

Cardigan Strategic Flood Consequences Assessment

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Glossary of Terms

Term	Meaning / Definition
CFMP	Catchment Flood Management Plan
DAMs	Development Advice Maps (published by Welsh Assembly Government within TAN15)
EA/ EAW	Environment Agency/ Environment Agency Wales
EWL	Extreme Water Level (tide level)
FAS	Flood Alleviation Scheme
FCA	Flood Consequence Assessment
FEH	Flood Estimation Handbook method (for hydrological assessment)
LDP	Local Development Plan
Lidar	Light Detection and Ranging data (ground level information)
LPA	Local Planning Authority
mAOD	Metres Above Ordnance Datum
NGR	National Grid Reference
PPW	Planning Policy Wales (Welsh Assembly Government's Planning Policy)
QMED	Median Annual Maximum Flood
STAM	Solutions for Total Asset Management database (Dwr Cymru Welsh Water records of reported sewer flood incidents)
SuDS	Sustainable Drainage Systems
TAN	Technical Advice Note
TAN15	PPW Technical Advice Note 15: Development and Flood Risk
Tuflow	Tuflow hydraulic modelling software
Zones A, B & C	Flood Zones defined on Welsh Assembly Government DAMs

Executive Summary

Atkins was appointed by Ceredigion County Council to assist in the development of the Local Development Plan (LDP) by undertaking a Strategic Flood Consequences Assessment (SFCA) for Cardigan. The goals of the SFCA are to assess the flood risk at candidate sites being considered for development within the LDP and to provide advice regarding management of the risk in order to meet requirements set forth by the Welsh Assembly Government, particularly those in Technical Advice Note 15 (TAN15).

The SFCA was undertaken in two phases. Phase 1 defined the areas that needed to be considered in the assessment, assigning preliminary risk levels to the identified candidate sites, and defining the extent and nature of the work required to complete an assessment at each site. This report comprises Phase 2 of the work, which details the results of the qualitative and quantitative assessments carried out at each site and the conclusions with regard to the potential for development and management of identified flood risks.

In general, the main flood risks at Cardigan are tidal flooding up the Teifi estuary and fluvial flooding from the Afon Mwldan. The latter risk was analysed in combination with the fluvial flood risk from ordinary watercourses in the area, and a Cardigan-wide hydraulic model was developed. Other potential risks to the town included flooding from sewers and surface water run-off. The risks from each of the sources were analysed for the sites within four areas: North Cardigan, the Mwldan Catchment, Central and East Cardigan, and South Cardigan. The results of the analysis were used to draw conclusions about the development potential of each of the candidate sites in accordance with TAN15 requirements.

To the north of Cardigan, limited flood risk was identified to the 5 sites proposed for extension of the quarry. Although only partial development of the site immediately adjacent to the Afon Mwldan was recommended since a buffer zone will be required against fluvial flooding.

Of the 38 sites identified within the Mwldan Catchment, 19 were considered to have limited risk of flooding or minor risk from surface water run-off and no problems with development are anticipated. A further 11 sites were considered developable with management of surface water run-off. The site at Tregibby Farm, Gwbert Road (S2017) may be at risk from minor watercourses in the area and a site-specific FCA is recommended to confirm that flood risk to the site can be adequately managed.

Anticipated fluvial flooding from the Mwldan may restrict full development at 4 sites (Capel Cwm and 3 sites at Bath House Farm) but partial development of each of the sites is anticipated to be possible. Tidal flooding is a significant risk at the downstream end of the Afon Mwldan, and the development of the 3 sites located along Middle Mwldan and in Greenfield Square is likely to be hard to justify under TAN 15 guidelines.

Tidal flood risk will limit development at up to 14 sites within Central and East Cardigan. Three of these sites are in the field to north of main roundabout opposite Cardigan Hospital and are also at risk of flooding from the minor watercourse that runs through the site. However, the extent of risk is limited and some development may be possible following a detailed FCA.

North of the town centre, minor risks have been identified and in general no problems are anticipated in the development of sites. At 3 sites potential risk from sewer flooding has been identified. It is noted that for the proposed development adjacent to the North Park Estate, an overall strategy ought to be developed with respect to the management of surface water run-off in the area so that an adequate drainage network is developed with capacity to handle all foreseeable future development.

To the East, surface water run-off is the main risk affecting the 7 sites identified adjacent to the Parc Teifi Business Park. Again, it is recommended that an area-wide approach to the management and discharge of surface water is developed. It is anticipated that a detailed FCA will confirm that some development in the area is possible.

In South Cardigan, three of the sites lie directly adjacent to the Afon Teifi and are at risk of tidal inundation. Development of these sites is not anticipated to be possible without impact to other areas. Further south, minor risks have been identified and development should be possible providing adequate consideration is given to the management of surface water. In particular, it is noted that site S0593 lies adjacent to an existing house development and further extension of development in the area could result in the piecemeal

development of an overly complex drainage system unless an overall strategy be developed with respect to management of surface water at the outset.

1. Introduction

1.1 Background

The Welsh Assembly Government's Planning Policy Wales (PPW) provides the planning policy framework under which the Local Planning Authorities (LPAs) must prepare their Local Development Plans (LDPs). PPW highlights the need to reduce flood risk by avoidance of development within high risk areas, as opposed to the previous approach of flood defence and mitigation of the consequences of flooding. The guidance requires LPAs to consider the catchment as a whole and take a strategic approach to flood risk.

PPW is supplemented by a number of Technical Advice Notes (TANs). Of key interest is TAN15: Development and Flood Risk which provides guidance to LPAs regarding the assessment of flood risk when they are preparing their LDPs. The advice note seeks to guide planning decisions so that new development is directed away from areas that are considered to be at high risk of flooding. Where development has to be considered within a high risk area it outlines justification tests in order to guide decisions regarding whether a specific development may proceed.

In October 2009 Atkins was appointed by Ceredigion County Council (Ceredigion CC) to assist in the development of the LDP in relation to Cardigan by undertaking a Strategic Flood Consequences Assessment (SFCA) for the town.

1.2 Purpose of the SFCA

The SFCA provides an assessment of the flood risk for the proposed development sites which are being considered within the local development plan (known as the candidate sites), and provide guidance regarding the management of this risk. It encompasses a broad level assessment and does not remove the requirement for more detailed site specific assessments which will follow the adoption of the LDP and which should subsequently be undertaken by developers at the planning application stage, as required under TAN15.

The overarching aim of the SFCA is to provide sufficient data and information to enable the LPA to apply a sequential approach to the allocating of sites, promoting flood Zones A and B before Zone C (of the Welsh Assembly Government's Development Advice Maps – DAMs).

The SFCA will assist Ceredigion County Council to:

- Prepare appropriate policies for the management of flood risk within the LDP;
- Inform the Sustainability Appraisal so that flood risk is taken account of when considering options and in preparation of strategic land use policies;
- Identify the need for site specific FCAs in particular locations, in order to determine the acceptability of flood risk in relation to emergency planning capability; and
- Identify issues relating to managing surface water and use for sustainable drainage.

1.3 Approach to the SFCA

The SFCA for Cardigan considers both fluvial and tidal influences on flood risk within the town, as well as other sources of flood risk. There are a number of ordinary watercourses in the vicinity and there may well be issues with the public sewer network.

Since the suitability of available information to inform the SFCA was not fully known at the start, the SFCA has been undertaken in two phases.

1.3.1 Phase 1

The first phase of this project involved scoping out the requirements to be considered within the SFCA of the area. This included defining the areas within Cardigan where the flood consequences needed to be determined and the extent and nature of the analytical assessments required to define the risks.

It was felt that the recommendations indicated in the Environment Agency Wales' guidance note to local authorities for SFCAs were too detailed for such a broad scale assessment, and that assessing all the sites in detail against the TAN15 guidance would be prohibitively expensive. Therefore, it was agreed at a meeting with Ceredigion County Council and the Environment Agency Development Control that it was acceptable to approach to the Strategic Flood Consequences Assessment using the same methodology adopted for the Aberystwyth SFCA.

Activities undertaken within Phase 1 and the agreed approach to Phase 2 are documented within the Phase 1 Report.

1.3.2 Phase 2

This report documents works undertaken within Phase 2 of the SFCA.

Candidate sites were categorised as High, Medium or Low flood risk and divided into four key areas for assessment. For Low Risk sites where minimal flooding is expected, it was agreed that only a qualitative assessment of the perceived risks would be undertaken.

Where Medium Risk sites are present a strategic level assessment was undertaken in order to better understand the level of risk. Initially it was proposed that simple steady-state modelling of individual watercourses would be undertaken; however, it was later decided that a simple two-dimensional model of the town and minor watercourses would provide more accurate results with little additional investment. An assessment of potential overland flow paths, and identification of any possible culvert or sewer issues in the area was also undertaken.

Along the banks of the Afon Teifi sites were identified as being at High Risk of flooding. Since there are no significant tidal defences in Cardigan, two-dimensional modelling of tidal inundation from overtopping/ breach was not necessary. Instead, a simple assessment of tidal flood extents made by mapping predicted tidal water levels, for both current and future events, using Lidar data was considered sufficient to define the risk.

2. The Study Area

2.1 Development Sites

A review of the various sites identified for development on Ceredigion CC Candidate Sites Map was undertaken within Phase 1. The initial risk categorisation of the sites within the defined SFCA study area is shown on Drawing Number 5037097.881/RCF/001 in Appendix A.

For the purposes of detailed analysis, the sites were divided into five areas (see drawing):

- North Cardigan;
- Mwdan Catchment;
- Central & East Cardigan; and
- South Cardigan.

A detailed description of each area is included in the area-specific sections within this report.

2.2 Climate and Hydrology

The town of Cardigan in Ceredigion, lies on the estuary of the River Teifi. Its average annual rainfall is around 1100mm. The drainage area of the River Teifi is 940km² at its tidal limit. The geology of the Teifi catchment is mainly Ordovician and Silurian deposits.

The land-use within the catchment is mostly hill farming, with dairy farming predominating in south of the catchment. Forest cover is approximately 5%. The soils are peaty in the uplands, and are seasonally wet. Apart from Tregaron bog, most of the lower areas have soils with a permeable substrate.

Flows in the upper catchment are regulated by public water supply impounding reservoirs in the upland areas, and flows are reduced by agricultural and water supply abstraction.

Cardigan is also served by several smaller streams and watercourses that drain through the town, with catchment areas up to 13km². The underlying geology of the area to the north of Cardigan is that of the Ashill rocks laid down in the late-Ordovician period, which include mudstones, siltstones and sandstones. There are superficial deposits of diamicton tills and glacial sands and gravels.

Since the catchment is mostly rural, runoff and flows to Cardigan is largely the product of land use and natural basin characteristics. Increased run-off is expected through the partially urbanised areas within the catchment, including Cardigan town.

2.3 Sources of Flooding

The main source of flood risk to Cardigan is from the tide and surges in Cardigan Bay propagating up the Afon Teifi; the main river which flows south-east to north-west, joining the sea approximately 5km downstream of the centre of the town.

In addition, the Afon Mwdan poses flood risk to the sites to the west of the town. A flood alleviation scheme was constructed in the 1990's to reduce the risk of flooding to the town centre from the watercourse; however, flooding upstream remains a significant risk. Flood risks from these three sources have been considered in some detail within Section 3 of this SFCA.

A number of other flood risks have also been identified. These include:

- Ordinary watercourses;
- Culverted watercourses;
- Sewers; and

- Surface water runoff.

The risks associated with each possible source of flooding are discussed on an area-specific basis in the relevant report section.

2.4 Development Design Life and the Impacts of Climate Change

Flood risk must be considered over the anticipated lifetime of each development. Until recently, Environment Agency Wales (EAW) policy has been to accept a development lifetime of 50 years. For residential developments, however, the EAW consider this to be too short a period and as best practice they now advise consideration of up to 100 years development life for residential developments. For other developments, a 70 year scheme life was been deemed appropriate¹. However, it should be noted that the EAW recommendations are subject to change and the latest advice from the EA indicates that a 75 year lifetime be used for all development except dwellings in order to conform to the PPS25 practice guide in England. For consistency with respect to guiding decisions regarding the LDP, the 70 year design life, along with the 50 and 100 years, has been considered for the developments in this SFCA. It should be noted that developers should seek clarification with respect to the required development design life for individual developments prior to submission of any site-specific FCA.

The design lifetimes of proposed developments are particularly important in light of the fact that TAN15 recommends consideration of the potential impacts of climate change when assessing the consequences of flooding. The latest DEFRA guidance for fluvial flooding is to apply a 20% increase to peak river flows in order to evaluate the influence of climate change. In this SFCA, the 1% (1 in 100) annual chance event peaks in all watercourses have been increased by 20%. No allowance for climate change was applied to the 0.1% (1 in 1000) annual chance event because of the high uncertainty already involved in estimating the peaks for this event.

Climate change was also taken into account in the case of tidal flooding by applying an allowance for the net rise in sea level. Detailed discussion regarding the allowance made is included in Section 4.3.1 of this report.

2.5 TAN15 Development Advice Maps

The Welsh Assembly Government's Development Advice Maps (DAMs) contained within TAN15 define flood areas as Zones A, B, C1 or C2. The assessment of flood risk and evidence required to justify development varies from zone to zone. Zone A is considered at low risk of flooding and the advice note seeks to encourage development within such areas rather than in higher risk areas. Land within Zone C is considered at high risk of flooding; Zone C1 is specified as areas that benefit from some level of flood defence, whilst Zone C2 is completely undefended.

