Cambridge Biomedical Campus

Hydraulic Modelling Summary

for Cambridgeshire County Council and the Pemberton family

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Document Control

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1 Introduction

Logika Consultants Ltd ('Logika') were commissioned by Cambridgeshire County Council and the Pemberton trustees (the Landowner) to undertake hydraulic modelling with regards to an emerging proposed expansion of the Cambridge Biomedical Campus (CBC). Expansion of the existing campus (henceforth referred to as the 'Proposed Development') is proposed to the south of the existing campus (henceforth referred to as 'the Site').

1.1 Site Description

The Site is located around the southern edge of the City of Cambridge and comprises greenfield land. It is bounded to the north by the existing Cambridge Biomedical Campus and an area of residential development. Babraham Road is located to the east, and Granham's Road passes through the south eastern area of the Site. The southern boundary of the Site is formed by farmland, and the Nine Wells nature reserve is situated adjacent to the western boundary. The embanked course of the Cambridge to Great Shelford railway line passes along the western side of the Nine Wells area, approximately 100m west of the Site at the nearest point.

A drainage ditch, which receives surface water runoff from the existing Biomedical Campus, and the residential development to the north, passes alongside the northern boundary of the Site. This ditch is part of a wider local network which drains the Nine Wells area and passes through the Cambridge to Great Shelford railway embankment to discharge into Hobson's Brook. Hobson's Brook becomes Vicar's Brook approximately 1.5km to the north, which then forms a tributary of the River Cam. Hobson's Brook flows south to north and is located approximately 500m west of the Site at the closest point.

1.1.1 Development Proposal

The Proposed Development comprises construction of new healthcare services, healthcare related R&D, education, associated amenity, access, parking and green landscaping. Access links will be provided to Dame Mary Archer Way, to the north west, and Babraham Road to the east.

Two development options are presently emerging. Option 1 includes realignment of Granham's Road, to provide additional commercial space at the eastern side of the Site. Option 2 comprises development within the existing Site bounded by the existing road network.

Option 1 was simulated within the model for the 'Proposed Development' scenario, as this option featured a greater land take. Potential displacement of flood flows would be potentially greater and a smaller area would be available to provide flood risk mitigation features at the eastern boundary of the Site.

1.2 Scope of Report

The Flood Map for Planning[1] indicates that part of the Site lies within fluvial Flood Zone 3 and therefore features a high probability of flooding. Review of available Environment Agency (EA) models for the local area indicate that the Flood Map for Planning extent was produced using JFLOW software. JFLOW is used for broad-scale modelling and is not considered suitable for simulation of flood risk at a site-specific level.

As part of a previous submission, a site-specific modelling exercise was undertaken in 2016 by Peter Prett Associates (PBA)[2]. This comprised the development of a pluvial hydraulic model (using Flood Modeller Pro software) and concluded that flood risk across the Site occurred due to surface water runoff from surrounding areas.

This report provides a summary of the updated hydraulic modelling undertaken to assess potential flood risk to the current Proposed Development, and identification of potential flood risk mitigation measures to facilitate development at the Site.

The existing biomedical campus is not being assessed as part of the hydraulic modelling exercise, which relates solely to the Proposed Development. Flood risk within the existing CBC, along with appropriate mitigation measures, has previously been considered as part of Local Plan allocations and planning applications.

A high level review of surface water drainage options has been undertaken as part of this report. Although surface water drainage represents a separate issue to the potential flood risk to the Site from overland flow, mitigation measures within Proposed Development will be related. The Proposed Development represents an opportunity for sustainable management of local flood risk and improvement of water quality within Hobson's Brook.

[1] Gov.uk [February 2023], *Flood Map for Planning Service [online]*. Available from: https://flood-map-for-planning.service.gov.uk/ (Accessed 10th February 2023)

[2] Peter Brett Associates, October 2016. Extension to Bio-Medical Campus, Cambridge: Flood Modelling and Drainage Strategy Report

2 Model Development

The previous site-specific modelling study indicated that flood risk occurred due to the propagation of overland flows onto the Site from elevated greenfield land to the east and north east, rather than from fluvial sources.

Review of EA model data indicated that the local pluvial hydraulic models did not include the Site area in detail. Accordingly, a direct rainfall model was developed to assess flood risk across the Site.

This pluvial model was developed using the ESTRY-TUFLOW software package. TUFLOW was selected as it can be used to simulate both fluvial and pluvial flooding in detail. The ESTRY 1D solver would allow detailed simulation of the local drainage ditch network.

ESTRY can simulate watercourses without the need for provision of a specific hydraulic inflow, hence dry channels can be modelled without compromising model stability. In this respect it offers an advantage over a Flood Modeller Pro hydraulic model, which would require a direct inflow to be applied to a channel in order to maintain stability.

2.1.1 Scenarios

The following scenarios were developed as part of this assessment:

- **Baseline**: Site in existing condition;
- **Future Baseline**: Existing Site condition, with inclusion of local approved developments around the Site. These included the 'Wort's Causeway' residential development (between Babraham Road and Wort's Causeway) and the Cambridge South East Transport (CSET) busway embankment through Nine Wells area;
- **Proposed Development:** Simulating the 'Option 1' development layout and features from Future Baseline Scenario.

2.2 Model Naming Convention

The model was designed as part of the study of flood risk across a specific area adjacent to the Cambridge Biomedical Campus and was therefore named 'CBC1'.

2.3 Software Versions

The latest available version of TUFLOW (2020-10-AE) was used for this hydraulic modelling exercise.

2.4 Model Parameters

Model development and simulation of design flood events was undertaken using suitable parameters for direct rainfall modelling, in accordance with guidance from the TUFLOW manual[3]. All simulations were run using the double precision version TUFLOW, in accordance with standard TUFLOW practice for direct rainfall modelling.

A 4m grid resolution was specified within the 2D model, therefore all simulations were run using a 1 second 2D timestep (between $^1/_2$ and $^1/_5$ of the 2D grid cell size). The ESTRY model utilised a 0.5 second timestep, as this was equally divisible into the 2D timestep.

All design flood events were run for a duration of 30 hours, as this was considered a sufficient time period for overland flow from surrounding areas to pass through the Site.

2.5 Boundary Conditions

2.5.1 Inflows

Rainfall inputs were developed using catchment data from the FEH Web Service[4]. Catchment data upstream of national grid reference point 545500,256000 was selected, as this included the complete catchment to the north and east of the Site, and also the extent of the existing Cambridge Biomedical Campus draining to the adjacent ditch network.

FEH catchment data was used to develop rainfall event data using the ReFH2.3 model. The ReFH2.3 recommended design storm duration for the catchment was 11 hours, which was utilised for this study. The 'summer' storm season variable was utilised, as this produced a significantly higher rainfall intensity in comparison with the 'winter' season.

Rainfall events were processed for use in TUFLOW using the TUFLOW plugin within the QGIS software package. Rainfall was applied to all areas of the 2D model using 2d_rf shapefiles, in accordance with standard TUFLOW practice.

No direct inflow was specified for the ditch network, which was assumed to collect overland flow from the surrounding area.

2.5.2 Downstream Boundaries

The main downstream boundary of the 2D model was located along the course of Hobson's Brook. Following initial model runs, additional boundaries were located at strategic locations around the northern extents of the model to allow localised flow paths to exit the model and prevent unrealistic accumulation of water against the limits of the 2D model ('glass walling').

The 1D model was initially modelled with a fixed water level downstream boundary (HT), based on channel bank levels and local topography at the downstream extent of the drainage ditch network. Following initial model runs, a flow-stage relationship was developed from results relating to the reach of the ditch network downstream of the Cambridge to Great Shelford railway embankment. This was applied to the ESTRY model as a water level-discharge (HQ) boundary.

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[3] BMT (2018) 'TUFLOW Classic / HPC User Manual'. Available at https://downloads.tuflow.com/_archive/TUFLOW/Releases/2018-03/ (Accessed: 10th October 2022)

[4] UK Centre for Ecology & Hydrology [October 2022], *Flood Estimation Handbook Web Service [online]*. Available from: https://fehweb.ceh.ac.uk/Map (Accessed 12th October 2022)

2.6 Rainfall Loss Value

British Geological Survey mapping[5] indicates that the Site is underlain by permeable chalk-based bedrock strata. Infiltration of runoff into the permeable strata was simulated through the application of a rainfall loss value to the model. This removed a percentage of the input rainfall hyetograph, to simulate the volume of rainfall lost to infiltration into the ground.

