# Bridge of Beich Caravan Park, Lochearnhead

*Flood Risk Assessment*

*January 2013*

MNV Consulting Ltd.

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## *Flood Risk Assessment*

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## 1 Introduction

A planning application is being developed on the north shore of Loch Earn, to extend the Bridge of Beich Caravan Park, which is owned by Drummond Estates (Figure 1). The existing caravan park has 6 parking bays, and the proposal is to develop a further 5 parking bays with associated access tracks.

The development site is situated on a delta feature formed by sedimentary deposits from the outflow of the Beich Burn into Loch Earn. Potential flood risk in this area will be highly dependent on complex interactions between water levels in the loch and in the burn. MNV Consulting Ltd was commissioned by Campbell of Doune, acting on behalf of the developer, to carry out a Flood Risk Assessment (FRA) of the site in January 2013.

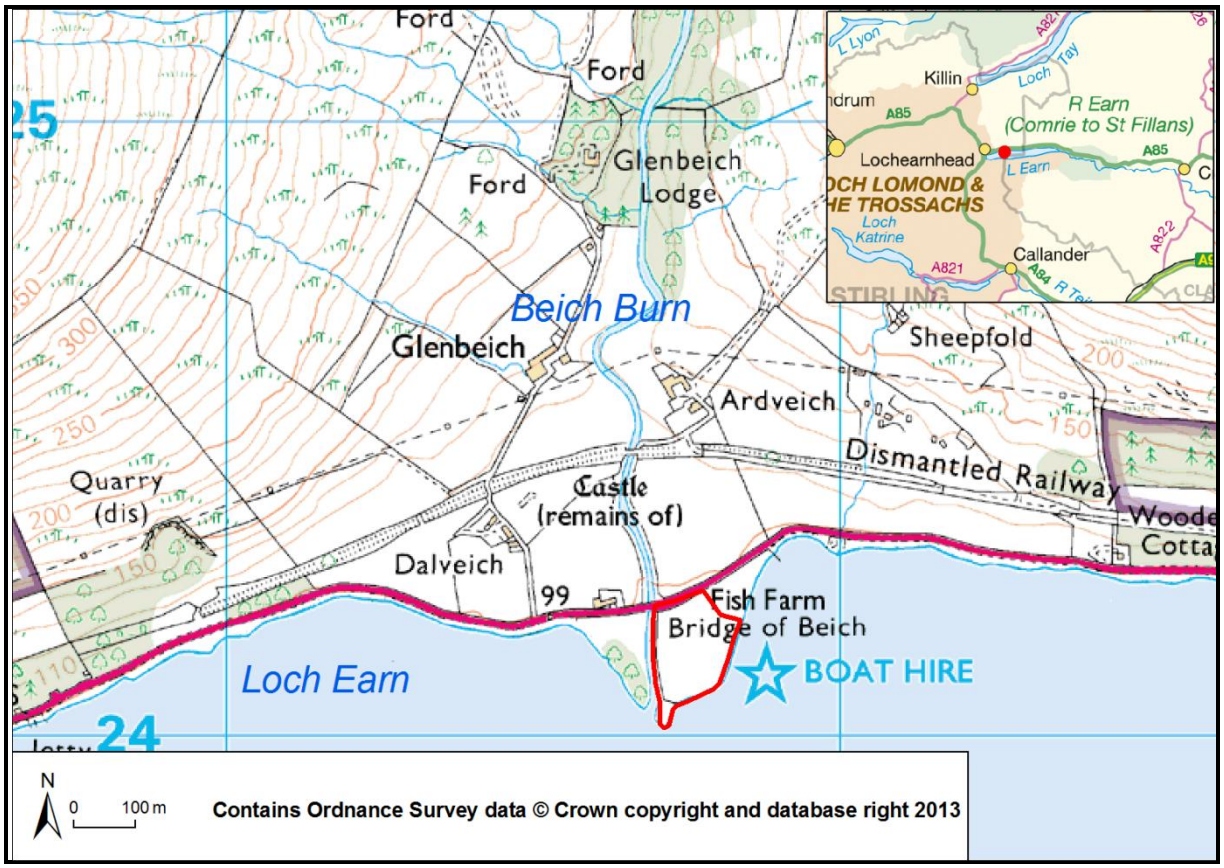



*Figure 1 Location of the development site (bounded in red)*

A site visit and topographic survey was carried out in January 2013 by MNV Consulting Ltd, with reference to the requirements of Scottish Planning Policy: Planning & Flooding (SPP)[1], and the recommendations of Planning Advice Note 69 (PAN69)[2]. The resulting FRA includes the following main components:

- Photographic survey
- Topographic survey of the development site, the Beich Burn channel, banks and floodplain, Bridge of Beich and other relevant infrastructure
- Augmentation of topographic survey with Digital Terrain Model of the wider area
- Review of existing flood risk information for the site
- Flood frequency estimation and verification for the Beich Burn, including an appropriate adjustment for climate change

[1] 2004 version, http://www.scotland.gov.uk/Publications/2004/02/18880/32952
[2] 2004 version, http://www.scotland.gov.uk/Publications/2004/08/19805/41595

- Construction of a hydraulic model to estimate the extent of the 'functional floodplain' at the study site (based on a theoretical flood with a return period of 1 in 200 years flood, including climate change)
- Sensitivity testing to determine how well the model represents the flood dynamics of the site
- Scenario testing to ascertain the potential impacts of both separate and combined flooding in the burn and in the loch, and the potential impact of a blockage in Bridge of Beich
- Presentation of inundation maps for the site, in relation to the proposed development site
- Recommendations for appropriate final floor levels, including appropriate safety margins
- Recommendations for land raising / compensatory flood storage requirements

It must be noted that this Flood Risk Assessment regards fluvial flooding only and for the site conditions as surveyed in January 2013. An independent Drainage Assessment may be required to cover flood risk posed by urban drainage systems. MNV does not assume responsibility for the accuracy of data from second parties.

## 2 Site description

The site proposed for redevelopment lies between the north shore of Loch Earn and the A85 road, around 2km east of the settlement of Lochearnhead. It is used during summer months only as a caravan park and boat hire facility. The development is situated on a delta, created over geological timescales by sedimentary deposits from the Beich Burn, at the point where it flows into Loch Earn.

The Beich Burn flows in a southerly direction, and passes under the A85 through the Bridge of Beich, at the northwest corner of the development site. The ground over the development site itself slopes gently downwards away from this corner and towards the Loch (Figure 2).

*Figure 2 Proposed development site, looking southward. Existing caravan plots can be seen in the foreground, with the banks of the Beich Burn to the right.*

The caravan park is accessed from the A85 from a point 40m east of the Bridge of Beich, and from this viewpoint, the layout of the site is illustrated in Figure 3 . The Beich Burn marks the western boundary of the site, and to the east there is a fish farm. The land to the north of the A85 is semi-improved pasture, and to the west of the Beich Burn the ground is rough and dominated by broad-leaved woodland. The banks of the burn are continuously lined by a narrow strip of mature riparian woodland.

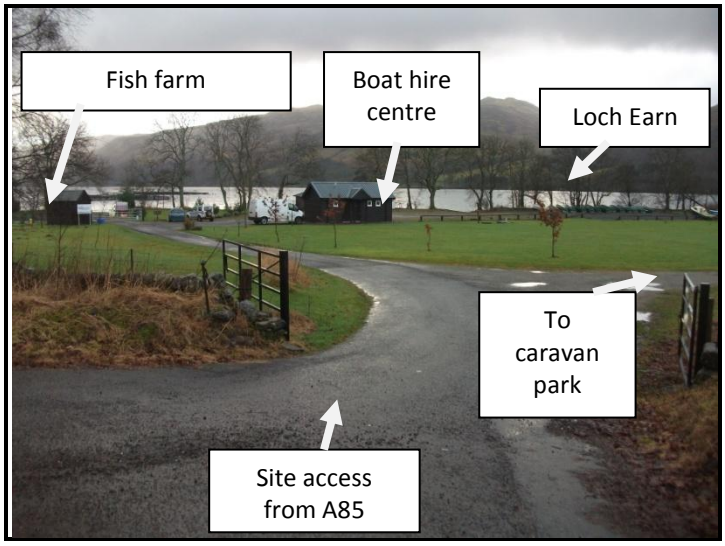



*Figure 3 View southwards from A85*

There is an informal earthen embankment just under a metre high along the eastern and southern sides of the development site, although in places the structure is degraded and it is not considered likely that it offers comprehensive protection from extreme water levels in Loch Earn.

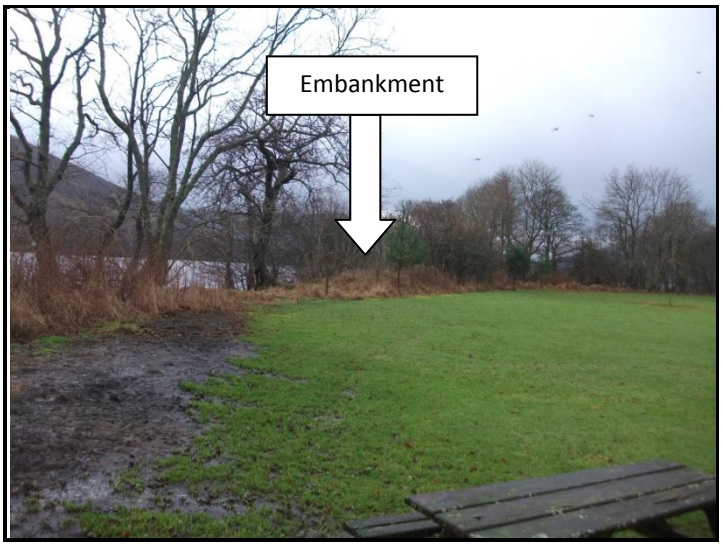



*Figure 4 Informal embankment along southern edge of site*

## 3 Watercourse characteristics

The Beich Burn rises on the slopes between Meall Daimh (690 mAOD) and Meall Odhar (628mAOD) to the northwest of Lochearnhead. Numerous steep tributaries join the burn as it flows southwards towards Loch Earn, which generally has a water level just under 100 mAOD. On the approach to Loch Earn, the slope of the burn decreases and it shows more signs of artificial modification including channel straightening, bank protection and a bridge. There is fairly continuous narrow strip of broadleaved woodland flanking the banks of the burn between elevations of 350mAOD and the loch. The upper catchment is dominated by rough grazing, and there are more signs of agricultural improvement at lower elevations, with several farm units, tracks and small coniferous plantations.

Two embankments cross the catchment, which may interrupt hydrological continuity (Figure 5). There is a disused railway embankment about 250m upstream of the Bridge of Beich, as well as the embankment of the

A85. During extreme storm events these features are likely to temporarily enhance water storage potential on their upslope sides, although this effect is not likely to be significant at the catchment scale.

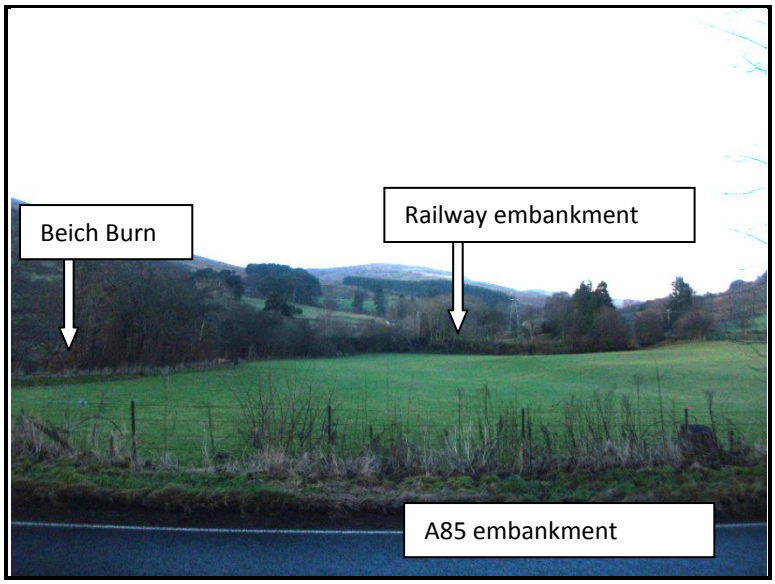



*Figure 5 View towards upper catchment from the A85, with the Beich Burn to the left of the image. Floodwater spilling out of the burn may be temporarily stored in this field, due to the A85 embankment*

Alongside the development site, the Beich Burn flows through a relatively straight, partially modified channel, with a rectangular profile (Figure 6). There are remnants of stone-built bank protection, particularly along parts of the left bank. Sediments in the channel are dominated by a mixture of cobble and boulder, with finer materials increasing towards the loch. The channel here appears to be relatively stable, with few erosional or depositional features of note. The banks are relatively well vegetated with tall grasses, shrubs and trees.

*Figure 6 Beich Burn adjacent to development site*

The Bridge of Beich crosses the burn to the northwest corner of the development site, and appears to exert little influence on the dynamics of the watercourse under normal flow conditions (Figure 7 and Figure 8). It is rectangular in profile and constructed of reinforced concrete with a stone wall parapet. The entrance to the bridge is approximately 10m wide and 2.3m deep and the length of the bridge is 8.9m. The structure appears to be in a good condition, without any significant accumulations of debris or sediments.

*Figure 7 Bridge of Beich (from downstream left bank)*

*Figure 8 Bridge of Beich (from upstream left bank)*

The channel gradient decreases towards the downstream end of the Beich Burn before it enters Loch Earn (Figure 9). This area appears to be relatively stable, with well vegetated banks and no major sedimentary or erosional features.

*Figure 9 Downstream limit of Beich Burn at Loch Earn.*

## 4 Controls on hydrology

Upstream of the development site, the Beich Burn is around 12 km in length and drains a catchment of 27.7 $km^2$. The average altitude of the catchment is 442mAOD, with a mean annual precipitation of 1724 mm. More detail on the characteristics of the catchment is provided in Table 6 in the Appendix.

The underlying geology of the catchment is dominated by a fault line which runs through the Beich Glen, representing a boundary between the Argyll and Southern Highland geological groups. Both sides of the fault are dominated by sandstones and mudstones, although the bedrock to the west is older. A narrow band of metalimestone is also found along the length of the fault line. The bedrock in the glen is overlain by superficial deposits of glacial till and peat. The geology of the catchment supports aquifers with limited groundwater potential, i.e. groundwater contribution to baseflows in the Beich Burn is expected to be fairly low (BFIHOST, an index of baseflow, is 0.344).

The catchment is steep and there are no significant floodplains, wetlands, lochs or reservoirs to provide water storage. Although the catchment is not significantly modified by artificial drainage, the natural drainage characteristics of the catchment are likely to mean that it will respond quickly to storm events, i.e. the hydrological regime will be 'flashy', with relatively high flood peaks.

Water levels within Loch Earn are controlled by operations of Scottish and Southern Energy (SSE), via a weir at the outflow in the town of St Fillans, 8.5km to the east of the development site (Figure 10).

*Figure 10 Loch Earn outflow control weir at St Fillans*

## 5 Review of existing flood risk information

SEPA's Indicative Flood Map indicates that the entire development site, as well as the access from the A85, would be flooded during 1 in 200 year +20% flood in Loch Earn. A previous flood risk assessment has been carried out for the site, by Millard Consulting, January 2009 (Doc ref 10491/21/AB/01-09/2576). Key points from this report:

- The rainfall-runoff method was used to determine a 1 in 200 year +20% flood peak of 87 $m^3sec^{-1}$ at the development site.
- The FEH statistical method was used to estimate 1 in 200 year +20% flows in Loch Earn of 140 $m^3sec^{-1}$, and this flow rate was applied to the weir equation representing the outflow weir in order to establish a loch level of 99.73 mAOD (2.96m above the weir crest).
- Hydraulic modelling concluded that the vast majority of the development site would be inundated if 1 in 200 year+20% flooding were to occur in the Beich Burn and / or in Loch Earn. The bridge was found to have insufficient capacity to contain the 1 in 200 year+20% flood event, causing water to back up and overtop the A85 embankment.
- Assuming a loch level of 98.3 mAOD (based on anecdotal evidence of loch levels during a flood in December 2006), the proposed plots were estimated to be at risk of flooding up to a depth of 0.6 m during a 1 in 200 year +20% flood in the burn, and so the final recommendation was that the development proposal was unsuitable in terms of flood risk legislation.

