be made concerning channel response and hydromorphic change following potential restoration options appraised in this report.

1.2 Approach

A desk and field based hydromorphological audit of the Trent was conducted on 9 March 2012, investigating the restoration proposals supplied by Staffordshire Wildlife Trust, the Environment Agency and Hansons. These proposals have consequently been built on following the audit. The audit places the character and dynamics of the river in the historic context of channel engineering and management. It considers the response to and consequences of a series of options linked to the restoration measures, ranking these in terms of their overall environmental and morphological acceptability.

The report also comments on the upstream and downstream flood risk aspects linked to the preferred restoration through associated hydraulic modelling.

1.3 Current catchment and channel condition

The River Trent is a sinuous alluvial single thread channel which is displaying a long-term general planform stability. This stability is in part due to boulder riprap defence protecting the bank toe along long reaches of the channel around Catton. Localised erosion is occurring, most notably on the outer bank of channel bends and also at the upstream limits of disrupted riprap toe protection.

The river has been subject to dredging creating an over-deep channel and reducing natural floodplain connectivity. Channel rerouting has also occurred moving the river east across the floodplain. The sinuous palaeo-channel has subsequently been destroyed by extensive floodplain gravel extraction, creating several lakes close to the left bank. Extraction has also generally reduced floodplain levels on the left bank. A smaller bifurcation existed at Cherry Holme opposite Catton Hall and the palaeo-channel is still present on the floodplain.

Over-deepening has removed considerable volumes of coarse river sediment from the channel leaving an unnatural gravel starved bed along considerable reaches. The over-deepening has led to bank instability with extensive rotational slipping noted on both banks along sinuous and straight reaches. Often these are stabilised as a stepped bank profile due to the riprap toe protection. Removal of the riprap would lead to vertical bank development along outer bends whilst the banks along straight reaches will be modified at a slower rate, retaining their stepped profile.

Excavated sediment from dredging has been used to raise the floodplain locally, either as adjacent narrow banks (particularly along the left bank) or as wider deposits across the right bank floodplain. In both cases this has exacerbated the disconnection between river and floodplain along the river.

Recent historic and contemporary depositional processes have created bar units that are far better connected with contemporary flows. These display a diverse hydromorphology and effectively help to accommodate flood flows, reducing fluvial stresses on outer bank areas where they are present as significant units. These morphologies offer excellent analogues for sustainable morphological restoration along the reach.

In-channel islands are also developing along the River Trent and are present along the restoration reach where they have formed along shallow plane-bed sections of channel. These features encourage flow bifurcation and create higher energy hydraulic habitats. They also display a varied sedimentology with finer deposits seen along their downstream edge.

Local coarse sediment sources are comparatively rare along the reach. This is most likely a result of the historic rerouting of the river through ancient fine overbank floodplain sediments which have not been reworked by the river and so are devoid of gravels. As such the gravel content of the reach is unnaturally low as a result of dredging. However, the channel cuts through one palaeo-channel upstream of Catton Hall and this source has created a natural gravel-bed reach in the reach downstream. This gravel supply must not be discontinued.

The study reach is shown below in Figure 1-1.

Figure 1-1: Trent at Catton Estate - Study Reach

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The Croxall Lakes geomorphological audit undertaken by JBA Consulting in 2009 (Appendix A) provides a summary of the catchment wide processes operating local to the Catton Estate. This should be used as background information to provide reasoning for the restoration measures proposed for the Catton Estate reach. Of particular note from this report is:

- *The Upper Trent and middle Tame have a propensity to alter their form and behaviour in response to climate and anthropogenic influences, switching from single thread, through braided and anastomosing channel types since the end of the last ice age (12ka BP). In particular gravel shoaling and island development have been significant in the historic past. However, at present the river exhibits a stable sinuous single-thread channel with limited gravel shoaling, indicating limited active gravel movement. It is also heavily protected against bank erosion preventing lateral migration, floodplain gravel reworking and inputs of coarse material into the river.*

  The river is currently supply limited and has over-deepened in response to an inability to migrate laterally creating a rather monotonous morphologically uniform channel.

  At Catton Estate there is a significant stabilised island located at the upstream extent of the study reach, which has remained at a similar size for the past 10 years (Figure 1-2), although there is evidence of some lateral erosion and widening. This provides a useful analogue feature for downstream island introduction. From Catton Hall Estate to the downstream extent of the study reach, the banks of the river are protected by stone pitching (Figure 1-3) along numerous sections (particularly the left bank to protect the narrow buffer strip of land between the river and Hansons lakes). This has prevented any significant lateral migration, however, where this has failed just downstream of Catton Hall along the left bank, outer bank erosion is significant (Figure 1-4 and Figure 1-5).

Figure 1-2: Trent aerial view of stabilised island (Copyright Google Earth 2012, Infoterra & Bluesky 2012)

2010

2000

Figure 1-3: Stone pitching providing bank protection

Figure 1-4: Bank erosion where stone pitching has failed

Figure 1-5: Trent aerial view of local bank erosion (Copyright Google Earth 2012, Infoterra & Bluesky 2012)

- *The river is presently supply limited as regards coarse sediment with low level headwater inputs and only minor floodplain inputs due to bank training and embankments. Fine sediment inputs are diffuse but significant. As such the development of gravel bars and islands will initially be through the reworking of local exposed gravels only slowly supplemented by upstream inputs.*

  Cessation of regular dredging of the channel at Catton Estate has led to channel bed recovery in some locations where gravels are accumulating to form riffles. One such location is at Catton Hall where a significant local source of gravel (approximately 1.5m deep along 200m of bank) along the right bank has been reworked at higher flows to supply the riffle development just downstream (Figure 1-6, Figure 1-7 and Figure 1-8).

Figure 1-6: Trent aerial view - right bank gravel source (Copyright Google Earth 2012, Infoterra & Bluesky 2012)

Figure 1-7: Local right bank gravel source

Figure 1-8: Riffle development

- *Analysis of web based imagery of the River Trent reveals widespread palaeo-channel preservation across the floodplain indicating considerable pre-historic movement of the river with channels in various states of preservation suggesting that lateral movement was once common across the floodplain before engineering works effectively constrained the river to its present course.*

  Adjacent to the Catton Hall building, over the left bank (labelled Cherry Holme on OS Mapping) there is a paleo-channel where the Trent once bifurcated, as shown below in Figure 1-9. Old maps indicate this channel was abandoned between 1955-1964, it is unclear whether this was through artificial inference (such as dredging) or through natural infilling of the left bank.

Figure 1-9: Paleo-channel adjacent to Catton Hall (Copyright Google Earth 2012, Infoterra & Bluesky 2012)

  Just downstream of Catton Hall, the historic route of the Trent meandered across the left bank floodplain where Hansons lakes are now located.

- *Connectivity with the floodplain has been lowered through channel dredging and flood embanking disrupting the hydrological regime and affecting the geomorphological and ecological dynamics of floodplain paleo - channels.*

  Throughout the Catton study reach flood embankments and dredged material deposited on the banks has reduced connectivity to the floodplain considerably. Particularly over the left bank where the embankment is 1-2m high in some locations. Therefore, bankfull shear stresses are higher, reducing the tendency for gravel deposition throughout the reach during elevated flows. There could be opportunities to reduce these embankment levels as part of the restoration proposals, to reconnect the floodplain and encourage deposition of material in transport.

Figure 1-10: Raised bank level through deposited dredged material

2 Hydromorphic Audit

2.1 Historic channel behaviour and response to restoration

Contemporary channel behaviour is relatively inactive with no gross instability (despite local pockets of erosion as witnessed through the Catton reach). This is mainly a result of bank training (stone pitching) and reduced connectivity with the floodplain.

Channel bifurcation and splitting is evident, despite this reducing since the 13th century (but mainly in the 20th century), as seen locally at Catton Hall and further upstream along the Tame and Trent.

Local areas of bank erosion along the Catton reach are not extreme but the left bank erosion close to the Hansons lakes does present a risk of breaching if left unmanaged. The other identified 'risk' area, the outer bend erosion at the Catton Hall building, does not currently pose a risk to the building itself.

At the island within the study reach, there is a lateral response to the feature with associated channel widening that has increased the channel width by approximately 50%. Therefore, introduction of these features through the Catton reach will initiate some channel widening, however, as discussed further in section 3, this could be managed through associated tree planting to provide a buffer to widespread lateral migration. This is demonstrated below in Figure 2-1 and Figure 2-2, with indicative dimensions which have been utilised in the indicative geomorphological modelling discussed in section 3. This data is used to predict the channel response if these features were installed based on the aspirational plan in Appendix A.

Figure 2-1: Island analogue information (Copyright Google Earth 2012, Infoterra & Bluesky 2012)

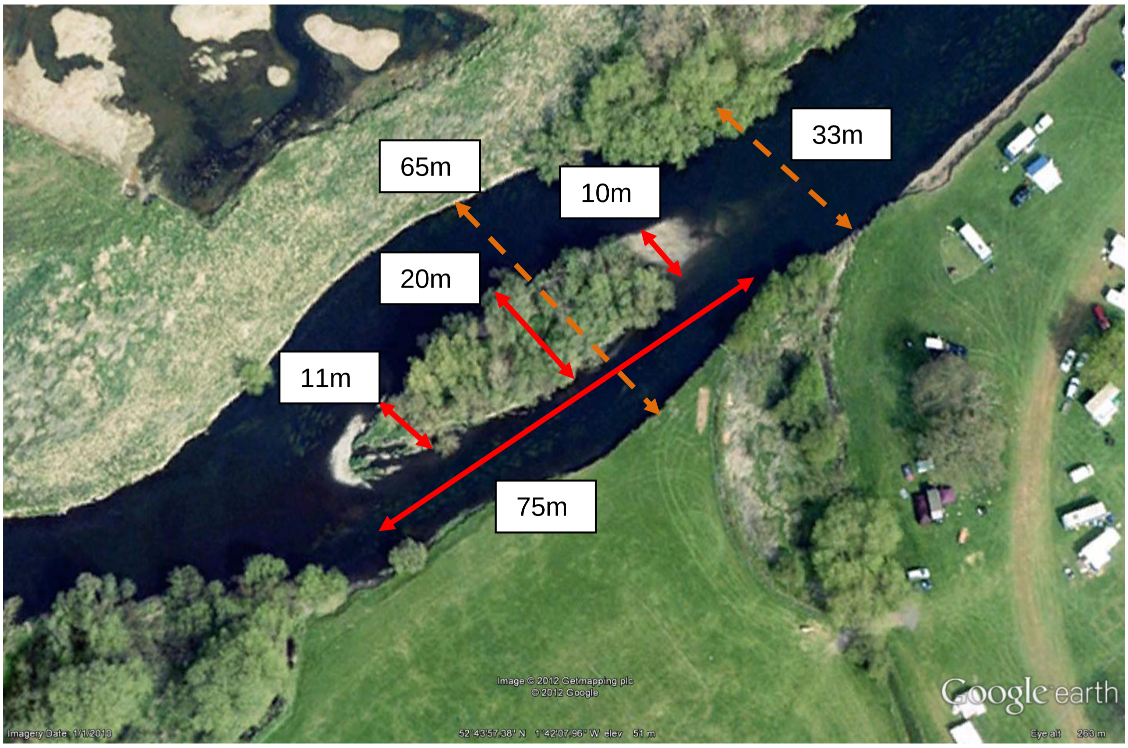


Figure 2-2: Island morphological feature

Morphological Feature Type	Sediment /Flow/ Vegetation Types	Feature Approximate Dimensions
Island	Generally composed of gravels, infilled with fine sediment Riffle entrance on both channels. Erosion on outer banks Stabilised through mature vegetation growth	Length ~75m Width - max ~20m Depth ~0.5-1.0m above low flow water level

The identified analogue point bar feature shown in Appendix A shows the hydromorphological and habitat diversity that could be created through reconnecting the point bar features throughout the study reach. These will also reduce bank erosion pressures identified along the study reach, in particular at the identified key point just downstream of Catton Hall on the left bank. This feature is demonstrated below in Figure 2-3. The lower level point bar is inundated frequently due to better connection with the channel, and there are local swales that have been scoured within the feature as a result.

Figure 2-3: Point bar analogue information

Morphological Feature Type	Sediment /Flow/ Vegetation Types	Feature Approximate Dimensions
Point bar	Gravels infilled with fine sediment deposits Well wooded, mature vegetation that is frequently wetted Flow diversity at times of higher flow would include marginal deadwaters, standing water when flow recedes, chute channels.	Length ~ 150m Width ~ 50m Depth ~ level of point bar set at approx 0.5-1.0m above low flow water level

There is a natural berm development at Ryelands Nook that is approximately 0.75m above the low flow water level (Figure 2-4). This should be used as an analogue to indicate the functional level at which proposed lateral berms, islands and point bars should be introduced at.