The PBA site-specific study utilised a rainfall loss value of 82.5%, which was calculated via comparison of outflow hydrographs for the Vicar's Brook watercourse with peak flow estimates for the watercourse developed using the FEH Statistical Analysis method. This calculation method was derived from an analysis undertaken as part of the Cambridge and Milton Surface Water Management Plan (SWMP)[6], which determined that a rainfall loss value of 50% would be appropriate for the south Cambridge area.

The 82.5% rainfall loss value was utilised for this study, as it had been calculated specifically for the Site and local catchment. Simulations using the 50% loss calculated by the Cambridge and Milton SWMP were also undertaken, to assess the effect of the rainfall loss parameter.

2.7 Model Structure

2.7.1 Ditch Network

The ditch network around the northern and western boundary of the Site was represented in 1D format using ESTRY. ESTRY represents watercourse channels through a series of cross sections snapped to a shapefile format network line containing chainage data.

The 2016 PBA modelling study included representation of the ditch network between Dame Mary Archer Way and the north western corner of Nine Wells nature reserve. The channel survey data used as part of the previous exercise was obtained and added to the model. The 1D network was then extended using channel cross section data extracted from a 1m resolution LiDAR DTM dataset. This allowed simulation of all ditch network reaches adjacent to the Site, from the northern extent of the Site to the confluence with Hobson's Brook.

Culverts present along the ditch network were represented as part the ESTRY model using 'Culvert' channels. Where existing structures were not included within the available channel survey data, structure dimensions were estimated from channel widths and bank levels.

The railway embankment within the Cambridge to Great Shelford railway embankment was situated within private land and therefore not included within the previous survey. Culvert dimensions were estimated in accordance with ditch depth and width and the height of the railway embankment. Accordingly, the culvert was modelled as a 2.7m width x 0.8m height box culvert.

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5 British Geological Survey [January 2023], *Geology of Britain Viewer [online]*. Available from: https://mapapps.bgs.ac.uk/geologyofbritain/ (Accessed 1st February 2023)

6 Cambridgeshire Flood Risk Management Partnership, November 2011. Cambridge and Milton Surface Water Management Plan: Detailed Assessment and Options Appraisal Report

In future stages a full channel survey would be undertaken, to include the culvert sections. However, the assumptions used to date are considered appropriate at this stage.

Bridge decks over all culvert structures were modelled using ESTRY Weir sections, in accordance with standard ESTRY modelling practice. Flows surcharging at culvert inlets would be allowed to spill over the structure in accordance with the level of the attached weir.

2.7.2 Floodplain Topography

A 4m resolution grid was specified for the 2D model domain. The extent of the 2D model was initially based on the FEH catchment extent and refined following initial model runs. The 2D model extent was made sufficiently large to ensure that flood flows passing through the Site and surrounding area would not accumulate against the limits of the model extent during any of the scenarios ('glass wall').

Topography of the 2D domain was derived from 2m resolution LiDAR DTM data, as obtained from the DEFRA data platform[7]. The DTM dataset was reviewed for gaps and inaccuracies. Localised topographic depressions were evident around the Addenbrooke's Hospital site, resulting from the removal of building extents as part of the LiDAR DTM production process. were filled using blank 2D Z Shape features, to more accurately reflect the actual ground level in these areas.

The spatial extent of the ESTRY model was deactivated from the 2D domain, to ensure that the channel volume was not double counted within the overall model. The 1D and 2D models were linked using a 2D 'HX' boundary, snapped to the edges of the 1D model extent. A Form Loss Coefficient (FLC) value of 0.1 was applied to all HX boundaries, to ensure stability of the 1D/2D link as flows passed between the channel and floodplain.

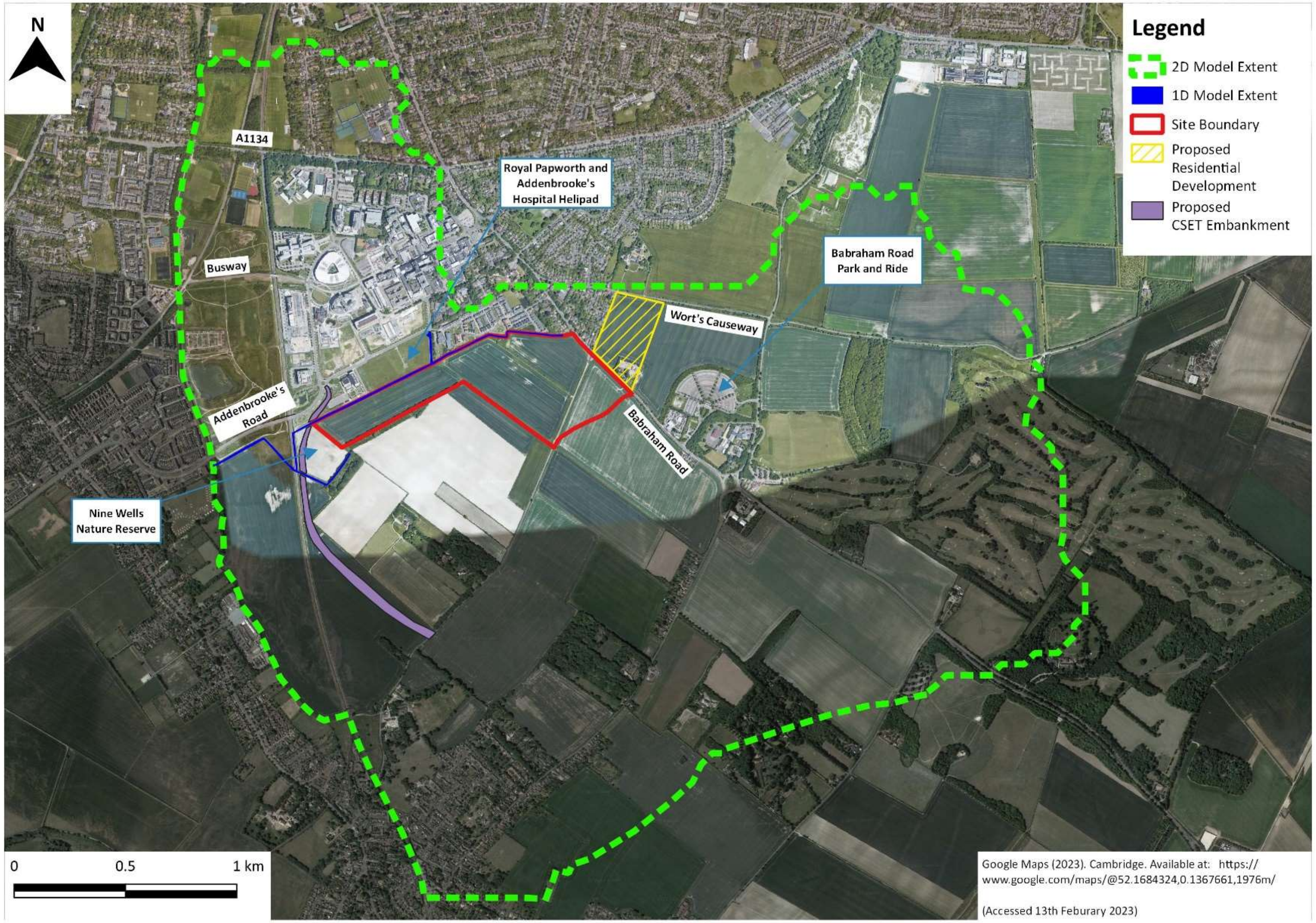
Bank levels along the ditch network were enforced using 2D Z Line features snapped to the HX boundaries. Bank elevations were derived from the edges of each channel cross section and applied to the Z Line features as point data, to ensure correspondence of bank levels along the link between the 1D and 2D models.

Stability patches were added to areas of the 2D model where high velocities were identified during initial model runs, in order to improve model stability.

The extent of the model is shown in Figure 3-1.

[7] DEFRA [October 2022], *Defra Data Services Platform [online]*. Available from: https://environment.data.gov.uk/ (Accessed 10th October 2022)

Figure 2-1 Hydraulic Model Extent



2.8 Building Thresholds

As building thresholds were not included within the LiDAR DTM dataset, these were applied to the 2D model in order to simulate obstructions to overland flows. Building extents were simulated in accordance with DEFRA hydraulic modelling guidance[8]

Existing buildings were identified using Ordnance Survey (OS) MasterMap shapefile format data. Building thresholds were modelled through the application of average ground elevations within each building extent plus an increment of 0.3m. Separate building threshold layers were developed for the Baseline, Future Baseline and Proposed Development scenarios.