Since the previous FRA was carried out, a more recent loch level analysis has been carried out by the operators, Scottish and Southern Energy. In light of this new information, the current FRA was commissioned to determine the impact of this updated information on flood risk at the development site.

## 6 Flood frequency analysis

According to Scottish Planning Policy (SPP), new developments must be outwith the extent of the estimated 1 in 200 year fluvial flood extent (also known as an 0.5% Annual Exceedance Probability, or 0.5% AEP, event), including an allowance for climate change. In this case, the proposed redevelopment must not result in any residents, either permanent or temporary, being placed at flood risk, and must not increase flood risk to any other property or public access route.

The Beich Burn is ungauged, and so no long-term water level records are available to carry out direct flood frequency analysis. The FEH CD-Rom was used to generate a set of 16 catchment characteristics from the outflow into the loch ((NN) 261700 724150), including variables such as catchment size and average annual rainfall (Table 6). Using this data a range of statistical methods were applied including: WINFAP-FEH, ReFH rainfall-runoff and ISIS FEH rainfall-runoff methods. The results of the flood frequency analysis are shown in . Table 1, and gave results for a 1 in 200 year flood ranging between 68.8 and 73 $m^3sec^{-1}$.

*Table 1 Flood frequency estimations for the Beich Burn (design flood highlighted yellow)*

| Flood Frequency Analysis | Method | Revitalised Flood Hydrograph rainfall-runoff | FEH rainfall-runoff method | FEH rainfall-runoff method | FEH Statistical |
|---|---|---|---|---|---|
| | **Software** | ReFH Spreadsheet | ISIS Free | CEH FEHcal spreadsheet | WINFAP-FEH v2, Hiflows UK v 3.1.2 |
| | **Analysis comments** | Storm duration: 4.75 hours. Profile: Winter | Storm duration: 7.25 hours. Profile: 75% winter | D: 7.82. Profile: 75% winter | Pooled Analysis (Generalised Extreme Value) |
| | **Return Period** | $m^3$/sec | $m^3$/sec | $m^3$/sec | $m^3$/sec |
| **Discharge ($m^3$/sec)** | **2** | 30.1 | | 21.75 | 41.05 |
| | **5** | 38.6 | 31.9 | 30.18 | 52.82 |
| | **10** | 45.1 | 38.6 | 36.95 | 60.1 |
| | **25** | 53 | 48 | 45.7 | 68.73 |
| | **50** | 60.2 | 56 | 53.4 | 74.76 |
| | **100** | 68.6 | 63.8 | 60.7 | 80.44 |
| | **200** | 78.7 | 73 | 68.6 | **85.82** |
| | **500** | 95.3 | 87.4 | 83 | 92.51 |
| **Discharge increased by 20% for climate change (m3/sec)** | **2** | 36.12 | 0.00 | 26.10 | 49.26 |
| | **5** | 46.32 | 38.28 | 36.22 | 63.384 |
| | **10** | 54.12 | 46.32 | 44.34 | 72.12 |
| | **25** | 63.6 | 57.60 | 54.84 | 82.476 |
| | **50** | 72.24 | 67.20 | 64.08 | 89.712 |
| | **100** | 82.32 | 76.56 | 72.84 | 96.528 |
| | **200** | 94.44 | 87.60 | 82.32 | **102.984** |
| | **500** | 114.36 | 104.88 | 99.60 | 111.012 |
| **Specific Discharge ($m3/sec/km^2$)** | **2** | 1.09 | 0.00 | 0.78 | 1.48 |
| | **5** | 1.39 | 1.15 | 1.09 | 1.91 |
| | **10** | 1.63 | 1.39 | 1.33 | 2.17 |
| | **25** | 1.91 | 1.73 | 1.65 | 2.48 |
| | **50** | 2.17 | 2.02 | 1.93 | 2.70 |
| | **100** | 2.47 | 2.30 | 2.19 | 2.90 |
| | **200** | 2.84 | 2.63 | 2.47 | 3.10 |
| | **500** | 3.44 | 3.15 | 2.99 | 3.34 |

The rainfall-runoff method was considered to be the most appropriate for this location, and so a design flow of 73 $m^3sec^{-1}$ has therefore been selected to represent a 1 in 200 year flood event in the Beich Burn. This is supported by the very similar flow rate estimated in the 2009 flood risk assessment, which was generated using the same software. Climate change has been accounted for by adding a further 20% onto this value, in

line with current precautionary climate change allowances recommended by the Environment Agency[3]; this equates to a flow of 87.6 $m^3sec^{-1}$.

Three different loch levels are available for analysis (Table 2). The most recent estimate has been made by the operators of the outflow weir, and was based on analysis of observed water levels (Appendix section 10.2). This value is considered to be the most accurate to date, and so a 1 in 200 year design level of 98.9 mAOD in the loch will be applied to the following analysis.

*Table 2 Extreme loch levels (design flood level highlighted in yellow)*

| Source | Magnitude | Level (mAOD) | Note |
|---|---|---|---|
| **SSE loch level analysis, 2011** | 1 in 200 year | 98.9 | Generated using flow monitoring data from operator of outflow weir (see appendix) |
| **2009 Flood Risk Assessment** | 1 in 200 year +20% | 99.73 | Generated using weir equation |
| **Anecdotal evidence** | December 2009 flood event | 98.6 | Unknown flood return period |

# 7 Hydraulic modelling

## 7.1 Model setup

A topographic survey was carried out by MNV Consulting Ltd in January 2013, using a C-NAV 3050 (GNSS receiver capable of generating positions with sub-decimetre accuracy on the basis of signals from various satellite constellations with known orbits) together with a Leica auto level (used under tree cover).

The survey was carried out in cross-sections perpendicular to the channel, including details of the development site, Beich Burn channel, banks and floodplain, as well as other relevant features such as the bridge. A benchmark from the previous FRA survey was measured to within 6cm of agreement. A 5m resolution Digital Terrain Model (DTM) was obtained in order to add further detail of the wider floodplain surface, resulting in more detailed flood outline maps.

ArcGIS (Geographic Information System) software was used to present the topographic data and model results against the relevant background maps. Cross-section data were extracted as eastings (x), northings (y) and elevations (z). The cross-section data were then imported into HEC-RAS 4.1, a one-dimensional hydraulic modelling package from the United State Army Corps of Engineers. Cross-section detail was enhanced where appropriate using cross-section interpolation tool in HEC-RAS as well as floodplain elevations taken directly from the DTM.

The model arrangement is outlined in Figure 11. The model covers a reach of around 190m, extending from around 40m upstream of the Bridge of Beich down to the loch. Over the 11 cross-sections, the total drop in water surface elevation over the reach is 1.68m, (average gradient 0.0091 m/m). The development site is located between cross-sections 5 and 1.5.

The bridge was added using the bridge editor and the A85 embankment was represented as a bridge deck. Key cross sections used in the model are shown in section 10.4 in the appendix.

For each cross-section, lateral variation in friction due to surface roughness was represented using Manning's (n) values. These values were extracted from standard photo keys and tables, according to features such as vegetation, sinuosity and substrate size, and averaged 0.035. The model was run in steady mode, starting out with downstream boundary of the loch level on the day of the survey (96.99 mAOD).

[3] http://www.environment-agency.gov.uk/research/planning/116769.aspx

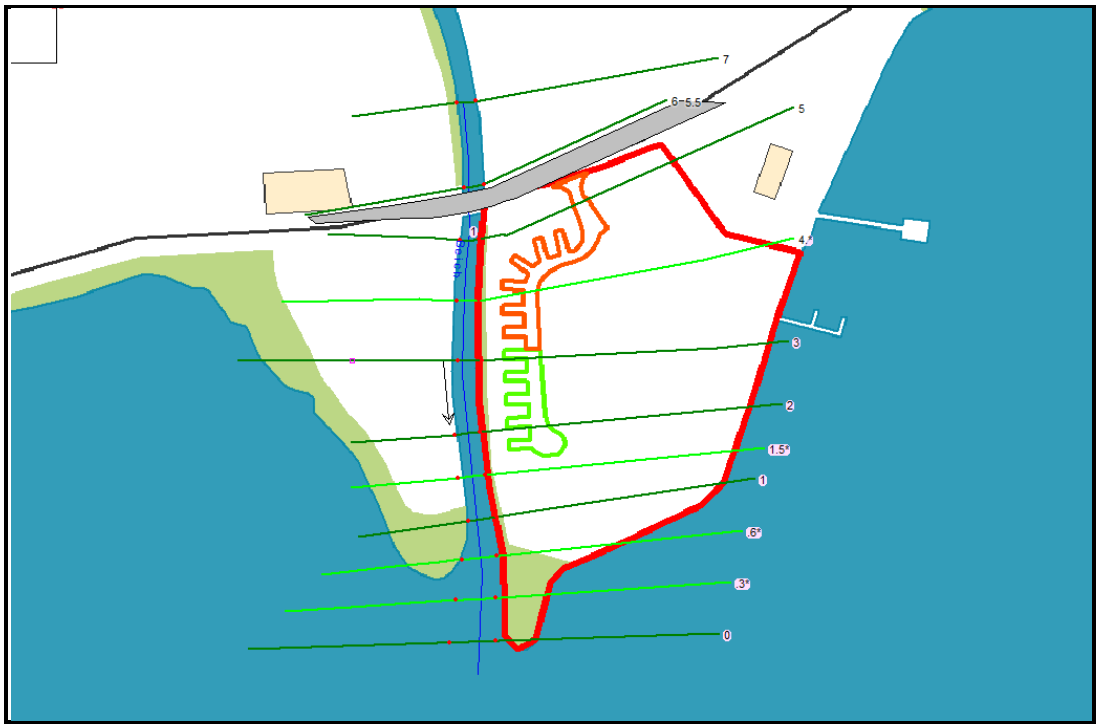



*Figure 11 Model setup in HEC-RAS (cross-sections are shown as green lines, the road deck is shown by a grey block. The existing caravan plots are outlined in orange and the proposed plots are outlined in green)*

## 7.2 Sensitivity analysis

Very little flood information was available to calibrate the model, and therefore sensitivity analysis was carried out to assess the significance of three key areas of uncertainty: flow estimate, friction and downstream boundary (loch level) conditions. The first addresses uncertainty in the statistical estimation of discharge, while the latter two influence the rate at which water drains through the model. The results of the sensitivity analyses are summarised at key cross-sections in Table 3.

*Table 3 Sensitivity analysis results at key cross-sections*

| Cross-section | 1 in 200 year water elevation (mAOD) | Water level change (m) | | |
|---|---|---|---|---|
| | | Manning's values increased 20% | 1 in 200 year discharge increased 20% | Downstream water surface increased by 0.5m |
| **5 (upstream of existing development)** | 98.94 | +0.09 | +0.04 | 0.00 |
| **3 (upstream of proposed development)** | 98.40 | +0.24 | +0.05 | 0.00 |
| **2 (downstream of development)** | 98.11 | +0.46 | +0.17 | 0.00 |

The results indicate that during a 1 in 200 year flood flow in the burn, the model is particularly sensitive to increased roughness, followed by changes in flow rates, and then moderate fluctuations in the level of Loch Earn at the downstream boundary. The model is most sensitive in the downstream cross-sections due to the shallower gradient. In the vicinity of the development site, a 20% increase in the roughness could result in an increase in the 1 in 200 year flood level of up to 0.46m. The impact of a 20% increase in flow (also representing the influence of land use or climate change) is an increase in water surface elevation of up to 0.17m. This relative sensitivity of this model is most likely due to the shallow gradient of the channel, combined with the 'roughness' of the channel and vegetated banks.

# 8 Results

## 8.1 Flood risk under current conditions

As the hydrological regime of the Beich Burn and Loch Earn are not likely to be synchronous, it is extremely difficult to determine the joint probability of flooding in the Beich Burn and in Loch Earn. A range of 3 possible scenarios are presented to illustrate the flooding dynamics at the site (Table 4). Scenario 3 is the most conservative, as it assumes coincident flooding in both waterbodies. It is recommended that scenario 3 is used to determine design flood levels, in accordance with best practice guidelines.

*Table 4 Scenarios*

| Scenario | Beich Burn flow ($m^3sec^{-1}$) | Loch level (mAOD) |
|---|---|---|
| **1** | 200 year + 20% flow | 96.99 (level on date of survey) |
| **2** | 25 year | 98.9 (200 year) |
| **3** | 200 year + 20% flow | 98.9 (200 year) |

The following presents key outputs from the model representing existing flood risk at the site. Figure 12 to Figure 15 relate the predicted flood extents to the proposed general layout of the development. It is evident that a considerable area of the existing development site is inundated during a 1 in 200 year flood event, adjusted for climate change, and that the proposed caravan plots are effectively located within the 'functional floodplain' of both the Beich Burn and Loch Earn. During the design flood (scenario 3), combined flooding in the burn and loch caused inundation of all 5 proposed plots as well as the 2 most southerly of the existing plots. Depths of water over these plots ranged from 0.13 to 0.80 m, increasing towards the loch.

