

Bedford Borough Council

Bedford Station Quarter

Flood Risk Assessment

October 2009

Halcrow Group Limited

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Contents

| | | |
|----------|--|-----------|
| 1 | Introduction | 1 |
| | 1.1 <i>Background</i> | 1 |
| | 1.2 <i>Planning and Flood Risk</i> | 1 |
| | 1.3 <i>Development Proposals</i> | 2 |
| | 1.4 <i>Objectives</i> | 2 |
| | 1.5 <i>Applying the Sequential and Exception Tests</i> | 5 |
| 2 | Flood Hazard | 8 |
| | 2.1 <i>Aims and Sources of Information</i> | 8 |
| | 2.2 <i>Fluvial Flooding</i> | 8 |
| | 2.3 <i>Surface Water and Sewer Flooding</i> | 14 |
| | 2.4 <i>Groundwater Flooding</i> | 14 |
| | 2.5 <i>Artificial Sources of Flooding</i> | 14 |
| | 2.6 <i>Tidal Flooding</i> | 15 |
| | 2.7 <i>Residual Risks</i> | 15 |
| | 2.8 <i>Summary of Flood Risk</i> | 15 |
| 3 | Flood Risk Management | 16 |
| | 3.1 <i>Flood Risk Management Hierarchy</i> | 16 |
| | 3.2 <i>Avoidance and Substitution measures</i> | 16 |
| | 3.3 <i>Control measures</i> | 16 |
| | 3.4 <i>Mitigation measures</i> | 17 |
| | 3.5 <i>Summary and Further Work</i> | 18 |
| 4 | Surface Water Management | 19 |
| | 4.1 <i>PPS25 Requirements</i> | 19 |
| | 4.2 <i>SUDS Options</i> | 19 |
| | 4.3 <i>Site Strategy</i> | 20 |
| 5 | Conclusions | 21 |

Since the preparation of this document the PPS25 Guidance Note has been updated. However there are no significant changes which it is considered affect the findings of this report.

1 Introduction

1.1 Background

This flood risk assessment supports an outline planning application for the redevelopment of the Bedford Station Quarter site. The assessment aims to identify the mitigation measures required to ensure that the redevelopment is safe, without increasing flood risk elsewhere, and where possible will reduce flood risk overall. The assessment identifies where details will need to be agreed in a reserved matters application at a later stage in the planning process.

1.2 Planning and Flood Risk

Planning Policy Statement 25: Development and Flood Risk (PPS25) requires that flood risk is taken into account at all stages in the planning process to avoid inappropriate development in areas at risk of flooding, and to direct development away from areas at highest risk. Where new development is necessary in such areas, the policy aims to make it safe without increasing flood risk elsewhere and where possible reducing flood risk overall. PPS25 classifies land into three Flood Zones, depending on the probability of flooding (Table 1). The Flood Zones refer specifically to flooding from rivers and the sea, however all sources of flooding including groundwater and surface water should be considered when assessing flood risk.

| Flood Zone | Definition | Appropriate land uses |
|--|---|--|
| Flood Zone 1: "Low Probability" | Land with less than a 1 in 1000 annual probability of river or sea flooding in any year (<0.1 %). | All land uses are appropriate. |
| Flood Zone 2: "Medium Probability" | Land with between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%), or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% - 0.1%) in any year. | Water-compatible, less vulnerable and more vulnerable land uses and essential infrastructure are appropriate. Highly vulnerable land uses are only appropriate if the Exception Test is passed. |
| Flood Zone 3a: "High Probability" | Land with a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year. | Water-compatible and less vulnerable uses are appropriate. More vulnerable and essential infrastructure uses are only appropriate if the Exception Test is passed. Highly vulnerable uses should not be permitted. |
| Flood Zone 3b: "The Functional Floodplain" | Land where water has to flow or be stored in times of flood. Land which would flood with an annual probability of 1 in 20 (5%) or greater in any year, or is designed to flood in an extreme (0.1%) flood, or at another probability agreed between the Local Planning Authority and Environment Agency, including water conveyance routes. | Water-compatible uses are appropriate. Essential infrastructure is only appropriate if the Exception Test is passed. All other land uses should not be permitted. |

Table 1: Flood Zones, referring to the probability of river and sea flooding, ignoring the presence of defences. Taken from PPS25 Table D.1.

The PPS25 Sequential Test states that the overall aim of decision makers should be to steer new development to Flood Zone 1 - land at lowest probability of flooding. Where there are no reasonably available sites in Flood Zone 1, sites in Flood Zone 2 may be considered, taking into account the vulnerability of land uses. Only where there are no reasonably available sites in Flood Zones 1 or 2 should sites in Flood Zone 3 be considered, taking into account the vulnerability of land uses.

For some land uses, the PPS25 Exception Test must be passed before development can be permitted in a particular Flood Zone. The Exception Test requires that:

- a) The development provides wider sustainability benefits to the community that outweigh flood risk;
- b) The development is on developable previously-developed land, or there are no reasonable alternative sites on developable previously-developed land;
- c) A flood risk assessment must demonstrate that the development will be safe, without increasing flood risk elsewhere, and where possible will reduce flood risk overall.

1.3 Development Proposals

The proposed development is a redevelopment of the Bedford Station Quarter site, shown in Figure 1. The site currently comprises a railway station, car park and former sidings. The proposal is to redevelop the site for mixed use including the station operational facilities, car parks and transport interchange, offices, retail units and residential properties. The illustrative proposed layout for the site is shown in Figure 2.

1.4 Objectives

The objectives of this flood risk assessment are as follows:

- To identify whether the proposed development is likely to be affected by current or future flooding from any source;
- To identify whether the proposed development will increase flood risk elsewhere;
- To identify appropriate measures to mitigate these effects and risks;
- To provide evidence for the application of the Sequential Test;
- To show that the development is safe and can pass the Exception Test if required.

As this flood risk assessment is in support of an outline planning application, with all detailed matters reserved, the site layout and drainage may subsequently change. This flood risk assessment therefore aims to set out the broad design principles for the site to ensure future development is acceptable. The matters to be held over are the details of the proposed flood risk mitigation measures and drainage design.