2.9 Roughness Coefficients

Channel roughness within the ESTRY model of the ditch network was simulated using Manning's 'n' values. Roughness coefficients were specified through review of aerial photography of the Site and consultation of Open Channel Hydraulics[9].

Roughness coefficients specified within the 1D model are shown in Table 2-1.

Table 2-1 1D Model Roughness Values

	Manning's 'n' Value	Comments
Channel	0.030	Excavated channel featuring grass and some weeds.
Culvert (Concrete)	0.013	Culvert featuring some debris.
Bank	0.050	Bank areas. Generally feature scattered brush and heavy weeds.

Variations in surface roughness within the 2D model were simulated using shapefile format OS MasterMap land use data. Roughness coefficients were applied to each ground surface type and added to the 2D model as a Materials layer, in accordance with standard TUFLOW modelling practice.

Building extents were modelled by specification of an increased Manning's 'n' roughness coefficient within each building extent, in addition to the raising of building threshold levels. Separate Materials layers were developed for the Baseline, Future Baseline and Proposed Development scenarios. These included variations in the extents of roads and buildings, in accordance with the proposed developments around the Site and the form of the Proposed Development.

Roughness coefficients applied are shown in Table 2-2.

[8] DEFRA [October 2022], *Represent buildings and infrastructure (receptor) [online]*. Available from: https://www.gov.uk/government/publications/river-modelling-technical-standards-and-assessment/represent-buildings-and-infrastructure-receptor (Accessed 20th November 2022)
[9] Chow, V. T. 1959, *Open Channel Hydraulics*, McGraw-Hill, Tokyo.

Table 2-2 2D Model Roughness Values

Land Use	Manning's 'n' Value
Building	0.5
Residential yards	0.04
Steps	0.025
Grass, parkland	0.03
Glasshouse	0.5
Heritage and antiquities	0.5
Water (inland)	0.035
Heavy woodland and forest	0.1
Roads, tracks and paths (manmade)	0.02
Roads, tracks and paths (tarmac / dirt)	0.025
Railway	0.05
Roads, tracks and paths (tarmac)	0.02
Pavement	0.02
Roadside structure	0.03
Structure (top of building)	0.5
Water (foreshore)	0.04
Land (unclassified – e.g., industrial yards, car parks)	0.04
Slope	0.035
Pylon	0.035
Grassland (assumed)	0.04
Cliff	0.04
Water	0.04

2.10 Bridge Decks

The decks of large scale bridge structures for the courses of the A1134, Addenbrooke's Road and a branch of the Cambridgeshire Guided Busway were not included within the LiDAR DTM dataset, as these were removed as part of the LiDAR filtering process. These bridges allow the roadways to cross Hobson's Brook and the Cambridge to Great Shelford railway line.

The missing bridge deck structures were added to the 2D model using Z Shape and Triangulated Irregular Network (TIN) features, to ensure that rainfall falling onto each structure would be intercepted and routed along the roadways, rather than falling directly to the floodplain around Hobson's Brook.

2.10.1 Cambridge South East Transport (CSET) Busway Embankment

A section of the Cambridge South East Transport (CSET) busway, intended to link Cambridge City centre and the Biomedical Campus with communities located to the south east, is proposed to cross the Nine Wells area. This would comprise an embanked busway, connected to the junction of Addenbrooke's Road and Dame Mary Archer Way to the north.

The Greater Cambridge Partnership agreed the route of the CSET and approved the submission of a Transport and Works Act Order to the Government in July 2021. It was therefore assumed that this transport link would be in situ either prior to or within the lifespan of the Proposed Development. It was therefore incorporated into the Future Baseline and Proposed Development scenarios.

The CSET embankment extent was identified in accordance with the proposed route, with elevation of the busway interpolated from the proposed connections at the Addenbrooke's Road and Dame Mary Archer Way junction and a proposed overpass at Granham's Road. An embankment profile of 1 in 3 was assumed. The embankment was incorporated as a 2D TIN feature, in accordance with standard TUFLOW practice.

Further discussions will be undertaken with the design team of CSET, to ensure that the final CSET design is taken into account as part of any future development and hydraulic modelling at the Site.

3 Results and Discussion

3.1 Design Event Simulation

To demonstrate that the Proposed Development can be incorporated safely within the Site, the CBC1 model was run for the following rainfall event:

- 100 Year (1% AEP) plus 40% climate change allowance.

The 40% rainfall allowance was specified to simulate anticipated changes in rainfall intensity up to the 2070s epoch (between the years 2061 and 2125), in accordance with the proposed design lifespan for the Proposed Development.

The naming convention for model simulations was as follows:

- **CBC1**(model name)**_xxxxYr**(storm event)**_XXXX**(scenario)**_v001**(version number)

The baseline scenarios were identified with the abbreviation 'BAS_vXX'. The future baseline scenarios were named 'FBAS_vXX' and Proposed Development scenarios were named 'PROP_vXX'.

3.2 Model Stability

Cumulative mass error within the TUFLOW model was within the expected tolerance of $^{+}/_{-}1\%$ for all simulations. Review of TUFLOW log files indicated that no negative depths occurred during the simulations. In addition, no warning messages were generated, indicating that the 2D model ran stably throughout.

3.2.1 Sensitivity Analysis

Rainfall or flow data from the ditch network was not available to verify the model. Sensitivity testing of the downstream boundary, roughness coefficients and inflows was therefore undertaken. Variables were tested through a $^{+}/_{-}$ 20% variation of each test parameter. The model was not overly sensitive to sensitivity testing undertaken and results were therefore considered appropriate.

3.3 Future Baseline Scenario

The existing baseline scenario model results indicated that flooding on Site occurred due to the propagation of overland flows from areas to the east and south east. Overland flows accumulate within rural land to the north east of Babraham Road and the south east of Granham's Road, before spilling into the Site if sufficient flows occur.

Flows pass through the Site in accordance with topography and drain into the Nine Wells area, before spilling into the drainage ditch network. Model results indicate that, flows only spill into the ditch within a small extent at the northern boundary of the Site. This occurs as ground levels within the Site fall away from the course of the ditch along the northern boundary.

Comparison of the present day Baseline scenario with the Future Baseline scenario results indicated that localised changes in flood risk would occur around the extent of the CSET embankment. This would occur due to reduction in flood storage within the Nine Wells area and the restriction of overland flow conveyance due to the proposed embankment.

Localised increases in flood risk were apparent around the downstream extent of the ditch network as a result. Minor increases in modelled flood depth were also apparent around the Wort's Causeway development, which occurred due to flows being retained within the proposed development layout in this area.

During the 100 year event (plus a 40% allowance for climate change), model results indicate that peak flood depths on Site are generally less than 300mm. These results suggested a good correlation with previous modelling exercise.

The Future Baseline model was used as the baseline for assessment of the Proposed Development, as the CSET embankment (and associated loss in floodplain storage) would be in place throughout the lifespan of the Proposed Development. The Future Baseline modelled flood extent is shown in Figure 3-1.

