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23 February 2021

Iain Hornshaw
Approvals Manager
Centennial Coal Company Pty Limited

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Dear Iain

Re: Property MS0127 Flood Assessment (2nd Order Stream)

1.0 Introduction and Background

Umwelt (Australia) Pty Limited was engaged by Centennial Coal (Centennial) to investigate potential changes in flood behaviour in the vicinity of the MS0127 dwelling (situated adjacent to a 2nd order stream) that may occur due to subsidence associated with the proposed Modification 9 (currently in the approval phase). This letter report outlines the assessment undertaken and results.

Flood behaviour on the subject watercourse was investigated and compared for two scenarios, as follows:

- **Base Case - current approved subsided landform**. This relates to the approved subsidence impacts for Longwalls (LW) 1 to 31, comprising the approved SSD 5144 Modification 5 (LW1 to 24A) and the approved Extraction Plan for LW25 to 31.
- **Modification 9 - post-mining landform**. This landform is based on the latest information for the extraction of LW1 to 33 (with LW30 to 33 reorientated).

Further detail on the two landforms is provided in **Section 2.0**.

2.0 Catchment Extent and Comparison

The watercourse catchment was defined and compared for the two landform scenarios. This provided the basis for comparing design flood behaviour for the two landform scenarios.

The subject catchment for the 2nd order watercourse extends from the uppermost limits of the watercourse including tributaries, down to the present limit of the RMA-2 hydraulic model domain, which is approximately 300 m downstream of the dwelling on Property MS0127. The RMA-2 model was originally established for 3rd order streams and above.

The catchment boundaries and areas were determined using relevant Digital Elevation Models (DEMs) for the approved subsided landform and for the Modification 9 post-mining landform. The DEMs are based on available LiDAR data, with allowance made for observed and predicted subsidence, as outlined below:

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- The current approved subsided landform employs observed subsidence for LW1 to 17 (per LIDAR dated 13 December 2015) and predicted subsidence for LW18 to 31 (refer Seedsman Geotechnics Pty Ltd, 2017 for LW18 to 24A and Ditton Geotechnical Services Pty Ltd, 2018 for LW25 to 31). This landform is described in detail in the report *"Centennial Coal Mandalong South Flood Assessment Longwalls 25 to 31"* (Umwelt, 16 July 2018).

- The Modification 9 post-mining landform employs observed subsidence for LW1 to 25 (per LIDAR dated 5 April 2020) and predicted subsidence for LW26 to 33 (refer Ditton Geotechnical Services Pty Ltd, August 2020). This landform is described in detail in the report *"Centennial Mandalong Flood Impact Assessment Full Subsidence Over Longwalls 1 to 33" (*Umwelt, 18 December 2020).

The boundaries of catchments are often determined by starting with a GIS plan displaying contours and tracing a polyline with a mouse along catchment watershed lines/ridges. This can include some subjectivity in the placement of the polyline. For this project an automated process to define catchment boundaries has been used that removes the possibility of subjectivity, and this is particularly important where catchments being compared may be close in size.

The automated GIS process firstly requires the user to define the catchment outlet position. The automated process can then create a depressionless DEM (needed to accurately define flow direction), then determines flow direction from each cell to its downslope neighbour or neighbours, which then allows drainage divide lines to be located and the catchment boundary to be defined.

NOTE: In some earlier preliminary work for Centennial, as described in Umwelt's email of 14/01/2021, the method of tracing a polyline with a mouse along catchment watershed lines was used to define the catchment boundary for the Modification 9 Post-Mining case. This approach included a small westerly sub-catchment draining to a dam within the overall catchment for the 2nd order stream. However, the subsequent automated process showed this small sub-catchment actually discharges to a separate watercourse to the west. Hence, this earlier preliminary work slightly overestimated the catchment area and 1% AEP peak discharge for the 2nd order stream.

Using the automated process, the resulting catchment boundaries are shown in **Figure 2.1** for the approved subsided landform and **Figure 2.2** for the Modification 9 post-mining case.