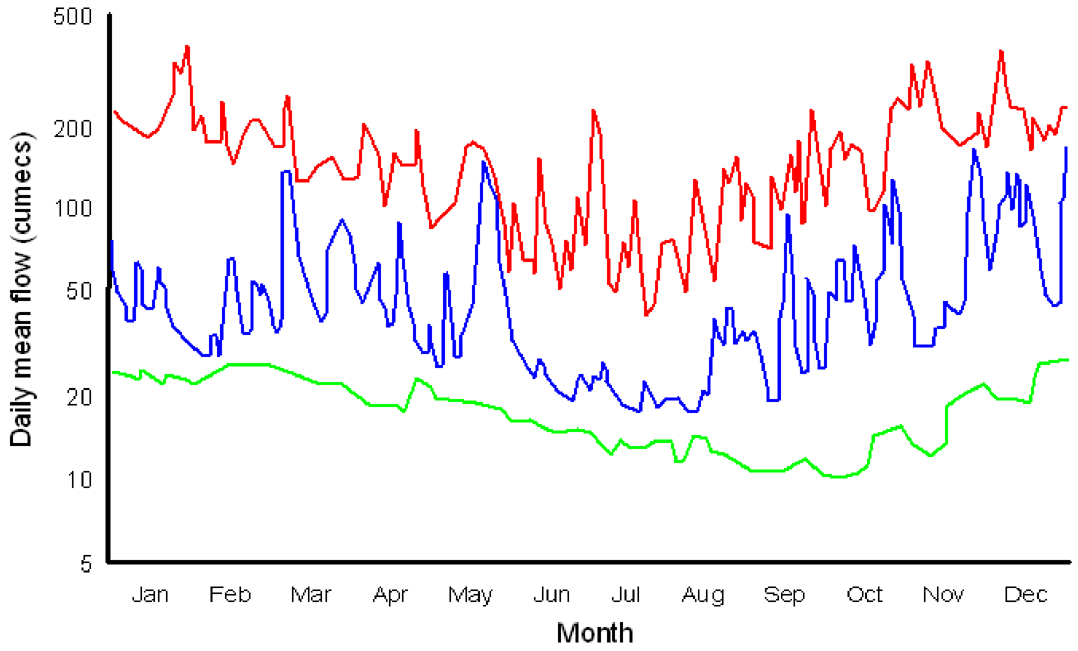
Figure 2-4: Natural berm analogue at Ryelands Nook

2.2 Hydrological characteristics

Upstream of the Trent-Tame confluence the system is quite complex, with the upper Trent and Sow systems draining some relatively steep narrow valleys but what is most common is wider lower gradient floodplain areas of relatively impermeable loamy soils. The wide valley of the River Tame is dominated by an impermeable mudstone-floodplain alluvium sequence and loamy soils, resulting in a relatively low gradient river system. The lower gradient reaches of the Trent and Tame are relatively impermeable and respond quite quickly to precipitation (the flood response time of the River Tame is approximately 11 hours). Aside from Blithfield reservoir and the Tame balancing areas (Sandwell), there are no significant flow storage areas and urbanisation in the Tame catchment in particular further reduces flood response time. Low flows in the Tame are strongly influenced by effluent inputs and show a diurnal fluctuation in discharge. As a result of these influences the flow at the confluence of the Trent and Tame (Figure 2-5) is characterised by variable low flows (20-40m^3s^{-1}) interspersed by flood flows that rapidly rise to peaks approaching 500m^3s^{-1} (greater than would be expected for an unmodified catchment).

Flows used for the purposes of geomorphological modelling undertaken in section 3 were; summer base flows (Q95) of 15.13m^3s^{-1} and estimated bankfull flow (QMED) of 180.8m^3s^{-1}. These were taken from the Drakelow Gauge information available on the NRFA website.

Figure 2-5: Mean daily average flows for the River Trent at Shardlow (red -max, blue -mean, green -minimum).



The following section details the aspirational restoration plan for the River Trent at Catton, which has been indicatively tested in the hydraulic model to predict likely channel response (linked to impacts on velocities and shear stresses), to propose mitigation measures where necessary and to assess the associated impacts on flood risk at a high level.

3 Restoration Options Appraisal

Following the fluvial audit undertaken by JBA and collation of restoration options for the Catton reach provided by Staffs Wildlife Trust, the Environment Agency and Hansons, an aspirational restoration plan has been developed for the study reach, shown in Appendix A.

The proposed restoration scheme works with current river processes to provide a channel form that balances the requirements of improving hydromorphological and ecological diversity, whilst managing the risks associated to breaching of the left bank that could affect Hanson's lakes and reducing the impacts on flood risk locally, upstream and downstream.

Whilst there are clearly existing local bank erosion issues that could result in breaching of the left bank (facing downstream), historical evidence suggests there is no widespread, gross lateral instability. This may be in response to river training (through stone pitchings along the bank toe), therefore removing this may encourage more lateral migration. However, the risk of a left bank breach into the lakes could be managed through associated river bank planting, to provide a buffer against significant lateral migration. This is discussed further in section 3.1.

The essential restoration activities identified and discussed further in the following sections are:

- Planting of the riparian margin (bankside planting with woody species) - this is discussed in the following sections, identifying key areas where this should be undertaken. Of particular importance is the strip of embankment between the gravel lakes and the main river, which will considerably enhance the overall stability of the channel banks, preventing the possibility of lake breaching in the near future. It is recommended that species such as Willow, Ash and Alder are used.
- Stone pitching (rip rap) removal from bank toe - bank toe protection should be removed wherever possible to encourage natural bankside processes. This lateral erosion risk after removal will be managed through bankside planting discussed above.
- Chute channel restoration - optimised locations for these are discussed in the following sections. This will improve hydromorphic diversity across meanders, as well as reduce erosion pressure on the outer banks of meanders.
- Embankment removal - these extend for long stretches throughout the study reach and floodplain connectivity can be dramatically improved through removing these banks or setting them back. Locations for this have been suggested in the following sections. It could also reduce erosion pressures at key points along the study reach by reducing the bankfull flow level and associated forces. Bed recovery could be improved as a result. This will also improve any downstream flood risk increases as a result of the proposed works.

It should be noted that the following constraints were identified during the audit:

- Presence of badger sets.
- Sand Martin nests in the channel banks.
- Areas of Japanese Knotweed.
- Areas of Himalayan Balsam.

Application for licenses to eradicate/move badger sets can take months to obtain and the process for eliminating Japanese Knotweed requires spraying months before groundwork can be started. Therefore, consideration should be given to these issues now if groundworks are likely to go ahead in the latter part of 2012.

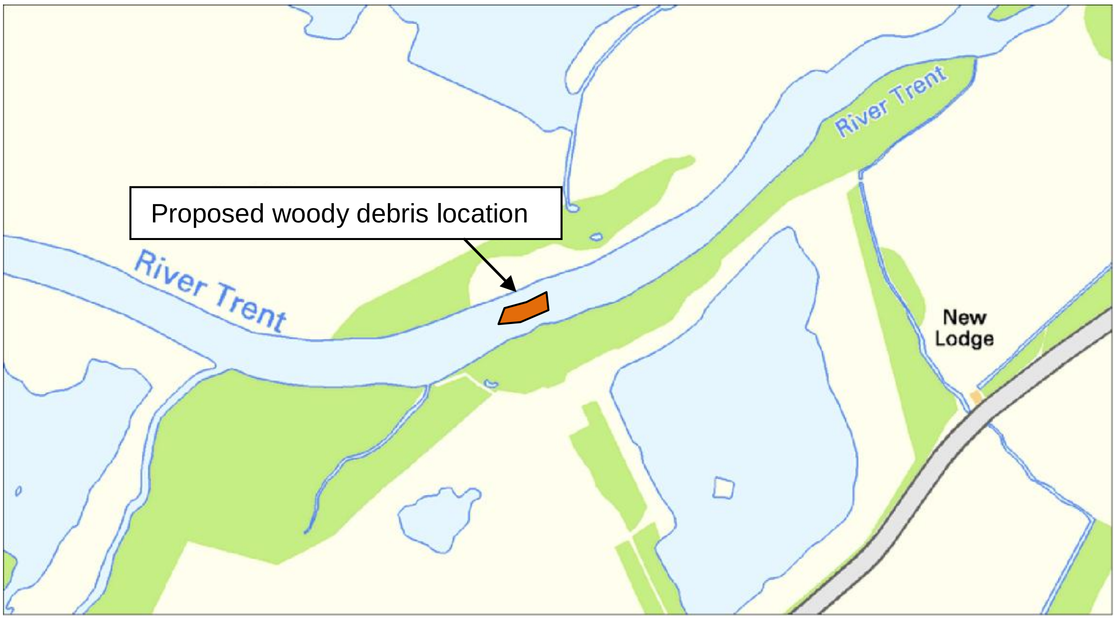
3.1 Aspirational restoration plan overview

3.1.1 Upstream woody debris introduction

The proposal here is to introduce large woody debris upstream of the island (Figure 3-2). Initial ideas involve importing two large poplars (1.5 times the channel width) that are to be placed into the Trent with roots facing upstream. Whilst this is feasible, there is opportunity to utilise local sources (Figure 3-1), potentially by felling bankside mature trees, leaving the trunks attached to the bank. This would create marginal habitat diversity. It is envisaged that limited channel response will be introduced as a result of this intervention.

Figure 3-1: Local mature trees that could be utilised for woody debris introduction

Figure 3-2: Woody debris introduction upstream



3.1.2 Selective left bank lowering or setting back embankment

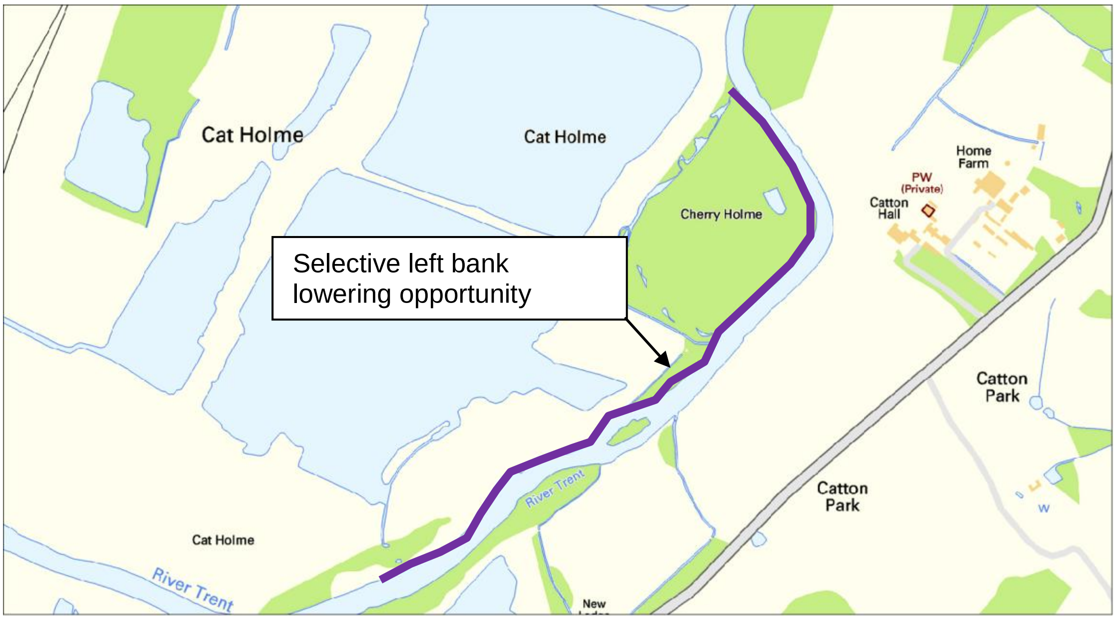
On the left bank (facing downstream) from the location of woody debris introduction to the downstream extent of Cherry Holme, there is an opportunity to reduce the height of the embankment created through dredging material that has been dumped (Figure 3-3 and Figure

3-4). If this is not feasible, then setting back the embankments from the bank edge should be considered (without destabilising existing oak trees), which would retain flood protection levels to the gravel lakes but also open up some of the floodplain. This would have numerous benefits including:

- Reconnecting the river to the floodplain;
- Reduced bed and bank erosive pressures through lower bankfull flows, especially on the right bank at Catton Hall Estate and the left bank just downstream where bank erosion is currently threatening the embankment between the Trent and Hanson's gravel lakes;
- Encourage in-channel gravel deposition to create a more diverse hydromorphology and habitat availability.

Figure 3-3: Left bank at Cherry Holme, opportunity to lower level and reconnect floodplain

Figure 3-4: Left bank lowering opportunities adjacent to Catton Hall Estate



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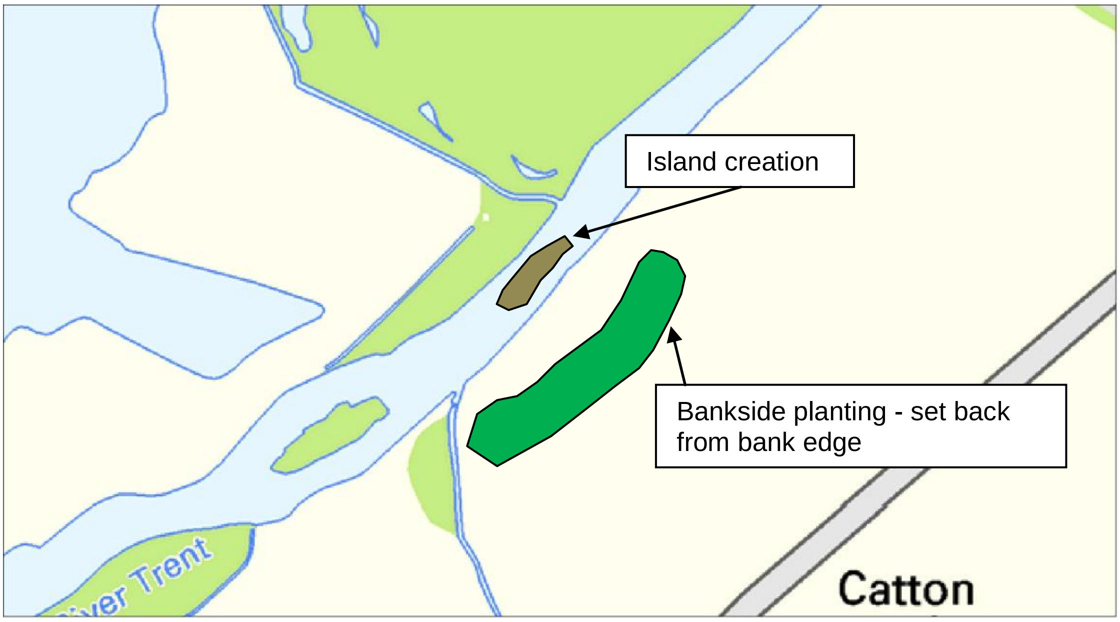
3.1.3 Island introduction - maintain local gravel source

Just downstream of the existing island feature shown in Figure 2-2 is a significant local coarse gravel source (Figure 1-7). It is important to retain this local source given the limited upstream inputs and the recovery of the gravel bed local to the source. The gravels suggest the current channel is running through a paleo-channel and the steep sided banks are enabling entrainment of gravels into the flow regime at higher flows. This process should be encouraged and therefore it is recommended that woody species are not planted close to the bank edge as this would result in bank consolidation and stabilisation (Figure 3-5). Tree planting should be set back further into the floodplain to allow the current bank erosion processes to continue.