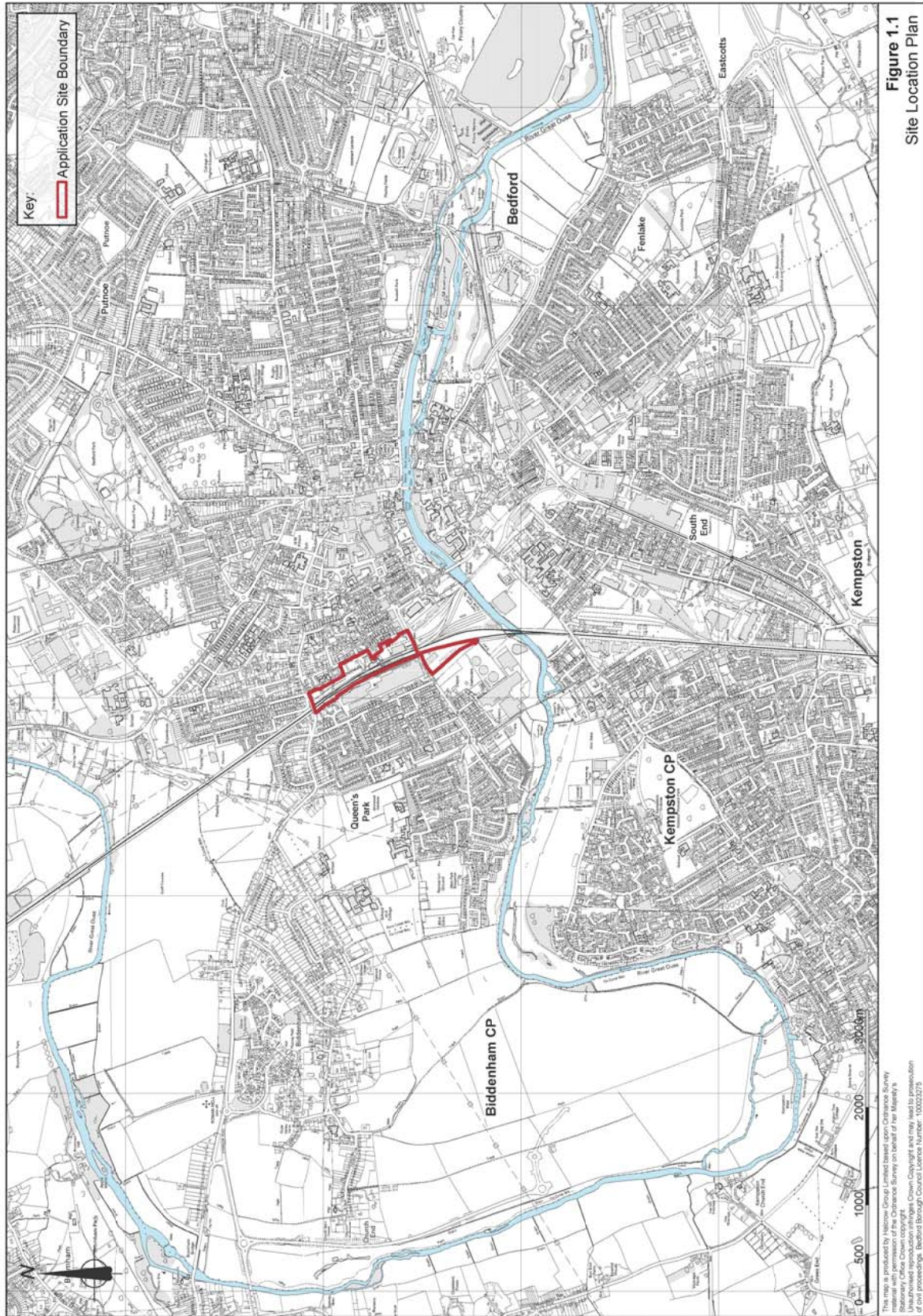


Figure 1: Location Plan showing the Bedford Station Quarter site.

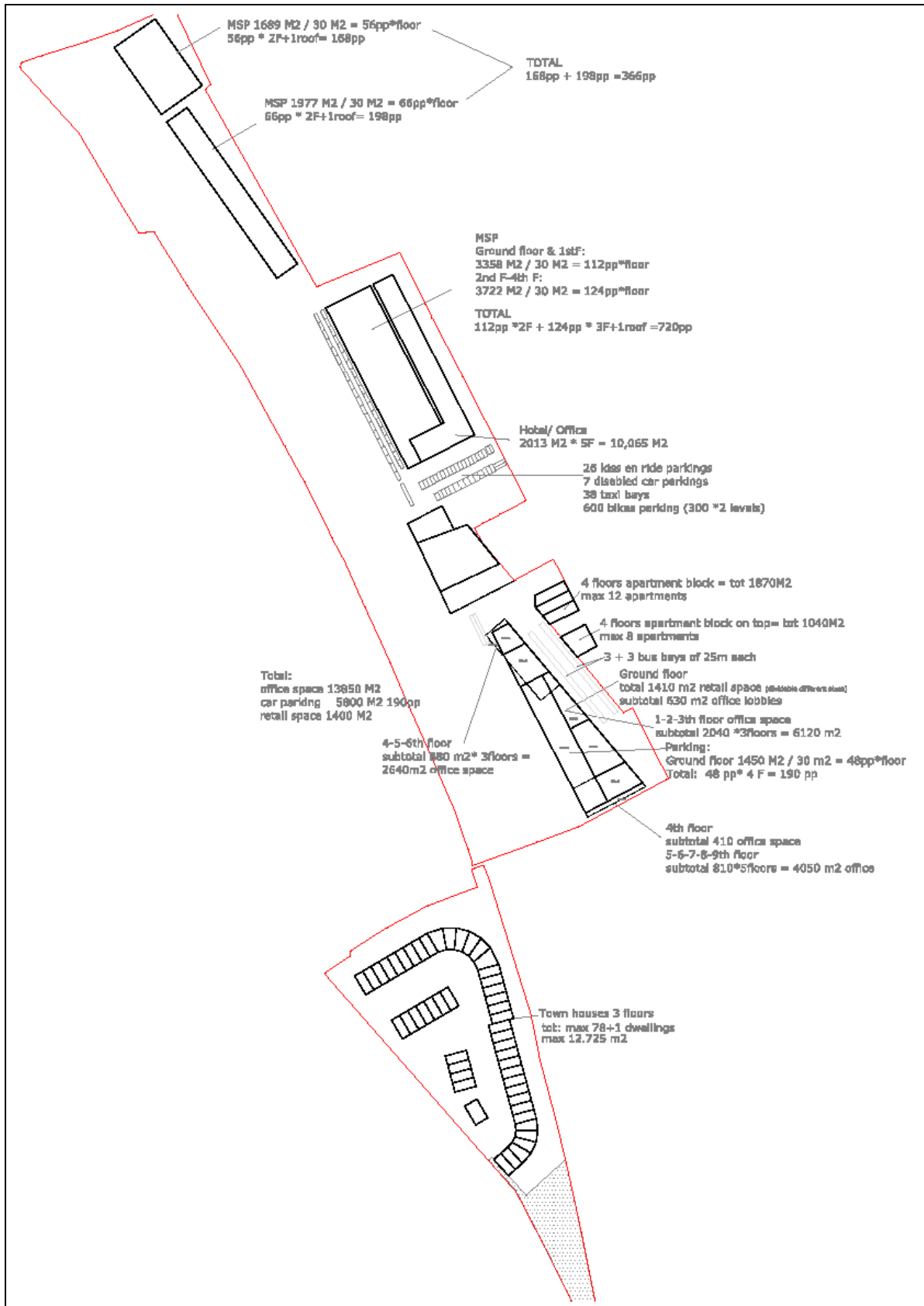


Figure 2: Illustrative layout for the redevelopment of the site.

1.5 *Applying the Sequential and Exception Tests*

The Station Quarter is a previously developed site and, while there are other previously developed sites in the area that may also be suitable for redevelopment, the need to redevelop the Bedford Station Quarter site has been specifically identified as a regeneration opportunity in the Adopted Bedford Town Centre Area Action Plan (AAP). Background and further details of the proposed Bedford Station development are set out on Page 19 of the AAP. The AAP lists land uses that are considered appropriate within the Bedford Station redevelopment. These are as follows: major office development, car parking, new station concourse and hub, residential units, affordable units. The masterplanning exercise for the site referred to in the AAP is the work that has been undertaken to inform the preparation of this planning application. Through the masterplanning exercise, consideration of the viability of the scheme and further discussions with Network Rail, the planning application was extended to include the land south of Ford End Road referred to in Paragraph 4.22 of the AAP.

Over the past eighteen months, a more detailed masterplanning exercise has been undertaken, that has had regard to technical and environmental constraints across the site, stakeholder consultation and the viability of the development proposals. This has led to the juxtaposition of uses proposed in this planning application. Residential development has been proposed on the former sidings area to the south of Ford End Road as there was a very strong view that both the proposed station car parking and office development should be located adjacent to the Station. This in turn led to the majority of the proposed housing being located on the former sidings site which is removed from the Station, being located on the opposite side of the railway line and Ford End Road.

