Appendix 2 - Climate Change Sensitivity Analysis for Myall River Downs (11th August 2008)

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File:

Peter Childs
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Dear Peter,

CLIMATE CHANGE SENSITIVITY ANALYSIS FOR MYALL RIVER DOWNS

WorleyParsons is pleased to present the results of our climate change sensitivity analysis for Myall River Downs. The study is based on the MOUSE flood model established for the study *Myall River Downs Water Management Report, Draft September 2006* (Patterson Britton and Partners, now incorporated into WorleyParsons) and the recommendations issued in the Floodplain Risk Management Guideline by the Department of Environment and Climate Change (DECC), titled *Practical Consideration of Climate Change, 2007*.

1. BACKGROUND

Parts of Myall River Downs is subject to flooding from both the Myall River and runoff from the local catchment.

The Myall River Downs Water Management Report (Draft 2006) concluded that the 100 year average recurrence interval (ARI) flood levels across the site can be accommodated through the incorporation of the following measures:

- Overland conveyance of flows in swales and channels;
- Wide trunk drainage channels;
- Minimisation of pipe lengths from the development to the channels;
- Minimisation of length major overland flowpaths within roads;
- Offline storage at the former sand mine; and
- Minimisation of longitudinal grades for swales and channels (main trunk drainage lines to incorporate wetlands).

The design of the channels requires the cut to be in the order of 2 m below the existing surface levels and the surrounding development area is to be above the 100 year ARI level (plus freeboard – 300 mm to roads and 500mm to floor levels), by filling of up to 1 metre.

2. CLIMATE CHANGE SENSITIVITY ANALYSIS

DECC's publication *Practical Consideration of Climate Change (2007),* discusses the potential impact climate change will have on flood levels. The report recommends the following sensitivity analyses for sea level where relevant to the study area:

- Increase by 0.18 m (low level ocean impacts);
- Increase by 0.55 m (mid range ocean impacts); and
- Increase by 0.91 m (high level ocean impacts).

The report also states that until more work is completed in relation to the climate change impacts on rainfall intensities the following sensitivity analyses are recommended:

- Increase intensity by 10% in peak rainfall and storm volume;
- Increase intensity by 20% in peak rainfall and storm volume; and
- Increase intensity by 30% in peak rainfall and storm volume.

The publication recommends that the combination of ocean event ARI with flood event ARI should be discussed with DECC floodplain risk management (FRM) staff due to joint probability issues.

In response to DECC's publication and recommendations, sensitivity analyses were carried out on the two scenarios presented in the Myall River Downs Water Management Report (Draft 2006):

- Scenario 1 – 100 year ARI rainfall combined with a 1 year ARI bay water level (RL 1.26 m AHD); and
- Scenario 2 – 20 year ARI rainfall combined with a 100 year ARI bay water level (RL 1.69 m AHD).

WorleyParsons discussed the combination of increased effects from both the increased rainfall intensity and increase in ocean levels with both DECC Floodplain Risk Management and Great Lakes Council to determine the modelling requirements for the joint probability of both changes occurring. These discussions yielded that the level of climate change is uncertain, but not expected to reach the highest levels for both rainfall and sea level increases. However, to present the full range of scenarios suggested in the DECC guideline, the following climate change scenarios were modelled for both Scenario 1 and Scenario 2:

- Existing peak rainfall and runoff with 0.18, 0.55 or 0.91 m increase in ocean water levels;
- Increase in existing rainfall hydrographs by 10%, 20% and 30% with existing tailwater levels;
- 10% increase in peak rainfall intensity combined with + 0.91 m increase in ocean water levels;

- 20% increase in peak rainfall intensity combined with + 0.55 m increase in ocean water levels;
- 30% increase in peak rainfall intensity combined with + 0.18 m increase in ocean water levels; and
- 30% increase in peak rainfall intensity combined with + 0.91 m increase in ocean water levels.

