RAB Consultants

Lincoln Western Growth Corridor
Technical Working Group
Flood Risk Report

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Revision History

Version	Date	Amendments	Issued to
1.0	15.05.2013		Technical Working Group
2.0	20.05.2013	Corrections based on feedback from the group	Technical Working Group
3.0	23.05.2013	Group feedback - Minor rewording to Exec Summary and Conclusion.	Technical Working Group

Quality Control

Action	Signature	Date
Prepared	G.M. Wilson	23.05.2013
Checked	R.A. Burton	23.05.2013
Approved	R.A. Burton	23.05.2013

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Executive Summary

The four partner authorities of the Central Lincolnshire Joint Planning Committee have identified the need for sustainable growth in Central Lincolnshire with a significant proportion within the Lincoln area. An assessment of flood risk and risk management options is needed to understand the contribution that the Sustainable Urban Extension site referred to as the Western Growth Corridor (WGC) could bring. This piece of work was instigated to provide supporting evidence to Central Lincolnshire Joint Planning Unit to assist with determining, in principle, the safe sustainable quantum of development.

Ground raising above the expected flood level is required to mitigate the risk to residential and other more vulnerable development. This work has shown, in principle, the extent of land raising that can be achieved without significantly impacting on third parties, when considering breaches in either the Fossdyke or Witham during a 1% annual probability flood taking account of climate change.

The importance of maintaining an eastern breach flow route onto the site has been shown. If the eastern flow route is closed, by extending land beyond the proposed Tritton Road junction, then New Boultham will experience an increase of flood hazard class during a breach on the Witham.

If the eastern flow route is taken into account within the arrangement, then the Technical Working Group consider that:

- *A ground raising extent (and hence 'more vulnerable' development platform) of approximately 98ha is feasible at the WGC without increasing flood risk to third parties when considering breaches in the Witham or Fossdyke Canal, if mitigation is provided by lowering the existing waste tip to match the surrounding land. It might be feasible to increase the ground raising extent to approximately 117ha with additional mitigation measures involving significant ground lowering, however some technical queries remain unanswered with this option, most notably sustainable management of ground water levels.*

When considering the feasible range of development platform, there still remains a significant amount of additional assessment work needed to determine the impact to / from the Upper Witham Internal Drainage Board systems and surface water. Additional mitigation works (beyond just lowering the tip) needed for the upper range of development extent, such as storage ponds and pumping of groundwater, has the potential to interfere with water levels in the local drainage systems and may not provide the required storage capacity in the event of a main river breach, when the full complexity of the water system is considered. For these reasons the Technical Group recommend to the JPC that the determining authorities (Lincoln City Council and North Kesteven District Council) should require a developer to provide:

- *A Detailed Flood Risk Assessment and Water Level Management Plan to accompany any planning proposal at the Western Growth Corridor in line with the brief given in Sections 5.1 and 5.2 of this report.*

As development is being proposed in an area outside of flood zone 1 (following the application of a Sequential Test) the Exception Test as prescribed by the National Planning Policy Framework will be applied. For the Exception Test to be passed, a site specific flood risk assessment must demonstrate that the development will be safe for its lifetime, without increasing flood risk elsewhere, will demonstrate that the development provides wider sustainability benefits to the community and, where possible, will reduce flood risk overall. To

assist with this, a list of flood resilience measures has been provided in this report that a developer should address to increase resilience to the development and provide flood risk mitigation to the wider community. Consequently the Technical Group further recommend to the JPC that the determining authorities should require a developer to provide:

- *Additional physical works as part of any development at the Western Growth Corridor to provide greater flood resilience to the site and the wider area, in line with the brief given in Section 5.3 of this report.*

Contents

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1.0 Introduction

The four partner authorities of the Central Lincolnshire Joint Planning Committee (JPC) have identified the need for sustainable growth within Central Lincolnshire as a whole, a significant proportion of which, is planned within the Lincoln area. Practically, this will involve significant expansion of residential and commercial development while taking account of flood risk. The JPC have selected three potential Sustainable Urban Extension (SUE) areas for this purpose, one of which is the Western Growth Corridor (WGC).

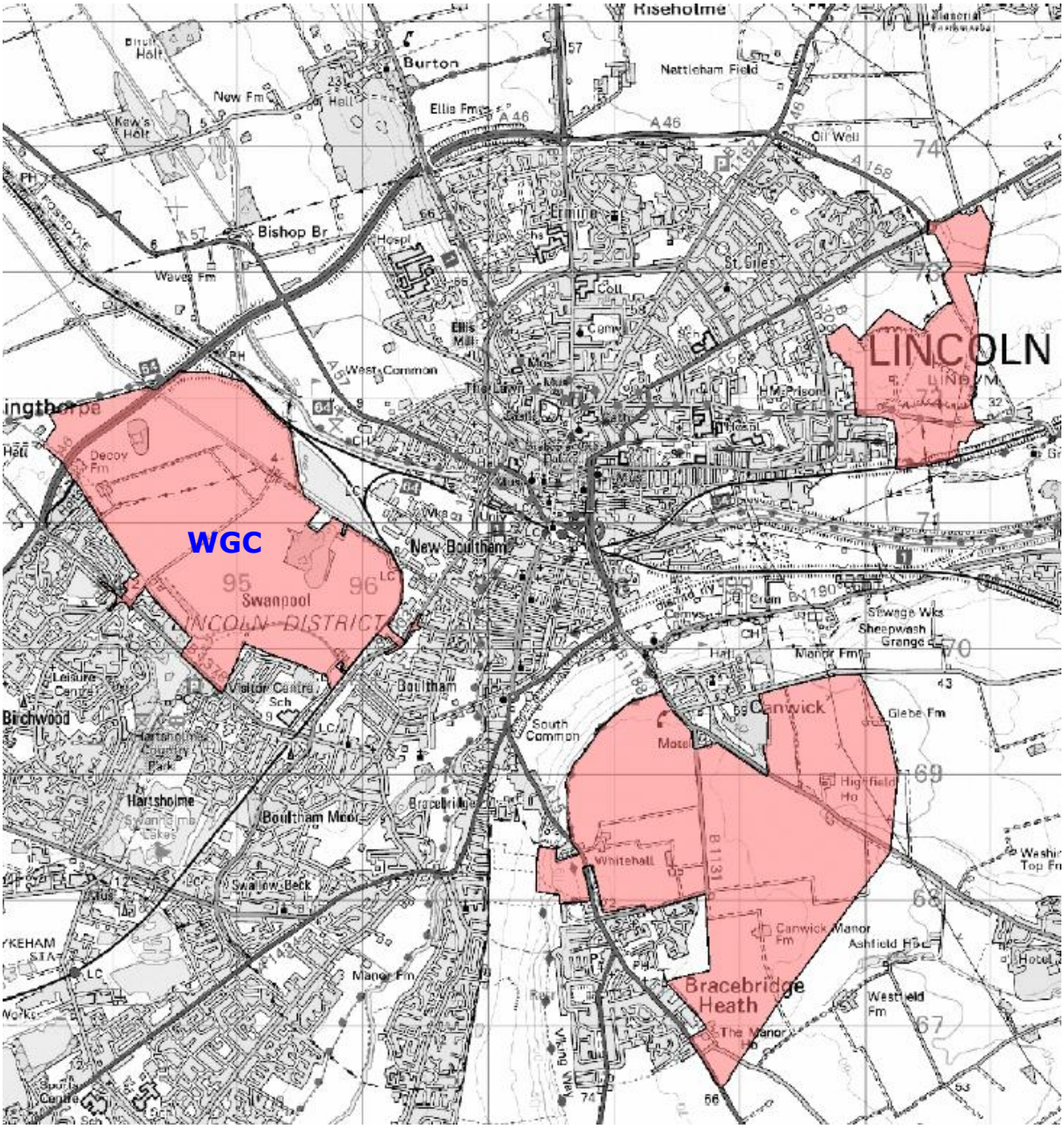


Figure 1 Map of Lincoln showing the WGC along with the other 2 SUEs

The Central Lincolnshire Joint Planning Unit (JPU) has undertaken a sequential test as prescribed by the National Planning Policy Framework to ensure that flood risk is

correctly accounted for when assessing the options and deciding how best to allocate growth across the wider Lincoln area.

The WGC is almost entirely located within flood zone 3, however the outcome from the sequential test shows that there is a shortfall of dwellings of between 4000 and 7000 units assuming full development of all currently available, suitable and achievable development sites. As such, some of the shortfall could be met by the WGC if the requirements of the Exception Test are met, principally safety. Therefore there is a justification for running an exception test for the development of the WGC. Consequently, an assessment of flood risk and risk management options is needed to understand the contribution the site could bring as part of a strategic partnership approach to development whilst ensuring flood risk is reduced now and for the future.

It is clear that any significant development of the WGC would require extensive flood risk management measures to make development safe while not increasing flood risk at the site or elsewhere. Taylor-Wimpey previously considered this challenge for an extensive development proposal by quantifying flood risk and proposing risk mitigation measures within the WGC site to achieve a minimal overall impact on flood risk.

The Taylor-Wimpey work prompted a discussion paper between the strategic flood risk and planning partners to consider the wider impact of the WGC development and the need to find integrated solutions and mutual benefits (LWGC Discussion Paper Version 5.0 TCR 18_04_12).

This led to the establishment of a Lincoln Western Growth Corridor Technical Working Group (WGC-TWG) with project aim:

- To provide evidence – to support the LDF.
- To set principles – to govern any potential development on the site.
- To achieve consensus – on the issues facing the area and appropriate future.

and group objectives:

- Provide evidence and technical advice to the Steering Group.
- Propose a range of FRM approaches.
- Propose a representative range of development options and extents for testing.
- Facilitate information sharing and resources between stakeholders for assessing FRM options and testing the optimum deliverable approach to safe and sustainable development.

2.0 Methodology

2.1. Sources of flooding at the WGC

At the first meeting of the WGC-TWG the watercourse / drainage arrangement relevant to the site was discussed and the expected impact on flood risk.

It was concluded by all that the description given in Taylor-Wimpey's Detailed Flood Risk Assessment December 2006 provides a reasonable summary of the complex watercourse

arrangement. A summary sheet of the watercourses affecting the WGC is given in Appendix A, along with two maps that show the complex arrangement extracted from Taylor-Wimpey's Detailed Flood Risk Assessment.

The site is surrounded by three embanked main river watercourses the Fossdyke Canal, River Witham and Boultham Catchwater. The Skellingthorpe/Boultham main drain passes through the site. The embankments of the watercourses are reported to provide a typical standard of flood protection to the site of 1% annual probability (a.p.) when operating in conjunction with the Lincoln Washlands, although the capacity of the IDB drains is more like 5 – 10% a.p. before flooding is expected. The site is located within one of several pumped catchments that are operated by the Upper Witham Internal Drainage Board (UWIDB). Two of the catchments operate independently and are usually pumped directly to the Fossdyke Canal in all but the most extreme events. The four catchments to the north of the Fossdyke Canal act as a tiered system and interact as pumping capacity is exceeded. Three of the catchments to the south of the Fossdyke also interact when pumping capacity is exceeded with the Oxpasture catchment only starting to interact through overland flow in extreme events. A siphon under the Fossdyke facilitates the flow of water from north-south and results in all catchments operating as one in extreme events. The Junction Sluice is used to maximise flood protection to the urbanised catchments of Boultham and Coulson, both of which pump to the River Witham.

2.2. Flood Risk Management options

Clearly development of the WGC will require extensive flood risk management (FRM) measures to mitigate the risk to the site and to others. The group proposed an initial set of potential FRM options for consideration:

- Attenuation storage of the main drain upstream of the A46.
- Increased attenuation storage at the upstream Lincoln Washlands associated with the River Till.
- Ground raising at the WGC.
- Use of WGC access road as a flood defence.
- Improvements to the flood defences (increase standard of protection and increase strength).
- Effective use of Sustainable Drainage Systems (SUDS), particularly source control to target reduction of runoff.

The Environment Agency's specific technical points that will need to be addressed as part of any development scheme are:

- The key risk to be considered, with regards to impact of any loss of floodplain, is breach of the raised defences protecting the site, which will affect extensive areas of Lincoln.
- There should be no increase of flood hazard class for any existing residents as a result of the development.
- Any breach analysis undertaken should be to the latest best practice with full 1D/2D integration.

- The Environment Agency has recently (2012/13) undertaken breach modelling for Lincoln City centre that could be used to test WGC development and FRM options. The modelling has been undertaken by Mott MacDonald using the software package InfoWorks.

WGC-TWG assessment of flood risk issues at the site:

- Through discussion within the group, sharing knowledge and experience, it was concluded that the only realistic way to manage flood risk at the site is by ground raising.

- The Environment Agency will want to see all 'more vulnerable' development (e.g. residential, schools, health services) to be built on land raised above the breach flood level.

- Significant ground raising at the WGC as part of a development scheme, has the potential to increase breach flood levels elsewhere. This is expected to have the biggest impact on adjacent residents to the east of the WGC. The key parameter to consider is flood hazard when looking at the effect of developing the site; hazard being a combination of water depth and velocity.

- The scale of flooding during a breach event will be large and as such even significant ground raising at the WGC will not require level-for-level floodplain compensation, so long as there is no increase of hazard class in already developed areas.

- Improvements to the existing flood defences are not a sustainable solution as it does not remove the residual risk of breach. The impact of a breach scenario would still need to be addressed.

- The benefit to Lincoln from additional upstream attenuation storage (expansion to the Lincoln Washlands) is being investigated as part of the Upper Witham Strategy. It is considered that any impact on the WGC would be negligible. The aim of the Strategy is to maintain the current standard of protection in the face of climate change, rather than providing flood risk reduction.

Breach analysis is therefore the fundamental test for assessing the impact of land raising on breach flood levels to the site and third parties. No increase of flood hazard class for existing residents is the criterion to be used for assessing feasible development extent. Other sources of flood risk to the site and potential impacts on third parties will still need to be considered.

Flood hazard is a combination of water depth and water velocity, which reflects the fact that shallow, slow moving water is less dangerous than deep, fast flowing water.

Hazard rating is formally defined by the equation:

$$HR = d \times (v + n) + DF$$

Where:

HR = flood hazard rating;

d = depth of flooding (m);

v = velocity of floodwaters (m/sec);

DF = debris factor (with a value of either 0, 0.5, or 1 depending on the probability that debris will lead to a hazard);

n = a constant of 0.5.

The flood hazard classes are defined by the following thresholds:

HR threshold	Degree of flood hazard	Description
<0.75	Low	Caution
0.75 – 1.25	Moderate	Danger for some
1.25 – 2.0	Significant	Danger for most people
>2.0	Extreme	Danger for all

2.3. Modelled flood scenarios

Agreement was obtained to use the Environment Agency's Lincoln breach model to establish, in principle, the maximum extent of land raising without significant detriment to flood hazard elsewhere. The full complexity of the pumped catchment is not represented within the model, although reasonable inputs of flow from the IDB system are included to mimic the wider catchment. The IDB main drain that passes through the site was added to the existing model for completeness. Despite the limitations, it is expected by the group that the detail contained within the model is sufficient and proportionate to establish, in principle, the impact of ground raising at the WGC on flood hazard elsewhere. However, confirmation of results using a more detailed model and development masterplan, including sensitivity testing, will be needed as part of a detailed Flood Risk Assessment. The modelling work was undertaken by Mott MacDonald.

A schematic diagram of the model is given in Figure 2.