The area of each catchment was calculated and used in the determination of the 1% Annual Exceedance Probability (AEP) peak flood discharge for each scenario. The 1% AEP peak discharge is determined at the downstream catchment boundary (present limit of the RMA-2 hydraulic model domain), using the Regional Flood Frequency Estimate (RFFE) method described in ARR2019.

A comparison of the catchment areas and 1% AEP flows are provided in **Table 2.1**. As shown, the difference in area and flow between the two cases is negligible (i.e. less than 1% difference).

Table 2.1 Catchments Areas and Estimated 1% AEP (100 year ARI) Peak Discharge

Case	Area (km^2)	Estimated 1% AEP Peak Discharge(m^3/s)
Base Case - Current Approved Subsided Landform	0.8852	46.39[1]
Modification 9 – Post-Mining Landform	0.8836	46.33[1]

Note [1]: The RFFE method provides discharge predictions to the nearest 0.1 m^3/s, so linear interpolation based on catchment area has been used to provide discharge estimates to two decimal places.

The Modification 9 Post-Mining landform shows a 0.18% reduction in catchment area (0.8852 to 0.8836 km^2) and a 0.13% reduction in 1% AEP peak discharge (46.39 to 46.33 m^3/s) compared to the Approved Case.

Relative to the catchment area for the pre-mining landform of 0.8857 km^2, the Modification 9 catchment of 0.8836 km^2 is 0.24% less, so again there is very little change for the Modification 9 catchment area. Note that the pre-mining landform is based on LiDAR dated 13 December 2015, 2 days after extraction was completed for LW18, meaning this LiDAR represents pre-mining for the MS0127 dwelling located over LW28.