The lateral bank erosion could be encouraged further through introduction of an island feature at this point on the plane-bed section (Figure 3-5). The upstream analogue feature discussed in section 2.1 should be referred to for indicative dimensions and likely channel response as a result of introducing this feature type. Floodplain planting could be used to provide a buffer strip where appropriate to prevent any lateral migration that may result in an embankment breach.

Figure 3-5: Island creation and planting at Catton Hall



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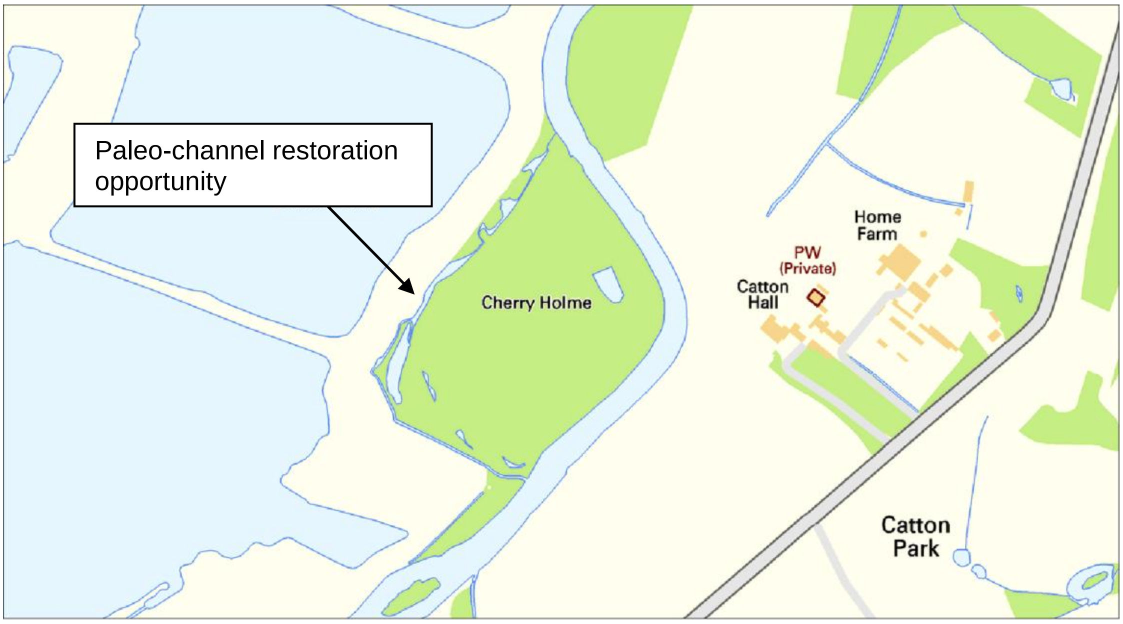
3.1.4 Paleo-channel reconnection

The area labelled Cherry Holme, adjacent to Catton Hall Estate over the right bank, was once an island and OS Maps show the previous route of the paleo-channel, which was abandoned between 1955-1964 (Figure 3-6). There was also a weir structure spanning half of the channel at the entrance to the paleo-channel where it branched off from the current main channel. There is an opportunity here to reconnect this paleo channel through excavation, which will improve the hydromorphic diversity across the meander. It will also relieve some of the erosion pressure on the right bank at Catton Hall Estate.

Figure 3-6: Paleo - channel at Cherry Holme



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3.1.5 Right bank planting at Catton Hall Estate

The right bank here is slumping due to the channel being over-deepened (a legacy of the dredging previously undertaken along this reach). The stone pitching (rip-rap) protecting the toe of the bank is preventing the natural steep sided bank profile being created and instead is maintaining a stepped bank profile (Figure 3-7). It is suggested that regrading of the bank is unnecessary here as this is working against the natural processes of the river at this point. To prevent any potential lateral migration towards the Catton Hall Estate, it is suggested that planting of the bankside with suitable woody species is undertaken (Figure 3-8). This will act to consolidate the banks and provide a buffer to any significant lateral erosion. An alternative to this option is to plant a line of smaller crated trees on the floodplain to maintain the view from the Catton Estate to the river. This would allow some lateral erosion to take place up to the line of trees.

Figure 3-7: Looking upstream at stepped bank profile at Catton Hall Estate

Figure 3-8: Right bank works at Catton Hall Estate

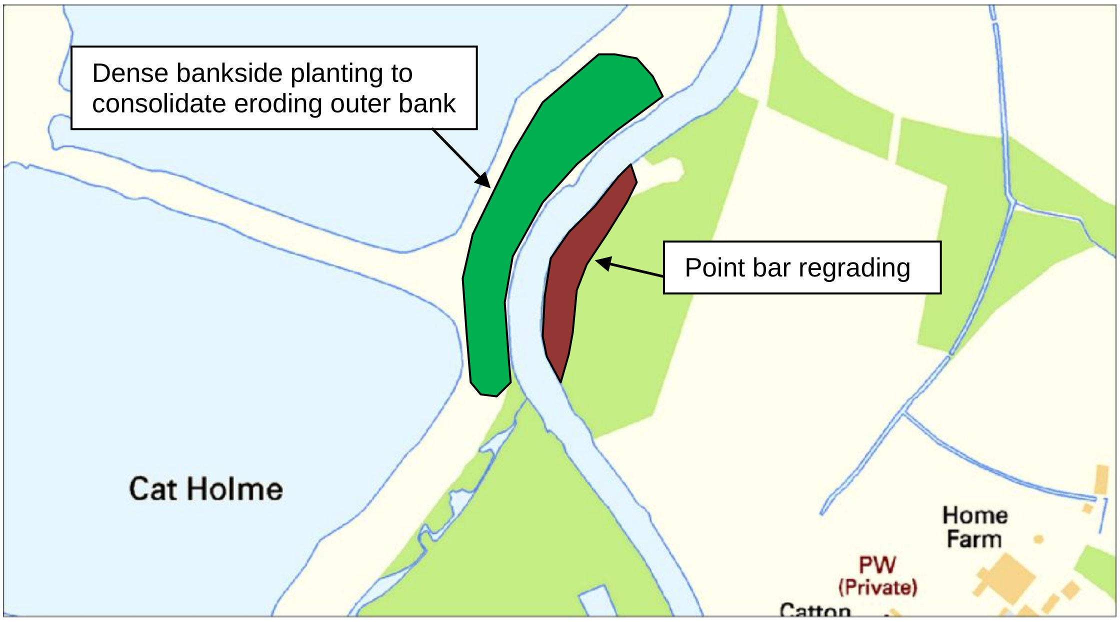
3.1.6 Point bar works at meander downstream of Catton Hall Estate

The preferred option at this location would be to allow the left bank where erosion is currently occurring to continue and to breach into the gravel lake. This could create significant ecological habitat improvements through wetland and backwater creation. The effects of a breach on flood risk have been discussed in section 4.4. The impacts on in-channel dynamics (section 4.3) have not been quantified as part of this study but will act to encourage natural channel and floodplain recovery. To minimise the risk of breaching between lakes it is recommended that banks between lakes are suitably strengthened.

An alternative to this option (if it is deemed breaching of the left bank is not a feasible option) at this meander is to regrade the point bar (Figure 3-9) by stripping around 1m off the ground level back into the forested area (by up to 30m). This would improve the connection with the floodplain at this location as well as reduce the erosion pressure on the right bank. Some micro-morphology could also be created on the point bar in the form of swales, the existing wooded island should be retained on the point bar. This will improve the hydromorphic and ecological diversity across this meander. This should also be undertaken alongside significant left bankside planting, as shown on Hanson's plans and in Figure 3-10 below.

Figure 3-9: Existing point bar where regrading is suggested

Figure 3-10: Point bar regrading location and bankside planting



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3.1.7 Mid-reach works

This section of the reach is experiencing bank slumping in response to the over-deepened channel. Stone pitching (rip rap) is protecting the toe of the left and right banks in numerous locations along this reach (Figure 3-12). There is potential to remove this stone pitching to allow a more natural bank profile to develop, particularly on the outer bank of the meander which currently exhibits a stepped profile rather than a steep faced bank that would normally occur under unprotected conditions. Significant lateral migration could be managed through bankside planting with woody species.

The proposed bank regrading of the right bank, downstream of the meander, should be undertaken as shown in Figure 3-11 and Figure 3-13 below. This would involve regrading the bank past the existing track into the floodplain (dropping immediate bankside levels by 1-2m). Therefore, the track would need to be moved if this is to be undertaken. It is not recommended to regrade the right bank at the outer bank of the meander bend, as this is working against the natural erosion pattern at this location.

The proposed point bar works by Hanson's are considered as suitable and follow similar principles identified for the point bar upstream. Regrading is to be undertaken and micro-morphology created to improve connectivity and reduce erosion pressure on the right bank.

Two islands are proposed along this reach and these have been located based on the channel planform, i.e. on shallower riffles at entrances and exits to meander bends. These could be of a similar configuration to the existing upstream island at Catton Hall Estate. Again some lateral response could be expected through channel widening, but this could be managed through suitable bankside planting to consolidate the banks.

Figure 3-11: Floodplain reconnection and bank regrading

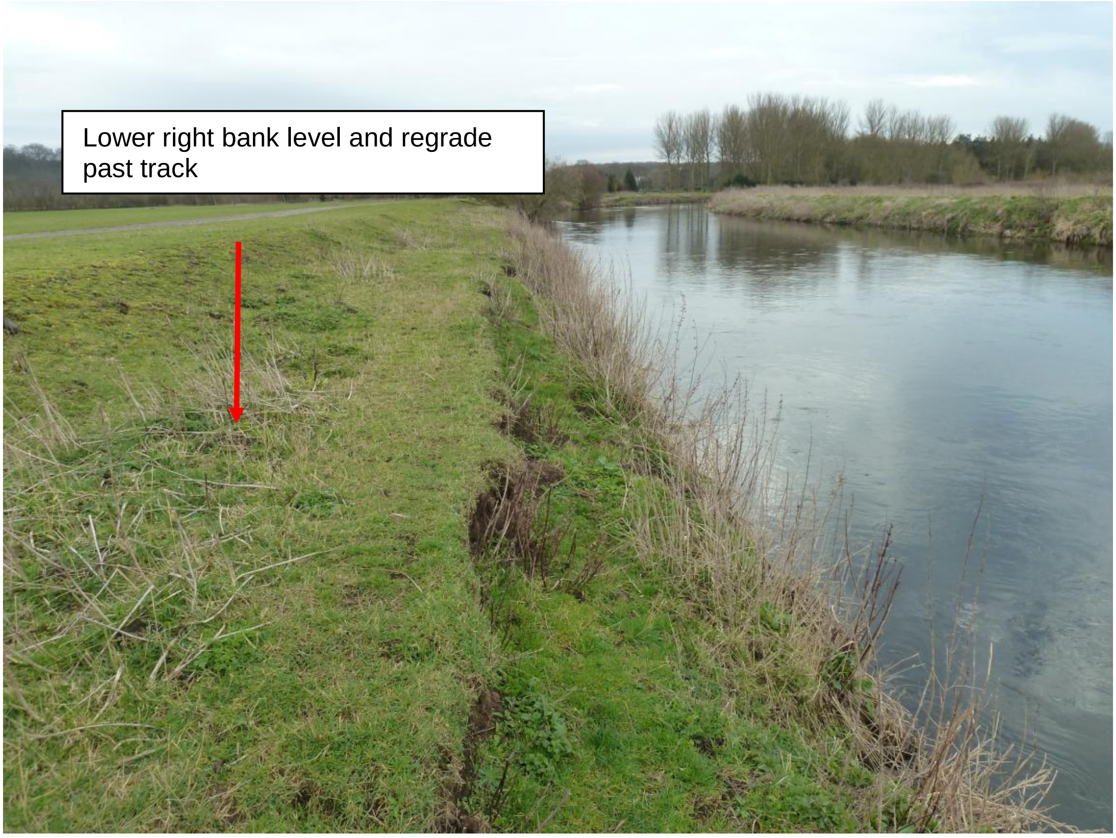
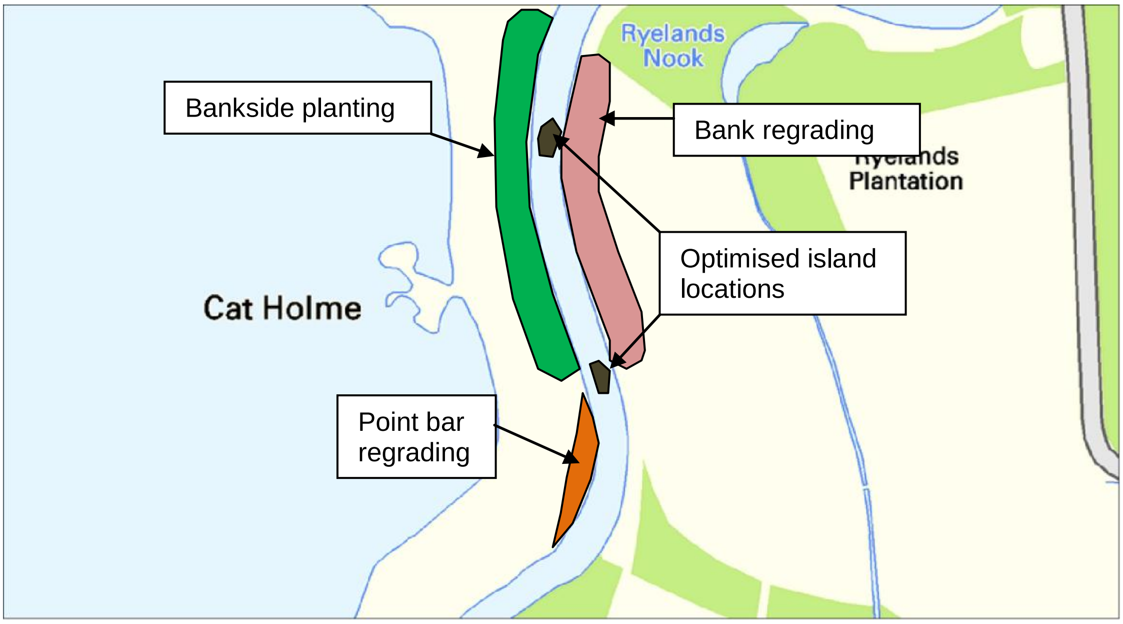


