MVV Umwelt - Energy from Waste Combined Heat and Power Facility North Yard, Devonport

Hydrology - Briefing Note

Final Report

February 2011

Prepared for

MVV Environment

Revision Schedule

Hydrology - Briefing Note
February 2011

Rev	Date	Details	Prepared by	Reviewed by	Approved by
01	January 2011	Draft Report for comment	**Mark Crussell** Assistant Hydrologist	**Dr Rob Sweet** Senior Flood Risk Specialist	**Peter Mansell** Associate
01	February 2011	Final Report (no changes)	**Mark Crussell** Assistant Hydrologist	**Dr Rob Sweet** Senior Flood Risk Specialist	**Peter Mansell** Associate

Scott Wilson
Mayflower House
Armada Way
Plymouth
Devon
PL1 1LD

Tel: 01752 676 700
Fax: 0870 238 6023

www.scottwilson.com

Table of Contents

1 Introduction

Following a meeting with the Environment Agency on the 3rd November 2010 and subsequent comments received on the 2nd December 2010 on the draft Flood Risk Assessment (FRA) (October, 2010), further work is required at the proposed Energy from Waste (EfW) Combined Heat and Power (CHP) facility at the North Yard, Devonport site to assess two main issues:

- To assess the impact of a combined (tidal/fluvial) event on the Devonport EfW facility site and associated site access;
- To assess the upstream impact of replacing the existing access bridges (over the Weston Mill Creek) with a single open span bridge.

In order to undertake the above assessment we propose to undertake a combined event analysis for use within a 1d hydraulic model to predict water levels at locations of interest adjacent to the site and access roads and areas upstream.

The water levels in the Weston Mill Stream are dependent on downstream levels associated with the Tamar Estuary, and upstream river flow, the relative importance of which may vary along the length of the watercourse.

1.1 Aim and Objectives

The aim of the combined event analysis desk based study is to estimate the probability of high downstream tide levels occurring simultaneously with upstream river flows. The combined event analysis identifies the relevant return period for tide levels and river flows, which form the downstream and upstream boundaries of the 1d hydrulic model.

The key objectives covered by the briefing note are:

- Obtain extreme tide level values for downstream boundary of model using the Report on Regional Extreme Tide Levels (February 2003);
- Obtain extreme river flow values for the Weston Mill Creek, Camel's Head Creek and Barne Brake Creek (inflow boundaries of the hydraulic model) using both the ReFH method and FEH Statistical method to ensure a conservative approach is adopted;
- Undertake the combined event analysis joint probability desk study approach in accordance with Defra / Environment Agency Best Practice Guidance (FD2308/TR2).

2 Obtaining Extreme Values

2.1 Extreme Sea Levels

Extreme tidal still water levels are required for the downstream boundary conditions in the hydraulic modelling study being undertaken for at the North Yard, Devonport site.

Extreme tidal still water levels (Year 2002) for Devonport (SX455540) have been drawn directly from the Environment Agency South West Region Report on Regional Extreme Tide Levels (Environment Agency, 2003). Due to the anticipated affects of climate change an allowance for net sea level rise has been calculated for Year 2011 and Year 2071 to represent present day and future extreme tide levels over the developments lifetime (PPS25 Table B-1).

Present and future extreme tidal still water levels for a range of return periods are provided in Table 2.1. In the absence of a published 2 year return period an estimate based on the 1 year and 5 year return period has been used.

Table 2-1: Present and future extreme tidal still water levels for Devonport, Plymouth

	Base Year	Present Day	Future Climate Change
Return Period (Year)	**2002**	**2011**	**2071**
1	2.95	2.98	3.45
2	3.06	3.09	3.56
5	3.16	3.19	3.66
10	3.25	3.28	3.75
25	3.38	3.41	3.88
50	3.46	3.49	3.96
100	3.59	3.62	4.09
200	3.68	3.71	4.18
500	3.83	3.86	4.33
1000	3.96	3.99	4.46

2.2 Extreme River Flows

Extreme river flows for the Weston Mill Creek and its tributaries, Camel's Head Creek and Barne Brake Creek are required for inclusion as upstream boundary conditions in the hydraulic modelling study being undertaken for at the North Yard, Devonport site.