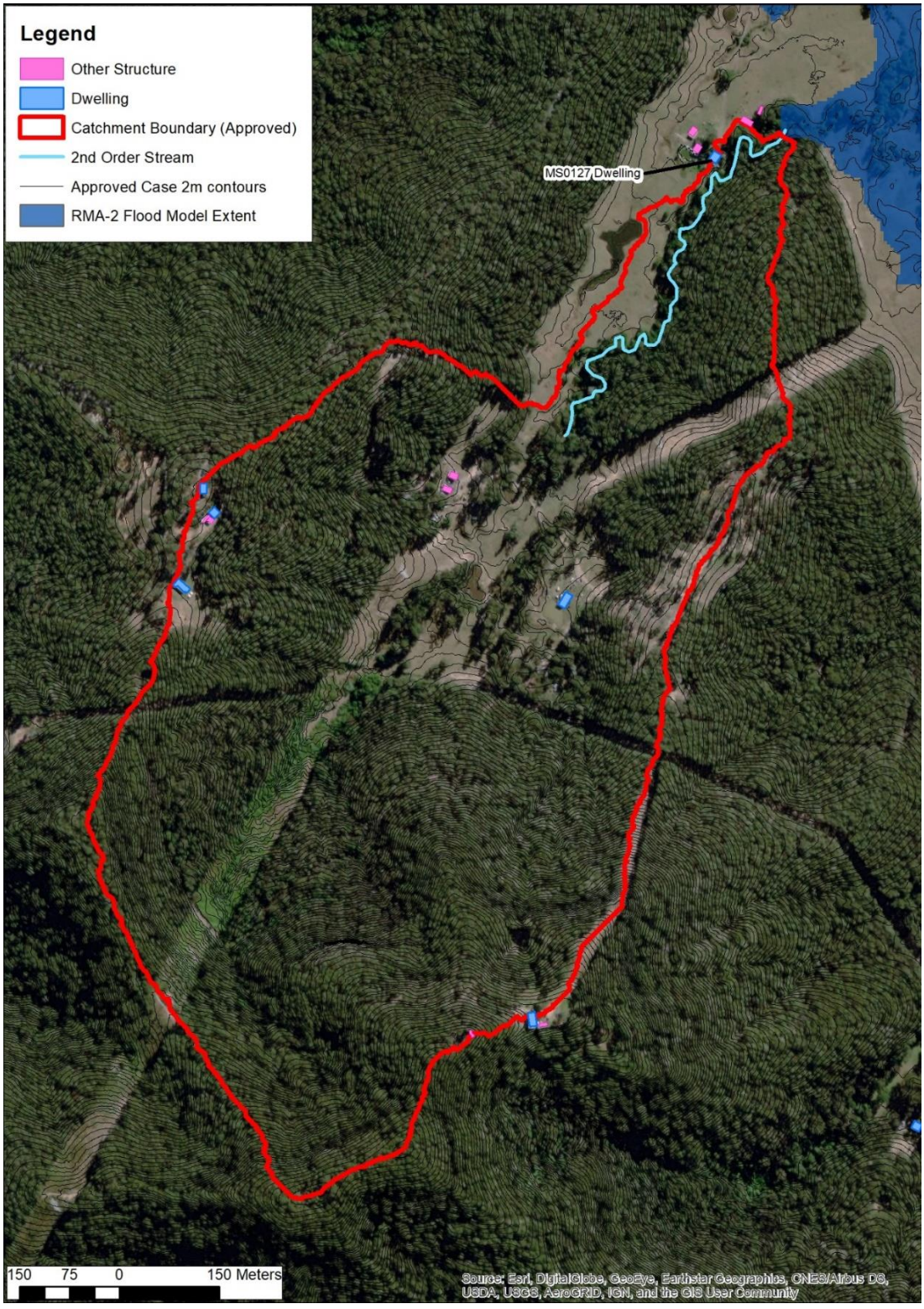

Figure 2.1 Approved Case Catchment Boundary

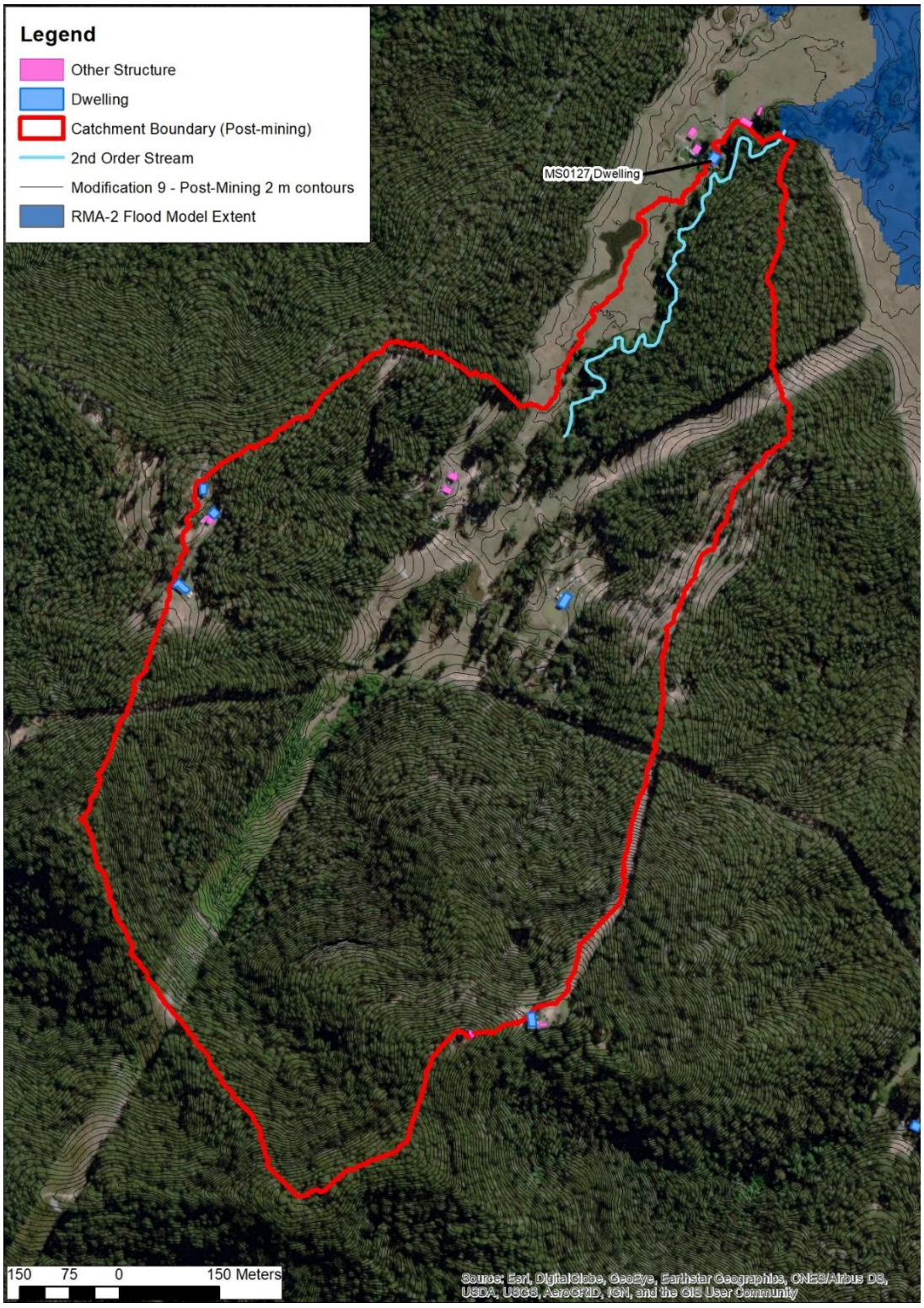

Figure 2.2 Modification 9 Post-Mining Catchment Boundary

3.0 Design Flood Comparison

The 1% AEP flood levels for each scenario were determined using the approach described below:

- Watercourse cross-sections were determined at four locations: at the dwelling, and 3 more in the reach downstream to the limit of the hydraulic model domain.

- The peak 1% AEP flood depth and flood level were estimated at each of the cross-sections using Manning's equation (assuming unform flow) and the 1% AEP peak discharge for each scenario. A Manning's 'n' of 0.06 was used throughout, reflecting the significant vegetation generally encountered along the creek bed/banks.

The flood assessment procedure outlined above provides an approximate method for estimating the 1% AEP peak flood level at the MS0127 dwelling, with the absolute accuracy of flood levels expected to be in the order of ±0.5 m. It is considered a reasonable approach to compare flood behaviour for the two scenarios.

The results of the flood assessment are summarised in **Table 3.1** below for Cross-Section 1 adjacent to the MS0127 dwelling.