¹ See Aberystwyth SFCA, Atkins report ref.: 5037097-760-DG02-3, October 2009

3. Key Flood Risks

3.1 Tidal Flood Risk

3.1.1 Tide Level Predictions

Tidal flooding to Cardigan is expected to result from propagation of the tidal Extreme Water Levels (EWLs) up the Afon Teifi. Current estimates suggest that the river is tidally influenced as far upstream as Cwm Plysgog (approximately 5km upstream).

The Environment Agency (EA) provided information with respect to predicted extreme water levels (EWLs) at the mouth of the Teifi. However, these levels do not wholly reflect those anticipated adjacent to the town centre since the funnelling of flows up the estuary will result in an increase in water levels.

Admiralty Tide Chart predictions were referenced and calculations undertaken, as described in Appendix B, in order to determine the tidal levels expected at Cardigan Town. The expected EWLs are summarised in Table 3.1 below.

Table 3.1 – Predicted Extreme Water Levels

YEAR	EWL (mAOD)	
	0.5% annual chance tidal event	0.1% annual chance tidal event
2010	4.04	4.14
2060 (50 year design life)	4.39	4.49
2080 (70 year design life)	4.62	4.72
2110 (100 year design life)	5.04	5.14

3.1.2 Extent of Flood Risk

There are no significant tidal defences along the banks of the Afon Teifi, although tidal defences are present along the lower reaches of the Afon Mwdan.

As the flood extents are confined to areas close to the rivers and the areas offered protection by any defence are small, it has been considered appropriate to apply the predicted extreme water levels across the whole of the potential flood risk area. Sophisticated two-dimensional inundation modelling has not been considered necessary within this study.

Predicted flood extents were mapped using available Lidar data. The predicted extents are shown on Drawing Numbers 5037097/881/RCF/010 and 011.

Discussion of the sites affected by the flooding is included in the area-specific sections of this report.

3.2 Fluvial Flood Risk from the Afon Teifi

3.2.1 Review of Flood Risk

The fluvial flood risk from the Afon Teifi is considered within the Pembrokeshire and Ceredigion Rivers Catchment Flood Management Plan (CFMP). Overall the river is approximately 122km long, making it the longest main river in South Wales, and it has a catchment area of approximately 1000 km². However, the large floodplain in the mid/lower reaches of the river, and the Cors Caron peak bog upstream, have an attenuating effect on flood peak resulting in the river having a relatively slow response to rainfall.

Although fluvial flooding occurs in many parts of the Afon Teifi catchment, hydraulic modelling undertaken as part of the CFMP indicates that the flooding at Cardigan is tidally dominated. Further hydraulic modelling of the river was not considered necessary at this stage.

3.3 Flood Risk from the Afon Mwldan (and Other Watercourses)

3.3.1 Available Data and Modelling Work

The Afon Mwldan flows from north to south through built-up areas at the western edge of Cardigan before discharging into the Afon Teifi just downstream of Cambrian Quay.

Flooding has occurred from the Mwldan in the past and in the early 1990's a flood alleviation scheme (FAS) was proposed to reduce the risk of flooding to the town from this source. Construction of the scheme was completed in 1998. A review of the scheme was undertaken as part of this SFCA.

A number of more studies were also available for review, including:

- Gwbert Road Flood Alleviation Scheme Project Appraisal Report (Atkins, 2005);
- FCA: Proposed Development at Bath House Farm (Waterman Quadrant, 2006); and
- Gwbert Road Culvert Hydraulic Modelling Report (Waterman Quadrant, 2009).

Key information gathered from these sources is detailed below. A more extensive review of the studies is included in Appendix B.

In addition, to complement the detailed studies and provide information regarding the potential flood risk from the Mwldan upstream, a two-dimensional (TufLOW) model was constructed of the watercourse as part of this SFCA.

3.3.2 Afon Mwldan Flood Alleviation Scheme

The flood alleviation scheme (FAS) was proposed in the early 1990's to reduce the risk of flooding to the town from the Afon Mwldan. The scheme involved the construction of a tunnel that enables flood flows to be diverted to the west of the town and discharge into the Afon Teifi approximately 150m downstream of the natural outfall. The tunnel intake structure is located to the north of Bath House.

As part of the scheme, local flood defence works were identified as potentially necessary upstream of the Bath House Bridge Culvert and at the downstream end of the river at Quay Street car park. However, by allowing flooding to the car park, the resulting reduction in predicted backwater levels enabled flood defence works in the vicinity of Bath House to be avoided. The adopted approach is evidenced by the warning signs visible today at Quay Street car park (see figure 3.1). It is worth noting that any plans to change the current status and protect the car park would result in the need for further defence works upstream.

Figure 3.1 – Warning Signs at Quay Street Car Park



3.3.3 Gwbert Road and Proposed Bath House Farm Development

Flooding to approximately 30 residential properties occurred in 1993 as a result of water backing up along the Afon Mwldan from the culvert under Gwbert Road. Public concern with respect to the ongoing flood risk from this culvert led to Ceredigion CC commissioning Atkins to undertake a study to look at the potential options for reducing the risk. A number of options were considered including the construction of a flood relief culvert and/or raised defences. However, it was concluded that the economic benefits of implementation of any scheme were low and construction works could not be justified at the time.

Since that time, the land at Bath House Farm has been proposed for development by Liberty Mercian Limited and Sainsbury's Supermarkets Limited. Development proposals include a supermarket, hotel, hospital, social services building (residential) and crèche. Car parking areas would be provided to serve each of these buildings, and a new access road is planned linking Bath House Road to Melin y Dre.

Waterman Quadrant undertook a FCA in 2006 to assess potential impacts of the proposed development on flood risk, this included construction of a hydraulic model; however it did not extend as far upstream as Gwbert Road. Since the public's perception is that the further urban development within the Afon Mwldan catchment could exacerbate flooding problems, following submission of the Bath House Farm FCA further detailed hydraulic modelling of the culvert was undertaken to assess the impacts of the proposed highway adjoining Melin y Dre/ Gwbert Road.

Hydraulic assessments concluded that flood risk from the Afon Mwldan in the vicinity of the proposed development site is minimal, and also confirmed that the development would not adversely affect the hydrological regime downstream. However, the tie in between the Link Road and Melin y Dre/Gwbert Road upstream remains of concern since the culvert crossing under Gwbert Road is of confirmed to be of low capacity and although it lies outside of the Bath House Farm development site, the issue may require addressing as part of the development in order to guarantee safe egress/access to the development during flood events. However, previous analysis indicates that a Flood Alleviation Scheme at Gwbert Road cannot be justified since the cost of works would outweigh the limited economic benefits associated with its construction.

Any development within the upstream catchment has the potential to increase the flood risk at Gwbert Road. However, the additional urban development areas proposed are small in comparison with the overall catchment area. Measures can be built into the development to manage surface water run-off to ensure that flood flows passing through the Gwbert Road Culvert are not increased. This is discussed in more detail in Section 5 of this SFCA.

3.3.4 TufLOW Modelling

During Phase 1 of this assessment, it was determined that available hydraulic models of the Afon Mwldan did not extend as far upstream as the North Cardigan sites and that further modelling would be beneficial to the study. Simple steady-state modelling of individual watercourses, including the Afon Mwldan, and the Nant Rhyd-y-fuwch to the east, was initially proposed. However, on further consideration it was concluded that a simplified two-dimensional TufLOW model of the two incorporating all the significant watercourses would provide a more cost-effective and detailed basis for analysis.

Discussion of the hydrological analysis and model construction is included in Appendix B.

The TufLOW model was run for the 1%, 1% + climate change, and 0.1% annual chance events. Results are shown on Drawing Numbers 5037097/881/RCF/020 – 025. The identified risk for the candidate sites is discussed in the area-specific sections below.

4. North Cardigan

4.1 Site Description

4.1.1 General Site Description

The North Cardigan area is a rural area located to the northeast of Cardigan at National Grid Reference (NGR) SN200485. To the south of the area are the village of Penparc and the main A487.

Ordinance Survey Maps label the central area as a 'Sand Pit'; the area consists of a large sand and gravel quarry.

4.1.2 Proposed Development

The 5 candidate sites identified in the area are all proposed extensions to the quarry, as shown in the summary table below.

Table 4.1 - Candidate Sites Summary

Site ID	Name	NGR	Development Type	Design Life
S2083	Sand and Gravel Quarry, Penyparc, Aberteifi	SN203482	Other – quarry extension	70
S2084	Sand and Gravel Quarry, Penyparc, Aberteifi	SN204484	Other – quarry extension	70
S2085	Sand and Gravel Quarry, Penyparc, Aberteifi	SN205487	Other – quarry extension	70
S2086	Sand and Gravel Quarry, Penyparc, Aberteifi	SN203489	Other – quarry extension	70
S2087	Sand and Gravel Quarry, Penyparc, Aberteifi	SN198486	Other – quarry extension	70

4.1.3 Hydrological Situation

The land rises to the north east of Cardigan away from the Afon Teifi floodplain. The quarry area is located on elevated ground between two ordinary watercourses. The Afon Mwldan runs to the north-west and the Ffynnon Pant-y-dwr-isaf runs to the south.

4.2 Data Review and Analysis

4.2.1 Information Available

A review of the available data has included the following:

- TAN15 Development Advice Map;
- Environment Agency Extreme Flood Outline Map;
- Environment Agency Surface Water Flood Map;
- Analysis of Flood Risk from Afon Mwldan (see Section 3.3);
- STAM Database (Dwr Cymru/Welsh Water Solutions for Total Asset Management Database); and
- Environment Agency NEXTMap data.

The NEXTMap was used to give an indication of the site elevation contours since Lidar data is not available for this area.

4.2.2 Analysis Approach

The majority of the candidate sites included in Phase 1 were categorised as Low Risk. The one exception to this is site S2087 which borders the Afon Mwldan.

A detailed assessment was considered unnecessary for the area, and a strategic assessment was considered sufficient to understand the risks associated with the proposed quarry development and to provide initial guidance for the management of the identified risks. The strategic assessment included:

- Review of likely overland flow paths using contour data;
- Review of potential extent of flooding from the Afon Mwldan; and
- Check for recorded sewer flooding.

4.3 Flood Risk from Main Rivers and Ordinary Watercourses

4.3.1 Flood Risk from Afon Mwldan

The Environment Agency Extreme Flood Outline Map indicates that the edge of site S2087 may be a risk from flooding from the Afon Mwldan; this is reflected in the fact that part of the site is shown to lie within zone C2 on the TAN15 Development Advice Maps.

The Tuflow modelling work confirmed the flood extents. The predicted flood boundaries for the 1% (1 in 100) and 0.1% (1 in 1000) annual chance events are shown on Drawing Number 5037097/881/RCF/030. However, it can be seen that due to the accuracy of the NextMap data used, the location of the predicted flooding does not entirely match up with the location of the watercourse indicated on the OS background map.

Confirmation of the exact flood extent would need to be confirmed by topographic survey and detailed modelling prior to development adjacent to the watercourse. However, it is estimated that approximately 16% of site S2087 will be flooded during a 1% annual chance event. During a 0.1% event this percentage will increase slightly to approximately 18%.

4.3.2 Flood Risk from Ffynnon Pant-y-dwr-isaf

Review of the contour data confirmed that the Ffynnon Pant-y-dwr-isaf is located within a narrow valley with high land, located at the southern edge of site S2083, diverting flood flows away from the existing quarry. Therefore, there is no flood risk to candidate sites from this watercourse, and hydraulic modelling of the watercourse was deemed unnecessary.

4.4 Flood Risk from Culverted Watercourses, Sewers and Groundwater

4.4.1 Flood Risk from Culverted Watercourses

The watercourses to the north of Cardigan flow through open land; there are no culverts in the area that could have an impact on the Candidate sites.

4.4.2 Flood Risk from Sewers

With little existing development in the area, the current sewer network is minimal and no sewer flooding incidents have been reported in the area. Flood risk from this source is considered to be negligible.

4.4.3 Flood Risk from Groundwater

Susceptibility to groundwater flooding was not included as a part of this assessment. However, analysis undertaken within the CFMP concludes that the risk of groundwater flooding within Cardigan is low. To the north of Cardigan, where current quarrying work would have exposed any

potential risk, the groundwater flood risk to candidate sites around the perimeter of the current quarry may be considered negligible.

4.5 Flood Risk from Surface Water Runoff

The available contour data was analysed to determine the likely direction of flows from the elevated land between the two watercourses. The topography suggests that surface water runoff generated within the quarry and adjacent candidate sites would flow overland along poorly defined flow paths until it discharges into one of the watercourses.

Sites S2086 and S2087 clearly slope towards the Afon Mwldan, as indicted on Drawing Number 5037097/881/RCF/030. However, the likely flow path of water from the sites to the south east is less well defined, and it is most likely that water will flow west into the existing quarry site before turning south and discharging into the Ffynnon Pant-y-dwr-isaf.

However, since the proposed development for all of the candidate sites in this area is an extension of the quarry, the profile of the land will be altered. Hence, the key factor in assessing flood risk from surface water is the potential runoff volumes and likely consequences of flooding.