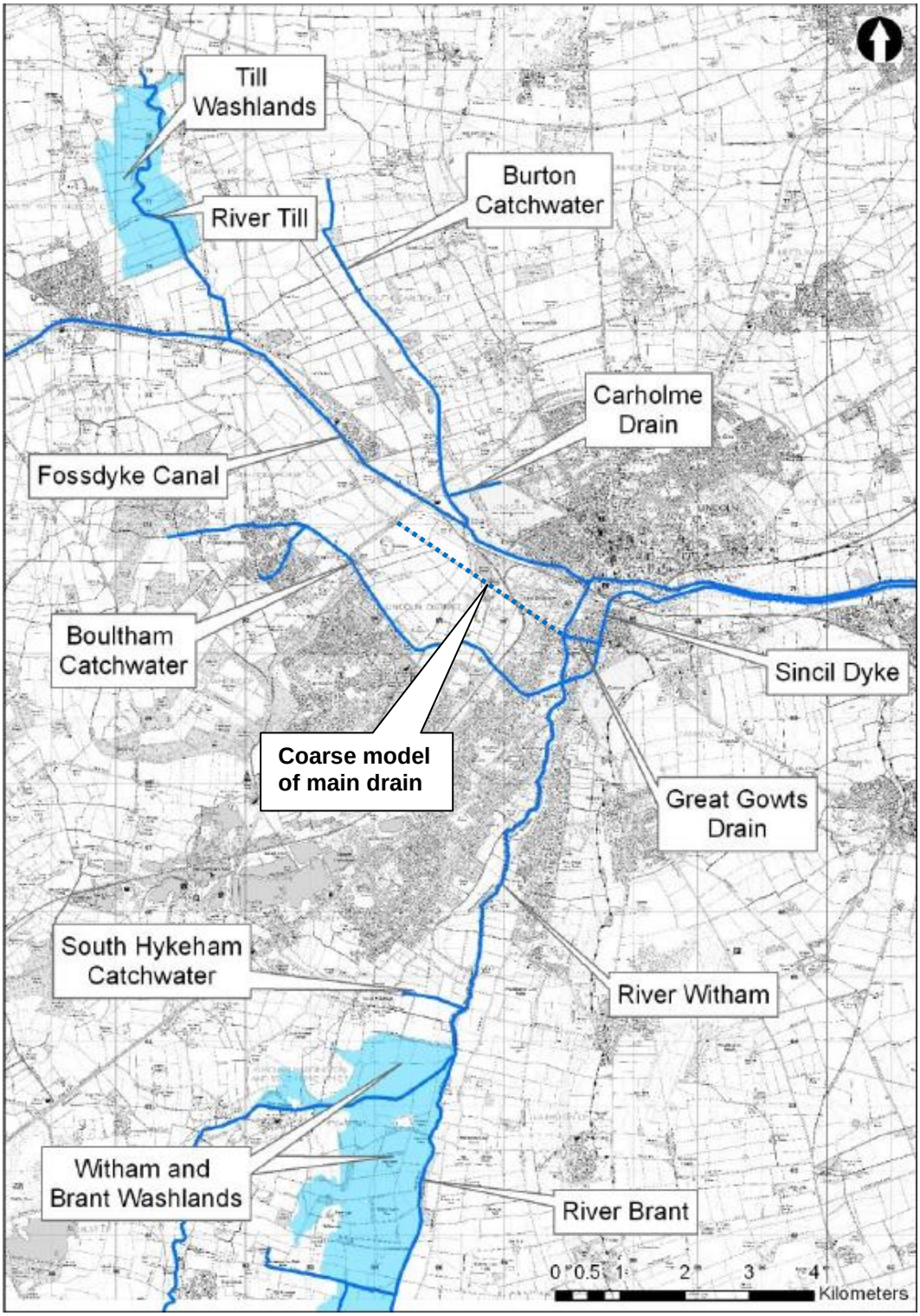


Figure 2 Schematic showing the watercourses included in the breach model. This is an amended version of Figure 2.1 contained in Mott MacDonald's technical note (Appendix B). This map is reproduced by permission of Ordnance Survey on behalf of the Controller Of Her Majesty's Stationary Office. © Crown Copyright. All rights reserved. Environment Agency 100026380, 2013.

The parameters of the breach modelling work were set at the second meeting of the WGC-TWG and during ongoing review teleconference calls.

The baseline breach modelling work had already been completed prior to setting the Technical Group's test parameters. This work showed the main drain running through the site overtops during a 1% a.p. plus climate change flood even without a breach operating, however the water levels are low compared with that generated during a breach on either the Fossdyke or Witham.

Baseline testing was a significant piece of work by Mott MacDonald which had considered 49 breach locations across the city centre including, on the Fossdyke Canal, River Witham and Boultham Catchwater. The scope of work required by the WGC-TWG and the time available meant that only the most critical breaches could be re-tested.

By viewing the results and animations from the baseline breach tests, it was decided that the most critical breach locations were on the River Witham and the Fossdyke Canal.

The breach location giving greatest flood extents and depths on the Witham was assessed to be close to the junction of the Witham / Catchwater, identified as breach 13 in the Lincoln breach model. This location is in fact on the Catchwater but the influence primarily comes from the Witham. The WGC provides the greatest degree of flood relief storage in the baseline model, as water accumulates in Boultham, during a breach at location 13, compared with the other breach locations. Ground raising on the WGC is therefore expected to have the greatest off-site impact (to Boultham) with a breach at location 13. An indication of the main water flow route in the baseline model from a breach at this location is shown in Figure 3.

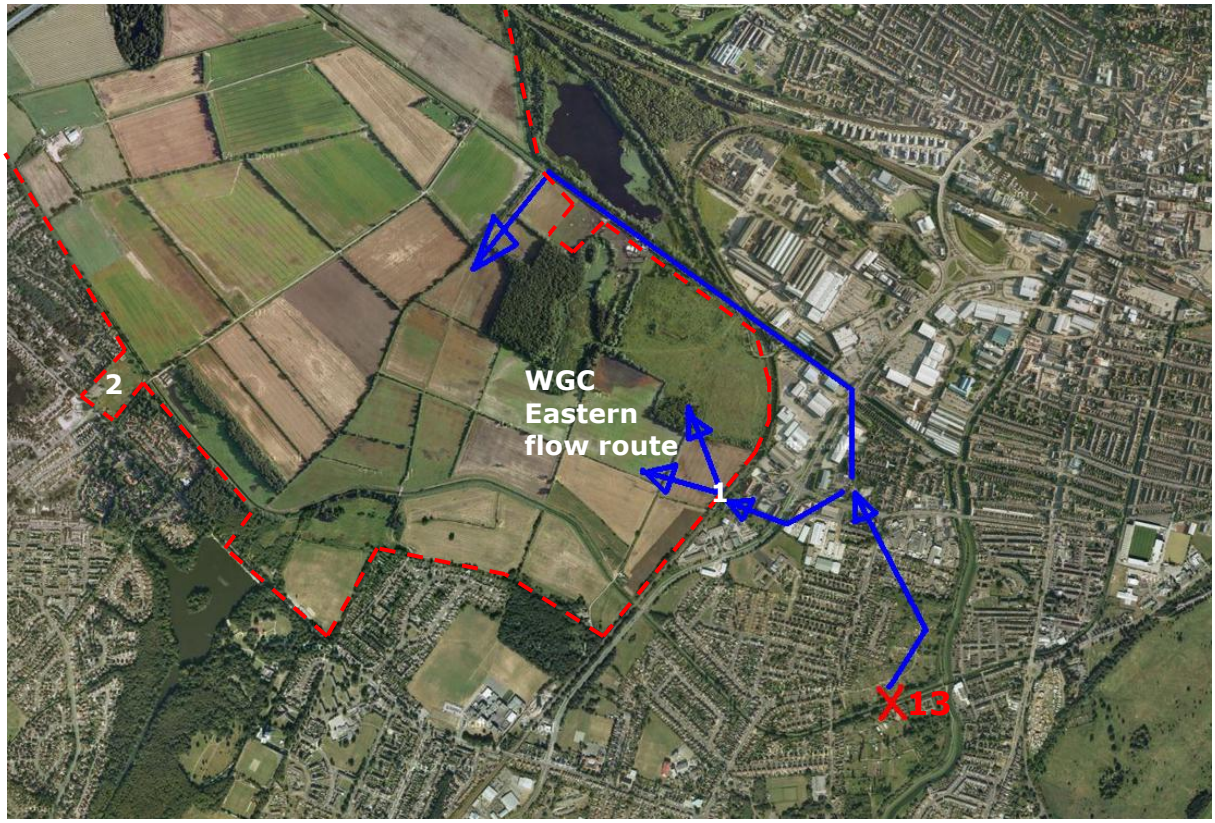


Figure 3 Breach 13 is indicated by a red cross. The main flow route from the breach is north towards Dixon Street, where it splits. A proportion continues north into the main drain at Coulson Road, where it back flows along the main drain adding to that overtopping onto the WGC. At the same time, a proportion heads west across Tritton Road then directly onto the WGC (eastern flow route). Two of the highway connection points are labelled (1 and 2). Background is a screenshot from googlemaps taken on 08/05/2013.

The breach location giving greatest flood extents and depths on the Fossdyke was assessed to be adjacent to the Pyewipe Inn, identified as breach 41 in the Lincoln breach model. A breach at this location inputs the greatest overall amount of water to the WGC, therefore ground raising is expected to have the greatest impact, as a result of the total reduction of flood storage volume. An indication of the main water flow route in the baseline model from a breach at this location is shown in Figure 4.

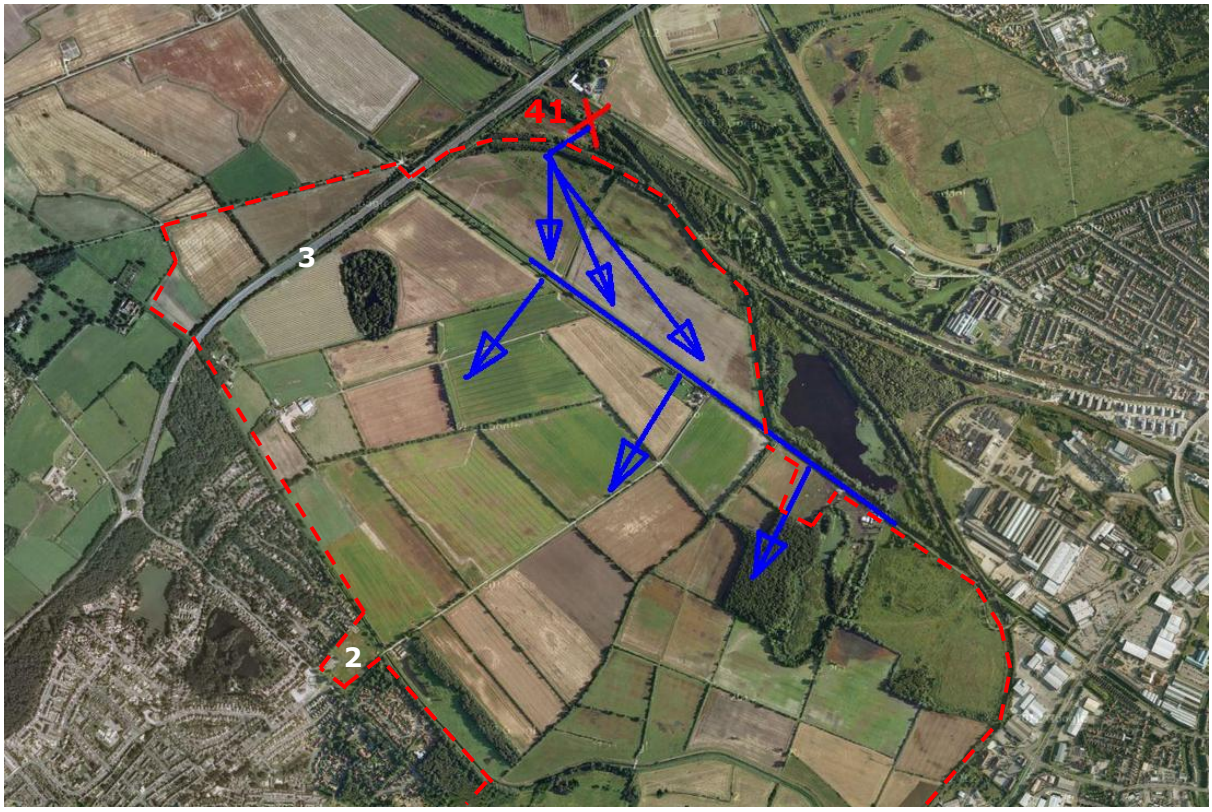


Figure 4 Breach 41 is indicated by a red cross. Escaping water from the breach flows south, entering the main drain. This causes more severe overtopping of the main drain southern bank resulting in a much larger volume of flood water entering the WGC site compared with the non-breach flood situation. Two of the highway connection points are labelled (2 and 3). Background is a screenshot from googlemaps taken on 08/05/2013.

Flood risk around Lincoln is complex with many interacting watercourses operating. The purpose of this work is to address flood risk from breach of main rivers only. A detailed assessment of flood risk from all sources would be required to support any development proposal.

2.4. Raised platform extents taken forward for testing

Six WGC platform extents were agreed by the group for testing, taking a sequential approach to flood risk. Starting with a narrow strip of ground raising along the edge of the lowest flood risk part of the site (adjacent to Boultham Catchwater), and then progressively extending out into the higher risk part of the site (towards to the main drain). The maximum extent tested exceeds the area of ground raising needed for the existing Taylor-Wimpey planning proposal. The next level down equals the existing Taylor-Wimpey area (although a different shape). The remaining tests progressively reduce the ground raising area down to a minimum.

The ground was raised in the model to a level significantly higher than the expected flood level, to provide dry platforms.

The baseline results show the important role that the eastern side of the WGC plays in receiving breach flows from the Witham, thus providing flood relief to Boultham. The effect of closing and opening the eastern flow route of the WGC was also tested as part of the six model runs (refer to Figure 3 where the eastern flow route is defined).

Three highway connection points were identified during the WGC-TWG meetings, that would need to be incorporated in any development scheme. All development extents were shaped to meet the three connection points. Refer to Figures 3 and 4 for the locations of the highway connection points.

The baseline results suggested that there would be a significant impact on flood hazard with larger ground raising extents, therefore flood mitigation measures would be needed. There is a landfill tip on the WGC set much higher than the surrounding ground, that could be lowered to compensate for some of the ground raising. This was tested as part of the six runs, along with a larger-scale ground lowering scheme.

The UWIDB pumps were modelled as operating within the model runs, and as such will be dealing with a large amount of water breach flow in addition to any catchment flow.

The water level in the UWIDB system is raised during the summer months to aid agricultural abstraction and reduced during the winter when irrigation is not required. It is understood that ground level data was obtained by LiDAR (light detection and ranging) during the winter, as such the modelling work will most closely reflect the lower winter level.

3.0 Results of breach modelling work

The output of the modelling work included a 2D animation mapping water depth and velocity across the landscape as a function of time, during a flood event with breach. In addition a flood extent map attributed with depth, velocity and hazard rating.

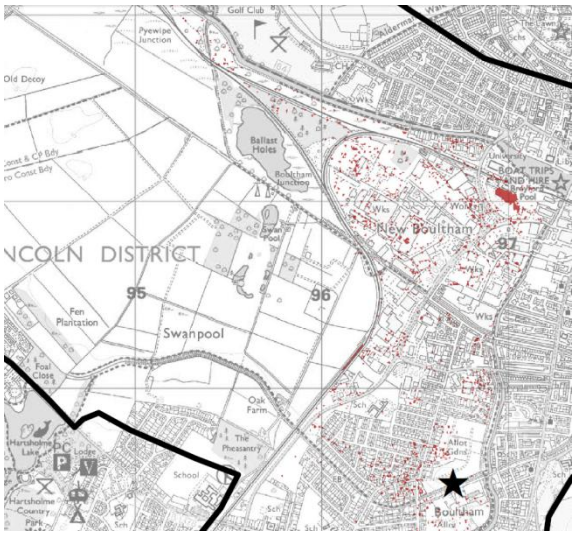
A baseline run was performed for each test with no ground raising in place and then this was repeated with ground raising included. The peak flood hazard outputs for the two runs were then subtracted to reveal whether a change occurred. The summary of results given below show, with red markings, where flood hazard increased so markedly that the hazard rating went up one class (for example ‘danger for most’ increased to ‘danger for all’).

A copy of Mott MacDonald’s technical report on the modelling work is given in Appendix B.