Figure 3-12: Stone pitching that could be removed on both banks

Figure 3-13: Proposed mid reach works



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3.1.8 Ryelands Nook works

The right bank through this section of the Trent has been elevated through previous dumped channel material. The outer (left bank) is subsequently subject to heightened flow forces which presents an erosion risk if stone pitchings (rip rap) are removed. The proposals here are to create a chute channel through the point bar on the right bank at Ryelands Nook to create linear island features which will maintain the local wooded vegetation to provide isalnd stabilisation (Figure 3-14). Some bank regrading works will also be undertaken to reduce the bank levels and improve connectivity to the floodplain. This would require the current access track to Catton Hall Estate to be moved into the Ryelands Nook wooded area, with associated tree removal. A wooded buffer strip would be maintained between the bank edge and the track.

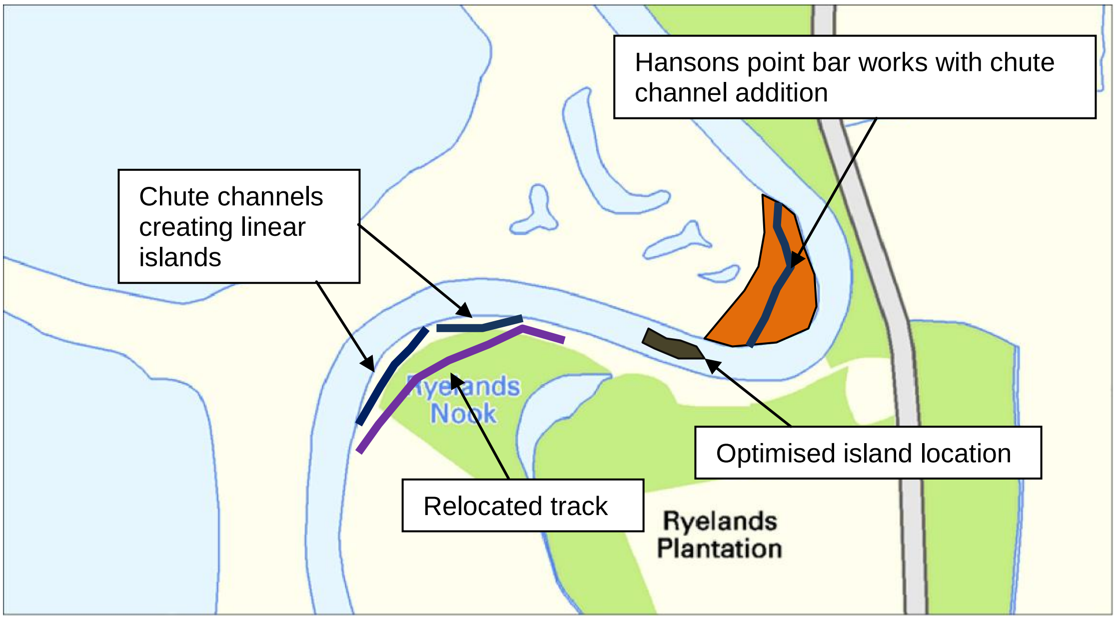
Similar point bar works are proposed by Hansons on the tight meander just downstream of Ryelands Book (Figure 3-15). One suggestion to the proposed works here would be to incorporate a chute channel through the point bar, which is shown on historic OS Maps, and is shown in Appendix A and Figure 3-16. In addition, point bar regrading could be extended beyond the plans shown by Hansons further into the floodplain.

The proposed in-channel island should be located at the entrance to the tight meander, as shown in Figure 3-16 below. This is based on the channel planform and is located in the shallower riffle entrance to the meander bend. A further option at this point would be to re-grade the point bar and let natural erosion take course.

Figure 3-14: Point bar at Ryelands Nook

Figure 3-15: Point bar on tight meander for Hansons proposed works

Figure 3-16: Ryelands Nook proposed works



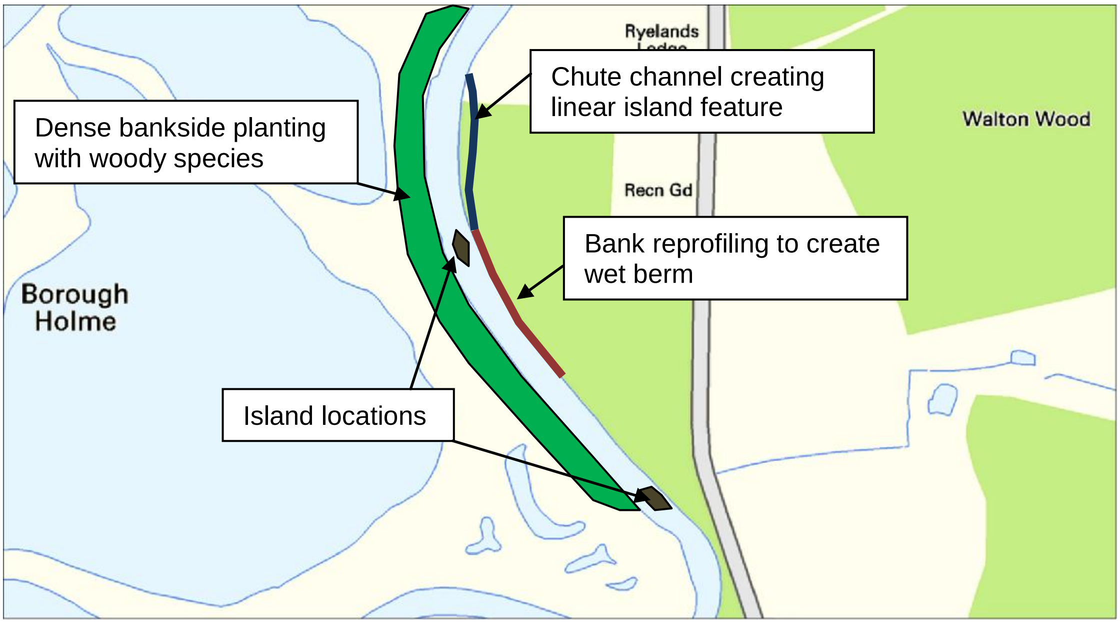
3.1.9 Downstream reach works

This section is a uniform, over-deepened channel with relatively steep banks, protected by stone pitchings in places (Figure 3-17). This should be removed wherever possible with associated bankside planting to manage any lateral erosion risk. At the downstream end of the reach, a small, low level right bank lateral berm has developed, the location of this should be used as the extent (approximately 150m length) for the introduced wet berm area shown in Figure 3-18. This will ensure the introduced morphological features are working with the current river processes. The proposed islands for this section should be located based on the channel planform and in shallower riffle areas, again, to ensure it is working with the current river processes. The optimised locations for these are shown in Figure 3-18.

There is also an opportunity to undertake works on the extended point bar downstream. This would relieve the erosion pressure on the left bank where there is only a thin buffer strip between the main Trent channel and the gravel lakes. The proposed works are regrading of the point bar to improve connectivity and introducing a chute channel similar to that proposed at Ryelands Nook, which would leave a linear island feature (Figure 3-17). It is also recommended that bankside woody species planting is undertaken over the left bank to consolidate the thin embankment between the channel and the gravel lakes.

Figure 3-17: Uniform, over-deepened channel

Figure 3-18: Downstream reach proposed work



Limited geomorphological modelling has been undertaken for some of the higher risk restoration ideas discussed in the previous sections. An assessment of the impacts on flood risk locally, upstream and downstream has also been undertaken in section 4.

4 Hydraulic modelling of aspirational plan

4.1 Description of the baseline model

A 1D segmented hydraulic model (HecRas) was used to model the impacts of the various restoration options proposed for the River Trent through Catton Estate. The model works on a cross-section basis to calculate water surface profiles for steady, gradually varied flow in open channels. Using the segmented flow analysis option a quasi-2D velocity field is generated allowing individual cross-sections to be split into smaller units to estimate local hydraulic parameters.

The model was constructed using sections from the Environment Agency ISIS model for this reach of the River Trent, infilling with additional sections provided by the Staffordshire Wildlife Trust for this project. The original ISIS model represented the left bank through the Catton Estate as a storage area and hence no detail of the narrow floodplain between the channel and the gravel pits was included in the model. This was updated using aerial LIDAR data for the area to allow proposed restoration features on the left bank to be represented in the model. The remaining area of gravel pits was allowed to fill by overtopping.

The configuration of cross-sections, modified to include the left bank floodplain, is shown in Figure 4-1 and Figure 4-2. This model was taken as the baseline conditions for the river and floodplain through the Catton Estate and was reintroduced into the Environment Agency ISIS model for the flood risk simulation work reported below.

The combination of sections allowed each of the proposed channel and floodplain modifications (Appendix A) to be represented in at least 1 cross-section. Sections were modified accordingly as detailed in Table 4-1. These modified sections and roughness parameters then formed the restored model and this was also reintroduced into the Environment Agency ISIS model for the flood risk simulation work reported below.

Figure 4-1 Location of downstream cross sections used in the HecRas model of the River Trent through Catton Estate.

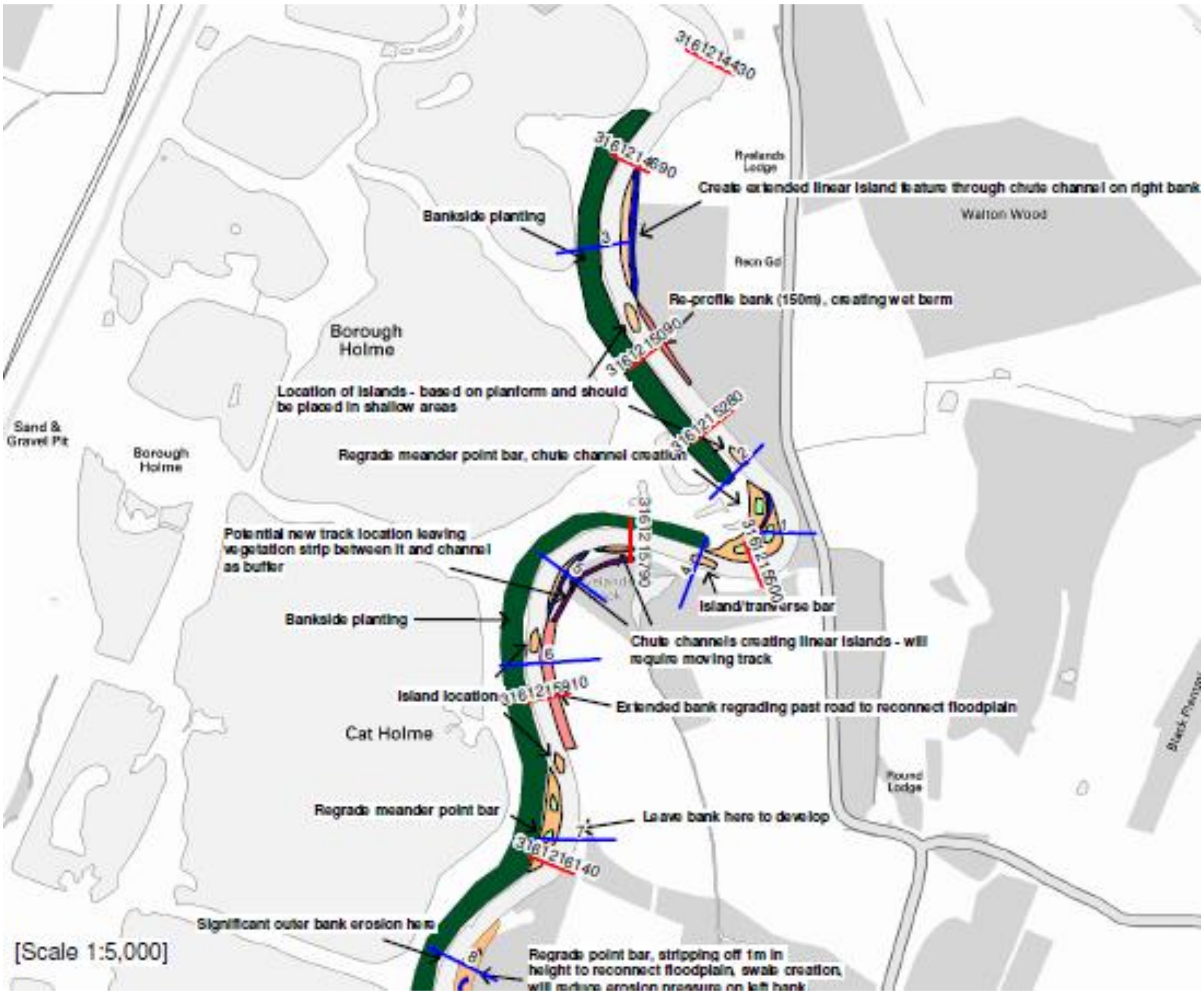


Figure 4-2 Location of upstream cross sections used in the HecRas model of the River Trent through Catton Estate.

