Flood Risk Assessment

Land at Marsh Lane
Hayle, Cornwall

Prepared for:
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Prepared by:
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1 INTRODUCTION

Background

1.1 RMA Environmental Limited was commissioned by Gary Gabriel Associates on behalf of Sainsbury's Supermarkets Limited to carry out a Flood Risk Assessment (FRA) for a proposed retail development on land at Marsh Lane in Hayle, Cornwall.

1.2 This FRA has been prepared in accordance with Planning Policy Statement (PPS) 25: Development and Flood Risk and associated guidance. It is has taken into account a previous draft FRA prepared by Asha Environmental Limited in April 2009. Supplementary flood risk assessment and hydraulic modelling has been carried out since the original draft FRA was issued and the additional work has been used to update this FRA.

1.3 The additional hydraulic modelling has been carried out by H2OK Systems Limited, who prepared the original flood model for the April 2009 FRA and have contributed to the modelling sections presented in this FRA. A Technical Report on the flood modelling was prepared by H2OK in September 2009 and was submitted to the Environment Agency (EA) for approval. The hydraulic modelling has been accepted in principle by the EA subject to some additional comments that were raised in an EA letter dated 4th March 2010; these additional comments are addressed in this FRA and associated appendices.

1.4 A PPS25 Sequential Test has been prepared by the planning consultants (WYG Planning & Design) and forms a separate document within the planning application package. The Sequential Test concludes that there are no available, suitable and viable alternative sites in lower risk flood zones that could accommodate the proposed development.

Site Location

1.5 The application site comprises an area of 16.34 hectares (ha), as shown in Figure 1.1. It lies to the east of Hayle, is centered on National Grid Reference 157820 38330 and is currently an open area of vegetated land that can be accessed from Marsh Lane via the A30 Loggan's Moor roundabout, approximately 150 m to the northwest of the site.

1.6 Marsh Lane borders the application site to the west and south. The recently developed West Cornwall Shopping Park is located beyond Marsh Lane to the west, whilst a rugby football club and Hayle industrial estate lie to the south-west and south respectively. A dismantled railway embankment bisects the site, north of which open marsh land extends to meet low grade agricultural fields.

1.7 Within the full application site, an area of 2.3 ha is proposed for the creation of a foodstore and associated facilities; this area of land is referred to hereafter as the 'foodstore site'. Further details on topography, geology and sources of flood risk are set out in Section 2.

Proposed Development

1.8 The development is for a new foodstore (Class A1) including a customer café; the building will be single storey with a net retail area of 3,042 m^2. A new 6-pump petrol filling station and kiosk will also be provided. The proposed car park is for 317 spaces and includes disabled bays, parent and child bays, trolley bays and a recycling centre. Land to the north and east of the foodstore will benefit from landscape enhancement, promoting ecology in the local area.

1.9 The proposed development is to be located south of the former railway embankment as shown in Appendix 1.1.

1.10 In order to facilitate the foodstore development and to ensure it will be served by public transport, it will be necessary to carry out some improvement works to the Loggan's Moor roundabout (principally some widening and signalisation), the provision of a new bus stop on Marsh Lane, some widening of Marsh Lane to facilitate access off the A30 and the creation of a public footway/cycleway (Appendix 1.1).

1.11 The finished floor level for the store is 9.40 mAOD. Car park levels range from 9.28 mAOD adjacent to the store to 8.23 mAOD in the south-west corner of the car park. A cut and fill exercise will be required to reduce levels for the southern half of the development and raise levels in the northern half.

Requirements for a Flood Risk Assessment

1.12 The requirements for FRA are provided in PPS25 which came into effect in December 2006 (updated in March 2010). This policy states that flood risk is a material consideration that must be taken into account when considering all applications for planning permission.

1.13 Paragraph E9 of PPS25 requires that a site-specific FRA should be submitted with planning applications for all sites greater than 1 ha in Flood Zone 1 or for sites of any size within Flood Zones 2 or 3. Flood Zone 1 is defined as land with little or no flood risk (an annual probability of flooding of less than 0.1%); Flood Zone 2 is defined as having a medium flood risk (an annual probability of between 0.1% and 0.5% for tidal areas and 0.1% and 1.0% for rivers); and Flood Zone 3 is defined as high risk (with an annual probability of flooding of greater than 0.5% for tidal areas and greater than 1.0% for rivers).

1.14 FRA should describe and assess all flood risks (from rivers, the sea, sewers and groundwater) to and from the development and demonstrate how they will be managed, including an evaluation of climate change effects.

1.15 Guidance on the content of FRAs is contained in Annex E of PPS25 and within PPS25 - Development and Flood Risk Practice Guide (June 2008). These documents have been consulted with regard to the acceptability of the development proposals described in this FRA.

Consultation

1.16 In preparing this FRA, the EA was consulted on the scope of the assessment and the extent of available information on flood risk affecting the proposed development site.

1.17 Preliminary data on predicted flood extents, depths and historical flooding events were obtained from the EA. This was supplemented by detailed hydraulic modelling to establish flood levels for extreme flood events, the scope of which was discussed and agreed with the EA.