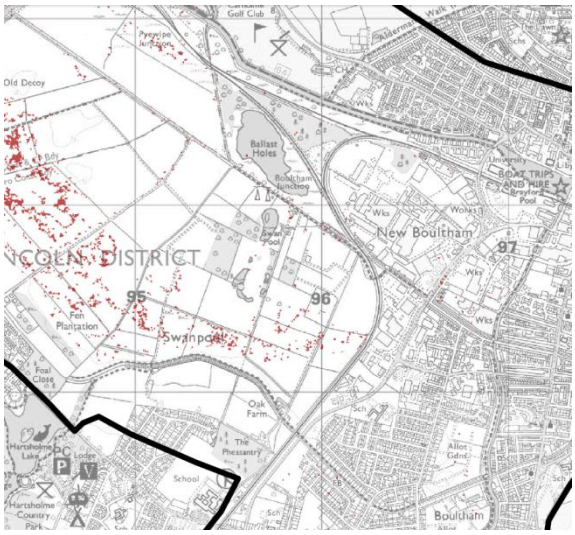
3.1. Ground raising extent A

- Minimum ground raising extent.
- Eastern flow route half open.
- No compensatory ground lowering.

Figure 5 Definition of extent A. Red lines show the area of ground raising superimposed onto a screenshot from googlemaps taken on 08/05/2013.



Witham breach (13)



Fossdyke breach (41)

Figure 6 Results from extent A. Red colouration shows where flood hazard category has increased.

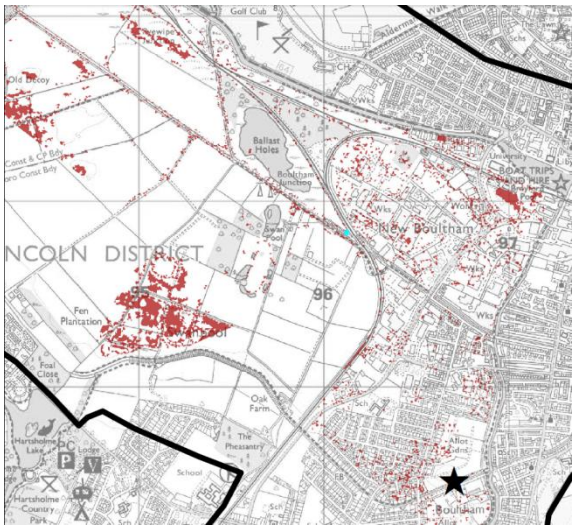
Summary of results for extent A:

- Witham breach – fine speckles of flood hazard category increase throughout New Boultham.
- Fossdyke breach – no significant change at the existing developed areas.

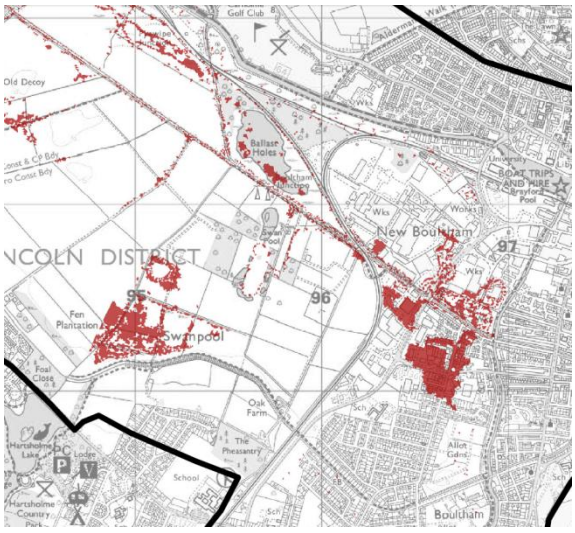
3.2. Ground raising extent F

- Maximum(+) ground raising extent, greater than Taylor-Wimpey's existing proposal.
- Eastern flow route closed.
- No compensatory ground lowering.

Figure 7 Definition of extent F. Red lines show the area of ground raising superimposed onto a screenshot from googlemaps taken on 08/05/2013.



Witham breach (13)



Fossdyke breach (41)

Figure 8 Results from extent F. Red colouration shows where flood hazard category has increased.

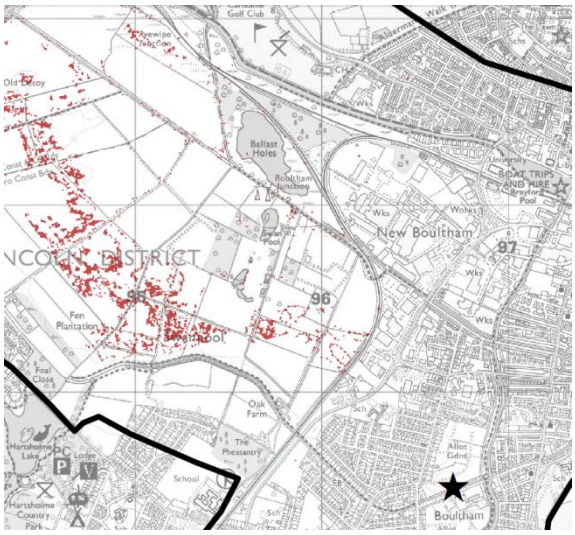
Summary of results for extent F:

- Witham breach – fine speckles of flood hazard category increase throughout New Boultham (a little more than Extent A).
- Fossdyke breach – overtopping of main drain both to the south and north in New Boultham.

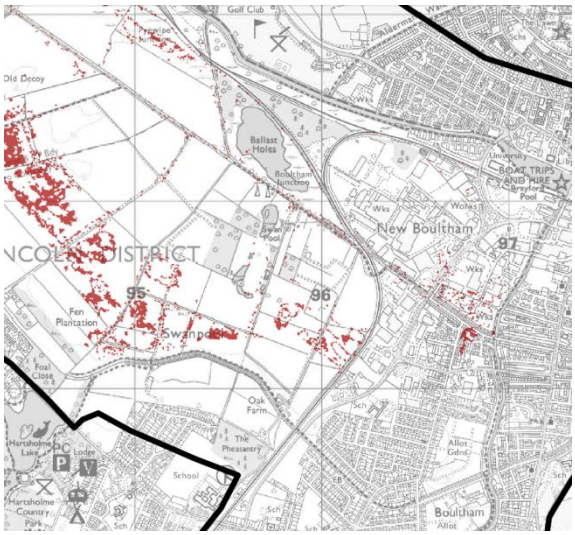
3.3. Ground raising extent C

- Medium ground raising extent.
- Eastern flow route open.
- No compensatory ground lowering.

Figure 9 Definition of extent C. Red lines show the area of ground raising superimposed onto a screenshot from googlemaps taken on 08/05/2013.



Witham breach (13)



Fossdyke breach (41)

Figure 10 Results from extent C. Red colouration shows where flood hazard category has increased.

Summary of results for extent C:

- Witham breach – no significant change at the existing developed areas.
- Fossdyke breach – slight overtopping of main drain to the south in New Boultham.

3.4. Ground raising extent E

- Maximum ground raising extent, equivalent to Taylor-Wimpey's current proposal.
- Eastern flow route open.
- Tip lowered to that of surrounding ground.

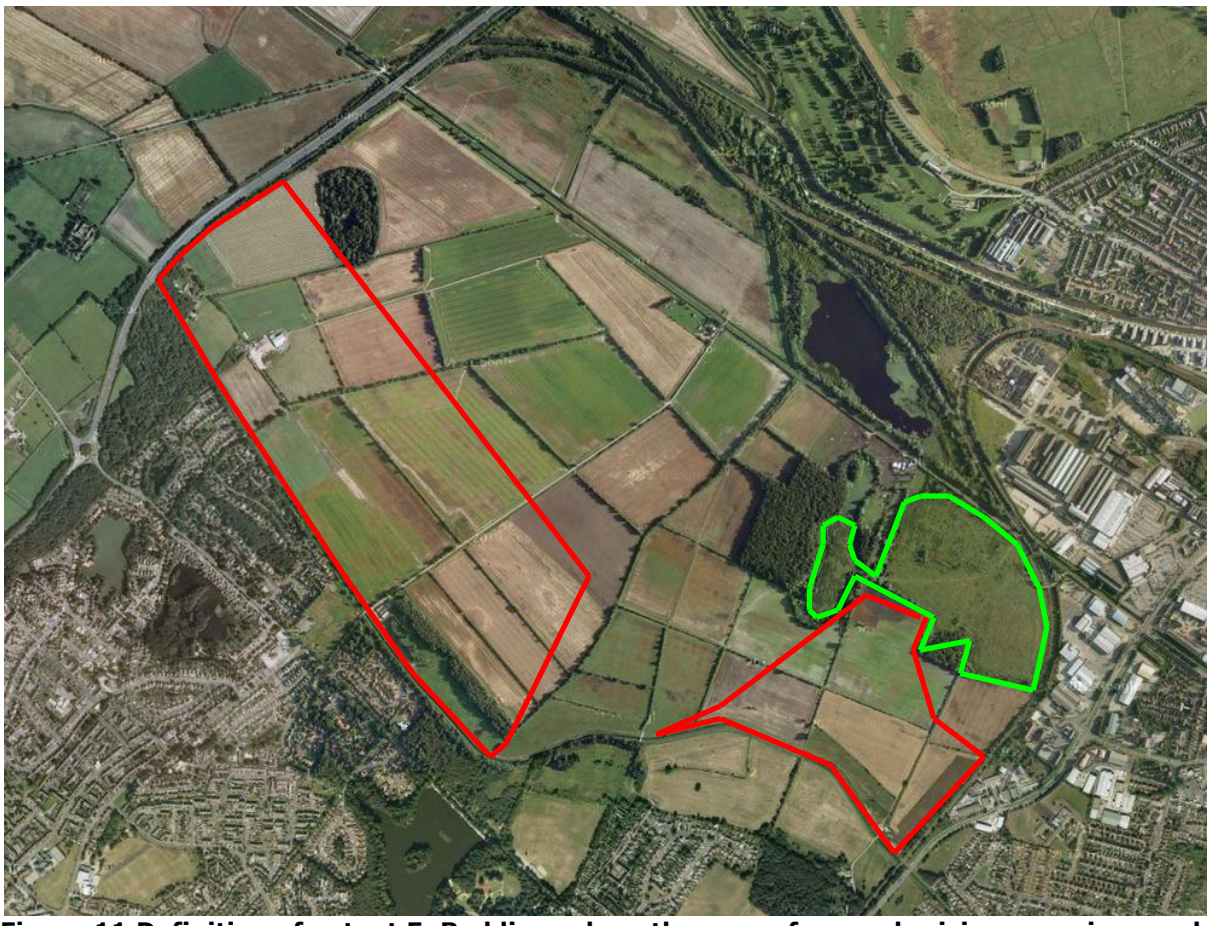
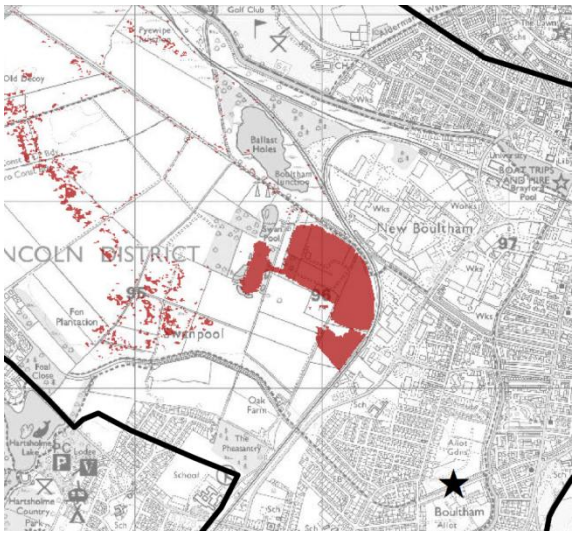
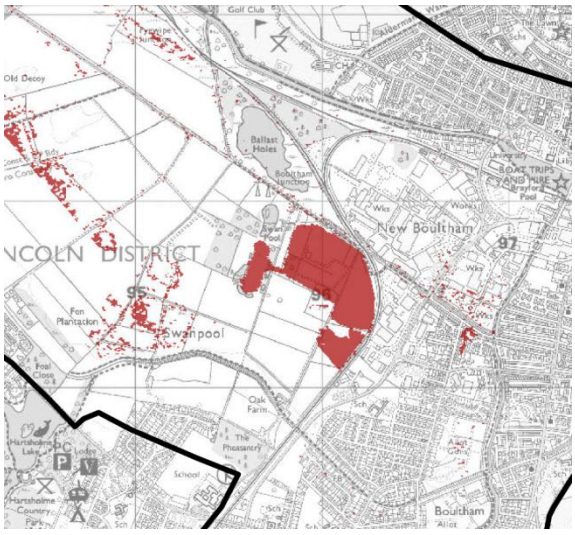


Figure 11 Definition of extent E. Red lines show the area of ground raising superimposed onto a screenshot from googlemaps taken on 08/05/2013. Green lines show the area of compensatory ground lowering down to the level of the surrounding ground.



Witham breach (13)



Fossdyke breach (41)

Figure 12 Results from extent E. Red colouration shows where flood hazard category has increased.

Summary of results for extent E:

- Witham breach – no significant change at the existing developed areas.
- Fossdyke breach – slight overtopping of main drain to the south in New Boultham (similar result to Extent C).

3.5. Ground raising extent D

- High ground raising extent, but less than TW's current proposal.
- Eastern flow route open.
- Tip lowered to that of surrounding ground.

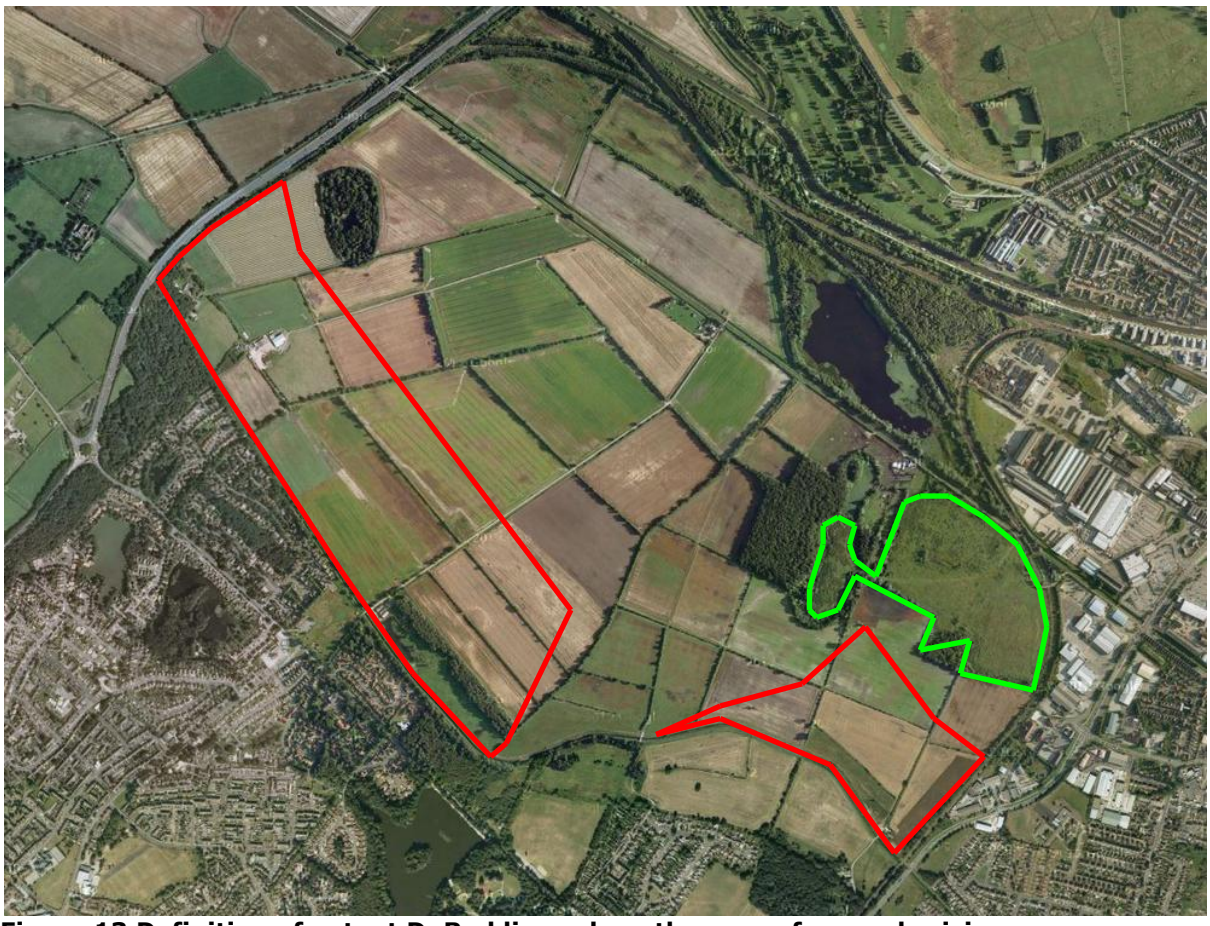
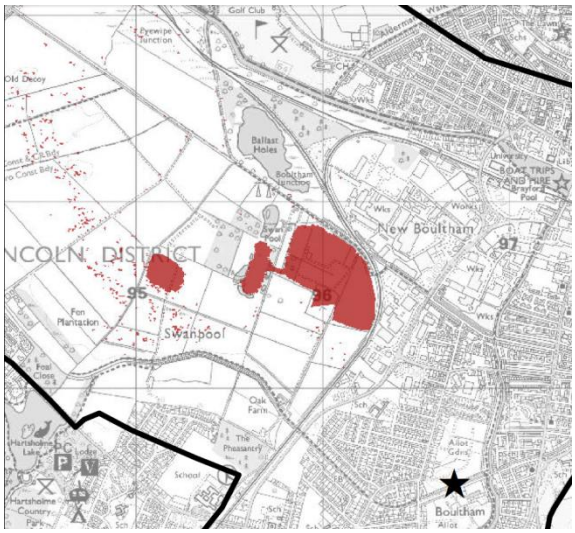
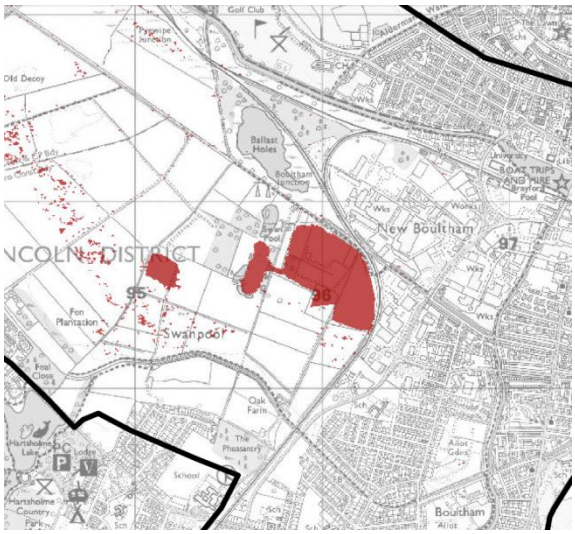