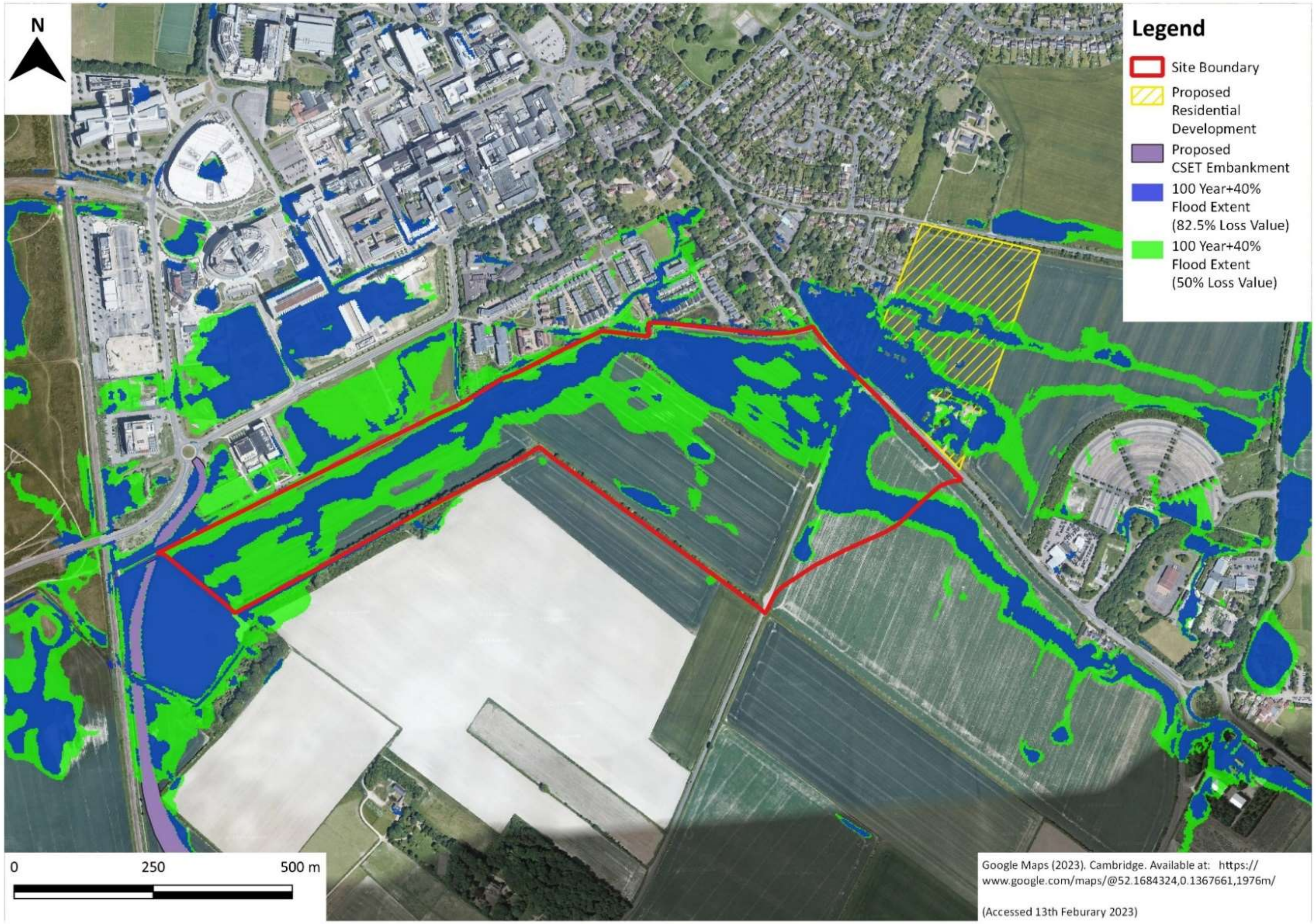
Figure 3-1 Future Baseline Scenario

3.3.1 50% Model Loss

The Future Baseline scenario was repeated with the rainfall loss variable reduced from 82.5% to 50%, in accordance with the Cambridge and Milton SWMP. This resulted in a general increase of flooding across the model domain, resulting from the increased volume of water applied to the 2D model.

The increased 100 Year (+40%) flood extent was particularly evident around the central and western areas of the Site. This occurred as these areas represent the main flow path into the Nine Wells area. See Figure 3-2.

Figure 3-2 Comparison of Rainfall Loss Value Flood Extents



3.4 Proposed Development Scenario

Review of the Future Baseline results suggested that a potential solution to the flood risk on Site was restriction of overland flows passing into the Site from the east. Land under the ownership of Cambridgeshire County Council is present around the east and north east of the Site, therefore the potential to utilise this land to provide mitigation for the Proposed Development was evaluated.

A version of the Proposed Development model was developed with storage areas incorporated within the Council owned land to the east of the Wort's Causeway residential development and within farmland at the eastern side of Granham's Road. Storage areas were simulated through the raising of existing ground elevations along the land boundaries around Babraham Road and Granham's Road. At this initial stage a nominal boundary height of 2m above existing ground level was specified, to ensure that all accumulated overland flows would be retained during the 100 year (+40%) event.

To improve drainage of flood flows within the Proposed Development, a section of the existing bund along the drainage ditch at northern boundary of the Site was removed. In addition, an existing land drain located along the south western boundary of the Site was connected to the drainage ditch network at the southern boundary of Nine Wells. Due to the absence of appropriate survey data, this ditch was previously assumed to be separate from the wider network.

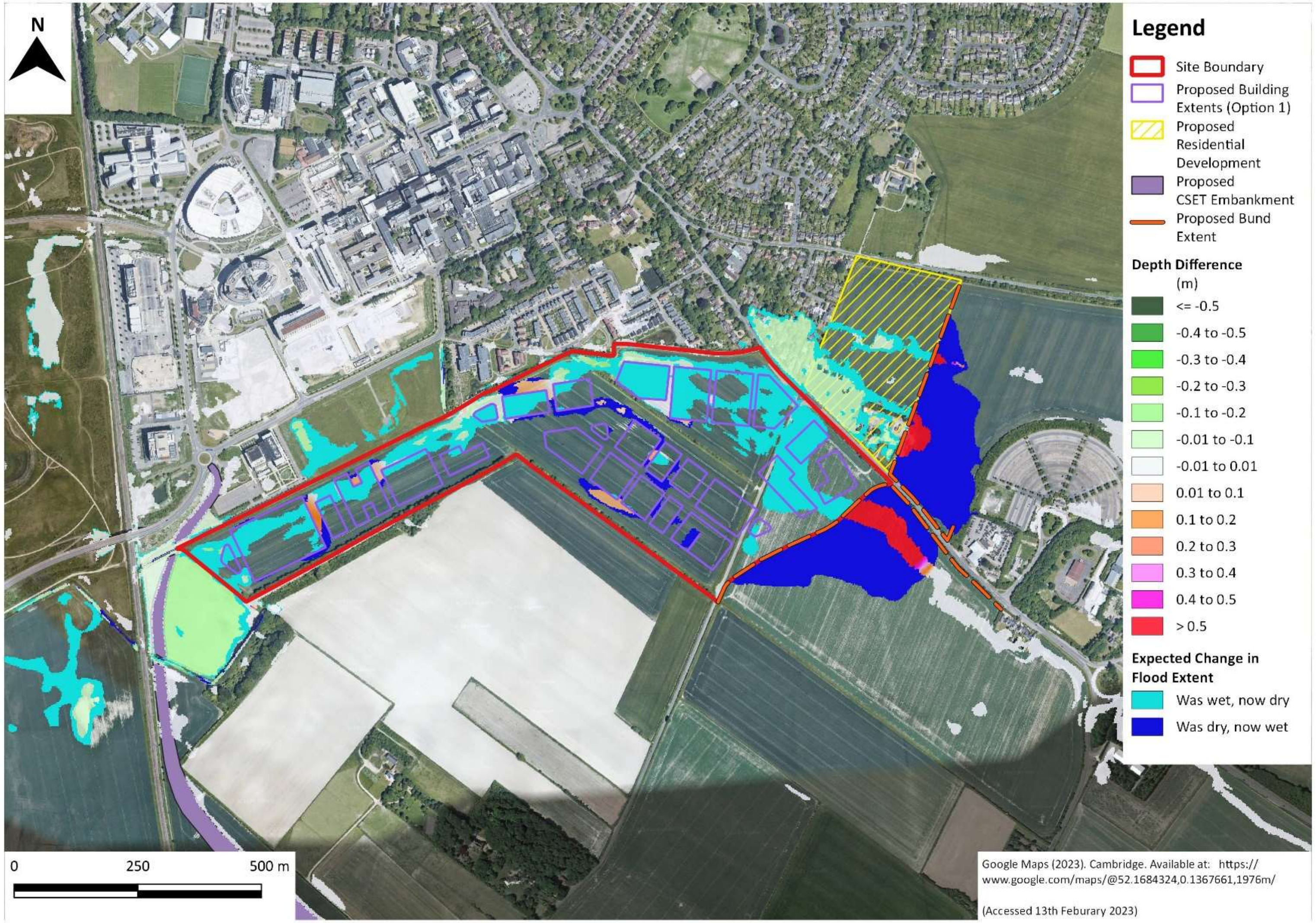
The model was run with the 100 year (+40%) event and results were compared with the Future Baseline scenario. This indicated that the proposed bunds would retain overland flow within land upstream of the Proposed Development, without being overtopped. Much of the Future Baseline flood extent across the eastern northern and western sides of the Site would be mitigated, as would the Future Baseline flood extent within the adjacent Royal Papworth and Addenbrooke's Hospital Helipad site, to the north of the drainage ditch network.