1.18 Pre-application consultation meetings were held with the EA on 8th September 2009, 14th October 2009, 18th February 2010 and 24th May 2010, to discuss the results of the hydraulic modelling exercise and the viability of a number of options for the scheme layout.

1.19 Further details on the scope of the hydraulic modelling work are provided in Section 3. As set out above, the hydraulic modelling reported by H2OK in September 2009 has been agreed in principle with the EA, subject to a number of comments that are addressed in the letter addendum included as Appendix 1.2 of this FRA.

2 BASELINE ENVIRONMENTAL CONDITIONS

Hydrology

2.1 The nearest main river to the foodstore site is the Angarrack Stream, which is located approximately 120 metres north of the site at its closest point. The Angarrack Stream flows in a westerly direction towards Hayle and is culverted under Carwin Rise and the A30 (Figure 1.1).

2.2 The Angarrack Stream is a 'perched' river. It's current course is understood to be man-made with water levels and bank heights being noticeably higher than adjacent natural land to the south. The current alignment of the Angarrack Stream was most likely created to raise water levels for a former mill located to the west of the site on the eastern edge of Hayle.

2.3 There are two off-take weirs on the Angarrack Stream. These convey higher flows to a channel (known hereafter as the off-take channel) which runs in a south-westerly direction exiting via two large box culverts located under Marsh Lane, approximately 110 m north of the foodstore site boundary (Figure 1.1).

2.4 The Angarrack Stream flows generally in a westerly direction and ultimately discharges into the tidally influenced Copperhouse Pool some 600 m to the west, before flowing into the sea via the Hayle River Estuary.

2.5 The Ordnance Survey map for the site shows a number of minor land drains and ditches within the application area and one located within the proposed foodstore site. This ditch is located just to the east of the breach in the disused railway embankment; it runs for a short distance from north to south and is not linked to any off-site areas and does not extend into the area proposed for the car park. The ditch is considered to have no hydrological function beyond acting as a minor land drain for the site itself and does not therefore pose a flood risk to the proposed development or the wider area.

Topography and Land Use

2.6 The foodstore site is currently a disused area of vegetated land, which is heavily overgrown and relatively inaccessible in places. An embankment associated with a dismantled railway forms the northern boundary of the site. A lorry park, which is currently in use, is located to the east of the foodstore site.

2.7 The foodstore site slopes from approximately 12.5 metres above Ordnance Datum (mAOD) along the south-eastern site boundary to 5.70 mAOD in the north-west corner of the site. In general, slope is to the west and north, with natural land levels being greatest in the north-east.

2.8 The topographic survey plan for the site is included as Appendix 2.1.

Flood Zone Classification

2.9 The EA's current 'indicative' flood map (Figure 2.1) shows that the foodstore site is located partly within Flood Zone 3 of the Angarrack Stream. It is understood that this flood map is based on historical flood records and some preliminary flood modelling carried out by the EA. The southern 50-60% of the foodstore site area (closest to Marsh Lane) is shown to lie within Flood Zone 1 (low risk).

2.10 The proposed highway widening works on Marsh Lane and improvement works to the Loggan's Moor roundabout are also shown to be located partly within Flood Zone 3, although the exact extents of the Zone 3 floodplain are not readily established from the 'indicative' flood map.

2.11 Given that part of the site is shown to lie within Flood Zone 3 and that the EA's flood modelling was only preliminary, the scope of this FRA was extended to include the construction of a detailed hydraulic model for the Angarrack Steam and the off-take channel, in order to provide a more accurate classification of flood zones. The scope and results of the hydraulic modelling exercise are discussed further in Section 3.

Historic Flooding Records

2.12 The British Hydrological Society database[1] of historical flood events has been reviewed for records of flooding in the area and no records for the application site have been found. However, the EA provided details of their historic flooding records for the April 2009 FRA, the data for which are provided in Table 2.1.

TABLE 3.1: HISTORIC FLOOD RECORDS FOR THE MARSH LANE AREA

Date	Location	Detail	Cause	Source	NGR
14/10/1966	Hayle	Loggan's Cross area flooded, Hayle / Angarrack alleviation scheme	Flooding from Angarrack Stream & Loggan's Mill Leat	Fluvial	SW 5737 3845
09/12/1974	Hayle	Foundry Square and Loggan's Cross area, Penmare Hotel & Golden Sands Caravan park	Flooding from Angarrack Stream & Loggan's Mill Leat	Fluvial	SW 5737 3845

[1] Chronology of British Hydrological Events (www.dundee.ac.uk/geography/cbhe/)

