1.0 Introduction

Scott Wilson Ltd was engaged by Mr Alastair Stewart to undertake a Flood Risk Assessment (FRA) for a proposed development site at Mounthooly Golf Range, near Jedburgh in the Scottish Borders.

The development site is situated approximately 4km to the northeast of the town of Jedburgh, just off the A698, near the confluence of the Jed Water and the River Teviot. The site is located within the Scottish Borders Council (SBC) local government area. The site is potentially at risk of flooding from either the Jed Water or the River Teviot. The land use surrounding the site is mainly mixed use agricultural land with localised areas of trees, shrubs and undergrowth.

The adjacent River Teviot floodplain has a width of some 500 to 1000m. The proposed site is located on an area of ground that is slightly raised above the general surrounds. Ten miles further downstream, the River Teviot joins the Tweed, which subsequently flows into the North Sea at Berwick-upon-Tweed.

This report has been prepared to assess flood risk to support a future planning application, since the site is shown to be prone to flooding on SEPA's Indicative River & Coastal Flood Map.

2.0 Background

2.1 Site Description

Mounthooly Golf Range is situated in Mounthooly, near Jedburgh. The proposed site is located off the A698 between Bonjedward and Crailing. The site, currently a golf range, is accessible through a car park, serving the golf range and an adjacent restaurant. A few outbuildings are also part of the existing development.

The site location is shown in Figure 1 and the topographical survey of the site is shown in Figure 2. Ground levels at the site are generally between 54.0m AOD and 55.0m AOD, with the lowest points at 53.78m AOD.

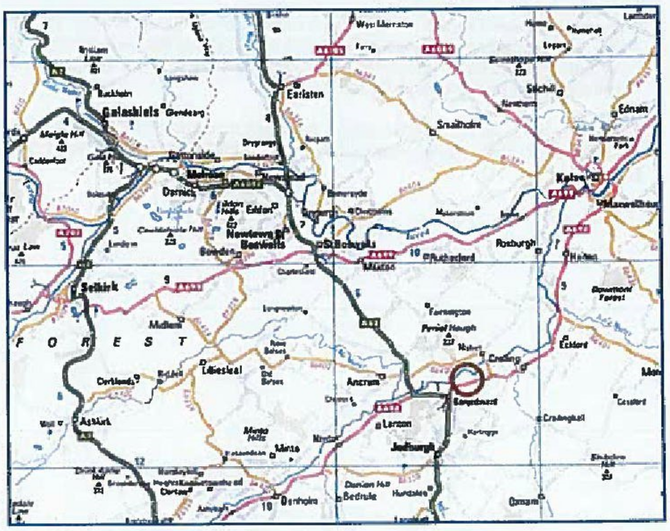


Figure 1: General Site Location

The proposed development comprises three housing plots with access through the adjacent car park.

This report has been prepared to assess the flood risk associated with the site to inform a potential future planning application.

2.2 Available Data

This FRA is based on information collected from the following sources:

- Ordnance Survey 1:50,000 Landranger map – Sheet 74: Kelso & Coldstream;
- Ordnance Survey 1:25,000 Explorer map – Sheet OL 16: The Cheviot Hills;
- SEPA indicative flood mapping;
- SEPA's gauging data for the Jed Water at Jedburgh gauging station and the River Teviot at Ormiston gauging station;
- Scott Wilson, 'Proposed Dwelling House: Mounthooly, Jedburgh – Flood Risk Assessment', May 2007;
- Detailed topographic survey of the site and levels across the River Teviot and the Jed Water floodplains;
- Detailed HEC-RAS model of the River Teviot and the Jed Water (from 2007) and the proposed development site;
- A site visit on August 4th, 2009;
- The Flood Estimation Handbook (Institute of Hydrology);
- Kjedsen *et al.*, 'Improving the FEH Statistical Method' – *Flood & Coastal Management Conference*, University of Manchester, July 2008;
- The SUDS Manual, CIRIA C697 (2007);
- SPP 7, Planning and Flooding – Scottish Executive, February 2004; and
- Extract from JBA Consulting, Jedburgh Flood Study Final Report, May 2006.

2.3 FRA Terminology and Limitations

Within this report, flood events are referred to in terms of their return period. A return period does not predict the period of time that will elapse between such events; rather it is an expression of the probability of that event occurring in any given year. A flood of any given magnitude may occur at any time, and two or more extreme events may occur in succession within any given year.

Table 1 summarises the return periods discussed in this report, and the probability of these flood events occurring in any given year.

Table 1: Probability of Flood Events of Given Return Periods

Return Period	Probability of Occurrence in any Year
1 in 2 year (Q2)	50 %
1 in 5 year (Q5)	20 %
1 in 20 year (Q20)	5 %
1 in 100 year (Q100)	1 %
1 in 200 year (Q200)	0.5 %
1 in 500 year (Q500)	0.2 %
1 in 1000 year (Q1000)	0.1 %

Where the left and the right of the river are referred to in this report, these are in relation to an observer facing downstream.

Flood flowrates and flood levels shown in this report are estimates based on a certain set of data and an error band is associated with all such estimates.

3.0 Regulatory Framework and Consultations

3.1 SPP7 – Planning and Flooding

SPP 7 develops a Risk Framework that characterises areas for planning purposes by their annual probability of flooding and gives the following planning response:

- Little or no risk area – less than 0.1% annual risk (1:1000 event) – no general constraints;
- Low to medium risk area - 0.1% to 0.5% (1:1000 – 1:200) – suitable for most development but not essential civil infrastructure such as hospitals, fire stations, emergency depots, schools, ground based electrical and telecommunications equipment; and
- Medium to high risk area - 0.5% (1:200) or greater – in built up areas with flood prevention measures most brownfield development should be acceptable for essential civil infrastructure; undeveloped and sparsely developed areas are generally not suitable for most development.

SPP 7 states that it is not national policy to add an additional allowance for climate change above the 0.5% (1:200) probability but planning authorities may do so if it can be justified, taking account of the most recent United Kingdom Climate Impacts Programme scenarios as applied to the area concerned. An allowance for 'freeboard' would be additional and may be required as a response to local circumstances.

In terms of planning policy, SPP 7 stipulates that new development should not:

- Materially increase the probability of flooding elsewhere;
- Add to the area of land which requires protection by flood prevention measures;
- Affect the ability of the functional floodplain to attenuate the effects of flooding by storing flood water;
- Interfere detrimentally with the flow of water in the floodplain; or
- Compromise major options for future shoreline or river management.

The functional floodplain is defined as the area that would store and convey floodwater during times of flood. For planning purposes SPP 7 defines the functional floodplain as that area that will generally have a greater than 0.5% (1:200) probability of flooding in any year.

3.2 Scottish Environment Protection Agency

This present study is based on work carried out by Scott Wilson in 2007 for an adjacent site at Mounthooly. SEPA objected to that development. The planning application was subsequently put to appeal and the Scottish Ministers granted planning permission (subject to conditions) in December 2008.

As it was planned to base the present study on the earlier HEC-RAS model, SEPA was consulted from at the outset. SEPA's hydrologist (Mr M MacConnachie) requested that the hydrology be reviewed, especially for the Jed Water, and that more details of flood levels in the Jed Water (and associated storage) be provided in the final report.

3.3 Scottish Borders Council

SBC requires that SPP7 and other relevant policy and guidance produced by the Scottish Executive be adhered to when preparing FRA's.

Based on other projects carried out in SBC area, design was based on 1:200 flood flows included an allowance for climate change (+ 20%) and 500mm freeboard.

4.0 Flood Flow Estimation

4.1 Catchment Description

The River Teviot flows parallel with the A698 and within 600m of the proposed site. Upstream of the site, approximately 500m to the west, is the confluence of the Jed Water and River Teviot.

The River Teviot has its headwaters southwest of the site. This watercourse drains a catchment area of approximately 711 km^2 upstream of its confluence with the Jed Water and 860km^2 at Mounthooly. Ten miles further downstream, the River Teviot joins the Tweed, which subsequently flows into the North Sea at Berwick-upon-Tweed.

The Jed Water has its headwaters south of the site. This watercourse drains a catchment area of approximately 147.3 km^2 upstream of its confluence with the River Teviot.

The general surroundings are mixed use agricultural land with localised areas of trees, shrubs and undergrowth. The adjacent floodplain has a width of some 500 to 1000m wide in this area.