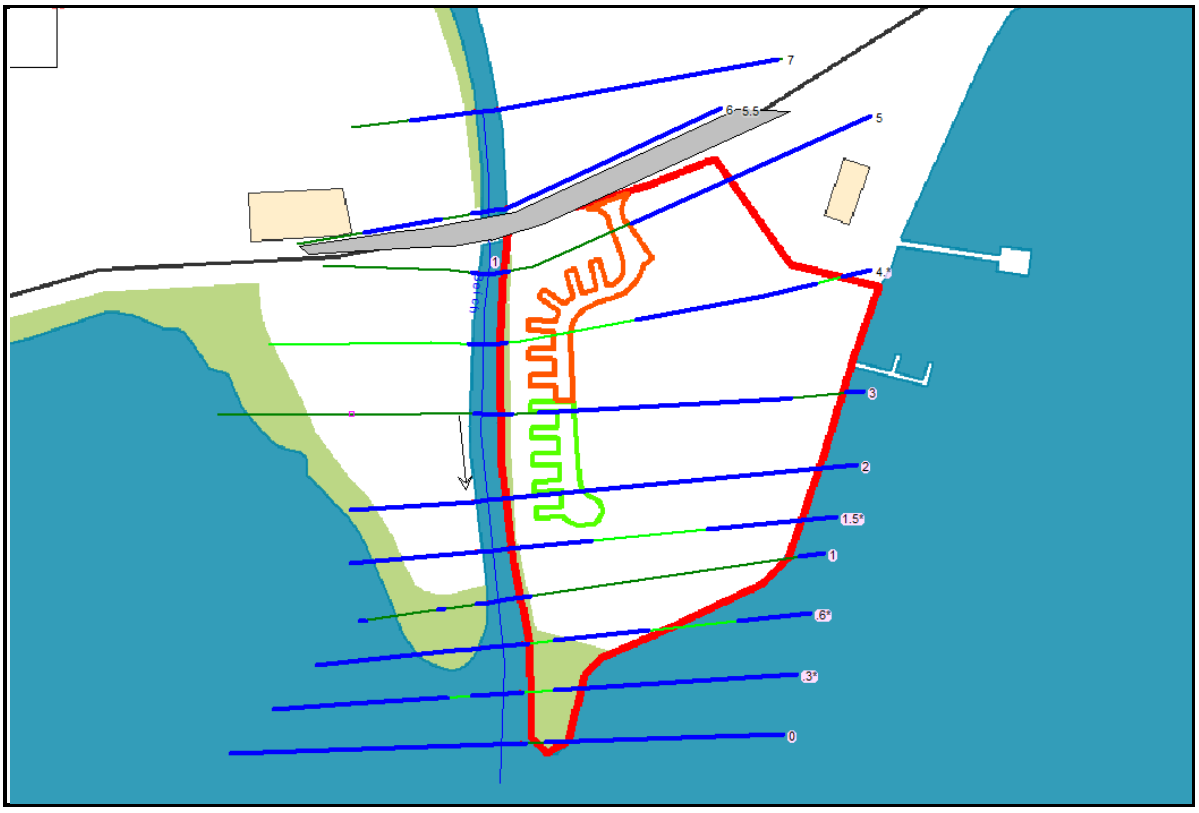



*Figure 12 Predicted flood extents during Scenario 1 (flood extents on each cross-section are represented by thick blue lines along the green cross-sections).*

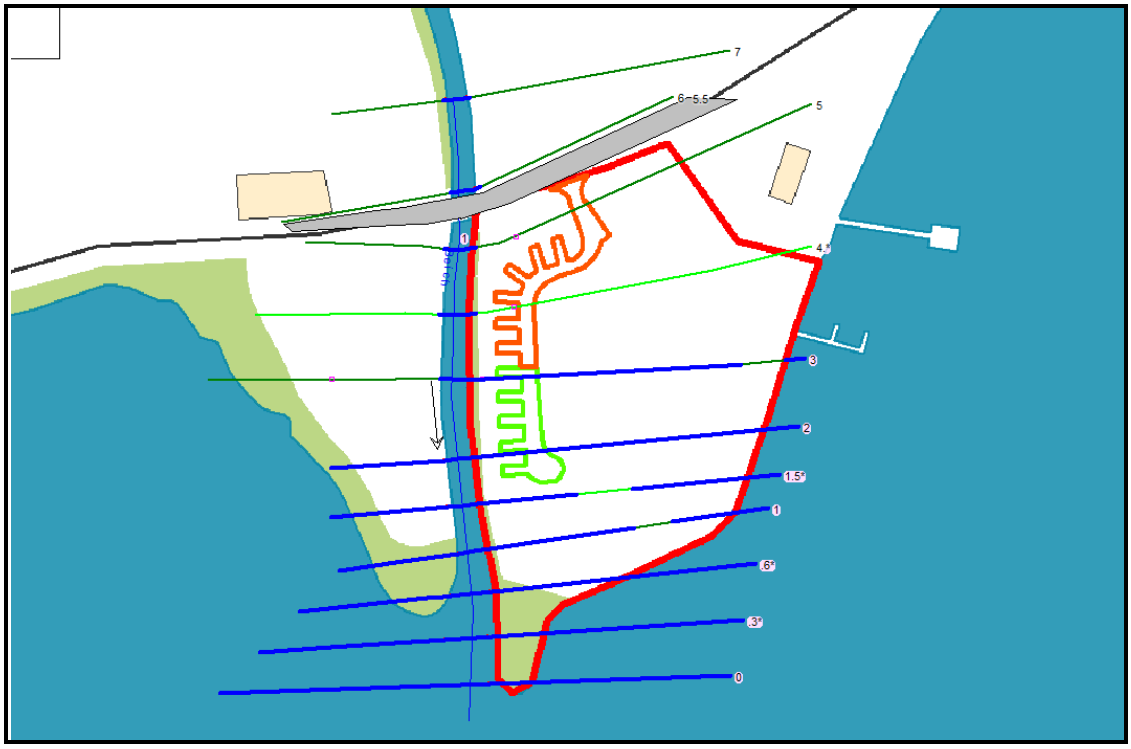



*Figure 13 Predicted flood extents during Scenario 2 (flood extents on each cross-section are represented by thick blue lines along the green cross-sections).*

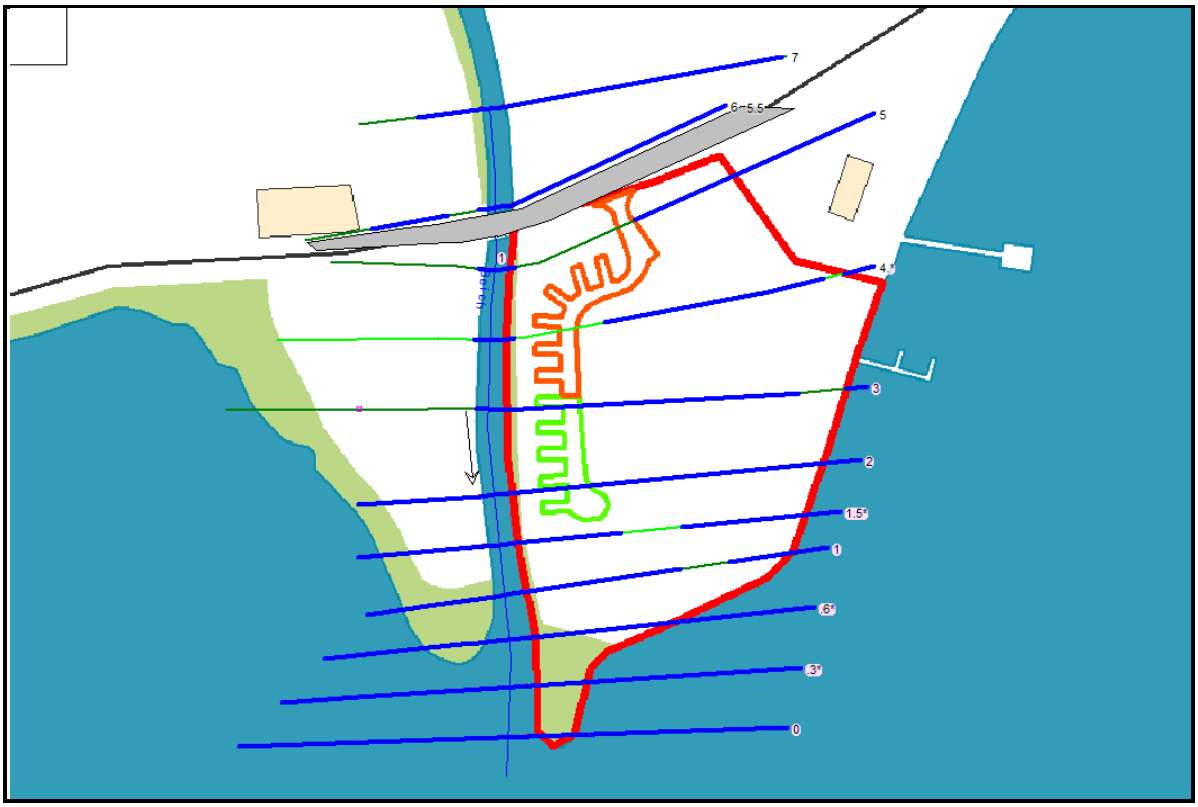



*Figure 14 Predicted flood extents during Scenario 3 (flood extents on each cross-section are represented by thick blue lines along the green cross-sections).*

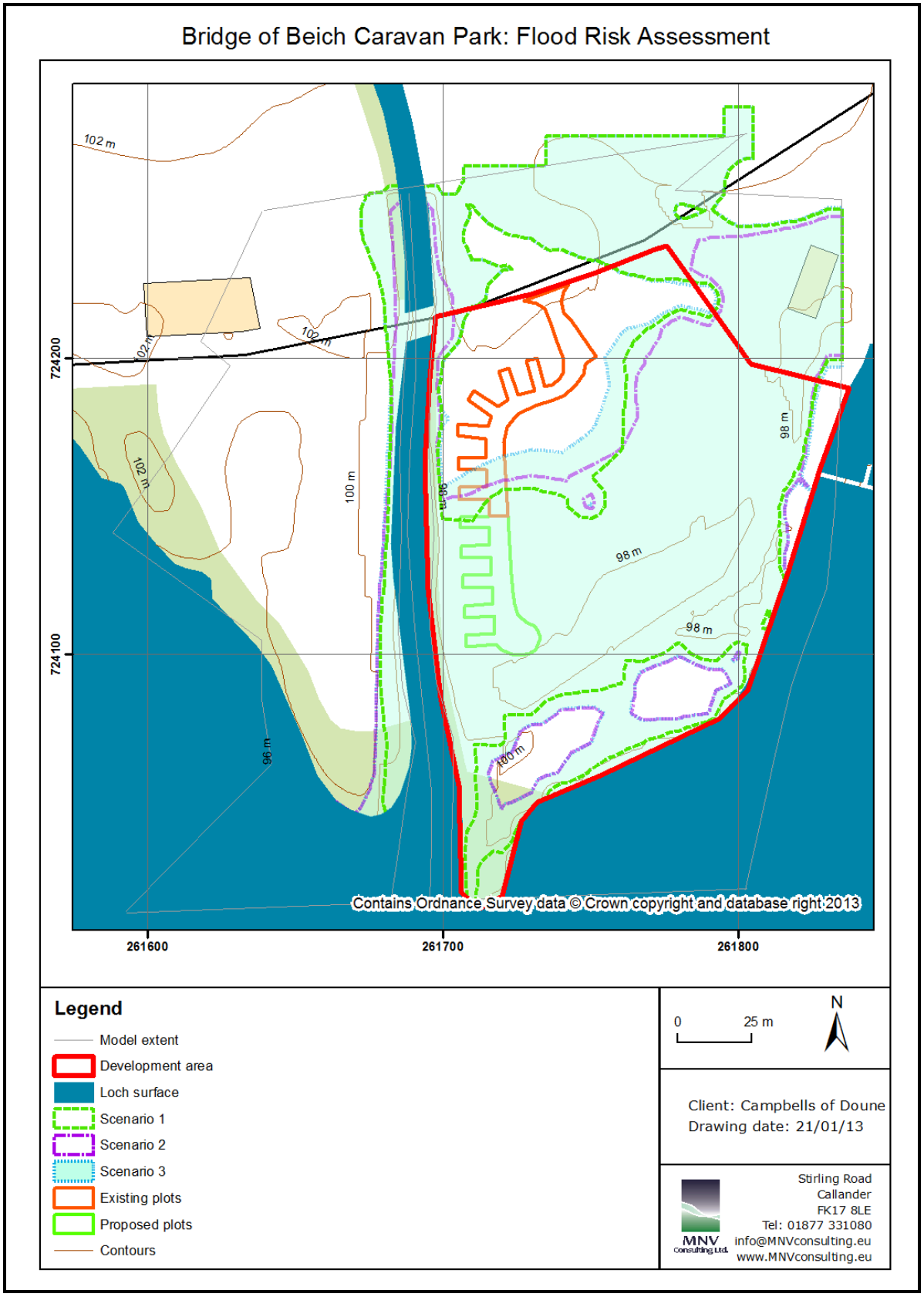



*Figure 15 Predicted flood depths over existing development site under 3 design scenarios*

Figure 16 and Figure 17 illustrate the influence of the Bridge of Beich during a 1 in 200 year flood, including an allowance for climate change. The bridge has sufficient capacity for the flow in the burn, and is far enough upstream to be insensitive to loch levels. However, it remains important to consider the effects of a blockage here, as it could cause water to back up further onto the development site.

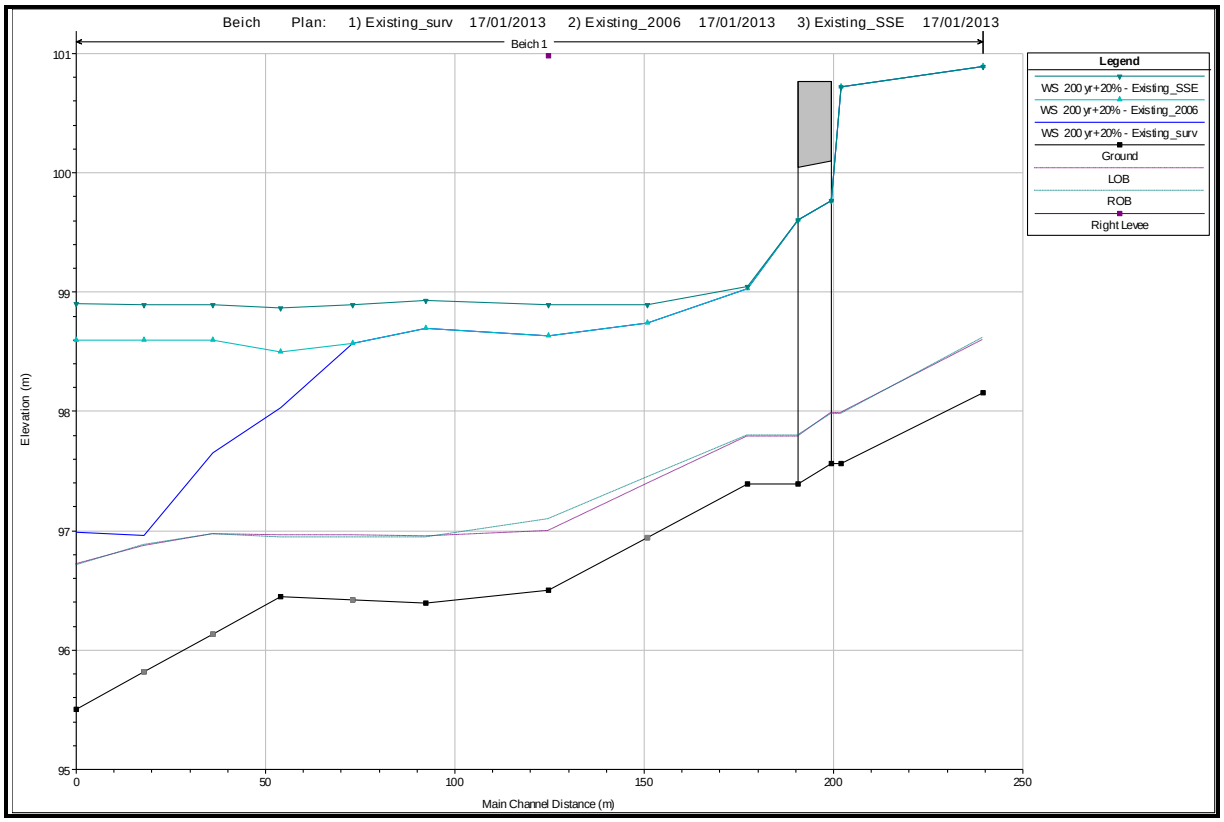



*Figure 16 Long profile of the Beich Burn during a 1 in 200 year +20% flood, assuming three different loch level scenarios listed in Table 2.*