Flow estimation has been undertaken for each watercourse using both the Revitalised Flood Hydrograph (ReFH) Method and WINFAP-FEH v3 (2009) Statistical Method to allow comparison of flow estimates to ensure conservative flow estimates are adopted within the hydraulic modelling study.

2.2.1 Catchment Analysis

The catchment descriptors for the Weston Mill Creek, Camel's Head Creek and Barne Brake Creek have been extracted from the FEH CD-ROM v3 (CEH, 2009). Figure 2-1 illustrates the catchment boundaries extracted from the FEH CD-ROM v3. A full list of the catchment descriptors used in the flow estimation process is shown in Table 2-2, Table 2-3 and Table 2-4.

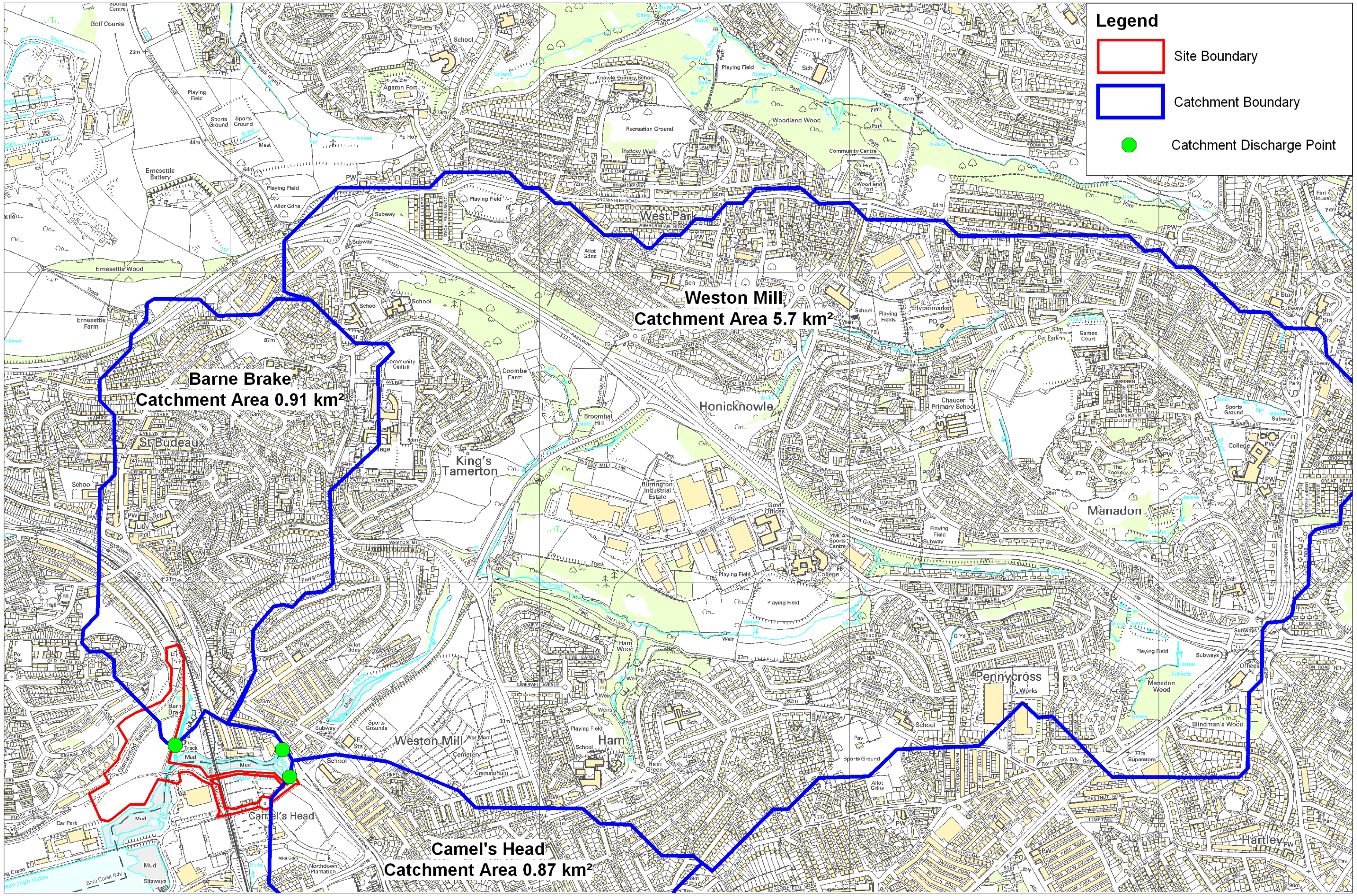

Figure 2-1: Overview of the catchment area boundaries extracted from FEH CD-ROM v3

Table 2-2: Weston Mill Creek Catchment Descriptors (NGR: SX 452575)

AREA (km^2)	5.7	**RMED-1D**	38.6	**D1**	0.41846
ALTBAR	60	RMED-2D	48.2	D2	0.28806
ASPBAR	251	SAAR	1099	D3	0.37212
ASPVAR	0.23	SAAR4170	1094	E	0.29822
BFIHOST	0.582	SPRHOST	32.04	F	2.48216
DPLBAR	2.48	URBCONC1990	0.868	C(1 km)	-0.029
DPSBAR	96.6	URBEXT1990	0.3736	D1(1 km)	0.423
FARL	0.964	URBLOC1990	1.027	D2(1 km)	0.292
FPEXT	0.0342	URBCONC2000	0.919	D3(1 km)	0.376
LDP	4.62	URBEXT2000	0.4045	E(1 km)	0.299
PROPWET	0.48	URBLOC2000	1.048	F(1 km)	2.481
RMED-1H	11.8	C	-0.029	-	-

Table 2-3: Camel's Head Creek Catchment Descriptors (NGR: SX452573)