The tailwater levels as modelled in the Draft Water Management Report (PBP, 2006) and Local Environment Study (Parsons Brinckerhoff, 2003) are based on storm surge plus high tidal water levels. Wave set up and wind set up were not included as the study area by its location is not subject to wind and wave runup. The tailwater levels which have been used in modelling through this report are based on the two tailwater levels used in the afore-mentioned reports (1.29 m AHD and 1.69 m AHD) plus the relevant increase in ocean water level (0.18, 0.55 or 0.91 m for the various degrees of climate change). The consideration of any increase in storm surge due to climate change has not been accounted for and is beyond the scope of this report.

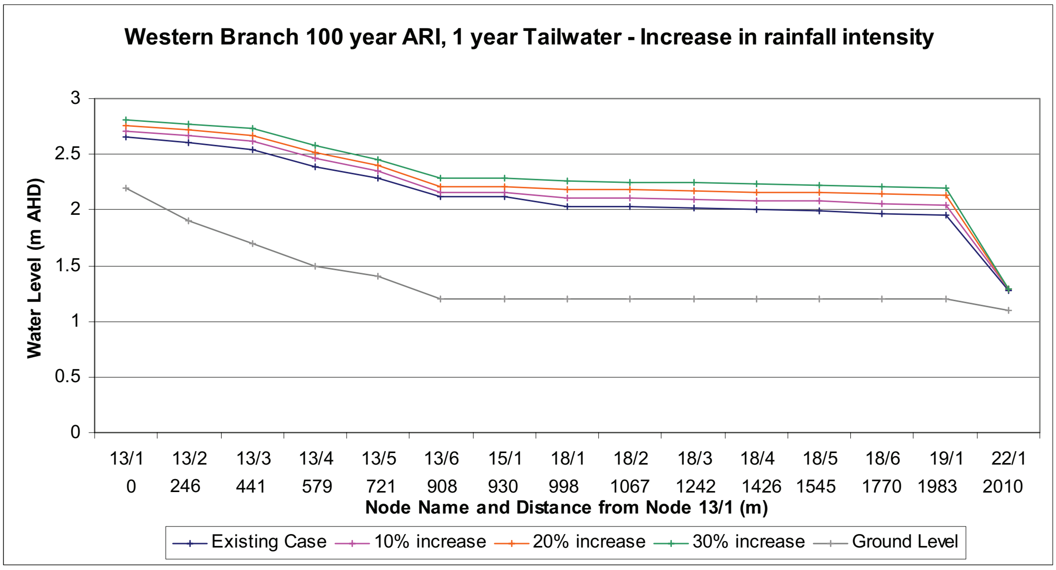
3. MODEL RESULTS

The model results are divided into the eastern and western sections of the proposed development and examine Scenarios 1 and 2. The western branch of the model consists of a vegetated channel, which is the major drainage path on the western side of the property. The eastern branch of the model is a vegetated channel which borders the north-eastern section of the proposed development, with the southern section following the eastern boundary of the Grange Retirement Village (constructed and occupied) and the Hermitage Retirement Village. Refer to **Figure 1** for the model layout. **Figures 2-23** show water levels at the nodes for each climate change scenario.

3.1 WESTERN BRANCH

3.1.1 Scenario 1 – 100 year ARI Rainfall Intensity Combined with 1 year ARI Baywater Level

Graph 1 shows long-section profile of the western branch from nodes 13/1 (uppermost node in the drainage channel) to 22/1 (the south side of the road at the southern end of the development). The effect of an increasing rainfall intensity compared to the existing case is illustrated. Increasing the rainfall intensity resulted in increased flood levels across the development, but not by more than 0.25 m.