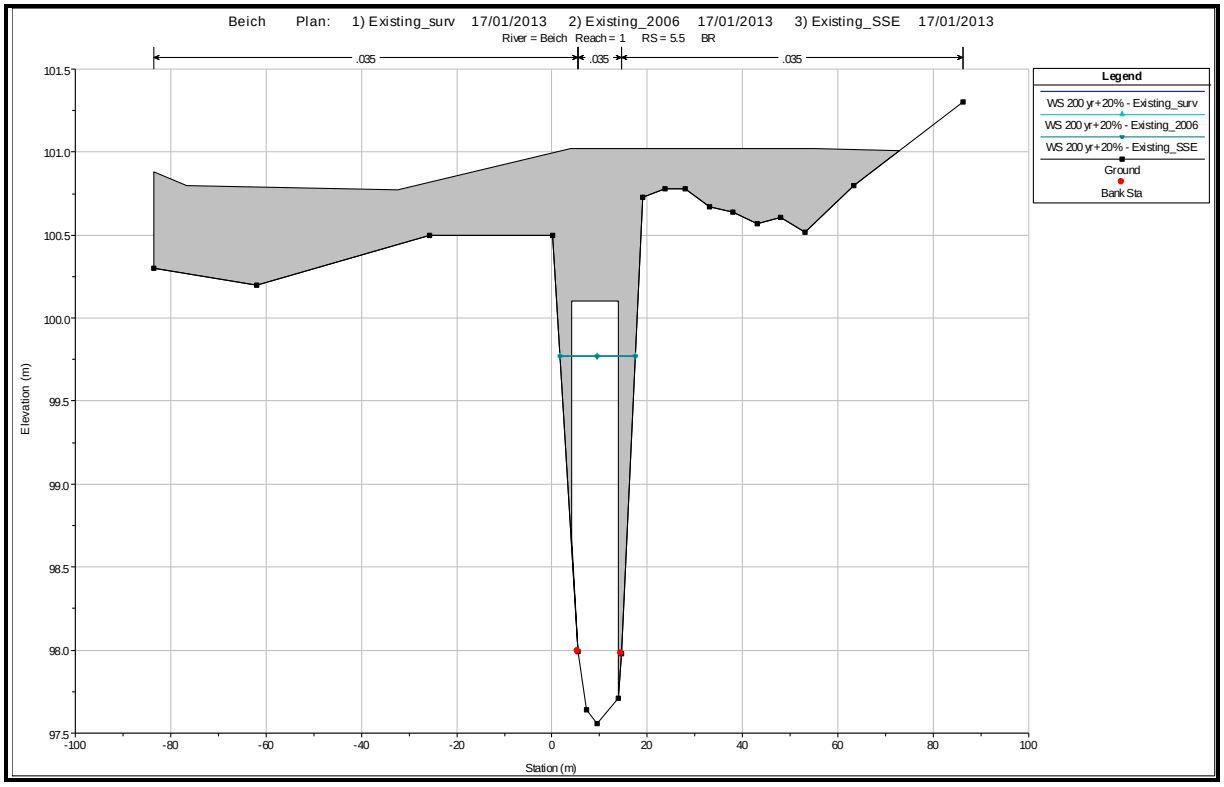



*Figure 17 Predicted water levels at the upstream face of the bridge during 1 in 200 year +20% flood; water level here is not influenced by loch level.*

## 8.2 Bridge blockage scenario

Due consideration must be given for the potential effect of a possible blockage in the bridge, caused by sediments or debris, for instance. A blockage of 50% has been assumed as standard. The key results of this modelling are shown in Figure 18, Figure 19 and Table 5, while the detailed results are provided in the appendix.

If the bridge were to block by 50% the highest flow it could accommodate would be a 1 in 10 year flood. During a 1 in 200 year flood results indicate that a 50% blockage would cause overtopping of the A85 embankment (up to depth of 35cm), but this would not exert a significant effect on flood levels over the proposed new caravan plots. Rather than flowing southwards onto the development site, the overtopping water on the road surface would be diverted along a topographic depression onto the access road and eastwards towards the fish farm and into the loch.

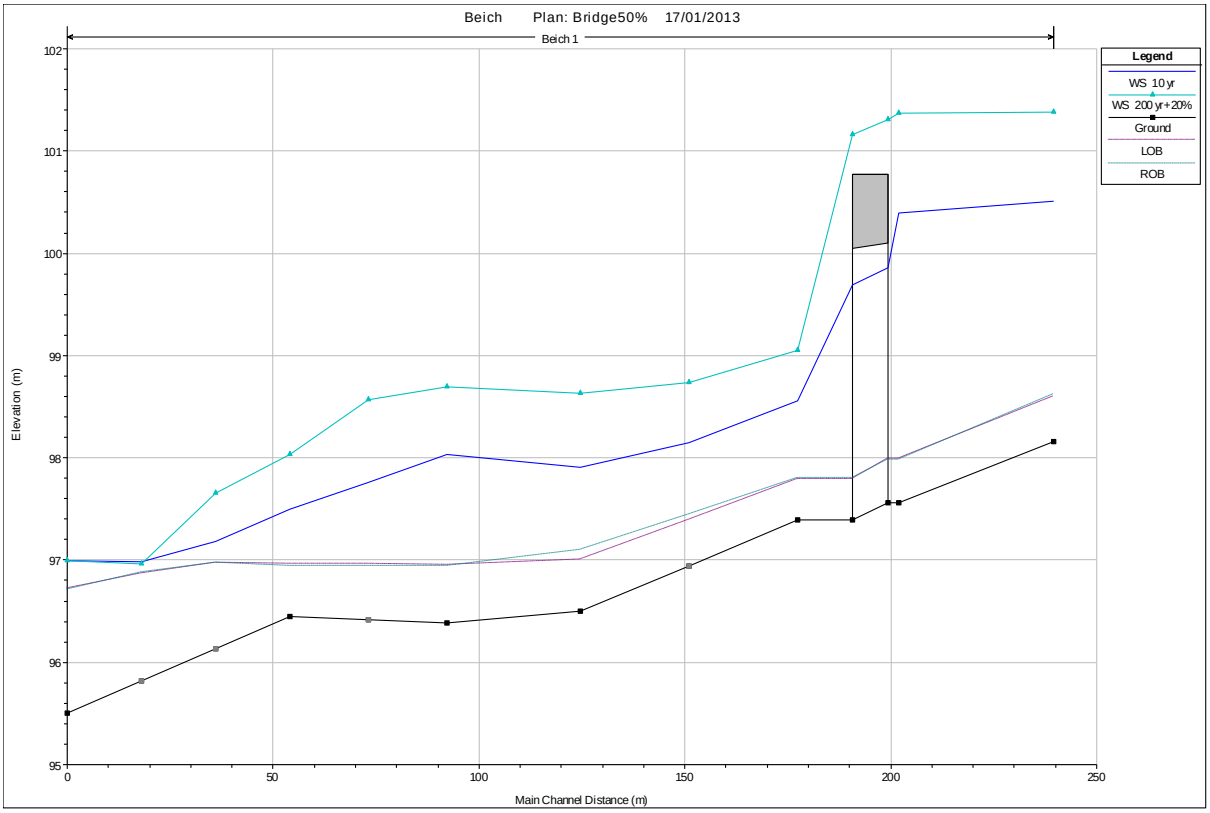



*Figure 18 Long profile of the Beich Burn under the 50% bridge blockage scenario*

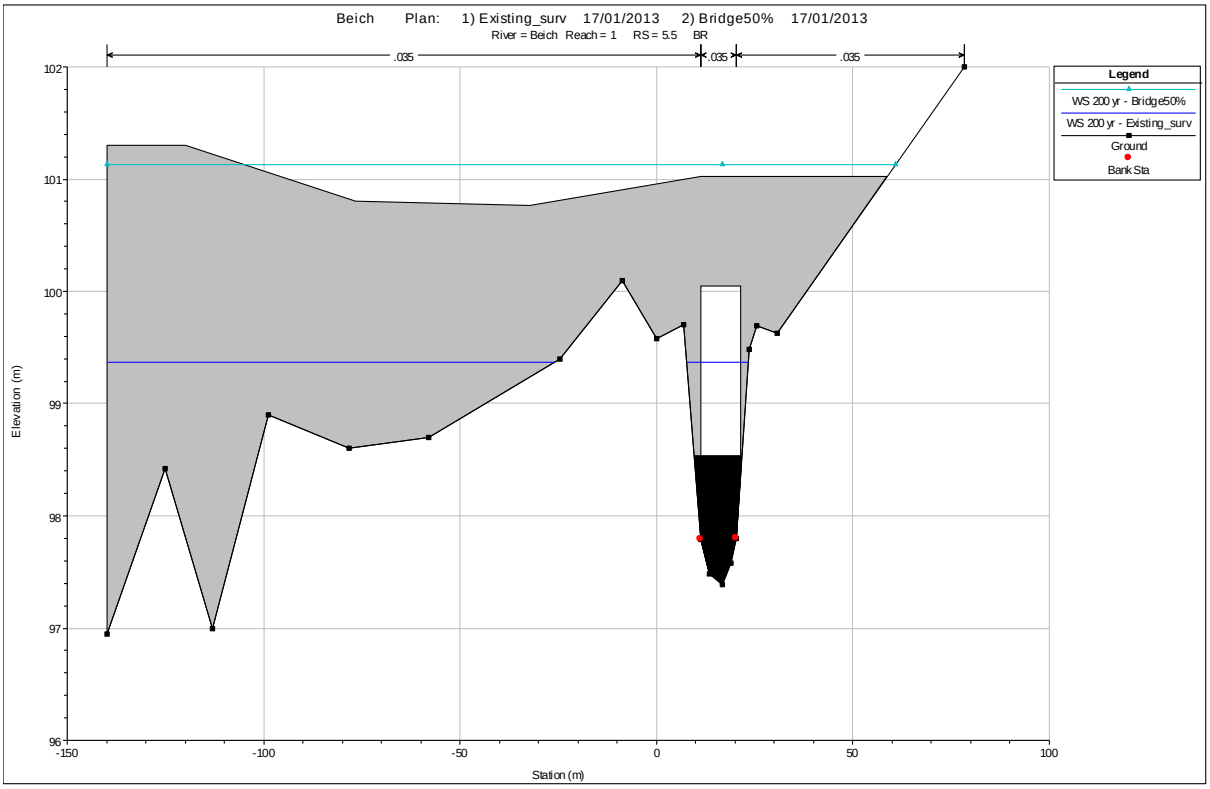



*Figure 19 Predicted water levels at the bridge during 0% and 50% bridge blocking scenarios*

*Table 5 Sensitivity to bridge blockage during 1 in 200 year +20% flood*

| Cross-section | 1 in 200 year water elevation (mAOD) | 50% depth blockage |
|---|---|---|
| **5** | 98.94 | +0.02 |
| **3** | 98.40 | 0.00 |
| **2** | 98.11 | 0.00 |

### 8.3 Discussion and recommendations

Despite the temporary use and seasonal nature of the caravan park, under Scottish Planning Policy (SPP) the same level of flood protection must be provided to this proposed development as for permanent residential developments. The development must not place people or property at risk of flooding during a 1 in 200 year flood in either the Beich Burn or in Loch Earn, including an allowance for climate change. Safe access and egress to the site must be maintained at all times to allow emergency access.

Under existing conditions, the predicted water level during a 1 in 200 year flood, including an allowance for climate change and a 1 in 200 year loch level, grades from 99.05 mAOD at the upstream end of the existing caravan plots to 98.93mAOD at the downstream end. In the event of a blockage in the bridge of up to 50%, which is considered to be realistic at this location, these levels would not be significantly affected, although safe access and egress may be compromised.

Flood walls or bunds are not recommended in this instance to protect the site from flooding, as they are not sustainable and may pose a risk of secondary flooding, whereby floodwater could become trapped within the development site. To protect the proposed caravan plots from flood risk, the plots should ideally be relocated outwith the functional floodplain. If this is not possible, the proposed development footprint and access routes would have to be raised. As the site has already been landscaped, this would be considered a 'brownfield' development, where land raising may be acceptable providing certain planning requirements are met.

It is recommended that a freeboard of 500mm should be added to over and above the design flood levels in order to comply with local development policy. Landraising within the functional floodplain has the potential to increase the flood risk to neighbouring properties. Under current planning policy, land-raising would need to be compensated for by adequate and appropriate compensatory flood storage. It is beyond the remit of the current report to design appropriate compensatory storage, but it is recommended that further analysis is carried out to inform the next phase of the design process. This is necessary to ensure that an appropriate balance is struck between land raising and compensatory storage, so that flood risk to other properties surrounding Loch Earn is either maintained or improved over the full range of potential flooding scenarios. Given the extent of land within the site boundary, it is considered likely that there will be sufficient scope for compensatory storage on site.

The modelling exercise indicates that due to the shallow gradient of the channel, the site is sensitive to increased roughness and potential debris blockages brought about by bankside vegetation. It is recommended that a robust maintenance regime is established, including regular maintenance of overhanging vegetation and removal of large woody debris. This should be done in a targeted manner to avoid adverse effects on riparian and channel habitats.

## 9 FRA Conclusions

This Flood Risk Assessment is considered to provide the most accurate flood level estimates for the development site to date. A hydraulic model of the Beich Burn was set up using up-to-date topographic and

hydrological information, and a comprehensive range of scenarios has been tested to assess flood risk at this location from both the Beich Burn and Loch Earn. A conservative approach has been taken, and uncertainties have been accounted for through sensitivity analysis, bridge blockage scenarios, and allowances for climate change.

The proposed development site lies within the functional floodplain, and is flooded by water in the burn and loch, during both individual and combined flood scenarios. To avoid flood risk to temporary residents, it is recommended that the plots are relocated outwith the functional floodplain in the first instance, or if this is not possible, the land under the plots should be raised to a safe level above the design flood levels. To accord with Scottish Planning Policy, any landraising within the flood envelope should be offset by appropriate compensatory flood storage, which should be designed on the basis of an extended analysis whereby the hydrological impact of various landscape designs can be thoroughly tested.

Routine maintenance of the bankside vegetation and woody debris in the channel is recommended to minimise the flood risk associated with bridge blockage, which may compromise safe access and egress to the site.

# 10 Appendix

## 10.1 Catchment characteristics

*Table 6 Beich Burn catchment characteristics (FEH CD-ROM)*

| Characteristic | Notation | Site |
|---|---|---|
| **Waterbody** | | Beich Burn |
| **Location** | | Bridge of Beich |
| **Grid reference** | NGR | NN,61700,24150 |
| **Catchment area ($km^2$)** | AREA | 27.72 |
| **Index of Attenuation by Lochs and Reservoirs** | FARL | 0.994 |
| **Proportion of time when soil moisture deficit was below 6mm during period 1961-90** | PROPWET | 0.65 |
| **Average altitude (mAOD)** | ALTBAR | 442 |
| **Average Aspect (degrees)** | ASPBAR | 192 |
| **Aspect variance** | ASPVAR | 0.16 |
| **Baseflow Index derived using HOST (Hydrology of Soil Types) classification** | BFIHOST | 0.344 |
| **Average Drainage Path Length (km)** | DPLBAR | 5.87 |
| **Average Drainage Path Slope (m/km)** | DPSBAR | 178.9 |
| **Longest Drainage Path (km)** | LDP | 12.44 |
| **Median annual maximum 1-hour rainfall (mm)** | RMED-1H | 10 |
| **Median annual maximum 1-day rainfall (mm)** | RMED-1D | 44.7 |
| **Median annual maximum 2-day rainfall (mm)** | RMED-2D | 62.4 |
| **Standard period (1961-1990) average annual rainfall (mm)** | SAAR | 1724 |
| **1941-70 average annual rainfall (mm)** | $SAAR_{4170}$ | 1805 |
| **Standard Percentage Runoff during storm. Derived using the HOST classification** | SPRHOST | 47.3 |
| **Index of urban concentration** | URBCONC | -999999 |
| **Index of urban extent in 1990** | URBEXT1990 | 0 |

## 10.2 Loch level analysis

SSE
Grampian House
200 Dunkeld Road
Perth
PH1 3AQ

18 November 2011

FAO Hugh Campbell
Campbell of Doune Ltd
Consulting Civil and Structural Engineers
78 King Street
Crieff
PH7 3HB

Dear Mr Hugh Campbell,

**Loch Earn Water Levels**

Thank you for your acceptance of our proposal by email dated 16 Nov 2011 by your Mark Westood. Please find below the data you requested:

1. A summary of the minimum and maximum raw water level observed at Loch Earn during the record length of our gauge.

| | |
|---|---|
| Record length: | 1965 -2010 25 y |
| Minimum raw water level: | 95.676 mAOD (2003) |
| Maximum raw water level: | 98.300 mAOD (1990) |
| Data gaps: | No maximum water level in year 2009. |

2. The estimated 200-year water level of Loch Earn by statistical means based on our recorded level data.

estimated Loch Earn 200year water level: between 98.9mAOD

Methodology:
Determine the return period of the annual maximum water level data using Gringorten plotting positions
Fit curve to the data and extrapolate
A check using the 1000-year stillwater level from internal reservoir report

Note:
The analysis follows a standard approach and for instance does not take into account the purpose for which this data was requested, data uncertainty issues or effects from waves.