4.2 Hydrological Model – Options and Development

The industry standard for the assessment of flood flows in the UK is the "Flood Estimation Handbook" (FEH), published by the Institute of Hydrology in 1999, which replaced the Flood Studies Report (FSR). Current methods of flood flow estimation in the UK can be broadly divided into two categories:

- Statistical analysis procedures using gauged data. The FEH recommends this as the preferred method in most instances;
- Rainfall-runoff based approaches using hydrological models and generating a runoff hydrograph;
- Combinations of the above.

The FEH discusses the factors influencing the choice between the methods for flow estimation. In general, flood flow estimations determined by the Rainfall Runoff method are typically more uncertain than those obtained from the statistical method. Furthermore, for use of either method, adjustments should be made by data transfers from nearby or similar catchments. Further details relevant to the selection of the flood flow estimation method for the subject site are provided below:

- Statistical methods are generally more applicable to large catchments exceeding 1,000 km^2. The catchment of the River Teviot at the site is slightly smaller than this threshold. For large catchments where it is considered unlikely to experience a catchment-wide design storm, the statistical approach should be used.

- A gauged record twice as long as the target return period (T) is required to provide a good degree of confidence in the statistical procedure applied to a single gauged site.

The FEH recognises that this is usually not possible due to the limited length of gauged records available and recommends a pooled analysis be used from a group of catchments to generate a gauged record of five times the target return period. Further details are provided below.

- Gauged flow data should always be used where possible. If gauged data is available for more than two or three years the statistical approach should be used.
- If no continuous flow record exists, but rainfall and flow data are available for five or more flood events then the rainfall runoff method is preferred.

Given gauging stations on both the River Teviot and the Jed Water, it was considered that the statistical approach would provide the best representation of flood behaviour and estimated flows in the area. A range of rainfall runoff methods were reported in 2007 and showed lower values than the statistical approaches. It was considered at the time that the rainfall-runoff approach, including the revitalised rainfall-runoff method, was less appropriate than the statistical methods. However, for completeness, they are also reported in this study.

4.2.1 Statistical Methods

The statistical approach used in the FEH estimates the median annual flow rate, and applies a probability distribution (growth curve) in order to derive the peak flow for any given return period. Wherever possible, the method should incorporate local data, particularly in estimating the median annual flow rate (Q_{MED}). It is recommended that for gauged records in excess of 13 years, Q_{MED} is taken as the median of the annual maxima series.

For a target return period of greater than 27 years and a gauged record length greater than 14 years, FEH recommends the use of pooled analysis to estimate the growth curve, and that a single site analysis be carried out for comparison purposes.

The closest flow gauge to Mounthooly on the River Teviot is Ormiston Mill and gauging data for this site was downloaded from the National River Flow Archive via the Centre for Ecology and Hydrology website. Annual maxima flow data were also obtained for the same station from SEPA[1]. A brief summary of the station is provided in Table 2.

Table 2: Ormiston Mill Gauging Station Summary

National River Archive Reference Number	21008
Grid Reference	NT 702 280
Catchment Area	1110.0km^2
Mean Flow	19.97m^3/s
Record Length	44 years (1961 to 2007)
Distance from subject site	Approx. 8km downstream of the subject site on the River Teviot

[1] It is noted that Annual Maxima provided by SEPA had some erroneous data, which was corrected in SEPA's letter of December 21, 2005 (see Appendix A).

There is also a flow gauge on the Jed Water at jedburgh, and data for this station was downloaded from the National River Flow Archive via the Centre for Ecology and Hydrology website. Annual maxima flow data were also obtained for the station from SEPA. A brief summary of the station is provided in Table 3.

Table 3: Jedburgh Gauging Station Summary

National River Archive Reference Number	21024
Grid Reference	NT 655 214
Catchment Area	139.0km^2
Mean Flow	2.32m^3/s
Record Length	48 years (1960 to 2007)
Distance from subject site	Approx. 3km upstream of the subject site on the Jed Water

Following are descriptions of the hydrological approaches adopted in (A) the earlier FRA by Scott Wilson for Mounthooly, and (B) this present report.

A. From Scott Wilson's 2007 FRA

Following the method outlined in the FEH, Q_{MED} at the subject site was obtained by calculating a first estimate of the value using the subject site catchment descriptors. A value was also obtained in this way for the gauged catchment. An adjusted value of Q_{MED} at the subject site was then obtained by scaling the calculated value based on the ratio between observed and calculated Q_{MED} values at the gauged donor site.

A statistical pooled analysis was carried out using WINFAP software to select a pool of broadly analogous stations around the UK, in order to compile a combined record length of 1000 years (i.e. five times the 1:200 return period). Certain stations with marked discordance were deleted, leading to an overall record length of 928 years. Iterations were carried out in order to modify the pooling group to increase the homogeneity and preserve the pooled record length. This pooling group was then used to obtain a fitted growth curve, which, when applied to the median flow, Q_{MED} provides flow values for a range of return periods.

The Q_{MED} values calculated by catchment descriptors and modified by the gauged donor catchment were then applied to the growth curve in order to generate flood flows at each key location for different return periods. These estimated flows are shown in Table 4.

Table 4: Q_{200} Flow Estimation (from 2007 report)

Return Period	Estimated Flow at Each Catchment Pooling Group Q(m^3/s)		
	Jed Water Upstream Mounthooly 147.3km^2	Teviot at Mounthooly 859.32km^2	Teviot Upstream Mounthooly 710.92km^2
2yrs	64.59	329.25	288.05
5yrs	82.48	420.45	367.84
10yrs	95.01	484.33	423.72
25yrs	112.64	574.21	502.36
50yrs	127.44	649.61	568.32
100yrs	143.84	733.24	641.49
200yrs	162.19	826.75	723.29
500yrs	189.83	967.67	846.58
1000yrs	213.73	1089.49	953.16

B. Updated Hydrology (see appendix B for details)

Since the 2007 report was issued, a new FEH Dataset (i.e FED CD-Rom Ver2.0) and new hydrological methodology (Kjeldsen, 2008) have been made available and as requested by SEPA, the hydrology of the River Teviot and the Jed Water were reviewed.

SEPA's hydrologist (Mr M MacConnachie) asked for a single site analysis to be carried out for the Jed Water as the value obtained by SEPA at Jedburgh gauging station (205.5 m^3/s) is significantly higher than the design flow of 162.2 m^3/s adopted in Scott Wilson's 2007 study.

Following the method outlined in the FEH, Jed Water Q_{MED} at the subject site was obtained using the data transfer and scaling technique. It is noted that the Jed Water Q_{MED} at Mounthooly is lower than the Jed Water Q_{MED} at Jedburgh, despite being located downstream of the gauging station.

The use of a single site growth curve is not recommended by the FEH unless a record twice as long as the required return period is available. Although the gauged record at Jedburgh has only 47 years of useable data compared to the target return period of 200 years, a single site analysis was run, as requested by SEPA. The Generalised Logistic distribution was used for this statistical analysis.

The pooling group of the River Teviot was also reviewed, given discrepancies in the original AM data and the short record used. The pooled growth curve of the River Teviot was reviewed and re-developed, with 998 years of data (within FEH recommended record length). Data analysis showed that the pooling group was homogeneous and a review of the pooling group was not required. The Pearson Type III distributions were used for the pooled growth curve analyses because data analysis showed that this distribution gave an acceptable fit and provided the most conservative growth factors.

The Q_{MED} values calculated by catchment descriptors and modified by the gauged donor catchment were then applied to the growth curve in order to generate flood flows at each key location for different return periods. These estimated flows are shown in Table 5 along with the results of the earlier analysis.

The Q_{MED} at the site was also calculated from the gauged data at Ormiston Mill and Jedburgh following the procedure recommended by SEPA and presented at the 2008 *Flood & Coastal Management Conference* (Kjeldsen *et al.*, 2008). This new method gave lower Q_{MED} values than the FEH method for both the River Teviot and the Jed Water, as detailed below:

- Jed Water: 62.27 m^3/s compared to 67.77 m^3/s using the FEH method; and
- River Teviot: 214.28 m^3/s compared to 301.31 m^3/s using the FEH method

The values estimated using the new Q_{MED} method were not adopted for conservatism.