TABLE 3.1: HISTORIC FLOOD RECORDS FOR THE MARSH LANE AREA					
Date	**Location**	**Detail**	**Cause**	**Source**	**NGR**
25/12/1974	Hayle	Loggan's Cross area flooded, Hayle / Angarrack alleviation scheme	Flooding from Angarrack Stream & Loggan's Mill Leat	Fluvial	SW 5737 3845
06/10/1977	Hayle	Loggan's Cross area flooded, Penmare Hotel, 1 property in Marsh Lane, Lover Lane and Beatrice	Flooding from Angarrack Stream & Loggan's Mill Leat	Fluvial	SW 5737 3845
27/12/1979	Hayle	Foundry Square and Loggan's Cross area flooded, Hayle / Angarrack alleviation scheme	Flooding from Angarrack Stream & Loggan's Mill Leat	Fluvial	SW 5737 3845
09/05/1983	Hayle	Marsh Lane flooded. New works at Penmare Hotel and sluice operated by A30 contractor	Unauthorised operation of sluice	Fluvial	SW 5781 3862
14/12/1983	Hayle	Loggan's Cross area flooded. No further details. Number of properties affected unknown.	Flooding from Angarrack Stream & Loggan's Mill Leat	Fluvial	SW 5737 3845
16/01/1984	Hayle	Loggan's Cross area flooded. New bypass channel being built. A30 flooding from new channel.	Flooding from Angarrack Stream & Loggan's Mill Leat	Fluvial	SW 5737 3845
04/03/1985	Angarrack	Angarrack near WWTW. Farmland flooded. Number of properties affected unknown.	Overtopping of flood banks	Fluvial	SW 5800 3850
24/04/1986	Hayle	Golden Sands caravan park. Number of properties affected unknown.	Water behind Angarrack flood alleviation scheme works	SW runoff	SW 5734 3835
01/08/1988	Hayle	Marsh Lane flooded. Pumping station installed 1995 to overpump during floods	SW drains blocked by high river levels	SW runoff	SW 5746 3842
30/12/1993	Hayle	Marsh Lane flooded. Pumping station installed 1995 to overpump during floods	SW drains blocked by high river levels	SW runoff	SW 5746 3842
30/12/1994	Hayle	Marsh Lane flooded	SW drains blocked by high river levels	SW runoff	SW 5746 3842
01/11/2001	Hayle	Trehayles Parc, Guildford Road. Flooding from Angarack Stream	Possible blocked storm drain	SW runoff and fluvial	SW 5732 3830

2.13 Fluvial flooding from the Angarrack Stream and Loggan's Mill leat, located to the west of the Loggan's Moor roundabout, is reported to have occurred to the south-west of the roundabout and downstream of the site on seven occasions since 1966.

2.14 Unauthorised operation of a sluice in the Angarrack Stream system north of the site is reported to have led to flooding in 1983. Overtopping of a fluvial channel is understood to have caused flooding of farmland close to the former sewage treatment works to the north-east of the site in 1985.

2.15 Pluvial flooding from surface water run-off occurred at Golden Sands caravan park and along Marsh Lane and Guildford Road to the south-west of Loggan's Moor roundabout on four occasions between 1986 and 1994. No flooding events along Marsh Lane to the east of Loggan's Moor roundabout have been reported.

Geology and Hydrogeology

2.16 The solid and drift geology of the site is illustrated on British Geological Survey (BGS) 1:50,000 mapping, Sheet Nos. 351 & 358 – Penzance. This indicates that the majority of the site is located on Quaternary alluvium deposits comprising cobbles and gravel, inter-bedded with sand, silt and clay extending north and west.

2.17 Devonian slates are shown to outcrop in the south-eastern corner of the site and beyond the site to the east and south. Devonian sandstone beds are shown at the surface approximately 250 m to the south-west. It is likely that Mylor slates and possibly the Gramscatho beds underlie alluvium deposits at the site.

2.18 A recent site investigation undertaken by Tweedie Evans Consulting for the application site confirmed the published geology with an area of made ground being identified in the extreme western section of the site. Near surface soils were reported to comprise soft sandy clay to a depth of 0.4 metres below ground level (mbgl). Underlying alluvium deposits comprising stiff gravelly sandy clay were encountered up to 4.3 mbgl across the site. Sand and gravel were also found between 1.2 m and 3.5 mbgl in the majority of trial pits.

2.19 Groundwater was generally struck between 0.9 m and 3.1 mbgl in the alluvium and was found to rise following strike.

2.20 The hydrogeology of the site is illustrated on Environment Agency 1:100,000 mapping, Sheet No. 53 – West Cornwall, which reports the site to be underlain by a minor aquifer of variable permeability. From the results of the site investigation, it is considered likely that hydraulic continuity exists between groundwater and local surface waters (i.e. the off-take channel from the Angarrack Stream).

3 EXTERNAL FLOOD RISK

Flooding Mechanisms

3.1 The Environment Agency's 1 in 100 year 'indicative' fluvial flood risk map (Figure 2.1) shows that the site lies partly within Flood Zone 3 of the Angarrack Stream and the off-take channel. The predominant source of flooding in the area arises when the culverts beneath Carwin Rise and Marsh Lane become overloaded, resulting in floodwaters backing up on land to the east.

3.2 No records have been found of flooding of the foodstore site from groundwater or other sources (e.g. sewers). The principal mechanism of flooding is therefore from surface watercourses as described above.

3.3 An overland flow route may potentially exist on land to the east of the foodstore site, although the existing topography of land within the foodstore site is sufficiently elevated not to be affected by this flow route. Should any overland flow occur east of the site, it would largely be conveyed north of the embankment towards the Marsh Lane culverts. However, a small proportion of this flow could be routed on land close to the southern face of the railway embankment to a drainage ditch along the south-west boundary of the site. This potential flood route would not affect any of the built footprint of the proposed development.