Yours sincerely,

Manuela Toth
Hydrologist, Civil O&M Team

## 10.3 Table of HEC-RAS results

| River Sta | Profile | Plan | Q Total | Min Ch El | W.S. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | (m3/s) | (m) | (m) | (m/m) | (m/s) | (m2) | (m) | |
| **7** | 2 yr | Normal loch lev | 22 | 98.16 | 99.17 | 0.012 | 2.81 | 8.27 | 11.27 | 0.95 |
| **7** | 2 yr | Dec_2006_loch | 22 | 98.16 | 99.17 | 0.012 | 2.81 | 8.27 | 11.27 | 0.95 |
| **7** | 2 yr | SSE 200 yr loch | 22 | 98.16 | 99.17 | 0.012 | 2.81 | 8.27 | 11.27 | 0.95 |
| **7** | 2 yr | Millard | 22 | 98.16 | 99.70 | 0.002 | 1.63 | 14.98 | 14.02 | 0.44 |
| **7** | 2 yr | SA-Mann+20% | 22 | 98.16 | 99.17 | 0.017 | 2.81 | 8.27 | 11.27 | 0.95 |
| **7** | 2 yr | SA-loch+0.5m | 22 | 98.16 | 99.17 | 0.012 | 2.81 | 8.27 | 11.27 | 0.95 |
| **7** | 2 yr | SSE 200 + levee | 22 | 98.16 | 99.17 | 0.012 | 2.81 | 8.27 | 11.27 | 0.95 |
| **7** | 2 yr | Bridge_block50% | 22 | 98.16 | 99.92 | 0.001 | 1.34 | 21.12 | 59.35 | 0.33 |
| **7** | 10 yr | Normal loch lev | 38.6 | 98.16 | 99.54 | 0.010 | 3.28 | 12.90 | 13.23 | 0.93 |
| **7** | 10 yr | Dec_2006_loch | 38.6 | 98.16 | 99.54 | 0.010 | 3.28 | 12.90 | 13.23 | 0.93 |
| **7** | 10 yr | SSE 200 yr loch | 38.6 | 98.16 | 99.54 | 0.010 | 3.28 | 12.90 | 13.23 | 0.93 |
| **7** | 10 yr | Millard | 38.6 | 98.16 | 99.60 | 0.009 | 3.12 | 13.63 | 13.51 | 0.87 |
| **7** | 10 yr | SA-Mann+20% | 38.6 | 98.16 | 99.54 | 0.014 | 3.28 | 12.90 | 13.23 | 0.93 |
| **7** | 10 yr | SA-loch+0.5m | 38.6 | 98.16 | 99.54 | 0.010 | 3.28 | 12.90 | 13.23 | 0.93 |
| **7** | 10 yr | SSE 200 + levee | 38.6 | 98.16 | 99.54 | 0.010 | 3.28 | 12.90 | 13.23 | 0.93 |
| **7** | 10 yr | Bridge_block50% | 38.6 | 98.16 | 100.51 | 0.000 | 0.89 | 79.98 | 121.28 | 0.19 |
| **7** | 200 yr | Normal loch lev | 73 | 98.16 | 100.52 | 0.001 | 1.66 | 81.67 | 122.76 | 0.35 |
| **7** | 200 yr | Dec_2006_loch | 73 | 98.16 | 100.52 | 0.001 | 1.66 | 81.67 | 122.76 | 0.35 |
| **7** | 200 yr | SSE 200 yr loch | 73 | 98.16 | 100.52 | 0.001 | 1.66 | 81.67 | 122.76 | 0.35 |
| **7** | 200 yr | Millard | 73 | 98.16 | 100.52 | 0.001 | 1.66 | 81.67 | 122.76 | 0.35 |
| **7** | 200 yr | SA-Mann+20% | 73 | 98.16 | 100.56 | 0.002 | 1.59 | 86.03 | 126.64 | 0.34 |
| **7** | 200 yr | SA-loch+0.5m | 73 | 98.16 | 100.52 | 0.001 | 1.66 | 81.67 | 122.76 | 0.35 |
| **7** | 200 yr | SSE 200 + levee | 73 | 98.16 | 100.52 | 0.001 | 1.66 | 81.67 | 122.76 | 0.35 |
| **7** | 200 yr | Bridge_block50% | 73 | 98.16 | 101.33 | 0.000 | 0.62 | 197.56 | 164.43 | 0.11 |
| **7** | 200 yr+20% | Normal loch lev | 87.6 | 98.16 | 100.89 | 0.001 | 1.20 | 130.67 | 141.16 | 0.24 |
| **7** | 200 yr+20% | Dec_2006_loch | 87.6 | 98.16 | 100.89 | 0.001 | 1.20 | 130.67 | 141.16 | 0.24 |
| **7** | 200 yr+20% | SSE 200 yr loch | 87.6 | 98.16 | 100.89 | 0.001 | 1.20 | 130.67 | 141.16 | 0.24 |
| **7** | 200 yr+20% | Millard | 87.6 | 98.16 | 100.89 | 0.001 | 1.20 | 130.67 | 141.16 | 0.24 |
| **7** | 200 yr+20% | SA-Mann+20% | 87.6 | 98.16 | 100.91 | 0.001 | 1.17 | 132.86 | 141.83 | 0.23 |
| **7** | 200 yr+20% | SA-loch+0.5m | 87.6 | 98.16 | 100.89 | 0.001 | 1.20 | 130.67 | 141.16 | 0.24 |
| **7** | 200 yr+20% | SSE 200 + levee | 87.6 | 98.16 | 100.89 | 0.001 | 1.20 | 130.67 | 141.16 | 0.24 |
| **7** | 200 yr+20% | Bridge_block50% | 87.6 | 98.16 | 101.38 | 0.000 | 0.71 | 206.42 | 165.40 | 0.13 |
| | | | | | | | | | | |
| **6** | 2 yr | Normal loch lev | 22 | 97.56 | 98.85 | 0.004 | 1.95 | 12.03 | 12.36 | 0.58 |
| **6** | 2 yr | Dec_2006_loch | 22 | 97.56 | 98.80 | 0.005 | 2.05 | 11.40 | 12.17 | 0.62 |
| **6** | 2 yr | SSE 200 yr loch | 22 | 97.56 | 98.88 | 0.004 | 1.89 | 12.46 | 12.49 | 0.55 |
| **6** | 2 yr | Millard | 22 | 97.56 | 99.72 | 0.001 | 1.02 | 24.21 | 15.66 | 0.23 |
| **6** | 2 yr | SA-Mann+20% | 22 | 97.56 | 98.89 | 0.005 | 1.87 | 12.56 | 12.52 | 0.54 |
| **6** | 2 yr | SA-loch+0.5m | 22 | 97.56 | 98.85 | 0.004 | 1.95 | 12.03 | 12.36 | 0.58 |
| **6** | 2 yr | SSE 200 + levee | 22 | 97.56 | 98.94 | 0.003 | 1.79 | 13.18 | 12.71 | 0.51 |
| **6** | 2 yr | Bridge_block50% | 22 | 98.70 | 99.83 | 0.002 | 1.53 | 15.77 | 16.09 | 0.46 |
| **6** | 10 yr | Normal loch lev | 38.6 | 97.56 | 99.32 | 0.003 | 2.32 | 18.33 | 14.16 | 0.58 |
| **6** | 10 yr | Dec_2006_loch | 38.6 | 97.56 | 99.32 | 0.003 | 2.32 | 18.33 | 14.16 | 0.58 |
| **6** | 10 yr | SSE 200 yr loch | 38.6 | 97.56 | 99.30 | 0.004 | 2.36 | 17.99 | 14.07 | 0.59 |
| **6** | 10 yr | Millard | 38.6 | 97.56 | 99.69 | 0.002 | 1.82 | 23.86 | 15.57 | 0.41 |
| **6** | 10 yr | SA-Mann+20% | 38.6 | 97.56 | 99.37 | 0.004 | 2.24 | 19.02 | 14.35 | 0.55 |
| **6** | 10 yr | SA-loch+0.5m | 38.6 | 97.56 | 99.32 | 0.003 | 2.32 | 18.33 | 14.16 | 0.58 |

| River Sta | Profile | Plan | Q Total | Min Ch El | W.S. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|
| **6** | 10 yr | SSE 200 + levee | 38.6 | 97.56 | 99.29 | 0.004 | 2.37 | 17.91 | 14.05 | 0.59 |
| **6** | 10 yr | Bridge_block50% | 38.6 | 98.70 | 100.39 | 0.002 | 1.66 | 30.62 | 62.96 | 0.41 |
| **6** | 200 yr | Normal loch lev | 73 | 97.56 | 100.21 | 0.002 | 2.60 | 32.45 | 21.22 | 0.52 |
| **6** | 200 yr | Dec_2006_loch | 73 | 97.56 | 100.21 | 0.002 | 2.60 | 32.45 | 21.22 | 0.52 |
| **6** | 200 yr | SSE 200 yr loch | 73 | 97.56 | 100.21 | 0.002 | 2.60 | 32.45 | 21.22 | 0.52 |
| **6** | 200 yr | Millard | 73 | 97.56 | 100.21 | 0.002 | 2.60 | 32.45 | 21.22 | 0.52 |
| **6** | 200 yr | SA-Mann+20% | 73 | 97.56 | 100.22 | 0.004 | 2.59 | 32.64 | 24.12 | 0.52 |
| **6** | 200 yr | SA-loch+0.5m | 73 | 97.56 | 100.21 | 0.002 | 2.60 | 32.45 | 21.22 | 0.52 |
| **6** | 200 yr | SSE 200 + levee | 73 | 97.56 | 100.21 | 0.002 | 2.60 | 32.45 | 21.22 | 0.52 |
| **6** | 200 yr | Bridge_block50% | 73 | 98.70 | 101.32 | 0.000 | 0.84 | 156.84 | 169.80 | 0.17 |
| **6** | 200 yr+20% | Normal loch lev | 87.6 | 97.56 | 100.72 | 0.001 | 2.13 | 74.27 | 132.33 | 0.39 |
| **6** | 200 yr+20% | Dec_2006_loch | 87.6 | 97.56 | 100.72 | 0.001 | 2.13 | 74.27 | 132.33 | 0.39 |
| **6** | 200 yr+20% | SSE 200 yr loch | 87.6 | 97.56 | 100.72 | 0.001 | 2.13 | 74.27 | 132.33 | 0.39 |
| **6** | 200 yr+20% | Millard | 87.6 | 97.56 | 100.72 | 0.001 | 2.13 | 74.27 | 132.33 | 0.39 |
| **6** | 200 yr+20% | SA-Mann+20% | 87.6 | 97.56 | 100.73 | 0.002 | 2.11 | 75.28 | 132.97 | 0.38 |
| **6** | 200 yr+20% | SA-loch+0.5m | 87.6 | 97.56 | 100.72 | 0.001 | 2.13 | 74.27 | 132.33 | 0.39 |
| **6** | 200 yr+20% | SSE 200 + levee | 87.6 | 97.56 | 100.72 | 0.001 | 2.13 | 74.27 | 132.33 | 0.39 |
| **6** | 200 yr+20% | Bridge_block50% | 87.6 | 98.70 | 101.37 | 0.000 | 0.94 | 165.43 | 169.80 | 0.18 |
| | | | | | | | | | | |
| **5.5** | | | Bridge | | | | | | | |
| | | | | | | | | | | |
| **5** | 2 yr | Normal loch lev | 22 | 97.39 | 98.19 | 0.002 | 0.93 | 25.33 | 42.15 | 0.37 |
| **5** | 2 yr | Dec_2006_loch | 22 | 97.39 | 98.63 | 0.000 | 0.55 | 46.34 | 59.40 | 0.17 |
| **5** | 2 yr | SSE 200 yr loch | 22 | 97.39 | 98.91 | 0.000 | 0.48 | 70.61 | 105.59 | 0.13 |
| **5** | 2 yr | Millard | 22 | 97.39 | 99.73 | 0.000 | 0.19 | 175.13 | 158.01 | 0.04 |
| **5** | 2 yr | SA-Mann+20% | 22 | 97.39 | 98.22 | 0.002 | 0.90 | 26.48 | 42.97 | 0.35 |
| **5** | 2 yr | SA-loch+0.5m | 22 | 97.39 | 98.19 | 0.002 | 0.93 | 25.33 | 42.14 | 0.37 |
| **5** | 2 yr | SSE 200 + levee | 22 | 97.39 | 98.84 | 0.003 | 1.72 | 13.98 | 13.40 | 0.48 |
| **5** | 2 yr | Bridge_block50% | 22 | 98.54 | 98.21 | 0.003 | | 19.73 | 32.07 | 0.00 |
| **5** | 10 yr | Normal loch lev | 38.6 | 97.39 | 98.55 | 0.001 | 1.05 | 42.33 | 50.65 | 0.33 |
| **5** | 10 yr | Dec_2006_loch | 38.6 | 97.39 | 98.69 | 0.001 | 0.90 | 50.75 | 77.65 | 0.26 |
| **5** | 10 yr | SSE 200 yr loch | 38.6 | 97.39 | 98.93 | 0.001 | 0.83 | 72.48 | 106.51 | 0.22 |
| **5** | 10 yr | Millard | 38.6 | 97.39 | 99.73 | 0.000 | 0.33 | 175.25 | 158.05 | 0.07 |
| **5** | 10 yr | SA-Mann+20% | 38.6 | 97.39 | 98.57 | 0.002 | 1.02 | 43.43 | 50.90 | 0.32 |
| **5** | 10 yr | SA-loch+0.5m | 38.6 | 97.39 | 98.55 | 0.001 | 1.05 | 42.33 | 50.65 | 0.33 |
| **5** | 10 yr | SSE 200 + levee | 38.6 | 97.39 | 98.76 | 0.010 | 3.27 | 12.80 | 13.01 | 0.94 |
| **5** | 10 yr | Bridge_block50% | 38.6 | 98.54 | 98.56 | 0.002 | 0.09 | 32.49 | 50.70 | 0.23 |
| **5** | 200 yr | Normal loch lev | 73 | 97.39 | 98.94 | 0.002 | 1.53 | 74.02 | 107.25 | 0.41 |
| **5** | 200 yr | Dec_2006_loch | 73 | 97.39 | 98.95 | 0.002 | 1.52 | 74.64 | 107.55 | 0.41 |
| **5** | 200 yr | SSE 200 yr loch | 73 | 97.39 | 99.00 | 0.001 | 1.40 | 80.57 | 110.38 | 0.37 |
| **5** | 200 yr | Millard | 73 | 97.39 | 99.73 | 0.000 | 0.62 | 175.72 | 158.23 | 0.13 |
| **5** | 200 yr | SA-Mann+20% | 73 | 97.39 | 98.98 | 0.002 | 1.45 | 77.89 | 109.11 | 0.38 |
| **5** | 200 yr | SA-loch+0.5m | 73 | 97.39 | 98.94 | 0.002 | 1.53 | 74.02 | 107.25 | 0.41 |
| **5** | 200 yr | SSE 200 + levee | 73 | 97.39 | 99.33 | 0.009 | 3.92 | 21.03 | 15.54 | 0.93 |
| **5** | 200 yr | Bridge_block50% | 73 | 98.54 | 98.96 | 0.003 | 0.87 | 65.84 | 108.17 | 0.43 |
| **5** | 200 yr+20% | Normal loch lev | 87.6 | 97.39 | 99.03 | 0.002 | 1.60 | 84.36 | 112.15 | 0.42 |
| **5** | 200 yr+20% | Dec_2006_loch | 87.6 | 97.39 | 99.03 | 0.002 | 1.60 | 84.36 | 112.15 | 0.42 |
| **5** | 200 yr+20% | SSE 200 yr loch | 87.6 | 97.39 | 99.05 | 0.002 | 1.56 | 86.08 | 112.95 | 0.40 |
| **5** | 200 yr+20% | Millard | 87.6 | 97.39 | 99.74 | 0.000 | 0.74 | 176.01 | 158.34 | 0.16 |
| **5** | 200 yr+20% | SA-Mann+20% | 87.6 | 97.39 | 99.06 | 0.002 | 1.54 | 87.41 | 113.55 | 0.40 |