Assessment of the catchment areas for each site indicates that they are small and limited runoff flow rates are anticipated. In addition, the permeable surface of a quarry will absorb more rainfall than an impermeable built development. If flooding does occur, the consequences are minimal – some quarry plant may be affected, and it will be vital to ensure safe egress routes for personnel working in low-lying areas. Anticipated impacts will be short-term; long-term interruption of operations would not be anticipated. However, developers should still consider surface water drainage requirements to ensure proposed changes to land topography do not result in flooding elsewhere.

It may be concluded that the overall risk of flooding from surface water runoff for the sites is low.

4.6 TAN15 Constraints

The majority of the candidate sites fall within TAN15 Zone A. Flood risk is low and few constraints are given within TAN15 for development within this zone. It is important, however, that development proposals give careful consideration to overland flow paths and the management of surface water runoff.

4.7 Summary of Flood Risk and Management

4.7.1 Candidate Sites S2083, S2084, S2085 and S2086

These sites fall within TAN15 Zone A and are located on high ground. Minimal flood risk has been identified, and no difficulties are anticipated in the development of these sites providing adequate consideration is given to the management of surface water runoff.

4.7.2 Candidate Site S2087

This steeply sloping site borders the Afon Mwldan. Flooding from the watercourse will effect approximately 16% of site during a 1% event. Under TAN 15 guidelines development of this area would not be permitted.

The site is proposed for extension of the quarry. Such operations would alter the topography of the site and could result in increased run-off into the Afon Mwldan and increased flood levels downstream. We would recommend that a buffer-zone be specified and that development is not permitted adjacent to the watercourse. The width of the buffer zone, will be dependent on the details of the proposed quarrying works and the accompanying proposals with respect to management of surface water run-off.

No other flood risks have been identified for this site.

5. Mwldan Catchment

5.1 Site Description

5.1.1 General Site Description

The Mwldan Catchment area is located to the north and west of Cardigan and incorporates existing development at North Park Estate (between the A487 and the Afon Mwldan) and along Gwbert Road (A4548), as well as undeveloped land in the vicinity of Bath House Farm.

The watercourse is situated within a steep valley and much of the undeveloped slopes either side are used for agricultural purposes.

5.1.2 Proposed Development

A number of significant sites have been identified within the LDP for potential development. The majority of the proposed developments are for housing, although some are specified as mixed or other use. The sites may be summarised as follows:

- 11 sites to the north of the North Park Estate along the A487 – housing/ other/ currently undefined use;
- 2 sites adjacent the Afon Mwldan at Capel – housing;
- 13 site on farmland to north of Gwbert Road – housing;
- 6 sites south of Gwbert Road at Stepside/ Bath House – housing/ other;
- 3 sites at Parc Radley, south of Old Castle Road – mixed/ other use; and
- 3 sites within the town centre adjacent to the downstream end of the Afon Mwldan – proposed use currently undefined.

The 38 candidate sites are summarised in Table 5.1 below.

Table 5.1 - Candidate Sites Summary

Site ID	Name	NGR	Development Type	Design Life
S0006	Capel Cwm	SN191476	Housing	100
S0116	Stepside Farm, Aberteifi	SN175470	Housing	100
S0189	Gwbert Road, Aberteifi	SN176476	Housing	100
S0524	Gotrel Farm	SN177477	Housing	100
S0525	Part of enclosure 7078	SN177477	Housing	100
S0526	Part of field 8700	SN178479	Housing	100
S0590	Adj. to Llwynpiod Farm, Aberteifi	SN179477	Housing	100
S0591	Adjacent to Llwynpiod Farm, Aberteifi	SN178474	Housing	100
S0596	land adj. to Trebared Farm, Gwbert Rd, Aberteifi	SN175475	Housing	100
S0619	Land at Stepside Farm, Gwbert Rd, Aberteifi	SN176471	Housing	100
S0620	Land at Stepside Farm, Gwbert Rd, Aberteifi	SN117469	Housing	100
S0832	Parc Radley	SN174464	Other	70
S0998	Show Field Cardigan	SN190470	Other	70
S0999	Show Field Cardigan	SN189470	Other	70

Site ID	Name	NGR	Development Type	Design Life
S1061	Land at North Road Park	SN189470	Unsure	100
S1070	Bath House Farm, Aberteifi	SN176466	Other	70
S1071	Showground Site, Aberteifi	SN189470	Other	70
S1204	149a/2 (The settlement boundary near Drws y Nant F	SN177475	Other	70
S1207	Maes Radley, Aberteifi	SN174462	Other	70
S1208	Field near Heol Felin Newydd	SN189470	Mix	100
S1242	Hen Cae Shoe	SN190470	Mix	100
S1243	Fferm y Gotrel, Heol Ferwig, Aberteifi	SN173476	Housing	100
S1245	Llwynpiod	SN178476	Housing	100
S2016	Aberteifi	SN186472	Unsure	100
S2017	Tregibby Farm, Gwbert Rd, Aberteifi	SN180472	Housing	100
S2038	Bath House Farm, Aberteifi	SN176466	Other	70
S2082	Caemorgan Road	SN195472	Housing	100
S2088	Capel Farm Buildings	SN187476	Housing	100
S2089	Feidrlas Fields	SN193472	Housing	100
S3112	Bath House, incl. Fire station, depot and car park	SN176466	Unsure	100
S3113	Land adj. Llwynpiod North Cardigan	SN177476	Unsure	100
S3114	Adjacent to Llwynpiod farm, Aberteifi	SN178474	Unsure	100
S3115	Land off Heol Derw, North Park	SN186471	Housing	100
S3124	Drawbridge, Middle Mwldan	SN176461	Unsure	100
S3125	Maes Radley, Aberteifi	SN174464	Mixed	100
S3126	Garage, Greenfield Square	SN17 462	Unsure	100
S3127	Furniture Shop, Greenfield Square	SN177462	Unsure	100
S3134	Fields Adj. Heol Felin Newydd, Cardigan	SN189470	Unsure	100

5.1.3 Hydrological Situation

The Afon Mwldan flows from north to south through built-up areas at the western edge of Cardigan before discharging into the Afon Teifi just downstream of Cambrian Quay. The watercourse has a catchment area of approximately 12.7km².

Flooding has occurred from the Mwldan in the past and a FAS was constructed in 1990's to reduce the risk of flooding to the town from this source. A review of the scheme is included in Section 3.3.

5.2 Data Review and Analysis

5.2.1 Information Available

A review of the available data has included the following:

- TAN15 Development Advice Map;
- Environment Agency Extreme Flood Outline Map;
- Environment Agency Surface Water Flood Map;

- Analysis of Flood Risk from Afon Mwldan (see Section 3.3), including:
 - Afon Mwldan Flood Alleviation Scheme As-built Drawings (Atkins, 1996);
 - Gwbert Road Flood Alleviation Scheme Project Appraisal Report (Atkins, 2005).
 - FCA: Proposed Development at Bath House Farm (Waterman Quadrant, 2006); and
 - Gwbert Road Culvert Hydraulic Modelling Report (Waterman Quadrant, 2009).
- STAM Database (Dwr Cymru/Welsh Water Solutions for Total Asset Management Database); and
- Light Detection and Ranging (Lidar) data.

5.2.2 Analysis Approach

The candidate sites within the Mwldan catchment area were categorised as Low or Medium Risk. The Medium risk sites were defined as those along the Afon Mwldan where risk from both fluvial and tidal flooding is possible. To the west, the ground rises and sites were considered at low risk of flooding. Sites on the eastern edge of the defined area, along the A487 road, were also initially classified as low risk.

Analysis of the risks to the area consisted of detailed review of the existing data and the new Mwldan modelling undertaken. Assessment included:

- Review of EA Surface Water Flood Maps;
- Review of possible overland flow paths using contour data;
- Review of potential extent of flooding from the Afon Mwldan;
- Review of tidal influence up the Mwldan; and
- Check for recorded sewer flooding.

5.3 Flood Risk from Tidal Sources

5.3.1 Flood Risk from Tidal Inundation

A review of the predicted tidal flood extents, as shown on Drawing Numbers 5037097/881/RCF/010 and 011, indicates that based on the Lidar contours flooding may extend up the Mwldan as far as Bath House Farm in the future.

As part of the Afon Mwldan FAS, defences were built to a level of 4.2 mAOD. These defences are expected to protect the town from flooding from the current day 0.5% and 0.1% annual chance tidal events. However, as sea levels rise with predicted climate change the current defences are expected to be overtopped. The current defence is expected to have a 30 year design life with respect to the 0.5% annual chance event, although a 0.1% event would be expected to overtop the existing defence by 2027.

If a 50 year design life is considered tidal inundation of Lower, Middle and Upper Mwldan roads as well as Greenfield Square would be anticipated. This would affect a number of the smaller proposed developments in the vicinity (sites S3124, S3126 and S3127). Some flooding of the Bath House development site is also anticipated.

The difference in predicted flood extents between the modelled scenarios for 50, 70 and 100 years in the future is minimal due to the slope of the land in the vicinity.

5.4 Flood Risk from Main Rivers and Ordinary Watercourses

5.4.1 Flood Risk from Afon Teifi

As discussed in Section 3.2, although fluvial flooding occurs upstream on the Afon Teifi, at Cardigan the river is tidally dominated.

5.4.2 Flood Risk from Afon Mwldan

Analysis of the flood risk from the Afon Mwldan is discussed in detail in Section 3.3.

The predicted flood boundaries for the 1% (1 in 100) and 0.1% (1 in 1000) annual chance events are shown on Drawing Number 5037097/881/RCF/031. The boundaries relate to the Tuflow hydraulic model results for the area upstream of the Gwbert Road culvert. However, since the model was considered to overestimate the flood extent downstream of the culvert, the predictions from the Waterman Quadrant study of the Bath House Farm site have been used. The Bath House Farm extents have been approved by EA Development Control as part of the site FCA, and hence provide the best estimate of possible flooding within the development at the site.

5.5 Flood Risk from Culverted Watercourses, Sewers and Groundwater

5.5.1 Flood Risk from Culverted Watercourses

A minor watercourse has been identified to the north of the North Park Estate. This starts in open channel but is culverted under much of the estate.

There have been previous flooding incidents in the vicinity in the past. It is unclear as to whether these incidents relate to issues the surface water drainage network or the culverted watercourse. A site visit revealed that there are sandbags along the footpath immediately downstream of the watercourse, on the route of the culvert, protecting properties from potential overland flows.

The main flood risk from this watercourse is flooding to existing development. Review of the existing ground profile indicates that new development is unlikely to be affected by overland flows originating from the watercourse or the downstream culvert. However, new development adjacent to the channel has the potential for adverse impacts downstream if surface water run-off is not adequately managed. Management of surface water discussed in more detail in Section 5.6.

In general, where flood risk from culverted watercourses is being considered, the Environment Agency require site specific FCAs to consider the effect of partial blockage of culverts and possible increase in risk. The extent of blockage is required to be at least 20% but may be more dependent on site circumstances.

5.5.2 Flood Risk from Sewers

Review of the Dwr Cymru/Welsh Water STAM Database indicates that there have been a number of isolated incidents reported at properties off North Road and Upper Mwldan. Although the incidents are isolated, consideration has been given to the impacts of repeated flooding in the vicinity.

The areas of concern are indicated on Drawing Number 5037097/881/RCF/031. Possible overland flow paths from sewer flood incidents were assessed with reference to Lidar contours. In general the flows are expected to be channelled down the roadways and discharge into the Afon Mwldan. However, this may include the routing of flows through sites S3126 and S3127. In addition, discharge into the lower reach of the Afon Mwldan at Greenfield Square may be restricted by the presence of the existing flood defence walls and flows may be diverted down Middle Mwldan Street flooding the low-lying properties.

A detailed investigation into the likely degree of risk is required prior to any development in the area, and mitigation measures may be required.

5.5.3 Flood Risk from Groundwater

Susceptibility to groundwater flooding was not included as a part of this assessment. However, analysis undertaken within the CFMP concludes that the risk of groundwater flooding within Cardigan is low.

5.6 Flood Risk from Surface Water Runoff

The Environment Agency Surface Water Flood Map indicates that in addition to the risk of surface water flooding adjacent to the Afon Mwldan, there are a number of potential flood risk areas within the North Park Estate. The routes are defined as 'Less Susceptible to Surface Water Flooding'. The maps are based on a number of factors including soil type and slope, as well as land use. It would be expected that any surface water would tend to flow along the highways rather than the routes indicated on the plans. Review of lidar contours and walkover survey of the area gives better indication of potential flow routes.

Potential surface water runoff from the high land to the north east of the North Park Estate has been assessed. To the far north, adjacent to Caemorgan Road, flow is expected to enter the minor watercourse that discharges into the Afon Mwldan. Flow from the open pastureland between Caemorgan Road and North Park Estate is likely to flow over the fields to the west, and some flow may find a route to the Mwldan via Heol Felin Newydd. Potential routes are indicated on Drawing Number 5037097/881/RCF/031.

Development of sites in the area will result in increased run-off volumes. Management of surface water run-off is expected to be an important consideration in the development proposals. A site-specific FCA will be required to demonstrate that surface water run-off can be managed so as to avoid adverse impacts to existing and proposed developments, particularly as there is already concern that the existing surface water drainage network within North Park Estate is of insufficient capacity.

To the north of Gwbert Road, run-off from the steeply sloping hillside may affect sites S0590, S0591, S1204 and S1245. The current surface water flows are eventually collected in the minor watercourses that run either side of Candidate site S2017, before discharging into the Afon Mwldan.