AREA (km^2)	0.87	**RMED-1D**	37.7	**D1**	0.41329
ALTBAR	33	RMED-2D	47.7	D2	0.29918
ASPBAR	292	SAAR	1050	D3	0.36427
ASPVAR	0.46	SAAR4170	995	E	0.298
BFIHOST	0.599	SPRHOST	29.67	F	2.4738
DPLBAR	0.85	URBCONC1990	0.959	C(1 km)	-0.029
DPSBAR	72	URBEXT1990	0.4928	D1(1 km)	0.416
FARL	1	URBLOC1990	1.002	D2(1 km)	0.305
FPEXT	0.0259	URBCONC2000	0.973	D3(1 km)	0.363
LDP	1.73	URBEXT2000	0.4971	E(1 km)	0.298
PROPWET	0.48	URBLOC2000	0.975	F(1 km)	2.468
RMED-1H	11.6	C	-0.029	-	-

Table 2-4: Barne Brake Creek Catchment Descriptors (NGR: SX 448575)

AREA (km2)	0.91	RMED-1D	39	D1	0.42243
ALTBAR	50	RMED-2D	48.7	D2	0.29182
ASPBAR	210	SAAR	1087	D3	0.37313
ASPVAR	0.56	SAAR4170	1030	E	0.29844
BFIHOST	0.583	SPRHOST	32	F	2.48222
DPLBAR	0.98	URBCONC1990	0.929	C(1 km)	-0.029
DPSBAR	101.2	URBEXT1990	0.4478	D1(1 km)	0.423
FARL	1	URBLOC1990	0.999	D2(1 km)	0.292
FPEXT	0.0137	URBCONC2000	0.961	D3(1 km)	0.376
LDP	1.6	URBEXT2000	0.5288	E(1 km)	0.299
PROPWET	0.48	URBLOC2000	1.018	F(1 km)	2.481
RMED-1H	11.7	C	-0.029	-	-

2.2.2 Flow Estimation

The hydrological assessment was undertaken using both the ReFH method and FEH Statistical method to allow a flow estimate comparison with existing flow estimates. These methods have been chosen due to the catchment being ungauged and no appropriate analogue or donor sites (in adjacent catchments) with similar hydrological characteristics.