On this basis, this flood risk assessment considered that the redevelopment of the site meets the requirements of the Sequential Test (as described in the PPS25 Practice Guide paragraphs 4.33 to 4.35). After meeting the requirements of the Sequential Test, the Exception Test may also then need to be applied. The requirement for the Exception Test is dependent on the vulnerability of the proposed development, which itself is determined by the specific amenities that will be included in the redevelopment. Table 2 lists the vulnerability classification for different land use types, as defined in PPS25. As the development proposals include residential properties, the development is classified as 'More Vulnerable'. On a mixed land-use site, PPS25 requires that the highest vulnerability category is adopted.

Table 3 indicates that for 'more vulnerable' land uses, the Exception Test must be applied if the development is within Flood Zone 3. The Environment Agency's Flood Maps indicate that the development site is partially within Flood Zone 2, with the remainder of the site in Flood Zone 1. Therefore the Exception Test does not need to be applied.

| Vulnerability Classification | Land Use |
|--------------------------------|---|
| Essential Infrastructure | <ul style="list-style-type: none"> • Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk, and strategic utility infrastructure, including electricity generating power stations and grid and primary substations. |
| Highly Vulnerable | <ul style="list-style-type: none"> • Police stations. Ambulance stations and Fire stations and Command Centres and telecommunications installations required to be operational during flooding. • Emergency dispersal points • Basement dwellings. • Caravans, mobile homes and park homes intended for permanent residential use. • Installations requiring hazardous substances consent. |
| More Vulnerable | <ul style="list-style-type: none"> • Hospitals • Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels. • Buildings used for: dwelling houses, student halls of residence; drinking establishments; nightclubs; and hotels. • Non-residential uses for health services, nurseries and educational establishments. • Landfill and sites used for waste management facilities for hazardous waste. • Sites used for holiday or short-let caravans and camping. Subject to a specific warning and evacuation plan. |
| Less Vulnerable | <ul style="list-style-type: none"> • Buildings used for: shops; financial, professional and other services; restaurants and cafes; hot food takeaways; offices; general industry; storage and distribution; non-residential institutions not included in 'more vulnerable'; and assembly and leisure. • Land and buildings used for agriculture and forestry. • Waste treatment (except landfill and hazardous waste facilities). • Minerals working and processing (except for sand and gravel working). • Water treatment plants. • Sewage treatment plants (if adequate pollution control measures are in place). |
| Water – compatible Development | <ul style="list-style-type: none"> • Flood control infrastructure. • Water transmission infrastructure and pumping stations. • Sewage transmission infrastructure and pumping stations. • Sand and gravel workings. • Docks, marinas and wharves. • Navigation facilities • MOD defence installations. • Ship building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location. • Water-based recreation (excluding sleeping accommodation). • Lifeguard and coastguard stations. • Amenity open space, nature conservation and biodiversity, outdoor sports and recreation and essential facilities such as changing rooms. • Essential ancillary sleeping or residential accommodation for staff required by uses in this category, subject to a specific warning and evacuation plan. |

Table 2: Flood Risk Vulnerability Classification, taken from PPS25 Table D.2.

| Flood Risk Vulnerability Classification | | Essential Infrastructure | Water Compatible | Highly Vulnerable | More Vulnerable | Less Vulnerable |
|---|---------------------------------|--------------------------|------------------|-------------------------|-------------------------|-----------------|
| Flood Zone | Zone 1 | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Zone 2 | ✓ | ✓ | Exception Test required | ✓ | ✓ |
| | Zone 3a | Exception Test required | ✓ | ✗ | Exception Test required | ✓ |
| | Zone 3b 'Functional Floodplain' | Exception Test required | ✓ | ✗ | ✗ | ✗ |

Table 3: Requirement for Exception Test, dependent on land use vulnerability and flood zone. A ✓ indicates that development is appropriate. A ✗ indicates that development should not be permitted. Based on PPS25 Table D.3.

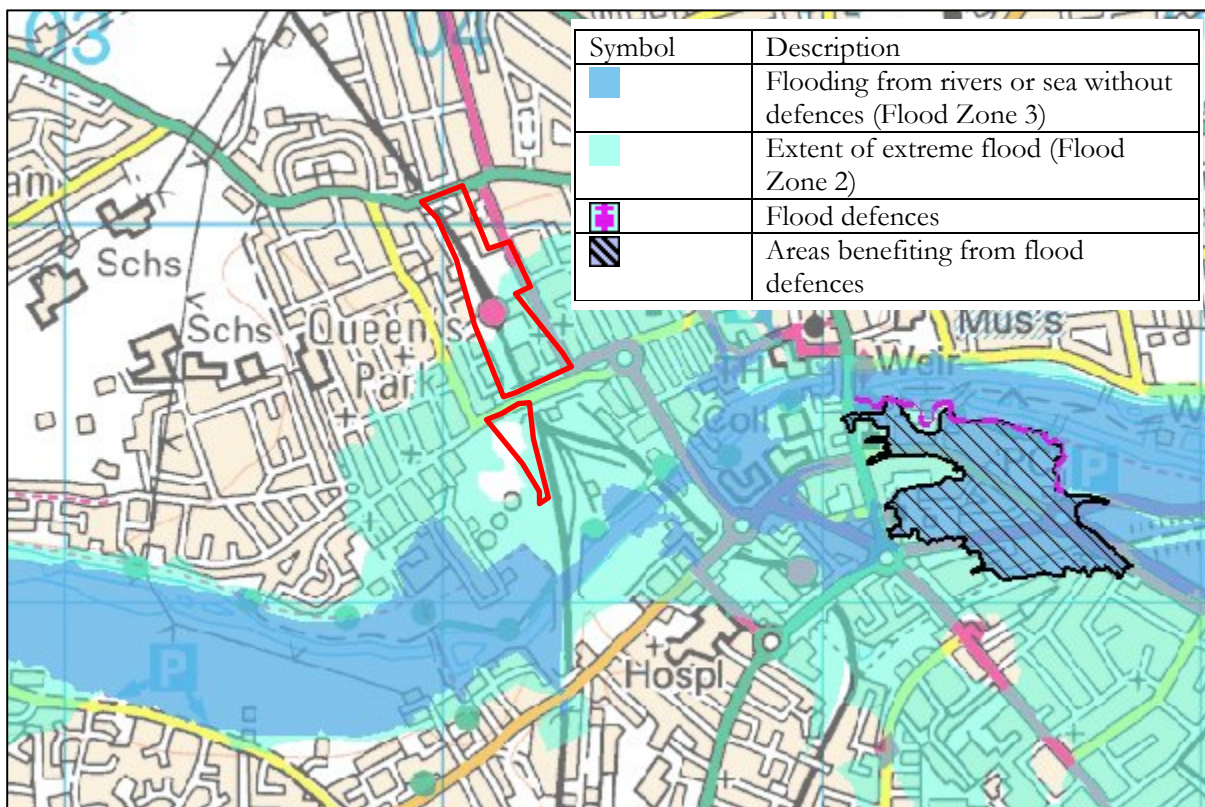


Figure 3: Environment Agency Flood Map for the site (Crown Copyright, Environment Agency, 100026380, 2008). Approximate site outline indicated by red boundary.