Figure 13 Definition of extent D. Red lines show the area of ground raising superimposed onto a screenshot from googlemaps taken on 08/05/2013. Green lines show the area of compensatory ground lowering down to the level of the surrounding ground.



Witham breach (13)



Fossdyke breach (41)

Figure 14 Results from extent D. Red colouration shows where flood hazard category has increased.

Summary of results for extent D:

- Witham breach – no significant change at the existing developed areas.
- Fossdyke breach – no significant change at the existing developed areas.

3.6. Repeat of ground raising extent E with increased mitigation

- Maximum ground raising extent, same as extent E, equivalent to Taylor-Wimpey's current proposal.
- Eastern flow route open.
- Tip lowered to that of surrounding ground and large strip of land each side of main drain lowered by 0.5m.

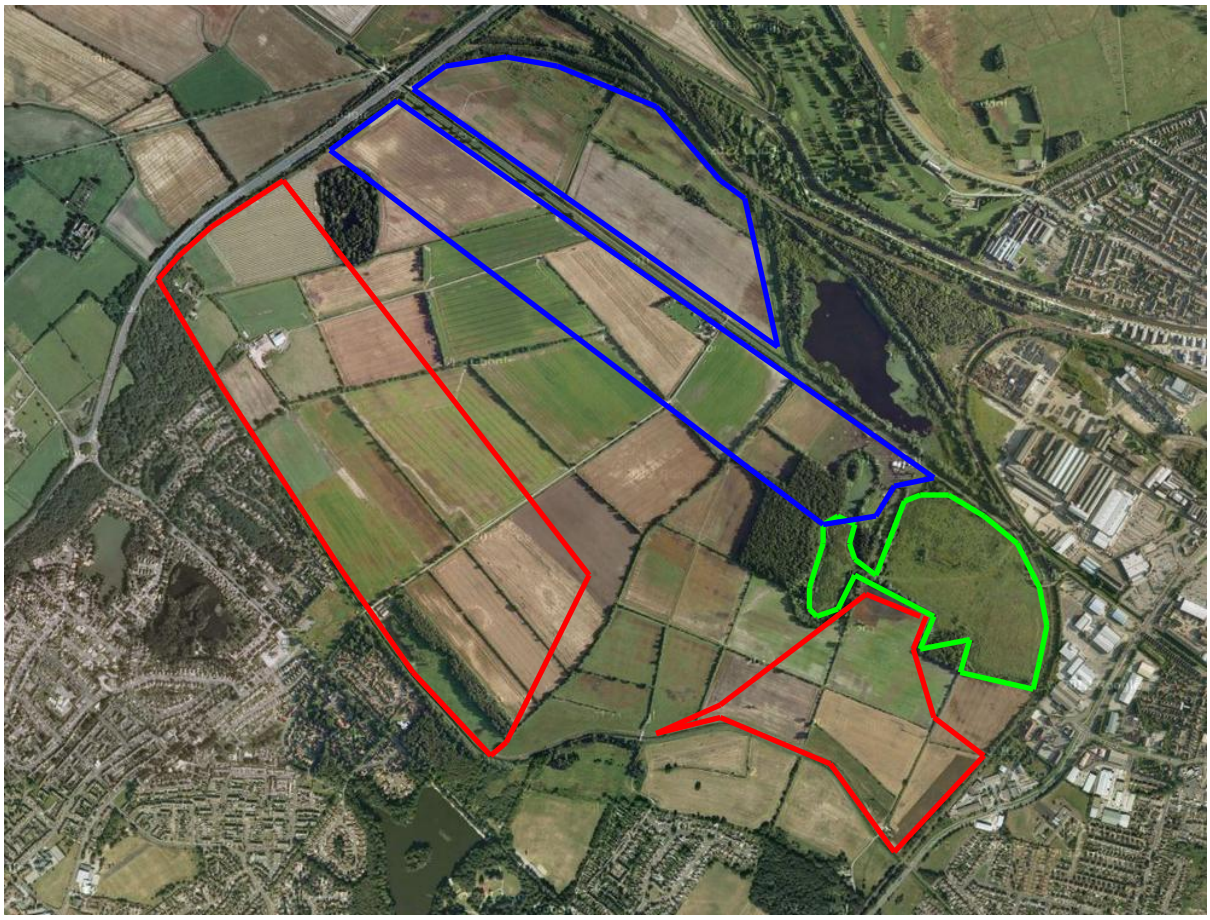
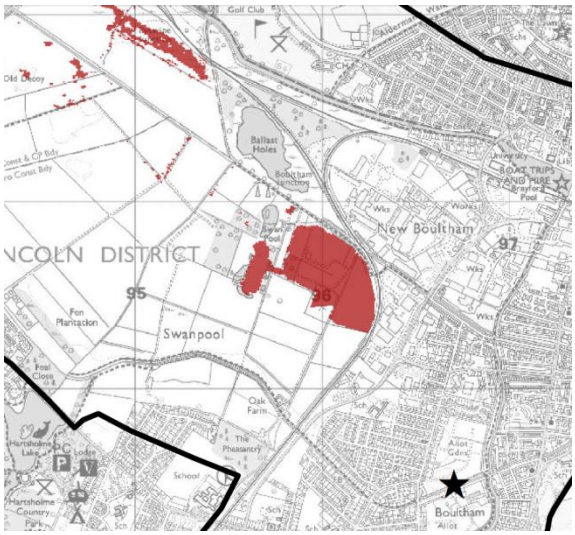
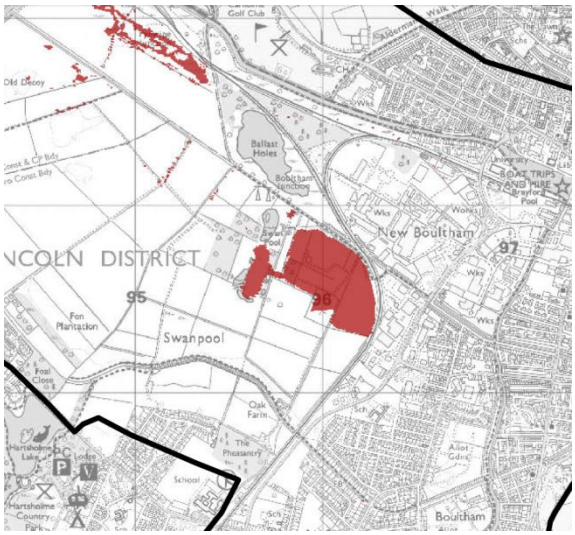


Figure 15 Definition of extent E with increased mitigation. Red lines show the area of ground raising superimposed onto a screenshot from googlemaps taken on 08/05/2013. Green lines show the area of compensatory ground lowering down to the level of the surrounding ground. Blue lines show additional areas where the ground has been lowered by 0.5.



Witham breach (13)



Fossdyke breach (41)

Figure 16 Results from extent E with increased mitigation. Red colouration shows where flood hazard category has increased.

Summary of results for extent E with increased mitigation:

- Witham breach – no significant change at the existing developed areas.
- Fossdyke breach – no significant change at the existing developed areas.

4.0 Conclusion and recommendations arising from the breach modelling work

The four partner authorities of the Central Lincolnshire Joint Planning Committee have identified the need for sustainable growth in Central Lincolnshire with a significant proportion within the Lincoln area. An assessment of flood risk and risk management options is needed to understand the contribution that the Sustainable Urban Extension site referred to as the Western Growth Corridor (WGC) could bring. This piece of work was instigated to provide supporting evidence to Central Lincolnshire Joint Planning Unit to assist with determining, in principle, the safe sustainable quantum of development.

This work has indicated the extent of land raising that can be achieved without significantly impacting on third parties, when considering breaches in either the Fossdyke or Witham, which is deemed to be the primary flood risk. It should be noted that the criterion used to make judgements is based on there being an increase of hazard class. Where no increase of hazard class has occurred, there might still have been an increase of hazard, just not so significant as to increase the class.

The importance of maintaining the eastern breach flow route onto the site has been proven. If the eastern flow route is closed, by extending land beyond the proposed Tritton Road junction, then New Boultham will experience an increase of flood hazard category during a breach on the Witham.

As long as the eastern flow route is kept open (as existing), then the ground raising extent has no significant effect on offsite flood hazard during a Witham breach. Flood hazard may increase but not enough to increase hazard class.

The ground raising extent does have a significant and detrimental effect on offsite flood hazard during a Fossdyke breach, with increased extent producing increased negative impact.

With no compensatory ground lowering, the maximum ground raising extent that has no significant effect elsewhere during a Fossdyke breach is expected to be a little less than extent C (refer to section 3.3).

With the tip lowered to match the surrounding land, ground raising extent D has no significant effect elsewhere during a Fossdyke breach (refer to section 3.5).

With just the tip lowered, ground raising extent E has a slight impact on New Boultham during a Fossdyke breach (refer to section 3.4).

With both the tip lowered and further, extensive, land lowering by 0.5m along the main drain, ground raising extent E then has no significant effect elsewhere during a Fossdyke breach (refer to section 3.3).

The results and conclusions were discussed by the Western Growth Corridor Technical Working Group with technical representation from Taylor-Wimpey. In the absence of cost-benefit analysis against each option, an initial view was taken regarding the expected viability based on the available information. The breach modelling work shows that in principle ground raising (and hence 'more vulnerable' development) is feasible within the range extent D to extent E, with just lowering of the tip being needed to mitigate the impact at the lesser extent but additional mitigation being needed towards the upper end of the range.

- *A significant ground raising extent (and hence 'more vulnerable' development extent) of approximately 98ha is feasible at the WGC, if mitigation is provided by lowering the existing waste tip to match the surrounding land. It might be feasible to increase the ground raising extent to approximately 117ha with additional mitigation measures involving significant ground lowering.*

This 'in principle' conclusion has been reached after considering just breaches in either the Fossdyke or Witham, which is deemed to be the primary flood risk. There remains however a significant amount of assessment work needed to determine impacts to / from the UWIDB systems and surface water, for example the WGC entirely depends on pumps evacuating surface water because the Witham and Fossdyke are high level carriers, with water levels higher than the ground level all year round.

Any further mitigation works (beyond just lowering the tip) which involve storage ponds and pumping of groundwater has the potential to interfere with water levels in the local drainage systems and may reduce the flood storage capacity of the WGC in the event of a main river breach. In any case, the complexity of the drainage system in this area and the potential impact on urban as well as rural areas will need careful consideration.

The Technical Group therefore recommend to the JPC that the determining authorities should require a developer to provide:

- *A Detailed Flood Risk Assessment and Water Level Management Plan to accompany any planning proposal at the Western Growth Corridor in line with the brief given in Sections 5.1 and 5.2 of this report.*

There are a number of physical works that both the Environment Agency and Upper Witham Internal Drainage Board would wish to see put in place to provide greater flood resilience to the site and wider area. This is needed to meet the Exception Test as required by the National Planning Policy Framework.

The Technical Group therefore further recommend to the JPC that the determining authorities should require a developer to provide:

- *Additional physical works as part of any development at the Western Growth Corridor to provide greater flood resilience to the site and the wider area, in line with the brief given in Section 5.3 of this report.*

It should be noted that the Upper Witham Internal Drainage Board cannot recommend any development in the floodplain, in principle, and its objection to the development as a whole will be sustained on that principle alone. It will be up to the developer and the planning authority to determine if development is required on floodplain.

5.0 Further work

A Detailed Flood Risk Assessment (DFRA) will be required to accompany a planning application for the site. The Technical Working Group recommends that a Water Level Management Plan (WLMP) should form part of the DFRA, detailing exactly how water levels in the channels and groundwater behaves in the existing condition and how this will be managed both during and post- development. A brief for the DFRA and WLMP is given in Sections 5.1 and 5.2.

In addition to providing a DFRA with WLMP, the Exception Test will need to be passed as prescribed by the National Planning Policy Framework:

'It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a Strategic Flood Risk Assessment where one has been prepared.'

To assist with the Exception Test, the Technical Working Group has provided a list of flood resilience measures that a developer should address to increase resilience to the development and provide flood risk mitigation to the wider community. It is expected that the need for the further flood resilience measures will be clearly demonstrated in the DFRA and WLMP.

5.1. Brief for DFRA and WLMP in line with Extent D

The preliminary breach modelling work undertaken by the Technical Working Group and detailed in this report provides a starting point for a DFRA. Further work is needed to support development in line with Extent D:

1. General requirements for DFRA and WLMP

The Detailed Flood Risk Assessment and Water Level Management Plan should consider all potential flood sources including:

- Environment Agency watercourses (including the River Till etc.).
- Environment Agency flood banks (including the River Till etc.).
- UWIDB watercourses.
- UWIDB flood banks.
- UWIDB pumping stations and catchments.
- Third party flood banks.
- Riparian water courses.
- Hartsholme Lake (refer to Appendix C for panel engineers comments).
- The River Trent (this should be considered however, as previously advised, this can be a 'light touch' approach).
- Surface water.

2. Flood risk model improvements

Consult UWIDB and add culverts that may contribute to flooding that have not been included in the Environment Agency model so far (e.g. the culvert that runs from the university to the main drain on Coulson Road).

Any proposed changes to Decoy and Fen Lane pumping station will need to be demonstrated within the model.

Show the impact of increased flows through the site if sewage from the site is treated at Skellingthorpe sewage treatment works.

Consider the effect of WGC development on other Lincoln watercourses. This may best be done by extending the relevant parts of the Environment Agency model to include the IDB drains as part of the Water Level Management Plan.

The work of WGC-TWG has shown that it is critical to maintain the eastern flow route on to the WGC site to prevent increased flood hazard to Boultham. Once the masterplan has been produced, this point should be proven by including the commercial buildings and highway / railway crossing into the breach model. It is expected that commercial buildings will be represented as 300mm raised stubs with increased Manning's n.