FEH Statistical Method

An initial pooling group was selected and reviewed for each watercourse to remove unsuitable stations. The subsequent revised pooling group was used to estimate a growth curve using the generalised logistic distribution. The revised pooling groups for each watercourse are shown in Table 2-5, Table 2-6 and Table 2-7.

Table 2-5: Weston Mill Creek - WINFAP-FEH 3 Revised Pooling Group Stations

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discord-ancy
45816 (Haddeo @ Upton)	0.461	14	3.427	0.318	0.449	1.056
44009 (Wey @ Broadwey)	0.684	31	1.679	0.345	0.259	0.897
28033 (Dove @ Hollinsclough)	0.710	29	4.608	0.262	0.406	0.326
27051 (Crimple @ Burn Bridge)	0.766	36	4.610	0.219	0.122	1.001
44006 (Sydling Water @ Sydling st Nicholas)	1.081	34	0.861	0.231	0.087	0.492
25011 (Langdon Beck @ Langdon)	1.298	22	15.362	0.254	0.405	1.258
25003 (Trout Beck @ Moor House)	1.454	35	15.090	0.173	0.346	0.826
25019 (Leven @ Easby)	1.488	30	5.538	0.361	0.411	1.053
206006 (Annalong @ Recorder 1895)	1.500	48	15.330	0.189	0.052	0.571
26802 (Gypsey Race @ Kirby Grindalythe)	1.614	9	0.142	0.236	0.134	0.219
91802 (Allt Leachdach @ Intake)	1.669	34	6.350	0.153	0.257	1.374
45817 (Rhb Trib to Haddeo @ Upton (trib))	1.694	15	1.317	0.304	0.313	0.535
54022 (Severn @ Plynlimon Flume)	1.703	36	15.054	0.158	0.170	0.549
27010 (Hodge Beck @ Bransdale Weir)	1.721	41	9.420	0.224	0.293	0.149
54091 (Severn @ Hafren Flume)	1.764	33	5.910	0.188	0.283	2.491
50009 (Lew @ Norley Bridge)	1.792	20	18.955	0.150	-0.233	2.952
44008 (Sth Winterbourne @ W'bourne Steepleton)	1.801	29	0.406	0.390	0.340	1.524
76011 (Coal Burn @ Coalburn)	1.818	31	1.805	0.188	0.368	0.726

Table 2-6: Camel's Head Creek - WINFAP-FEH 3 Revised Pooling Group Stations

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discord-ancy
45817 (Rhb Trib to Haddeo @ Upton (trib))	1.009	15	1.317	0.304	0.313	0.669
76011 (Coal Burn @ Coalburn)	1.030	31	1.805	0.188	0.368	0.816
54092 (Severn @ Hore Flume)	2.490	33	6.320	0.116	-0.075	2.169
54091 (Severn @ Hafren Flume)	2.549	33	5.910	0.188	0.283	2.357
45816 (Haddeo @ Upton)	2.893	14	3.427	0.318	0.449	0.976
44009 (Wey @ Broadwey)	3.109	31	1.679	0.345	0.259	1.344
28033 (Dove @ Hollinsclough)	3.131	29	4.608	0.262	0.406	0.457
27051 (Crimple @ Burn Bridge)	3.154	36	4.610	0.219	0.122	0.459
91802 (Allt Leachdach @ Intake)	3.298	34	6.350	0.153	0.257	1.132
54022 (Severn @ Plynlimon Flume)	3.617	36	15.054	0.158	0.170	0.723
44006 (Sydling Water @ Sydling st Nicholas)	3.693	34	0.861	0.231	0.087	0.509
25003 (Trout Beck @ Moor House)	3.782	35	15.090	0.173	0.346	0.904
25011 (Langdon Beck @ Langdon)	3.813	22	15.362	0.254	0.405	1.515
206006 (Annalong @ Recorder 1895)	3.964	48	15.330	0.189	0.052	1.106
27073 (Brompton Beck @ Snainton Ings)	3.973	28	0.739	0.210	0.017	0.894
25019 (Leven @ Easby)	4.012	30	5.538	0.361	0.411	1.352
26802 (Gypsey Race @ Kirby Grindalythe)	4.105	9	0.142	0.236	0.134	0.506
27010 (Hodge Beck @ Bransdale Weir)	4.303	41	9.420	0.224	0.293	0.113