2 Flood Hazard

2.1 *Aims and Sources of Information*

This section aims to identify the flooding issues affecting the site and appraise the risk of flooding from all sources using the available information listed in Table 4. Where insufficient information is available, this section identifies where further qualitative analysis is required to assess flood risk to the site, to be included in the flood risk assessment accompanying the detailed planning application at a later date.

| Source of Information | Contents | Comment |
|---|--|---|
| Bedford Town Centre Strategic Flood Risk Assessment Final Report (Bedford Borough Council, June 2006) | Identifies potential sources of flood risk. Identified and maps flood zones. Provides guidance on flood risk assessment content for development site. | Prepared to the requirements of PPG25, the precursor to PPS25, but an addendum updates the assessment to PPS25. |
| Great Ouse Catchment Flood Management Plan (Summary of Draft Plan, February 2007) | Identifies main factors influencing river flows and flood risk and how these may change over time. Outlines sustainable flood risk management policies for the next 50 to 100 years. | Final report not yet available. Action plan presented in Draft CFMP may be subject to change. |
| Modelled Flood Levels | Flood levels from the Bedford Physical Model (1988) for the 1 in 100 year event, provided by the Environment Agency (reference CCC/2009/15789). | Flood levels for 1 in 1000 year event not available. |
| Historic Flood Levels | Flood levels from the 1949 flood event, provided by the Environment Agency (reference CCC/2009/15789). | Approximately equal to a 250 to 500 year event. |
| Site levels | Detailed site topographic survey undertaken in 2009. | |
| British Geological Survey maps | Information on bedrock and superficial geology at the site. | Detailed site ground investigations have not yet been commissioned. |
| Environment Agency 'What's in your backyard' website | Information on extents of Flood Zones 2 and 3; information on Source Protection Zone extents; information on flood warning cells. | Environment Agency have indicated that flood Zone extents are inaccurate in this area. |
| Ordnance Survey maps | Information on location of potential sources of artificial flood risk. | |

Table 4: Sources of information used in this flood risk assessment.

2.2 *Fluvial Flooding*

The main flood risk in terms of duration, depth and extent of flooding to the development is from the River Great Ouse, which flows in an easterly direction to the south of the site. The river is designated 'Main River' and is managed by the Environment Agency who have permissive powers to undertake maintenance and improvement works. Key properties of the river are summarised in Table 5.

Flooding would occur when levels in the river are sufficiently high to spill over the river banks and adjacent land. Although flood defences were implemented downstream of the site

in the late 1990s (the Bedford Flood Alleviation Scheme), there are no specific flood defences that reduce flood risk to the site itself.

| | |
|--------------------------------|------------------------------|
| Catchment area | 1465 km ² |
| Nearest gauging station | 33002, 1.5 km downstream |
| Median annual flood | 91 m ³ /s |
| Peak recorded flow | 278 m ³ /s (1947) |

Table 5: Key properties of the River Great Ouse at Bedford.

Flooding could also occur due to blockage of structures crossing the River Great Ouse. In the vicinity of the site, the railway bridge, County Bridge and Prebend Street Bridge all act as hydraulic throttles in flood events. Further downstream, there are a number of weirs and sluice gates that allow the Environment Agency to divert flood flows into secondary flood channels to control river levels. It is not known if their influence extends upstream to affect water levels at the site. The risk of flooding due to structural failure is considered further in Section 2.7 (Residual Risks).

There have been no recent modelling studies to estimate flood levels along the watercourse in Bedford. A physical model of the river was constructed by HR Wallingford in 1988. A review of the model by Posford Haskoning in 2003 indicated that the model was still an accurate representation of the system. Flood levels for the 1 in 100 year flood event were provided by the Environment Agency as listed in Table 6 and plotted as a long-section in Figure 4, along with observed flood levels from the 1947 event (estimated by the Environment Agency to have a return period of 250 to 500 years). These indicate a drop in water levels of approximately 0.6 m from upstream of the Railway Bridge to County Bridge across the southern boundary of the site.

| Location | NGR | Modelled flood level (m AOD) | 1947 observed flood level (m AOD) |
|------------------------------------|----------------|-------------------------------------|--|
| Railway Bridge (upstream) | TL 04316 49007 | 27.17 | 27.48 |
| County Bridge | TL 04580 49274 | - | 26.88 |
| Prebend Street Bridge (upstream) | TL 04634 49364 | - | 26.83 |
| Prebend Street Bridge (downstream) | TL 04669 49362 | 26.45 | 26.80 |

Table 6: Flood levels for the River Great Ouse at Bedford Station Quarter, as provided by the Environment Agency (reference CCC/2009/15789).

As a conservative estimate, the levels for upstream of the Railway Bridge have been used in this flood risk assessment to define the extents of Flood Zone 3 across the site. Figure 5 shows the estimated outline of Flood Zone 3, based on the site topographic survey and a flood level of 27.17 m AOD. This shows that Flood Zone 3 extends across the railway sidings part of the site, but does not extend across the areas proposed for redevelopment for residential, office or commercial use. The outline compares well with the Environment Agency Flood Map in Figure 3, when areas disconnected from the river are ignored.

The impacts of climate change were estimated in the SFRA as potentially resulting in a 220 mm increase in water levels at County Bridge (based on a 20% increase in flows over the next 100 years). Therefore the 100 year flood level including climate change is estimated as

27.39 m AOD at the railway bridge. This flood level is mapped against the existing site topography in Figure 6, which shows that some levels in the sidings area proposed for residential use are lower than this flood level. However, although the land is low-lying, the flood outline in this area is disconnected from the river by the higher ground of the railway line in between. This study considers that these disconnected areas would not be flooded during this event due to there being no positive hydraulic connection to the river. This conclusion is in line with the Environment Agency flood mapping principles (Environment Agency Guidance for Identification of Areas Benefiting from Flood Defences and Producing the Flood Map, Example 12).

Flood levels for the 1 in 1000 year event were not provided by the Environment Agency. Discussions revealed that the Flood Zone 2 and 3 outlines were created from a combination of historical flood mapping and coarse national flood mapping data. The latter does not generate flood levels suitable for use in flood risk assessments. Therefore it has not been possible to evaluate in detail the extents of Flood Zone 2 across the site. However, the 1947 flood event had a return period estimated in the order of 250 to 500 years. This is mapped against the existing site topography in Figure 7. This also shows that the area proposed for residential use is lower than the flood level, but again separated from the river by the higher ground of the railway line in between. This study considers that these disconnected areas would not be flooded during this event due to there being no positive hydraulic connection to the river.