Peak flood depths within the Nine Wells area, beyond the western boundary of the Site, would be reduced by up to 300mm. Water depths of up to 1.2m would be retained behind the bunds. See Figure 3-3.

The small and localised areas of dark blue and orange shown within the Site are due to localised rainwater falling on the Site itself adjacent to the proposed buildings, and is not due to overland flows from the east and south east. Rainwater falling on the Site itself would be captured within the proposed Sustainable Drainage System (SuDS) incorporated as part of the Proposed Development, and is not considered to be a risk of flooding. These areas are therefore not of concern to future development.

The potential water depth is a worst case scenario, as this assumes no discharge of flow from these features for the duration of the model. In reality, flows would continually be allowed out of these features at a controlled rate and in a controlled manner (e.g. through perimeter ditches), to ensure that flows are maintained to Hobson's Brook. Therefore overland flows would not accumulate to the maximum modelled flood depth. Further modelling would be undertaken as the Site progresses.

Figure 3-3 Depth Difference: 82.5% Rainfall Loss Value



3.4.1 50% Rainfall Loss

To test the potential management concept, the Proposed Development scenario was repeated with the rainfall loss value reduced from 82.5% to 50%. As within the 82.5% scenario, water was retained within the areas adjacent to Babraham Road and Granham's Road, without the retention bunds being overtopped. Water was retained behind the bunds to depths of up to 2m. As set out previously, this maximum depth is not anticipated to be reached in reality, as flows would continually be released in a controlled manner to Hobson's Brook. Further modelling would be undertaken as the scheme progresses.

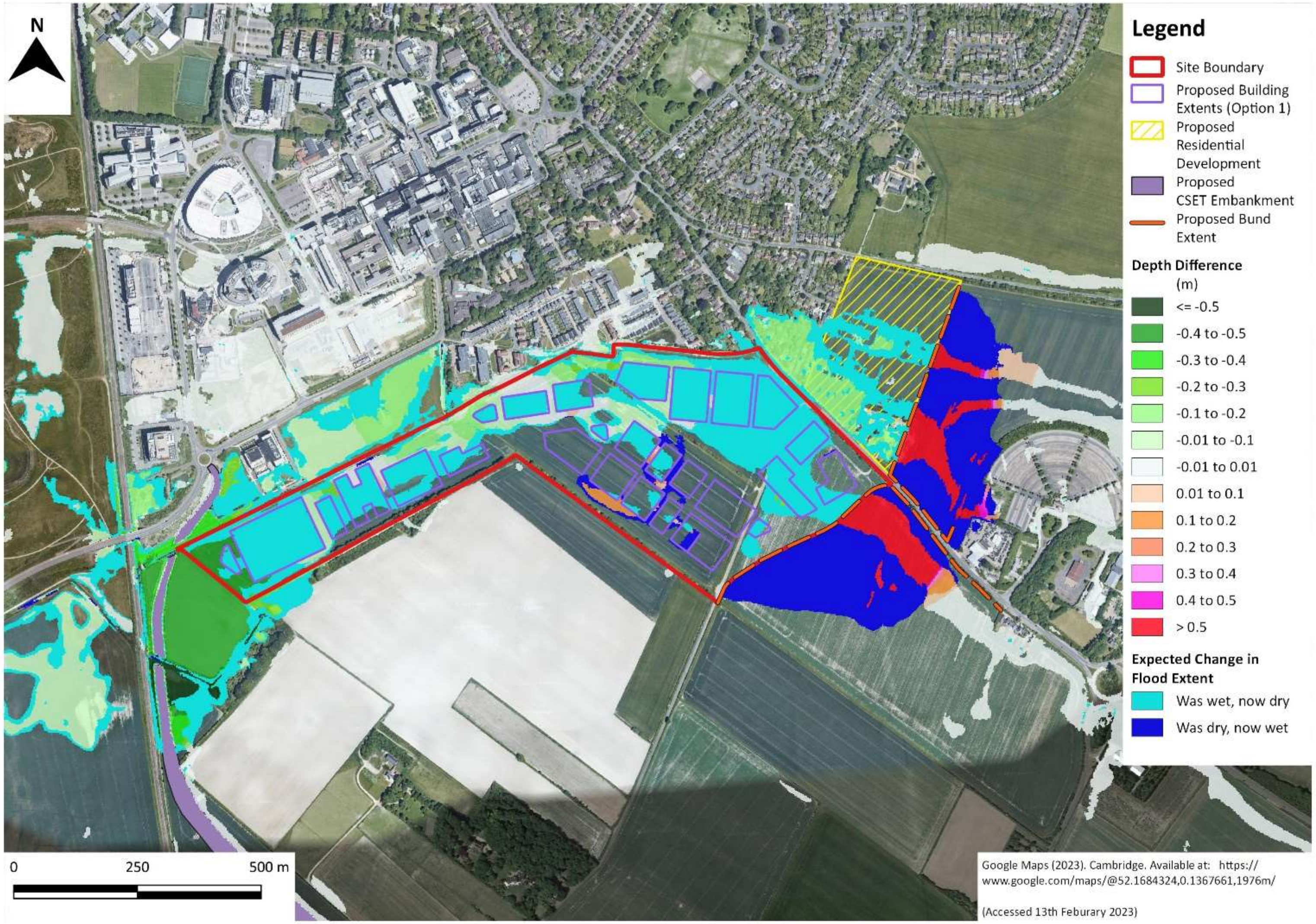
Peak flood depths within the northern area of the Site were reduced by up to 250mm. Across the western extent of the Site, peak depths were reduced by up to 500mm.

As set out previously, the small and localised areas of dark blue and orange shown within the Site are due to localised rainwater falling on the Site itself adjacent to the proposed buildings, and is not due to overland flows from the east and south east. Rainwater falling on the Site itself would be captured within the proposed Sustainable Drainage System (SuDS) incorporated as part of the Proposed Development, and is not considered to be a risk of flooding. These areas are therefore not of concern to future development.

With both rainfall loss scenarios, changes in existing flood risk were limited to the immediate area around the Site. The modelled management concept would result in betterment of existing flood risk at Nine Wells and the Royal Papworth and Addenbrooke's Hospital Helipad site.

The flood risk extent increases would be restricted to the designated storage areas and areas of open space. See Figure 3-4.

Figure 3-4 Depth Difference: 50% Rainfall Loss Value



4 Flood Mitigation Options

4.1 Flood Mechanism

The hydraulic modelling exercise indicated that flood risk to the Site will largely result from local flow paths passing from land south-west of Fulbourn, through to the course of Hobson's Brook. As the ground becomes saturated during a rainfall event, runoff will propagate along local topography and pass through the Site from east to south west, towards Hobson's Brook. During severe rainfall events, flooding will occur within the flow path and immediate surroundings.

As stated in Section 3-1, the hydraulic model simulated the 1 in 100 year rainfall event (with a 40% allowance for climate change). The flood extents represented by the model outputs therefore only have a 1% probability of occurring, or being exceeded, in any given year.

4.2 Proposed Mitigation

Retention of overland flow within the Council owned land to the east of the Wort's Causeway residential development, and at the eastern side of Granham's Road, was discussed in Section 3-4 as a potential mitigation measure for surface water flood risk within the Proposed Development. Water would be retained behind raised ground along the boundaries of these adjacent areas, truncating the overland flow paths into the Site and utilising natural storage volume within the existing topography.

Flood water would also accumulate within the Council owned land during smaller, more frequent rainfall events than those simulated as part of the modelling exercise. However, smaller volumes of water will result and it is likely that the proposed retention areas will be dry for the majority of the year.

Raising of ground levels would create functional earthworks (bunds), which could incorporate soft landscaping to blend the features into existing land boundaries and the surrounding green belt. A clay core would be specified at the centre of each earthwork feature, to prevent seepage of overland flows.

Appropriate tree planting and landscaping can be used to create an attractive visual feature. This would also 'soften' the edges of the Proposed Development and help to blend the eastern extent of the Biomedical Campus into the wider Cambridge green belt. See Figure 4-1.

Figure 4-1 Potential Raised Earthwork Landscaping

The proposed bund crest level was modelled as 2m above existing ground elevations, in order to determine the worst case scenario water depths likely to be retained during severe rainfall. It was intended as an overestimation of a realistic bund height, to ensure that the structure would not be overtopped during the model simulations.