Scope of Hydraulic Modelling

3.4 In order to establish accurate flood levels for the proposed development site, a detailed hydraulic model was constructed to define flood levels for the 1 in 20 year (Flood Zone 3b – the 'nominal' functional floodplain) and the 1 in 100 year (Flood Zone 3a) and 1 in 1000 (Flood Zone 2) events, corrected for climate change. Fluvial flood modelling was performed using HEC-RAS Version 4.0.0 released in March 2008, developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Center.

3.5 Various flood modelling studies were undertaken for the site between January 2009 and October 2009. Until the end of July 2009, all of the flood modelling performed was based on steady state analysis, where flood depth and velocity remained constant. However, unsteady state modelling was considered necessary in order to provide a more accurate definition of flood zones as defined within PPS25. Flood depths and velocities in unsteady modelling are varied with time and provide a more accurate representation of actual flooding events.

3.6 An unsteady state model was therefore used to define the 1 in 20, 1 in 100 and 1 in 1000 year fluvial flooding events, with appropriate allowances for the predicted impacts of climate change as outlined in Table B.2 of PPS 25.

3.7 A total of 20 cross sections was used to represent the application site and surrounding area. Three dimensional cross sections were created using AutoCAD 2008 LT and geo-referenced to the topographical survey plan. Cross sectional data were exported from AutoCAD as a CSV file. The cross sectional data were then manipulated within a spreadsheet to be imported directly into HEC-RAS.

3.8 A summary of the key assumptions made in the model set up is provided under the following subheadings.

Estimation of Flood Flows

3.9 Flood flows for the Angarrack Stream were derived from WINFAP-FEH using a local donor catchment (station 49002 Hayle at St Erth) to correct estimates of the 2 year flood flow (QMED) and a pooling group to provide a growth curve to allow flood flows for higher return periods to be derived. A 20% correction was made to the resulting flood flow to account for the likely increase in rainfall intensities as a result of climate change predictions, in accordance with Table B.2 of PPS25.

3.10 A full description of the derivation of the hydrology data that was used in the flood model is provided in Appendix 3.1 of this report.

3.11 For the purposes of summarising the fluvial flood flows used within the hydraulic model, the peak flows are as set out in Table 3.1 below.

TABLE 3.1 – SUMMARY OF PEAK FLOW ESTIMATES				
Return Period	**1 in 20 year**	**1 in 20 year + 20% climate change**	**1 in 100 year**	**1 in 100 year + 20% climate change**
Peak Flood Flow Estimate (m^3/s)	5.71	6.85	8.21	9.85

3.12 For the climate change corrected 1 in 20 year event, a flood flow of 6.85 m^3/s was used; for the climate change corrected 1 in 100 year event, a flood flow of 9.85 m^3/s was used. A flood flow of 16.66 m^3/s was derived for the 1000 year plus climate change event.

Model Assumptions

3.13 The hydrology in the area surrounding the site is complex, with the off-take weirs and associated channel conveying higher flows away from the perched Angarrack Stream via the Marsh Lane culverts. The sensitivity of the hydraulic model was therefore tested for a range of input parameters in order to establish conservative (but realistic) input values for deriving flood levels. The key assumptions used in the model set up are summarised in Table 3.2.

TABLE 3.2: KEY MODEL ASSUMPTIONS	
Parameter	**Notes**
Carwin Rise Culvert	• Percentage conveyance of total flow, 0%, 5% & 10% were tested through flow hydrograph *pro rata* adjustment. The Carwin Rise road bridge culvert was observed to have a low soffit level relative to the water surface level within the channel under normal conditions. It is considered that during high flow conditions this culvert would not have sufficient hydraulic capacity to convey a significant flow and may therefore be prone to blockage
Flow	• Upstream Boundary Condition - flow hydrographs (20yr+20%CC, 100yr+20%CC, 1000yr+CC) as provided within the hydrology report enclosed in Appendix A, were utilised within the model. • In addition to the standard 20% climate change allowance, an additional 20% allowance was provided as requested by the Environment Agency • Downstream Boundary Condition - set to Normal Depth using the average slope of the channel invert (0.0137). This was measured from the topographical survey plan as provided by Berry Yates Ltd. • Initial Conditions - this was set to the initial flow for each of the hydrographs that were simulated.
Geometric Data	• Culvert Blockage Ratios – 20% to 60% (A30 and Marsh Lane Box Culverts). These blockage ratios were selected based on observations taken during the site visits having considered the size, shape and construction of the culverts in conjunction with the upstream catchment – a full review in included in Appendix B. • Culvert Entrance Loss Coefficient – 0.5. Reference was made to the HEC-RAS Reference Manual Table 6-4, 'Entrance Loss Coefficients for Reinforced Concrete Box Culverts' with wingwalls set at 10-25 degrees to barrel. An entrance loss coefficient of 0.4 was considered and rejected following testing, as this had an impact of reducing flood levels and creating instability during one of the trial simulations. • Culvert Exit Loss Coefficient – 1.0. The normal assumed value of 1.0 was assigned throughout the simulations to provide a conservative result. • Manning's n values. Channel n values were set at 0.07 (± 10%). Reference was made to the Manning's n values table (Chow, 1959) for descriptions of n values for a variety of natural and manmade channels. A conservative value was selected given the complex and overgrown marsh areas surrounding the edges of the channel. Overbank areas were also attributed a value of 0.07 (± 10%). The concrete box culverts were also given conservative values (Top 0.016 ± 10%, Bottom 0.02 ± 10%) to account for sediment and vegetative build up around the culvert entrances/exits. • Cross Section Interpolation. This was typically set to 10m; however, during the 20% blockage scenario, 5m interpolation was used to reduce instability in the model.