Table 3.1 Manning's Equation Results for 1% AEP (100 year ARI) Flood – At MS0127 Dwelling (Cross-Section 1)

	Approved Case	Mod 9 Post-Mining Case
Peak Discharge (m^3/s)	46.39	46.33
Flood Level (m AHD)	37.72	38.14
Velocity (m/s)	2.01	2.01
Creek Invert (m AHD)	35.00	35.70
Water Depth (m)	2.72	2.44
Floor Level (m AHD)	39.23[1]	40.01[2]
Freeboard (m)	1.51	1.87

Note [1]: Floor level based on the difference (0.94 m) between the pre-mining DEM and the Approved Case DEM at the centre of the dwelling.
Note [2]: Floor level based on survey and subsidence monitoring installed at the dwelling provided by Centennial. Pre-mining floor level is 40.17 m AHD and 160 mm of subsidence was monitored, therefore post-mining floor level was estimated as 40.01 m AHD. By comparison, anticipated Approved Case subsidence was 940 mm.

As can be seen in the results, the predicted 1% AEP flood level adjacent to the dwelling for the Modification 9 post-mining scenario is 38.14 m AHD. Centennial have advised that the habitable floor level of the dwelling (following subsidence) is 40.01 AHD, which represents a freeboard of 1.87 m to the 1% AEP flood level. The predicted Modification 9 Post-Mining freeboard has increased by 360 mm relative to the Approved Case freeboard of 1.51 m.