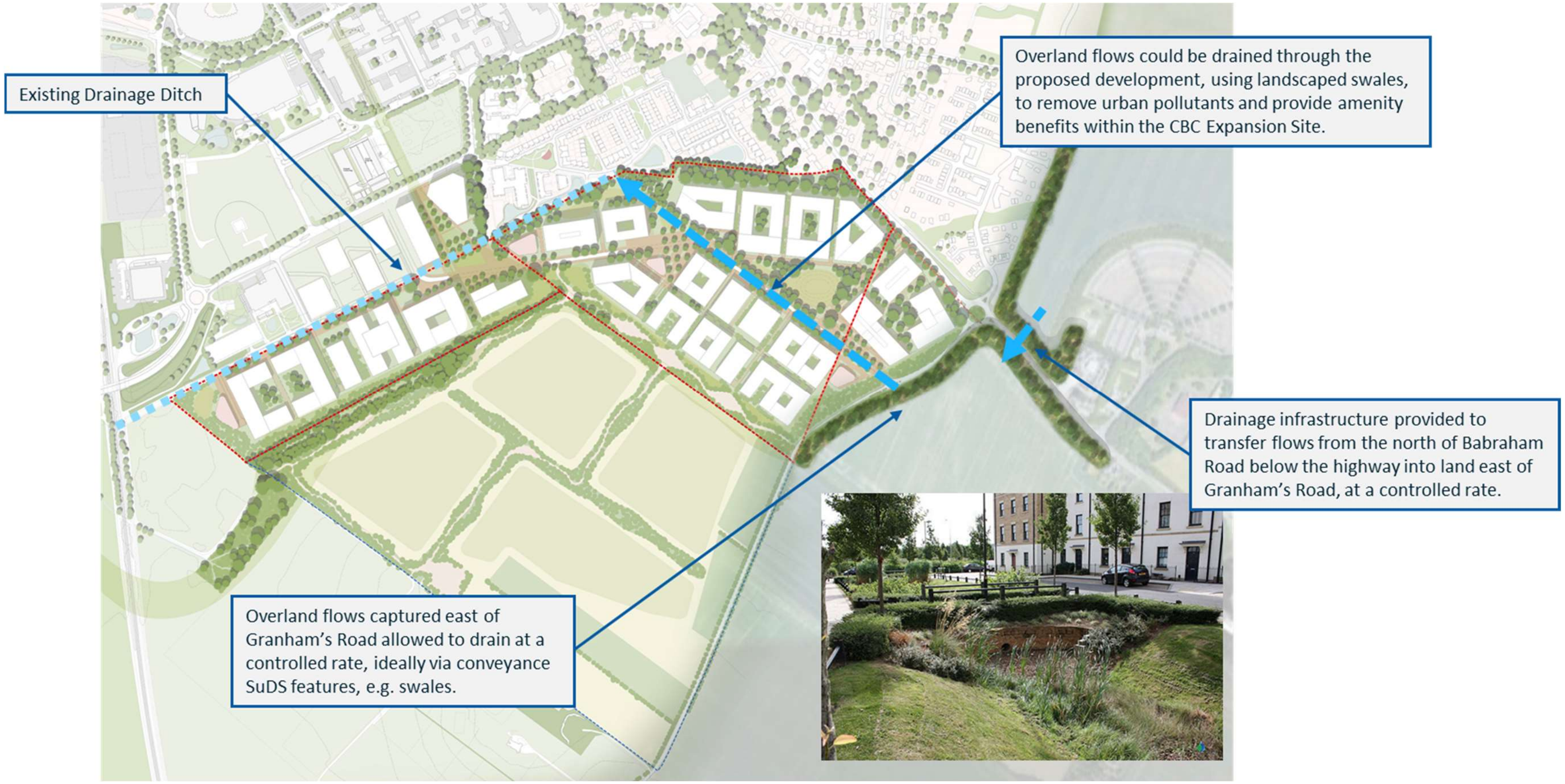
Specification of a lower bund elevation will be possible if retained flows are discharged to the local drainage ditch network. Discharge of flows from the attenuation areas was not simulated, as the modelling exercise was designed to demonstrate the feasibility of overland flow interception as a flood risk management option. It is anticipated that water retained behind each bund can be drained via gravity to the existing drainage ditch along the northern boundary of the Site.

Provision of a culvert beneath the course of Babraham Road would be necessary to allow water to drain from the north into the retention area east of Granham's Road. From this area, flows would then be discharged beneath the course of Granham's Road and either through, or around, the Proposed Development and into the existing drainage ditch network.

Captured runoff would be discharged at controlled rates, to ensure that existing flood risk downstream of the Site is not increased. Detailed review of topography around the Site and the adjacent Council owned land will be necessary to confirm that gravity discharge to the existing ditch network will be feasible.

A broad-scale examination of topography around the Site indicated that outflow from the retention area east of Granham's Road could be drained through low lying land within the northern Site extent, and into the existing drainage ditch network. See Figure 4-2.

Figure 4-2 Proposed Drainage of Retention Areas



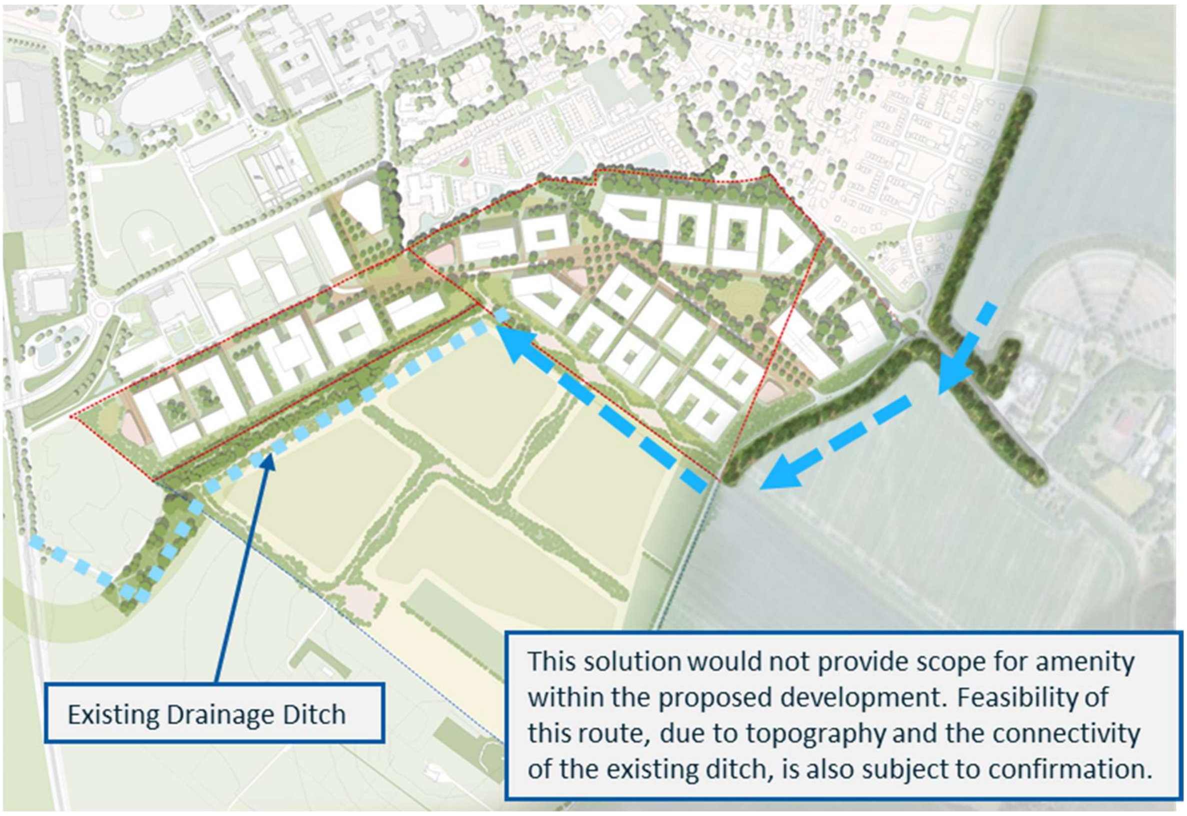
Controlled discharge of runoff to the existing ditch network through the Site will allow the incorporation of green and blue corridors into the Proposed Development layout. These can be used to provide amenity and biodiversity benefits, as well as contributing to the safe management of surface water flood risk.