Table 5: Q_{200} Flow Estimation (2009 Hydrology)

Return Period	Estimated Flow – River Teviot Upstream Mounthooly Pooling Group Q(m^3/s)			Estimated Flow – Jed Water Upstream Mounthooly Single Site Q(m^3/s)		
	2007 Report Pooling Group	2009 Hydrology Pooling Group		2007 Report Pooling Group	2009 Hydrology Single Site	
		FEH Q_{MED}	NEW Q_{MED}		FEH Q_{MED}	NEW Q_{MED}
200yrs	723.29	608.05	432.36	162.19	203.85	187.76
200yrs +CC	867.95	729.66	518.83	194.63	244.62	225.31

4.2.2 Rainfall Runoff Methods

The FEH Rainfall-Runoff (FEH R-R) method applies a unit hydrograph to standardised rainfall data in order to compute a final flood hydrograph. The FEH R-R method relies on three key variables to reflect the catchment characteristics: TP(0) (time to peak of the unit hydrograph), SPR (standard percentage runoff) and BF (base flow). Local data for verification of the above parameters was not readily available, and therefore initial flow estimates had initially been estimated in the 2007 report using catchment descriptors only.

In July 2005, a Defra/Environment Agency joint research project was completed, providing a revitalised rainfall runoff method. Using this method, the unit hydrograph and losses model used in the FSR/FEH RR approaches are replaced by three distinct components – a loss model, a routing model and a baseflow model. The report states that one of the main drivers behind the research was concern that the FEH rainfall model caused the FEH RR method to overestimate design floods in comparison to statistical methods.

A basic assessment using the Revitalised FEH method was also undertaken in 2007 using catchment descriptors to calculate peak flows, although the Revitalised FEH method remains uncalibrated for return periods greater than 150years.

Finally the FEH also provides a methodology for improving the catchment descriptor estimates of the three key variables defined above. Extreme event analysis results are published within the FEH and the ReFEH report for a wide range of catchments around the UK, allowing a comparison to be made of calculated and observed events, and the calculated parameters modified if appropriate. Donor catchments (i.e. Tyne Water at East Linton and Lyne Water at Lyne Station) were used to adjust flood flow estimates at Mounthooly.

Although there are common features between the catchments such as the underlying geology and maximum catchment altitude, there are also significant dissimilarities: the catchment areas and mean flows for the Tyne and Lyne are significantly smaller than for the Teviot. Discrepancies in catchment characteristics reduce the suitability of the donor catchment for flow modification.

Flow values for a range of return periods using both the FEH RR method and the Revitalised FEH method, with and without adjustment made in light of the Tyne and Lyne Extreme Event data, for the Teviot just upstream of Mounthooly were all lower than the estimated obtained using Statistical Analysis methods.

The various RR methods produced a range of results with a spread of over 200 m^3/s (for 1:200 events). The maximum 1:200 flow on the Teviot upstream of the Jed confluence, estimated using the FEH Rainfall-Runoff Method adjusted by the Tyne Water, was 711.23 m^3/s, approximately 10 m^3/s below the Statistical Pooled Analysis estimates at the same location.

4.3 Adopted Hydrological Approach

The FEH guidance indicates that for large catchments, defined as those in excess of 1000km^2, the statistical approach is favoured. Although smaller than 1000km^2, the catchment area of the Teviot at Mounthooly is certainly approaching this size, at 860km^2. Although no continuous flow data is required for effective application of rainfall runoff methods, the FEH does advise that specific data for more than 5 known events is necessary.

Acting on the recommendations of the FEH, it was considered that the statistical methods were the most appropriate method for the subject site at Mounthooly, both for the Jed Water and the River Teviot.

Given SEPA's recent comments (see Section 3.2) and for conservatism, it was considered that:

- The Single Site Analysis was more appropriate to estimate flood flows in the Jed Water upstream of Mounthooly. The Single-Site statistical analysis method compares satisfactorily to the JBA flood study and offers some degree of conservatism compared to the Pooled Analysis; and
- The Pooling Group analysis was more appropriate to estimate flood flows in the River Teviot upstream of Mounthooly. The 2007 estimate was conserved as it provides higher and more conservative flow values, although recent hydrological methods suggest it may be over-conservative.

The adopted peak flows can be seen in Table 6 below.

Table 6: Adopted Peak Flows

Return Period	Report	Estimated Flow Upstream Mounthooly (m^3/s)	
		Jed Water	River Teviot
200yrs	2009	**208.5**[2]	**723.29**
	2007	162.19	723.29
200yrs +CC	2009	**250.2**	**867.95**
	2007	194.63	867.95

[2] As calculated at Jedburgh gauging station, to provide an additional degree of conservatism.

5.0 Flood Risk Estimation

A hydraulic model of the relevant reaches of the River Teviot and the Jed Water was developed in 2007 to predict flood levels for another proposed development at Mounthooly. The original model of the watercourse created using HEC-RAS was based on cross-sectional survey information obtained from Becker Geomatics (Surveyors). The survey sections were taken at various centres along both the Teviot and the Jed, from upstream of the confluence to downstream of the B6400 road bridge across the Teviot. Additional surveyed cross-sections were recently obtained east of the Nisbet Bridge and used to update the downstream end of the model. The golf range at Mounthooly is within this modelled reach.

HEC-RAS can be used to calculate water surface profiles for gradually varied flow under both subcritical and supercritical flow conditions. HEC-RAS is also able to model the hydraulic controls that influence flows in the vicinity of the subject site.

5.1 Assessment of Flooding Mechanisms

The site is potentially subject to flood waters overtopping the banks of the River Teviot and the Jed Water. Factors relating to fluvial flooding at the site are considered to be as follows:

- There are a series of embankments running parallel to the watercourses, set back by between 10 and 200m, approximately 0.5-1m above surrounding ground levels;
- Outwith river bank level the surrounding topography along the Teviot is largely flat, and in some areas there is a slight decline in levels away from the watercourse;
- The Jed Water is crossed by the Jedfoot road bridge (A698) upstream of the confluence;
- Upstream of the A698, the Jed Water channel does not have sufficient conveyance capacity to convey extreme flood flows without bursting its banks. Outwith river bank level the surrounding topography east of the Jed Water slopes downward in an easterly direction, along the A698 and towards the site;
- The land on the southern side of the Teviot is generally lower than on the northern side;
- Site inspections and topographical survey work were carried out during the 2007 winter and it was observed during these periods that the river flows were high and at the bank-full limit on occasion;
- Approximately 500m northwest of the site is the confluence of the Jed Water and the River Teviot. Should the Jed Water peak flow coincide with the River Teviot peak flow there is the possibility of a flow path being formed parallel with and on the south side of the A698;
- Downstream of the confluence and nearer the downstream end of the project area, the River Teviot is crossed by the Nisbet Bridge (B6400).

5.2 Hydraulic Parameters

The model of the watercourse was reviewed and updated to account for previous comments from SEPA. The river system has been modelled as a series of channel cross sections, crossed by bridge where appropriate. There are two contributing watercourses and one junction within the model.

The embankments mentioned previously are modelled as a series of lateral weirs, allowing flow to pass over them once water in the channel rises above their crest height. Water exiting the channel in this way flows into a series of storage cells, connected by weirs representing natural storage divisions such as tracks, roads and topographical features. Compared to the 2007 model, the storage area (Jed 1) immediately south of the Mounthooly Golf Range was split into two, to more accurately estimate flood levels adjacent to the site.

Locations of the cross-sections and storage areas in the model are shown in Figure 3 and 4.

Cross-sections A & B were surveyed in 2009 and added to the 2007 model. Interpolated cross-sections were also included downstream of the Nisbet Bridge.

