Our Ref: KC1707 – Sandystones, Scottish Borders - **FINAL**
Your Ref:

Kaya Consulting Limited

12th August 2019

Sandystones Ltd
Ancrum
Jedburgh
Scottish Borders
TD8 6UP

For the attention of Hugo Lee and Jamie Murray

Dear Sirs,

Sandystones, Scottish Borders
Water Level Assessment - FINAL

Kaya Consulting Ltd. was commissioned by Sandystones Ltd, via Murray Land & Buildings, to undertake an assessment to determine water levels within the Ale Water adjacent to the site.

As part of this assessment the following was undertaken:

- Estimation of river flows in the River Ale using standard methods;
- Translate river flows to water levels within the River Ale, using surveyed data;
- Provision of 1 in 200-year and 1 in 1000-year water levels and other information such as velocities;
- Short memo-style report presenting results.

Site Background

The site lies within Sandystones close to Ancrum in the Scottish Borders. The proposed development is for a "Treehouse", a raised building to be located within a wooded area adjacent to the Ale Water. This building will be used as a holiday let. The proposed holiday let lies close to a number of other similar properties used for holiday letting. The site measures approximately 0.3ha.

The Ale Water flows close to the site to the south of the site. The Ale Water is a large watercourse with a catchment area of over 151km² upstream of the site.

A former Mill Lead runs through the site. The part of this channel within the site still exists but it has been filled in further downstream. The Mill Lead does not normally receive flows from the Ale Water and only surface water enters the drain in most scenarios. The flood risk posed by the Mill Lead is related to that from the Ale Water as the Mill Lead floods once flows from the Ale Water spill out of bank and into the Mill Lead.

A topographic point survey was commissioned of the site specifically for this assessment. It was undertaken to metres above ordnance datum (m AOD). Ground levels within the site slope down in a south-easterly direction from highs of approximately 105.6m AOD to lows of approximately 100.5m AOD along the southern site boundary. Levels continue to slope down towards the Ale Water with bed levels in the watercourse adjacent to the site reducing to 98.75m AOD. Spot levels from the topographical survey are shown in Figure 2. Figure 3 shows a cross-section through the site and Ale Water along the line of XS2.

A topographical cross-section survey was also undertaken of the Ale Water upstream and downstream of the site. Three main cross-sections were surveyed. One upstream of the site; one perpendicular to the site and one downstream of the site. A further cross-section was taken further downstream at the road bridge over the Ale Water. This section included points to represent the bridge in case it poses a restriction to flows.

The site is shown in Photo 1. The River Ale in Photo 2.

Hydrological Analysis

A Hydrological Analysis was undertaken to determine flows in the Ale Water adjacent to the site.

It was noted that a gauging station exists on the Ale Water at Ancrum (21025), around 6km downstream of the site. An FEH single-site statistical analysis was undertaken for this site.

The observed QMED was estimated at 51.67 m^3/s, based on the AMAX data, which extends over 33 years. The QMED from Catchment Descriptors was lower at 45.99 m^3/s. The higher observed value was used.

The growth curve for the gauge suggested factors of 2.513 for the 1 in 200-year event and 3.152 for the 1 in 1000-year event, both based on extrapolation from the gauged data. These factors gives the following peak flows of:

- **1 in 200-year:** 129.8 m^3/s
- **1 in 1000-year:** 162.8 m^3/s

SEPA guidance dictates that a climate change allowance for the Tweed catchment for catchments in excess of 50km^2 is 33%. Therefore, climate change flows for the 1 in 200-year event are 172.64 m^3/s.

The catchment area of the Ale Water just downstream of the site was estimated to be approximately 151km^2. The catchment area at the gauging station is 174 km^2, according to the National River Flow Archive (NRFA). This means that the peak flows at the site are likely to be lower than those estimated at the gauging site above.

For the purposes of conservatism, the above design flows were used in the hydraulic model.

Hydraulic Model

A simple 1D hydraulic model was developed to represent the Ale Water. The model was built using Flood Modeller and the cross-sections obtained as part of the topographical survey. The bridge over the Ale Water was represented in the model using a BRIDGE unit. Interpolates were added between XS3 and the Bridge.

A hydrograph was added to the head of the model upstream of the site to enter flows into the model. The hydrograph was obtained from the FEH Rainfall-Runoff model and has a total duration of over 30 hours. The hydrograph was scaled to represent the peak 1 in 200-year and 1 in 1000-year flows estimated using the FEH Single-site statistical method.

A “normal depth” downstream boundary was added to the end of the model to allow flows to leave the system. The slope gradient was set to 1 in 260 based on the slope between the two last surveyed cross-sections in the model.

Manning's *n* friction values were set to 0.04 for the main channel, to represent a relatively straight watercourse with a gravel bed with cobbles. Values for the overbank areas varied between 0.04 and 0.08, with the higher values used to represent the areas of heavy vegetation and tree cover.

The model was run using an adaptive timestep with a maximum timestep of 5 seconds and a minimum timestep of 0.25 seconds. The model was permitted to run a number of iterations to provide the best water level estimates. Mass errors were less than 4%.

Figure 4 shows the 1D model schematic.

Model Results

The model was run for the 1 in 200-year and 1 in 1000-year events. The predicted water levels for each cross-section are shown in Table 1. The predicted velocities for each cross-section are shown in Table 2. XS2 lies immediately upstream of the site and is the relevant cross-section to consider when making recommendations for the site.