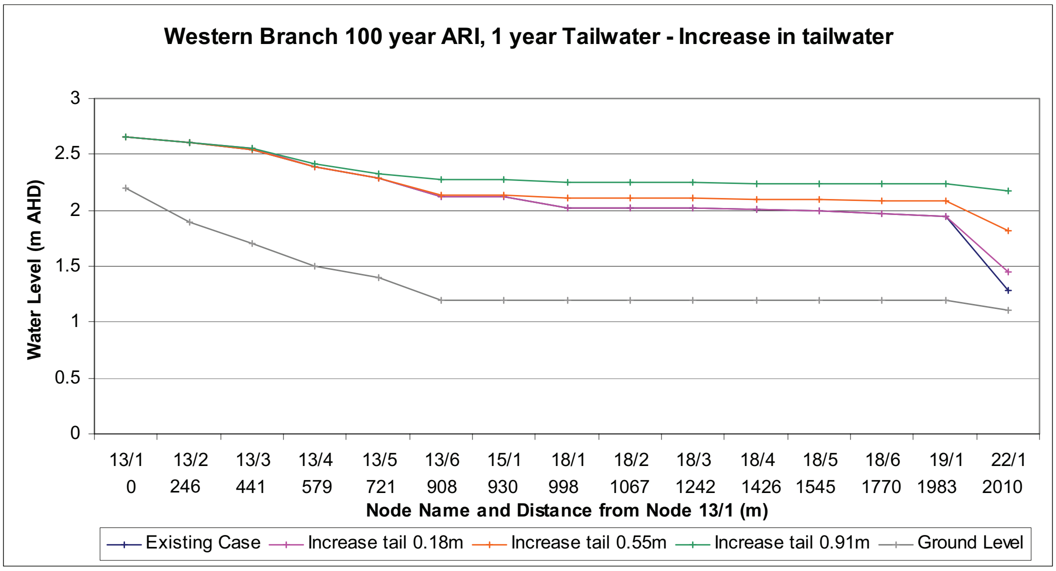


Graph 1 - Scenario 1, Effect of Increased Rainfall Intensity on Western Branch

The results also indicated that:

- The effect of a 10% increase in rainfall intensity is an increase of flood levels by an average of 0.07 m, with a maximum increase of 0.1 m at node 19/1;
- The effect of a 20% increase in rainfall intensity is an increase of flood levels by an average of 0.14 m, flood levels at nodes from 18/1 to 19/1 increase by 0.15 m to 0.18 m; and
- The effect of a 30% increase in rainfall intensity is an increase of flood levels by an average of 0.20 m, flood levels at from nodes 18/1 to 19/1 increase by 0.22 to 0.25 m

Graph 2 shows the effects of increasing the tailwater levels on the western branch of the model. The larger tailwater increases raised the flood levels by not more than 0.29 m. The upper reach of the branch is not affected by the increase in tailwater levels.



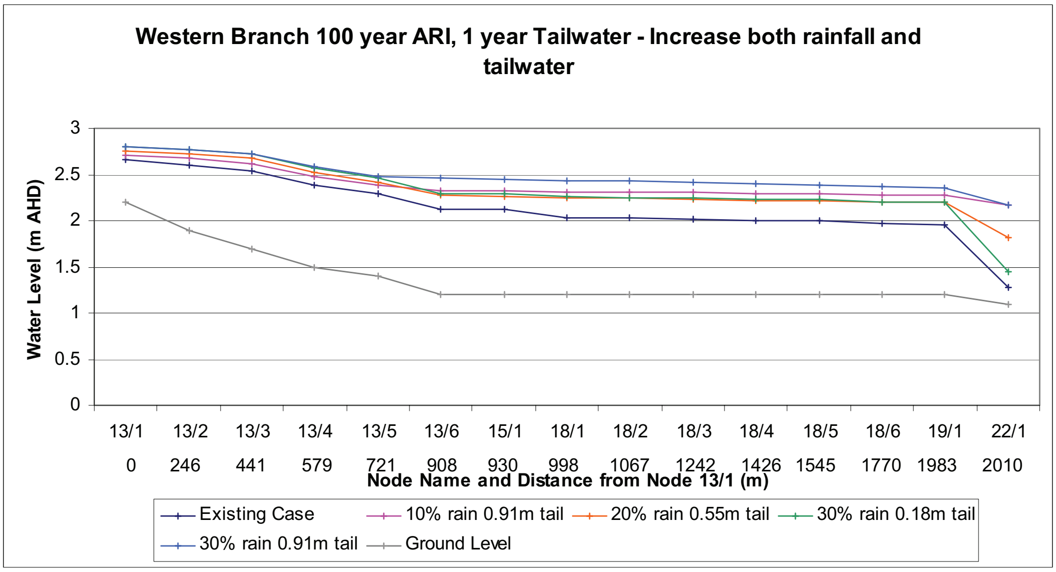
Graph 2. Scenario 1, Effect of Increased Tailwater Levels on Western Branch

The results also indicated that:

- The 0.18 m increase in tailwater level does not affect flood levels on the western branch within the proposed development;
- The 0.55 m tailwater level increase results in increased flood levels south of and including node 13/4 of 0.04 m. South of node 15/1, the increase varies from 0.08 to 0.15 m;

The effect of a 0.91 m tailwater level increase is an increase in flood levels south of node 13/3 (increase by 0.08 m). The increase in flood levels south of node 13/6, varies from 0.15 m to 0.29 m.