4.3 Alternative Risk Management Solutions

4.3.1 Drainage of Flow to South

If management of flows through the Proposed Development is not favoured, e.g. due to the potential space requirement for blue and green corridors, flows could be drained around the southern boundary of the Site, to discharge to Hobson's Brook via an existing drainage ditch located in this area. See Figure 4-3.

Figure 4-3 Drainage Route Around Southern Boundary



Feasibility of this potential solution will be subject to topography around the eastern and southern boundaries of the Site. Capacity of the receiving drainage ditch, and its connectivity to Hobson's Brook, will also be subject to confirmation. Drainage around the Site would reduce the potential amenity and biodiversity provision possible within the Proposed Development.

4.3.2 Revision of Proposed Development Layout

If the surface water management option within the adjacent Council owned land is not considered viable, an alternative flood risk management strategy must be developed to ensure that flood risk within and around the Proposed Development can be managed effectively.

If external management of overland flows is not provided, the Proposed Development layout could be revised to position buildings outside the existing surface water flow path. This solution would significantly reduce the quantum of development possible within much of the Site.

To facilitate drainage of overland flows into the existing drainage ditch along the northern edge of the Site, topography within the Site could be suitably regraded. However, without management of flow within the ditch, this is likely to increase existing flood risk downstream of the Site, and thus not be accepted by the EA.

4.3.3 Upper Catchment Storage

Overland flows could be attenuated within areas located within the upper extent of the local catchment. The overall volume requirement would then be broken down across multiple smaller-scale sites, rather than provided within the two areas adjacent to the Site.

A larger scale modelling assessment would be necessary to identify strategic sites for the attenuation of overland flows, as well as to determine the overall storage volume requirement to manage downstream flood risk.

Multiple attenuation sites would be required, as flow paths within the upper catchment extent are likely to be smaller and more numerous. This potential solution will then be limited by the availability of land in appropriate areas and there may be land ownership issues to resolve.

4.3.4 Below Ground Attenuation

If above ground retention of surface water is not favoured, a more heavily engineered risk management solution will be necessary. This could comprise storage of runoff within underground tanks on Site. Pumped discharge of flows to the local drainage ditch network may then be necessary, due to the potential level difference between the storage feature(s) and the existing drainage ditch network.

This type of engineered solution would be costly to implement, due to the likely scale and complexity, and unlikely to be accepted by the EA who favour strongly more natural flood management. In addition, it would not provide wider sustainability benefits to the Proposed Development.

5 Drainage Options Review

The drainage strategy for the Proposed Development is presently emerging. This section of the report considers the opportunity to integrate SuDS within the Proposed Development, alongside the opportunity for retrofitting SuDS within the existing campus should it be necessary.

5.1 Review of Existing Studies

5.1.1 Emerging Spatial Framework

An emerging spatial framework[10] for the Proposed Development was issued during 2022. The report sought to demonstrate how the Proposed Development could be used to improve existing drainage from the Site to Hobson's Brook, through the creation of resilient landscapes that attenuate water.

Sketch layouts included as part of the document indicate that blue infrastructure will form part of the Proposed Development layout. The indicative locations for blue infrastructure shown within the spatial framework resemble the proposed routes for the management of overland flow through the Site, as identified within Section 4.3 of this document. Features for the management of overland flows should be separated from on-Site SuDS drainage system for the purpose of attenuation.

5.1.2 Drainage Strategy Options Paper

A Drainage Strategy Options Paper[11] for the Proposed Development was issued during 2022. This intended to identify key themes, aims and objectives to be considered as part of development design.

The strategy considered the topography of the Site and depths of the local drainage network and the potential effects of this on the depth of any below-ground attenuation system specified within the Proposed Development. Above-ground SuDS, such as swales and channel drains, were advocated to reduce the potential depth required within a drainage system design, to ensure that gravity drainage of runoff will be achievable.

The specification of SuDS such as swales, in place of traditional subsurface sewers, was seen as a means to allow the potential depth of storage features to be maximised whilst potentially allowing a gravity connection to the local ditch network. These types of SuDS can also be used to improve water quality through the filtration of runoff. The report recommends that the existing drainage network, soil strata and topography on Site are all surveyed in detail to inform the design of the Proposed Development and drainage system.

The report builds upon the 2016 PBA hydraulic modelling exercise[12], adopting the allowable discharge rate from the Site of 2.0 l/s/ha, as agreed via consultation with Cambridge City Council and the EA.

Greenfield runoff rates for the Site were calculated for the 1 in 1 year, 1 in 30 year and 1 in 100 year events, as well as the mean annual flood (Q_{bar}). Estimated storage volumes to allow attenuation of runoff to 2.0 l/s/ha were then determined, based on these calculated greenfield rates.

[10] Hawkins\Brown, December 2022. CBC Emerging Spatial Framework
[11] Hydrock, November 2022. Cambridge Biomedical Campus: Drainage Strategy Options Paper
[12] Peter Brett Associates, October 2016. Extension to Bio-Medical Campus, Cambridge: Flood Modelling and Drainage Strategy Report

The report indicated that each hectare of impermeable area within the Proposed Development will require between 880m^3 and 1,130m^3 of attenuation volume to accommodate a 1 in 100 year plus 40% climate change event.

5.2 Recommendations and Opportunities

The placement of blue infrastructure features shown within the Spatial Framework sketch layouts was informed by the development layout of the time and the requirement for appropriate transport corridors and pedestrian networks as part of the Proposed Development. As the layout of the Proposed Development continues to emerge, it is recommended that potential blue infrastructure should be considered in accordance with Site topography, and also in terms of the requirement to manage both overland flow from off Site areas and surface water runoff.

Localised low points across the Site will form the most suitable locations for flow management and drainage infrastructure. However, it is important that the on Site SuDS features are retained for attenuation and treatment purposes, and not inundated by off Site overland runoff. Otherwise the attenuation volumes will not be available when they are required.

Allowances should be made for drainage of runoff from the Proposed Development into the local ditch network via gravity as much as is possible. The use of SuDS features such as swales and filter drains will be advantageous in maximising the fall across the drainage system, as well as the provision of water quality and amenity benefits. Blue infrastructure design should be considered in terms of the off Site overland flow management, as highlighted by the hydraulic modelling exercise described in Chapters 2 - 4 of this document, however it is important that this is kept slightly detached from the management of surface water runoff from the Proposed Development (albeit the discharge locations will ultimately be the same).

The Proposed Development will be situated within greenfield land. Current local planning policy indicates that runoff from greenfield developments must be attenuated to equivalent greenfield rates for the 1 in 1 year rainfall event and the 1 in 100 year rainfall event. The management of runoff from the Proposed Development must therefore be based on principles of maintaining existing greenfield runoff rates from the Site.

The runoff rates to be achieved will determine the management techniques specified as part of the Proposed Development. Increasing the spatial requirement for attenuation features within the spatial framework would reduce the burden on individual development plots.

The calculated 1 in 1 year and Q_{bar} runoff rates included within the Drainage Strategy Options report are less than the 2.0 l/s/ha runoff rate recommended for the Proposed Development within the same report. A drainage strategy based the 2.0 l/s/ha runoff rate, from historic consultation with Cambridge City and the Environment Agency, will need to tested with the LLFA. Consultation is recommended at an early stage in the planning process, in order to agree an acceptable discharge rate, and confirm whether the historic 2.0 l/s/ha can still be relied upon.

The attenuation requirement and potential land take within the Proposed Development should be updated in accordance with the conclusion of the discussions with the LLFA. Should the greenfield runoff rates be revised at any stage, it may be necessary to review the area allocated for attenuation in the emerging Spatial Framework.

As the Site is located within an area where variable chalk-based bedrock is present, conditions for infiltration of runoff may be favourable. Given the greenfield nature of the Site, the Council will likely request that infiltration testing is undertaken (as this is top of the discharge hierarchy). This will need to be discussed, and testing undertaken upfront in order to inform the design.

The Drainage Strategy Options report states that CCTV survey and private drainage records covering the existing Biomedical Campus were not available. CCTV survey of the existing sewer systems around the Phase 3 and Phase 4 land is recommended, as these types of survey will be necessary to inform the drainage design of any proposed expansion of the existing Biomedical Campus.