Table 1: Predicted Peak Water Levels (m AOD)

Cross-section	1 in 200-year (m AOD)	1 in 1000-year (m AOD)	1 in 200-year + 33% CC (m AOD)
XS1	101.7	101.9	102.0
XS2	101.15	101.5	101.65
XS3	100.5	101.1	101.3

Table 2: Predicted Peak Velocities (m/s)

Cross-section	1 in 200-year	1 in 1000-year)	1 in 200-year + 33% CC
XS1	1.83	1.86	1.87
XS2	2.10	2.10	2.10
XS3	1.77	1.78	1.79

Water levels throughout the modelled reach vary from highs of approximately 102m AOD, upstream of the site, to lows of 100.5m AOD, downstream of the site.

The results suggest that peak water levels at the site vary between 101.15 m AOD for the 1 in 200-year event up to 101.65m AOD for the 1 in 200-year plus 33% climate change event. The results for the 1 in 1000-year event are slightly lower at 101.5m AOD.

With respect to velocities these vary between 1.83 m/s and 1.87 m/s at XS1 and 1.77 and 1.79 m/s at XS3. Peak velocities are mostly uniform for all return periods at XS2 with velocities of approximately 2.10 m/s. The suggestion is that the peak velocities in the watercourse are controlled by the shape of the channel rather than the peak flows in the channel. It is recommended that these estimates are used with caution. If they are used to support the design of a structure, then an allowance for uncertainty and potential variations across the channel should be incorporated.

Sensitivity Analysis

A model sensitivity analysis provides an illustration of the effect of changing key model parameters on the important model outputs (in our case flood levels). By re-running the model for a range of scenarios and changing one input parameter for each model run, the effect of each input on the model results can be isolated. If model parameters are varied within the range of possible input values, then a sensitivity analysis can also provide an indication of uncertainty associated with the model predictions.

A sensitivity analysis was undertaken considering the following parameters:

- Allowance for climate change via a 33% flow uplift;
- Reduction in the normal depth downstream boundary from 1 in 260 to 1 in 400 (resulting in higher water level at the boundary);
- Manning's *n* friction values increased by 20% from design values;

The results suggest that increasing manning's *n* friction values for 20% results in an increase in water levels of between 0.15m and 0.3m, depending on the cross-section. This is broadly in line with expectations considering that some parts of the cross-section will already have high manning's *n* values and the impact the 20% uplift with therefore have on water levels.

Reducing the downstream slope boundary from the bed slope of 1 in 260 to a shallower gradient of 1 in 400 results in an increase in waters levels within the lower parts of the reach. Water levels increase by 0.2m at XS3, reducing to 0.05m at XS2. This means that adjusting the downstream boundary does have a impact on water levels at the site, although the impact is relatively minor (0.05m). It is proposed to make an additional allowance for this uncertainty by providing a small additional uplift of 0.3m in the final water level predictions for uncertainty.

Table 3: Sensitivity Analysis

Cross-section	1 in 200-year (m AOD)	1 in 200-year (m AOD) – Manning's *n +20%*	1 in 200-year (m AOD) – Downstream Boundary 1 in 400
XS1	101.7	101.85	101.7
XS2	101.15	101.38	101.2
XS3	100.5	100.82	100.7

Flood Maps

The results of the sensitivity analysis suggested a small uncertainty with respect to the model. An additional uplift of 0.3m has been proposed to account for these water level uncertainties.

This gives a 1 in 200-year water level at the site of 101.45m AOD and a 1 in 1000-year water level of 101.8m AOD and a 1 in 200-year plus climate change level of 101.95m AOD. Using these water levels, the southern part of the proposed development site lies within both the 1 in 200-year and 1 in 1000-year flood extent. The 1 in 1000-year event is shown in Figure 5.

Flood depths within the southern part of the site could reach depths of approximately 1.45m in a 1 in 200-year plus climate change event, accounting for the site topography and estimated peak water levels.

SEPA use their Land-Use Vulnerability criteria to determine whether development is suitable within the floodplain. SEPA are likely to consider this development to be a "most vulnerable use" as it is a holiday let. This generally means all development should be located outwith the 1 in 1000-year floodplain.

Therefore, to meet SEPA guidelines it is recommended to locate all development outwith the 1 in 1000-year floodplain. However, the development is for a "treehouse" and the developer considers the proposed site location to be the only one suitable for the treehouse. The argument is that a treehouse needs to be located within the tree-line. The developer is therefore proposing a number of mitigation measures, as detailed below.

Mitigation Measures

The highest predicted peak water level (with uncertainty allowance) is 101.95m AOD.

The proposed treehouse will be located within this floodplain, elevated above the water level by a raised structure. To mitigate against the flood risk the following is recommended:

- Finished Floor Levels of the entire development should be raised a minimum of 0.6m above the level of 101.95m AOD. This means a minimum level of 102.55m AOD.
    - The client has confirmed the proposed finished floor levels are 103.5m AOD, approximately 1.5m above the highest predicted peak water level with uncertainty allowance.
- A raised access walkway or platform, or similar, should be provided to give access from the access track adjacent to the site boundary to the treehouse. This walkway should also be raised to a minimum of 102.55m AOD.
    - The access track is raised up at levels of approximately 105m AOD, outwith the floodplain.
- The supporting structure that raises the treehouse above the floodplain should be designed to withstand the forces exerted by the water levels in the Ale Water by a qualified structural engineer. Channel velocities are provided in this document. These should be considered as estimates and the structural engineer should make an additional uncertainty allowance to ensure that the structure can continue functioning in all possible scenarios.
    - The structural engineer should also make allowances for the potential for debris to hit the structure.
- The proposed development will be raised up outwith the floodplain via a suitable structure, such as stilts or similar. Technically, these stilts will constitute a reduction in floodplain storage, however small, and may result in very marginal increases in water levels locally. This is unlikely to result in a tangible increase in flood risk, due to the rural nature of the development. However, it should be noted that SEPA may ask for the provision of compensatory storage to account for this.