TABLE 3.2: KEY MODEL ASSUMPTIONS	
Parameter	**Notes**
Modelling	• Computational Interval. A computational interval of 30 seconds was generally adopted. During several of the simulations a 15 second time step was utilised where model became unstable. Generally using a computational time step of less than 30 seconds is considered to be unfavourable. Comparison of the results was carried out following the reduced computation interval to ensure that there were no anomalous results.

3.14 The key influences on flood levels were found to be flood flow and the blockage ratios for the Carwin Rise and Marsh Lane culverts.

Hydrology and Flood Flows

3.15 A number of techniques were used to provide estimates of the 20 year, 100 year and 1000 year flood levels corrected for climate change. The statistical method used in the WINFAP-FEH modelling software provided flood flows with the highest levels of confidence and therefore these were used as input data for the hydraulic model. A detailed comparison of these methods is provided in the hydrology annex to this report (Appendix 3.1).

Culvert Blockage Ratios

3.16 There is no standard guidance to assist in the derivation of blockage ratios for culverts in England and Wales. The ratios to be used in hydraulic modelling must therefore be estimated on a site specific basis, taking into account local conditions including the likelihood of significant debris being washed downstream from the upper areas of the catchment (e.g. where the upstream catchment is heavily urbanised and/or has large areas of mature or ancient woodland). The size and shape of the culverts also have a critical influence on blockage risk.

3.17 The results of the review of culvert blockage ratios concluded that the Carwin Rise culvert, due to its small size and low soffit height, was prone to blockage. As a consequence, the model was set up to allow the Carwin Rise culvert to convey a maximum of 5% of the total flow in the Angarrack Stream; flows in excess of this value were assumed to be routed via the off-take channels and/or overtopping of the left bank of the Angarrack Stream, ultimately leading to the Marsh Lane culverts.

3.18 The off-take channel is routed under Marsh Lane by a double box culvert. In the village of Angarrack, upstream of the site, the Angarrack Stream is crossed by numerous access bridges and therefore the likelihood of large debris being washed down river, passing over one of the off-take weirs and then being conveyed to the Marsh Lane culverts was considered to be relatively low. As a result of the review, the best estimate of blockage for the Marsh Lane culverts was taken as 30%.

Estimated Flood Levels

3.19 Using the climate change corrected flood flows presented in Table 3.1 and the assumptions set out above concerning blockage ratios for the Carwin Rise and Marsh Lane culverts, flood levels have been estimated for the 1 in 20 year, 1 in 100 year and 1 in 1000 year plus climate change flood events.

3.20 The modelled flood extents are presented in Appendix 3.2. It is evident that the proposed foodstore site lies within Flood Zone 1; the only elements of the proposed development in floodplain are part of the highway improvements on the A30 roundabout, which are located in Flood Zone 2. [check once received final flood map]

Sensitivity Testing

3.21 In order to sensitivity test the model, the flood flow and blockage ratios used for the 100 year event were varied to show worst-case estimates. The following three scenarios were run as part of the sensitivity testing exercise for the model:

- main scenario: 100 year flow plus 20% for climate change and 30% blockage of the Marsh Lane culverts;
- sensitivity test (flow): 100 year flow plus 20% for climate change plus an additional 20% on flow and 30% blockage of the Marsh Lane culverts; and
- sensitivity test (culvert blockage): 100 year flow plus 20% for climate change and 50% blockage of the Marsh Lane culverts.

3.22 The results of the sensitivity testing exercise are shown in Appendix 3.3. For the main scenario and the sensitivity test on flow, no part of the foodstore site lies within Flood Zone 3a. For the sensitivity test on culvert blockage, using a conservative estimate of 50% for blockage of the double box culverts on Marsh Lane, a very minor area of land along the footpath to the store would be classified as Flood Zone 3a.

3.23 A discussion on the flood risk vulnerability and the suitability of the proposed development in relation to the modelled flood zones is provided in the subsection on land use vulnerability below.

Flood Alleviation Opportunities

3.24 There is potential within land north of the railway embankment to provide flood alleviation benefits as part of the mitigation and enhancement proposals for biodiversity and landscape.

3.25 These flood alleviation measures could comprise a range of techniques, including the construction of a new off-take from the Angarrack Stream to further control flood levels in that watercourse, utilising natural flood storage upstream of the Marsh Lane culverts during times of high flow. These measures would be designed to provide wider environmental benefits by reducing overall flood risk to downstream areas including the A30 at the Loggan's Moor roundabout and downstream residential areas within Hayle.