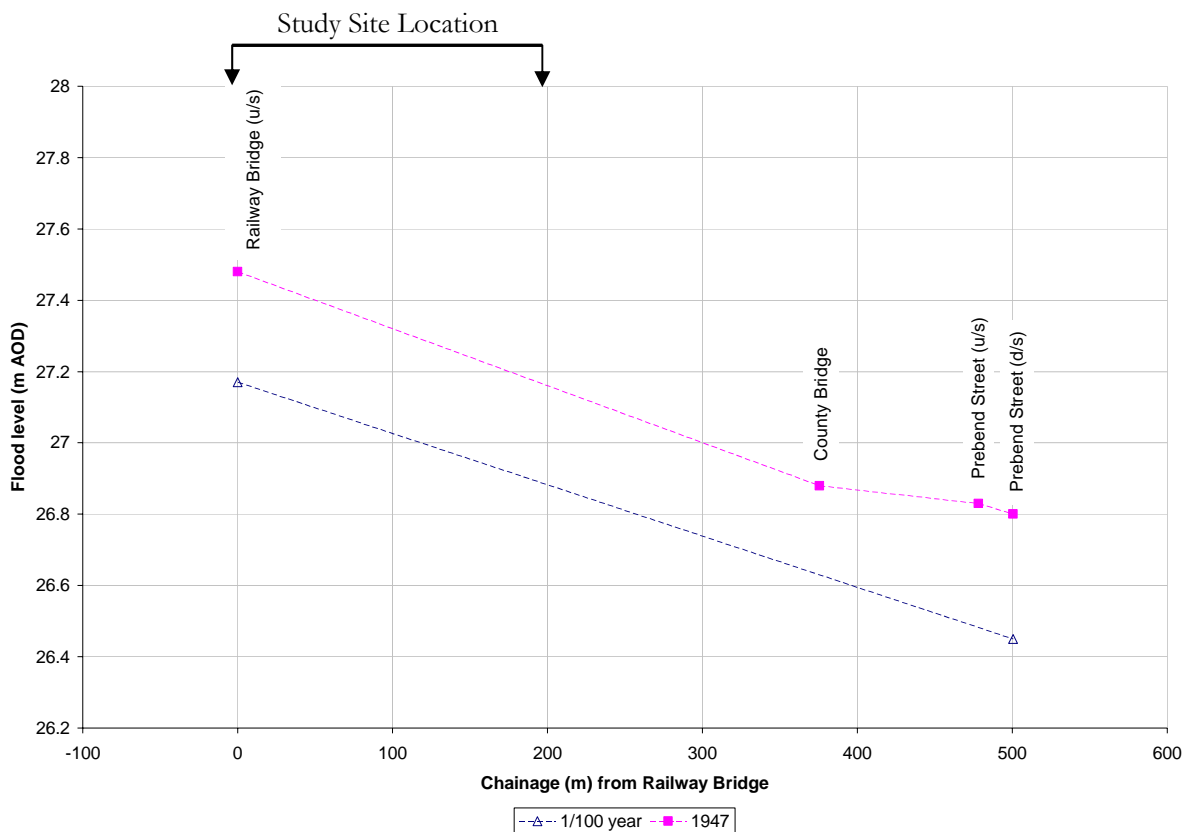


Figure 4: Flood levels for the River Great Ouse, plotted relative to chainage from the Railway Bridge.

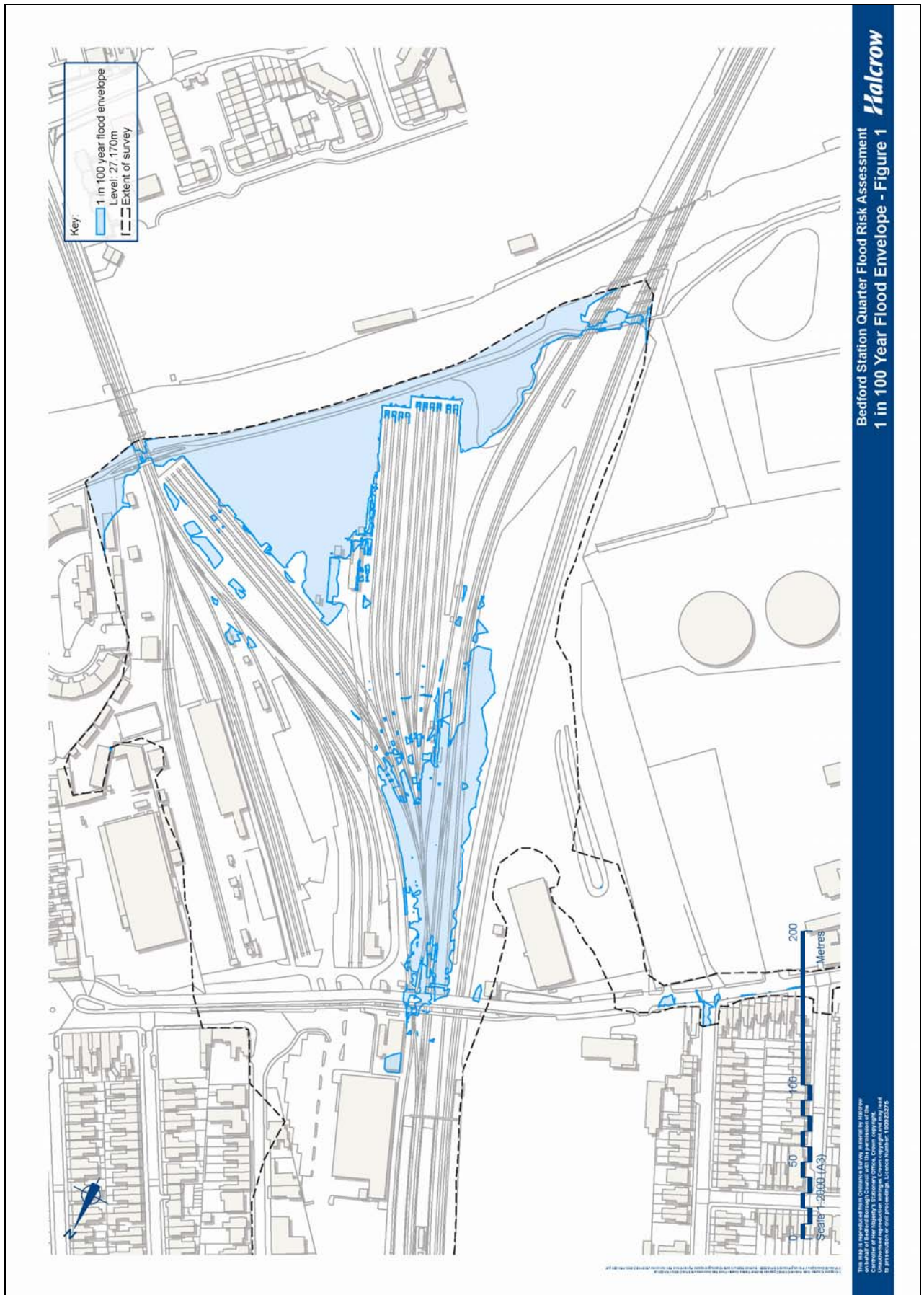


Figure 5: Estimated flood levels for the 1 in 100 year flood event mapped against the existing site topography.