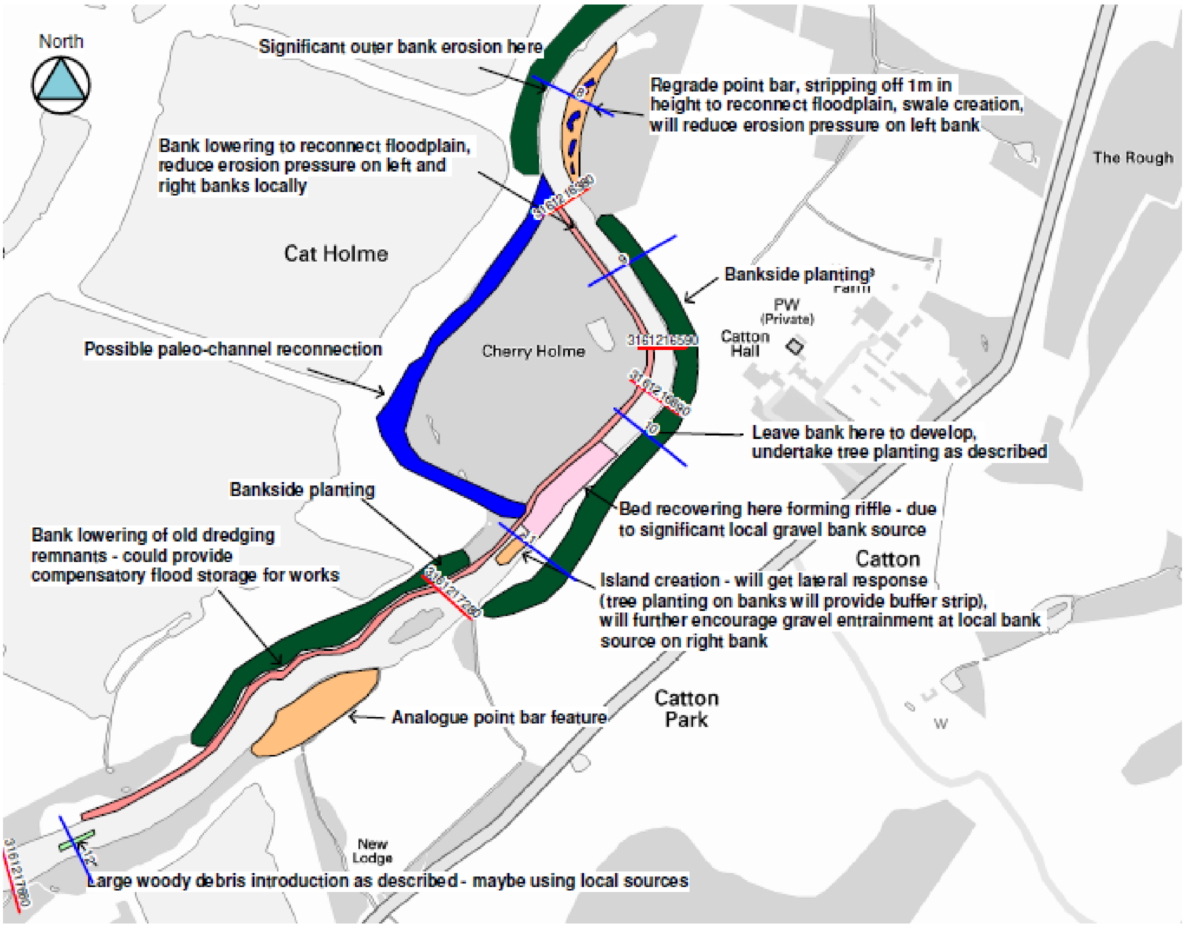


Table 4-1 Details the HecRas cross-sections altered by the restoration options proposed for the River Trent through Catton Estate.

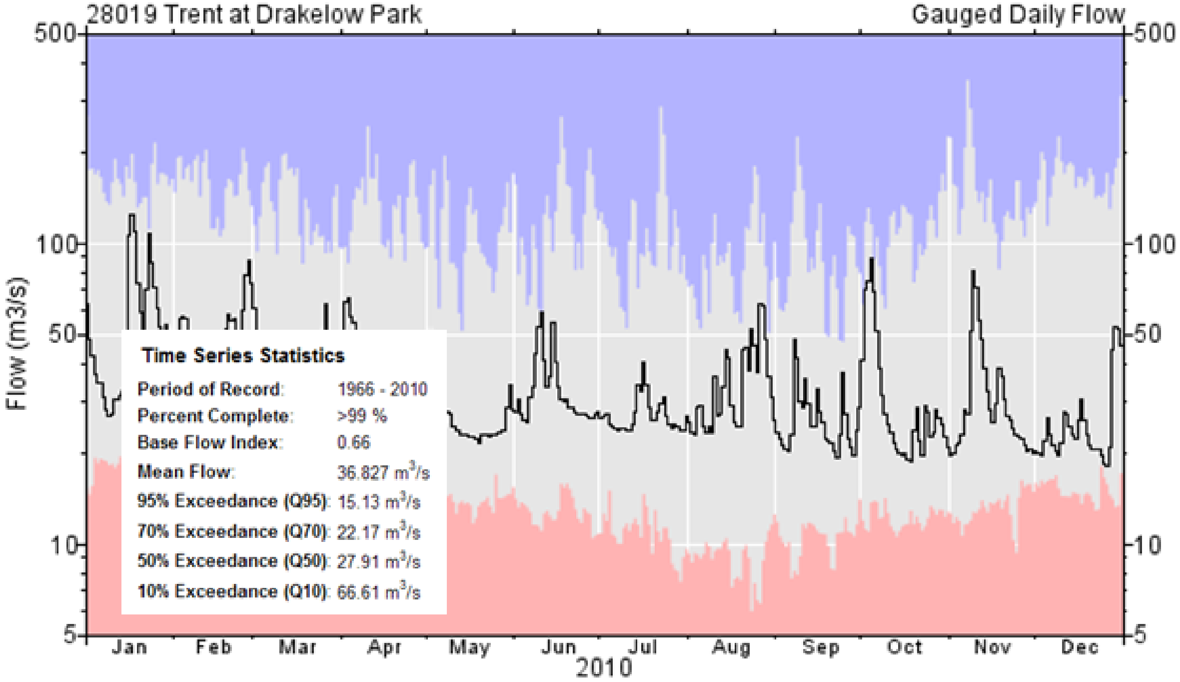
Restoration option	ISIS model cross-section number	Staffordshire Wildlife Trust cross-section number	Alterations to cross-section
Large Woody debris		12	In-channel mannings 'n' raised
Levee lowering	7280, 6890, 6590, 6380	11, 10, 9	Lower left bank levee to general level of the floodplain
Island creation		11	Central island added to level of winter high flow
		6	Central island added to level of existing floodplain
		2	Central island added to level of summer high flow
Palaeo-channel reconnection	6890, 6590	11, 10, 9	Palaeo-channel re connected at winter flow level
Riparian planting	6140, 5910, 5196	8, 7, 6, 5, 4	Left bank mannings 'n' raised
	5280, 5090	2, 3	Left bank mannings 'n' raised
Point-bar creation	6380	8	Right bank floodplain scraping and in-channel gravel reprofiling
	6140	7	Left bank floodplain scraping and in-channel gravel reprofiling
Bank regarding	5190	6	Right bank floodplain scraping
Chute creation	5790	6	Right bank chute excavated to level of winter flow
	4690	3	Right bank chute excavated to level of winter flow
Anastomosing channel creation	5500	1	Multi channel sequence excavated to level of winter flow
Revetment removal			Not represented in the model

4.2 Local hydraulic conditions for the present River Trent through Catton Estate

4.2.1 Simulated flows

The flow regime for the River Trent through the Catton Estate is approximated by the data from the Environment Agency gauge station at Drakelow Park (Figure 4-3). Hydraulic conditions were simulated for the Q95 flow, the Q50 flow the Q10 flow and the QMed flow, 15, 30, 70 and 180 m3/s respectively. Data on flow velocity, shear stress, stream power and Froude number were extracted based on the segmented flow output which split the channel into 21 vertically averaged segments and the left and right floodplain split into a further 11 segments each.

Figure 4-3 Summary hydrology for the River Trent at Drakelaw Park.



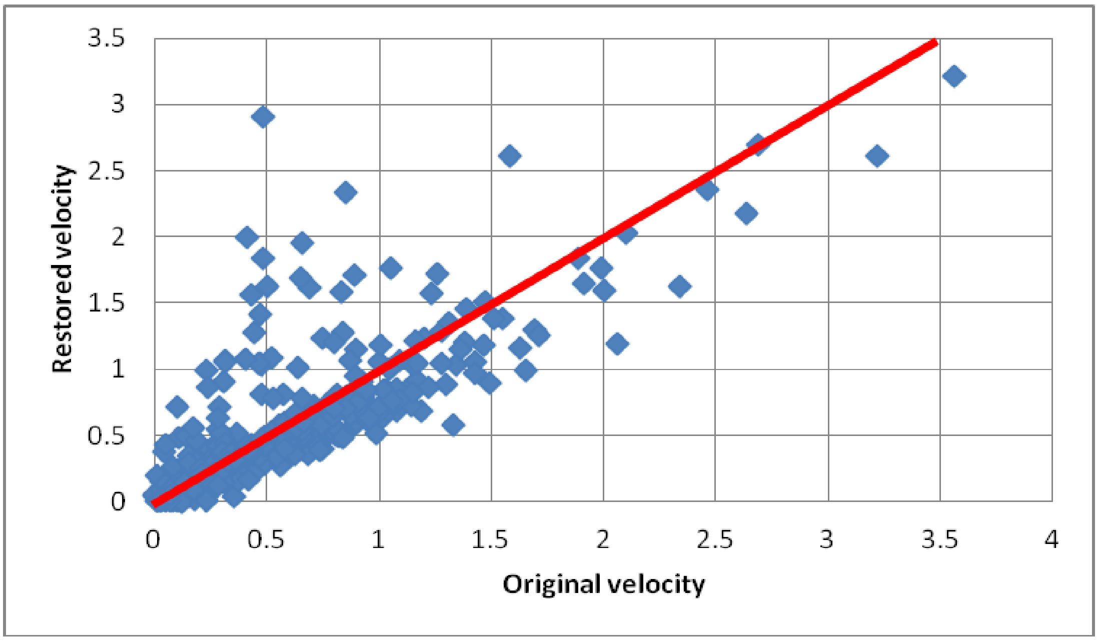
4.2.2 Local hydraulic conditions

Overall velocity change for the Q95, Q50, Q10 and QMed flow along the River Trent through the Catton Estate is summarised in Table Table 4-2. It is clear that the maximum velocities generally decrease following the introduction of the proposed restoration measures. Importantly too, the standard deviation of the velocity measurements increases for all simulated flows. This is a simple measure of velocity variation or diversity and clearly demonstrates that both spatial and temporal flow variability are improved from the generally uniform low energy types seen at present. This improved variation can be seen graphically in Figure 4-4 where the scatter in the data represents the variation introduced to the velocity in the restored channel.

Table 4-2 Velocity characteristics for the River Trent through Catton Estate.

		Original Velocity	Restored Velocity	% change
Q95	MAX	0.80	0.77	-3.64
	MEAN	0.53	0.48	-8.96
	MIN	0.13	0.12	-10.38
	STD DEV	0.19	0.22	16.59
Q50	MAX	1.09	0.95	-13.60
	MEAN	0.77	0.64	-17.00
	MIN	0.17	0.20	19.96
	STD DEV	0.23	0.24	6.96
Q10	MAX	1.26	1.07	-15.22
	MEAN	0.79	0.63	-19.78
	MIN	0.15	0.10	-33.25
	STD DEV	0.29	0.32	9.09
QMed	MAX	0.89	1.34	50.62
	MEAN	0.59	0.72	21.46
	MIN	0.09	0.11	15.79
	STD DEV	0.40	0.39	-2.05

Figure 4-4 Alterations to local velocity predictions following restoration on the River Trent at Catton.