To the south of Gwbert Road, surface-water run-off from the hillside is likely to be divided, flowing partially towards to Afon Mwldan, and partially towards the Nant-y-ferwig. The watershed between the two watercourses is indicated on Drawing Number 5037097/881/RCF/031. Bath House Farm and surrounding sites are potentially at risk from the flows directed towards to the Mwldan.

5.7 TAN15 Constraints

The Afon Mwldan area incorporates sites at risk from tidal flooding from the Afon Teifi as well as fluvial flooding from the Afon Mwldan. The at risk areas are defined as Zone C2 on the TAN 15 DAMs. The majority of the remaining area is classified as Zone A.

TAN 15 encourages new development to be directed away from Zone C and towards suitable land in Zone A. To this end, TAN15 has different requirements for sites depending on the type of development proposed and the zones into which they fall. Where development is proposed within Zone C it must meet the justification tests outlined within the section.

Where consideration of a development site can be justified, the development must then meet the acceptability criteria detailed in TAN15 Section 7 and Appendix 1. In summary, development within Zone C must be flood free in the 1% (1 in 100) annual chance fluvial event and the 0.5% (1 in 200) annual chance tidal event including climate change, with the exception of emergency services that must remain flood free during the 0.1% (1 in 1000) annual chance fluvial and tidal events. All development must have acceptable consequences of flooding in the extreme [0.1% (1 in 1000) annual chance] event as defined by TAN15 A1.15. In addition the development must not adversely affect flood risk elsewhere.

Table A1.15 requires consideration of the maximum flood depth within the site, the maximum rate of rise of floodwater, maximum speed of inundation, and maximum velocity within the site. In addition, any flood defences must be shown to be structurally adequate under extreme overtopping conditions, and an emergency flood plan, including flood warning system and identified evacuation routes, must be in place. Emergency services and highly vulnerable

development (as defined by TAN15 Section 5 and including residential development) should not be permitted within Zone C2.

All development, including that within Zone A (which has few constraints to development), must give due consideration to the management of surface water; guidance is provided in TAN15 Section 8. Any development will result in changes to the natural hydrology of the catchment as a result of increased runoff from impermeable ground and built-up areas. TAN15 states that SuDS should be employed to manage surface water runoff wherever possible, and if the use of conventional drainage systems is proposed, improvements to the status quo must be made and developers must give good reasons why SuDS cannot be implemented.

5.8 Summary of Flood Risk and Management

5.8.1 Candidate Sites S0998, S0999, S1061, S1071, S1208, S1242, S2016, S2082, S2089, S3115 and S3134.

Land to the north of the North Park Estate is being considered for potential housing and other development.

The main flood risk to the area is from surface water run-off. Since there is already concern that the existing surface water drainage networks within the current residential development are of insufficient capacity, it is recommended that an independent drainage system be developed. An overall strategy ought to be developed with respect to area so that an adequate drainage network is developed with capacity to handle all foreseeable future development. This could potentially incorporate existing run-off from Heol Felin Newydd and the diversion of the currently culverted watercourse to reduce current flood risk to the North Park Estate.

In general highway drainage systems are designed to cope with a 1 in 30 year event. However, TAN 15 requires that no increase in flooding to other areas results from development during extreme events. Increased run-off from development to the north of the North Park Estate could increase flows in the Afon Mwldan and result in an increase in flood risk downstream, particularly at Gwbert Road. In order to ensure that no increase in run-off results from development, measures to manage surface water run-off from the sites will need cater for a 0.1% (1 in 1000) annual chance event. This is likely to mean that a significant surface water storage area would be required to attenuate flows in the area prior to discharge into the Afon Mwldan. Details of the system would need to be developed as part of an area-specific FCA. A discharge point just upstream of Melin y Coed is anticipated; this would require the routing of flow through site S2016.

5.8.2 Candidate Sites S0006 and S2088

Land at Capel Cwm is proposed for housing development. Some risk from surface water run-off from the hillsides about the sites has been identified. However, this risk is likely to be manageable.

Site S0006 lies immediately adjacent to the Afon Mwldan and may be subject to fluvial flooding along the boundary. Any proposed development would need to be set back from this flood risk area, although loss of development area will be minimal and unlikely to adversely affect the perceived development potential of the whole site.

5.8.3 Candidate Sites S2017

Tregibby Farm off Gwbert Road is also proposed for housing development. The site lies just outside the Afon Mwldan fluvial flood risk zone, and it is anticipated that surface water run-off from the sloping land to the northwest will be collected in the minor watercourses that run along the borders of the site. However, a site-specific FCA would be recommended to fully assess potential risk from the minor watercourses.

Developers will also need to confirm how the anticipated increase in runoff from development will be managed in order to ensure that there will be no adverse impact on the existing property and infrastructure in the already sensitive area around Gwbert Road culvert. In order to meet the TAN 15 requirement that there is no increase in flood risk elsewhere during an extreme event, measures to manage the surface water run-off from the site will need cater for a 0.1% (1 in 1000) annual chance event.

5.8.4 Candidate Sites S0590, S0591, S1204 and S1245

A number of sites adjacent to Llwynpiod Farm are proposed for potential housing development.

The sites are at risk from surface water run-off from the steeply sloping hillside to the northeast. However, it is anticipated that there will be few problems in managing this risk with the surface water run-off collection and attenuation systems that will be required as part of the development. It will be important that developers give adequate consideration to the attenuation of flows prior to any discharge into the Afon Mwldan since the Gwbert Road culvert is already at risk of flooding during storm events. Management of flows expected during a 0.1% (1 in 1000) annual chance event will be required to ensure that there is no increase in flood risk within the area.

5.8.5 Candidate Sites S0189, S0524, S0525, S0526, S0596, S1243, S3113 and S3114

Further housing developments are proposed to the north of the area off Gwbert Road. The sites are located at the crest of the hill and surface water run-off is expected to drain from the area into both the Afon Mwldan and the Nant-y-ferwig. No flood risks to the area have been identified.

Sites lie with TAN 15 Zone A, and no problems with developing the sites are anticipated providing adequate consideration is given to the management of the increased surface water runoff expected from the development.

5.8.6 Candidate Sites S2038, S1070 and S3112

Extensive review of the Bath House Farm site has already been undertaken, and the recent FCA² and further modelling of the culvert at Gwbert Road³ have confirmed that the proposed housing development in the area will have no adverse effect on flooding. These findings have been accepted by the Environment Agency.

This study concurs that development at the site is justifiable in accordance with TAN 15 guidelines providing no development within the identified flood risk area along the Afon Mwldan corridor occurs.

5.8.7 Candidate Sites S0116, S0619 and S0620

Land at Stepside Farm is located along the watershed between the Afon Mwldan and the Nant-y-ferwig/ Afon Teifi.

Surface water flood risk to the area is considered low although run-off from the sites contributes to the Afon Mwldan catchment downstream of Gwbert Road and adequate consideration must be given to the management of the increased surface water runoff expected from the development in order that there is no adverse affect on the existing FAS.

No other flood risks have been identified, and no problems with developing the sites are anticipated.

5.8.8 Candidate Sites S0832, S1207 and S3125

The sites at Maes Radley lie on the steep slopes above the Afon Teifi floodplain. The TAN15 DAMs classify the southern edge of the area as Zone C2; however, review of the anticipated tidal flood extents concludes that the sites will remain flood-free over the lifetime of the proposed development.

As indicated on Drawing Number 5037097/881/RCF/031, the sites lie on the line of the Mwldan Flood Alleviation Tunnel. In general, the Environment Agency advises against development over the top of culverts. However, since the Flood Alleviation Tunnel is deep, it is considered that the Environment Agency may approve development in this instance.

² FCA: Proposed Development at Bath House Farm, Waterman Quadrant, 2006

³ Gwbert Culvert Hydraulic Modelling Report, Waterman Quadrant, 2009

No significant risks from current surface water run-off have been identified and providing increases in surface water run-off are adequately managed, development of the sites is considered possible.

5.8.9 Candidate Sites S3124, S3126 and S3127

Analysis undertaken within this SFCA suggests that the development sites identified along Middle Mwdan and in Greenfield Square are at risk from tidal flooding once the current tidal defences are overtopped. Predicted sea level rises indicate that the existing defence would be overtopped by the 0.1% (1 in 1000) annual chance tidal event in 17 years' time, and the 0.5% (1 in 200) event in approximately 30 years' time.

Flood risk from surface water and potentially sewer flood incidents has also been identified.

The sites are located within TAN15 Zone C2, and significant difficulties in justifying any development at these sites would be anticipated under current guidelines.

6. Central and East Cardigan

6.1 Site Description

6.1.1 General Site Description

East Cardigan has been defined as the area to the east of the main A487 to Aberaeron. The land slopes from the dual carriageway down to the Afon Teifi floodplain, and consists mostly of pastureland. The Parc Teifi Business Park is situated to the west just off the A487.

Central Cardigan lies to the north of the Afon Teifi and is bordered by the B4548 to the north and the Afon Mwdan to west. Castle Street Bridge crosses the main river at a bend and the remains of the old castle are located on a high mound immediately adjacent to the river at this point. The main town centre retail area lies to the north of the castle. Land rises towards the residential area in the north. A school and local hospital are located to the east.

6.1.2 Proposed Development

Seven of the 12 proposed development sites to the east of the A487 are potential extensions to Parc Teifi Business Park. The majority of the rest are proposed for retail, housing or mixed development, with a car park development proposed on land at Priory Bridge.

Within the town centre, many of the 22 candidate sites identified are re-developments of existing property. Proposed developments are mostly specified for retail, employment or mixed development. Limited additional residential development is expected.

The candidate sites are summarised in Table 6.1 below.

Table 6.1 - Candidate Sites Summary

Site ID	Name	NGR	Development Type	Design Life
S0048	Land adj. to Cardigan and District Hospital roundabout	SN182461	Other	70
S0081	Land at Argoed	SN189466	Retail	70
S0082	Agricultural Building at Feidrhenffordd	SN186464	Housing	100
S0833	Pwllhai Development	SN178460	Mix	70
S1060	Aberteifi	SN178459	Employment	70
S1124	Parc Teifi Business Park, Aberteifi	SN188461	Employment	70
S1184	Extension to Parc Teifi Business Park, Aberteifi	SN189463	Employment	70
S1185	Extension to Parc Teifi Business Park, Aberteifi	SN191461	Employment	70
S1203	The Old Health Centre	SN178462	Other	70
S1206	Pwllhai, Aberteifi	SN178460	Mix	70
S1241	Ysbyty Aberteifi	SN181460	Other	70
S2039	Y Wenallt, Napier Gardens, Cardigan	SN181463	Mix	100
S2068	Land at Priory Bridge	SN183460	Other	70
S2081	Ael y Bryn	SN195470	Mix	100
S2091	Field adj. to Glantegfan	SN197470	Housing	100
S3107	St. Mary's old School Hall, Pont Y Cleifiion	SN180461	Unsure	100

Site ID	Name	NGR	Development Type	Design Life
S3108	Cardigan Hospital	SN181460	Housing	100
S3109	Field to North of main round about, opp. Hospital	SN182461	Mix	100
S3110	Y Wenallt, Napier Gardens, Cardigan	SN181463	Unsure	100
S3111	Napier Gardens, Y Wennallt	SN181463	Mix	100
S3117	Allotments at Feidr Henffordd	SN185464	Housing	100
S3118	Parc Teifi, Aberteifi	SN188462	Mix	70
S3119	Old Scout Hut, Cardigan	SN179459	Housing	100
S3120	Old Garage, The Strand Cardigan	SN179459	Housing	100
S3121	PO Sorting Office, Cardigan	SN180460	Unsure	100
S3123	Aberteifi Quays	SN176459	Mix	100
S3128	Pwllhai Development, Vets, Power tools Shop, Yard	SN178460	Unsure	100
S3129	TM Daniels Garage, Finches Square	SN179460	Mix	100
S3130	Extension to Parc Teifi Business Park, Aberteifi	SN189463	Employment	70
S3131	Extension to Parc Teifi Business Park, Aberteifi	SN189463	Employment	70
S3132	Extension to Parc Teifi Business Park, Aberteifi	SN191424	Employment	70
S4076	Pendre	SN178462	Car Park	70
S4077	Market Lane area	SN176460	Unknown	100
S4078	Cardigan Hospital site	SN181460	Unknown	100
S4079	Land adj. to Cardigan and District Hospital roundabout	SN182461	Other (Park and Ride)	70

6.1.3 Hydrological Situation

A large number of watercourses are present in the area, eventually draining into the Afon Teifi. The main tributary to the east is the Nant Rhyd-y-fuwch, which has a catchment area of approximately 4.4km², incorporating a number of small tributaries and drainage ditches.

To the west of the A487, another minor watercourse has been identified running through the field to north of the main roundabout opposite the hospital (site S3109). The watercourse discharges directly into the Teifi via a culvert under the roundabout. The watercourse has a small catchment area but was considered potentially significant due to its location and the potential for flooding from the culvert.

6.2 Data Review and Analysis

6.2.1 Information Available

A review of the available data has included the following:

- TAN15 Development Advice Map;
- Environment Agency Extreme Flood Outline Map;
- Environment Agency Surface Water Flood Map;
- Analysis of Fluvial Food Risk (see Section 3.3.5);

- STAM Database (Dwr Cymru/Welsh Water Solutions for Total Asset Management Database); and
- Light Detection and Ranging (Lidar) data.