The above mitigation measures should be discussed with SEPA and the Local Authority to confirm their suitability. However, it should be noted that Kaya Consulting do not necessarily condone development within the floodplain.

Safe Access

The access road that gives access to the site lies at an elevation of 105m AOD, above the predicted 1 in 1000-year water level. So long as the proposed raised access walkway or platform is designed in line with recommendations above then both dry pedestrian and vehicular access should be possible to the treehouse.

Reservoir

Alemoor Reservoir and Hellmoor Loch lie within the headwaters of the Ale Water. The SEPA Reservoirs Map shows that parts of the site closest to the Ale Water may be at risk of flooding in the event of failure of these reservoirs. However, the mapping does not appear to show flooding in excess of that estimated as part of this study for the 1 in 200-year plus climate change event. Therefore, the flood risk posed by a reservoir failure is not likely to be significantly greater than that from the Ale Water itself.

Other sources of flood risk

The proposed development is for a treehouse, raised above the surrounding ground levels. Therefore, the development is likely to be at “low” risk of flooding from surface water flooding.

With respect to groundwater flooding, a high water table may impact on the foundations of the proposed development. The risk from groundwater flooding should be considered as part of the ground investigation.

The design of the drainage is not part of this commission. Site drainage should be designed by a suitable drainage engineer and in line with SEPA and council requirements.

Conclusion

A Water Level Assessment has been undertaken to assess the potential water levels in the Ale Water adjacent to the site. This is to support the development of a Treehouse.

The results suggest that the proposed Treehouse would be likely to lie within both the 1 in 200-year and the 1 in 1000-year floodplain. This is against SEPA Land Use Vulnerability Criteria. However, the developer is proposing to provide mitigation measures to support development. Recommendations to reduce flood risk are provided in the report. These mitigation measures should be discussed with SEPA and the Local Authority to confirm their suitability.

Closure

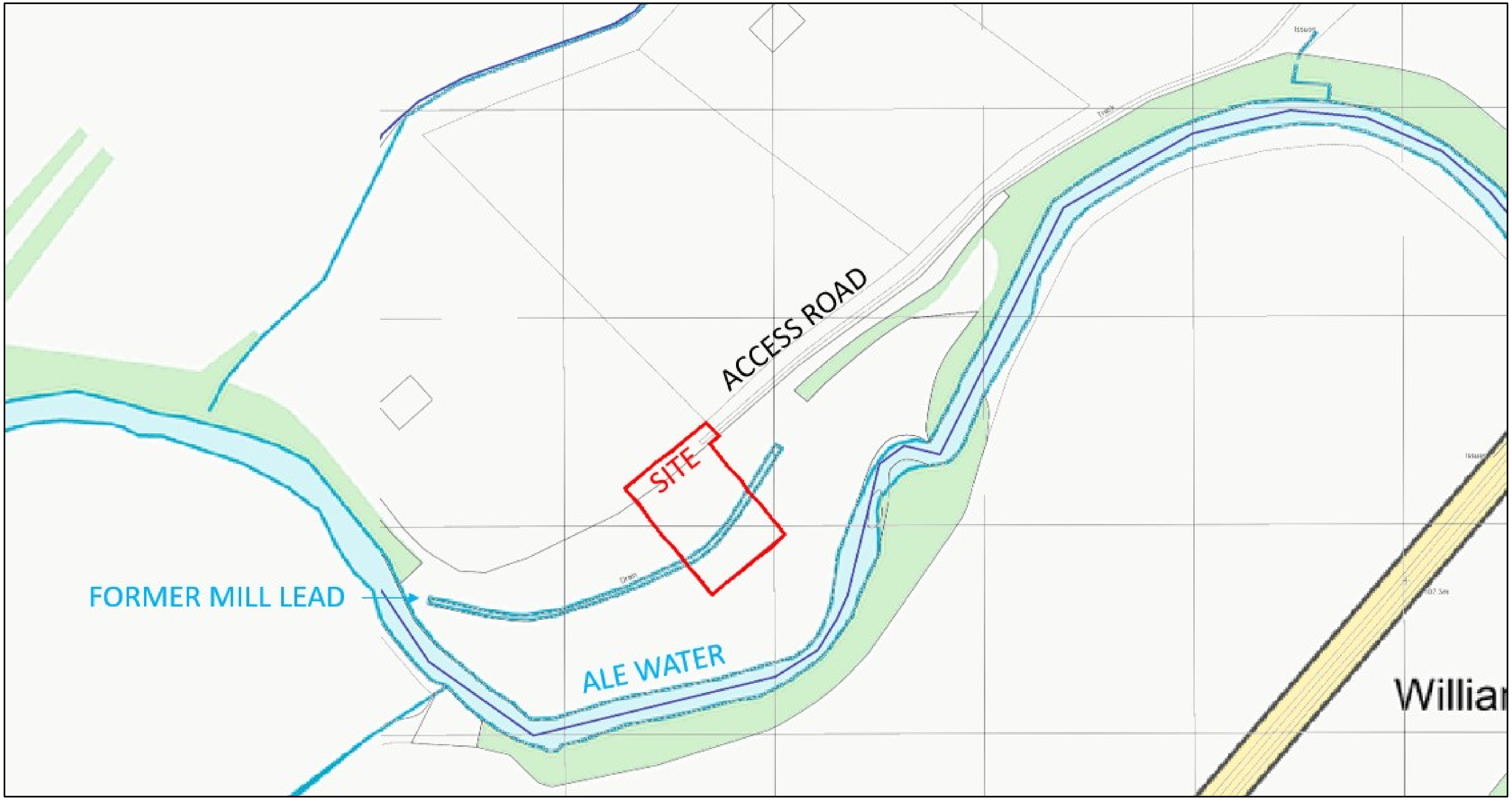
We trust the above satisfy your current requirements. If you have any queries regarding this response, please do not hesitate to contact the undersigned.