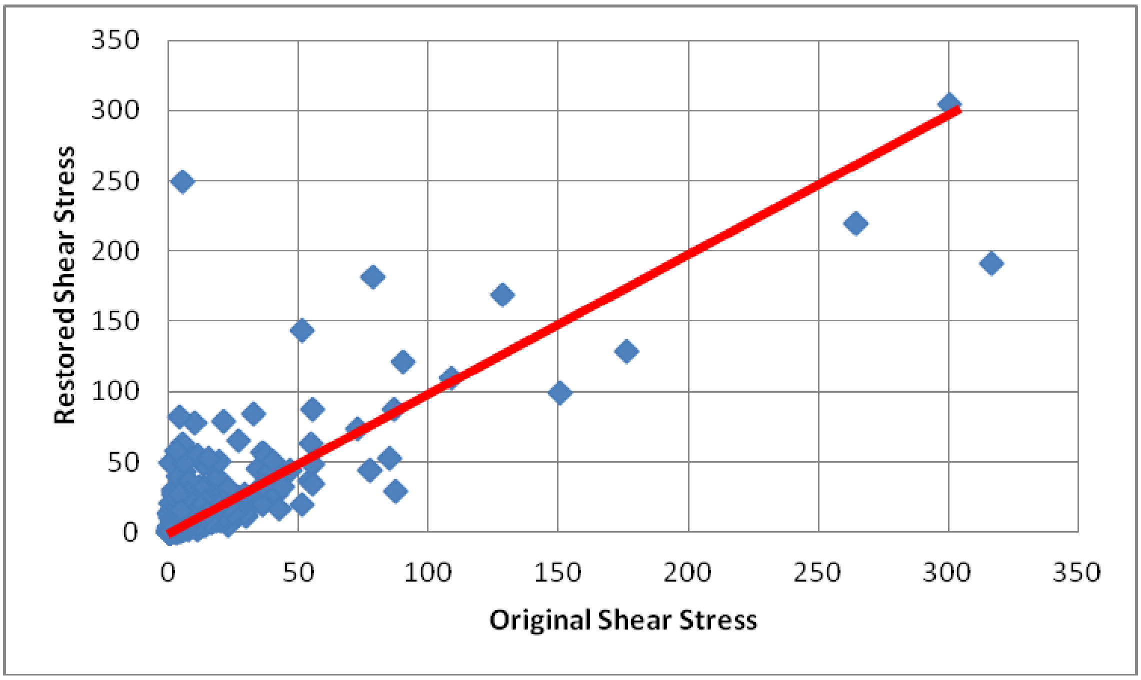


Local shear stress change for the Q95, Q50, Q10 and QMed flow along the River Trent through the Catton Estate is summarised in Table 4-3. There is some variability in the impact of the restoration measures across the flows suggesting that increased velocities are associated with new shallow flow areas. This combination results in shear stresses that are generally incapable of initiating sediment motion (Figure 4-5). Episodic bed material movement will occur with movement of material up to around 70 mm at the QMed flow, reducing to around 40 mm during a high winter event. The coarse sediment in the channel bed is in the fine-gravel – coarse-gravel range generally with significant quantities of finer sands and silts infilling the void spaces. The predicted shear stresses would not significantly alter this sediment mix. The increased channel area created by the restoration would, however, improve the availability of new hydromorphic environments over the present situation.

Table 4-3 Shear stress characteristics for the River Trent through Catton Estate.

		Original Shear	Restored Shear	% change
Q95	MAX	23.06	27.17	17.85
	MEAN	11.31	13.01	14.97
	MIN	1.46	1.60	9.85
	STD DEV	6.20	8.53	37.51
Q50	MAX	30.59	24.98	-18.32
	MEAN	17.67	14.33	-18.89
	MIN	2.68	3.26	21.47
	STD DEV	6.85	7.26	5.96
Q10	MAX	29.83	29.44	-1.31
	MEAN	16.02	13.89	-13.29
	MIN	1.13	0.85	-25.17
	STD DEV	7.30	10.02	37.26
QMed	MAX	24.36	45.89	88.35
	MEAN	15.46	20.40	31.93
	MIN	0.88	1.08	23.06
	STD DEV	12.82	14.54	13.46

Figure 4-5 Alterations to local shear stress predictions following restoration on the River Trent at Catton.



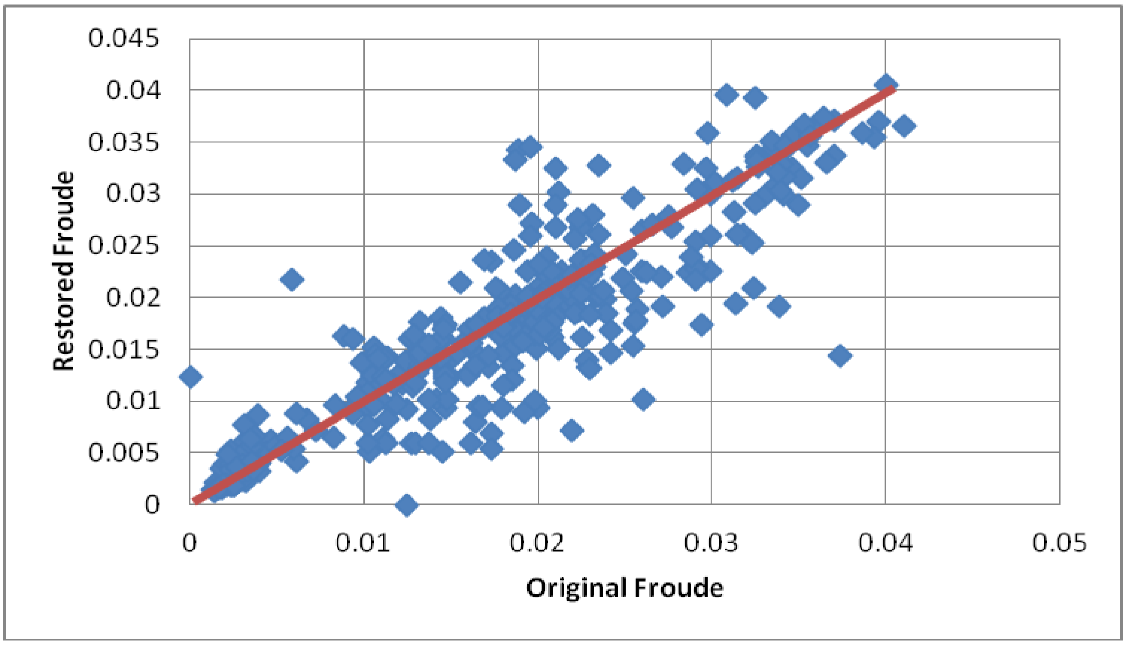
A useful measure of the change to overall hydraulic habitat can be gained from the calculation 'f' the Froude number for the reach. This parameter has been directly linked to flow type (riffles, runs, glides, cascades etc.) and increasing Froude number suggests higher energy flow types and increased Froude number variability suggests an improved hydromorphology over the generally uniform glide flow that exists at present. Froude number summary statistics for the Q95, Q50, Q10 and QMed flow along the River Trent through the Catton Estate are summarised in Table 4-4.

It is clear that Froude number levels remain generally low through the restored reach. This is not surprising as the overall energy slope on the channel remains unchanged. New high energy habitats will not be created through the restoration, however, significant new seasonally flowing habitat will be created becoming backwater areas at lower flows (hence the overall reduction in Froude values in Table 4-4). What is clear from Figure 4-6 is that Froude number variability increases significantly at higher flows suggesting an overall improvement in hydraulic habitat diversity at the local scale.

Table 4-4 Froude number characteristics for the River Trent through Catton Estate.

		Original Froude	Restored Froude	% change
Q95	MAX	0.024	0.022	-5.07
	MEAN	0.021	0.020	-6.91
	MIN	0.014	0.013	-3.05
	STD DEV	0.003	0.003	-3.82
Q50	MAX	0.025	0.024	-3.54
	MEAN	0.022	0.021	-4.68
	MIN	0.015	0.015	1.89
	STD DEV	0.003	0.003	-1.04
Q10	MAX	0.030	0.025	-15.23
	MEAN	0.024	0.020	-15.76
	MIN	0.015	0.011	-22.74
	STD DEV	0.003	0.004	24.12
QMed	MAX	0.026	0.031	17.99
	MEAN	0.022	0.022	1.24
	MIN	0.014	0.012	-14.38
	STD DEV	0.005	0.006	16.03

Figure 4-6 Alterations to local Froude number predictions following restoration on the River Trent at Catton.



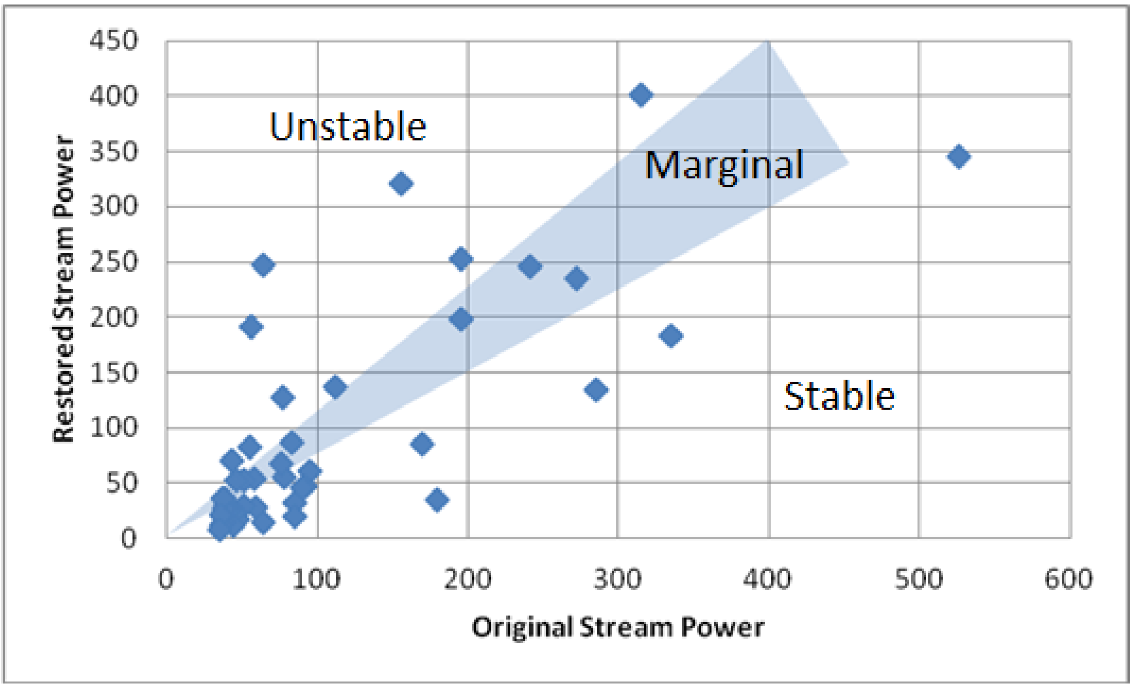
Stream Power has been used as a measure to predict channel stability based on local slope and discharge characteristic and a threshold value of around 35 W/m2 has been suggested for the instigation of channel change. This value must be treated with extreme caution as it is an average value derived from a highly variable dataset. However a review of the stream power results from the model for the Q95, Q50, Q10 and QMed flow along the River Trent through the Catton Estate (Table 4-5) suggest that even under the QMed flow the average values do not exceed this threshold. As such general dynamic stability is anticipated under the restored channel conditions. Figure 4-7 illustrates the change in steam power for model predictions exceeding 35 W/m2 and an uncertainty band has been introduced to reflect the widespread variability on the calculation. Only in a few cases is the stream power expected to be increased significantly locally above present values. In these locations heightened erosion can be expected. These are already locations where erosion is presently occurring and should not be a cause for concern in this generally low energy system.

Table 4-5 Stream Power characteristics for the River Trent through Catton Estate.

		Original Stream power	Restored Stream power	% change
Q95	MAX	40.08	49.58	23.70
	MEAN	12.71	16.20	27.42
	MIN	0.40	0.51	29.32
	STD DEV	11.49	16.01	39.38
Q50	MAX	57.94	39.51	-31.81
	MEAN	23.35	16.95	-27.43
	MIN	1.60	1.85	15.99
	STD DEV	14.20	12.51	-11.90
Q10	MAX	47.53	38.94	-18.08
	MEAN	20.89	14.42	-30.98

	MIN	0.31	0.18	-40.16
	STD DEV	10.33	13.60	31.63
QMed	MAX	56.65	103.47	82.66
	MEAN	31.52	37.29	18.34
	MIN	0.19	0.33	76.12
	STD DEV	28.36	33.11	16.75

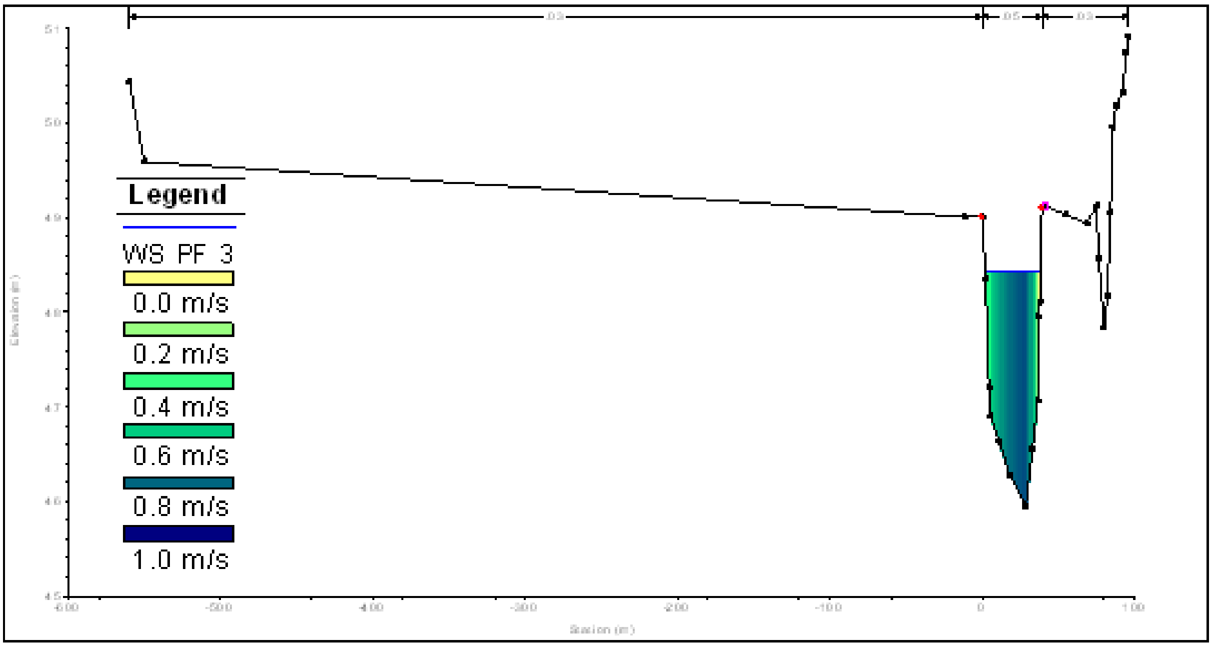
Figure 4-7 Alterations to stream power predictions following restoration on the River Trent at Catton.