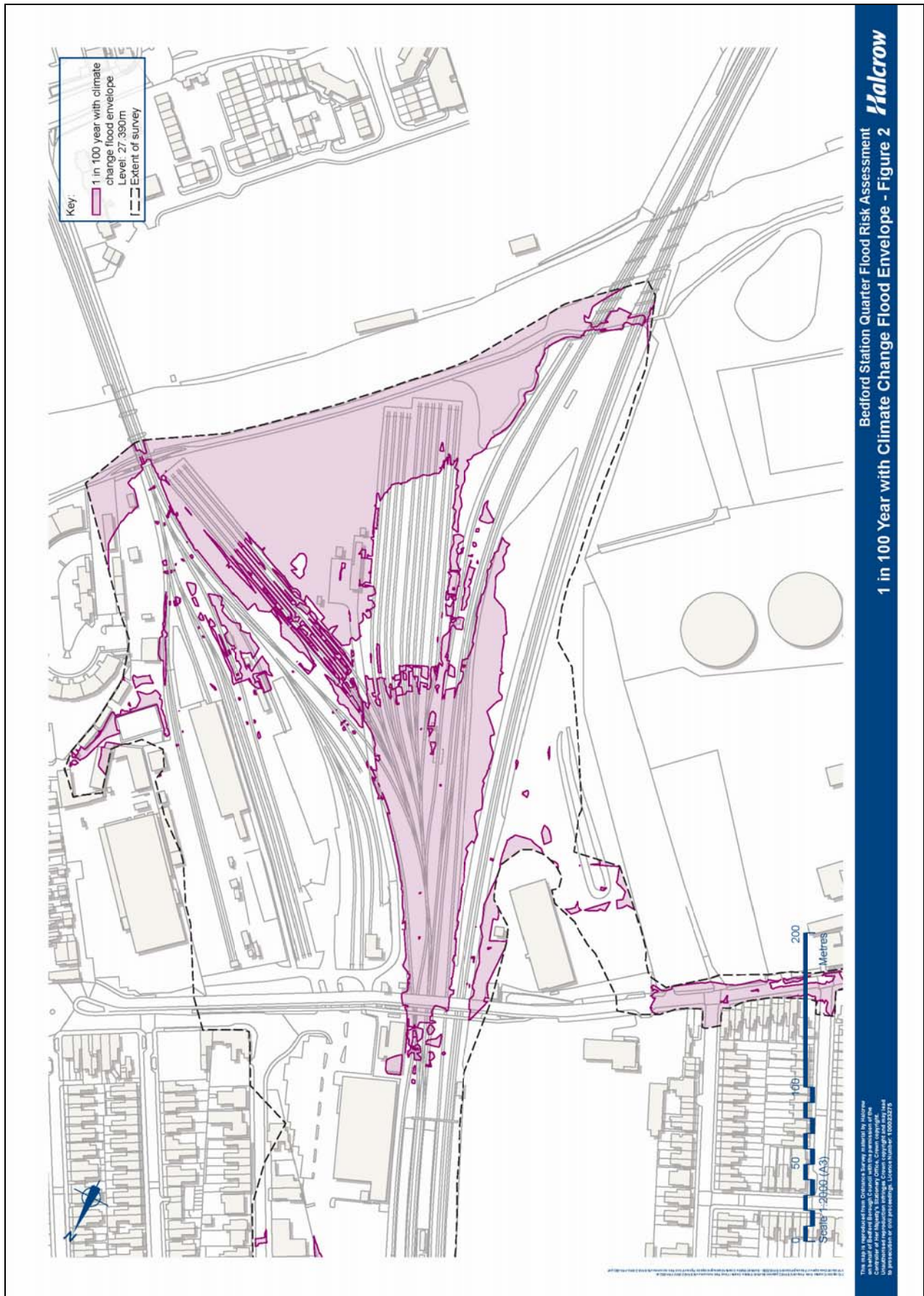


Figure 6: Estimated flood levels for the 1 in 100 year including climate change flood event mapped against the existing site topography.

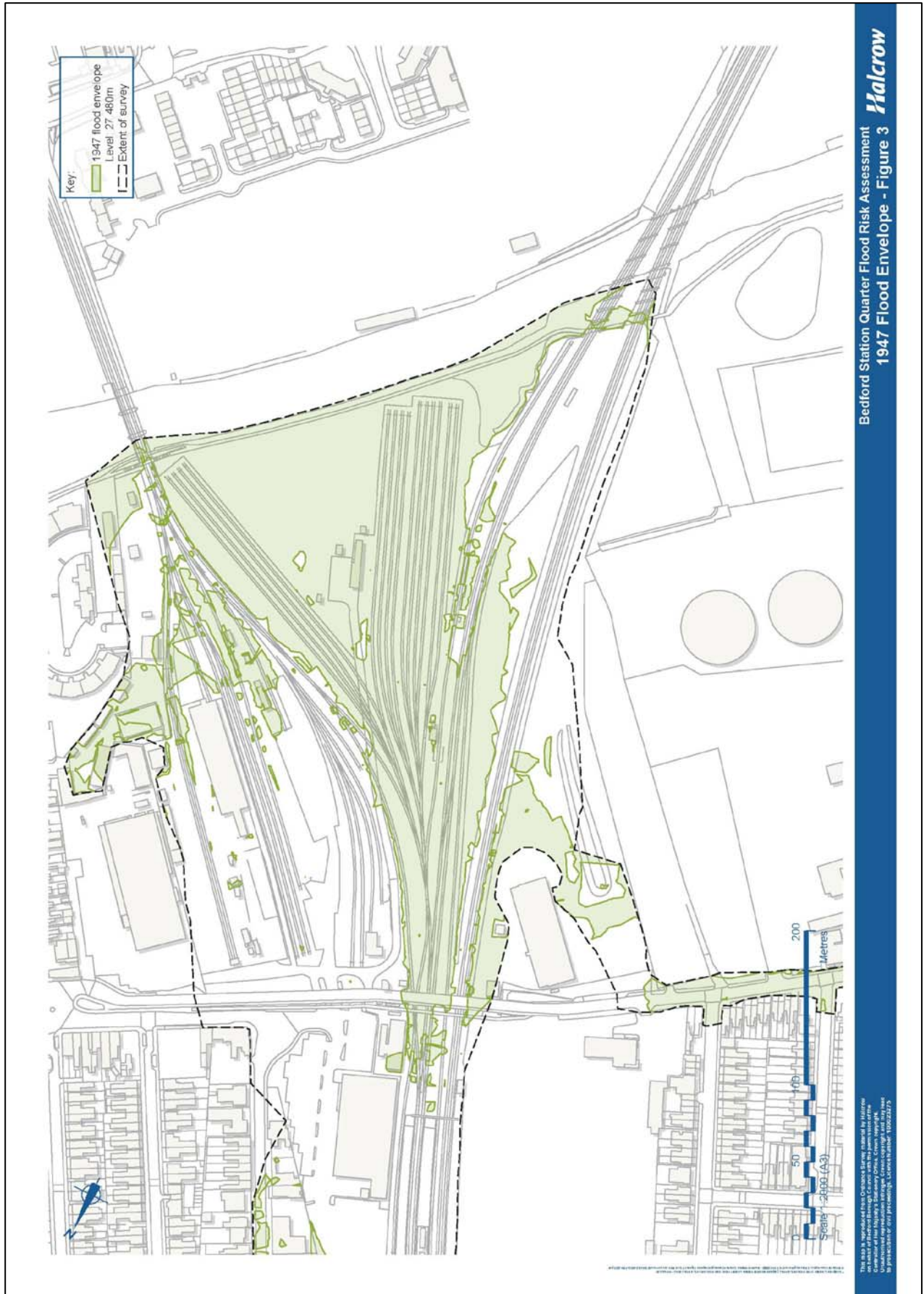


Figure 7: Estimated flood levels for the 1947 flood event mapped against the existing site topography.

2.3 ***Surface Water and Sewer Flooding***

Flooding from surface water runoff (water flowing overland towards river channels) can occur during intense rainfall storms, when the rate of rainfall is faster than the ability of water to soak into the ground. The direction and depth of flow is strongly influenced by topography and flooding can occur in local low-lying areas. In urban areas, surface water flooding can occur when drainage sewers are overwhelmed by heavy rainfall or become blocked. When flooding occurs from combined sewers containing both surface and waste water, there is a high risk of pollution of rivers and flooding of land and properties by water contaminated with raw sewage.

The SFRA indicates that an Award Drain may flow beneath the railway sidings in a culvert adopted by Anglian Water Services (AWS). The sewer records reproduced in the SFRA do not indicate whether there are flap valves preventing water from the River Great Ouse from backing up the culvert during flooding conditions. This could not be verified on-site by the SFRA as the outfall is submerged under normal water conditions. The design capacity and flows of the culvert are unknown. This culverted watercourse therefore poses an unknown flood risk to the site at the present time and further work will be required to investigate the culvert capacity, flows and outfall to support the detailed planning application.

The areas surrounding the site are primarily drained by combined sewers. The age of these sewers suggests that their performance standard is likely to be below the 1 in 30 years design standard for new drainage systems. The SFRA obtained information on recent flooding events from the DG5 register kept by AWS, which records all properties affected by flooding in the past 10 years. Of the six locations listed, Midland Road is the only location near to the development site. The SFRA states that AWS have confirmed in a letter to Bedford Borough Council that the Midland Road area is an area of specific concern. However, the drainage of Midland Road is away from the development site, indicating that excess flows would not be routed onto the site.