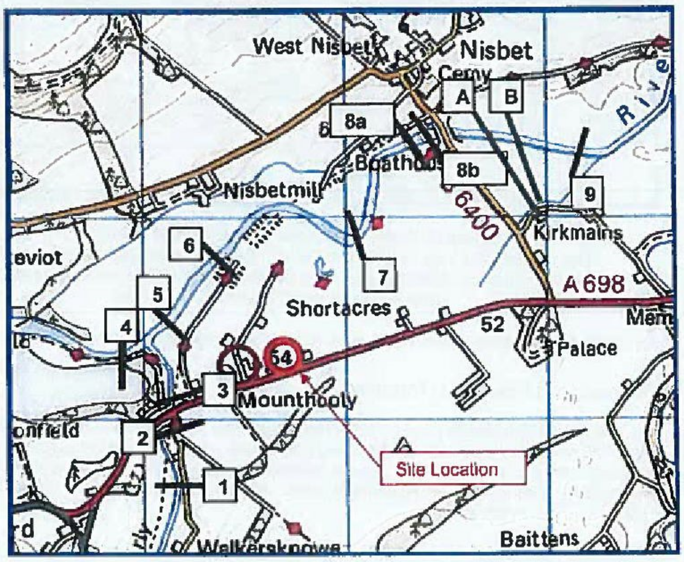


Figure 3: Site Location and Survey Cross-Sections

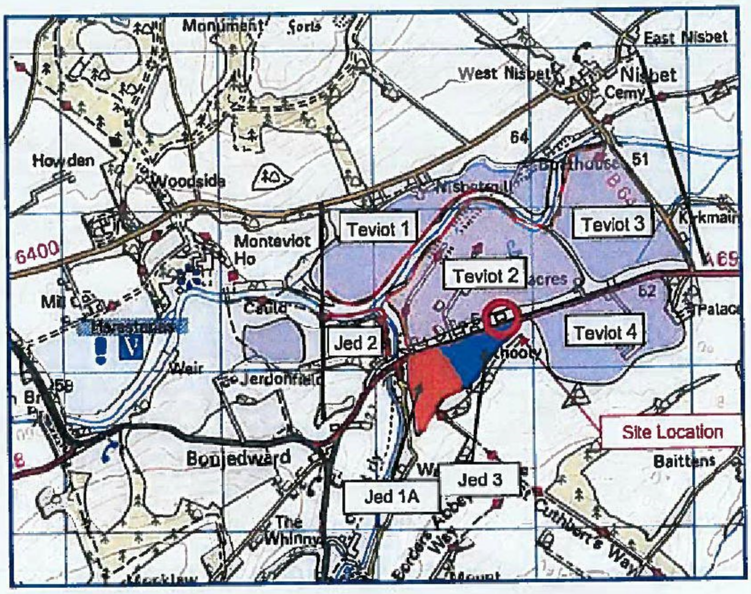


Figure 4: Model Schematic (from the 2007 report)
The storage Jed 1 was split in two distinct Storage Areas, Jed 1A and Jed 3 both located south of the A698 but east of St Cuthbert's Way. The embankments and the A698 act as connecting weirs in the model.

An unsteady analysis approach was used, to allow for modelling of storage effects.

5.2.1 Channel and Floodplain Parameters

The Manning's Equation is used in HEC-RAS to estimate flow depths in river reaches assuming normal flow conditions. Manning's 'n' values are used in this equation to reflect the roughness of the flow channel. Large Manning's 'n' values imply higher degrees of roughness and consequently higher flood levels. Manning's 'n' values selected for this hydraulic study varied as follows:

- 0.04 for the defined channel line that was observed to be relatively straight and without overgrown vegetation;
- 0.065 for floodplain areas outwith the channel with grass cover and limited taller vegetation (e.g. shrubs and trees); and

- 0.05 for floodplain areas downstream of the Nisbet Bridge with are generally barley fields and grassland.

These 'n' values are within the range generally used although towards the conservative end recommended in the HEC-RAS technical reference manual as well as in other standard references.

5.2.2 Model Boundary and Initial Conditions

The upstream boundary condition was set to 'flow hydrograph', tributary flow conveyance was set to lateral inflow hydrograph and the downstream boundary condition was set to a normal depth slope of 0.26 % using an energy slope estimated from the survey data, including surveyed floodplain slope.

A mixed subcritical and supercritical flow regime was adopted for hydraulic modelling purposes to account for both backwater effects as well as possible supercritical conditions through the hydraulic controls and steeper portions of the watercourse.

5.2.3 Bridges and Control Structures

Both the A698 bridge crossing of the Jed Water and the B6400 Nisbet Bridge crossing of the River Teviot were included in the model to account for possible backwater effects.

Contraction and expansion coefficients of 0.1 and 0.3 were used for gradual transitions. Higher coefficients of 0.3 and 0.5 were adopted immediately upstream and downstream of the two bridges

Weir coefficients of 2.6 were adopted for the embankment within the study reach (whether along the channel or separating storage areas), as recommended for broad crested weirs in HEC-RAS literature.

5.3 Hydraulic Modelling

5.3.1 Calibration

Two significant flood events were recently recorded in the catchment, one in October 2002 and the other in January 2005. SEPA provided photos and survey levels of the trash line at Nisbet (NGR NT 6747 2547 - upstream of the Bridge) and Crailing (NGR NT 6977 2530). The data at Nisbet Bridge was used to calibrate the current model.

In the January 2005 event, a gauged flow of 652m^3/s at Ormiston Mill caused an estimated water level of 51.78m AOD (based on the trash line) upstream of the Nisbet Bridge. The recorded flow was used to estimate flows at Mounthooly by scaling using areal comparison (similar to the approach used in the 2007 calibration), as detailed below:

- 85.64 m^3/s for the Jed Water
- 413.01 m^3/s for the River Teviot

The updated model was calibrated satisfactorily against the survey level provided by SEPA, as shown in Table 7.

Table 7: Model Calibration

Section	Description	Level recorded by SEPA	2009 updated Model
River Teviot – Section 8a	30m upstream of Nisbet Bridge	~51.78m AOD	51.84m AOD
River Teviot – Section 8b	Immediately upstream of Nisbet Bridge	~51.78m AOD	51.76m AOD

5.3.2 Summary of Model Results

Hydraulic modelling was carried out for the 1 in 200 year and the 1 in 200 year plus climate change events (the "design" flood event for the purposes of this study). Flood levels in the vicinity of the site are shown in Table 8 below. For comparison, Table 8 also shows the results from the 2007 FRA study.

Details of the cross-sections on the River Teviot and the Jed Water are shown in Figures 5a to 5c.

The effects of the higher estimated flows in the Jed Water is greatest in the flood storage areas, and particularly in Jed 1A, which is principally fed from the Jed upstream of the Jedfoot Bridge. In this storage area, flood level has increased by 750mm. As expected, the effect of the higher flows in the Jed diminishes further downstream, where flood levels are affected by levels in the River Teviot and in adjacent storage cells.

Table 8: Hydraulic Model Results
Locations of cross-sections and storage areas are shown in Figure 3 and 4.
Results of the 2007 model (where available) are shown for comparison in brackets.

Cross Section		Water Level (m AOD)	
Section	Description	1:200 year	1:200 year + 20% climate change
River Teviot - Section 5	Immediately downstream confluence	54.34 (54.46)	54.55 (54.54)
River Teviot – Section 6	Adjacent to Mounthooly Golf Range	54.10 (54.13)	54.29 (54.34)
Jed Water – Section 2	Immediately upstream Jedfoot Bridge (A698)	55.44 (55.57)	55.53 (55.75)
Storage Area			
Jed 1A*	Immediately adjacent to right-hand embankment of the Jed Water upstream A698 – approximately 150m west of site	55.33 (54.65)	55.39 (54.65)

Cross Section		Water Level (m AOD)	
Section	Description	1:200 year	1:200 year + 20% climate change
Jed 3 (new)	Immediately south of site, separated by the A698	53.57 (NA)	53.80 (NA)
Teviot 2	Site is located within Teviot 2	53.57 (53.40)	53.81 (53.56)
Teviot 4	Approximately 300m east of site	53.56 (53.40)	53.79 (53.56)

* Jed 1 storage cell re-defined.

5.3.3 Sensitivity Analysis

A sensitivity analysis was undertaken to determine the sensitivity of flood levels to modelling parameter assumptions. The results are summarised below, and were found to have no significant impact on flood levels within the subject site:

- Varying Manning's 'n' values by +/- 10% produces a maximum change in flood levels of around +/- 50mm in the storage areas and the river cross-sections;
- Varying weir coefficient values by +/- 10% produces a maximum change in flood levels of less than 100mm in the storage areas and the river cross-sections.

The sensitivity analysis undertaken as part of the 2007 FRA indicated that an 'error band' of +/- 150mm was considered appropriate for the estimated flood levels.

Although the model has been well calibrated and the above indicates a low sensitivity to parameter assumptions, a freeboard to development levels would still be recommended, as discussed below.

5.4 Flood Risk

5.4.1 Flood Risk to Existing Site

It is considered that the flood standard required for this development would be the 1:200 year event with an allowance for climate change, as recommended by SEPA and described previously in this report. The flood levels for the design event are shown in Table 7, and the most appropriate flood level would be that of the storage area Teviot 2. In this storage area, the 1:200 + CC flood level is estimated to be 53.81m AOD.

The lowest points on the proposed development site are at levels of 53.83m AOD, and are therefore marginally above the estimated design event flood level.

5.4.2 Flood Risk to Proposed Development

The ground levels adjacent to the proposed plot 2 are between 53.83m and 54.28m AOD. Therefore there would be virtually no freeboard above the design flood event level. The two other proposed housing plots are however, located above the 54.0m AOD contour. The flood levels for the design event are shown in Table 8 and the mapped flood extents are shown in Figure 6.