4.2.3 Local Hydraulic change

Figure 4-8 to Figure 4-10 illustrate the local improvements to the hydraulic habitats at a cross-section level based on the proposed morphologic improvements. The winter high flow (Q10) model results are shown. The anastomosed channel network (Figure 4-8) has only a marginal effect on in-channel hydraulics but does open up significant ephemeral channel habitat. Floodplain scraping (Figure 4-9) reduces in-channel hydraulic energy, potentially reducing outer bank erosion and encouraging inner bank deposition. It also creates a new area of generally shallow low energy flow during elevated discharges. The effect of island creation is variable, Figure 4-10 shows how an island has caused preferential flow along one of the two distributary channels creating both lower and higher energy hydraulic habitats and forming a stable isolated in-channel deposit which will be colonised by vegetation and where succession will proceed without grazing pressure.

Figure 4-8 Anastomosed channel creation on the River Trent at Catton



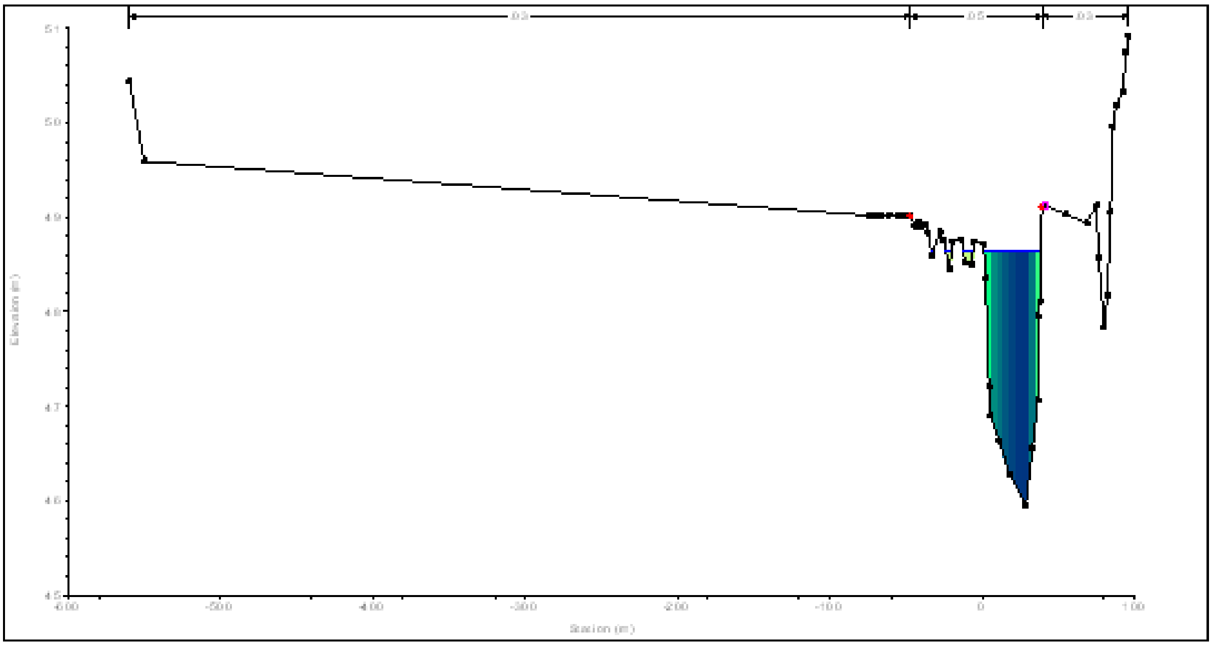


Figure 4-9 The effect of floodplain scraping on the River Trent at Catton

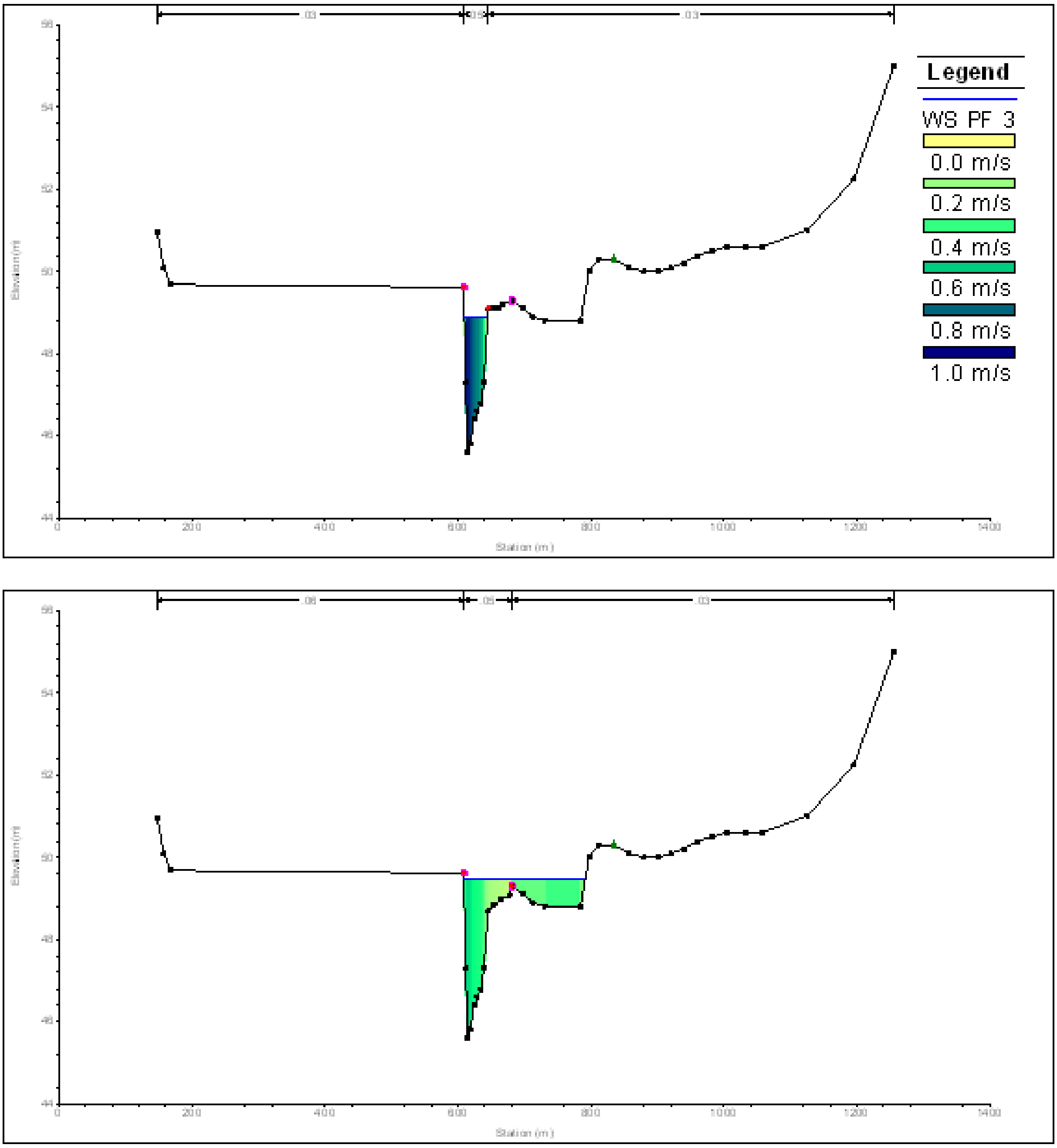
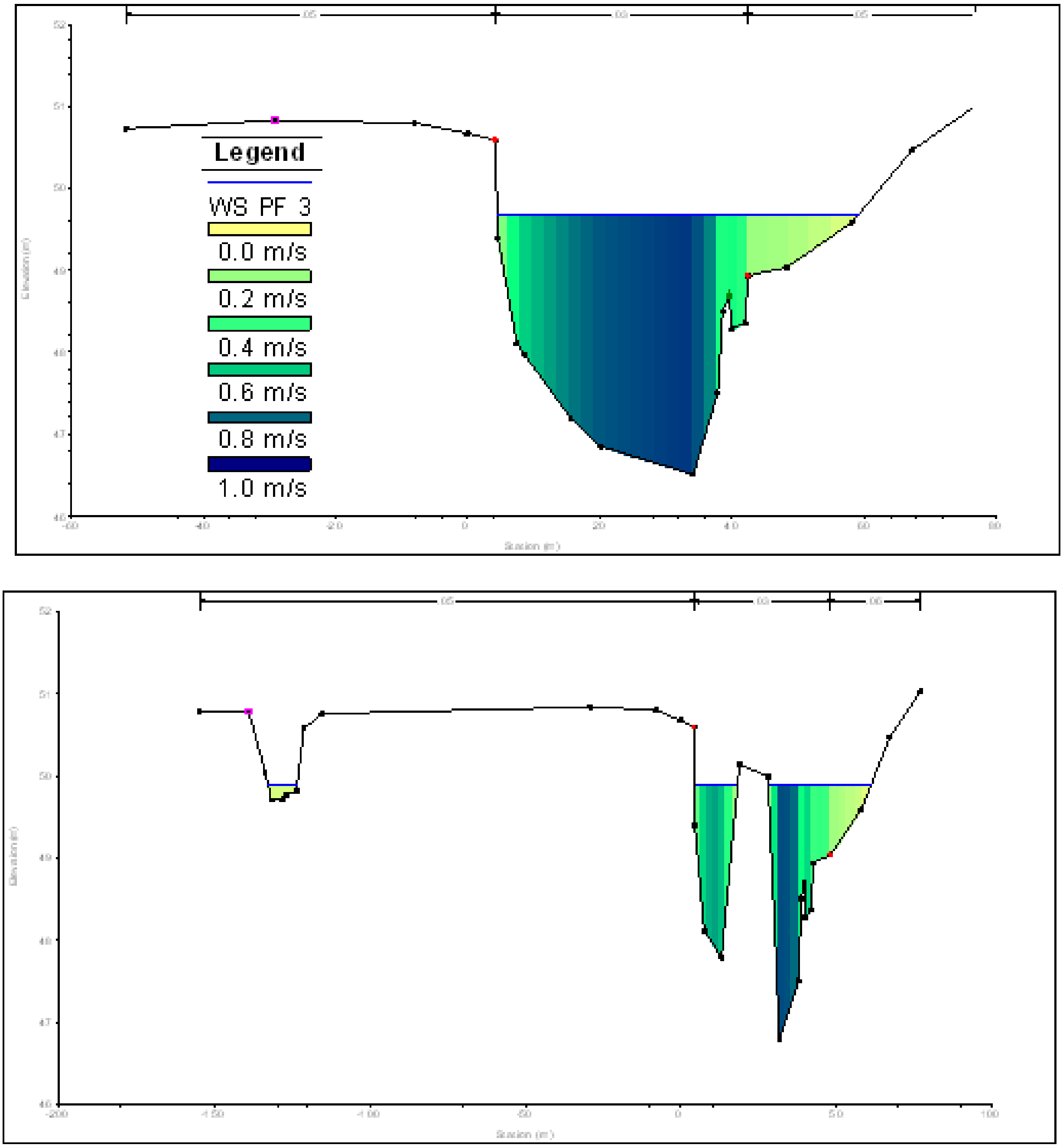


Figure 4-10 Island creation on the River Trent at Catton



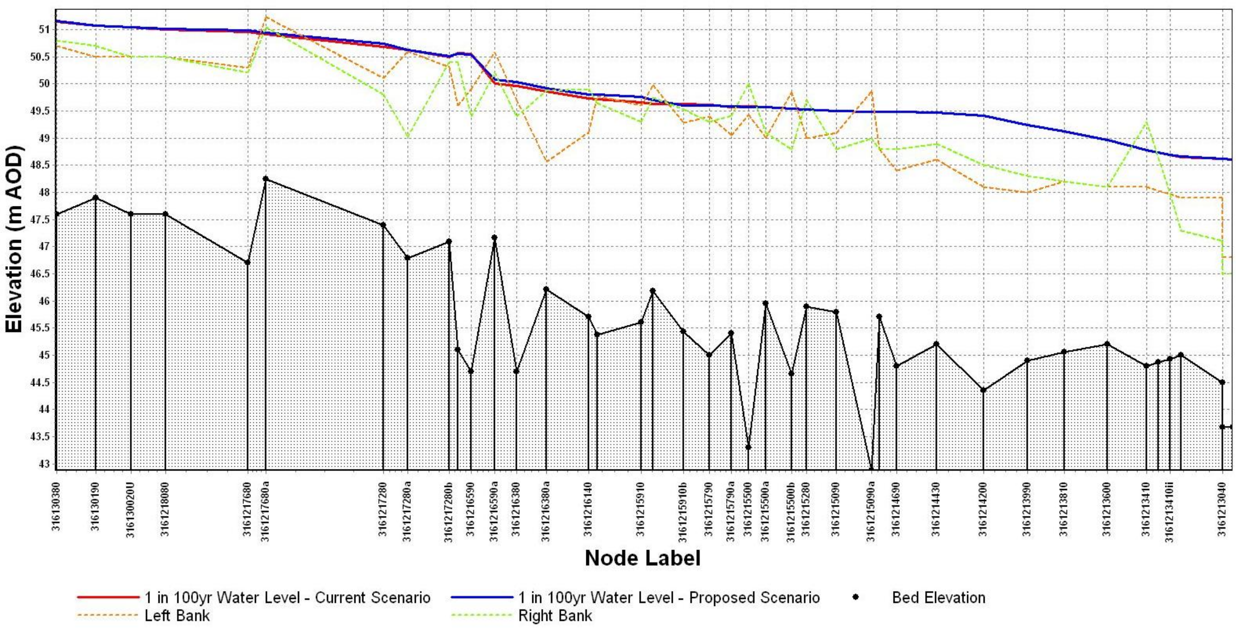
4.3 Comparison of flood risk results for the present and restored River Trent through Catton Estate

A comparison between pre and post restoration flood levels was been undertaken along the study reach in order to determine what impact the proposed modifications would have in terms of flood risk to the surrounding land. Two models were used for this comparison using ISIS, the first representing existing conditions (pre-restoration) and the second representing proposed conditions (post restoration).