Table 2-7: Barne Brake Creek - WINFAP-FEH 3 Revised Pooling Group Stations

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discord-ancy
45817 (Rhb Trib to Haddeo @ Upton (trib))	0.929	15	1.317	0.304	0.313	0.669
76011 (Coal Burn @ Coalburn)	1.055	31	1.805	0.188	0.368	0.816
54092 (Severn @ Hore Flume)	2.388	33	6.320	0.116	-0.075	2.169
54091 (Severn @ Hafren Flume)	2.454	33	5.910	0.188	0.283	2.357
45816 (Haddeo @ Upton)	2.820	14	3.427	0.318	0.449	0.976
44009 (Wey @ Broadwey)	3.052	31	1.679	0.345	0.259	1.344
28033 (Dove @ Hollinsclough)	3.054	29	4.608	0.262	0.406	0.457
27051 (Crimple @ Burn Bridge)	3.098	36	4.610	0.219	0.122	0.459
91802 (Allt Leachdach @ Intake)	3.203	34	6.350	0.153	0.257	1.132
54022 (Severn @ Plynlimon Flume)	3.527	36	15.054	0.158	0.170	0.723
44006 (Sydling Water @ Sydling st Nicholas)	3.630	34	0.861	0.231	0.087	0.509
25003 (Trout Beck @ Moor House)	3.711	35	15.090	0.173	0.346	0.904
25011 (Langdon Beck @ Langdon)	3.737	22	15.362	0.254	0.405	1.515
206006 (Annalong @ Recorder 1895)	3.890	48	15.330	0.189	0.052	1.106
25019 (Leven @ Easby)	3.957	30	5.538	0.361	0.411	1.352
27073 (Brompton Beck @ Snainton Ings)	4.020	28	0.739	0.210	0.017	0.894
26802 (Gypsey Race @ Kirby Grindalythe)	4.057	9	0.142	0.236	0.134	0.506
27010 (Hodge Beck @ Bransdale Weir)	4.239	41	9.420	0.224	0.293	0.113

As no recorded flow data was available, QMED was estimated using catchment descriptors and adjusted using the revised donor station method (Kjeldsen, 2009). The selection of a suitable donor station takes into account the catchment centroid distance and whether the station is suitable for estimating QMED. The most suitable donor station for estimating QMED was deemed to be Station 47011 (Plym@Carnwood) for each of the watercourses. The Urban Adjustment Factor (UAF) (Kjeldsen, 2009) has been applied to the flood frequency curve as the catchments are considered to be very heavily urbanised based on catchment descriptors..

ReFH Method

The ReFH Method has been run using the summer and winter design rainfall parameters. The recommended design input for heavily urbanised catchments is the summer design rainfall parameter, as this combination of conditions would normally be expected to give a higher flood peak than a winter event.

However, for the heavily urbanised catchments specific to this study the ReFH model gives a higher peak when a winter event is applied. Faulkner and Barber (2009) suggests that this occurrence may result from the design event for urban catchments being calibrated using only seven such catchments during the development of the ReFH model.

2.2.3 Comparison of flows

The estimated flows using the FEH Statistical Method and the ReFH model for the Weston Mill Stream, Camel's Head Creek and Barne Brake Creek for a range of return periods are provided in Table 2-8.