It would be recommended that a minimum freeboard of 500mm be allowed for any finished floor or underfloor cavity levels. It is also recommended that the housing be set with levels 200mm above levels of the access road and current ground, to account for possible overland sheetflow. Consequently, the finished floor levels should be set at a minimum of 54.31m AOD.

The model shows significant connectivity between the storage areas around the site, with floodwater overtopping the A698 west and east of the Mounthooly Golf Range, for over 24hours in some locations.

A maximum 900mm depth of water over the A698 is predicted east of the site (i.e. at the linkage between Jed 3 and Teviot 2, and between Jed 3 and Teviot 4), effectively causing the road to be flooded and impassable for a time. The maximum water depth predicted by the model west of the site is below 400mm. Although the A698 is also shown as flooded approximately 100m west of the site, the predicted depth should not prevent emergency services to access the site if required. Further consultation with the Fire Department and SEPA may be required to confirm this.

The A698 dips east and west of the site, with elevated levels immediately south of the site. Given this road profile, shown in Figure 7 below, it is considered that A698 would be overtopped at low points away from the site.

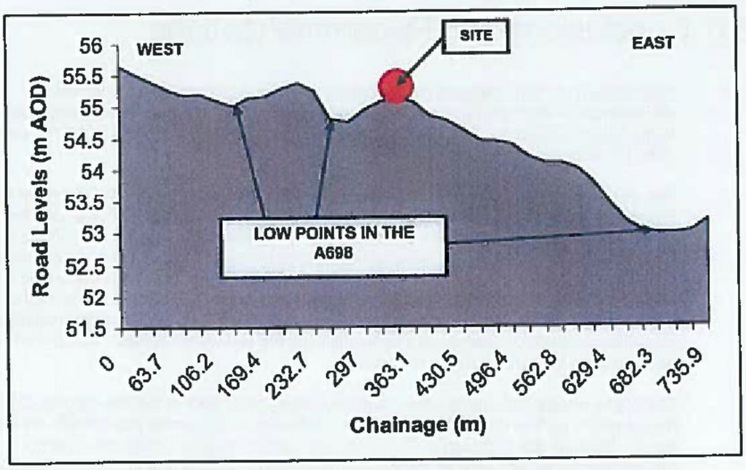


Figure 7 – A698 Profile near Mounthooly Golf Range

Flooding effects on the wider transportation networks in the area have not been assessed in this report.

In accordance with SPP 7, the proposed development at the existing Golf Range would not:

- Materially increase the probability of flooding elsewhere (provided appropriate SUDS provisions are made on-site);
- Add to the area of land which requires protection by flood prevention measures;
- Affect the ability of the functional floodplain to attenuate the effects of flooding by storing flood water;
- Interfere detrimentally with the flow of water in the floodplain; or
- Compromise major options for future shoreline or river management.

Should the emergency services be satisfied that the site is accessible during design flood events the proposed re-development of the site would be considered to conform to the requirements of SPP 7 in respect of flood risk.

6.0 Conclusions and Recommendations

Scott Wilson Ltd was engaged by Mr Alastair Stewart to undertake a Flood Risk Assessment (FRA) for a proposed development at Mounthooly Golf Range, near Jedburgh in the Scottish Borders. The proposed site is located within the Scottish Borders Council (SBC) local government area.

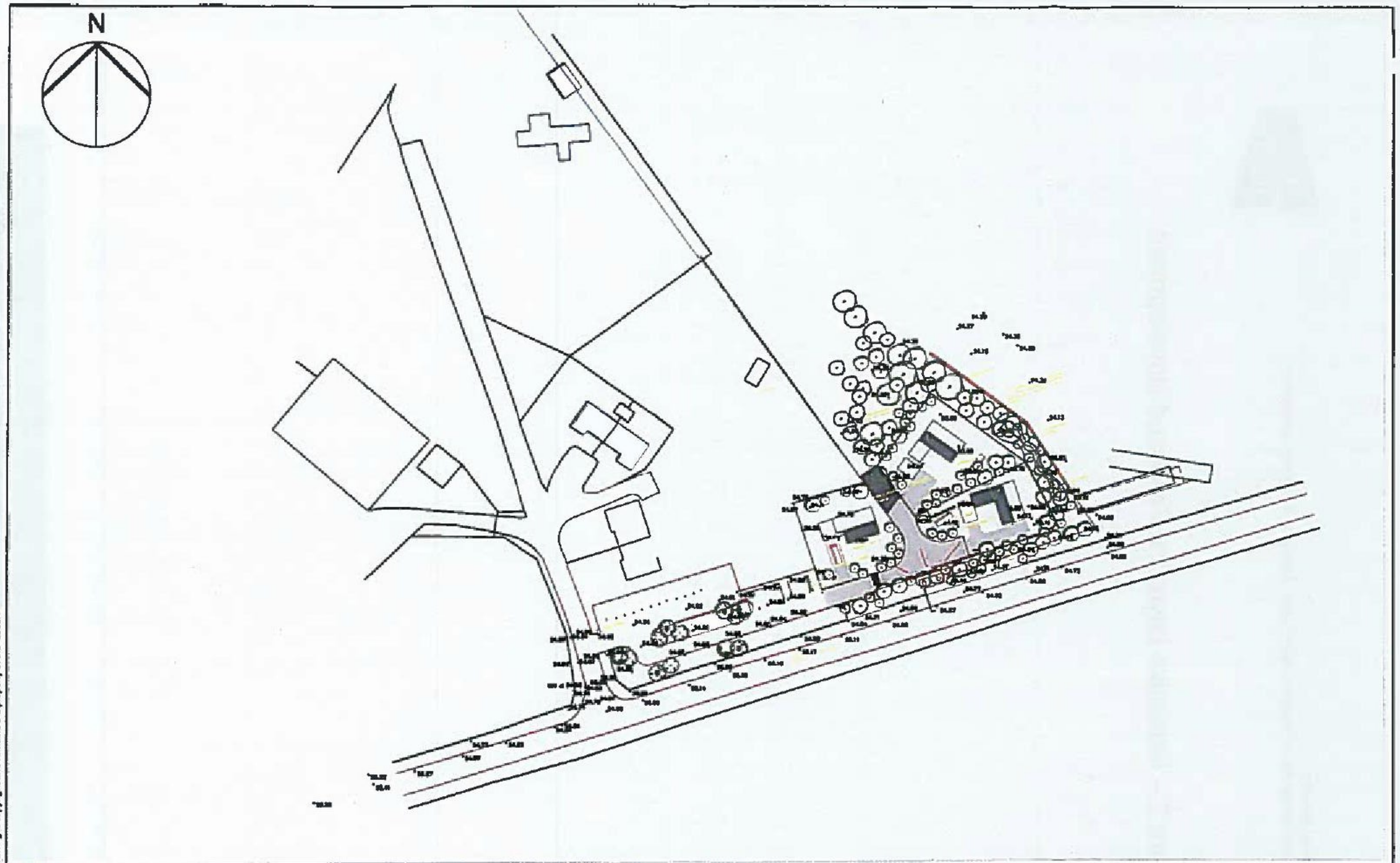
This FRA has been prepared in accordance with the CIRIA Report C624 (Development and Flood Risk), SEPA Policy No 41 as update (Development at Risk of Flooding) and the associated Technical Flood Risk Guidance and SPP7 (Planning and Flooding Policy). This FRA has utilised best-practise approaches as recommended in the FEH to determine the peak flows in the River Teviot and the Jed Water within the vicinity of the site during the 1 in 200 year storm event plus an allowance for climate change. A hydraulic model of the junction between these two watercourses was developed for an earlier study, including potential overland flow paths and storages linking the two watercourses. This model has been updated with new survey information.

The model results indicate that the intended development area at the Mounthooly Golf Range would be free of flooding during the 1:200 year return period plus climate change event. Although the A698 would flood west and east of the site during design events, maximum flood depths west of the site are not considered sufficient to prevent site access for emergency services. However, further consultation with the Fire Department and SEPA would be required to confirm this.

Therefore, the proposed development of three housing plots with access through the adjacent car park is considered to conform to the requirements of SPP 7 in respect of flood risk. It is however recommended that a freeboard of 500mm above the design flood levels should be allowed for when designing living accommodation floor levels and at least 200mm freeboard for access road levels to account for uncertainty.

This assessment has not considered pre and post surface water runoff rates for any development at the site. It is recommended that a Sustainable Urban Drainage System (SUDS) is employed to minimise the potential effects of increased runoff. The development of any SUDS system should be considered from the outset of any proposals in consultation with SEPA, the Scottish Borders Council and Scottish Water.