2.4 ***Groundwater Flooding***

Groundwater flooding can occur in low-lying areas underlain by permeable rocks (aquifers) when groundwater levels rise above surface elevations. The Bedford Station Quarter site is underlain by Cornbrash, Oxford Clay and Kellaway Beds bedrock. Cornbrash is based on limestone and therefore has the potential to store groundwater and pose a flood risk. However, it is not classed as a Principal Aquifer and therefore the volume of water stored is small. Oxford Clay and Kellaway Beds are impermeable and do not pose a groundwater flood risk.

The bedrock is overlain by superficial river terrace deposits. These are formed of sand and gravel and have the potential to store groundwater. However their spatial extent is small and the volume of water will not be large. It is likely that any flooding through these deposits would be due to high river levels causing seepage into the surrounding land.

The SFRA states that groundwater flooding is not deemed to be a significant source of flood risk in Bedford Town Centre. Therefore this risk has not been considered further in this study.

2.5 ***Artificial Sources of Flooding***

Artificial sources of flooding include reservoirs, canals and lakes. Flooding from these sources can occur as a result of the facilities being overwhelmed and/or bank failure. Breaching of storage facilities where water is retained above natural ground level can result in rapidly flowing deep water posing a significant risk to life and property.

There are no canals or lakes near to the site. There are no raised reservoirs in the immediate vicinity upstream of Bedford. Therefore there are considered to be no sources of artificial flooding to the site.

2.6 *Tidal Flooding*

Bedford is approximately 80 km upstream of the tidal limit of the River Great Ouse and therefore tidal flooding is not considered to pose a risk to the development site.

2.7 *Residual Risks*

As there are no flood defences protecting the site, there are no residual risks of flooding in the event of a breach. The site is located between two bridges (the Railway Bridge and County Bridge) and blockage of these structures by debris could result in higher river levels. This risk is considered low because the topography of the site rises sufficiently steeply to limit any extension to Flood Zone 3 to the railway sidings area only, as shown on Figures 5 and 6.

The flood control structures approximately 1.5 km downstream of the site include weirs and sluices which allow the Environment Agency to divert flood flows into secondary channels. If these structures failed in the 'closed' position, flood levels in the main channel would potentially be increased. It is not known if the backwater effects would extend upstream to affect water levels at the site. However, the topography of the site rises sufficiently steeply to limit any extension to Flood Zone 3 to the railway sidings area only, and therefore the risk of flooding due to failure of defences downstream is considered low.

2.8 *Summary of Flood Risk*

Table 7 summarises the flood risk to the site as identified using the available information and the requirements for further work to support a detailed planning application.

| Source of Flood Risk | Risk Assessment | Further work required to assess flood risk |
|---|--|---|
| Fluvial (River Great Ouse) | Moderate risk: the site partially overlies Flood Zones 2. | No further work required. |
| Surface water and sewers | Moderate risk from backing up of water in Award Drain culvert. | Further investigation of whether the Award Drain is flapped, its design capacity and probability of flooding. |
| Groundwater | Low risk as no history of groundwater flooding. | No further work required. |
| Artificial sources | No risks identified. | No further work required. |
| Tidal | No risks identified. | No further work required. |
| Residual (breach of defences or structural failure) | Low risk of increased flood envelopes due to blockage of structures or failure of downstream defences. | No further work required. |

Table 7: Summary of flood risk to the site from all sources.

3 Flood Risk Management

3.1 *Flood Risk Management Hierarchy*

The PPS25 Practice Guide (Communities and Local Government, June 2008) recommends a flood risk management hierarchy for identifying potential mitigation measures:

- **Assess:** undertake studies to collect data at the appropriate scale and level of detail to understand what the flood risk is. This was completed in the previous chapter.
- **Avoid:** allocate development to areas of least flood risk and apportion development types vulnerable to the impact of flooding to areas of least risk.
- **Substitute:** Substitute less vulnerable development types for those incompatible with the degree of flood risk.
- **Control:** Implement flood risk management measures to reduce the flood risk to the development.
- **Mitigate:** Implement measures to mitigate risk such as flood resilient construction.

For the Bedford Station Quarter, a range of measures will be implemented to manage both the design flood risk (the 100 year event) and residual flood risk (flooding in events more severe than the 100 year event).

3.2 *Avoidance and Substitution measures*

The first options for flood risk management are to avoid development or substitute less vulnerable land uses in flood risk areas. At the Bedford Station Quarter site, the opportunities to substitute less vulnerable land uses are limited by the site boundary and station requirements. The majority of the development to the north of the site is located in Flood Zone 1. The residential, retail, office and station areas proposed immediately north of Ford End Road located in Flood Zone 2, as is the residential development in the sidings area to the south of Ford End Road. PPS25 indicates that all of these land uses are permissible in Flood Zone 2.

3.3 *Control measures*

The next most preferable option is to implement control measures such as flood defences or raised floor levels.

New primary flood defences such as embankments or flood walls are not suitable for use in preventing flooding from the River Great Ouse at this site. The defences would have a detrimental impact on flood risk elsewhere during the design event due to loss of floodplain storage. There would be an increased residual risk of flooding in more extreme events or defence breach scenarios due to rapid inundation of the land behind. There would also be a potential loss in amenity and conservation value of the river bank at this location.

Raised floor levels above the design flood level is recommended as the main method to protect the proposed development against flooding during the design event. It is proposed that the ground levels of the residential development proposed for the sidings area is used for non-habitable purposes, e.g. garages. This will ensure that all habitable areas are raised significantly above the 100 year, 100 year plus climate change, and 1947 flood levels, and will therefore provide a high standard of protection.

Should flooding occur, there is a requirement for safe access and egress from the properties, to avoid the formation of isolated islands. It is anticipated that the reserved matter applications will include pedestrian and vehicular access routes to the development that are

raised to a suitable design level, to be agreed with the Environment Agency (for example, the 100 year flood level plus a freeboard of 300 mm, i.e. 27.47 m AOD).

As there will be no raising of ground levels within Flood Zone 3, the Environment Agency have confirmed that no compensation floodplain storage will be required.

The risk from the culverted Award Drain flowing underneath the railway sidings is currently unknown. Site investigations are required to clarify its outfall structure, and further enquiries are required to evaluate its design flows and capacity. Flood control measures may include fitting a flap to the outfall structure, increasing the culvert capacity, retaining a buffer zone over and alongside the culvert, or de-culverting the watercourse. The proposed use of the ground floor of the sidings site developments for non-habitable purposes will also reduce the consequences of any flooding. The culvert has been adopted by Anglian Water who should be consulted. These investigations should be undertaken by the developer to support the full planning application.

3.4 *Mitigation measures*

The risk of flooding to the residential properties in the sidings area will be managed through raising habitable areas to the first floor. This large freeboard allowance also gives a high standard protection against more extreme flood events, for example due to blockage of structures crossing the river.

Protection to other areas of the development to the north of Ford End Road will be provided by flood resistant and flood resilient building methods. The type of flood resistance and resilience measures that are possible depend on the depth of flooding after ground levels have been raised, as follows:

- **Flood depths of less than 0.3 m:** apply flood proofing measures to prevent water entering. This will include construction materials with a low permeability and demountable flood defences such as barriers to prevent water opening through doorways.
- **Flood depths of between 0.3 m and 0.6 m:** apply flood proofing measures to at least 0.3 m, dependent on structural assessment. Use flood resilient materials and designs in case of partial water entry, including easy access to all spaces to permit drying and cleaning.
- **Flood depths of greater than 0.6 m:** allow water through the property to avoid risk of structural damage. Use flood proofing measures to 0.3 m to prevent water entry in low flood depths. Design for water passage at higher water depths using flood resilient materials, including design for water to drain away after flooding and access to all spaces to permit drying and cleaning. At these depths, it may not be practicable to have living accommodation on the ground floor due to restrictions on suitable materials and the difficulties of enforcing restrictions in the future.