3.26 [Potential to increase height of flood defence bund west of the A30 roundabout – these gives the greatest downstream benefits. Could utilise the EA's CPO powers if there are issues with land ownership]

3.27 Initial discussions on flood alleviation opportunities have been undertaken with the EA as part of the consultation on this FRA. The exact nature of the measures to be provided is yet to be defined in detail. However, further hydraulic modelling is being carried out to quantify the downstream benefits for a number of flood alleviation opportunities and these will be worked up further in consultation with the EA.

3.28 The flood alleviation opportunities would integrate into a Management Plan covering long-term maintenance of the ecological interests of the site and also to set out a regime for long-term riparian management of the Angarrack Stream and off-take channels. Improved riparian management of the Angarrack Stream and off-take channel is likely to considerably reduce the risk of a serious blockage of the Marsh Lane and Carwin Rise culverts.

3.29 It is recommended that the future design and provision of these management and flood alleviation works are controlled by a suitable planning condition.

Land Use Vulnerability

3.30 The retail store and car parking are classified as 'less vulnerable' land uses in Table D.2 of PPS25. The petrol filling station would be classified as 'highly vulnerable' if the volume of fuel stored on site exceeded 5,000 tonnes; if not, it would be classified as 'more vulnerable'. In either case, the retail store, car park and petrol filling station and kiosk are all considered to be appropriate land uses within Flood Zone 1 as set out in Table D.3 of PPS25.

3.31 The proposed widening works to Marsh Lane and improvements to the Loggan's Moor roundabout are located in Flood Zones 1 and 2 and are therefore considered acceptable in flood vulnerability terms.

3.32 On the basis of the land vulnerability classifications set out in PPS25, the retail development should be deemed appropriate in planning policy terms in its proposed location.

4 DRAINAGE ASSESSMENT

Introduction

4.1 PPS25 states that those proposing development are responsible for drainage designs which reduce flood risk to the development and elsewhere, ideally through the use of Sustainable Drainage Systems (SUDS).

4.2 Surface water arising from a developed site should, as far as is practicable, be managed to mimic the surface water flows arising from the site prior to the proposed development, whilst reducing the flood risk to the site itself and elsewhere. The EA 'Drainage Guidance for Cornwall' document, published in March 2004 and updated in April 2009, covers the preferred design standards for SUDS features in Cornwall. The document takes into account catchment areas with specific drainage and flooding problems and provides guidance for particular areas of risk as well as proposed development types and scales.

4.3 The application site is located within a problem drainage catchment area, for which advice is given by the EA for the design of any drainage systems. Principles which apply from this guidance are summarised as follows:

- positive discharge from the site to be restricted to greenfield mean annual flow rates;
- on site attenuation capacity to allow for design 100 year flood including climate change; and
- drainage interception and conveyance capacity to allow for this same flood event.

4.4 The drainage design for the proposed development has taken the requirements of PPS25 and the EA's Drainage Guidance for Cornwall into account.

Runoff Rates for Existing Land Use

4.5 The foodstore site is essentially a greenfield site. An estimate of the greenfield runoff rate is therefore required for the site area in order to progress a conceptual drainage design for the proposed development.

4.6 The ADAS 345 method is a runoff estimation procedure which was developed to predict runoff rates from large areas of farmland. It is also a suitable and generally accepted method in Cornwall for estimating greenfield runoff rates for land drainage design. The method enables an annual peak flood flow rate to be generated based on a variety of input data specific to the local catchment.

4.7 The greenfield runoff rate for the proposed development area has been estimated using the ADAS 345 calculator.

4.8 The greenfield runoff rate for the foodstore site has been determined using the following criteria:

• Catchment (impermeable site area)	=	2.3 hectares
• Highest point	=	12.5 mAOD
• Lowest point	=	5.7 mAOD
• Length (highest to lowest)	=	300 metres
• Average annual rainfall (from FEH)	=	1067 mm
• Soil type factor (from WRAP class)	=	0.8
• Region (Cornwall)	=	8

4.9 Review of the winter rain acceptance potential (WRAP) class map for the area shows that the site should actually be classified as being in WRAP Class 1 or possibly Class 2. However, in order to provide a cautious estimate of the greenfield runoff rate for the site, the soil type factor has been increased by two WRAP classes. This has the effect of underestimating the greenfield rate for the purposes of the drainage design for the development (i.e. attenuated runoff from the proposed development would be released at a rate lower than natural greenfield runoff).

4.10 Based on the above calculation, a conservative greenfield runoff rate of 15.4 l/s has been estimated for the site.

Runoff Rates for Proposed Development

4.11 Runoff rates for the proposed development have been calculated using the Modified Rational Method as described by the Wallingford Procedure. Flood Estimation Handbook (FEH) modelling software has been used to generate statistical data on rainfall events for a range of specified return periods, as follows:

- FEH to establish rainfall depths for a range of return periods and catchment descriptors such as annual average rainfall;
- the Wallingford Procedure to determine values for soil index (SOIL) and urban catchment wetness index (UCWI); a soil index value of 0.15 and a UCWI value of 116 have been determined for the site;
- the Modified Rational Method to calculate storm run-off volumes for each return period;

- the percentage impermeable surface was estimated as 90% for the proposed development which, using the Wallingford Procedure, equates to a percentage run-off (PR) value of 66.70;
- the Time of Concentration (Tc) for the catchment was determined as an estimate of critical storm duration using the formula:
  - Tc = (7.44 x LENGTH^0.133)*(SLOPE^-0.274);
- LENGTH and SLOPE were derived from analysis of site topography with values of 305 m and 0.022 respectively. Tc was therefore estimated at between 45 and 60 minutes; for the purposes of this FRA, the critical storm duration has been taken as 60 minutes; and
- peak discharges for the 60 minute storm were determined from storm volumes using the standard hydrograph approach.