Figure 2 – Indicative Layout of Proposed Development



for any use of this document other than by its client and only for the purposes for which it was prepared and provided. This drawing is to be read in conjunction with all related drawings. This drawing may be used only for the purpose intended and only written dimensions shall be used. All dimensions must be checked and verified on site before commencing any work or producing shop drawings. The originator should be notified immediately of any discrepancy. This drawing is copyright and remains the property of the issuer.

NOTES

Reproduced from OS Landranger map 1:25,000 scale by permission of Ordnance Survey on behalf of The Controller of Her Majesty's Stationary Office.

Ref. Drawing No.	Rev	Revision Details	Date	dr	ck	ap

Job Title: MOUNTHOOLY GOLF RANGE FLOOD RISK ASSESSMENT	Project No. S106852	Date 10.09.2009	Scale at A3 1:1000
Drawing Title: INDICATIVE LAYOUT OF SITE	Drawn By GH	Checked By BS	Approved By DRW
Drawing Status: PRELIMINARY	Drawing Number FIGURE 2		Rev -

Scott Wilson

www.scottwilson.com

DB3

Figures 5 – Hydraulic Model Cross-Sections

Figure 5a - River Teviot - Cross Section 5

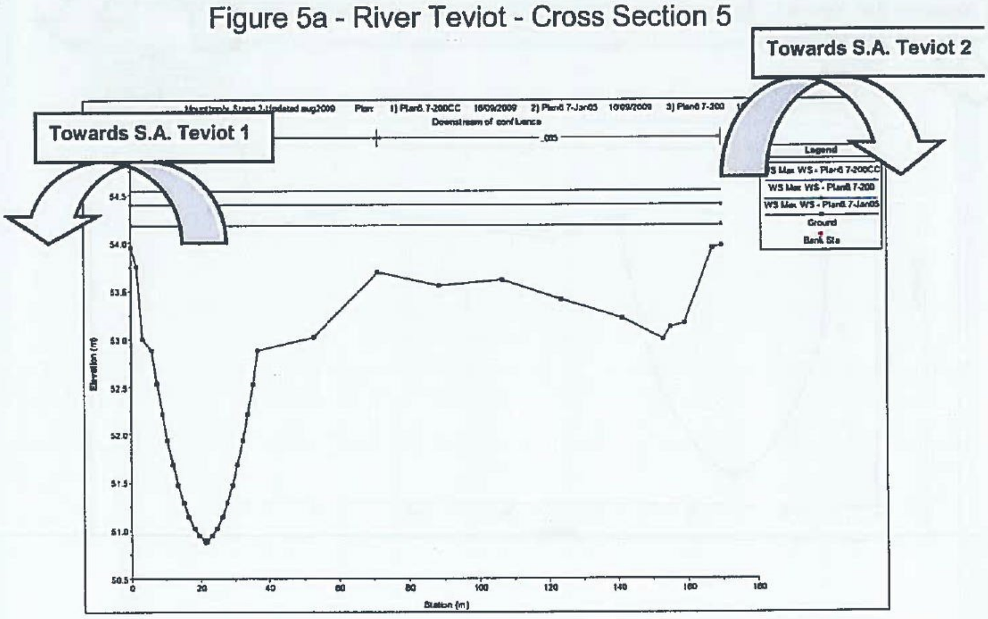


Figure 5b - River Teviot - Cross Section 4

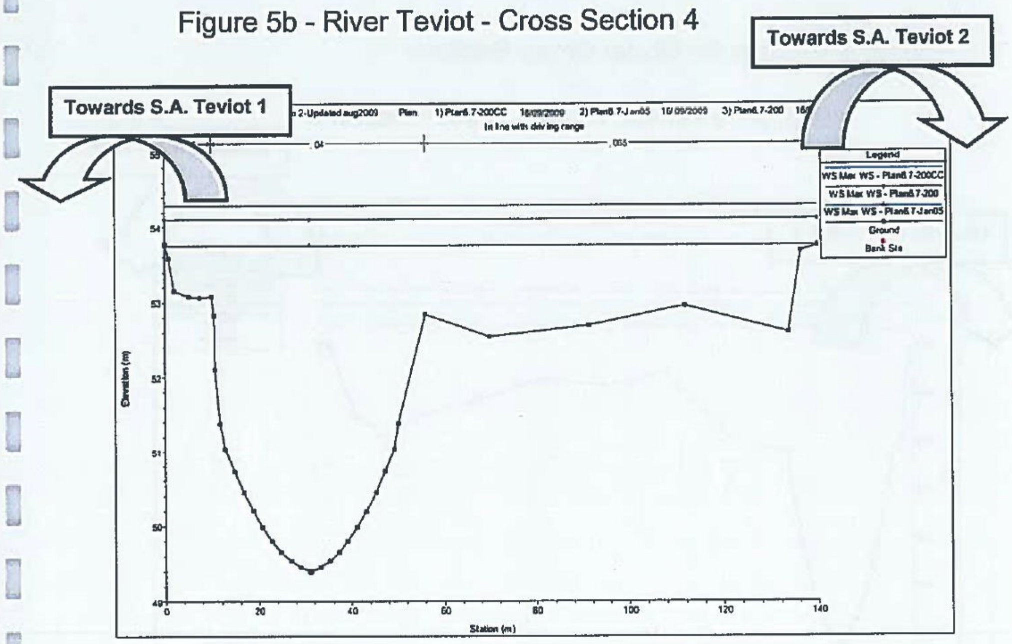
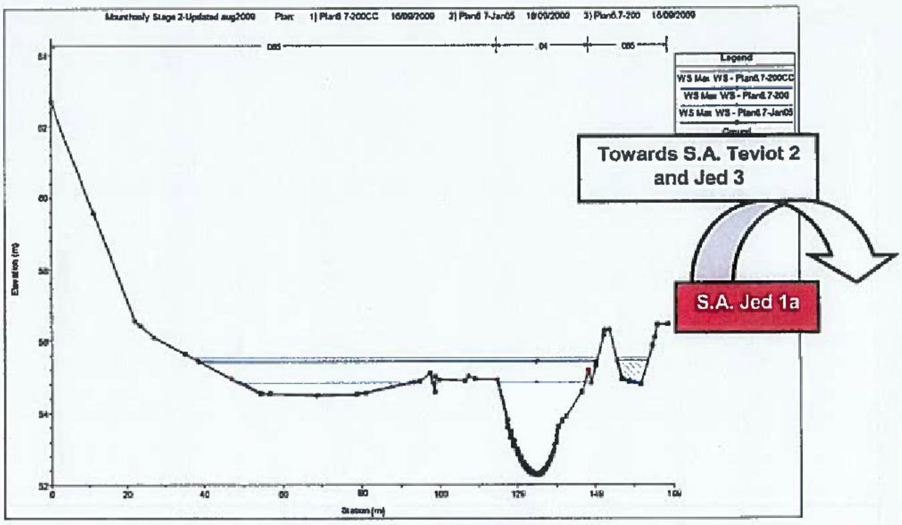
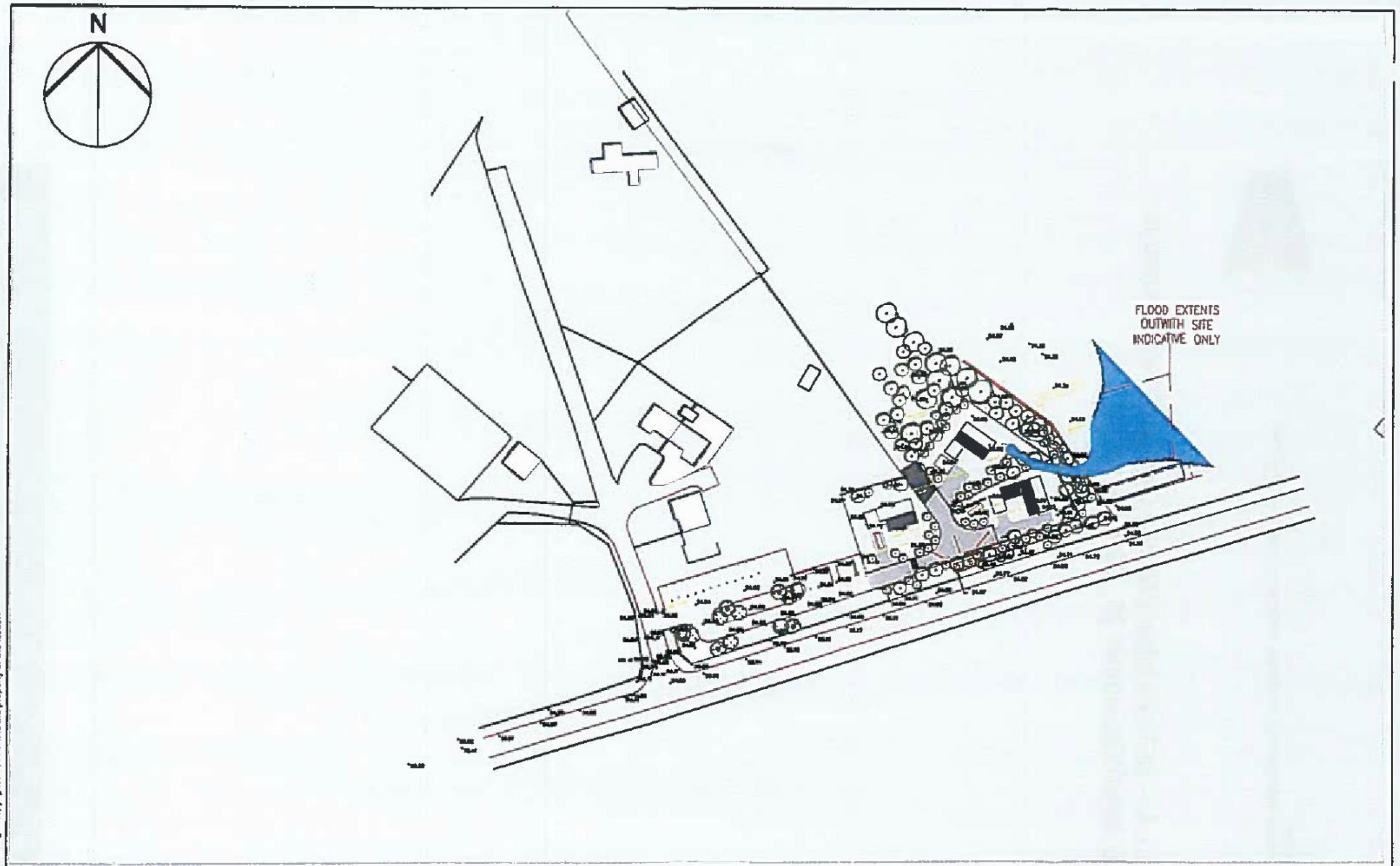