Yours faithfully,

Yusuf Kaya
Director

APPENDIX – Figures and Photos

Figure 1: Site location & important features



APPENDIX – Figures and Photos

Figure 2: Spot Levels within the site and of the three main cross-sections

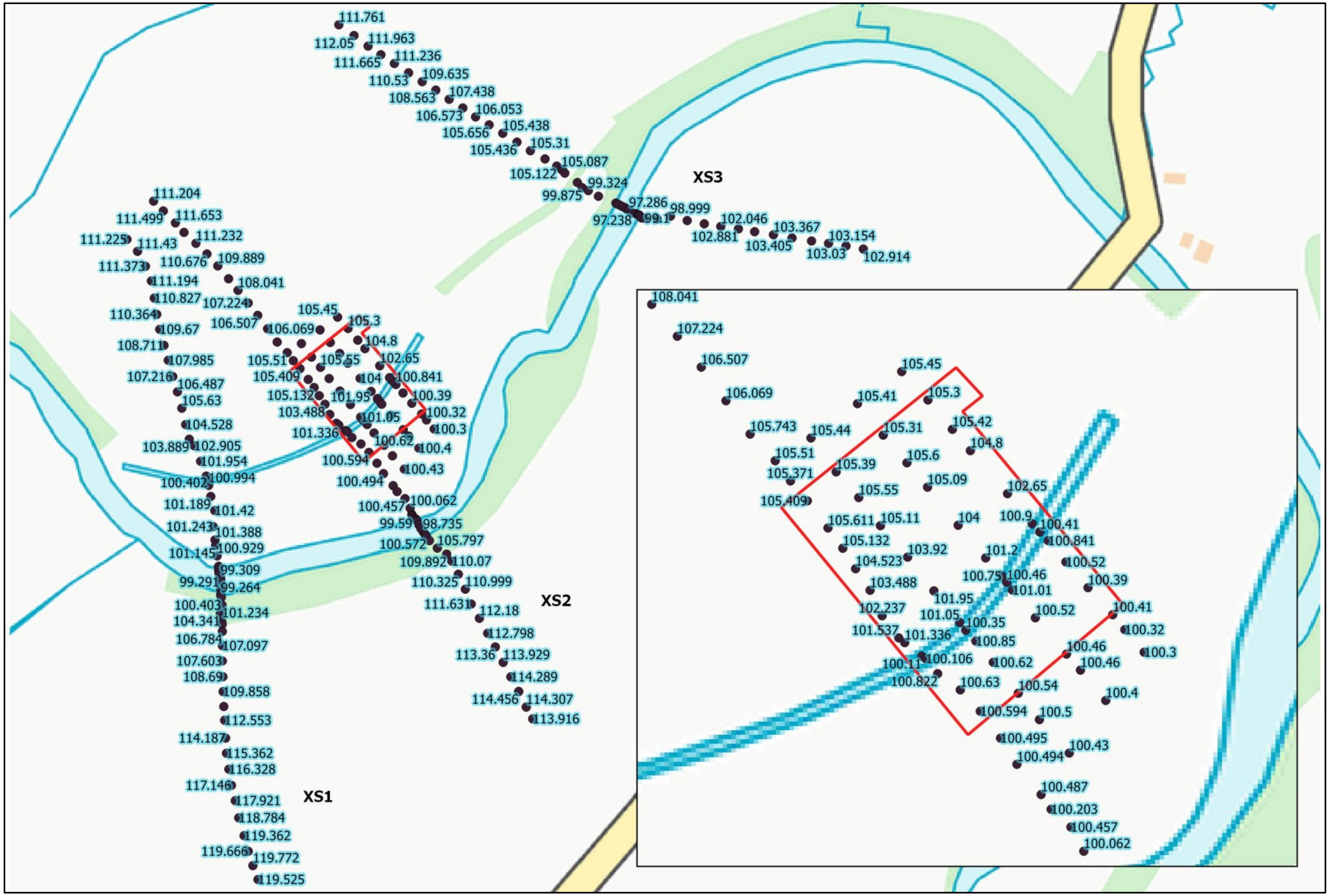


Figure 3: Representation of the XS2 Cross-section through the site and Ale Water

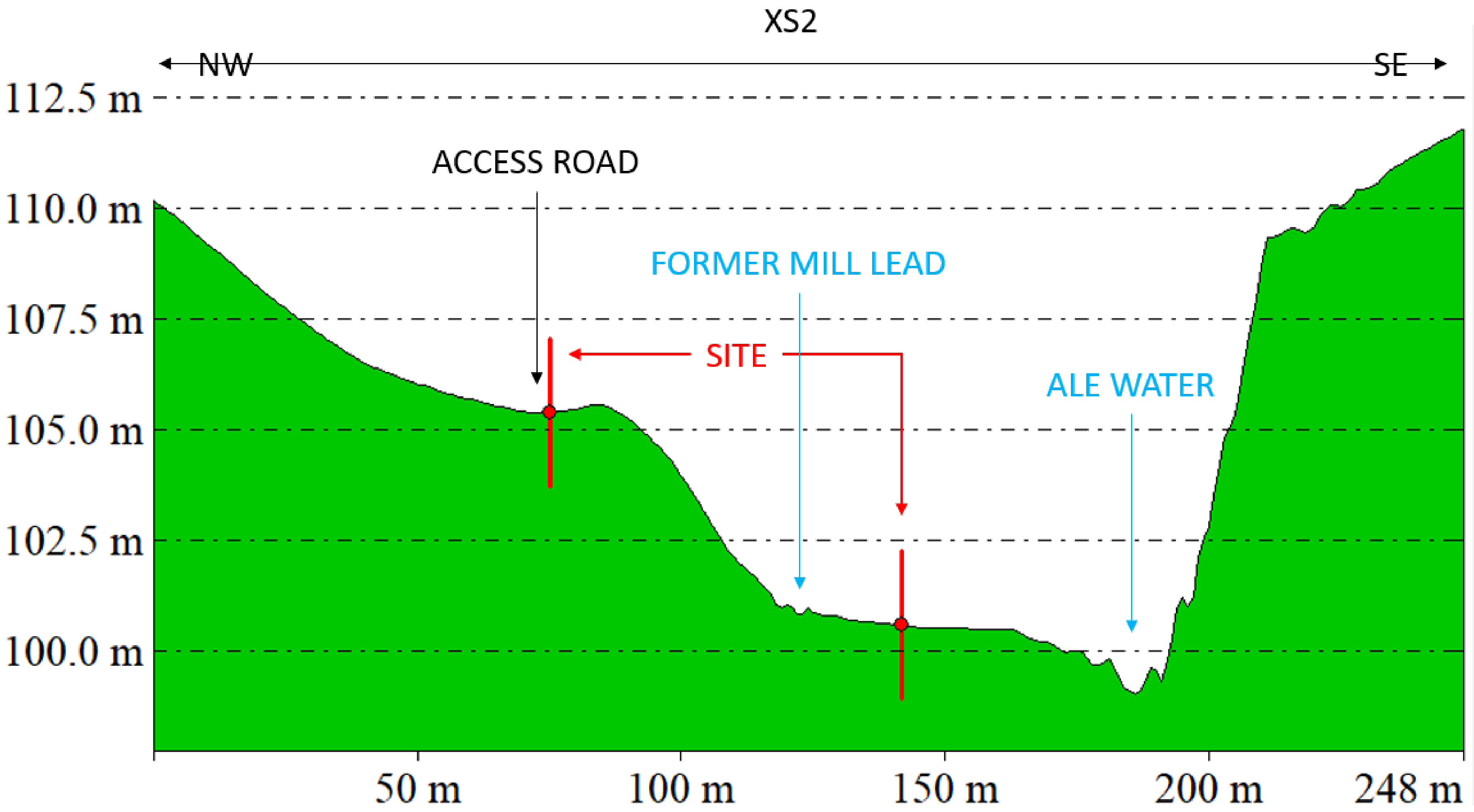