| River Sta | Profile | Plan | Q Total | Min Ch El | W.S. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|
| **5** | 200 yr+20% | SA-loch+0.5m | 87.6 | 97.39 | 99.03 | 0.002 | 1.60 | 84.36 | 112.15 | 0.42 |
| **5** | 200 yr+20% | SSE 200 + levee | 87.6 | 97.39 | 99.48 | 0.009 | 4.27 | 23.39 | 16.20 | 0.98 |
| **5** | 200 yr+20% | Bridge_block50% | 87.6 | 98.54 | 99.05 | 0.003 | 0.96 | 76.44 | 113.15 | 0.43 |
| | | | | | | | | | | |
| **4.*** | 2 yr | Normal loch lev | 22 | 96.94 | 97.79 | 0.014 | 2.60 | 9.36 | 16.10 | 0.99 |
| **4.*** | 2 yr | Dec_2006_loch | 22 | 96.94 | 98.60 | 0.001 | 0.92 | 37.21 | 84.05 | 0.24 |
| **4.*** | 2 yr | SSE 200 yr loch | 22 | 96.94 | 98.90 | 0.000 | 0.57 | 66.90 | 115.20 | 0.13 |
| **4.*** | 2 yr | Millard | 22 | 96.94 | 99.73 | 0.000 | 0.19 | 196.21 | 184.24 | 0.04 |
| **4.*** | 2 yr | SA-Mann+20% | 22 | 96.94 | 97.87 | 0.014 | 2.31 | 10.62 | 16.75 | 0.84 |
| **4.*** | 2 yr | SA-loch+0.5m | 22 | 96.94 | 97.79 | 0.014 | 2.59 | 9.37 | 16.11 | 0.99 |
| **4.*** | 2 yr | SSE 200 + levee | 22 | 96.94 | 98.86 | 0.001 | 1.16 | 20.68 | 15.77 | 0.28 |
| **4.*** | 2 yr | Bridge_block50% | 22 | 96.94 | 97.79 | 0.014 | 2.60 | 9.36 | 16.10 | 0.99 |
| **4.*** | 10 yr | Normal loch lev | 38.6 | 96.94 | 98.14 | 0.010 | 2.85 | 16.01 | 28.44 | 0.89 |
| **4.*** | 10 yr | Dec_2006_loch | 38.6 | 96.94 | 98.60 | 0.002 | 1.61 | 36.96 | 83.77 | 0.42 |
| **4.*** | 10 yr | SSE 200 yr loch | 38.6 | 96.94 | 98.90 | 0.001 | 1.00 | 66.86 | 115.14 | 0.24 |
| **4.*** | 10 yr | Millard | 38.6 | 96.94 | 99.73 | 0.000 | 0.33 | 196.24 | 184.24 | 0.06 |
| **4.*** | 10 yr | SA-Mann+20% | 38.6 | 96.94 | 98.21 | 0.011 | 2.63 | 17.85 | 30.29 | 0.80 |
| **4.*** | 10 yr | SA-loch+0.5m | 38.6 | 96.94 | 98.14 | 0.010 | 2.85 | 16.01 | 28.44 | 0.89 |
| **4.*** | 10 yr | SSE 200 + levee | 38.6 | 96.94 | 98.76 | 0.003 | 2.18 | 19.17 | 15.06 | 0.54 |
| **4.*** | 10 yr | Bridge_block50% | 38.6 | 96.94 | 98.14 | 0.010 | 2.85 | 16.01 | 28.44 | 0.89 |
| **4.*** | 200 yr | Normal loch lev | 73 | 96.94 | 98.72 | 0.004 | 2.48 | 48.12 | 95.19 | 0.62 |
| **4.*** | 200 yr | Dec_2006_loch | 73 | 96.94 | 98.66 | 0.005 | 2.74 | 42.60 | 89.73 | 0.70 |
| **4.*** | 200 yr | SSE 200 yr loch | 73 | 96.94 | 98.90 | 0.002 | 1.89 | 66.77 | 115.03 | 0.45 |
| **4.*** | 200 yr | Millard | 73 | 96.94 | 99.73 | 0.000 | 0.62 | 196.35 | 184.26 | 0.12 |
| **4.*** | 200 yr | SA-Mann+20% | 73 | 96.94 | 98.78 | 0.005 | 2.25 | 54.15 | 101.04 | 0.55 |
| **4.*** | 200 yr | SA-loch+0.5m | 73 | 96.94 | 98.72 | 0.004 | 2.48 | 48.12 | 95.19 | 0.62 |
| **4.*** | 200 yr | SSE 200 + levee | 73 | 96.94 | 98.87 | 0.009 | 3.84 | 20.75 | 15.80 | 0.92 |
| **4.*** | 200 yr | Bridge_block50% | 73 | 96.94 | 98.72 | 0.004 | 2.48 | 48.12 | 95.19 | 0.62 |
| **4.*** | 200 yr+20% | Normal loch lev | 87.6 | 96.94 | 98.74 | 0.005 | 2.89 | 50.06 | 97.05 | 0.72 |
| **4.*** | 200 yr+20% | Dec_2006_loch | 87.6 | 96.94 | 98.74 | 0.005 | 2.89 | 50.06 | 97.05 | 0.72 |
| **4.*** | 200 yr+20% | SSE 200 yr loch | 87.6 | 96.94 | 98.90 | 0.003 | 2.26 | 66.85 | 115.13 | 0.54 |
| **4.*** | 200 yr+20% | Millard | 87.6 | 96.94 | 99.73 | 0.000 | 0.75 | 196.42 | 184.27 | 0.15 |
| **4.*** | 200 yr+20% | SA-Mann+20% | 87.6 | 96.94 | 98.84 | 0.005 | 2.47 | 60.15 | 107.48 | 0.60 |
| **4.*** | 200 yr+20% | SA-loch+0.5m | 87.6 | 96.94 | 98.74 | 0.005 | 2.89 | 50.06 | 97.05 | 0.72 |
| **4.*** | 200 yr+20% | SSE 200 + levee | 87.6 | 96.94 | 99.08 | 0.008 | 4.04 | 24.24 | 17.52 | 0.92 |
| **4.*** | 200 yr+20% | Bridge_block50% | 87.6 | 96.94 | 98.74 | 0.005 | 2.89 | 50.06 | 97.05 | 0.72 |
| | | | | | | | | | | |
| **3** | 2 yr | Normal loch lev | 22 | 96.50 | 97.65 | 0.005 | 1.90 | 12.42 | 15.29 | 0.61 |
| **3** | 2 yr | Dec_2006_loch | 22 | 96.50 | 98.60 | 0.000 | 0.70 | 52.89 | 116.52 | 0.16 |
| **3** | 2 yr | SSE 200 yr loch | 22 | 96.50 | 98.90 | 0.000 | 0.43 | 91.87 | 135.33 | 0.09 |
| **3** | 2 yr | Millard | 22 | 96.50 | 99.73 | 0.000 | 0.16 | 227.09 | 175.38 | 0.03 |
| **3** | 2 yr | SA-Mann+20% | 22 | 96.50 | 97.72 | 0.005 | 1.76 | 13.50 | 15.71 | 0.55 |
| **3** | 2 yr | SA-loch+0.5m | 22 | 96.50 | 97.66 | 0.005 | 1.89 | 12.49 | 15.32 | 0.61 |
| **3** | 2 yr | SSE 200 + levee | 22 | 96.50 | 98.90 | 0.000 | 0.43 | 91.87 | 135.33 | 0.09 |
| **3** | 2 yr | Bridge_block50% | 22 | 96.50 | 97.65 | 0.005 | 1.90 | 12.42 | 15.29 | 0.61 |
| **3** | 10 yr | Normal loch lev | 38.6 | 96.50 | 97.91 | 0.006 | 2.56 | 16.51 | 16.84 | 0.74 |
| **3** | 10 yr | Dec_2006_loch | 38.6 | 96.50 | 98.59 | 0.001 | 1.25 | 51.85 | 115.67 | 0.29 |
| **3** | 10 yr | SSE 200 yr loch | 38.6 | 96.50 | 98.90 | 0.000 | 0.75 | 91.70 | 135.29 | 0.16 |
| **3** | 10 yr | Millard | 38.6 | 96.50 | 99.73 | 0.000 | 0.28 | 227.09 | 175.38 | 0.05 |
| **3** | 10 yr | SA-Mann+20% | 38.6 | 96.50 | 98.00 | 0.007 | 2.37 | 18.02 | 17.50 | 0.66 |

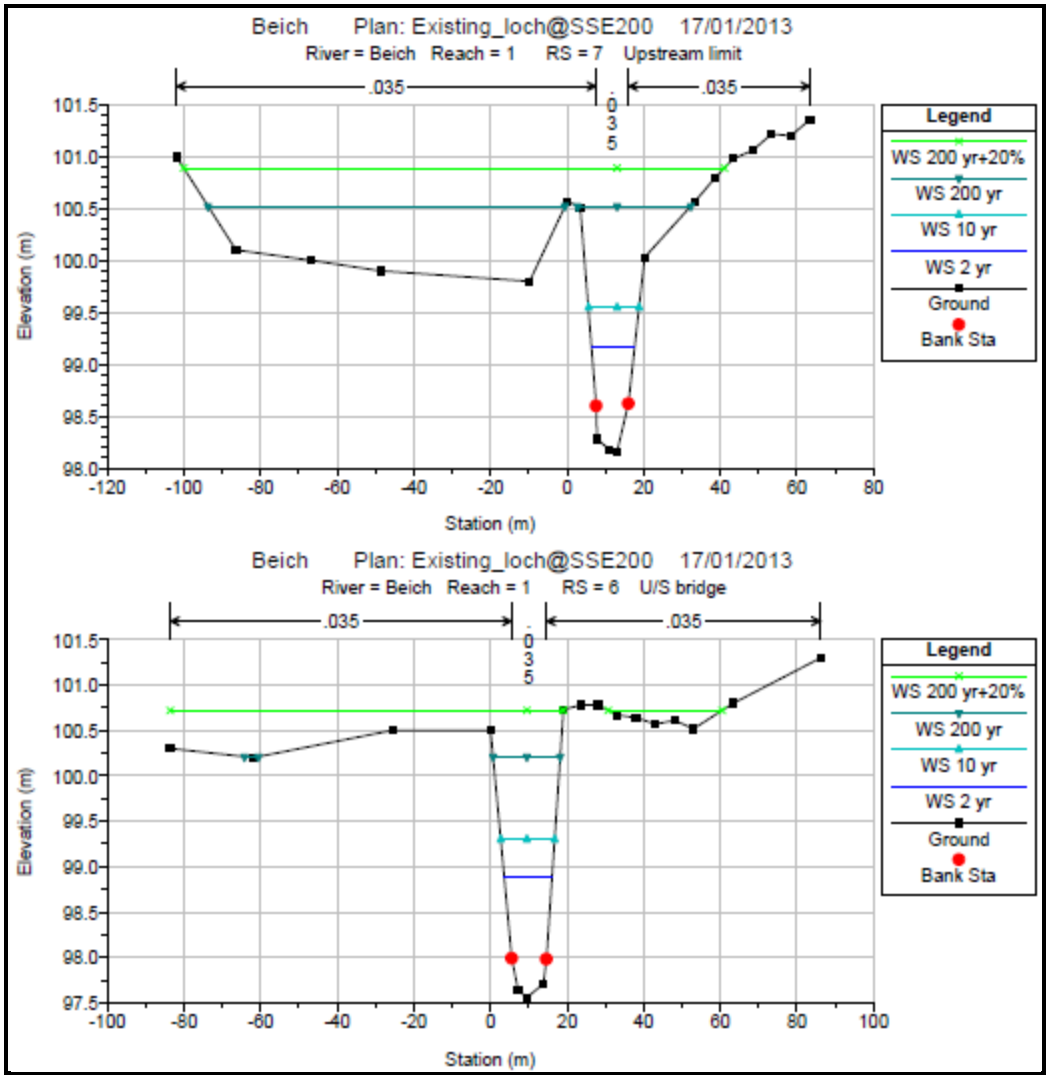
| River Sta | Profile | Plan | Q Total | Min Ch El | W.S. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|
| **3** | 10 yr | SA-loch+0.5m | 38.6 | 96.50 | 97.91 | 0.006 | 2.57 | 16.50 | 16.83 | 0.74 |
| **3** | 10 yr | SSE 200 + levee | 38.6 | 96.50 | 98.90 | 0.000 | 0.75 | 91.70 | 135.29 | 0.16 |
| **3** | 10 yr | Bridge_block50% | 38.6 | 96.50 | 97.91 | 0.006 | 2.56 | 16.51 | 16.84 | 0.74 |
| **3** | 200 yr | Normal loch lev | 73 | 96.50 | 98.40 | 0.006 | 3.00 | 34.42 | 66.38 | 0.73 |
| **3** | 200 yr | Dec_2006_loch | 73 | 96.50 | 98.50 | 0.004 | 2.67 | 41.82 | 96.95 | 0.63 |
| **3** | 200 yr | SSE 200 yr loch | 73 | 96.50 | 98.89 | 0.001 | 1.44 | 91.13 | 135.16 | 0.31 |
| **3** | 200 yr | Millard | 73 | 96.50 | 99.73 | 0.000 | 0.53 | 227.05 | 175.38 | 0.10 |
| **3** | 200 yr | SA-Mann+20% | 73 | 96.50 | 98.45 | 0.007 | 2.84 | 37.71 | 74.06 | 0.68 |
| **3** | 200 yr | SA-loch+0.5m | 73 | 96.50 | 98.40 | 0.006 | 3.00 | 34.42 | 66.38 | 0.73 |
| **3** | 200 yr | SSE 200 + levee | 73 | 96.50 | 98.89 | 0.001 | 1.44 | 91.13 | 135.16 | 0.31 |
| **3** | 200 yr | Bridge_block50% | 73 | 96.50 | 98.40 | 0.006 | 3.00 | 34.42 | 66.38 | 0.73 |
| **3** | 200 yr+20% | Normal loch lev | 87.6 | 96.50 | 98.64 | 0.004 | 2.62 | 57.59 | 120.24 | 0.60 |
| **3** | 200 yr+20% | Dec_2006_loch | 87.6 | 96.50 | 98.64 | 0.004 | 2.62 | 57.59 | 120.24 | 0.60 |
| **3** | 200 yr+20% | SSE 200 yr loch | 87.6 | 96.50 | 98.89 | 0.001 | 1.73 | 90.78 | 135.08 | 0.37 |
| **3** | 200 yr+20% | Millard | 87.6 | 96.50 | 99.73 | 0.000 | 0.63 | 227.04 | 175.37 | 0.12 |
| **3** | 200 yr+20% | SA-Mann+20% | 87.6 | 96.50 | 98.64 | 0.005 | 2.62 | 57.59 | 120.24 | 0.60 |
| **3** | 200 yr+20% | SA-loch+0.5m | 87.6 | 96.50 | 98.64 | 0.004 | 2.62 | 57.59 | 120.24 | 0.60 |
| **3** | 200 yr+20% | SSE 200 + levee | 87.6 | 96.50 | 98.89 | 0.001 | 1.73 | 90.78 | 135.08 | 0.37 |
| **3** | 200 yr+20% | Bridge_block50% | 87.6 | 96.50 | 98.64 | 0.004 | 2.62 | 57.59 | 120.24 | 0.60 |
| | | | | | | | | | | |
| **2** | 2 yr | Normal loch lev | 22 | 96.39 | 97.64 | 0.002 | 1.29 | 24.84 | 57.72 | 0.39 |
| **2** | 2 yr | Dec_2006_loch | 22 | 96.39 | 98.60 | 0.000 | 0.31 | 133.38 | 191.40 | 0.07 |
| **2** | 2 yr | SSE 200 yr loch | 22 | 96.39 | 98.90 | 0.000 | 0.20 | 190.27 | 191.40 | 0.04 |
| **2** | 2 yr | Millard | 22 | 96.39 | 99.73 | 0.000 | 0.09 | 348.85 | 191.40 | 0.02 |
| **2** | 2 yr | SA-Mann+20% | 22 | 96.39 | 97.69 | 0.002 | 1.18 | 27.78 | 61.73 | 0.35 |
| **2** | 2 yr | SA-loch+0.5m | 22 | 96.39 | 97.65 | 0.002 | 1.27 | 25.29 | 58.35 | 0.39 |
| **2** | 2 yr | SSE 200 + levee | 22 | 96.39 | 98.90 | 0.000 | 0.20 | 190.27 | 191.40 | 0.04 |
| **2** | 2 yr | Bridge_block50% | 22 | 96.39 | 97.64 | 0.002 | 1.29 | 24.84 | 57.72 | 0.39 |
| **2** | 10 yr | Normal loch lev | 38.6 | 96.39 | 98.04 | 0.001 | 1.15 | 53.87 | 88.54 | 0.30 |
| **2** | 10 yr | Dec_2006_loch | 38.6 | 96.39 | 98.61 | 0.000 | 0.53 | 135.21 | 191.40 | 0.12 |
| **2** | 10 yr | SSE 200 yr loch | 38.6 | 96.39 | 98.90 | 0.000 | 0.34 | 190.91 | 191.40 | 0.07 |
| **2** | 10 yr | Millard | 38.6 | 96.39 | 99.73 | 0.000 | 0.16 | 348.90 | 191.40 | 0.03 |
| **2** | 10 yr | SA-Mann+20% | 38.6 | 96.39 | 98.08 | 0.001 | 1.07 | 58.15 | 91.83 | 0.27 |
| **2** | 10 yr | SA-loch+0.5m | 38.6 | 96.39 | 98.04 | 0.001 | 1.15 | 53.79 | 88.48 | 0.30 |
| **2** | 10 yr | SSE 200 + levee | 38.6 | 96.39 | 98.90 | 0.000 | 0.34 | 190.91 | 191.40 | 0.07 |
| **2** | 10 yr | Bridge_block50% | 38.6 | 96.39 | 98.04 | 0.001 | 1.15 | 53.87 | 88.54 | 0.30 |
| **2** | 200 yr | Normal loch lev | 73 | 96.39 | 98.61 | 0.001 | 1.01 | 134.20 | 191.40 | 0.22 |
| **2** | 200 yr | Dec_2006_loch | 73 | 96.39 | 98.66 | 0.000 | 0.92 | 144.07 | 191.40 | 0.20 |
| **2** | 200 yr | SSE 200 yr loch | 73 | 96.39 | 98.92 | 0.000 | 0.64 | 193.58 | 191.40 | 0.13 |
| **2** | 200 yr | Millard | 73 | 96.39 | 99.73 | 0.000 | 0.30 | 349.10 | 191.40 | 0.05 |
| **2** | 200 yr | SA-Mann+20% | 73 | 96.39 | 98.61 | 0.001 | 1.01 | 134.41 | 191.40 | 0.22 |
| **2** | 200 yr | SA-loch+0.5m | 73 | 96.39 | 98.61 | 0.001 | 1.01 | 134.20 | 191.40 | 0.22 |
| **2** | 200 yr | SSE 200 + levee | 73 | 96.39 | 98.92 | 0.000 | 0.64 | 193.58 | 191.40 | 0.13 |
| **2** | 200 yr | Bridge_block50% | 73 | 96.39 | 98.61 | 0.001 | 1.01 | 134.20 | 191.40 | 0.22 |
| **2** | 200 yr+20% | Normal loch lev | 87.6 | 96.39 | 98.70 | 0.001 | 1.04 | 151.37 | 191.40 | 0.23 |
| **2** | 200 yr+20% | Dec_2006_loch | 87.6 | 96.39 | 98.70 | 0.001 | 1.04 | 151.50 | 191.40 | 0.23 |
| **2** | 200 yr+20% | SSE 200 yr loch | 87.6 | 96.39 | 98.93 | 0.000 | 0.75 | 195.33 | 191.40 | 0.16 |
| **2** | 200 yr+20% | Millard | 87.6 | 96.39 | 99.73 | 0.000 | 0.36 | 349.23 | 191.40 | 0.06 |
| **2** | 200 yr+20% | SA-Mann+20% | 87.6 | 96.39 | 98.72 | 0.001 | 1.00 | 156.46 | 191.40 | 0.22 |
| **2** | 200 yr+20% | SA-loch+0.5m | 87.6 | 96.39 | 98.70 | 0.001 | 1.04 | 151.37 | 191.40 | 0.23 |