Determine the optimum use for Junction Sluice on the UWIDB Main Drain in the post development scenario.

Establish the number of houses affected by an increase of flood hazard class for each scenario run.

3. Sensitivity testing

Additional breach modelling work is required to:

(i) Test the effect of the latest climate change estimates. The standard test for climate change is based on estimates from 2002 as per PPS25. More recent estimations have been made (2009). Although the later estimates have not yet been adopted as a standard, sensitivity testing should be undertaken to record the effect. Climate Change should be applied to the fluvial flows and sea level as boundary condition.

(ii) Test the effect of having all UWIDB pumps off.

(iii) Test summer/winter UWIDB water levels. The IDB raises the water level to 3mAOD (an increase of approx. 1m) during the summer months to satisfy abstraction demand for irrigation.

(iv) Demonstrate the effect on normal operating regimes (summer and winter) and main river breach scenario of all flood resilience measures proposed as part of the development (refer to Section 5.3 for details of flood resilience measures).

(v) Establish the number of houses affected by an increase of flood hazard class.

The development does not necessarily have to be designed for the worst result under sensitivity testing. It is for the planning authority to decide what level of risk is acceptable and what level of risk requires mitigation.

4. Establish the 1 in 20 annual probability functional floodplain

The model has been re-run by the Environment Agency without breaches to establish the functional floodplain. There should be no development in this zone.

At this return period, water flows are likely to be beyond the IDB pump capacity, so overflow between pumped areas may occur. The modelling work undertaken by WGC-TWG took some account of this effect by adjusting flows accordingly. This should be considered as part of any further modelling work.

A 9m easement will also apply to all watercourses.

5. Additional breach analysis

It is understood that there is a raised bank protecting land to the south of Boultham Catchwater, at the eastern side of the WGC (near Westwood Drive). This risk will need to be determined and managed. It may be appropriate to raise a strip of land along this bank.

The breach risk from Hartsholme Lake should be considered and the appropriateness of the breach flow corridor demonstrated. The existing Hartsholme Lake inundation maps are based on an extremely conservative hydrological analysis. It would be prudent to carry out further dam-break analysis using realistic parameters.

6. Review of flood defences

Produce a comprehensive map detailing ownership / responsibility / level of protection of all flood risk assets protecting the site, including any additional relevant information (for example, the railway line along the Fossdyke right bank is subject to the Great Northern Railway Act 1848 which stipulates the standard of protection to be provided).

7. Free movement of fish/eels

Consider fish and eel regulations on any proposed mitigation / resilience works.

8. Surface water drainage strategy

Understand surface water overland flow routes to and from the development with particular attention given to the interaction of flow routes with watercourses and the Hartsholme Lake system.

It is expected that a sustainable solution to surface water drainage will be sought, to minimise the use of pumping, therefore source control should significantly feature in the drainage strategy.

If attenuation storage is proposed in the floodplain then this will need to be proven capable during a flood. There must still be sufficient capacity available to accept runoff as per national and local SUDS standards. Flood water must not compromise the site's ability to drain, particularly given the Coulson Road pumping station will stop pumping when the River Witham is high.

The drainage strategy should be tested under both summer and winter IDB water levels.

There are at least 2 drains that cross land south of the catchwater (near Westwood Drive and Oak Farm Hall). This drainage route should be maintained.

The Water Level Management Plan should demonstrate how drainage operates across the site in combination with the surrounding watercourses and how drainage will be maintained during the development phase and within the proposed new development.

5.2. Brief for additional work needed as part of the DFRA and WLMP when considering Extent E

The Technical Working Group has concerns that any additional flood storage, gained through ground lowering below the existing level, can be kept water free, such that all of the assumed storage volume is available at the time that it's needed.

There are concerns over the use of pumping to maintain the storage volume in a lowered area. Pumping groundwater from the lowered areas would inevitably pump water out of most of the WGC site. Pumping 24/7 does not seem to be a sustainable solution. If the UWIDB system is able to manage the additional continuous load, then a commuted sum would likely be needed to cover the ongoing additional expense.

Consequently the following will need consideration in addition to that discussed in Section 5.1.

- Long term groundwater monitoring is required, commencing as soon as possible.
- The Water Level Management Plan must demonstrate that any ground lowering scheme will work under normal conditions and flood conditions with account of the surface water drainage strategy and sensitivity testing.

5.3. Flood resilience measures

There are a number of physical works that both the Environment Agency and UWIDB would wish to see put in place to provide greater flood resilience to the site and wider area. These are required due to the increased impact of flooding in the post development scenario and are applicable for both Extent D and Extent E.

1. Works connected with Coulson Road Pumping Station

1.1 The pumping station has two pumps (each with capacity 0.67cumecs) but was constructed with capacity for a third to deal with any future development in the catchment. A third pump of 0.67cumecs capacity will need to be installed as part of this development.

1.2 With increased development upstream, the pumping station will be more prone to blockage from debris. An automated weedscreen cleaner would be required to deal with this risk to reduce flood risk to the site and the wider area.

1.3 There is a redundant culvert under the River Witham at Coulson Road, which allowed the Main Drain to discharge direct to Great Gowts Drain on the right bank of the Witham. This was blocked some time ago, however its use may provide a more sustainable gravity discharge at lower flows. The DFRA should consider re-opening / replacing this culvert and installing automated penstocks at either end to close the culvert during higher flows and thus divert water to the pumping station. Works would be required to Great Gowts Drain to receive the culvert. This should provide a more sustainable means of draining the site and would also have benefits to the wider area. Increased base flows in Great Gowts Drain would provide improvements in water quality downstream, especially during the summer and for lower reaches where Canwick sewer treatment works discharges.

1.4 Consider whether the existing culvert under Coulson Road is large enough and upgrade if required.

2. Works connected with Pyewipe Pumping Station

2.1 Vehicular access to Pyewipe pumping station will be required through the site and over the railway line. Current access is via the bank top of the Fossdyke Canal though this cannot be guaranteed and would not be possible in the event of a breach. Alternative vehicular access through the site would provide greater resilience, reducing risk to the site and wider area.

2.2 With increased development upstream the pumping station will be more prone to blockage from debris. An automated weedscreen cleaner would be required to deal with this risk, reducing the flood risk to the site and wider area.

3. Floodplain Compartmentalisation

3.1 There are a number of siphons / culverts across or adjacent to the WGC site that currently allow the spread of floodwater onto or from the site. These flow routes should be closed off through the installation of penstocks to compartmentalise the floodplain, resulting in increased flood resilience to the site and the wider area. This includes:

- The culvert under Coulson Road from the Main Drain to the pumping station.
- The culvert under the Fossdyke Canal connecting Pyewipe pumping station with the UWIDB system to the north of the canal.
- The culvert under Burton Catchwater Drain immediately upstream of the Pyewipe culvert.
- The culvert under Boultham Catchwater outfall.
- The Culvert under Pike Drain outfall.
- The culvert from the university to Coulson Road.

3.2 Water levels in the main rivers around the site are relatively flat. A failure in any of the raised defences would lead to significant volumes of water entering the floodplain. A series of pointing doors will be required at each open outfall to prevent backflow and significantly reduce the volume of water that can flow though potential breaches on certain main rivers. Pointing doors are required at the outfalls of the following watercourses:

- Boultham Catchwater Drain to the River Witham
- Burton Catchwater Drain to the Fossdyke Canal

3.3 It will need to be shown that the proposed compartmentalisation has no impact on flood risk elsewhere as part of the DFRA and WLMP.

4. Other Resilience Measures

4.1 The embankments of the Boultham Catchwater should be incorporated into any development platform, such that they are no longer simple raised embankments but

are part of a wider development platform and maintained as part of the development, e.g. as public open spaces, whilst maintaining 9m byelaw distance for access.

4.2 Include a controlled overspill from the Boultham Catchwater as part of the Hartsholme reservoir overflow arrangement. This will reduce the likelihood of a breach in other (downstream) reaches of the watercourse thus reducing risk to the site and the wider area. It would also reduce / remove the required maintenance expenditure provided by the Environment Agency, saving money for use in the wider area.

4.3 Installation of telemetry on key watercourses to assist with flood monitoring and warning.

4.4 Installation of a screen on the outlet from Hartsholme Lake to reduce the risk of blockage of the overflow culvert which is the most likely trigger for a breach of the reservoir embankment.

4.5 Taking ownership of and maintaining land to the north of Skellinghthorpe Road, where the downstream face of Hartsholme Lake dam is located, would enable effective surveillance for the early signs of dam failure and provide easy access for repair.

5. Cost recovery for any additional pumping including sewage discharge.

Appendix A – Summary of watercourses affecting the site

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Project: Western Growth Corridor – Flood Risk Mitigation
Document: Summary sheet of watercourses affecting the WGC
Version: 3.0
Date: 17th May 2013

Watercourse	Model	Defences	Comment
Boultham Catchwater (EA)	InfoWorks	Less than 100 year in places. EA response to FRA says 50 year at present and 10 year future for whole of Lincoln.	Overtopping/breach affects Lincoln (Coulson Road PS/Boultham PS/Pyewipe PS including WGC) Controlled overflow at Skellingthorpe discharges into Skellingthorpe pump drain via cliftons drain
Boultham Pump Drain (UWIDB)	Coarse InfoWorks model	EA response to FRA says 50 year at present and 10 year future for whole of Lincoln.	Water is pumped out at Boultham PS and Coulson PS into River Witham. No gravity outfall. Connection into Pyewipe Pumped area. This is the discharge for part of WGC.
Burton Catchwater (EA)	InfoWorks	EA response to FRA says 50 year at present and 10 year future for whole of Lincoln.	Receives pumped water from Burton PS. And Carholme Dyke discharges into this watercourse Overtopping/breach affects Lincoln (Burton PS/Pyewipe PS including WGC)
Burton Pump Drains (UWIDB)		EA response to FRA says 50 year at present and 10 year future for whole of Lincoln.	Receives overflow from Thorpe PS, Broxholme PS and Ingleby PS. Water is pumped out at Burton PS into Burton Catchwater. No gravity outfall. Connection into Pyewipe Pumped area.

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Fossdyke Canal (EA)	InfoWorks	100 year (EA NaFRA). 100year +cc with washlands. EA response to FRA says 50 year at present and 10 year future for whole of Lincoln.	Receives water from River Till, Torksey PS and Burton Catchwater and pumped water from Oxpasture PS and Saxilby PS and Pyewipe PS and Drinsey Nook PS (Trent Valley IDB). Overtopping/breach affects Lincoln (Coulson Road PS/Boultham PS/Pyewipe PS/Burton PS etc including WGC).
Hartsholme Lake / Prial Drain (Riparian)			Discharges into Boultham Catchwater
Skellingthorpe Pump Drain (UWIDB)	Coarse InfoWorks model	100 year (EA NaFRA). 100year +cc with washlands. EA response to FRA says 50 year at present and 10 year future for whole of Lincoln.	Water is pumped out at Pyewipe PS via Junction drain into Fossdyke Navigation. No gravity outfall, connection into Coulson Road PS/Boultham PS Pumped area. Receives pumped water from watercourses in the Fen Lane and Decoy PS catchments. Receives overflow from Saxilby PS and Burton PS Could receive overflow from Boultham/Coulson area. This is the discharge for part of WGC .

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Till (EA)	InfoWorks	EA response to FRA says 50 year at present and 10 year future for whole of Lincoln.	Receives water pumped from Thorpe PS (via Cricket Till), Broxholme PS and Ingleby PS.
Trent (EA)	Breach analysis SFRA.	Tidal Trent flood cell is Spaldford, with 1 in 50 year SoP. EA response to FRA says 50 year at present and 10 year future for whole of Lincoln.	SFRA breach modelling only shows flooding at site during a 200 year tidal event of two cycles and then less than fluvial event. Overtopping/breach can affect valley to Lincoln, Pyewipe pumped area etc including WGC
Witham (EA)	InfoWorks	100 year (EA NaFRA). 100year +cc with washlands. EA response to FRA says 50 year at present and 10 year future for whole of Lincoln.	Overtopping/breach affects Lincoln (Coulson Road PS/Boultham PS/Pyewipe PS including WGC)
Junction Drain (UWIDB)	No Model Available at present	unknown	Connection between Skellingthorpe Pump Drain to Pyewipe PS
Fossdyke Delph (UWIDB)	No Model Available at present	unknown	Connection between University site, Beevor Street area water is pumped out at Pyewipe PS, overflow into WGC area
Skewbridge Balancing Pond (UWIDB)	No Model Available at present	unknown	Constructed to allow development in the Tritton Road area and lies off Boultham Pump Drain that overflows into the WGC area.
Riparian Pipe system/culvert St Marks	No Model Available at present	unknown	Connection between Fossdyke Delph and Boultham Pump drain

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Pike Drain (UWIDB)	No Model Available at present	unknown	Overflow into Boultham Pump Drain Pumped System
Decoy PS System (UWIDB)	No Model Available at present	unknown	There are 2 Board maintained watercourses in this system and a number of riparian systems that serve land in the WGC area.
Fen Lane PS System (UWIDB)	No Model Available at present	unknown	There are 2 Board maintained watercourses in this system and a number of riparian systems that is is served by the pump.

Note from Upper Witham Internal Drainage Board:

Please note that the Pyewipe PS was the first PS constructed by the Board to serve Lincoln. It is in the area that could allow all the drains in the city to flow to this point. The lowest lying land (agricultural) is served by Fen Lane & Decoy Pumping stations, Decoy being in the centre of the proposed WGC development.

WGC lies in the lowest area of land upstream of Lincoln, all catchments upstream whether pumped or gravity must be considered as they could have an influence on the site, particularly the River Till system to Gainsborough, as witnessed in 2007.

Potential works at the site to protect the WGC area could affect or influence those pumped catchments under the control of the Board and land immediately upstream.

Please note that the Pyewipe PS was the first PS constructed by the Board to serve Lincoln. This is the station that would serve the majority of the WGC, however there are areas that would naturally discharge to the Board's Coulson Road PS. The Pyewipe PS is in the area that could allow all the drains in the city to flow to this point. In addition water can flow into this area from a number of the pumping station catchments that are under the control of the Board from as far afield as Gainsborough in the north, Harby and Saxilby in the west, Thorpe on the Hill in the South and, of course Lincoln in the east. The area does not have a gravity discharge and some of the area is served by a dual pumping system. The lowest lying land (mainly agricultural) is served by Fen Lane & Decoy Pumping stations, Decoy being in the centre of the proposed WGC development.

WGC lies in the lowest area of land upstream of Lincoln, all catchments upstream whether pumped or gravity must be considered as they could have an influence on the site, particularly the River Till system to Gainsborough, as witnessed in 2007.

Potential works at the site to protect the WGC area could affect or influence those pumped catchments under the control of the Board and land immediately upstream.

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There are in excess of 50 watercourses in the various catchments that could contribute to the volume of water in the WGC area. Some are tributaries of the watercourses mentioned above. To assist in the explanation of the complexity in the watercourse system a description of the pumping station operation follows. All those stations listed can contribute to the volume in the WGC should failure occur or if the storm event is such that the station is overwhelmed:

Boultham/Coulson Road

The catchment is largely urban. The two pumping stations, Boultham and Coulson Road, pump out of the same drain but work independently on their own control rods. The link to the Pyewipe pumped area normally only allows water out of the Boultham/Coulson Road pumped area, via two flaps but there is a penstock and structure that could allow the water to flow in the opposite direction.

An automatic cut out stops the Coulson Road pumps when the water level in the River Witham reaches 5.6m A.O.D.(N).

Pyewipe

Pyewipe Pumping Station retains three old Gwynnes centrifugal pumps driven by Ruston diesel engines, all in working order. In 1979 half their capacity was replaced by an automatic electric pump and in 1993 the other half was replaced. The diesels are retained as a standby system. A link into the Boultham/Coulson Road pumped area is available via a penstock and there is an ancient cast iron syphon under the Fossdyke Navigation links with the Burton pumped area

Vehicle access to this site is along the bank of the Fossdyke Canal although the Board retains pedestrian access from the WGC site. It is possible that at certain times this station may not be safe to visit.

Fen Lane / Decoy.