4.12 The resulting runoff rates for a range of return periods are presented in Table 4.1.

TABLE 4.1: POST-DEVELOPMENT SITE RUNOFF RATES

Return Period (yrs)	Modified Rational Method Calculations		
	60 min Rainfall (mm)	Storm Volume (m^3)	Peak Flow (l/s)
2	10.7	213.4	59.3
5	14.7	293.2	81.5
10	18.2	363.0	100.9
30	25.0	498.6	138.6
50	29.0	578.4	160.8
100	35.2	702.1	195.2
100 + 20%	42.24	842.5	234.2

4.13 To account for the predicted increases in rainfall intensities as a result of climate change, the 100 year runoff rates and volumes have been increased by 20% in accordance with Table B.2 of PPS25 (i.e. the highest % increase specified for the period 2010 to 2085). This produces a climate change corrected peak runoff rate of 234 l/s for the 100 year storm and a total storm volume of 842.5 m^3.

4.14 After consideration of predicted climate change effects, the surface runoff rate must be reduced to greenfield rate (15.4 l/s). However, for the purposes of the conceptual drainage design, it has been assumed that attenuation should be provided for the entire 100 year plus climate change rainfall event (i.e. a volume of 843 m^3), thus ignoring any greenfield rate loss for the duration of the critical storm.

Feasibility of Sustainable Drainage Techniques

4.15 Table 4.2 provides an overview of the feasibility of a range of SUDS techniques in order to identify which may be suitable for the application site. Further details are then provided on the techniques which are considered to be most appropriate for application site.

TABLE 4.2: SUDS FEASIBILITY MATRIX		
Technique	**Comments**	**Feasibility**
Permeable pavement	Ideally requires a level site and favourable underlying ground conditions. Car park runoff could be routed to an engineered substrate for attenuation. However, permeable pavement for car parking areas not ideal for shopping trolleys.	**Feasible but not desirable**
Underground storage beneath car park	Engineered sub-base or cellular units beneath car parking areas. Roof and car park runoff could be transferred to these areas for attenuation.	**Feasible**
Green roofs	Requires flat or minimal slope roofs. Limited value for runoff attenuation in comparison with other techniques due to the structural strength requirements of the proposed roof area.	**Not Feasible**
Bio-retention – landscaped infiltration areas	Primarily used to remove pollutants from runoff and due to their shallow nature are not as effective at runoff attenuation as other SUDS techniques. Not practical due to space limitations within the proposed development and proximity of floodplain.	**Not Feasible**
Soakaways and infiltration trenches	Require infiltration rates of 1 x 10-6 m/s or greater. Shallow soakaways or infiltration trenches would be required where groundwater is shallow (i.e. less than 2.0 mbgl). Soakaways are likely to be restricted by shallow groundwater levels.	**Not Feasible**
Infiltration basins / swales	Are widely applicable for attenuation and treatment of surface runoff by infiltration into the ground. Require slope of no more than 4-10% and can act as a substitute for soakaways where groundwater is shallow. Not feasible due to space restrictions, proximity of floodplain and shallow water table.	**Not Feasible**
Non-infiltration swales	Used in the same way as carrier ditches or storage bunds. Feasible but not ideal as the principal solution due to space limitations within the proposed development.	**Feasible**

TABLE 4.2: SUDS FEASIBILITY MATRIX		
Technique	**Comments**	**Feasibility**
Filter drains	These are normally used adjacent to areas of car parking or roads and convey runoff via flow through an engineered substrate. These could potentially be installed along access roads or around internal and external boundaries of the car park.	**Feasible**
Balancing ponds	These are permanent ponds that provide storage above the resting water level in the pond. Are appropriate for most sites but require suitable space. Require impermeable soils or can be lined. Not feasible due to space restrictions and proximity of floodplain.	**Not Feasible**

Proposed SUDS Strategy

4.16 Table 4.2 concludes that there are several SUDS measures that could potentially be adopted on the site to provide the desired rate of attenuation. However, given the space limitations and proximity of the site to floodplain, the preferred option to manage site drainage is geocellular storage units underneath the car park to manage runoff from the impermeable areas of the site.

4.17 The area of car park within the proposed development has been estimated as 10,000 m^2. The target volume of attenuation required from Table 4.1 is 843 m^3. A conservative assumption is that the required attenuation volume for the entire 100 year plus 20% storm event will be provided beneath the car park area.