The existing conditions model was solely an update of the supplied Environment Agency ISIS model of the River Trent. This model was updated with additional cross sections provided by the Staffordshire Wildlife Trust. The new cross sections were linked to the storage area representing the left bank floodplain area (taken from the original EA model).

The proposed conditions model was constructed using sections developed in the 1D segmented hydraulic model (HecRas). These sections were imported into ISIS and connected to the existing storage areas (representing the left bank floodplain).

Figure 4-11 Comparison between existing and proposed water levels along the study reach



A comparison of pre and post restoration water levels has shown minimal differences. The maximum differences in water level within the channel which were found to occur were 0.09m (increase) and 0.02 (decrease). Within the floodplain the maximum difference in water level was 0.006m. These are considered to be minimal differences given the scale of flood events along the River Trent.

4.4 Breach Analysis

A separate model run was carried out to investigate the effect of a breach occurring along the left bank of the Trent into the Gravel Pit Lakes. The breach analysis was carried out using the 1 in 100 year flood event scenario. A 20m wide breach was modelled with bank levels reduced to ground level by approximately 1 metre.

Figure 4-12 Location of Breach modelling

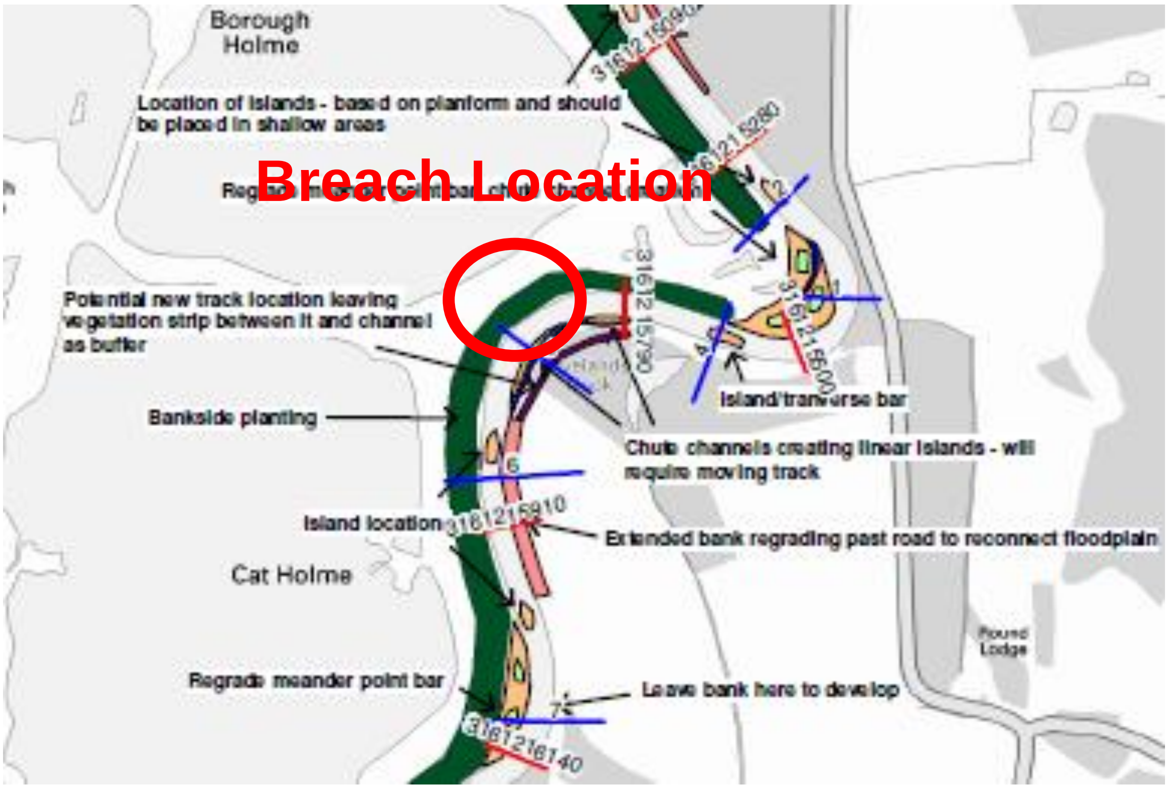


Figure 4-13 Comparison of overtopping and breach scenario flows

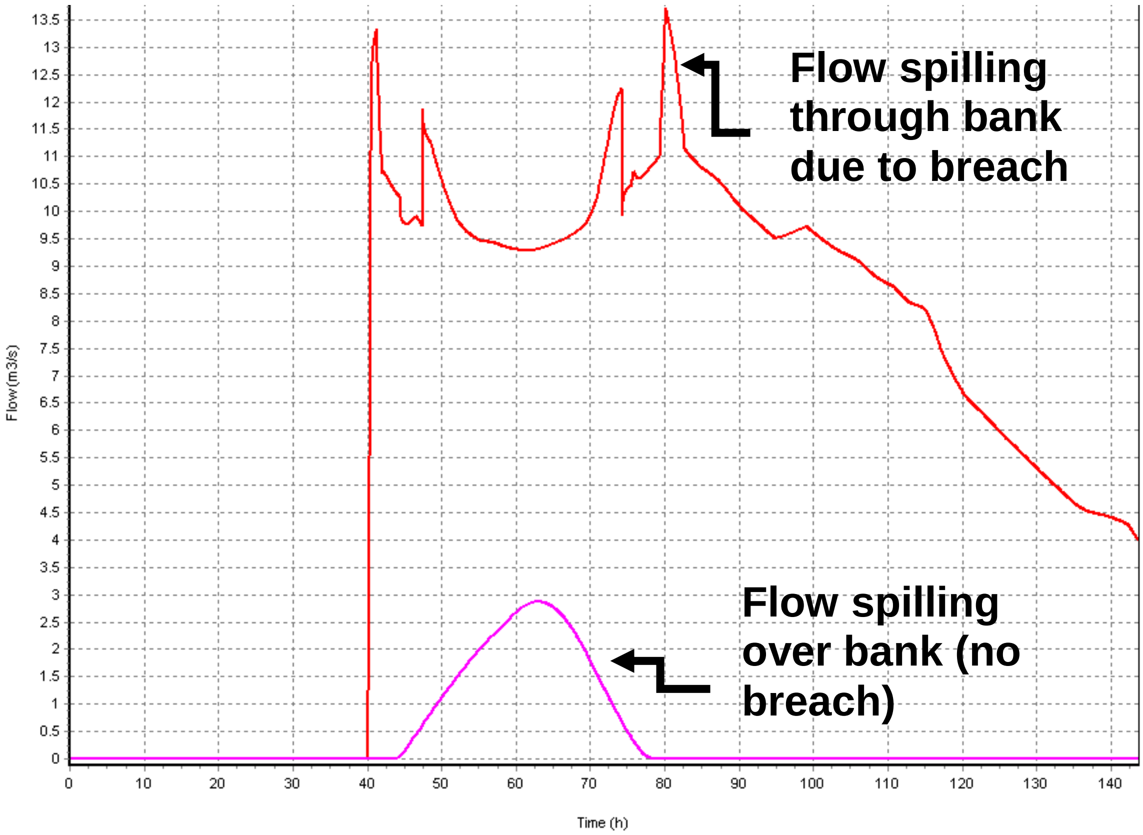
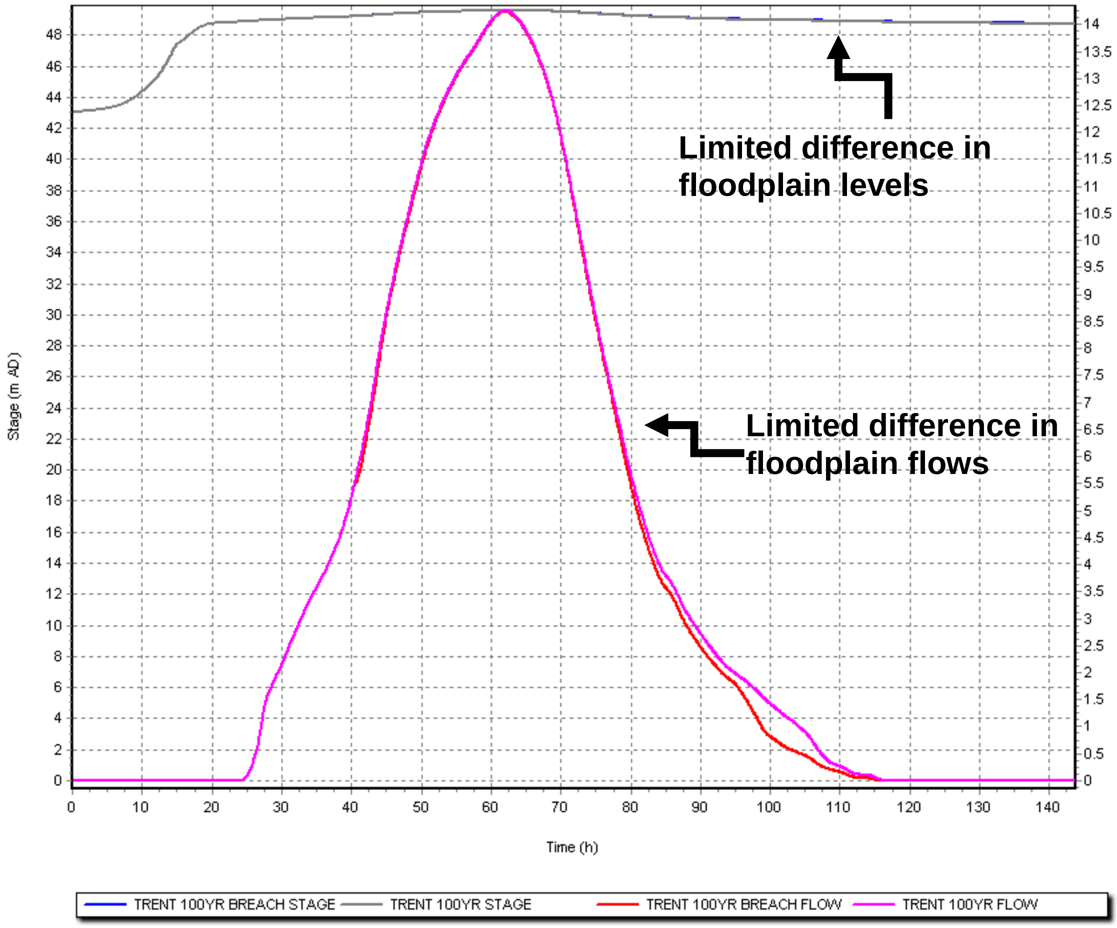


Figure 4-14 Floodplain flow and stage comparisons with breach and without breach



No significant difference in floodplain or river levels was found as a result of the breach occurring. An increased amount of flow was observed entering the floodplain as a result of the breach, however, increased flow leaving the floodplain area and re-entering the river was found at other location which balanced any effect, hence the limited difference in levels.

5 Conclusions

It is clear from the 1D segmented modelling exercise that the proposed restoration measures will increase hydromorphic diversity along the reach. In particular it will create new habitats and dramatically improve the connectivity between the river and its floodplain. It will also create a more diverse, albeit low energy, set of hydraulic habitats.

Several restoration options have been identified. Chute channel restoration will make way for increased diversity whilst decreasing outer bank erosive pressures in a number of locations. The removal of and regrading of river banks will also reduce some erosive pressures and will allow the channel to reconnect with its floodplain and the introduction of island features in shallower areas (based on upstream analogues) will also be of benefit. Further measures such as the introduction of large woody debris will give rise to increased channel ecological diversity.

Hydraulic modelling has been undertaken to determine shear stress and stream power estimates. These suggest that overall channel dynamic stability will be maintained. Some local increases in erosive energy are predicted but it is suggested that this is a positive thing on this reach promoting natural channel change along areas where more limited change is already occurring. In the longer term other schemes could be introduced in the reaches up and downstream of the Catton Hall reach, potentially using similar methods and options (following further investigation and analysis) to those identified in this study.

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