Within the Pyewipe pumped area lies the lower secondary pumped area of Fen Lane/Decoy. These two archemedian screw pumping stations are located on either side of the Main Drain which they pump into, with syphon underneath linking them.

Saxilby.

Saxilby Pumping Station drains an area south of the Fossdyke Navigation adjacent to the Pyewipe pumped area but at a higher retained level. A flap provides a one way link to Pyewipe

Burton.

Burton is a main pumping station north of the Fossdyke Navigation. It is linked to the Pyewipe area by the syphon under the Fossdyke.

An open channel links into the Broxholme pumped area

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Broxholme.

Broxholme pumping station drains an area east of the River Till, west of Burton. A syphon under the River Till at the Environment Agency Till Washland site can link to the Ingleby pump area.

Ingleby.

This pumping station is linked to Broxholme (and into Burton) by the syphon under the River Till at the Environment Agency Till Washland site

Both Ingleby and Broxholme Pumping Stations assist the Environment Agency with their washland management.

Thorpe.

Thorpe Pumping Station retains water at a higher level than Burton with a sill linking them allowing Thorpe area to spill over.

Oxpasture.

Oxpasture Pumping Station is isolated from other pumping stations. It has a relatively large capacity. There is a flood bank at Oxpasture, which if breached, could allow water from either the Oxpasture catchment and the Fossdyke canal into the Saxilby pumped system and thence to the WGC.

Appendix B – Mott MacDonald's technical report

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Lincoln Western Growth Corridor Modelling

Technical Note

April 2013

City of Lincoln Council

CITY OF Lincoln COUNCIL

Mott MacDonald

Lincoln Western Growth Corridor Modelling

Technical Note

April 2013

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Issue and revision record

Revision	Date	Originator	Checker	Approver	Description
A	30 April 2013	WJ Goh	G Morrison	R Gamble	First Issue

Contents

1 Introduction

1.1 Aims

In January 2013, RAB Consultants, as consultants to the Lincolnshire Joint Planning Unit, commissioned Mott MacDonald to undertake breach modelling and mapping to assess the possibility of developing a large plot of greenfield land in Lincoln, referred to as the Western Growth Corridor (WGC). The overall aim of this study is to improve the understanding of the effects the proposed development is likely to have on flood hazard within the Lincoln area.

1.2 Scope of Work

The scope of work is summarised as follows:

- Modify the existing Lincoln Breach Model to incorporate six options as identified by RAB, which include raising land for development and lowering land for compensatory storage within the WGC area. The six options are described in Section 2.3.2.
- Identify two breach locations which have the most significant impact on the WGC area, these were located along the River Witham and the Fossdyke Canal. The locations are shown in Figure 2.2.
- Carry out model runs for the six options with breaching at the two chosen locations during a 1% AEP (1 in 100) scenario in 2115 climate change conditions.
- Produce flood maps for each breach location and option. These are to show: maximum flood depth, velocity and hazard; depth comparison with the baseline scenario; extent comparison with the baseline scenario, and; hazard rating comparison with the baseline scenario.
- Produce a technical note summarising the work undertaken.

2 Modelling Methodology

2.1 Existing Lincoln Breach Modelling

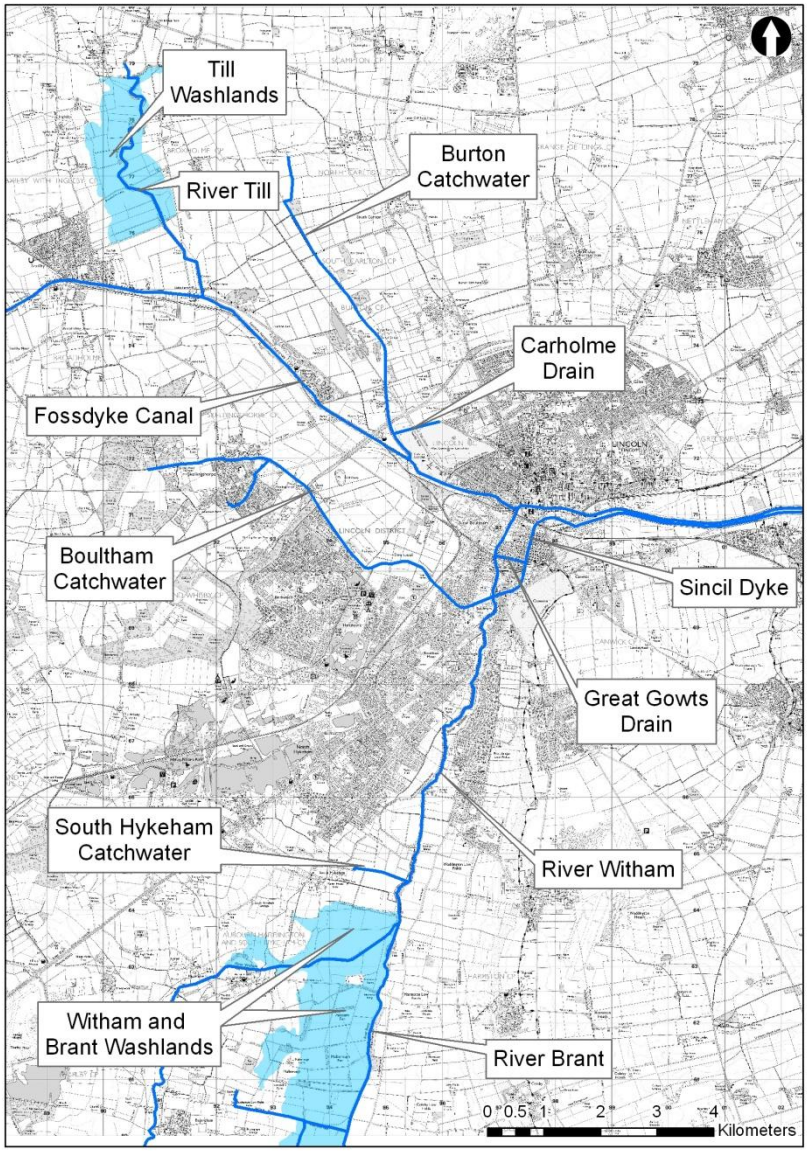
The modelling work carried out was based on the existing InfoWorks RS 1D-2D Lincoln Breach Model, commissioned by the Environment Agency in August 2012. Mott MacDonald has been involved in the design and development of this model in conjunction with the Environment Agency.

The existing model represents the major sources of flood risk to Lincoln: the Rivers Till, Brant and Witham. The model also includes a number of smaller watercourses (Figure 2.1) that join these three rivers in the vicinity of Lincoln, including:

- Fossdyke Canal;
- Burton Catchwater;
- Boultham Catchwater;
- South Hykeham Catchwater;
- Carholme Drain;
- Sincil Dyke, and
- Great Gowts Drain.

Details of the model construction can be found in Appendix A (Lincoln Breach Mapping Report, Mott MacDonald, 2013).

Figure 2.1: Lincoln Breach Model Study Area Overview



2.2 Hydrology

No modifications have been made to the underlying model hydrology used in the existing Lincoln Breach Model. Details of the model hydrology can be found in Appendix A (Lincoln Breach Mapping Report, Mott MacDonald, 2013).

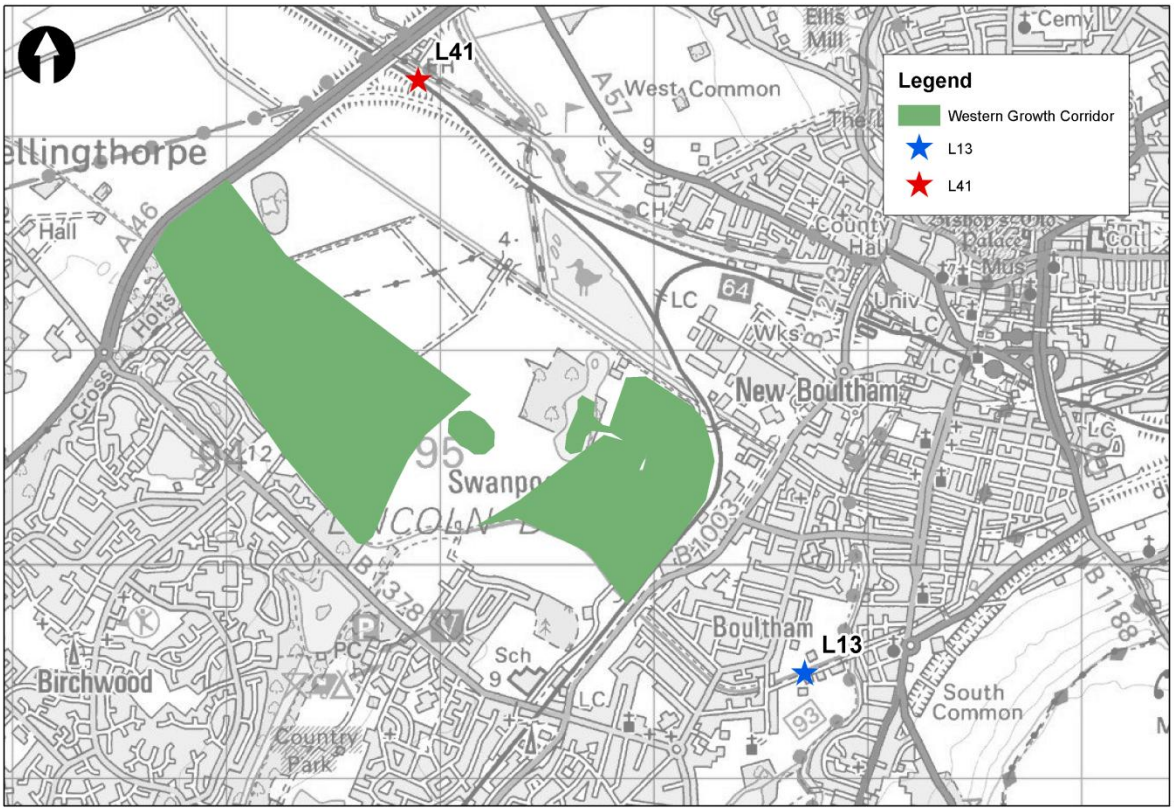
2.3 Hydraulic Modelling

2.3.1 Breach Locations

The Lincoln Breach Mapping Study (2013) produced modelled flood depths and hazard values resulting from breaching of the river embankments at a number of locations within the Lincoln area. Using these model results two breach locations were identified as having the most significant impact in the WGC area. The two chosen breach locations have been agreed with the EA.

The first breach is located at Altham Terrace (L13); where there is a simulated breach of the left bank of the Boultham Catchwater, a tributary of the River Witham. The second breach is located at Pyewipe Inn (L41); this occurs on the right bank of Fossdyke Canal. These locations are shown in Figure 2.2.

Figure 2.2: Breach Locations



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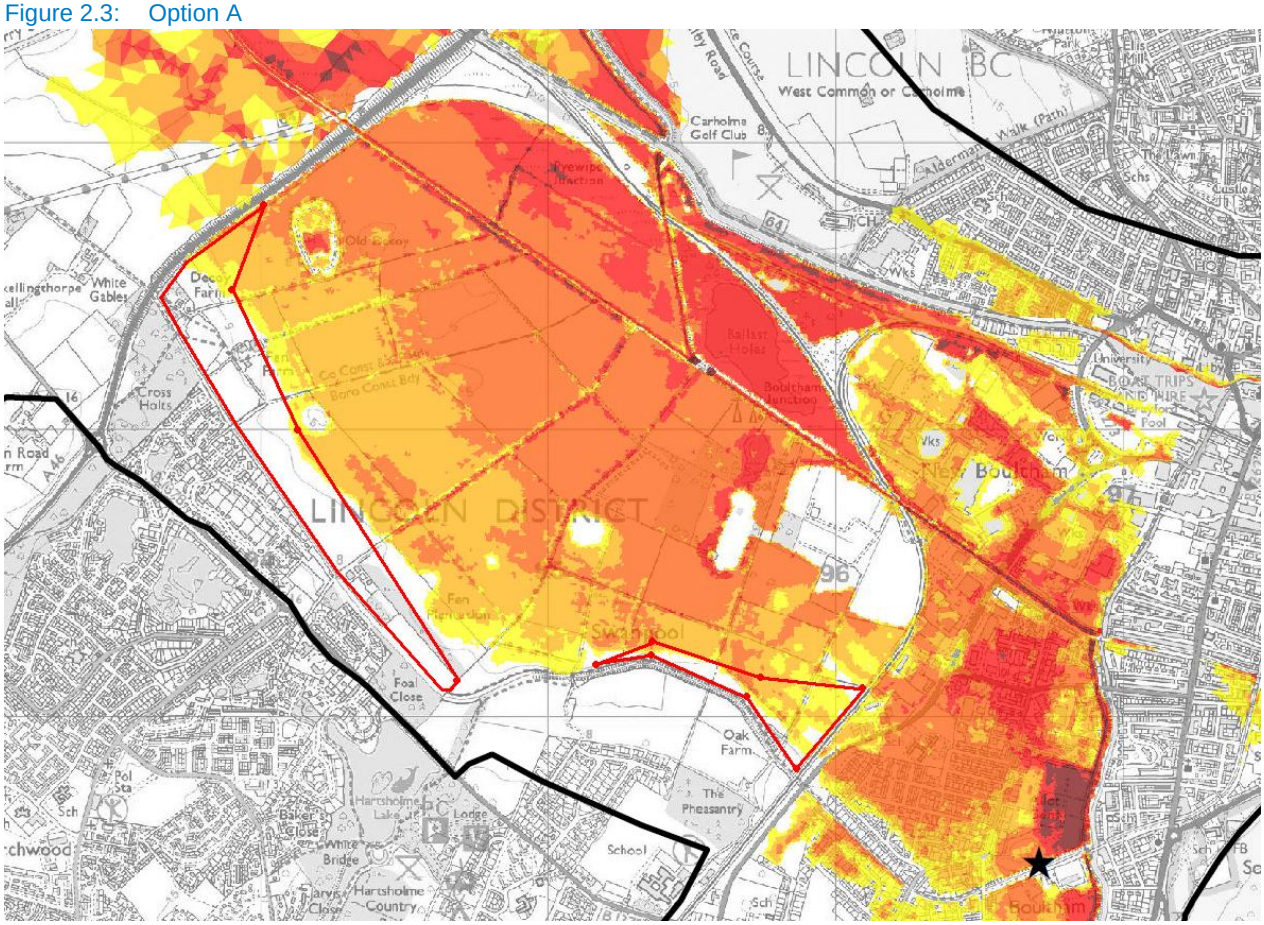
2.3.2 Proposed Development Options

The six proposed development options are discussed below.

2.3.2.1 Option A

The proposed Option A involved raising two sections of land, the extents are shown by the red lines in Figure 2.3. This option involved raising the smallest parcels of land out of all the options analysed.