6.2.2 Analysis Approach

During Phase 1 a large number of candidate sites were categorised as Medium Risk due to their proximity to minor watercourses. Although the sites fall within TAN15 Zone A and are outside the Environment Agency extreme flood outline, a detailed assessment of the risk was considered necessary to determine the risk from these watercourses. The assessment was undertaken in the form of the Tuflow hydraulic modelling described in Section 3.3.5.

To the north, the sites on higher ground were categorised as at Low Risk of flooding. These sites fall within TAN15 Zone A and are outside the Environment Agency extreme flood outline. A strategic review of existing data was considered sufficient to understand the risks for these sites. The strategic assessment included:

- Review of likely overland flow paths using Lidar data; and
- Check for recorded sewer flooding.

The Afon Teifi lies along the southern border of the defined area. A number of candidate sites fall within Zone C2 on the TAN15 DAMs. These sites were defined as High Risk within Phase 1 of this study. A review of flooding issues associated with from the Afon Teifi was undertaken to confirm whether management of the risk in order to facilitate development was possible.

6.3 Flood Risk from Tidal Sources

6.3.1 Flood Risk from Tidal Inundation

Analysis of the tide levels expected on the Afon Teifi are discussed in detail in Section 3.1. The predicted flood extents are shown on Drawing Numbers 5037097/881/RCF/010 and 011. It can be seen that due to the steeply sloping land at the edge of the Teifi floodplain, there is little difference between the predicted flood extents over the 100 years of climate change modelled. The current day 0.5% (1 in 200) and future 0.1% (1 in 1000) annual chance tidal event for 2110 (the worst case scenario) are shown on Drawing Number 5037097/881/RCF/032 for ease of comparison.

To the east of Priory Bridge, the tide is expected to inundate the low-lying area to the south of the B4570, including Candidate site S2068.

A significant area of the town centre will also be inundated. A site visit was undertaken to confirm the likely extent of flooding and any restrictions to flow paths through the town. The area along The Strand and east to Gloster Row lies level with the riverbank. Flow paths exist from this location along St Mary's Street, Morgan Street and Pwllhai towards the retail areas within the town. Raised several metres above the low-lying areas, Priory Street and Chancery Lane provide the north and west extents, respectively, of the floodplain area. Partial flooding of the Pwllhai area is expected unless ground levels are raised. The feasibility of doing this is doubtful due to the density of existing development and the significant impact that even localised ground raising would have on the drainage, sewer and other service networks within the area.

Construction of a tidal flood defence may be possible in order to protect the town centre; however, the Environment Agency would not support this as a means of facilitating further development. The consequences of flooding due to overtopping or failure of defences would be more severe than at present due to the potential for rapid inundation, and there would also be a risk of inundation of the area from overland flows trapped behind the defence. In addition, a compensatory storage area may also be required to ensure that displaced tidal waters do not funnel further up the estuary and flood currently unaffected areas; although it is possible this storage could be provided by the further lowering of land to the south of the B4570. As well as the monetary cost of the defence, there would also be significant visual impact since a defence height exceeding 2m would be required to cater for predicted sea level rises over the development design life. It is unlikely that the benefits of providing a defence will be sufficient to outweigh the

costs and impacts of construction. It is unlikely that this option would provide a feasible solution to town centre development.

Modelling confirms that the minor watercourses that discharge into the Afon Teifi are also tidally influenced. Flooding is predicted to extend up the watercourses to flood the field to the north of the A487 roundabout, affecting land adjacent to the Nant Rhyd-y-fuwch.

6.4 Flood Risk from Main Rivers and Ordinary Watercourses

6.4.1 Flood Risk from Afon Teifi

As discussed in Section 3.2, although fluvial flooding occurs upstream on the Afon Teifi, at Cardigan the river is tidally dominated.

6.4.2 Flood Risk from Nant Rhyd-y-fuwch and Tributaries

The Tuflow modelling work indicates that limited flooding is expected from the Nant Rhyd-y-fuwch, other than at the downstream end where tidal flooding issues exist.

Flooding from the two streams to the north is expected to affect parts of the proposed sites for extending the Parc Teifi Business Park. However, the flood risk should be manageable. Culverting of the watercourses in order to facilitate development would be discouraged by the Environment Agency, but options exist to divert the watercourses or incorporate the watercourses and floodwater storage ponds into the development as landscaping features.

6.4.3 Flood Risk from Watercourse to the North of the A487 Roundabout

The watercourse which runs through Sites S0048, S3109 and S4079 is located within a steeply sloping valley. Predicted flooding is limited to a narrow width. However, this is located centrally within the site and options to divert the watercourse are limited.

Fluvial flood risk to the site could currently be considered low, but the layout of the proposed housing development will need careful consideration to ensure that there is no increase in flood risk to the site or to adjacent land.

6.5 Flood Risk from Culverted Watercourses, Sewers and Groundwater

6.5.1 Flood Risk from Culverted Watercourses

There are a number of short culverts under the roadways. According to model predications, the culverts under the B4570, A484 and A487 roundabout are of sufficient capacity so as not to cause significant backwater effects up the watercourses. As a result, there is no anticipated flood risk associated with these culverts. However, where culverts are present, the site-specific FCAs will need to confirm that the risk remains low if the culverts become partially blocked. The Environment Agency requires consideration of the effect of at least a 20% blockage, although this may be more depending on site circumstances.

No other watercourses are known to be culverted in the area. However, it is expected that a significant surface water drainage channel is present along the A487 collecting run-off from the road. Change in land use and an increase in water entering this system may result in flooding of the road leading to surface water runoff entering lower-lying land to the south, which includes the Parc Teifi Business Park. A full investigation into the existing system would be required prior to any development adjacent to the road. A full discussion of potential surface water runoff routes is included in Section 6.6 below.

6.5.2 Flood Risk from Sewers

Review of the Dwr Cymru/Welsh Water STAM Database indicates that there have been a number of sewer flooding incidents in the town centre area. Incidents appear to be concentrated along St Mary's Street, which is already at high risk of tidal flooding. Detailed investigation regarding the exact locations and cause of flood incidents will need to be undertaken as part of any site-specific

FCA. At this strategic level, sewer problems are considered minor compared with the tidal flooding problem in the vicinity.

A number of isolated incidents are also reported at properties just west of Pendre and North Road. Sites S4076 and S1203 could potentially be affected by overland flows generated if such incidents are repeated. A full investigation into the degree of risk should be undertaken as part of a site-specific FCA prior to development of these sites.

No risk of flooding from sewers has been identified for the sites to the east of the A487.

6.5.3 Flood Risk from Groundwater

Susceptibility to groundwater flooding was not included as a part of this assessment. However, analysis undertaken within the CFMP concludes that the risk of groundwater flooding within Cardigan is low.

6.6 Flood Risk from Surface Water Runoff

Surface water runoff is not considered to be a significant risk factor for the town centre sites. Land slopes toward the Afon Teifi floodplain area. Surface water runoff is expected to be collected within the existing natural watercourses and man-made drainage channels, and routed through the area to discharge into the Teifi. Proposals for any development should include assessment of these current surface runoff routes and channel/ culvert capacities and give due consideration to the use of SuDS as required by TAN15.

The Environment Agency Surface Water Flood Map confirms that the risk to the town centre area is limited to the natural watercourse flow paths and the main roadways of the A487, A4548 and North Road.

To the east, the largely undeveloped hillside drains to a network of natural channels. Risk to the identified candidate sites is considered to be generally low.

A review of Lidar contours was undertaken as part of this assessment, and potential run-off routes in the event of flows diverging from the roadways were considered. Key predicted flow paths are shown by arrows on Drawing Number 5037097/881/RCF/032. Other than the sites already identified as at risk from fluvial flooding, only the south-west corner of site S1124 (the Parc Teifi Business Park) and site S1185/S3132 was identified as at risk. Management of these risks is considered possible, as discussed below.

6.7 TAN15 Constraints

As previously mentioned, the sites adjacent to the Afon Teifi fall within TAN15 Zone C2. Any new development should thus meet the application of the justification test (Section 6 in TAN15). The sites should also meet the acceptability criteria of being flood free in the 1% (1 in 100) annual chance fluvial event and the 0.5% (1 in 200) annual chance tidal event including climate change (with the exception of emergency services that must remain flood free during the 0.1% (1 in 1000) annual chance fluvial and tidal events), having acceptable consequences of flooding in the extreme [0.1% (1 in 1000) annual chance] event as defined by TAN15 A1.15, and not causing flooding elsewhere. In addition, flood defences must be shown to be structurally adequate under extreme overtopping conditions, and an emergency flood plan, including flood warning system and identified evacuation routes, must be in place.

Away from the Afon Teifi, the candidate sites fall within TAN15 Zone A. Fluvial and tidal flood risk is low and few constraints are given within TAN15 for development within this zone. It is important, however, that development proposals give careful consideration to overland flow paths and the management of surface water runoff. TAN15 notes that any development will result in changes to the natural hydrology of a catchment due to an increase in runoff from impermeable ground and built-up areas. Developers should give due consideration to surface water drainage requirements to ensure proposed developments do not result in flooding elsewhere.

TAN15 states that SuDS should be employed to manage surface water runoff wherever possible, and if the use of conventional drainage systems is proposed, developers must give good reasons why SuDS cannot be implemented.

6.8 Summary of Flood Risk and Management

6.8.1 Candidate Sites S1060, S3119, S3120 and S3123

The four sites adjacent to the Afon Teifi fall within TAN 15 Zone C2 and are shown to be at risk of tidal flooding. Analysis has confirmed that the majority of these sites are at risk of flooding from the 0.5% (1 in 200) and the 0.1% (1 in 1000) annual chance tidal events both now and in the future.

The flood risk associated with development in this area is considered to be unacceptable, and justification will be difficult under TAN15 guidelines.

6.8.2 Candidate Sites S0833, S1206 and S3128

The proposed development at Pwllhai also falls partially within TAN 15 Zone C2, and is shown to be a risk of tidal flooding. Currently the sites do not meet the TAN 15 acceptability criteria. However, it may be possible to justify development on the basis of required town regeneration if adequate mitigation measures can be provided.

As discussed above In Section 6.3.1, construction of a tidal flood defence may be possible in order to protect the town centre. However, a 2m defence height would be required, and there would need to be provision of compensatory storage for displaced tidal waters and management of surface water behind the defences. Full investigation into the issues and benefits is required to assess the feasibility of the options.

6.8.3 Candidate Site S3129

The garage at Finches Square is proposed for mixed redevelopment. It lies at the edge of the anticipated tidal flood area and, providing building floor levels are sufficiently high (above 5.14m AOD), the development should remain flood-free. Access/ egress may be provided onto Priory Street, away from the flood risk area.

No notable flood risks have been identified for these sites. No significant surface water run-off paths have been identified in the area, and risk from sewers and the current road drainage network is considered low. If sufficient consideration is given to the management of any increase surface water run-off from the site, then no problems with developing the sites would be anticipated.

6.8.4 Candidate Site S3121

The Post Office Sorting Office also lies outside of the anticipated tidal flood area; however, the site is at a slightly lower elevation and is close to the reported sewer flooding incidents along St Mary's Street.

Although the site lies within TAN 15 Zone A, a site-specific FCA will be required determine the cause of previous sewer flood incidents and assess the potential risk to the new development site. However, we would anticipate that it will be possible to manage any identified flood risk and development of the site may proceed with the inclusion of suitable mitigation measures.

6.8.5 Candidate Site S3107

St Mary's Old School Hall lies within TAN 15 Zone A, and no risk of flooding from tidal, fluvial or surface water run-off has been identified. No difficulties in developing this site are anticipated.

6.8.6 Candidate Sites S1241, S3108 and S4078

The Cardigan Hospital site is located to the north west of Priory Bridge and is currently at risk of tidal flooding. Approximately 41% of Site S1241 (63% of site S3108 and 61% of S4078) is expected to be inundated during a 0.5% annual chance tidal event. This risk is reflected in the fact

that the TAN 15 DAMs categorise this area as Zone C2. Significant difficulties in justifying the proposed housing development would be anticipated under TAN15 guidelines.

However, part of the site is expected to remain flood-free, and since safe access/ egress may be provided onto Priory Street, partial development of site S1241 could be considered.

6.8.7 Candidate Sites S0048, S3109 and S4079

The field to the north of the hospital is proposed for housing or park and ride development.

A minor watercourse flows through the centre of the site. As the site slopes steeply towards the watercourse the fluvial flood extents are limited.

However, tidal flood risk to the site has also been identified. As Drawing Number 5037097/881/RCF/032 shows, the extent of the tidal flood risk at the southern end of the site exceeds the fluvial flood risk extent. Development over the southern part of the site for residential purposes could be difficult to justify under TAN 15 guidelines.

The northern part of the site might be developed for housing, but the developer would need to give consideration to the provision of a flood-free access/ egress route and the management of surface water run-off. Review of the Environment Agency's Surface Water Flood Maps and Lidar contours indicates that there is a potential run-off route to the north that may impact on the site. Management of this flow will be required to ensure that any new development does not exacerbate flood risk in the locality.

Less onerous requirements would be applied if the site was to be used for the provision of park and ride facilities for the town. However, a site-specific FCA would still be required prior to any (partial) development at this site to demonstrate that flood risk could be managed.

6.8.8 Candidate Sites S2039, S3110 and S3111

The sites at Napier Gardens are currently undeveloped land. No notable flood risks have been identified for these sites, and because they lie within TAN15 Zone A, no problems with developing the sites are anticipated.