4.18 Assuming that the sub-base beneath the car parking area is a geocellular unit ('egg crate') system with a void space value of 95%, the drainage proposals are to provide storage in an area of 1706 m^2 at a depth of 0.52 m. This represents less than 18% of the total area of the car park available. The layout of the proposed drainage system is illustrated in Appendix 4.1.

4.19 Clean runoff from the roof of the store would be routed directly to the attenuation system and runoff from car park and paved areas would be routed via an oil interceptor. Silt traps would be provided to prevent the attenuation system from silting up.

4.20 The proposed drainage design shows that it is readily feasible to create 843 m^3 of storage beneath the car park. The attenuation system would discharge to either the ecology pond adjacent to the breach in the railway embankment or to the realigned channel along the south-western site boundary at no more than the estimated greenfield runoff rate for the site (i.e. 15.4 l/s).

4.21 A detailed drainage design will be prepared following determination of the application based on the conceptual SUDS strategy described in this FRA. Detailed design drawings and full supporting hydraulic calculations would be submitted to the EA and Cornwall Council for review and approval.

Designing for Exceedance Events

4.22 Current best practice guidance on flood risk requires an evaluation of how rainfall events beyond the design capacity of the proposed drainage system would be managed and what effects they are likely to have on flood risk at the site or surrounding areas.

4.23 For the drainage proposals described above, should a rainfall event exceeding the 100 year plus 20% event occur, then it is expected to result in shallow flooding of the car park area only.

4.24 In order to illustrate this, should the 1000 year storm occur with the same critical storm duration as used in the design (i.e. 60 minutes), it would require a total attenuation volume of 1,454 m^3; i.e. an additional 611 m^3 above that provided by the proposed drainage system. As this additional volume could not be accommodated by the underlying geocellular storage units, it would pond on car park areas to an estimated depth of 61 mm.

4.25 This depth of ponded surface water runoff would be expected to be retained on the car park surface and would gradually be released at the greenfield rate via the proposed sub-base attenuation system.

Long Term Maintenance of SUDS

4.26 The long-term management and maintenance responsibilities for the proposed SUDS system, including the oil interceptor, silt traps, gullies and discharge channel, would lie with Sainsbury's Supermarkets Limited. These responsibilities will be described fully at the detailed design stage.

5 CONCLUSIONS

5.1 The requirements for a Flood Risk Assessment are provided in Planning Policy Statement Note 25: Development and Flood Risk (PPS25) together with the Environment Agency's Guidance Notes. This policy and associated guidance has been followed in the preparation of this FRA.

5.2 Detailed consultation has been undertaken with the Environment Agency with regard to development options and the scope of the hydraulic modelling exercise that was undertaken to establish accurate flood zones for the application site. As a consequence of this consultation, various scheme options were sequentially tested in relation to flood risk and this resulted in the current scheme being put forward that located the site outside of the modelled 100 year floodplain.

5.3 Flood levels for the 20, 100 and 1000 year plus climate change flood events have been derived from hydraulic modelling using conservative assumptions and are shown in Appendix 3.2. This shows that the significant majority of the proposed development lies within Flood Zone 1 (low risk) with only the minor works to the A30 roundabout being located in Flood Zone 2. [check]

5.4 A review of the feasibility of a variety of SUDS techniques has been undertaken to identify those that are feasible at the application site. It has been concluded that the 100 year plus climate change rainfall event would give rise to an attenuation requirement of 843 m^3, which could be readily stored in geocellular storage units beneath the car parking areas.

5.5 Furthermore, the SUDS assessment has demonstrated that there is significant additional capacity available to increase the volume of attenuation should that be required at the detailed design stage. The geocellular storage would discharge at no more than the estimated greenfield rate for the site. Roof runoff and car park/road/pavement runoff would be routed separately to the SUDS system to ensure that the oil separator on the car park discharge is not overloaded with clean runoff. Silt traps would be provided on all drainage to the attenuation system to prevent siltation.

5.6 There is potential within land north of the railway embankment to provide flood alleviation benefits as part of the mitigation and enhancement proposals for biodiversity and landscape. These flood alleviation measures could comprise a range of techniques, including the construction of a new off-take from the Angarrack Stream to further control flood levels in that watercourse, utilising natural flood storage upstream of the Marsh Lane culverts during times of high flow.

5.7 These flood alleviation measures would be designed to provide wider environmental benefits by reducing overall flood risk to downstream areas including the A30 at the Loggan's Moor roundabout and downstream residential areas within Hayle.

5.8 A Management Plan would be implemented for the application site to cover long-term maintenance of the ecological interests and also to set out a regime for improved riparian management of the Angarrack Stream and off-take channel. The latter would reduce the risk of culvert blockage and therefore reduce flood risk to the site and surrounding areas.

5.9 A PPS25 Sequential Test has been prepared by the planning consultants (WYG Planning & Design) and forms a separate document within the planning application package. The Sequential Test concludes that there are no reasonably available alternative sites in lower risk flood zones that could accommodate the proposed development.

5.10 In conclusion, based on the flood risk vulnerability classifications set out in Table D.3 of PPS25 and the achievement of greenfield runoff rates on site drainage, the proposed retail development and highway improvement works are considered appropriate forms of development and should be considered acceptable in planning policy terms.

Figures

Appendices