Table 2-8: Comparison of Peak Flow Estimates using ReFH and WINFAP-FEH 3 Methods

		Weston Mill	Camel's Head	Barne Brake
	Area (km^2)	5.7	0.87	0.91
Return Period	Method	Flow (cumecs)		
1.1	ReFH Summer	1.60	0.40	0.40
	ReFH Winter	**3.00**	**0.70**	**0.70**
	WINFAP-FEH3	NA	NA	NA
2	ReFH Summer	2.30	0.60	0.60
	ReFH Winter	**4.30**	**1.00**	**1.00**
	WINFAP-FEH3	2.08	0.41	0.49
5	ReFH Summer	3.40	0.80	0.80
	ReFH Winter	**5.90**	**1.40**	**1.50**
	WINFAP-FEH3	2.73	0.53	0.61
10	ReFH Summer	4.20	1.00	1.10
	ReFH Winter	**7.30**	**1.80**	**1.80**
	WINFAP-FEH3	3.27	0.62	0.72
25	ReFH Summer	5.20	1.30	1.30
	ReFH Winter	**9.10**	**2.20**	**2.30**
	WINFAP-FEH3	4.14	0.77	0.90
50	ReFH Summer	6.20	1.50	1.60
	ReFH Winter	**10.90**	**3.50**	**2.80**
	WINFAP-FEH3	4.97	0.92	1.07
100	ReFH Summer	7.60	1.90	2.00
	ReFH Winter	**13.00**	**3.30**	**3.40**
	WINFAP-FEH3	6.00	1.10	1.28
200	ReFH Summer	9.60	2.40	2.50
	ReFH Winter	**15.60**	**4.00**	**4.10**
	WINFAP-FEH3	7.28	1.33	1.55
500	ReFH Summer	13.60	3.50	3.60
	ReFH Winter	**20.20**	**5.20**	**5.50**
	WINFAP-FEH3	9.48	1.71	2.00
1000	ReFH Summer	18.40	4.80	4.90
	ReFH Winter	**24.90**	**6.50**	**6.80**
	WINFAP-FEH3	11.63	2.09	2.45

The results displayed in Table 2-8 indicate that the peak flow estimates for each of the watercourses are more conservative when adopting the ReFH winter design rainfall parameters compared to the ReFH summer design rainfall parameters and the FEH Statistical Method.

With regards to the FEH Statistical Method a number of stations had to be removed from the initial pooling group as they were deemed unsuitable for pooling. The revised pooling group included stations where the similarity distance measures (SDM) were greater than those removed; therefore greater uncertainty within the flow estimates is likely.

As mentioned previously the design event for urban catchments was calibrated using only seven such catchments during the development of the ReFH model, this may be a potential reason for the considerably lower flow estimates experienced when adopting the recommended ReFH summer design rainfall parameters.

A comparison between the 1 in 100 year flow rates for the Weston Mill Stream and flow rates for the Ham Brook and Honicknowle Stream (tributaries of the Weston Mill Stream) is shown in Table 2-9. The Ham Brook and Honicknowle Stream flow rates were estimated using the FSR/FEH Rainfall Runoff Rate method (superseded by ReFH) for a hydraulic modelling study undertaken as part of an FRA in 2006 for a nearby residential unit at Mowhay Road, Plymouth (App. No.: 06/00410/OUT)).

Table 2-9: 1 in 100 year flow rate comparison between Weston Mill Stream and the Ham Brook and Honicknowle Stream

Station	Catchment Area (km2)	ReFH Summer (100Yr)	ReFH Winter (100Yr)	WINFAP-FEH3 (100Yr)	FEH Rainfall-Runoff Method (Summer) (100Yr)
Weston Mill Stream	5.7	7.60	13.00	6.00	-
Ham Brook	2.53	-	-	-	5.07
Honicknowle Stream	2.41	-	-	-	5.9

Table 2-9 illustrates that the flows estimated for the Weston Mill Stream using the ReFH winter design rainfall parameters are comparable to those approved by the Environment Agency used within the previous FRA.

For the purposes of this study, the ReFH winter design rainfall parameters (see Table 2-8) peak flow estimates, (and associated hydrographs) have been used to ensure a conservative approach to the combined approach analysis and subsequent model inputs and development design.

3 Combined Event Analysis

3.1 Level of Dependence

The desk study approach to joint probability analysis presented in the Defra/Environment Agency R&D Technical Report FD2308/TR2 has been adopted for the purpose of this study. Within the best practice guidance document, Figure 2 catergorises the dependence between river flow and surge along the coastline, in the vicinity of the site it is identified as being 'super dependent' (0.13 ≤X).

Although this categorisation is not a site specific value of dependence, it provides a fair approximation for the purpose of this study.