However, developers should note that the implementation of SuDS to manage the increased surface water runoff generated by the development will be required. And any proposed discharge into existing sewer networks will need to be agreed with the local drainage authority.

6.8.9 Candidate Sites S1203 and S4076

The Old Health Centre and Car Park at Pendre lies within TAN 15 Zone A. There is no risk from tidal or fluvial flooding, and the risk from surface water run-off is considered low. Review of Lidar contours suggest that flows along North Road are most likely to divert to the west toward the Afon Mwldan.

A number of isolated sewer incidents are also reported at properties to the west and there is a slight risk that the sites could be potentially affected by overland flows generated if such incidents are repeated. An investigation into the flood risk from sewers should be undertaken as part of a site-specific FCA prior to development of these sites. However, it is anticipated that mitigation of the identified risk will be possible.

6.8.10 Candidate Site S4077

A small site in the Market Lane area has been included in the proposed candidate sites. No notable flood risks have been identified for the site, and because it lies within TAN15 Zone A, no problems with developing the sites are anticipated.

6.8.11 Candidate Site S3117

Site S3117, the allotments at Feidr Henffordd, lies adjacent to the A487 and is proposed for housing development. It is anticipated that access to the new housing would be via Feidr Henffordd.

No significant flood risks to the site have been identified. Surface water run-off from the A487 is collected in road-side drainage ditches and is not considered to be a risk to the site. The developer would need to give due consideration to the management of additional run-off generated by development of the site, and use of SuDS would be required.

No problems with developing the sites are anticipated.

6.8.12 Candidate Sites S2081 and S2091

Adjacent to the A487 to the north east of Cardigan, two undeveloped sites are proposed for housing and mixed development.

The sites lie on the hillsides above Cardigan and could be at risk of flooding from surface water runoff. Overland flow routes along the A487 crossing the open land to feed into the tributaries of the Nant Rhyd-y-fuwch have been identified. However, it is anticipated that the risk to the development sites can be managed. The development of the sites is likely to lead to an increase in surface water runoff. Additional run-off in this location is unlikely to pose a threat to any of the existing developments, and could be managed through the implementation of SuDS.

No significant issues regarding the development of these sites are anticipated.

6.8.13 Candidate Site S0081

To the north of the existing Parc Teifi Business Park, Land at Argoed has been proposed for retail development.

The site was classified as Medium Risk during Phase 1 of this study due to the minor watercourse that runs along part of the eastern boundary of the site. However, analysis determined that the catchment area of this watercourse is small and minimal flood risk is expected from this source. Prior to development of the site detailed hydraulic modelling, including a topographic survey of the channel, would be recommended in order to confirm the risks. Should flooding from the watercourse be identified, overland flows are likely to be directed away from the site and development over the majority of the site will be possible if a buffer zone is provided.

There are concerns with site development related to the impact of increased surface water run-off from hard standings on adjacent land - particularly the Parc Teifi Business Park to the south. A site-specific FCA would be required to address this issue, and we would recommend that an area-wide approach be adopted as discussed below.

6.8.14 Candidate Sites S0082, S1124, S1184, S1185, S3118, S3130, S3131 and S3132

Much of the land around the existing Parc Teifi Business Park is proposed for extension of the business park for employment purposes. A small area of housing development to the north immediately adjacent to the A487 (site S0082) is proposed, and there could be potentially some mixed development (S3118).

The tidal flood risk to the area has been identified as low. However, there are a significant number of minor watercourses in the area.

As shown on the fluvial flood risk drawings (numbers 5037097/881/RCF/020 to 025), the risk of flooding from the Nant Rhyd-y-fuwch and its tributaries is low. However the location of the watercourses may pose some difficulties for the layout of the development. Culverting the watercourses in order to facilitate development would be discouraged by the Environment Agency, but options may exist to divert the watercourses or incorporate the watercourses and floodwater storage ponds into the development as landscaping features. The site-specific FCA should consider potential options in detail.

There is concern that the piecemeal extension of the business park could lead to inadequate sewer systems and surface water drainage networks. We would recommend that an overall strategy be developed with respect to area so that an adequate drainage network is developed with the capacity to handle all foreseeable future development.

In order to comply with Tan 15 guidelines, the system should be able to cope with the management of surface water run-off for a 0.1% (1 in 1000) annual chance event, rather than the

typical 1 in 30 year event for highway drainage. Discharging collected flows directly into the Afon Teifi must not cause adverse impacts on existing developments.

6.8.15 Candidate Site S2068

The Land at Priory Bridge is proposed for a Park and Ride, it falls within TAN 15 Zone C2 and is at risk of tidal flooding. Tuflow modelling of the fluvial flooding indicated that a significant part of the site is inundated by the MHWS on the Afon Teifi.

The flood risk associated with development in this area is considered to be unacceptable, and justification will be difficult under TAN15 guidelines.

7. South Cardigan

7.1 Site Description

7.1.1 General Site Description

The majority of development to the south of the Afon Teifi is concentrated in a triangle between the two river crossings and the roundabout junction of the A487 and A478.

The A487 runs north to south, crossing the river to the east of the main town. The road is raised above the Teifi and Afon Piliau floodplain and forms the eastern extent of development. From the roundabout junction of the A487 and A478, the B4546 runs north west to the Castle Street bridge. Residential properties are located on both sides of this steeply sloping road, and an industrial estate and cattle market lies to the east. At the bridge, the road turns west along the southern bank of the Teifi towards St Dogmaels Llandudoch.

The steep slopes to the south and west of the B4546 area are mostly arable and pasture land.

7.1.2 Proposed Development

The candidate sites identified to the south of the river are a mixture of new developments and re-developments.

Five sites in undeveloped areas have been identified for potential housing development, of varying size. A further four sites, including the current industrial estate/ cattle market, have been identified for re-development for employment or mixed use. The table below provides a simple summary of the sites.

Table 7.1 - Candidate Sites Summary

Site ID	Name	NGR	Development Type	Design Life
S0593	Pentop Fields, Aberteifi	SN178454	Housing	100
S0622	Land adj. to Roby Villa, Spring Gardens, St Dogmaels Road	SN174457	Housing	100
S0623	Land adj. to Roby Villa, Spring Gardens, St Dogmaels Road	SN174457	Housing	100
S0831	Cardigan Mart Ground & the Old Station	SN179458	Mix	100
S1058	Aberteifi	SN217457	Employment	70
S1059	Aberteifi	SN178457	Employment	70
S1205	Pentood Industrial Estate	SN180456	Mix	100
S3106	Tenby road South	SN180453	Housing	100
S3116	Jnct Tenby road North and B4546	SN180454	Housing	100

7.1.3 Hydrological Situation

The South Cardigan area lies to the south of the Afon Teifi and to the east of the Pentood Marsh floodplain area.

The hills to the south of the developed area are drained by a number of minor watercourses which flow north to the Afon Teifi. Flows are generally culverted under the development or collected by the surface water drainage systems prior to their discharge into the main river.

Historical flooding problems in the low-lying area adjacent to the river were addressed in the mid 1990's by the construction of the Eagle Inn/ Castle Street Flood Alleviation Scheme (FAS).

7.2 Data Review and Analysis

7.2.1 Information Available

A review of the available data has included the following:

- TAN15 Development Advice Map;
- Environment Agency Extreme Flood Outline Map;
- Environment Agency Surface Water Flood Map;
- Analysis of Tidal Flood Risk (see Section 3.1);
- Analysis of Fluvial Flood Risk from the Afon Teifi (see Section 3.2);
- Eagle Inn/ Castle Street FAS data (design drawings, Atkins, 1995);
- STAM Database; and
- Light Detection and Ranging (Lidar) data.

7.2.2 Analysis Approach

The Environment Agency extreme flood outline indicates that the land immediately adjacent to the Afon Teifi is at risk of flooding; the area is defined as Zone C2 on the TAN15 Development Advice Map. For this reason, many of the sites to the south of the river were initially classified as at high or medium risk of flooding.

Analysis of risks for this area has drawn on works undertaken in the assessment of other areas within Cardigan. The key flood risks from tidal and fluvial water levels on the Afon Teifi are discussed in detail in Section 3. Assessment of other potential risks included:

- Review of the management of flow from watercourses to the south, including the Eagle Inn/ Castle Street FAS.
- Review of likely overland flow paths using contour data; and
- Check for recorded sewer flooding.

7.3 Flood Risk from Tidal Sources

7.3.1 Flood Risk from Tidal Inundation

Analysis of the tide levels expected on the Afon Teifi is discussed in detail in Section 3.1. The predicted flood extents are shown on Drawing Numbers 5037097/881/RCF/010 and 011.

It can be seen that the low-lying area between the river and Station Road would be inundated by the current 0.5% (1 in 200) annual chance tidal event. Only at the eastern end of site S0831 is there any noticeable difference in the flood extents predicted for the current and future scenarios.

A steep drop exists between the residential properties along the raised B4546 road and the Teifi to the north; this is reflected in the tidal boundary being located centrally within site S1058. The layout of any planned development at this site is currently unknown; however, given the topography it is assumed that the planned employment development would be concentrated to the eastern end of the site adjacent to Eagle Inn, and as such would be subject to tidal flood risk.

Site S1059 is expected to be fully inundated during a present day 0.5% annual chance event. By the end of its anticipated 100 year design life, site S0831 is expected to flood completely.

In general, for sites with an open marine aspect, flood risk can be mitigated by ground raising works without the need to consider the impacts caused by loss of flood storage. However, Cardigan does not have an open marine aspect. If ground raising works were undertaken there may be an impact arising from the loss of flood storage. In addition, the complex surface water drainage and sewage networks within the area, and the maintenance of historic buildings, would give rise to considerable engineering challenges. An alternative to ground raising would be required to mitigate flood risk if any of these sites are to be developed.

7.4 Flood Risk from Main Rivers and Ordinary Watercourses

7.4.1 Flood Risk from Afon Teifi

As discussed in Section 3.2, although fluvial flooding occurs upstream on the Afon Teifi, at Cardigan the river is tidally dominated.

7.4.2 Flood Risk from Watercourses to the Hillside to the South

The watercourses to the south of the defined candidate sites have not been modelled within this study. The catchment areas are small and flows are not expected to be significant.

The one exception to this is the watercourse to the south west of Eagle Inn which flows through site S1059 to a confluence with the Afon Teifi. Improvement works to the lower reaches were undertaken as part of the Eagle Inn/ Castle Street FAS. The watercourse is culverted and a new intake was constructed as part of the FAS, at the location shown on Drawing Number 5037097/881/RCF/033. If the capacity of the scheme is exceeded, then overland flow paths will develop towards the Afon Teifi through the eastern part of site S1058.

Another watercourse, to the south of The Ridgeway, is reported to drain into the ditch that leads to the new culvert intake. The flow path, whether in open ditch or culvert, has not been ascertained. Reported concerns indicate that although flood risk initially appears low, development within this area will require careful consideration to the collection and routing of flows from the watercourse in order to avoid an increased risk from overland flow paths developing.

7.5 Flood Risk from Culverted Watercourses, Sewers and Groundwater

7.5.1 Flood Risk from Culverted Watercourses

The works undertaken circa 1995 for the Eagle Inn/ Castle Street FAS reduced the flood risk from the watercourses culvert beneath Castle Street by separating the old fluvial flow culvert from the sewer network. The previous combined system meant flood flows within the watercourse entered a non-sealed system and flooding of the combined drainage system resulted. The FAS involved the construction of a dedicated culvert for the watercourse, with new outfall situated at high level (above MHWS level) just upstream of Castle Street Bridge.

The culvert was originally designed to carry a 1% (1 in 100) annual chance event. However, changes in hydrological assessment methods and urban development within the catchment may have eroded the standard of protection. The routing of additional flows into the culvert from proposed new developments would increase the risk for the commercial and residential communities around Eagle Inn. In light of this, the risk of flooding from the culverted watercourses must be considered as part of any flood management strategy for the area.

A detailed review of the culvert capacity should be undertaken as part of any FCA for developments within this area, including a review of the effect of partial blockage (at least 20%) of the culvert. Options to manage flows from new developments, or increase the capacity of the culvert, will also need to be considered within any site-specific FCA.

7.5.2 Flood Risk from Sewers

Following construction of the Eagle Inn/ Castle Street FAS, only one reported sewer flood incident has been identified. The incident concerned a well within the garden of a property in the vicinity of Eagle Inn, and it is not felt that the report indicates any notable risk of flooding to the area from the current sewer network.

7.5.3 Flood Risk from Groundwater

Susceptibility to groundwater flooding was not included as a part of this assessment. However, analysis undertaken within the CFMP concludes that the risk of groundwater flooding within Cardigan is low.

7.6 Flood Risk from Surface Water Runoff

The Environment Agency's Surface Water Flood Map suggests that risk of flooding from surface water is minimal in this area. Some potential flooding is indicated along Castle Street and along the line of the culverted watercourse.

Review of the Lidar contours confirms that surface water run-off from the steeply sloping land to the south of the currently developed area will be collected in the minor watercourses. Direct risk to the majority of proposed candidate sites from surface water run-off is minimal, with the exception of site S0593 which may be at risk from flows from the south. However, mitigation of this risk would not be difficult.

The key issue with respect to surface water run-off is the impact that new developments will have on existing property. As already noted, the watercourse culverted under Castle Street may already be at its maximum capacity during flood events and routing of further flows into the system may not be acceptable. Constraints on development and potential mitigation options are discussed below.