Figure 5c - Jed Water - Cross Section 2



Note: Storage Area Jed 1 is connected to the Jed water upstream of the Jedfoot Bridge, although the Jed Water is not shown to overtopped its right-hand embankment immediately upstream of the bridge.

Figure 6 – Flood Envelope



for any use of this document other than by its client and only for the purposes for which it was prepared and provided. This drawing is to be read in conjunction with all related drawings. This drawing may be used only for the purpose intended and only written dimensions shall be used. All dimensions must be checked and verified on site before commencing any work or producing shop drawings. The originator should be notified immediately of any discrepancy. This drawing is copyright and remains the property of the issuer.

NOTES

Ref. Drawing No.	Rev	Revision Details	Date	dr	ck	ap

Job Title: MOUNTHOOLY GOLF RANGE FLOOD RISK ASSESSMENT

Drawing Title: INDICATIVE FLOOD ENVELOPE

Drawing Status: PRELIMINARY

Project No.	Date	Scale at A3
S106652	16.09.2009	1:1000
Drawn By	Checked By	Approved By
GH	BS	DRW
Drawing Number		Rev
FIGURE 6		-

Scott Wilson
www.scottwilson.com

OB3

Appendix A – SEPA's letter (Wendy Campbell) addressed to SBC and dated December 21, 2005.

SEPA

Economic Development
Environmental Planning

-4 JAN 2006
To CM
Action
File
Comments
Ref No

Our Ref: WC/KM/SBC/2004/1004/
Your Ref: 03/01384/FUL

Scottish Borders Council
Planning & Economic Development
Area Office
High Street
HAWICK
TD9 9EF
FAO: Craig Miller

If telephoning ask for:
Wendy Campbell

21 December 2005

Dear Sir

TOWN AND COUNTRY PLANNING SCOTLAND ACT 1997
PLANNING APPLICATION: 03/01384/FUL
PROPOSED ERECTION OF DWELLINGHOUSE, SITE AT FIELD NO 4666, MOUNTHOOLY

Thank you for your consultation that SEPA received on the 21st October in connection with the above. I can confirm that SEPA's Flood Risk Hydrology department have now reviewed the latest information and comments sent in by Alastair Burrell Associates (ABA) and would provide the following comments in response:

Unfortunately the flow figure communicated by SEPA Galashiels to ABA for the 8 January 2005 flood on the River Teviot at the Ormiston Mill gauging station (i.e. 752 cumecs), was incorrect. A new member of staff in the Galashiels Office unfortunately applied the wrong rating equation to the recorded stage value for that event. Using the most appropriate high flow calibration for the station (i.e. the one SEPA have made reference to in previous correspondence on this application) the flow value of 8 January 2005 is 652.4 cumecs (approx. 100 cumecs lower). At the time, this event had an estimated rarity of 1 in 53 years or an annual exceedance probability of 1.89%. Incorporating this flood event into an updated flood frequency analysis, the 200-year (0.5% annual exceedance probability) flood estimate at Ormiston Mill gauging station increases from 731 cumecs to 814 cumecs.

Subsequent to ABA's letter of 10 October 2005, another large flow event occurred on the River Teviot on 12 October 2005 which led to flooding in Hawick. The flow further downstream at Ormiston Mill during this event was less than in the January 2005 event due to the very localised nature of the intense rainfall storm, i.e. it was predominantly centred over the upper Teviot catchment, hence the flooding in Hawick. On 8 January 2005, the rainfall was more widespread and the runoff contribution from the Jed Water and the Ale Water was more significant, resulting in a higher peak flow as recorded at Ormiston Mill gauging station. The flow figure at Ormiston Mill for 12 October 2005 was 579.5 cumecs, which is slightly less than the October 2002 event at 600 cumecs. Incorporating the 12 October 2005 event into the flood frequency analysis, the 200-year (0.5% annual exceedance probability) flood estimate increases again from 814 cumecs to 846 cumecs. This greater record length, which incorporates the two large flows of 2005 (i.e. 8 January 2005 and 12 October 2005) which are Rank 1 and 3 respectively within the entire flow record from 1960, now estimates the 8 January event as a 1 in 43-year event (or 2.3% annual probability).

Continued.../2

+ A 700 cumecs
given by SEPA

Clearwater House, Heriot Watt Research Park
Avenue North, Riccarton, Edinburgh EH14 4AP
tel 0131 449 7296 fax 0131 449 7277
www.sepa.org.uk

Considering the above, it can be appreciated that a flood greater than the estimated 200-year event has not occurred on the River Teviot at Ormiston Mill, as suggested by ABA. SEPA understand why they thought this was the case and indeed have explained the reasons for this above.

Flood frequency analysis is embedded in statistical non-stationarity, and the occurrence of one or two large events increases the overall sample of floods analysed and may thus alter the design flow estimates from what they were previously. This is a normal and accepted part of the science of statistical flood analysis and that is what has happened here in 2005 with the occurrence of both the January and October events. The total record (from 1960) is now 45-years in length – the largest event on record (January 2005) has an estimated return period of 43-years, which is statistically sensible. The probability of experiencing the 200-year flood in a 45-year period of record is only 20%.

ABA previously stated that the level of the Oct 2002 flood at the site was 52.96 mAOD. This flood extent reached the very edge of the proposed site (or even inundated a small area of it) as was shown in a plan diagram previously supplied by ABA. The observed level ABA now quote for the January 2005 flood is 53.10 mAOD, which is obviously higher than in October 2002. However, in their most recent letter, ABA state that the minimum existing ground level is 600mm above the January 2005 flood level.

Considering the January 2005 event is now currently assessed as a 43-year flood event, it remains the opinion of SEPA that the 200-year design flood will inundate the development site, and indeed the development site lies within the Functional Floodplain. Previously, ABA had not demonstrated anything to the contrary as their overall approach to modelling flood risk at this site was considered insufficient by SEPA.

SEPA still recommend to the Planning Authority that ABA take on board the advice provided by SEPA in December 2004, with respect to calibrating their model to observed events - there are now three recent flood events instead of one which they can use (i.e. Oct 2002, Jan 2005 and Oct 2005) which will reduce the uncertainty in the roughness parameter estimation.