3.2 Application of the Desk Study Approach

The desk study software tool included within the R&D Technical Report FD2308/TR2 has been used to calculate the relevant combinations of sea level and river flow return periods to represent the 1 year, 10 year, 50 year, 100 year, 200 year and 500 year joint exceedence return periods. A level of dependence CF value of 1500 has been used (see Table 3.5 of FD2308/TR1). Figure 3-1 provides a screenshot of the desk study software tool user input sheet.

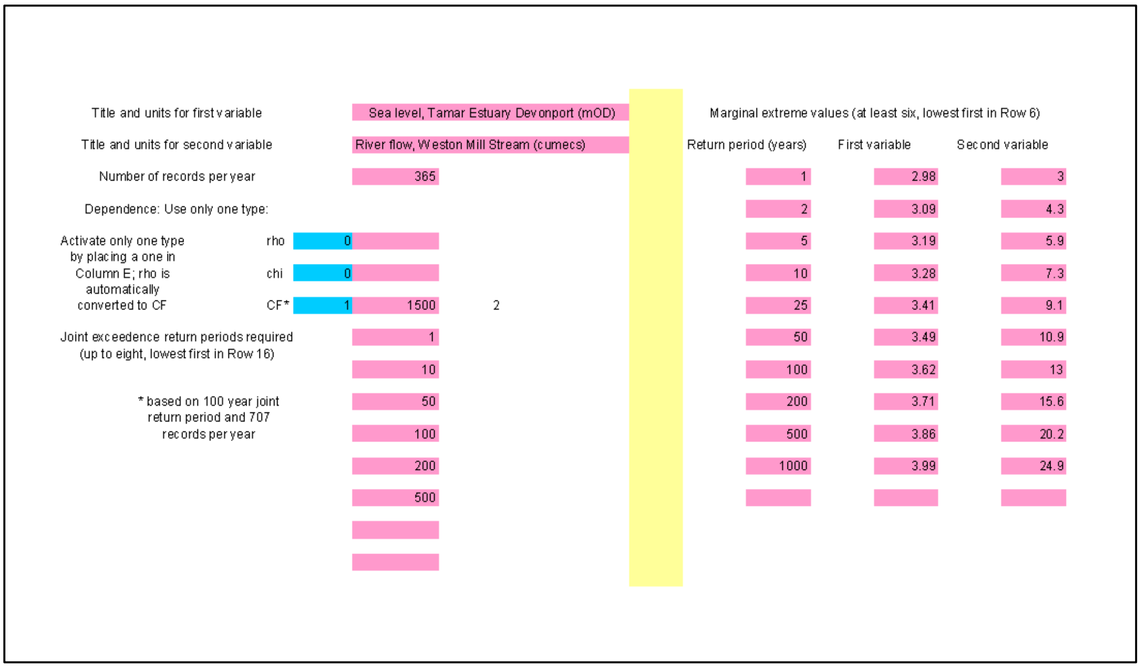

Figure 3-1: Input to the desk study software tool (R&D Technical Report FD2308/TR2)

Figure 3-2 is a screenshot of the resulting 'source variable output' sheet. The best practice guidance indicates that the 'worst case' combinations of sea level and river flow, for any particular joint exceedence return period are found on the diagonal part of the curve. The results corresponding to the diagonal part of the curve are highlighted as ovals in the table shown in Figure 3-2.

	Joint exceedence return period (years)							
Value of first variable:	1	10	50	100	200	500	#N/A	#N/A
Sea level, Tamar Estuary Devonport (mOD)	Value of second variable:		Riverflow, Weston Mill Stream (cumecs)					
2.68	3.00	7.30	10.90	13.00	15.60	20.20	#N/A	#N/A
2.77	2.84	7.30	10.90	13.00	15.60	20.20	#N/A	#N/A
2.89	0.71	7.30	10.90	13.00	15.60	20.20	#N/A	#N/A
2.98	-0.59	6.37	10.90	13.00	15.60	20.20	#N/A	#N/A
3.09	#N/A	5.10	10.55	13.00	15.60	20.20	#N/A	#N/A
3.19	#N/A	3.44	8.39	11.14	14.94	20.20	#N/A	#N/A
3.28	#N/A	2.14	7.03	9.31	12.47	18.74	#N/A	#N/A
3.41	#N/A	#N/A	5.27	7.46	9.86	14.51	#N/A	#N/A
3.49	#N/A	#N/A	4.05	6.06	8.32	12.12	#N/A	#N/A
3.62	#N/A	#N/A	#N/A	4.83	6.94	10.15	#N/A	#N/A
3.71	#N/A	#N/A	#N/A	#N/A	5.59	8.53	#N/A	#N/A
3.86	#N/A	#N/A	#N/A	#N/A	#N/A	6.71	#N/A	#N/A
3.99	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