For the pre-mining landform the dwelling floor level is 40.17 m AHD (as advised by Centennial) and the 1% AEP flood level is 38.33 m AHD, giving a freeboard of 1.84 m. Hence, the Modification 9 Post-Mining freeboard of 1.87 m is slightly greater than the pre-mining freeboard.

Further comparison of flood behaviour for the two scenarios in **Table 3.1** shows that Modification 9 shows a small reduction in flood hazard, as measured by the 'velocity x depth' product which reduces from 5.47 m^2/s (2.01 m/s x 2.72 m) to 4.9 m^2/s (2.01 m/s x 2.44 m).

Cross-Section 1 for the Modification 9 Post-Mining Case is displayed on **Figure 3.1**, which shows the creek cross-section adjacent to the MS0127 dwelling, the 1% AEP flood level and the habitable flood level for the dwelling.

Flood assessment results for the Modification 9 Post-Mining Case are also displayed below on a longitudinal section for the 2nd order stream (**Figure 3.2**). The longitudinal section displays the creek invert, 1% AEP peak flood level profile, as well as the ground elevation and habitable floor level at the MS0127 dwelling.

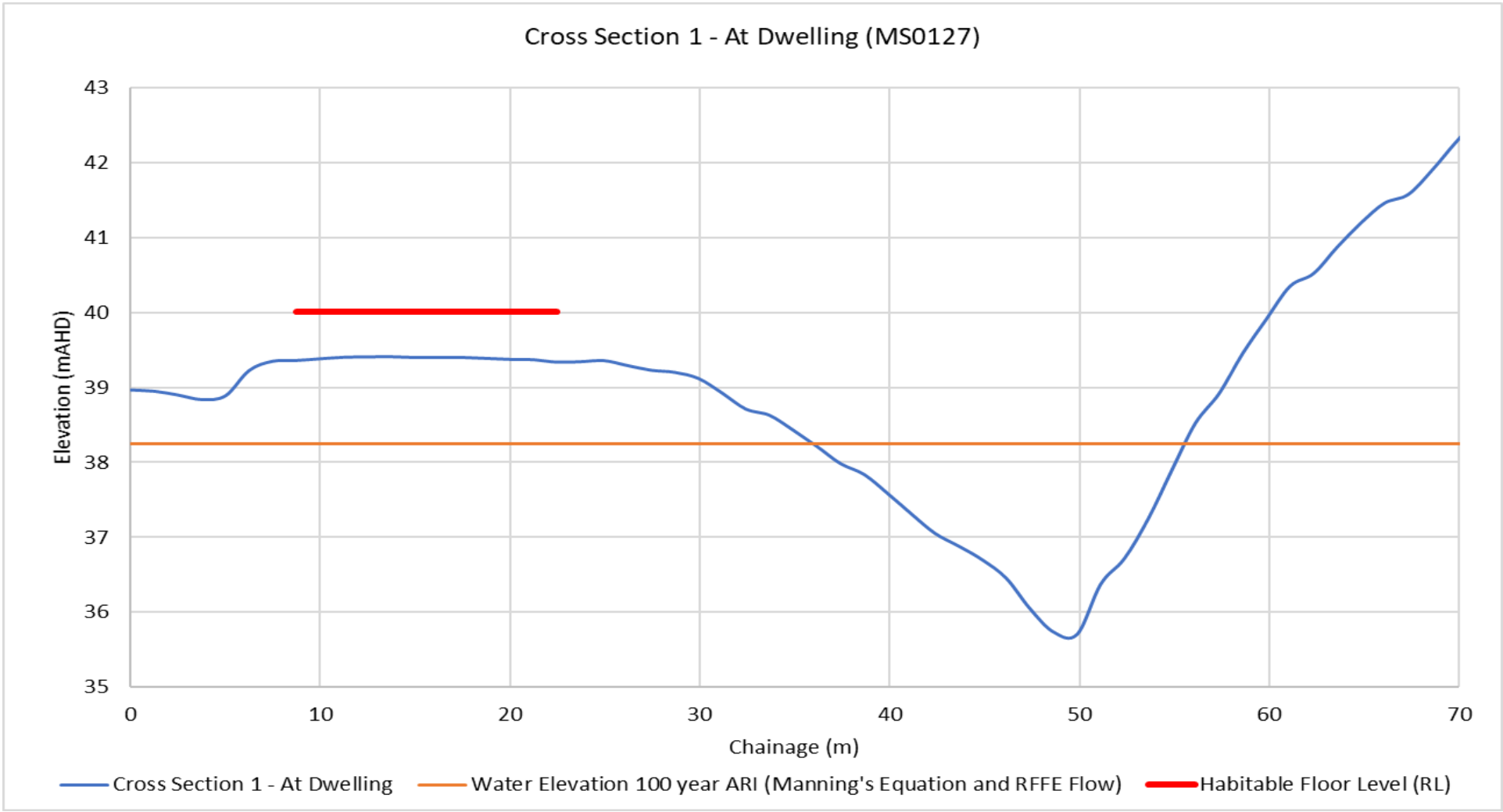

Figure 3.1 Cross-Section 1 at MS0127 Dwelling – Modification 9 Post-Mining Case

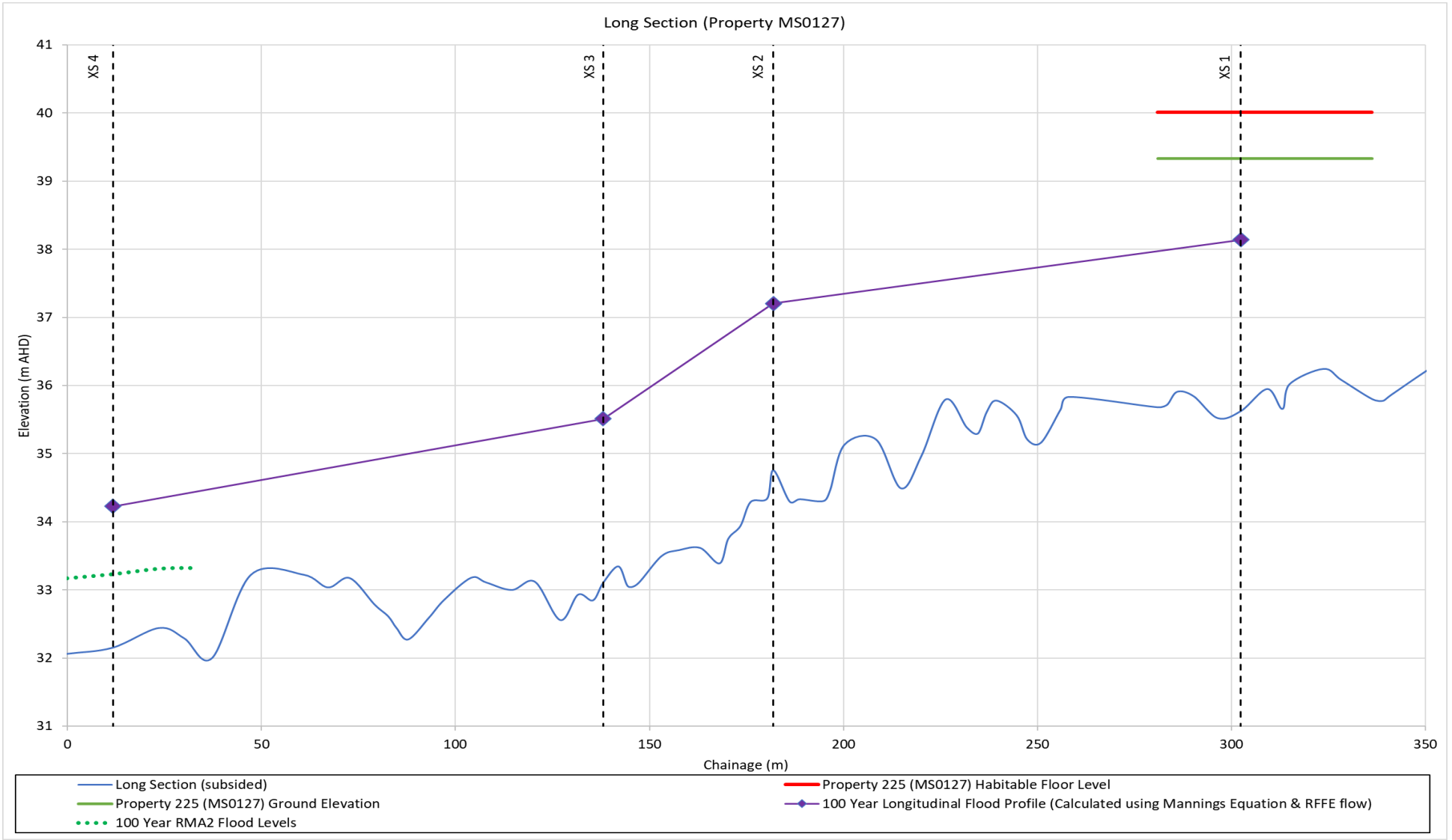

Figure 3.2 Longitudinal Section 2nd Order Stream – Modification 9 Post-Mining Case