7.7 TAN15 Constraints

The candidate sites adjacent to the Afon Teifi fall within TAN 15 Zone C2, these are undefended areas at risk of flooding. To the south, sites are defined as Zone A. Section 6 of TAN15 states that new development should be directed away from Zone C and towards suitable land in Zone A.

Where development is proposed within Zone C it must meet the justification tests outlined within the section. Where consideration of a development site can be justified, the development must then meet the acceptability criteria detailed in TAN15 Section 7 and Appendix 1. Key criteria include the fact that development within Zone C2 (or C1) must be flood free in the 1% (1 in 100) annual chance fluvial event and 0.5% (1 in 200) annual chance tidal event with climate change (with the exception of emergency services that must remain flood free during the 0.1% (1 in 1000) annual chance fluvial and tidal events), have acceptable consequences of flooding in the 0.1% (1 in 1000) annual chance event as defined by TAN15 A1.15, and must not cause flooding elsewhere.

Few constraints are placed on development within Zone A, providing due consideration is given to the management of surface water.

7.8 Summary of Flood Risk and Management

7.8.1 Candidate Sites S1058, S1059, and S0831

These sites lie within TAN15 Zone C2 and are at direct risk of flooding from the Afon Teifi during a tidal flood event.

Drawing Number 5037097/881/RCF/010 indicates that if a 50 year design life is considered (as required by current guidelines) the majority of site S0831 and all of site S1059 would be inundated by the 0.5% annual chance tidal event and would not meet the acceptability criteria outlined in TAN 15 Appendix A. Should a 100 year design life be considered, then virtually all of site S0831 would be inundated.

Along the southern part of the Candidate site S1058 the existing properties along St Dogmaels Road are elevated well above the low lying land adjacent to the Afon Teifi. The low-lying area is susceptible to tidal inundation and there is a risk of fluvial flooding if the capacity of the FAS scheme culvert is exceeded. The low lying part of the site would not meet the TAN 15 acceptability criteria. Re-development along the elevated part of the site off St Dogmaels Road would be acceptable.

The high risk from tidal flooding means development of sites S1059, S0831 and the low lying part of S1058 would be hard to justify.

7.8.2 Candidate Site S1205

The Pentood Industrial Estate is proposed for mixed re-development. It lies partially within TAN 15 zone C2, but predicted tidal flood extents indicate that the site should remain flood free for both the 0.5% and 0.1% annual chance events for the next 100 years.

The site slopes towards the river, and is bounded on the east and south-west by the A487 and B4546, respectively. The A487 road is situated on an embankment that protects the site from the tidal floodplain to the east. However there is a minor risk of run-off into the site from road drainage should it prove to be of insufficient capacity to contain flood flows.

In general, minimal flood risk to the site has been identified, and development should be possible providing adequate consideration is given to the management of surface water and the implementation of SuDS.

7.8.3 Candidate Sites S0622 and S0623

The land adjacent to Roby Villa off St Dogmaels Road is proposed for a housing development. It lies within Zone A and no significant flood risk has been identified.

Potential surface water run-off from the hillsides to the south and west are likely to be intercepted by the access road to the farm. However, developers must demonstrate adequate consideration is given to the management of surface water and the used of SuDS to ensure that development does not result in flooding elsewhere.

No difficulties are anticipated in the development of these sites.

7.8.4 Candidate Sites S3116 and S3106

These small sites are situated within an existing developed area. There is no identified risk of flooding and development of these sites is considered possible. However, development of these sites may result in the increased flood risk elsewhere if insufficient consideration is given to the capacity of existing drainage systems. In particular these sites contribute to the flow toward the low lying area adjacent to Eagle Inn. To avoid increases in flood risk to the low lying area, surface water run-off must be managed.

It is usual practice for small developments to join into the existing sewer and surface water drainage systems. TAN15 discourages this practice and specifies the use of SuDS to deal with surface water run-off unless good reason is given as to why it cannot be implemented. Although there is no evidence of sewer flooding in the vicinity, developers must investigate the capacity of the existing sewer system to handle any additional flows that may result from the new development.

7.8.5 Candidate Site S0593

This site falls with TAN 15 Zone A and is located on the sloping hillside to the south of the Afon Teifi. Minor watercourses collect surface water run-off flows from the hillside; however, some risk to the site from surface water run-off remains. This risk may be addressed by provision of a drainage ditch to collect flows along the southern boundary of the site. However, discharge of the collected waters and potential impact on existing property requires careful consideration.

Further development within this area has the potential to increase flood risk to other properties in the locality. If additional flows are routed into the watercourse to the west, flows in the culvert under Castle Street may exceed its maximum capacity during flood events and flooding within the vicinity of Eagle Inn may result. If flows are discharged into the current drainage system along Castle Street, sewer flooding may result. Increasing the capacity of either the culvert or the sewer system is unlikely to be economically feasible, and is unsustainable as a long-term approach.

TAN 15 specifies the use of SuDS to deal with the additional surface water run-off resulting from new development. This may include the use of additional measures such as attenuation ponds, or collection and routing of flows to discharge to the floodplain to the east of the A487.

Development of Candidate site S0593 is possible. However, the management of surface water run-off particularly during extreme (0.1%) events needs to be considered in order to ensure that

there is no increase in flood risk elsewhere. Development of an overall strategy with respect to management of surface water is recommended, in order that any extension of the development area in the future does not result in the piecemeal development of an overly complex drainage system.

8. Conclusions

8.1 Site Summaries

The four study areas have been assessed in detail. Conclusions have been drawn in the area-specific sections regarding flood risk and the potential for justification of the proposed development under TAN15.

Tables 8.1 to 8.4 below summarise the conclusions drawn.

Table 8.1 - Summary of North Cardigan Development Sites

Site ID	Name	Main Flood Risk	Potential for Development
S2083	Sand and Gravel Quarry, Penyparc, Aberteifi	Limited risk	No problems anticipated
S2084	Sand and Gravel Quarry, Penyparc, Aberteifi		
S2085	Sand and Gravel Quarry, Penyparc, Aberteifi		
S2086	Sand and Gravel Quarry, Penyparc, Aberteifi		
S2087	Sand and Gravel Quarry, Penyparc, Aberteifi	Fluvial from Afon Mwldan	Partial development of area possible

Table 8.2 - Summary of Afon Mwldan Development Sites

Site ID	Name	Main Flood Risk	Potential for Development
S0006	Capel Cwm	Surface water run-off and fluvial from Afon Mwldan	Partial development of area possible
S0116	Stepside Farm, Aberteifi	Limited risk	No problems anticipated
S0189	Gwbert Road, Aberteifi	Limited risk	No problems anticipated
S0524	Gotrel Farm		
S0525	Part of enclosure 7078		
S0526	Part of field 8700		
S0590	Adj. to Llwynpiod Farm, Aberteifi	Surface water run-off	No problems anticipated
S0591	Adjacent to Llwynpiod Farm, Aberteifi		
S0596	land adj. to Trebared Farm, Gwbert Rd, Aberteifi	Surface water run-off	No problems anticipated
S0619	Land at Stepside Farm, Gwbert Rd, Aberteifi	Limited risk	No problems anticipated
S0620	Land at Stepside Farm, Gwbert Rd, Aberteifi		
S0832	Parc Radley	Limited risk	No problems anticipated
S0998	Show Field Cardigan	Surface water run-off	Development possible with management of surface water runoff
S0999	Show Field Cardigan		
S1061	Land at North Road Park		

Site ID	Name	Main Flood Risk	Potential for Development
S1070	Bath House Farm, Aberteifi	Surface water run-off and fluvial from Afon Mwldan	Partial development of area possible
S1071	Showground Site, Aberteifi	Surface water run-off	Development possible with management of surface water runoff
S1204	149a/2 (The settlement boundary near Drws y Nant F	Surface water run-off	No problems anticipated
S1207	Maes Radley, Aberteifi	Limited risk	No problems anticipated
S1208	Field near Heol Felin Newydd	Surface water run-off	Development possible with management of surface water runoff
S1242	Hen Cae Shoe		
S1243	Fferm y Gotrel, Heol Ferwig, Aberteifi	Limited risk	No problems anticipated
S1245	Llwynpiod	Surface water run-off	No problems anticipated
S2016	Aberteifi	Surface water run-off	Development possible with management of surface water runoff
S2017	Tregibby Farm, Gwbert Rd, Aberteifi	Surface water run-off and minor watercourses	Detailed FCA required but no problems anticipated
S2038	Bath House Farm, Aberteifi	Surface water run-off and fluvial from Afon Mwldan	Partial development of area possible
S2082	Caemorgan Road	Surface water run-off	Development possible with management of surface water runoff
S2088	Capel Farm Buildings	Surface water run-off	No problems anticipated
S2089	Feidrlas Fields	Surface water run-off	Development possible with management of surface water runoff
S3112	Bath House, incl. Fire station, depot and car park	Surface water run-off and fluvial from Afon Mwldan	Partial development of area possible
S3113	Land adj. Llwynpiod North Cardigan	Surface water run-off	No problems anticipated
S3114	Adjacent to Llwynpiod farm, Aberteifi		
S3115	Land off Heol Derw, North Park	Surface water run-off	Development possible with management of surface water runoff
S3124	Drawbridge, Middle Mwldan	Tidal inundation	Significant problems anticipated
S3125	Maes Radley, Aberteifi	Limited risk	No problems anticipated
S3126	Garage, Greenfield Square	Tidal inundation	Significant problems anticipated
S3127	Furniture Shop, Greenfield Square		
S3134	Fields Adj. Heol Felin Newydd, Cardigan	Surface water run-off	Development possible with management of surface water runoff

Table 8.3 - Summary of Central and East Cardigan Development Sites

Site ID	Name	Main Flood Risk	Potential for Development
S0048	Land adj. to Cardigan and District Hospital roundabout	Tidal and fluvial risk from minor watercourse	Detailed FCA required to confirm possibility of development
S0081	Land at Argoed	Minor watercourse	Detailed FCA required to confirm possibility of development
S0082	Agricultural Building at Feidrhenffordd	Surface water run-off	Detailed FCA required to confirm possibility of development
S0833	Pwllhai Development	Tidal inundation	Significant problems anticipated - Detailed FCA required to confirm feasibility of mitigation
S1060	Aberteifi	Tidal inundation	Significant problems anticipated
S1124	Parc Teifi Business Park, Aberteifi	Surface water run-off	Detailed FCA required to confirm possibility of development
S1184	Extension to Parc Teifi Business Park, Aberteifi		
S1185	Extension to Parc Teifi Business Park, Aberteifi		
S1203	The Old Health Centre	Sewer flood incidents	Detailed FCA required to confirm possibility of development
S1206	Pwllhai, Aberteifi	Tidal inundation	Significant problems anticipated - Detailed FCA required to confirm feasibility of mitigation
S1241	Ysbyty Aberteifi	Tidal inundation	Significant problems anticipated - Detailed FCA required to confirm possibility of development
S2039	Y Wenallt, Napier Gardens, Cardigan	Limited risk	No problems anticipated
S2068	Land at Priory Bridge	Tidal inundation	Significant problems anticipated
S2081	Ael y Bryn	Surface water run-off	No problems anticipated
S2091	Field adj. to Glantegfan		
S3107	St. Mary's old School Hall, Pont Y Cleifiion	Limited risk	No problems anticipated
S3108	Cardigan Hospital	Tidal inundation	Significant problems anticipated
S3109	Field to North of main round about, opp. Hospital	Tidal and fluvial risk from minor watercourse	Detailed FCA required to confirm possibility of development

Site ID	Name	Main Flood Risk	Potential for Development
S3110	Y Wenallt, Napier Gardens, Cardigan	Limited risk	No problems anticipated
S3111	Napier Gardens, Y Wennallt		
S3117	Allotments at Feidr Henffordd	Limited risk	No problems anticipated
S3118	Parc Teifi, Aberteifi	Surface water run-off	Detailed FCA required to confirm possibility of development
S3119	Old Scout Hut, Cardigan	Tidal inundation	Significant problems anticipated
S3120	Old Garage, The Strand Cardigan		
S3121	PO Sorting Office, Cardigan	Sewer flood incidents	Detailed FCA required to confirm possibility of development
S3123	Aberteifi Quays	Tidal inundation	Significant problems anticipated
S3128	Pwllhai Development, Vets, Power tools Shop, Yard	Tidal inundation	Significant problems anticipated - Detailed FCA required to confirm feasibility of mitigation
S3129	TM Daniels Garage, Finches Square	Limited risk	No problems anticipated
S3130	Extension to Parc Teifi Business Park, Aberteifi	Surface water run-off	Detailed FCA required to confirm possibility of development
S3131	Extension to Parc Teifi Business Park, Aberteifi		
S3132	Extension to Parc Teifi Business Park, Aberteifi		
S4076	Pendre	Sewer flood incidents	Detailed FCA required to confirm possibility of development
S4077	Market Lane area	Limited risk	No problems anticipated
S4078	Cardigan Hospital site	Tidal inundation	Significant problems anticipated
S4079	Land adj. to Cardigan and District Hospital roundabout	Tidal and fluvial risk from minor watercourse	Detailed FCA required to confirm possibility of development

Table 8.4 - Summary of South Cardigan Development Sites

Site ID	Name	Main Flood Risk	Potential for Development
S0593	Pentop Fields, Aberteifi	Surface water run-off	Detailed FCA required to confirm possibility of development
S0622	Land adj. to Roby Villa, Spring Gardens, St Dogmaels Road	Limited risk	No problems anticipated
S0623	Land adj. to Roby Villa, Spring Gardens, St Dogmaels Road		
S0831	Cardigan Mart Ground & the Old Station	Tidal inundation	Significant problems anticipated
S1058	Aberteifi		
S1059	Aberteifi		
S1205	Pentood Industrial Estate	Limited risk	No problems anticipated
S3106	Tenby road South	Limited risk	No problems anticipated
S3116	Jnct Tenby road North and B4546		

Appendix A - Drawings

Appendix B – Key Flood Risks: Data Review and Further Calculations

B.1 Tidal Flood Risk

B.1.1 Extreme Water Levels

The Admiralty Tide Charts list predictions for both 'Port Cardigan' and 'Cardigan (Town)'. The mean high water spring (MHWS) level at Cardigan (Town) was approximately 100mm higher than that anticipated at the mouth of the river, and is comparable to the MHWS expected at Fishguard.