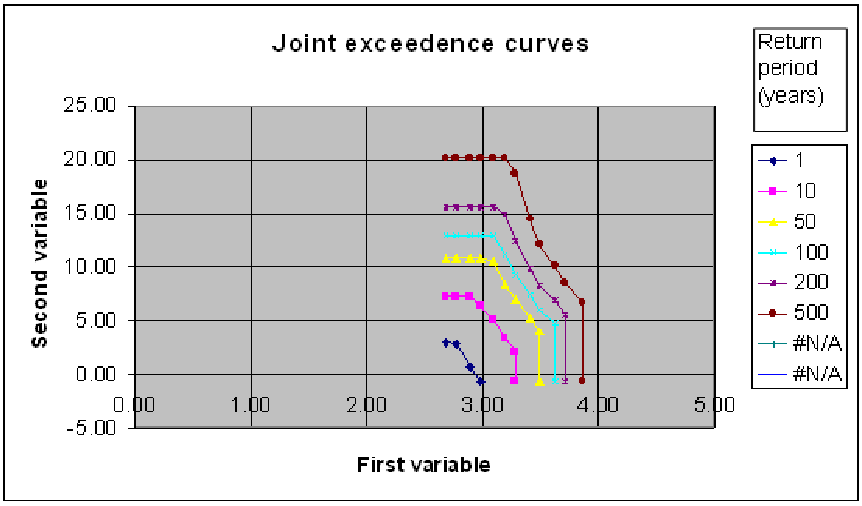

Figure 3-2: Output from the desk study software tool (R&D Technical Report FD2308/TR2)

When considering the 60 year lifetime of the proposed development at North Yard, Devonport the joint exceedence return periods of interest are the 100 year and 200 year events. Table 3-1 provides a summary of the combination of sea level and river flow return periods, which represent the 100 year and 200 year joint exceedence return periods.

Table 3-1: Summary of 100 year and 200 year joint exceedence return periods river flow and sea level combinations

Joint Exceedence Return Period	River Flow Return Period (m^3)	Sea Level Return Period (m AOD)
100 Year	100 Year (13.0)	2 Year (3.09)
	~2 Year (4.83)	100 Year (3.62)
200 Year	200 Year (15.60)	2 Year (3.09)
	~5 Year (5.59)	200 Year (3.71)

The combined sea level and river flow return periods and values shown in Table 3-1 are the proposed present day boundary conditions to be adopted within the 1d hydraulic model.

An allowance for sea level rise (see Table 2-1) and an increase in peak river flows due to climate change affects over the developments lifetimes (60 years) will be accounted for within the 1d hydraulic model in accordance with PPS25 recommedations (Table B.2 in PPS25).

4 References

- Communities and Local Government (Revised 2010) Planning Policy Statement 25: Development and Flood Risk. London: TSO;
- Defra/Environment Agency (2005) Joint Probability: Dependence Mapping and Best Practice: Technical report on dependence mapping. R&D Technical Report FD2308/TR1;
- Defra/Environment Agency (2005) Use of Joint Probability Methods in Flood Management, A Guide to Best Practice. R&D Technical Report FD2308/TR2;
- Environment Agency (2003) South West Region Report on Regional Extreme Tide Levels;
- Faulkner, D. S. and Barber, S. (2009) Performance of the Revitalised Flood Hydrograph method, Journal of Flood Risk Management Vol 2 254–261, Blackwell Publishing Ltd.