SEPA also still recommend that the effect that a high River Teviot has on the Jed Water at their confluence (whilst both are in flood), should also be modelled. No previous assessment of the flood risk from the Jed Water was made and the recommendation that this factor was looked at was also detailed in SEPA's response of December 2004. SEPA are unsure whether such analysis has yet been undertaken.

The advice contained in this letter is supplied to you by SEPA in terms of Section 25(2) of the Environment Act 1995 on the basis of information held by SEPA as at the date hereof. It is intended as advice solely to Scottish Borders Council as Planning Authority in terms of the said Section 25(2).

On the basis of the above comments, SEPA would wish to maintain their objection in respect of this proposed development. In the event that the planning authority proposes to grant planning permission contrary to this advice on flood risk the application must be notified to the Scottish Ministers as per the Notification of Applications Direction 1997.

Continued.../3

The applicant/agent's appropriate SEPA contact for further liaison will be Alistair Cargill (Flood Risk Hydrologist), tel: 01738 627 989

Yours faithfully

[redacted]

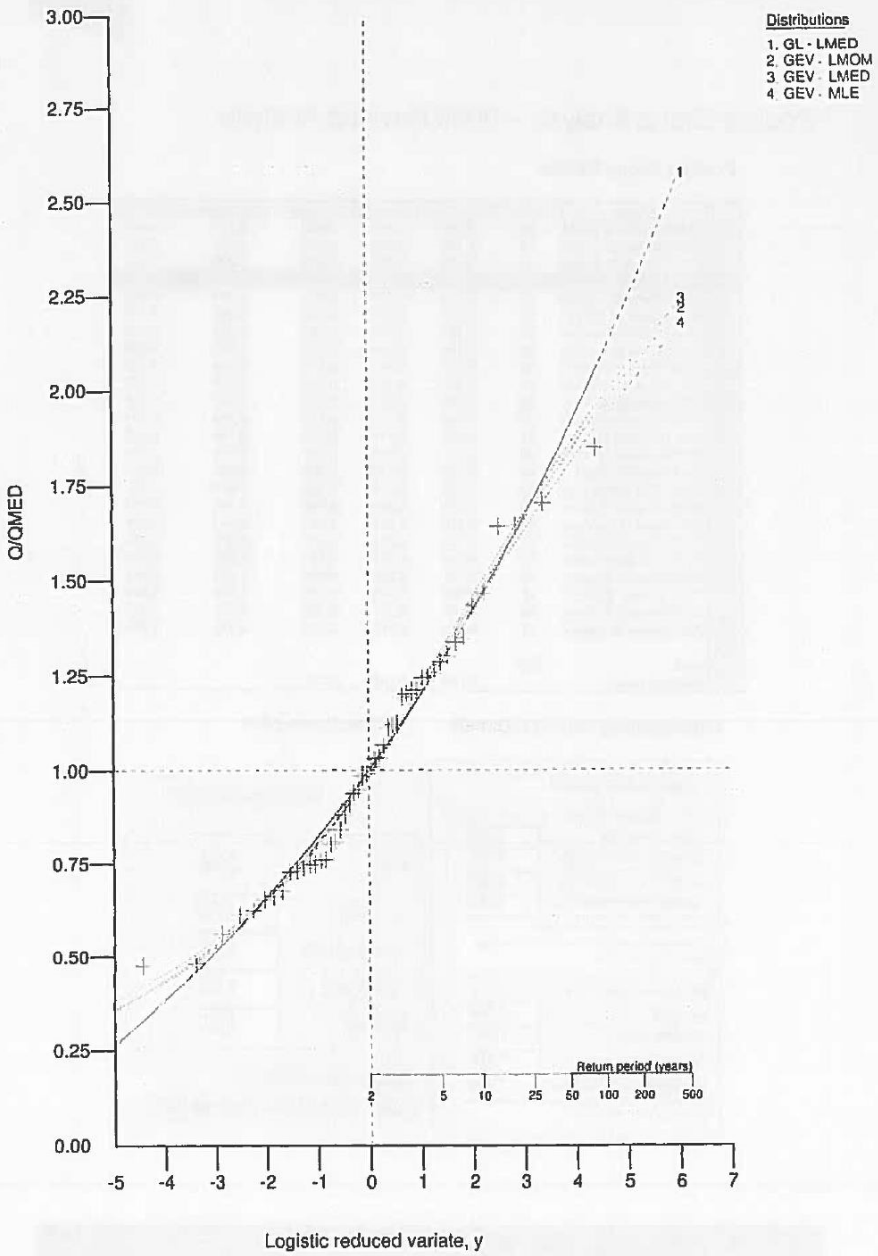
Wendy Campbell
Planning Officer

cc Alastair Burrell Associates, Windygates, Lanton, Jedburgh, Scotland, TD8 6SX
Scottish Borders Team Leader

Appendix B - Hydrological Analysis

Single-Site Analysis at Jedburgh Gauging Station – Growth Curve

Teviot @ Ormiston Mill



Pooling Group Analysis – 2009 Revised Analysis

Pooling Group Details

	Station	Years	L-CV	L-Skewness	L-Kurtosis	Discordancy	Distance
1	21008 (Teviot @ Ormist	48	0.185	0.101	0.083	0.238	0.000
2	27008 (Swale @ Leckb	29	0.108	0.063	0.106	1.459	0.351
3	27071 (Swale @ Crakel	48	0.108	0.024	0.064	1.632	0.351
4	203010 (Blackwater @	33	0.145	0.002	[illegible]	[illegible]	[illegible]
5	28018 (Dove @ Marsto	42	0.130	0.005	0.075	1.099	0.483
6	6008 (Enrick @ Mill of T	24	0.219	0.139	0.130	1.385	1.516
7	27007 (Ure @ Westwicl	48	0.167	0.165	0.195	0.599	0.544
8	25009 (Tees @ Low Mo	33	0.190	0.048	0.018	1.525	0.569
9	16004 (Earn @ Forteviu	30	0.132	0.081	0.168	0.928	1.135
10	8004 (Avon @ Delnash	51	0.221	0.166	0.076	0.908	0.587
11	27089 (Wharfe @ Tadc	12	0.195	0.056	0.057	1.648	0.591
12	27009 (Ouse @ Skelton	117	0.140	0.132	0.156	0.744	0.594
13	9001 (Deveron @ Avoc	44	0.219	0.174	0.109	0.460	0.596
14	203093 (Maine @ Shan	20	0.112	0.052	0.151	1.106	0.597
15	9003 (Isla @ Grange)	44	0.218	0.179	0.086	0.947	0.977
16	12007 (Dee @ Mar Lod	22	0.157	0.110	0.181	1.040	1.232
17	22001 (Coquet @ Morw	40	0.244	0.253	0.189	1.378	0.613
18	8001 (Spey @ Aberlour)	62	0.215	0.208	0.143	0.543	0.696
19	15006 (Tay @ Ballathie	51	0.158	0.154	0.187	0.555	1.333
20	15007 (Tay @ Pitnacre	52	0.166	0.163	0.111	1.655	1.932
21	11002 (Don @ Haughto	32	0.227	0.243	0.154	1.123	0.790
22	21003 (Tweed @ Peebl	57	0.182	0.186	0.219	1.135	0.695
23	15013 (Almond @ Almo	30	0.197	0.167	0.159	0.272	1.438
24	3002 (Carron @ Sgodac	29	0.176	0.151	0.131	0.192	1.890
25							
26	Total	998					
27	Weighted means		0.166	0.109	0.112		

Heterogeneity Measure Details

Number of simulations: 500

L-CV / L-skewness distance

Observed average	0.0658
Simulated mean of average	0.0587
Simulated S.D. of average	0.0085
Standardised test value H2	0.9430

The pooling group is acceptably homogeneous and a review of the pooling group is not required

Standard deviation of L-CV

Observed	0.0388
Simulated mean	0.0183
Simulated S.D.	0.0026
Standardised test value H1	7.8265

Strongly Heterogeneous

Goodness-of-fit

Number of simulations: 500

Fitting	Z value	
Gen. Logistic	4.9229	
Gen. Extreme Value	0.8474	*
Pearson Type III	0.8297	*
Gen. Pareto	-7.6477	

* Distribution gives an acceptable fit (absolute Z value less than the critical value (1.645))

Pooling Group Analysis at Ormiston Mill Gauging Station – Growth Curve (2009 revised)

Pooling-group - Lothian Estate