Figure 4: 1D Model schematic

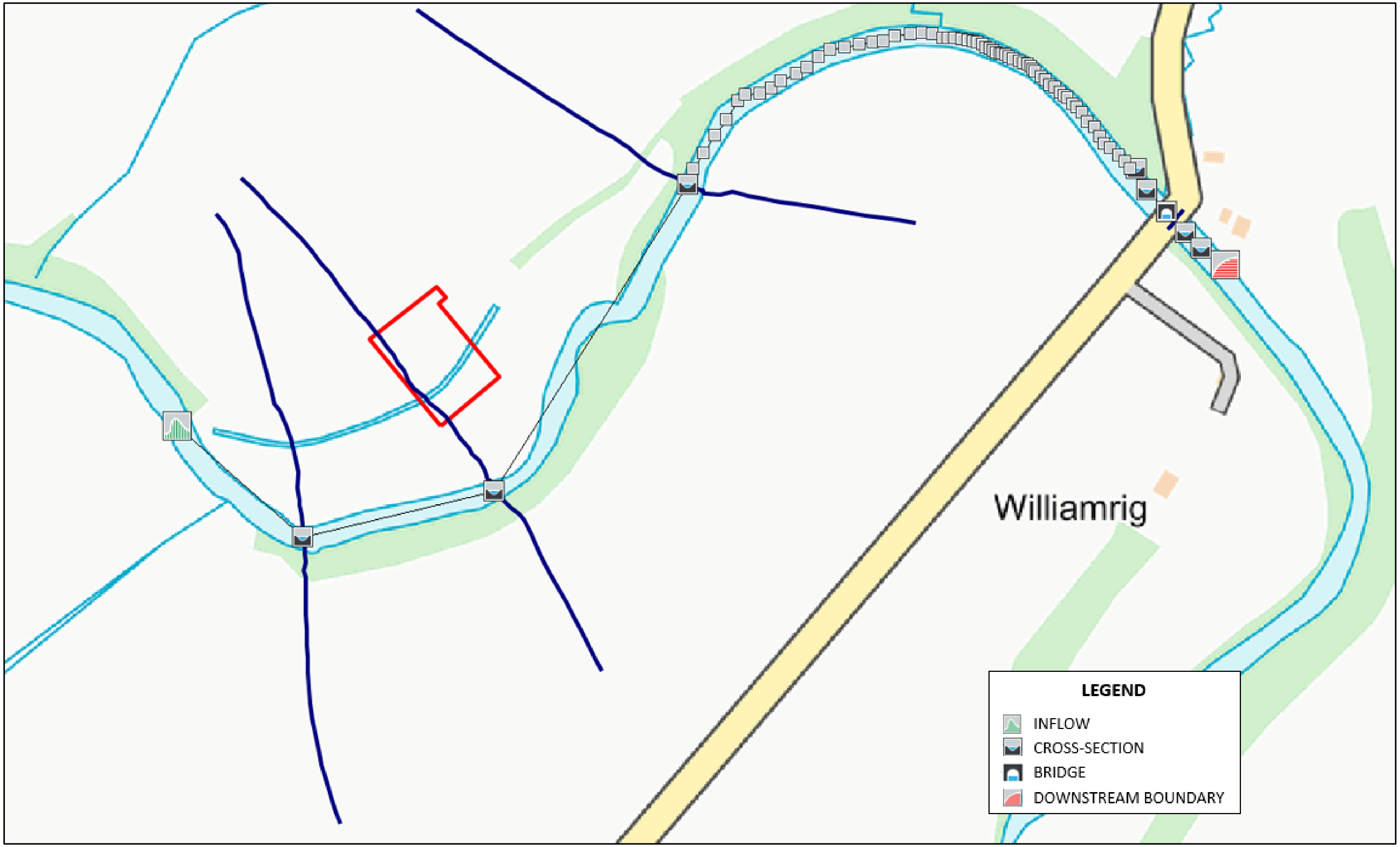


Figure 5: 1 in 1000-year flood extent – Cross-section

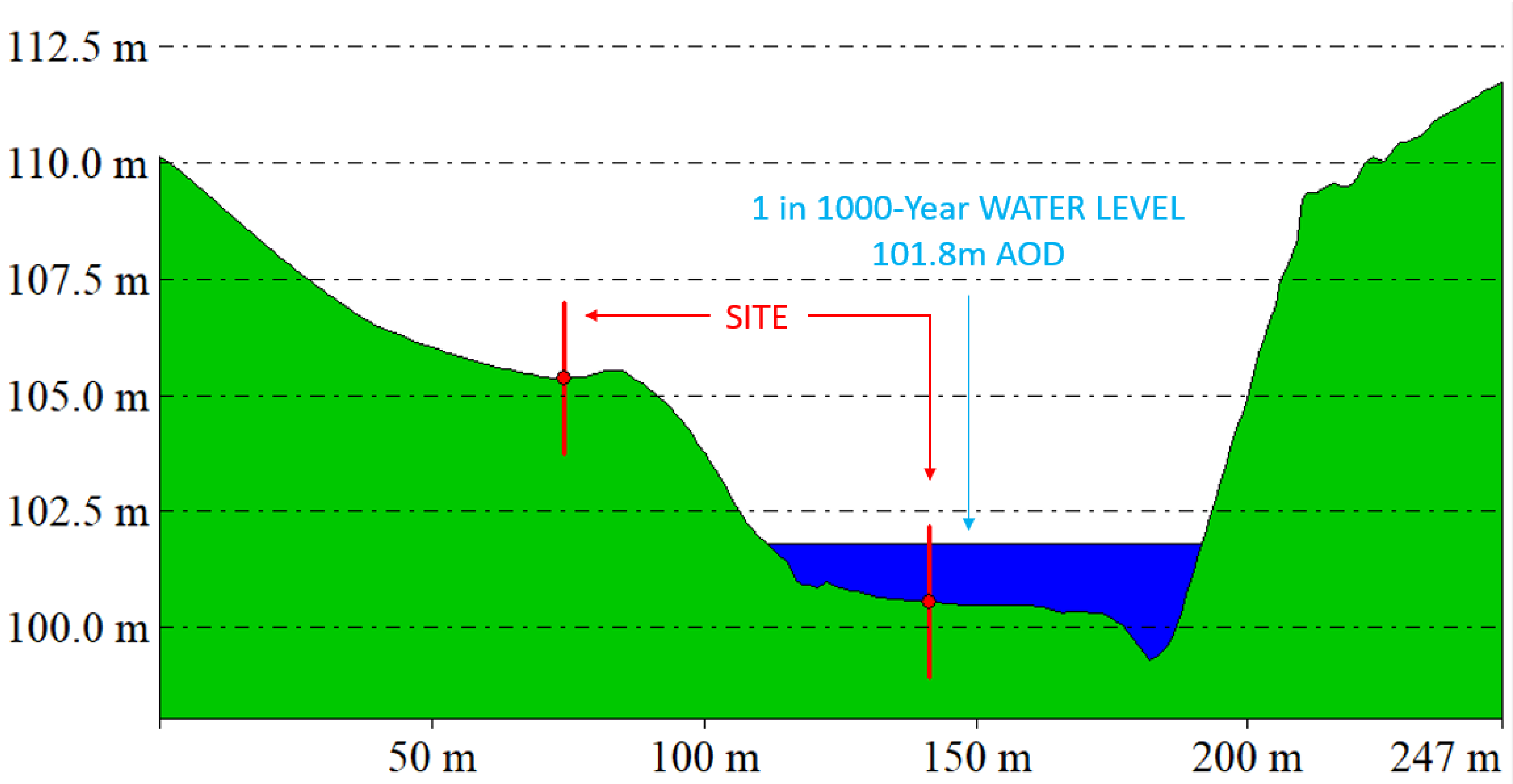