Figure 2.3: Option A



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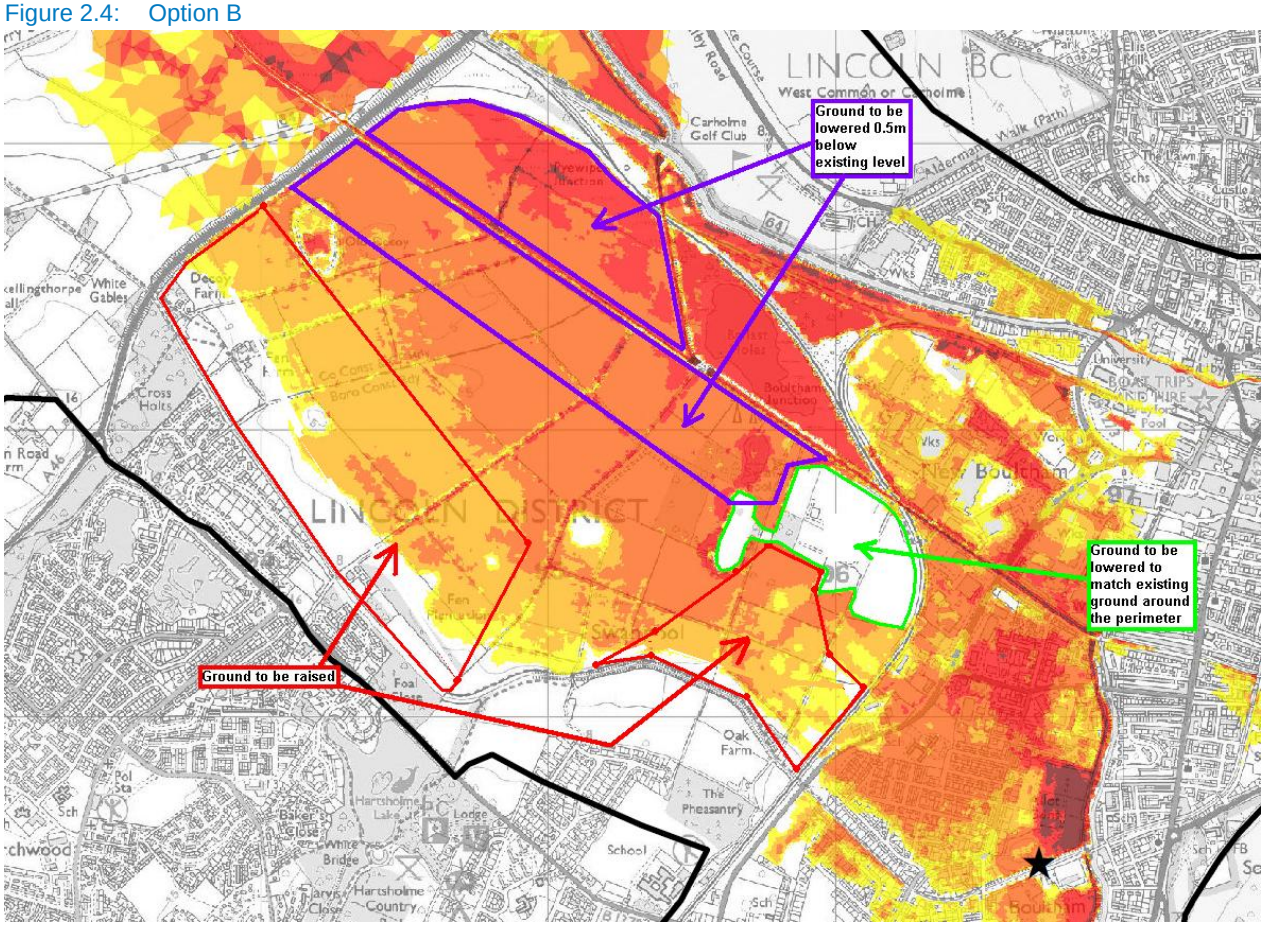
2.3.2.2 Option B

The proposed Option B has the same land parcels to be raised as Option E (see Section 2.3.2.5), but also includes lowering of three land parcels as shown outlined in green and purple in Figure 2.4. The purple areas are to be lowered to 0.5m below existing ground level, whilst the green area is to be lowered to match the surrounding ground level. The green area indicates a former landfill site that has been earmarked as part of the possible mitigation measure to reduce the impact of flooding on third parties in Lincoln. Lowering this land also improves the flow route to the north of the proposed development.

Figure 2.4: Option B



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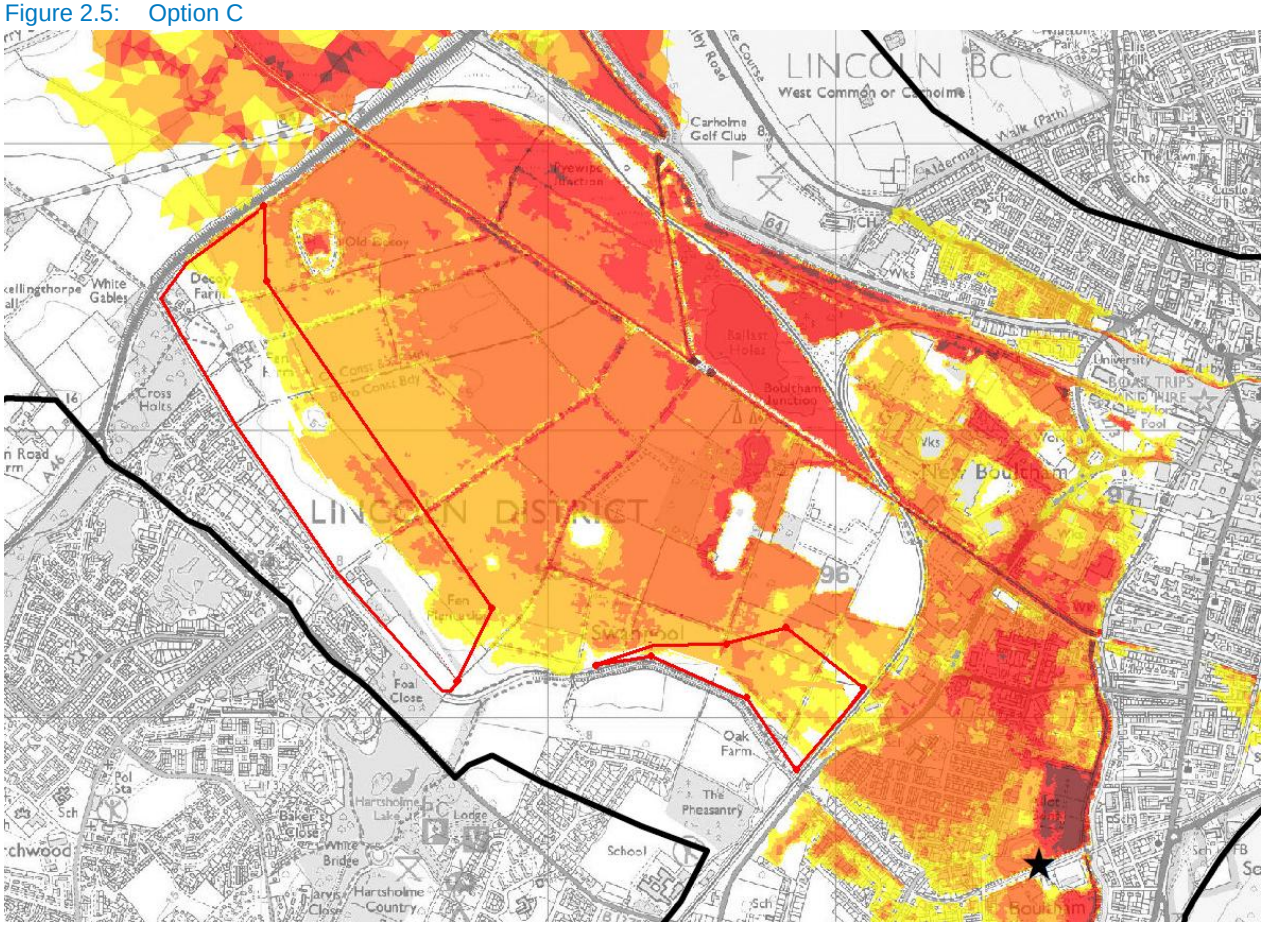
2.3.2.3 Option C

The proposed Option C involves raising two areas of land. The extents of these are shown by the red lines in Figure 2.5. The flow route across the railway line to the north of the proposed development is maintained.

Figure 2.5: Option C



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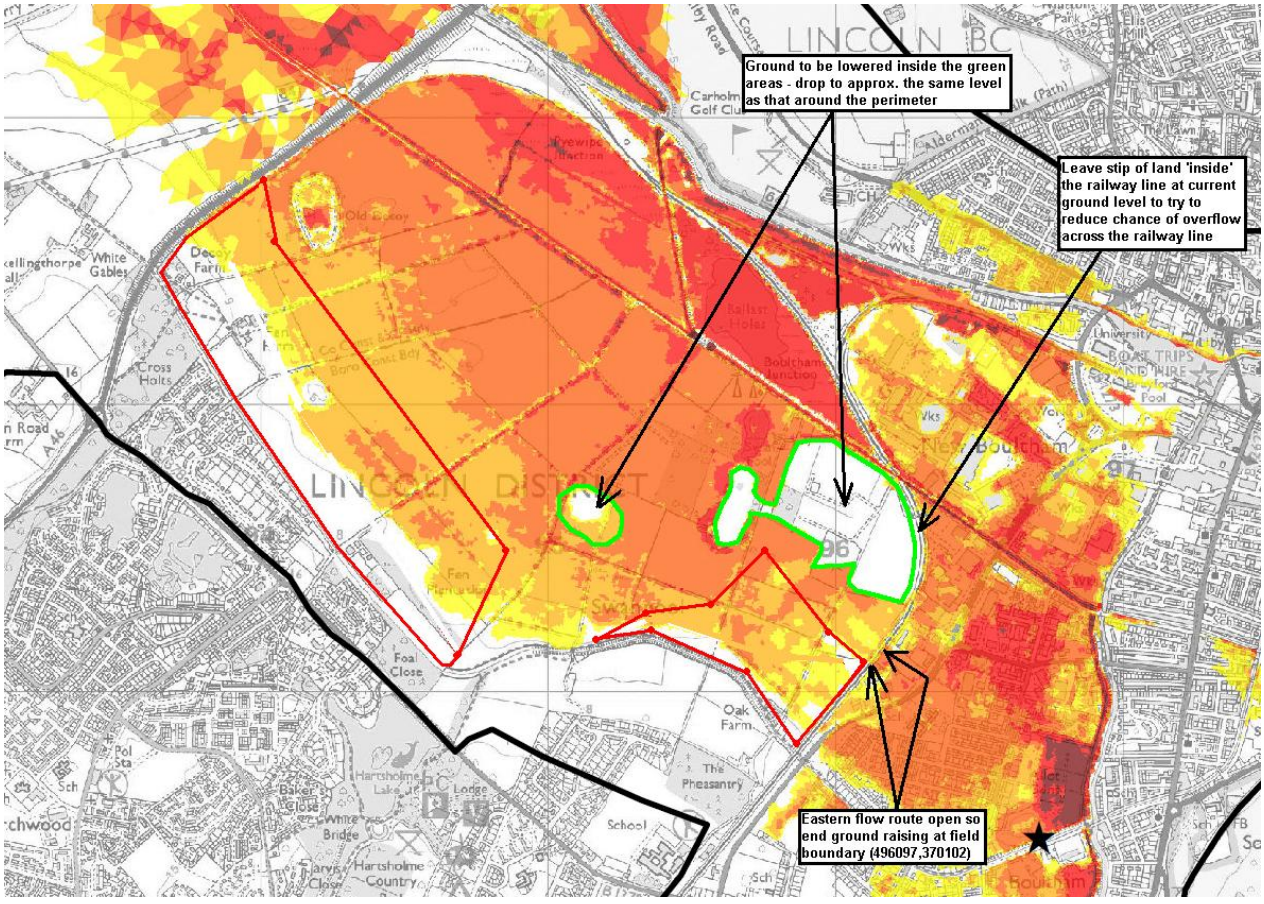
2.3.2.4 Option D

The proposed Option D extents are shown in Figure 2.6. The two areas outlined in red indicate the parcels of land to be raised for development. The two green areas are to be lowered to the surrounding ground level. The flow route to the north of the proposed development is maintained and enlarged, by the lowering of the areas outlined in green.

Figure 2.6: Option D



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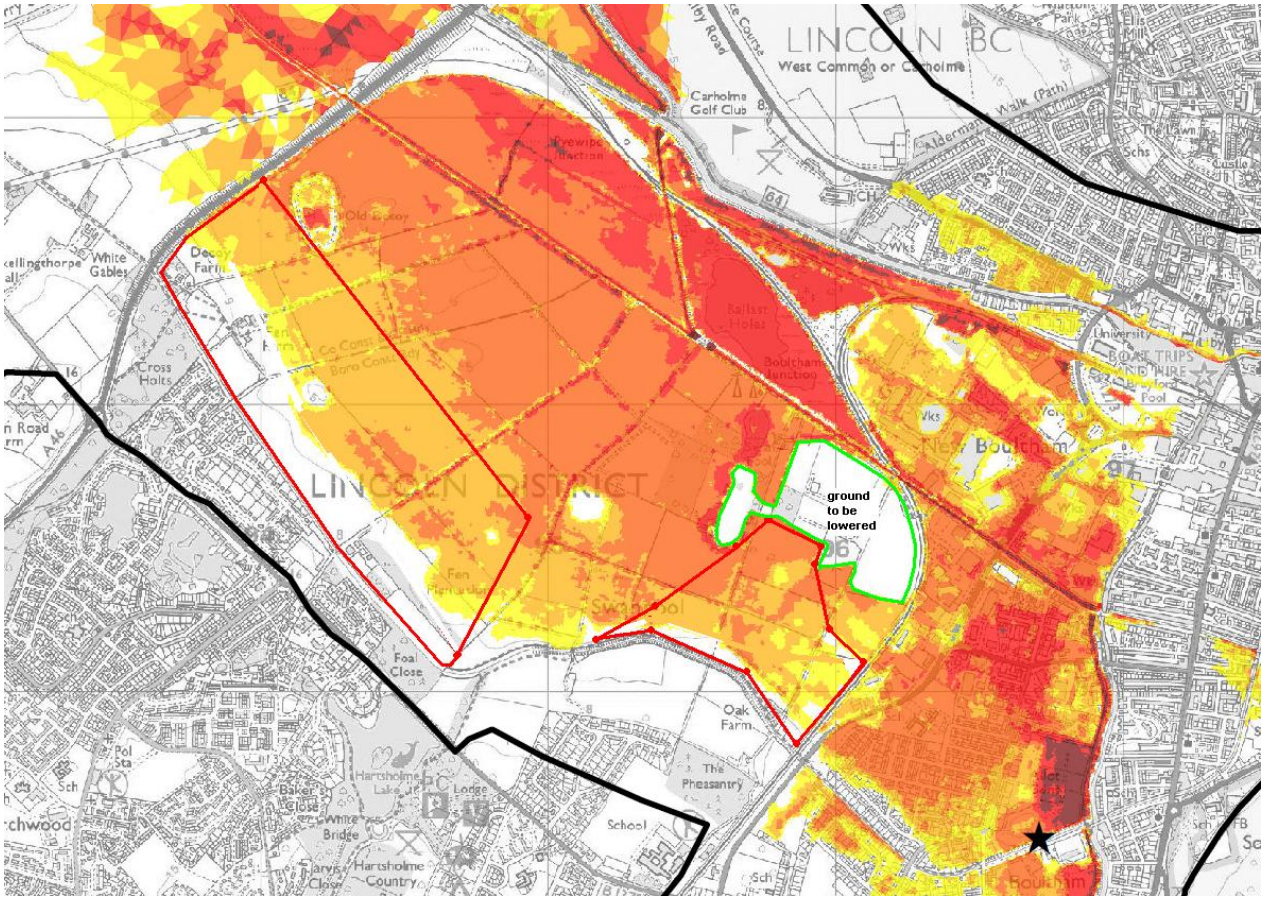
2.3.2.5 Option E

The proposed Option E extents are shown in Figure 2.7. The two areas outlined in red indicate the parcels of land to be raised. The green area indicates the parcel of land to be lowered, creating a flow route to the north of the proposed development.