As design flood levels for Flood Zone 2 (the 1000 year event) are not available, it is not possible to calculate the maximum design flood depth for development to the north of Ford End Road.

The limitations of flood proofing measures are that residents / staff must have sufficient knowledge, ability and warning to be able to deploy demountable barriers, and this knowledge should be passed on to future residents / staff. There is currently no mechanism to ensure they are correctly deployed. As the location of the development to the north of Ford End Road is some distance from the river and disconnected by the higher ground of the railway sidings, the risk of flooding is low and it is unlikely that the demountable door barriers would be frequently used. Therefore there is a high possibility of the equipment being misplaced or the knowledge of how to deploy them lost, and it is recommended that demountable defences are not used.

Flood resilient measures include: tiled or treated timber floorings; plastic or steel kitchen and bathroom fittings; plastic doors, window frames and skirting boards; movement of electrical items such as boilers to the second floor; raising of electrical points above the flood level; use of cell insulation; and chemical damp proofing of wall joists. These types of measures will prevent people from being excluded from their homes or businesses for long periods after flooding has occurred, and the stress and potential health problems this can cause. These measures should be used as appropriate to development type in all ground-floor areas of all developments, to protect against flooding not only from the River Great Ouse but also from sewer and overland sources. There is a risk that household / business renovations at a later date will replace these fittings with less resilient measures. It is therefore important that all home and business owners across the lifetime of the development are aware of the purpose of the measures, for example, through property information packs or communal notice boards.

The Environment Agency provide a flood warning service for the River Great Ouse from Bedford to Offord. The Flood Warnings Direct is a free service that provides flood warnings direct to subscribers by telephone, mobile, email, SMS text message and fax. Residents must register voluntarily with the service to receive warnings. Warnings are also broadcast over local radio and TV stations. It is recommended that residents and businesses subscribe to the service. As this is voluntary, resident awareness of the service should be raised through home information packs or communal notice boards.

3.5 *Summary and Further Work*

The area of the site at highest risk of flooding is the sidings area where residential use is proposed. This area is within Flood Zone 2 of the River Great Ouse and therefore residential use as considered permissible by PPS25. A design level for the 1000 year event is not available. The proposed design will raise habitable areas to the first floor, leaving ground floor levels as non-habitable uses such as garages, to reduce the risk. Safe access and egress will be maintained through pedestrian and vehicular access ways raised to a level to be agreed with the Environment Agency.

An unknown risk is posed by the Award Drain flowing underneath the railway sidings. Further investigations are required to clarify the risk and required mitigation measures, to be submitted with the reserved matter applications.

For the remaining development areas north of Ford End Road, the majority of the area is in Flood Zone 1 with areas immediately to the north of Ford End Road in Flood Zone 2. It is proposed that flood resilient measures are installed to these developments to reduce the impacts of any flooding. The specification of the flood resilient measures will be submitted with the reserved matter applications.

It is recommended that all residents and businesses are encouraged to subscribe to the Environment Agency's flood warning service.

4 Surface Water Management

4.1 *PPS25 Requirements*

PPS25 requires that there is no detrimental impact of development on flood risk elsewhere, and if possible, there is an improvement in flood risk to other properties. Development can increase surface water flood risk elsewhere through reduced permeability of the site leading to increased volume and rate of runoff. This effect should be mitigated through the use of Sustainable Drainage Systems (SUDS) to mimic the flows from the site prior to development.

In the case of the Bedford Station Quarter, the application site is already developed. The site has mainly impermeable surface coverings which drain to the combined sewer system. To satisfy PPS25, the redevelopment of the Bedford Station Quarter must ensure no additional runoff is generated compared to the existing state. However, there are opportunities for decreasing the runoff generated and thereby providing an improvement in flood risk elsewhere in Bedford. This section discusses the potential SUDS measures that could be implemented on the site.

4.2 *SUDS Options*

For sustainable drainage to be most effective, a management train should be implemented that includes measures for source control (generation of run-off), site control, and regional control. Regional control measures should be planned and implemented through a wider spatial strategy such as a Water Cycle Strategy. For the Bedford Station Quarter development, source and site control measures could be considered:

- Site control measures would typically involve routing water to one or more surface or subsurface storage sites, where water could be slowly infiltrated to groundwater, or attenuated and released at greenfield rates and volumes. The storage may be provided at the surface level in pond or wetland features, or subsurface using crate structures.
- Source control measures would typically involve small-scale elements introduced at the house or street level provide the quickest and most localised response to managing run-off generation. The limitation of source control measures is that they rely on appropriate maintenance and management typically by the residents of the property, and may not have the desired cumulative effect on runoff rates and volumes particularly in more extreme rainfall events. Typical measures include:
 - a) **Green roofs.** These are vegetated layers that sit on top of conventional roof surfaces of a building. The roofs intercept, slow, absorb and evaporate rainwater, thereby reducing the rate and volume of run-off.
 - b) **Rainwater harvesting.** Collection of rainwater on-site and use for grey water (non-potable) uses reduces demands on the water supply system and can reduce rates and volumes of run-off from the site. There may however be conflicts in the use of rainwater harvesting for surface water attenuation versus water supply. For water supply purposes, the storage areas are ideally full, while for surface water attenuation purposes, storage areas are ideally empty.
 - c) **Permeable pavements.** The use of permeable paving materials for pavements, parking areas and roads allows water to infiltrate into the ground below, thereby reducing the rate and volume of run-off. There may also be water quality improvements as pollutants are trapped in the infiltration layers. The disadvantages are a higher cost than conventional asphalt, and more onerous maintenance requirements.

- d) **Soakaways.** These are gravel-filled trenches or special containers than water is piped into and allows to soak into the ground. These may be located to drain water from properties, roads and pavements, provided the soakaway is positioned at least 5m from roads and buildings.

4.3 Site Strategy

The site overlies superficial river terrace deposits, which are permeable, but bedrock deposits varying permeability. The site does not overlie any Source Protection Zones which might impose additional water quality constraints on infiltration.

The detailed drainage design for the site will be included in the reserved matter applications following consultation with the Environment Agency.

The site is currently drained by a combined sewer system. As SUDS will be used to manage surface water run-off, only foul water will drain to the existing sewer system.

5 Conclusions

The principal flood risk to the site is from the River Great Ouse to the south. There are no existing flood defences at the site, which lies within Flood Zone 2 (return period of flooding of between 100 and 1000 years). The vulnerability of the development is appropriate for this zone. A second unknown flood risk is from the Award Drain which is culverted beneath part of the site. A third flood risk is from surface water and sewer flooding.

Flood risk to the residential development to the south of Ford End Road will be managed by substituting non-habitable uses such as garages to the ground floor, and providing pedestrian and vehicular access ways that are designed to maintain safe egress during a flood event. This will provide a high standard of protection in the event of an extreme event, including potential blockage of structures crossing the river.

Flood risk to the mixed development to the north of Ford End Road will be managed through the use of flood resilient building construction techniques, appropriate to each type of development. This will reduce the impacts of flooding and ensure rapid reoccupation of businesses affected.

The impact of the development on flood risk elsewhere will be mitigated through the use of SUDS drainage measures.

The remaining issues to be resolved through reserved matter applications are:

- Investigation of the flood risk from the culverted Award Drain and proposal of suitable mitigation measures if found to be necessary.
- Agreement of design of pedestrian and vehicular access ways to ensure safe access and egress from railway sidings area south of Ford End Road during a flood event.
- Specification of flood resilient measures required to reduce the consequences of flooding to mixed development north of Ford End Road.
- Specification of the SUDS measures and drainage design to be used to reduce surface water rate and volume from existing conditions.