In line with the drainage hierarchy, rainwater reuse should be actively promoted where possible. Ideally this would be for internal reuse such as toilet flushing. Alternatively rainwater could be collected for irrigation of the surrounding landscape. This is of great importance, particularly given that Cambridge is in a water scare area.

Above ground SuDS features should be maximised where possible within the soft landscaped areas, and this will be expected given the greenfield nature of the Site. Attenuation will be needed downstream of the proposed impermeable surfaces, and upstream of the proposed outfall, aiming for a gravity discharge. It is therefore expected that any attenuation would need to be relatively shallow (requiring a comparatively larger land take), given the shallow discharge locations.

At-source SuDS features such as green roofs and raingardens should be incorporated across the Site. All external surfaces should be designed as permeable where possible, with sub base storage beneath. Aggregate sub base will provide treatment of runoff, alongside attenuation of flows.

To provide sufficient storage of runoff, blue roofs may be required on the buildings themselves (beneath green roofs). This will reduce the pressure on the ground floor external areas of the Site which need to perform many functions. Providing attenuation at high level, will also maximise the potential for gravity discharge from the Site.

5.3 Existing Campus SuDS Opportunities

All new buildings on the existing campus would be expected to incorporate their own SuDS solutions as the detailed design is developed. All opportunities for new measures would be assessed as development comes forward. Should additional capacity be required beyond an individual development plot (to be assessed at the time of the application), additional mitigation could be provided in surrounding areas.

The presence of private surface water sewers within the existing Biomedical Campus will determine the scope for retrofitting of SuDS, therefore it is recommended that a detailed survey of these features is undertaken. The existing Biomedical Campus is densely built up around a road network, therefore opportunities for larger scale features will be limited.

Potential for the retrofitting of blue and green roof storage could be evaluated, as this would allow runoff to be attenuated within the footprints of existing buildings. Water attenuated within roof areas could be used for irrigation or grey water purposes. An additional benefit of blue and green roofs is that they are considered to provide a cooling effect to an underlying building.

However, the potential for utilisation of blue and green roofs within the existing Biomedical Campus would be dictated by the structural design of existing buildings. Consideration of potential costs relating to construction and maintenance requirements would also be necessary and may be prohibitive.

Depending on existing infrastructure within these areas, below-ground attenuation could be incorporated as part of the staff car parks at the eastern and western sides of the campus. These car parks represent the largest areas of open space within the campus.

Space for SuDS is limited at ground level within the existing Biomedical Campus, due to the presence of buildings and the existing road network. Provision of SuDS designed to convey and treat runoff may be possible where sufficient space is available around highway corridors. These types of SuDS feature could be used to replace the existing below-ground surface water drainage network, or increase capacity of the existing system.

Accordingly, SuDS such as bioretention areas, filter trenches, filter strips and swales could be considered around access routes to the existing campus. These types of features can be incorporated into green landscaping around roads and pedestrian areas. They will provide treatment of existing surface water runoff and could be used to improve the overall water quality of surface water discharge from a site. These types of SuDS do not provide significant quantifiable attenuation, but assist in slowing water entering the wider drainage network.

6 Summary

Logika were commissioned to undertake a hydraulic modelling assessment of the proposed Cambridge Biomedical Campus extension, to confirm whether development would be appropriate at the Site. Flood risk within the Site was determined to be pluvial in nature.

Accordingly, a linked 1D-2D model of the Site and local catchment was built using ESTRY-TUFLOW software. The model comprised a 2D direct rainfall model of the local catchment and floodplain, dynamically linked to a 1D model of the local drainage ditch network.

Flows for the model were estimated using data from the FEH Web Service and the ReFH2.3 model. The model was based on a topographic survey of the ditch, undertaken as part of a previous modelling exercise from 2016, and from the latest LiDAR DTM data. The model was tested using the 1 in 100 year (plus 40% climate change allowance) event. Rainfall loss parameters of 82.5% (from the 2016 site-specific modelling study) and 50% (calculated as part of the Cambridge and Milton SWMP) were tested to assess the effect of the local permeable chalk bedrock on pluvial flood risk.

The existing scenario was superseded by the 'Future Baseline' scenario, which included a residential development at Wort's Causeway and the extent of the Proposed CSET guided busway embankment across the Nine Wells area, to the west of the Site. Both developments have gained planning approval and are likely to be in situ for the lifespan of the Cambridge Biomedical Campus extension.

The potential exists to manage flood risk within the Site through the provision of storage features within land to the east, around Babraham Road and Granham's Road. This land is in full control and ownership of Cambridgeshire County Council. Placement of retention bunds around these areas would truncate existing flow paths into the Site from land to the east and south east, and allow overland flows to be captured and controlled upstream of the Site.

This design concept was simulated using a 2m bund along the edges of the attenuation areas, which was sufficient to capture overland flows resulting from the 100 year flood event (plus 40% climate change). This potential management option was considered to be an outline design only, as the storage areas allowed flows to accumulate, but not to drain, and therefore simulated a worst case scenario in terms of expected storage depths.

As part of the detailed design, a controlled outfall to the local drainage ditch network from each storage area would be incorporated, therefore flows would not accumulate to the depths simulated by the model. in addition, this would ensure maintenance of flows to Hobson's Brook.

Alternative risk management options for the Proposed Development were considered, in addition to the attenuation of flows within adjacent land. These comprised the provision of attenuation volume across multiple sites within the upper catchment extent, and an engineered solution to retain flood flows in below ground tanks on Site.

Provision of attenuation volume within the upper catchment was considered to be less practical, as multiple sites are likely to be required in strategic locations, in order to restrict existing overland flow paths. The availability of land in appropriate areas is not guaranteed. A larger scale modelling assessment will be required to test the feasibility of this type of scheme.

Retention of overland flows within an engineered below ground tank was not considered feasible, as pumped discharge of flows to the drainage ditch network is likely to be necessary. This type of solution would offer no amenity or biodiversity benefits and would not be accepted by the EA.

The proposed off-site attenuation solution adjacent to Babraham Road and Granham's Road comprises the most technically practical option, in that it will utilise existing topography to store water and facilitate drainage and all required land for the scheme is currently under Council ownership. Furthermore, the solution will offer additional benefits such as visual amenity and biodiversity / habitat creation.

Further work would be undertaken as the scheme develops to refine the hydraulic modelling and management proposals. This will include undertaking a detailed survey of the full extent of the drainage ditch network, associated culverts, and incorporating detailed plans for the CSET proposal.

The modelling undertaken proves that the land can be appropriately developed, and that through the Proposed Development flood risk could potentially be slightly reduced in the immediate area downstream of the Site. A robust solution is achievable to manage the potential for overland flow routes through the Site, and the Site is therefore in accordance with associated flood risk policy and guidance.

Blue infrastructure within the Proposed Development should be designed to manage the overland flow risk resulting from off-site areas and to attenuate and discharge runoff resulting from the Proposed Development. Detailed survey of the existing ground conditions and sewer network on Site is recommended to inform the development of a sustainable drainage strategy. Features for the management of overland flows should be separated from on-Site SuDS drainage systems for the purpose of attenuation. As part of the emerging drainage strategy, the acceptable discharge rates should be confirmed with the LLFA.

Within the Site, above ground SuDS should be incorporated where feasible. At-source SuDS such as green roofs, raingardens, and permeable surfacing should also be considered. Swales and filter drains should be considered in terms of conveyance. Blue roofs may be necessary to provide sufficient attenuation and allow flexibility of ground floor external areas. Surface water should aim to discharge by gravity.

New buildings on the existing campus would be expected to incorporate their own SuDS solutions on-plot. Should additional capacity be required beyond development plots (to be assessed at the time of the application), additional mitigation could be provided in surrounding areas. The densely urbanised nature of the Site will, however, limit the scale of any features to be provided.

Retrofitting attenuation may be possible within existing staff car park areas around the eastern and western edges of the Site, however this is likely to be dependent upon the existing surface water sewer provision and utility constraints around these areas.

The use of blue and green roof features to attenuate runoff within existing building footprints could be explored, however this may be a prohibitively expensive option and will depend upon suitability of existing building structures.

Conveyance SuDS, such as bioretention features, filter drains, filter strips and swales, could be incorporated at ground level around the existing Biomedical Campus. These could be used to extend the existing surface water drainage network and provide additional treatment of runoff. These types of SuDS will reduce the speed at which runoff enters the wider drainage network.