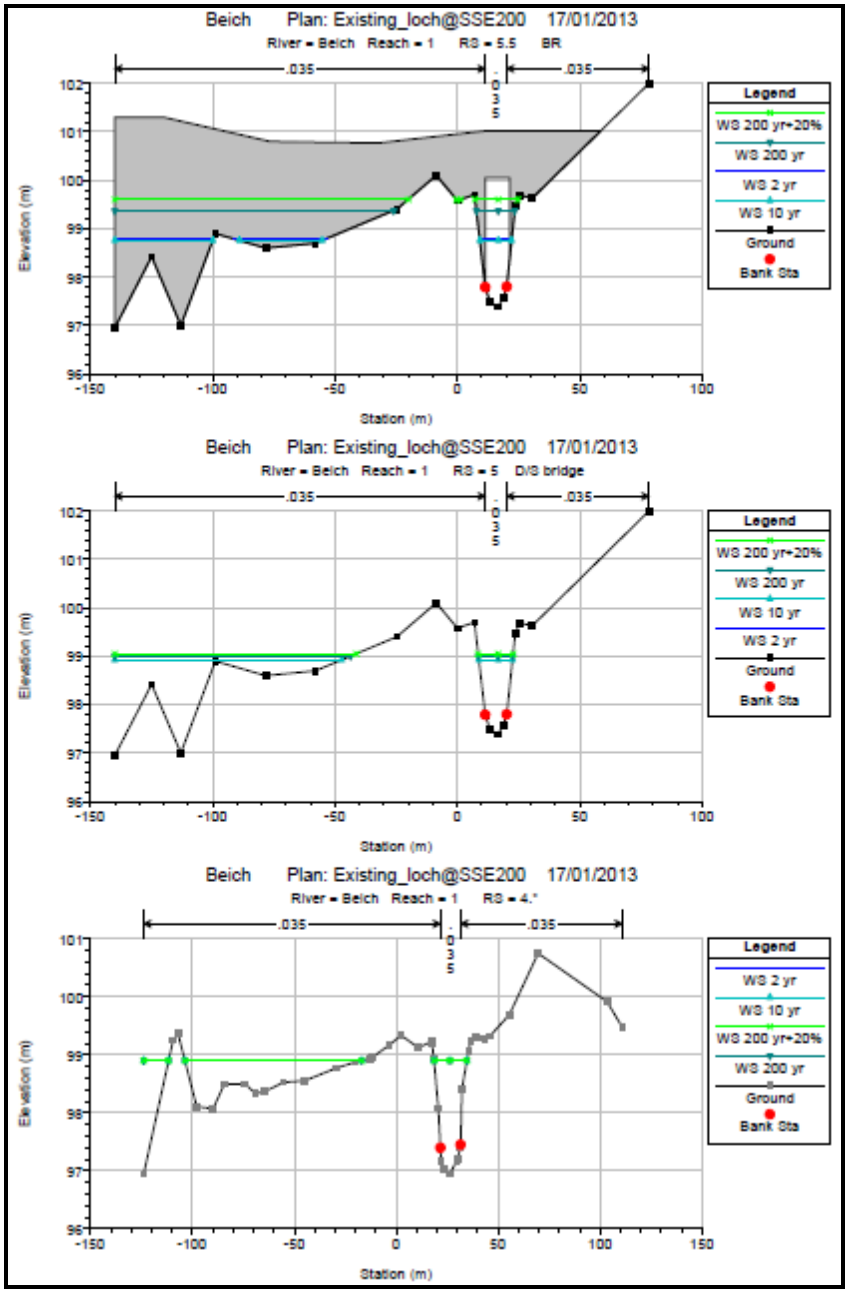
| River Sta | Profile | Plan | Q Total | Min Ch El | W.S. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|
| **2** | 200 yr+20% | SSE 200 + levee | 87.6 | 96.39 | 98.93 | 0.000 | 0.75 | 195.33 | 191.40 | 0.16 |
| **2** | 200 yr+20% | Bridge_block50% | 87.6 | 96.39 | 98.70 | 0.001 | 1.04 | 151.37 | 191.40 | 0.23 |
| | | | | | | | | | | |
| **1.5*** | 2 yr | Normal loch lev | 22 | 96.42 | 97.48 | 0.004 | 1.83 | 13.13 | 18.66 | 0.60 |
| **1.5*** | 2 yr | Dec_2006_loch | 22 | 96.42 | 98.60 | 0.000 | 0.48 | 83.29 | 142.17 | 0.11 |
| **1.5*** | 2 yr | SSE 200 yr loch | 22 | 96.42 | 98.90 | 0.000 | 0.31 | 128.98 | 161.52 | 0.06 |
| **1.5*** | 2 yr | Millard | 22 | 96.42 | 99.73 | 0.000 | 0.13 | 277.95 | 184.30 | 0.02 |
| **1.5*** | 2 yr | SA-Mann+20% | 22 | 96.42 | 97.53 | 0.005 | 1.73 | 14.05 | 19.27 | 0.55 |
| **1.5*** | 2 yr | SA-loch+0.5m | 22 | 96.42 | 97.50 | 0.004 | 1.80 | 13.39 | 18.83 | 0.58 |
| **1.5*** | 2 yr | SSE 200 + levee | 22 | 96.42 | 98.90 | 0.000 | 0.31 | 128.98 | 161.52 | 0.06 |
| **1.5*** | 2 yr | Bridge_block50% | 22 | 96.42 | 97.48 | 0.004 | 1.83 | 13.13 | 18.66 | 0.60 |
| **1.5*** | 10 yr | Normal loch lev | 38.6 | 96.42 | 97.76 | 0.005 | 2.35 | 18.92 | 22.25 | 0.67 |
| **1.5*** | 10 yr | Dec_2006_loch | 38.6 | 96.42 | 98.59 | 0.000 | 0.86 | 82.57 | 141.88 | 0.19 |
| **1.5*** | 10 yr | SSE 200 yr loch | 38.6 | 96.42 | 98.90 | 0.000 | 0.54 | 128.79 | 161.43 | 0.11 |
| **1.5*** | 10 yr | Millard | 38.6 | 96.42 | 99.73 | 0.000 | 0.22 | 277.91 | 184.30 | 0.04 |
| **1.5*** | 10 yr | SA-Mann+20% | 38.6 | 96.42 | 97.84 | 0.006 | 2.19 | 20.61 | 23.73 | 0.61 |
| **1.5*** | 10 yr | SA-loch+0.5m | 38.6 | 96.42 | 97.76 | 0.005 | 2.35 | 18.86 | 22.22 | 0.67 |
| **1.5*** | 10 yr | SSE 200 + levee | 38.6 | 96.42 | 98.90 | 0.000 | 0.54 | 128.79 | 161.43 | 0.11 |
| **1.5*** | 10 yr | Bridge_block50% | 38.6 | 96.42 | 97.76 | 0.005 | 2.35 | 18.92 | 22.25 | 0.67 |
| **1.5*** | 200 yr | Normal loch lev | 73 | 96.42 | 98.11 | 0.007 | 3.24 | 29.23 | 41.37 | 0.82 |
| **1.5*** | 200 yr | Dec_2006_loch | 73 | 96.42 | 98.57 | 0.001 | 1.67 | 80.00 | 140.81 | 0.37 |
| **1.5*** | 200 yr | SSE 200 yr loch | 73 | 96.42 | 98.89 | 0.000 | 1.03 | 128.15 | 161.16 | 0.21 |
| **1.5*** | 200 yr | Millard | 73 | 96.42 | 99.73 | 0.000 | 0.42 | 277.75 | 184.30 | 0.07 |
| **1.5*** | 200 yr | SA-Mann+20% | 73 | 96.42 | 98.28 | 0.006 | 2.71 | 42.02 | 104.76 | 0.65 |
| **1.5*** | 200 yr | SA-loch+0.5m | 73 | 96.42 | 98.11 | 0.007 | 3.24 | 29.23 | 41.37 | 0.82 |
| **1.5*** | 200 yr | SSE 200 + levee | 73 | 96.42 | 98.89 | 0.000 | 1.03 | 128.15 | 161.16 | 0.21 |
| **1.5*** | 200 yr | Bridge_block50% | 73 | 96.42 | 98.11 | 0.007 | 3.24 | 29.23 | 41.37 | 0.82 |
| **1.5*** | 200 yr+20% | Normal loch lev | 87.6 | 96.42 | 98.57 | 0.002 | 2.02 | 79.40 | 140.57 | 0.45 |
| **1.5*** | 200 yr+20% | Dec_2006_loch | 87.6 | 96.42 | 98.57 | 0.002 | 2.01 | 79.64 | 140.67 | 0.45 |
| **1.5*** | 200 yr+20% | SSE 200 yr loch | 87.6 | 96.42 | 98.89 | 0.001 | 1.24 | 127.80 | 161.01 | 0.26 |
| **1.5*** | 200 yr+20% | Millard | 87.6 | 96.42 | 99.73 | 0.000 | 0.50 | 277.66 | 184.30 | 0.09 |
| **1.5*** | 200 yr+20% | SA-Mann+20% | 87.6 | 96.42 | 98.61 | 0.002 | 1.88 | 85.40 | 143.03 | 0.41 |
| **1.5*** | 200 yr+20% | SA-loch+0.5m | 87.6 | 96.42 | 98.57 | 0.002 | 2.02 | 79.40 | 140.57 | 0.45 |
| **1.5*** | 200 yr+20% | SSE 200 + levee | 87.6 | 96.42 | 98.89 | 0.001 | 1.24 | 127.80 | 161.01 | 0.26 |
| **1.5*** | 200 yr+20% | Bridge_block50% | 87.6 | 96.42 | 98.57 | 0.002 | 2.02 | 79.40 | 140.57 | 0.45 |
| | | | | | | | | | | |
| **1** | 2 yr | Normal loch lev | 22 | 96.45 | 97.19 | 0.012 | 2.46 | 9.32 | 17.14 | 0.94 |
| **1** | 2 yr | Dec_2006_loch | 22 | 96.45 | 98.60 | 0.000 | 0.47 | 80.12 | 125.87 | 0.10 |
| **1** | 2 yr | SSE 200 yr loch | 22 | 96.45 | 98.90 | 0.000 | 0.32 | 123.65 | 161.63 | 0.07 |
| **1** | 2 yr | Millard | 22 | 96.45 | 99.73 | 0.000 | 0.13 | 269.96 | 177.20 | 0.02 |
| **1** | 2 yr | SA-Mann+20% | 22 | 96.45 | 97.22 | 0.016 | 2.36 | 9.81 | 17.67 | 0.88 |
| **1** | 2 yr | SA-loch+0.5m | 22 | 96.45 | 97.41 | 0.005 | 1.79 | 13.54 | 21.23 | 0.60 |
| **1** | 2 yr | SSE 200 + levee | 22 | 96.45 | 98.90 | 0.000 | 0.32 | 123.65 | 161.63 | 0.07 |
| **1** | 2 yr | Bridge_block50% | 22 | 96.45 | 97.19 | 0.012 | 2.46 | 9.32 | 17.14 | 0.94 |
| **1** | 10 yr | Normal loch lev | 38.6 | 96.45 | 97.50 | 0.010 | 2.81 | 15.47 | 22.85 | 0.89 |
| **1** | 10 yr | Dec_2006_loch | 38.6 | 96.45 | 98.59 | 0.000 | 0.84 | 78.88 | 124.69 | 0.19 |
| **1** | 10 yr | SSE 200 yr loch | 38.6 | 96.45 | 98.89 | 0.000 | 0.56 | 123.06 | 161.19 | 0.12 |
| **1** | 10 yr | Millard | 38.6 | 96.45 | 99.73 | 0.000 | 0.23 | 269.88 | 177.20 | 0.04 |
| **1** | 10 yr | SA-Mann+20% | 38.6 | 96.45 | 97.50 | 0.014 | 2.81 | 15.47 | 22.85 | 0.89 |
| **1** | 10 yr | SA-loch+0.5m | 38.6 | 96.45 | 97.50 | 0.010 | 2.81 | 15.46 | 22.84 | 0.89 |