The flood level predictions for both scenarios are considered somewhat conservative for the following reasons:

- A Manning's 'n' of 0.06 was used at all four (4) cross-sections. Some locations along the creek are likely to be less vegetated and a lower Manning's 'n' may be applicable at such locations.
- Due to the significant vegetation along the creek bed/banks, the LiDAR (used in establishing the DEMs) has not picked up creek invert levels at numerous locations, as can be seen on the longitudinal section. This means that in some locations the actual creek conveyance would be greater than the calculations indicate.
- The RFFE 1% AEP peak discharge estimate is greater than the RMA-2 boundary inflow at the RMA-2 model domain limit. Hence, the calculated flood levels using Manning's Equation are greater than would be obtained if the RMA-2 model was extended upstream to Cross-Section 1 (adjacent to the MS0127 dwelling).

4.0 Conclusions

The following conclusions have been made:

- For the 2nd order stream adjacent to the MS0127 dwelling, the catchment area to the boundary of the RMA-2 hydraulic model was determined using an automated GIS processes for both the Approved case and the Modification 9 Post-mining case. The difference in catchment area between the two scenarios was found to be very small. For the Modification 9 Post-mining case there is a very small reduction from 0.8852 to 0.8836 km^2 (-0.19%).
- Design flows for the 1% AEP event (100 year ARI) were estimated using the Regional Flood Frequency Estimation (RFFE) method for both the Approved and Post-mining cases. The difference in peak 1% AEP discharge at the catchment boundary for the two scenarios was found to be very small. For the Modification 9 Post-mining case there is a very small reduction in flow from46.39 to 46.33 m^3/s (-0.13%).
- At four locations along the 2nd order stream, including adjacent to the MS0127 dwelling, peak 1% AEP flood depth and flood level were estimated using Manning's equation (assuming unform flow) and the RFFE 1% AEP peak discharge, for each of the two scenarios.
- The results indicate that for the Modification 9 Post-mining case there has been a small reduction in flood hazard adjacent to the MS0127 dwelling, measured as the 'velocity x depth' product (5.47 to 4.9 m^2/s).
- The predicted Modification 9 Post-Mining freeboard is 1.87 m, which is 360 mm higher than the anticipated freeboard of 1.51 m for the Approved Case.

We trust this information meets with your current requirements. Please do not hesitate to contact the undersigned on 0436 632 088 should you require clarification or further information.

Yours sincerely

Glenn Mounser
Manager Water Group