Tide predictions for a period of 7 days were examined for Port Cardigan, Cardigan (Town) and Fishguard. The comparison confirmed that levels at Cardigan (Town) were similar to those at Fishguard. Therefore, it was concluded that EWL predictions for Fishguard may be applied to Cardigan in order to take account of the funnelling effect of the river, rather than attempting to add a level increase to the EWL predictions at the mouth of the Teifi.

The EWLs for Fishguard were provided by the EA. Levels related to the year 2000 and sea level rises⁴ were applied to reflect the anticipated effects of climate change.

The EA listed the level for a 0.4% (1 in 250) annual chance tidal event. TAN 15 requires consideration of the 0.5% (1 in 200) annual chance event. Typically this may be determined through interpolation of levels; however, the variation in the anticipated EWL for the 1% and 0.1% annual chance events was so little that it was concluded that no difference between the 0.4% and 0.5% event could be discerned given the level of accuracy to which predictions are made.

EWLs were determined to be as detailed in Table B3.1 (Section 3.1).

B.2 Review of Fluvial Risk from the Afon Mwldan

B.2.1 Afon Mwldan Flood Alleviation Scheme

Although the flood alleviation scheme (FAS) to reduce the risk of flooding to the Cardigan from the Afon Mwldan was proposed in the early 1990's, detailed design of the scheme did not take place until a few years later.

Hydrological and hydraulic calculations were undertaken in 1995, and were based on the guidance available at the time. The flood frequency relationship for the Afon Mwldan catchment was based on the 1975 Flood Studies Report (FRM) method modified to reflect known flooding to the town in June 1993. The scheme was designed to the 0.5% (1 in 200) annual chance event peak flow of 23.4m³/s predicted at the time; during an event, the flood alleviation tunnel was designed to discharge 15m³/s, hence reducing flows through the town to 8.4m³/s. The peak tunnel flow was designed to discharge against a Mean High Water Spring (MHWS) tidal level of 2.51mAOD. This level was calculated using the accepted guidance for sea-level rise at the time, assuming a 50 year design life from 1993.

As part of the FAS, the capacity of the Afon Mwldan downstream from the tunnel intake was assessed to ensure that the peak to 8.4m³/s would be retained in channel. With this flow, local flood defence works were identified as potentially necessary upstream of the Bath House Bridge Culvert and at the downstream end of the river at Quay Street car park. However, by allowing flooding to the car park, the resulting reduction in predicted backwater levels for the entire reach indicated that flood defence works in the vicinity of Bath House could be avoided.

⁴ Sea level rises as published by the IPCC 2007 report: 3.5mm/yr to 2025, 8.0mm/yr 2025- 2055, 11.5mm/yr 2055- 2085, 14.5mm/yr after 2085.

B.2.2 Bath House Farm Development

Waterman Quadrant undertook an FCA in 2006 to assess potential impacts of the proposed Bath House Farm development on flood risk. It was noted that the anticipated flood outline shown on the EA flood map failed to reflect the benefits of the flood alleviation tunnel and reflects the pre-FAS case, or the scenario in which the tunnel entrance control structure is closed.

To address the uncertainty regarding the flood outlines, a new hydraulic model was constructed of the Afon Mwldan from a point downstream of Gwbert Road to Bath House Bridge. A new topographical survey was undertaken of the reach and the model was constructed using HEC-RAS software. Flows were re-assessed using Flood Estimation Handbook (FEH). The 1% (1 in 100) and 0.1% (1 in 1000) annual chance event flows were estimated to be 21.6m³/s and 38.3m³/s respectively.

The model was run for existing and proposed scenarios with the tunnel control both open and closed. The existing-closed control scenario was compared against the EA flood map for calibration purposes. From model runs for the proposed scenario, it was concluded that the development sites will remain flood-free during a 1% event providing the side weir overflow control into the tunnel is operational. If the control is closed then some flooding is anticipated, but this will remain within the confines of the development site and will not flood buildings to depths exceeding those allowable under TAN 15.

Flooding during a 0.1% event was also shown to remain localised with predicted depths of flooding remaining below those allowable under TAN 15 guidelines.

The Assessment concluded that flood risk from the Afon Mwldan in the vicinity of the proposed development site is minimal, and also confirmed that the development would not adversely affect the hydrological regime downstream.

The only area of concern raised by the FCA work relates to the tie in between the Link Road and Melin y Dre/Gwbert Road upstream, because the culvert crossing under Gwbert Road is of low capacity. Works to the culvert may be required in order to guarantee safe egress/access to the development during flood events.

B.2.3 Gwbert Road Culvert

The public's perception that further urban development within the Afon Mwldan catchment could exacerbate flooding problems remains an important consideration for Ceredigion CC. Following submission of the Bath House Farm FCA, further detailed hydraulic modelling of the culvert was undertaken by Waterman Quadrant to assess the impacts of the proposed highway adjoining Melin y Dre/ Gwbert Road.

Their modelling assessment confirmed that for the existing situation the limited capacity of the Gwbert Road culvert causes flood water to spill out of the channel upstream of the culvert and subsequently generate overland flooding. Flow paths originate from several points. From the left bank upstream, waters flow across Gwbert Road towards Clos Llyn y Felin. Part of this flow crosses Gwbert Road towards the right bank downstream of the culvert, combining with flow that originates over the right bank upstream of the culvert. The flow to the right of the watercourse is shown to flood property on the west of Gwbert Road, and also enter Melin y Dre (see Drawing Number 5037097/881/RCF/031).

With the proposed new highway, the model indicates a marginal increase in levels on Gwbert Road at the roundabout junction with the new road, and peak flood levels are increased along part of the new highway. However, levels throughout the remainder of the model are little changed, and it can be concluded that the development would not exacerbate problems upstream of the culvert.

The modelling work undertaken by Waterman Quadrant did not consider the effects of increasing the capacity of the Gwbert Road culvert or undertaking any other works upstream to alleviate flood risk. However, potential options for reducing the flood risk from the culvert were previously considered within the 2005 Atkins Project Appraisal Report.

Cereigion CC commissioned an appraisal of options for a Flood Alleviation Scheme at Gwbert Road. Options considered included the construction of a flood relief culvert, raised defences upstream, improvement of the overland flow path on Melin-y-Dre, raising ground levels between Ger-y-Nant and Old House Farm at Felin Ban, raising defences upstream of the Felin Ban access bridge, and the use of demountable defences. However, the appraisal concluded that implementation of a scheme could not be justified since the cost of works would outweigh the limited economic benefits associated with its construction.

B.3 Tuflow Modelling

B.3.1 Hydrological Analysis

The Environment Agency provided flow data for the Afon Mwldan at Gwbert Road Bridge, and at its confluence with the Afon Teifi. However, the accompanying note stated that *since calculations were carried out, the Revitalised Flood Hydrograph (ReFH) method has become available. As it is considered more suitable for very long return period flow estimation, flows for 1000 years are now calculated by applying the ReFH ratio between the 100 year and 1000 year flows to the FEH statistical estimate of the 100 year flow. In addition, Version 2 of the HiFlows-UK data set has been released, as has a new equation for calculating QMED, therefore, FEH Statistical calculations carried out now would most likely produce different flow estimates to those quoted above. Therefore it cannot be guaranteed that the flows provided here would be accepted if submitted as part of a Flood Consequence Assessment.* Therefore, revised calculations were undertaken using the new HiFlows data set, applying the ReFH ratio for the long return periods.

Reference was also made to hydrological data used with the recent modelling of the Mwldan at Gwbert Road. In the Atkins study⁵ it was noted that the time to peak at Gwbert Road was more rapid than suggested by the catchment characteristics (this is a common error for the catchments in South Wales) and calculated flows required adjusting accordingly. This adjustment was also applied by Waterman Quadrant in their Bath House Farm study⁶ and flows were approved by the Agency. The 1% and 0.1% probability flood flows were estimated to be 21.6m³/s and 38.3m³/s respectively.

The approved flows corresponded to the expected flow at Gwbert Road. Additional flows were calculated for the upper reach of the Mwldan (down to its confluence with the Ffynnon Pant-y-dwr-isaf) and for the Ffynnon Pant-y-dwr-isaf. The flow hydrographs were calculated using the ReFH analysis and were adjusted in line with the Gwbert Road flows. The calculated peak flows are summarised in Table B3.1 below.

Flows for the watercourses to the east of Cardigan were calculated according to current methodologies without the need for adjustment since catchment areas were relatively small.

⁵ Gwbert Road Flood Alleviation Scheme Project Appraisal Report, Atkins, 2005.

⁶ FCA: Proposed Development at Bath House Farm, Waterman Quadrant, 2006.

Table B3.1 – Summary of Calculated Peak Flows

WATERCOURSE	PEAK FLOWS (m ³ /s)			
	QMED	1%	1% + CC	0.1%
Afon Mwldan (Upstream reach)	5.7	16.1	19.4	27.9
Afon Mwldan (to Gwbert Road)	7.4	21.6	25.9	38.3
Ffynnon Pant-y-dwr-isaf	0.7	2.2	2.7	4.0
Nant Rhyd-y-fuwch	1.9	5.3	6.4	9.3
Eastern tributary of Nant Rhyd-y-fuwch	0.05	0.14	0.17	0.24
Western tributary of Nant Rhyd-y-fuwch	0.07	0.20	0.24	0.36
Watercourse north of A487 roundabout	0.12	0.27	0.32	0.42

B.3.2 Hydraulic modelling

The Tuflow model was constructed using Lidar Data, except for the upstream extent of the Afon Mwldan where NextMap data was utilised in the absence of Lidar information.

As stated in Phase 1 of this study, Lidar data does not provide sufficient detail to define the watercourses fully, so in the absence of detailed topographic survey it was assumed that the watercourse channel capacity is QMED and that all flows exceeding this value would be routed down the floodplain. This is simulated within the Tuflow model by subtracting the peak QMED value from the extreme event flow hydrographs.

Difficulties arise when it comes to routing flows through the culverts. Dimensions for the culverts on the watercourses to the east of Cardigan were determined during a site visit. The culverts were to be included in the model in order to complete the watercourse reach since the Lidar data picks up ground levels that would act as a barrier to watercourse flow paths. However, inclusion of the full culvert dimensions when modelled flows had been reduced by QMED would give a false indication of culvert capacity and under estimate degree of the restriction during a flood event. It was therefore determined that the culverts should be modelled with the QMED flow routed through them to determine the cross-sectional flow area in during that event, and then when modelling the extreme flow events an equivalent area of the culverts was simulated as blocked.

This approach proved satisfactory for the watercourses to the east; however, modelling of QMED through the Gwbert Road culvert indicated that the culvert would already be surcharged by the flows. Modelling of the Gwbert Road culvert with 100% blockage would not reflect the true situation where additional flow through the structure would be facilitated by the head difference. Therefore, the culvert was modelled as fully open with an additional in-flow of QMED applied just upstream. This approach was considered to provide a better simulation of the backwater effects of the culvert and potential upstream flooding; however, given the limited channel definition inherent in Lidar data, the modelling of the full extreme event flows downstream of the culvert could result in an over-estimation of the flood extents. Reference to modelling results from the Waterman Quadrant studies⁷ enables the estimation of the probable flood extents for this area, as shown on Drawing Number 5037097/881/RCF/031.

In addition to defining in-flow hydrographs, the downstream boundaries for the Afon Mwldan and other watercourses required definition. For watercourses to the east, the downstream boundary is their confluence with the Afon Teifi. Since the Teifi is tidally

⁷ FCA: Proposed Development at Bath House Farm, Waterman Quadrant, 2006; and Gwbert Road Culvert Hydraulic Modelling Report, Waterman Quadrant, 2009.

dominated, a fixed MHWS tidal level was considered most appropriate. The current-day level was estimated to be 2.36 mAOD. For the climate change scenario a level of 3.37 mAOD, corresponding to the predicted MHWS in 100 years time, was used.

For the Afon Mwldan, the model downstream boundary is the Flood Alleviation Tunnel inlet. Attempting to model the backwater effect from the tunnel and control weir was considered unnecessary given the accuracy expected from the modelling of this section of the watercourse (due to issues already highlighted with modelling of the Gwbert Road culvert) and a free-flow boundary was considered sufficient.

The Tuflow model was run for the 1%, 1% + climate change, and 0.1% annual chance events in line with EA and TAN15 requirements.