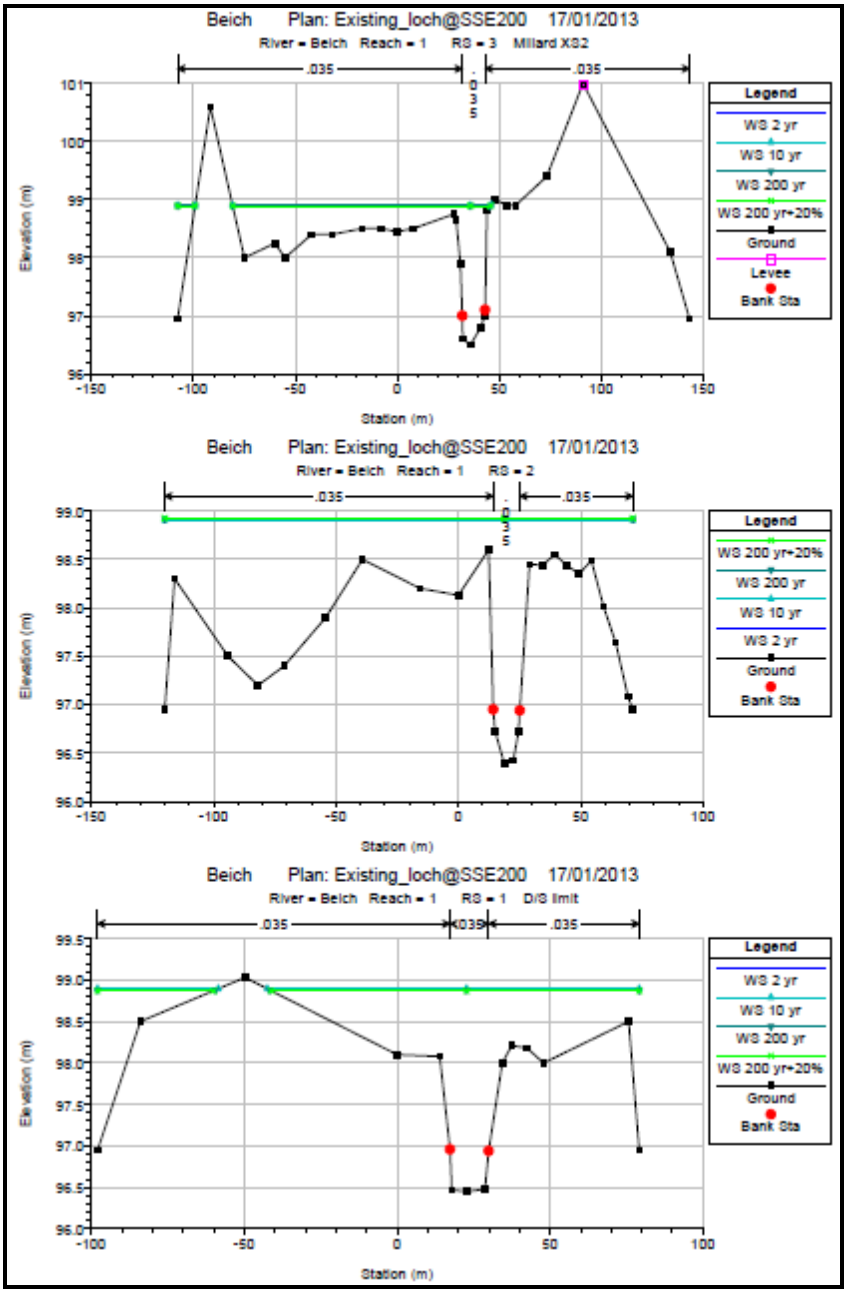
| River Sta | Profile | Plan | Q Total | Min Ch El | W.S. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 yr | SSE 200 + levee | 38.6 | 96.45 | 98.89 | 0.000 | 0.56 | 123.06 | 161.19 | 0.12 |
| 1 | 10 yr | Bridge_block50% | 38.6 | 96.45 | 97.50 | 0.010 | 2.81 | 15.47 | 22.85 | 0.89 |
| 1 | 200 yr | Normal loch lev | 73 | 96.45 | 97.94 | 0.008 | 3.25 | 27.41 | 31.08 | 0.86 |
| 1 | 200 yr | Dec_2006_loch | 73 | 96.45 | 98.54 | 0.001 | 1.69 | 73.21 | 119.21 | 0.38 |
| 1 | 200 yr | SSE 200 yr loch | 73 | 96.45 | 98.88 | 0.001 | 1.09 | 120.71 | 159.47 | 0.22 |
| 1 | 200 yr | Millard | 73 | 96.45 | 99.73 | 0.000 | 0.43 | 269.57 | 177.20 | 0.08 |
| 1 | 200 yr | SA-Mann+20% | 73 | 96.45 | 97.94 | 0.012 | 3.25 | 27.41 | 31.08 | 0.86 |
| 1 | 200 yr | SA-loch+0.5m | 73 | 96.45 | 97.94 | 0.008 | 3.25 | 27.41 | 31.08 | 0.86 |
| 1 | 200 yr | SSE 200 + levee | 73 | 96.45 | 98.88 | 0.001 | 1.09 | 120.71 | 159.47 | 0.22 |
| 1 | 200 yr | Bridge_block50% | 73 | 96.45 | 97.94 | 0.008 | 3.25 | 27.41 | 31.08 | 0.86 |
| 1 | 200 yr+20% | Normal loch lev | 87.6 | 96.45 | 98.03 | 0.009 | 3.61 | 30.12 | 35.35 | 0.93 |
| 1 | 200 yr+20% | Dec_2006_loch | 87.6 | 96.45 | 98.50 | 0.002 | 2.12 | 68.79 | 114.74 | 0.48 |
| 1 | 200 yr+20% | SSE 200 yr loch | 87.6 | 96.45 | 98.87 | 0.001 | 1.32 | 119.13 | 158.29 | 0.27 |
| 1 | 200 yr+20% | Millard | 87.6 | 96.45 | 99.73 | 0.000 | 0.52 | 269.38 | 177.20 | 0.09 |
| 1 | 200 yr+20% | SA-Mann+20% | 87.6 | 96.45 | 98.03 | 0.013 | 3.61 | 30.12 | 35.35 | 0.93 |
| 1 | 200 yr+20% | SA-loch+0.5m | 87.6 | 96.45 | 98.03 | 0.009 | 3.61 | 30.12 | 35.35 | 0.93 |
| 1 | 200 yr+20% | SSE 200 + levee | 87.6 | 96.45 | 98.87 | 0.001 | 1.32 | 119.13 | 158.29 | 0.27 |
| 1 | 200 yr+20% | Bridge_block50% | 87.6 | 96.45 | 98.03 | 0.009 | 3.61 | 30.12 | 35.35 | 0.93 |
| | | | | | | | | | | |
| 0 | 2 yr | Normal loch lev | 22 | 95.50 | 96.99 | 0.000 | 0.07 | 268.92 | 201.62 | 0.02 |
| 0 | 2 yr | Dec_2006_loch | 22 | 95.50 | 98.60 | 0.000 | 0.03 | 603.87 | 208.70 | 0.01 |
| 0 | 2 yr | SSE 200 yr loch | 22 | 95.50 | 98.90 | 0.000 | 0.03 | 666.47 | 208.70 | 0.01 |
| 0 | 2 yr | Millard | 22 | 95.50 | 99.73 | 0.000 | 0.03 | 839.68 | 208.70 | 0.00 |
| 0 | 2 yr | SA-Mann+20% | 22 | 95.50 | 96.99 | 0.000 | 0.07 | 268.92 | 201.62 | 0.02 |
| 0 | 2 yr | SA-loch+0.5m | 22 | 95.50 | 97.49 | 0.000 | 0.05 | 372.20 | 208.70 | 0.01 |
| 0 | 2 yr | SSE 200 + levee | 22 | 95.50 | 98.90 | 0.000 | 0.03 | 666.47 | 208.70 | 0.01 |
| 0 | 2 yr | Bridge_block50% | 22 | 95.50 | 96.99 | 0.000 | 0.07 | 268.92 | 201.62 | 0.02 |
| 0 | 10 yr | Normal loch lev | 38.6 | 95.50 | 96.99 | 0.000 | 0.11 | 268.92 | 201.62 | 0.04 |
| 0 | 10 yr | Dec_2006_loch | 38.6 | 95.50 | 98.60 | 0.000 | 0.06 | 603.87 | 208.70 | 0.01 |
| 0 | 10 yr | SSE 200 yr loch | 38.6 | 95.50 | 98.90 | 0.000 | 0.06 | 666.47 | 208.70 | 0.01 |
| 0 | 10 yr | Millard | 38.6 | 95.50 | 99.73 | 0.000 | 0.04 | 839.68 | 208.70 | 0.01 |
| 0 | 10 yr | SA-Mann+20% | 38.6 | 95.50 | 96.99 | 0.000 | 0.11 | 268.92 | 201.62 | 0.04 |
| 0 | 10 yr | SA-loch+0.5m | 38.6 | 95.50 | 97.49 | 0.000 | 0.09 | 372.20 | 208.70 | 0.02 |
| 0 | 10 yr | SSE 200 + levee | 38.6 | 95.50 | 98.90 | 0.000 | 0.06 | 666.47 | 208.70 | 0.01 |
| 0 | 10 yr | Bridge_block50% | 38.6 | 95.50 | 96.99 | 0.000 | 0.11 | 268.92 | 201.62 | 0.04 |
| 0 | 200 yr | Normal loch lev | 73 | 95.50 | 96.99 | 0.000 | 0.22 | 268.92 | 201.62 | 0.07 |
| 0 | 200 yr | Dec_2006_loch | 73 | 95.50 | 98.60 | 0.000 | 0.11 | 603.87 | 208.70 | 0.02 |
| 0 | 200 yr | SSE 200 yr loch | 73 | 95.50 | 98.90 | 0.000 | 0.10 | 666.47 | 208.70 | 0.02 |
| 0 | 200 yr | Millard | 73 | 95.50 | 99.73 | 0.000 | 0.08 | 839.68 | 208.70 | 0.01 |
| 0 | 200 yr | SA-Mann+20% | 73 | 95.50 | 96.99 | 0.000 | 0.22 | 268.92 | 201.62 | 0.07 |
| 0 | 200 yr | SA-loch+0.5m | 73 | 95.50 | 97.49 | 0.000 | 0.17 | 372.20 | 208.70 | 0.05 |
| 0 | 200 yr | SSE 200 + levee | 73 | 95.50 | 98.90 | 0.000 | 0.10 | 666.47 | 208.70 | 0.02 |
| 0 | 200 yr | Bridge_block50% | 73 | 95.50 | 96.99 | 0.000 | 0.22 | 268.92 | 201.62 | 0.07 |
| 0 | 200 yr+20% | Normal loch lev | 87.6 | 95.50 | 96.99 | 0.000 | 0.26 | 268.92 | 201.62 | 0.08 |
| 0 | 200 yr+20% | Dec_2006_loch | 87.6 | 95.50 | 98.60 | 0.000 | 0.14 | 603.87 | 208.70 | 0.03 |
| 0 | 200 yr+20% | SSE 200 yr loch | 87.6 | 95.50 | 98.90 | 0.000 | 0.12 | 666.47 | 208.70 | 0.02 |
| 0 | 200 yr+20% | Millard | 87.6 | 95.50 | 99.73 | 0.000 | 0.10 | 839.68 | 208.70 | 0.02 |
| 0 | 200 yr+20% | SA-Mann+20% | 87.6 | 95.50 | 96.99 | 0.000 | 0.26 | 268.92 | 201.62 | 0.08 |
| 0 | 200 yr+20% | SA-loch+0.5m | 87.6 | 95.50 | 97.49 | 0.000 | 0.21 | 372.20 | 208.70 | 0.05 |
| 0 | 200 yr+20% | SSE 200 + levee | 87.6 | 95.50 | 98.90 | 0.000 | 0.12 | 666.47 | 208.70 | 0.02 |

| River Sta | Profile | Plan | Q Total | Min Ch El | W.S. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 200 yr+20% | Bridge_block50% | 87.6 | 95.50 | 96.99 | 0.000 | 0.26 | 268.92 | 201.62 | 0.08 |

## 10.4 HEC-RAS cross-sections




Beich Plan: Existing_loch@SSE200 17/01/2013
River = Beich Reach = 1 RS = 5.5 BR
.035
.035
.035
Legend
WS 200 yr+20%
WS 200 yr
WS 2 yr
WS 10 yr
Ground
Bank Sta
Elevation (m)
Station (m)
Beich Plan: Existing_loch@SSE200 17/01/2013
River = Beich Reach = 1 RS = 5 D/S bridge
.035
.035
.035
Legend
WS 200 yr+20%
WS 200 yr
WS 10 yr
WS 2 yr
Ground
Bank Sta
Elevation (m)
Station (m)
Beich Plan: Existing_loch@SSE200 17/01/2013
River = Beich Reach = 1 RS = 4.*
.035
.035
.035
Legend
WS 2 yr
WS 10 yr
WS 200 yr+20%
WS 200 yr
Ground
Bank Sta
Elevation (m)
Station (m)


Beich Plan: Existing_loch@SSE200 17/01/2013
River = Beich Reach = 1 RS = 3 Millard XS2
.035
.035
.035
Legend
WS 2 yr
WS 10 yr
WS 200 yr
WS 200 yr+20%
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
Beich Plan: Existing_loch@SSE200 17/01/2013
River = Beich Reach = 1 RS = 2
.035
.035
.035
Legend
WS 200 yr+20%
WS 200 yr
WS 10 yr
WS 2 yr
Ground
Bank Sta
Elevation (m)
Station (m)
Beich Plan: Existing_loch@SSE200 17/01/2013
River = Beich Reach = 1 RS = 1 D/S limit
.035
.039
.035
Legend
WS 2 yr
WS 10 yr
WS 200 yr
WS 200 yr+20%
Ground
Bank Sta
Elevation (m)
Station (m)