Figure 2.7: Option E



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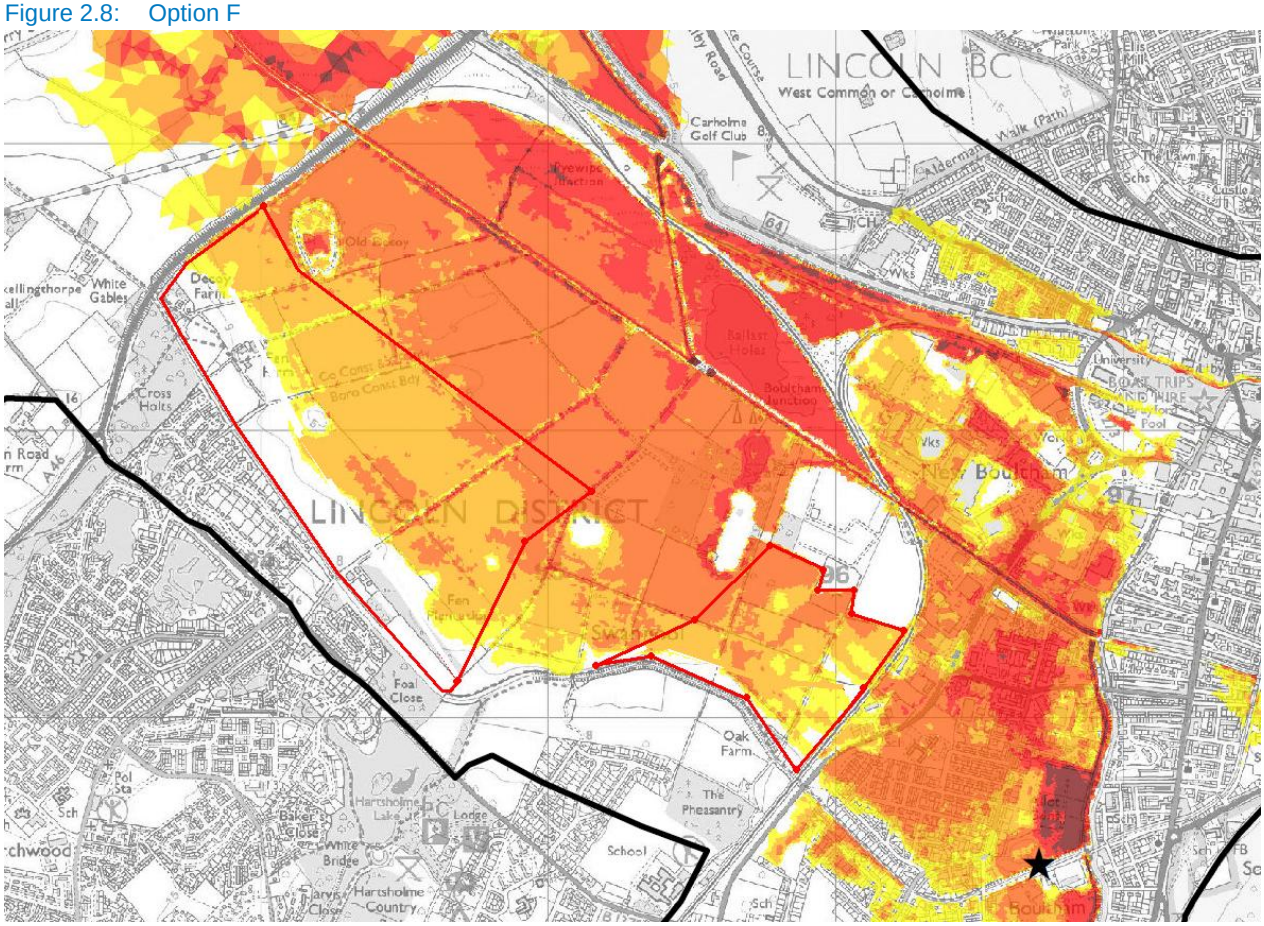
2.3.2.6 Option F

This option involves raising two areas of land, the largest areas considered within this study. The proposed Option F extents are shown in Figure 2.8 outlined in red. There are no other proposed ground profiling measures considered in this option.

Figure 2.8: Option F



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3 Model Results

3.1 Summary of Results

Table 3.1 to Table 3.3 below summarise the results from the breach modelling and mapping for the six options described in Section 2. The maximum depth, velocity and hazard maps, depth comparison, extent comparison, and hazard comparison maps are collated in Appendix B.

The summary tables are as follows:

- Table 3.1 summarises the impacts on flood extents
- Table 3.2 summarises the impacts on flood depths
- Table 3.3 summarises the impacts on hazard categories

Table 3.1: Summary of Impacts on Flood Extents

Proposed Option	Description for Breach L13	Description for Breach L41	Relevant Appendix
Option A	Minor increases in flood extents are observed near the Fossdyke Canal in the New Boultham area of Lincoln.	No significant impacts are observed.	Appendix B.1
Option B	No significant impacts are observed.	No significant impacts are observed.	Appendix B.2
Option C	Minor increases in flood extents are observed in the Skellingthorpe area. No significant impacts are observed in the New Boultham area of Lincoln.	Minor increases in flood extents are observed in the Skellingthorpe area. Increase in flood extents are observed for properties in the New Boultham area of Lincoln along Main Drain.	Appendix B.3
Option D	Minor increases in flood extents are observed in the Skellingthorpe area. No significant impacts are observed in the New Boultham area of Lincoln.	Minor increases in flood extents are observed in the Skellingthorpe area. No significant impacts are observed in the New Boultham area of Lincoln.	Appendix B.4
Option E	Minor increases in flood extents are observed in the Skellingthorpe area. No significant impacts are observed in the New Boultham area of Lincoln.	Minor increases in flood extents are observed in the Skellingthorpe area. Increase in flood extents are observed for properties in the New Boultham area of Lincoln along Main Drain.	Appendix B.5
Option F	Increase in flood extents observed in the Boultham and New Boultham areas of Lincoln. There are also increases in flood extents are observed in the Skellingthorpe area.	Increase in flood extents in the areas close to Main Drain in Lincoln. There are also significant increases in flood extents in the Skellingthorpe area.	Appendix B.6

Source: Mott MacDonald, 2013

Table 3.2: Summary of Impacts on Flood Depths

Proposed Option	Description for Breach L13	Description for Breach L41	Relevant Appendix
Option A	Increase in flood depth is observed on the right bank of Fossdyke Canal in the New Boultham area of Lincoln. An increase in flood depth of up to 0.25m is expected in this area	No significant impacts are observed.	Appendix B.1
Option B	Increase in flood depths by more than 0.25m is observed in the areas with ground level lowered as part of the proposed mitigation measures. No significant impacts are observed in the New Boultham area of Lincoln.	Increase in flood depths by more than 0.25m is observed in the areas with ground level lowered as part of the proposed mitigation measures. No significant impacts are observed in the New Boultham area of Lincoln.	Appendix B.2
Option C	Increase in flood depth of up to 0.25m is expected in the WGC area except the proposed land raising for Option C. Increase in flood depth is also observed on the right bank of Fossdyke Canal near Skellingthorpe.	Increase in flood depth of up to 0.25m is expected in the WGC area except the proposed land raising for Option C. There is an increase in flood depth of up to 0.25m for properties in the New Boultham area of Lincoln along Main Drain. Increase in flood depth is also observed on the right bank of Fossdyke Canal near Skellingthorpe.	Appendix B.3
Option D	Increase in flood depths by more than 0.25m is observed in the areas with ground level lowered as part of the proposed mitigation measures. No significant impacts are observed in the New Boultham area of Lincoln.	Increase in flood depths by more than 0.25m is observed in the areas with ground level lowered as part of the proposed mitigation measures. No significant impacts are observed in the New Boultham area of Lincoln.	Appendix B.4
Option E	Increase in flood depths by more than 0.25m is observed in the areas with ground level lowered as part of the proposed mitigation measures. There is also an increase in flood depth of up to 0.25m in the WGC area and on the right bank of Fossdyke Canal near Skellingthorpe. No significant impacts are observed in the New Boultham area of Lincoln.	Increase in flood depths by more than 0.25m is observed in the areas with ground level lowered as part of the proposed mitigation measures. There is an increase in flood depth of up to 0.25m for properties in the New Boultham area of Lincoln along Main Drain. There is also an increase in flood depth of up to 0.25m in the WGC area and on the right bank of Fossdyke Canal near Skellingthorpe.	Appendix B.5
Option F	There is an increase in flood depth of up to 0.25m in the WGC area and on the right bank of Fossdyke Canal near Skellingthorpe. There is an increase in flood depth of up to 0.25m for properties in the Boultham and New Boultham areas of Lincoln. There is also an increase in flood depth by more than 0.25m for an area near Brayford Pool.	There is an increase in flood depth of up to 0.25m in the WGC area and on the right bank of Fossdyke Canal near Skellingthorpe. There is an increase in flood depth of up to 0.25m for properties in the New Boultham area close to Main Drain. There is also an increase in flood depth by more than 0.25m for an area in New Boultham south of Main Drain and north of the A46 near Skellingthorpe.	Appendix B.6

Source: Mott MacDonald, 2013

Table 3.3: Summary of Impacts on Hazard Categories

Proposed Option	Description for Breach L13	Description for Breach L41	Relevant Appendix
Option A	Increase in hazard category is observed near Brayford Pool in Lincoln.	Increase in hazard categories to the north of the proposed land raising.	Appendix B.1
Option B	Increase in hazard category is observed in the areas where ground level has been lowered as part of the proposed mitigation measures. No significant impacts are observed in the New Boultham area of Lincoln.	Increase in hazard category is observed in the areas where ground level has been lowered as part of the proposed mitigation measures. No significant impacts are observed in the New Boultham area of Lincoln.	Appendix B.2
Option C	Increases in hazard category to the north of the proposed land raising and in the Skellingthorpe area are observed.	Increase in hazard category to the north of the proposed land raising is observed. There is also an increase in hazard category for properties in the New Boultham area of Lincoln along Main Drain.	Appendix B.3
Option D	Increase in hazard category is observed in the areas with ground level lowered as part of the proposed mitigation measures. No significant impacts are observed in the New Boultham area of Lincoln.	Increase in hazard category is observed in the areas with ground level lowered as part of the proposed mitigation measures. No significant impacts are observed in the New Boultham area of Lincoln.	Appendix B.4
Option E	Increase in hazard category is observed in the areas with ground level lowered as part of the proposed mitigation measures. No significant impacts are observed in the New Boultham area of Lincoln.	Increase in hazard category is observed in the areas with ground level lowered as part of the proposed mitigation measures. There is also an increase in hazard category for properties in the New Boultham area of Lincoln along Main Drain.	Appendix B.5
Option F	Increase in hazard category is observed in the Boultham and New Boultham areas of Lincoln. There is an increase in hazard category in the Skellingthorpe area. There is also an increase in hazard category in the land area in between the two raised land parcels as part of Option F.	Increase in hazard category is observed in the Boultham area of Lincoln, within the vicinity of Main Drain and in the Skellingthorpe area. There is also an increase in hazard category in the area between the two raised land parcels as part of Option F.	Appendix B.6

Source: Mott MacDonald, 2013

Appendices

Appendix A. Lincoln Breach Mapping Report

Appendix B. Model Results

Notes:

- The reference on the maps to Region A, Region B etc. correspond to Option A, Option B etc.
- The baseline scenario referenced in the maps refers to the model outputs produced in the Lincoln Breach Mapping project (see Appendix A).
- The flood extent comparison maps show the baseline and proposed scheme flood depths in the left and centre map frames respectively. Although flood depths are indicated, the map frames also indicate the maximum flood extents in the respective scenarios.

B.1 Option A

B.2 Option B

B.3 Option C

B.4 Option D

B.5 Option E

B.6 Option F

Appendix C – Hartsholme Lake panel engineer's report

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HARTSHOLME LAKE – COMMENTS OF THE INSPECTING ENGINEER

- A bit of background info to the lake, including opinion on dam condition, breach risk, overtopping risk – anything we should know about?

Background

Hartsholme Lake has a normal top water level of 7.78 m OD and a surface area of about 8.7 hectares. The stated capacity is 33,000 m^3, all of which lies above the level of the lowest adjacent ground. It is therefore defined under the Reservoirs Act 1975 as a large raised reservoir. The Lake is vaguely triangular in shape with a large island near its centre and a long tail that extends south towards Swanholme Lakes

The Lake impounds flow down the Prial Drain, a tributary stream of the River Witham. Water is held back behind a 3 m high dam embankment at the north end of the Lake. The embankment has a length of about 300 m and a public highway (B1378) runs along its crest. An overflow culvert passes through the centre of the dam. Low embankments along the southeast and southwest flanks reduce the Lake footprint and these divert some local runoff around the Lake.

The reservoir was originally created in 1847 to provide drinking water to the City of Lincoln. It was in service for over 50 years but was discontinued as a water resource in 1904 following an outbreak of typhoid. Thereafter it became a public amenity and it now forms an integral part of Hartsholme Country Park.

Dam condition

The dam and the castellated wall along its upstream face in particular, has deteriorated over the years. The structure has cracked, settled and moved prompting repairs on several occasions. The most recent episode was in 2009, when a 15 m long section of the wall near the western end was in danger of toppling into the Lake. A buttress of cobble fill was dumped in front of the wall in order to stabilise the section below the waterline.

I have not visited the dam since 2010 but my conclusion following that inspection was that the dam was in reasonable condition for its age. I consider that the main dam embankment is a relatively safe structure because of the following attributes:

- It is broad, low and level
- It is composed largely of granular material
- It is capped by a surfaced public highway
- It has a relatively large freeboard
- It is regularly visited and routinely monitored.

Breach risk

The Lake is very shallow and the embankment is very broad. The hydraulic gradient is therefore very low and the presence of widely graded sands and gravels within the dam means that the embankment shoulders probably has very good self-filtering capacity. The probability of the main dam breaching through internal erosion is therefore considered to be very small. The risk increases slightly in those areas immediately alongside the overflow culvert and outlet pipework but the factors influencing continuation are such that the likelihood of erosion progressing to failure remain acceptably low.

There is a greater risk of failure with the flank embankment on the western side of the reservoir. The structure is even lower than the main dam (circa 1m high) and very narrow. The theoretical outflow from the reservoir through a breach would be less than through the main dam but would still be much greater than the capacity of the existing storm water sewer which drains the enclosed, low-lying area adjoining the western side of the Lake. In those circumstances, the area would probably fill until the water surfaces equalise on either side of the breached embankment; however, by visual inspection, few if any properties would actually be inundated.

Overtopping risk

The capacity of the overflow structure was increased in the mid-1970s in advance of construction of the Birchwood housing estate. The EA installed sensors and telemetry system at the Lake over a decade ago and actively monitor its level. There is an automated callout system in place whereby the dam is visited whenever the level rises above 8.40 m OD, so that action can be taken to lower the level. However, the operation of the overflow is vulnerable to blockage because the Lake margins are heavily wooded and the opening to the culvert is narrow and unprotected. Improvements to the arrangement have been recommended on several occasions but the Environment Agency have vetoed proposals each time.

- Thoughts on the open flow route we are setting aside to mitigate breach risk (see attached sketch).

In my opinion, this corridor would be more than sufficient.

- Any particular issues that you feel would need proving as part of a detailed FRA?

The map illustrating the "risk of flooding from reservoirs" published on the Environment Agency's website indicates widespread flooding both upstream and downstream of the Lake, however this is a little misleading. This map is an amalgam of individual reservoir inundation maps and in this case mostly reflects flooding from the EA's own River Till and River Witham Flood Washlands, rather than Hartsholme Lake itself.

The individual reservoir inundation maps for Hartsholme show two flooding scenarios arising out of breaches of the dam embankments. Copies of these maps are attached for information but please note that there are restrictions on the handling, transmission and storage should you wish to publish copies.

The first map shows that if the main dam was to fail by overtopping, then the ensuing flood wave would temporarily inundate an area of about 1.5 km^2 of farmland to the north of the reservoir. The second map shows that if the low, subsidiary embankment on the southwest flank was to fail then some properties in the Birchwood estate alongside the Lake might be at risk of shallow flooding. This outcome seems likely in extreme flood events regardless of whether or not breaching is involved.

These conclusions need to be considered in context. The maps were originally undertaken for the purposes of emergency planning (i.e. the evacuation of residents). The original analysis therefore made the assumption that the dam embankment would be overtopped by 600 mm, which lacks hydrological credibility in these circumstances. The extent of flooding is therefore very conservative and lacks realism. It would therefore be prudent to carry out further dam-break analysis using realistic parameters so as to achieve a more reliable solution.

- Any critical improvements that could be unlocked from funding that could be made available as part of a major development?

The largest threat posed by the reservoir is the release of its contents through a breach arising out of overtopping of the embankment. The most likely trigger mechanism that would lead to overtopping is the blockage of the existing overflow culvert. A significant improvement in reservoir safety would be achieved if the existing structure were to be modified to prevent this from happening. It is envisaged that a screened arrangement would be appropriate, i.e. one similar to those used by the EA in similar circumstances elsewhere.

In the event of a leak developing in the main dam embankment then the speed of its discovery and of action to remedy is crucial for a successful and economic outcome. At the moment, the land to the north of Skellingthorpe Road is not owned by CoLC and the downstream face of the dam is overgrown and not maintained. This hampers effective surveillance, however if this land was to be purchased as part of the proposed development, then there would be an opportunity to improve the situation.

Ian Carter 12/5/2013