Figure 6: 1 in 1000-year flood extent – Indicative Flood Map

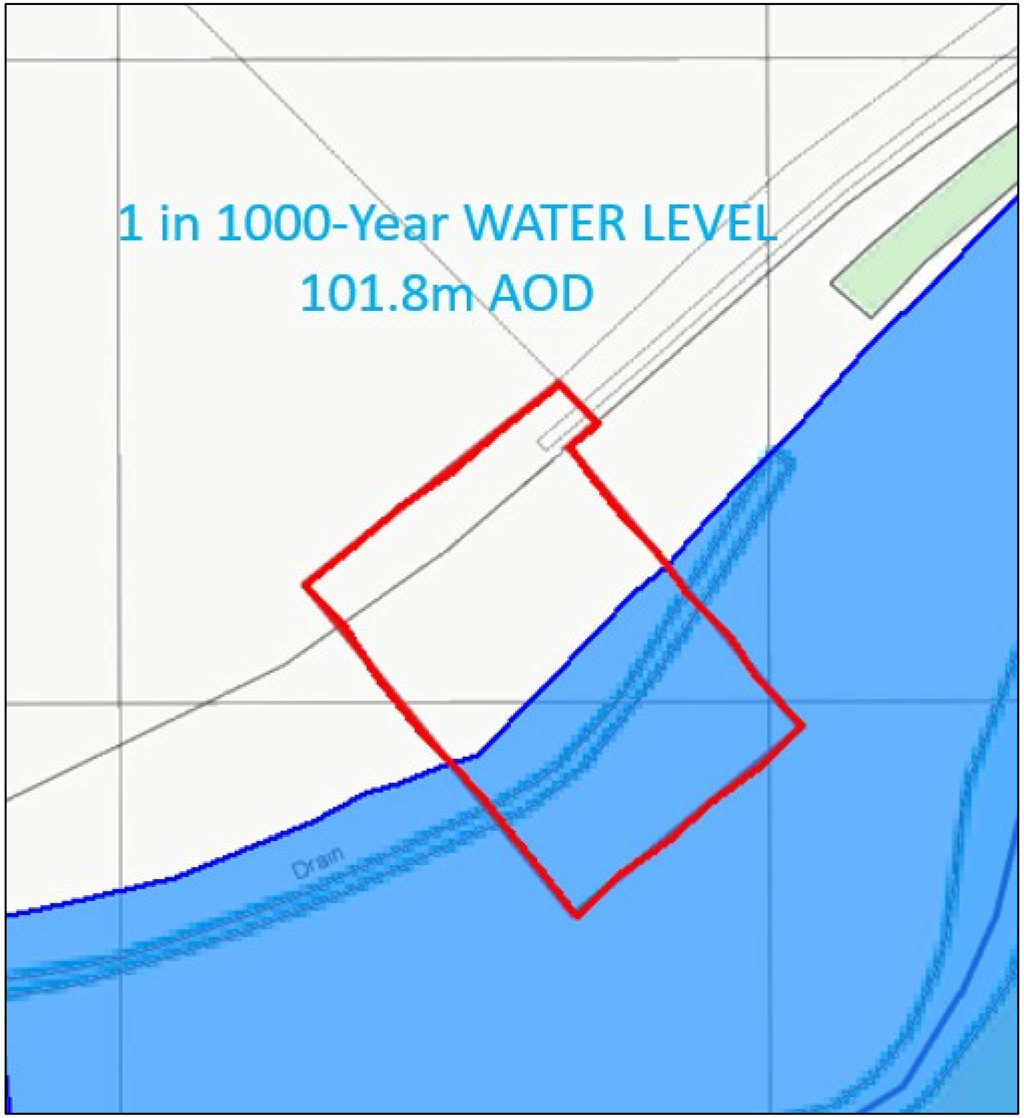
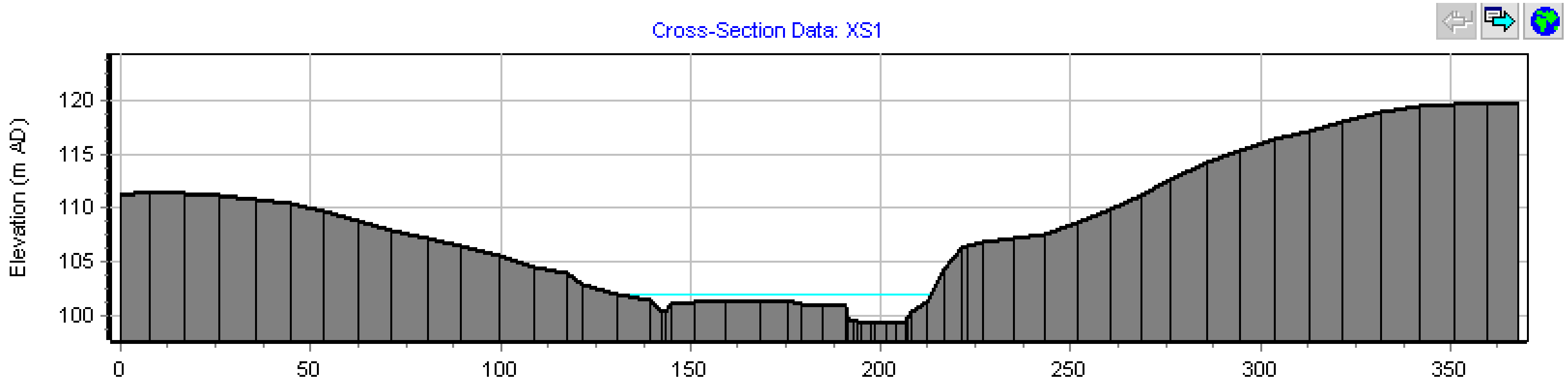
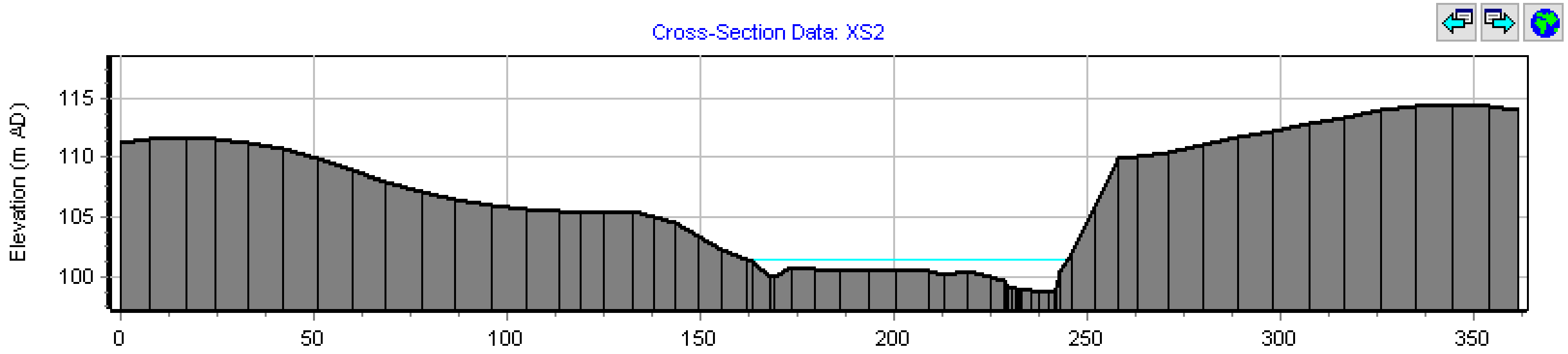


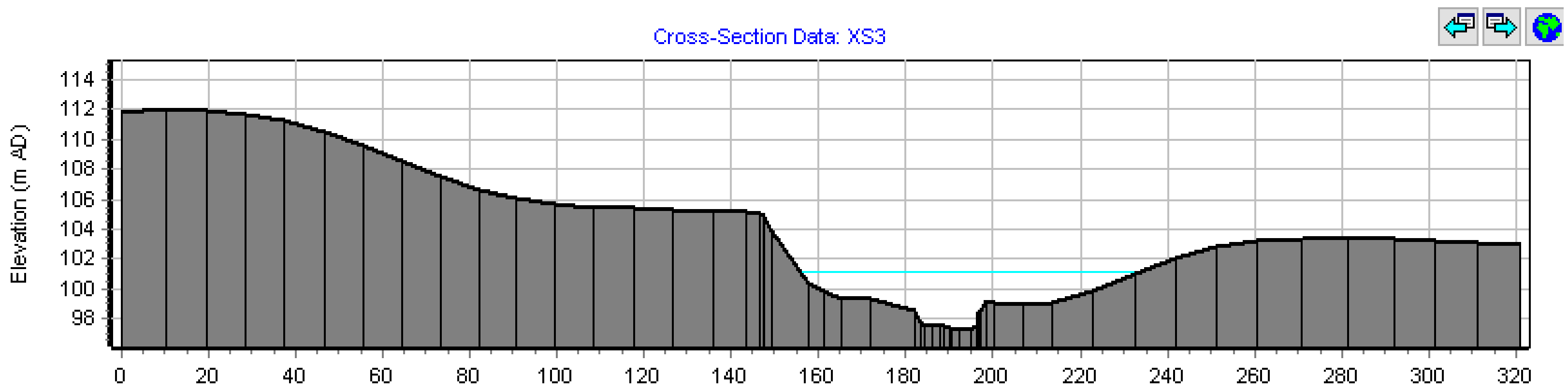
Photo 1: Proposed Site location looking towards the north-east. Note the access track where the car is seen

Photo 2: River Ale adjacent to the site looking upstream

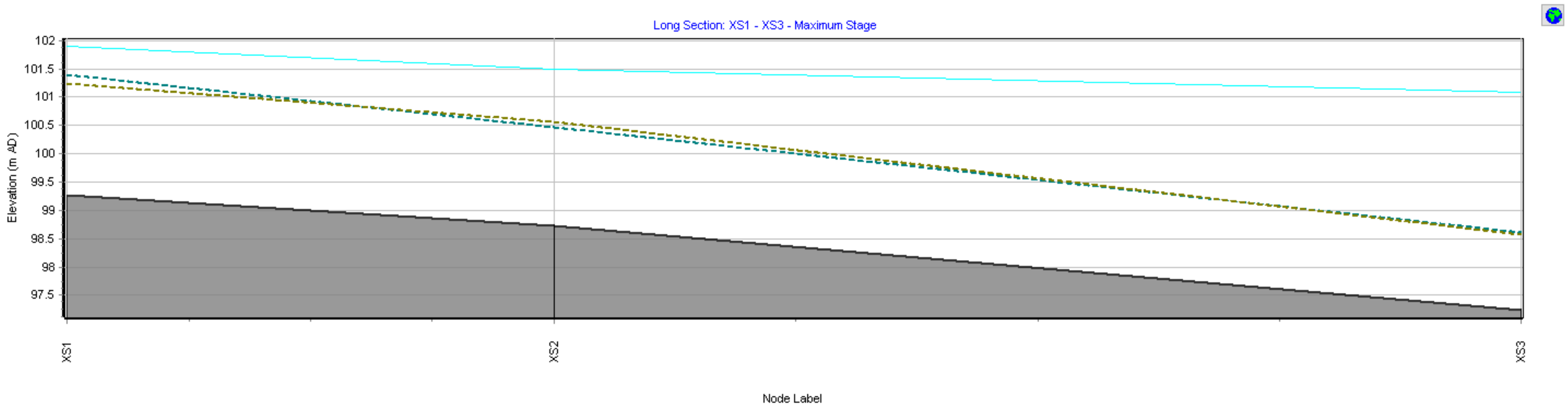
CROSS-SECTIONS – 1 in 1000-YEAR WATER LEVEL







LONG SECTION - 1 in 1000-YEAR WATER LEVEL



REPRESENTATIVE RATING CURVE – 1 in 1000 YEAR