Graph 3 shows the effect of a combination of joint occurrences, with both increased rainfall intensity and increased tailwater levels. The combined scenarios generally result in increases in flood levels no greater than 0.25 m, except in the case of the most extreme scenario, where increases up to 0.4 m were predicted. It should be noted that the most extreme scenario is a combination of the greatest increases for both rainfall intensity and tailwater level and is considered unlikely.



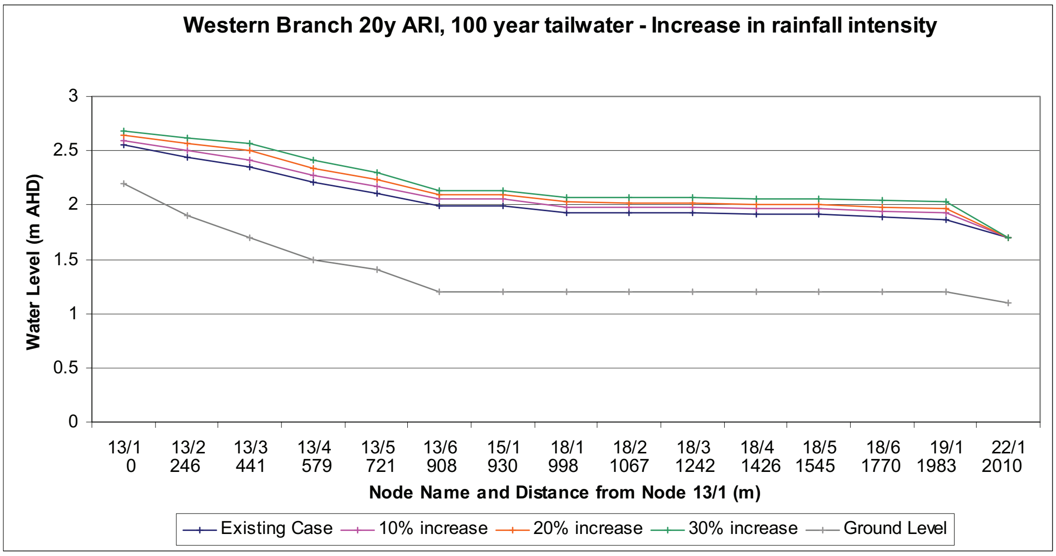
Graph 3. Scenario 1, Effect of Increasing both Rainfall Intensity and Tailwater Levels on Western Branch

The dominant effect of either increased rainfall intensity or tailwater varies in the four scenarios, as summarised below:

- +10% rainfall intensity and +0.91 m tailwater level: The increase in tailwater results in an increase of flood levels south of node 13/6 by 0.21 to 0.33 m. Upstream of node 13/6, flood levels increase from 0.05 to 0.09 m;
- +20% rainfall intensity and +0.55 m tailwater level: Increase in flood levels south of and including node 18/1 by 0.22 to 0.25 m. Increase in flood levels from nodes 13/1 to 15/1 by 0.1 to 0.15 m;
- +30% rainfall intensity and +0.18 m tailwater level: Increase in flood levels south of and including node 18/1 by 0.23 to 0.25 m. Increase in flood levels north of node 18/1 by 0.14 to 0.17 m; and
- +30% rainfall intensity and +0.91 m tailwater level: Increase in flood levels south of and including node 13/6 by 0.33 to 0.40 m. Increase in flood levels north of node 13/6 by 0.14 to 0.19 m.

3.1.2 Scenario 2 – 20 year ARI Rainfall Intensity Combined with 100 year ARI Baywater Level

Graph 4 shows the effect of increasing the rainfall intensity on the western branch for Scenario 2. The flood levels increase by no more than 0.21 m.

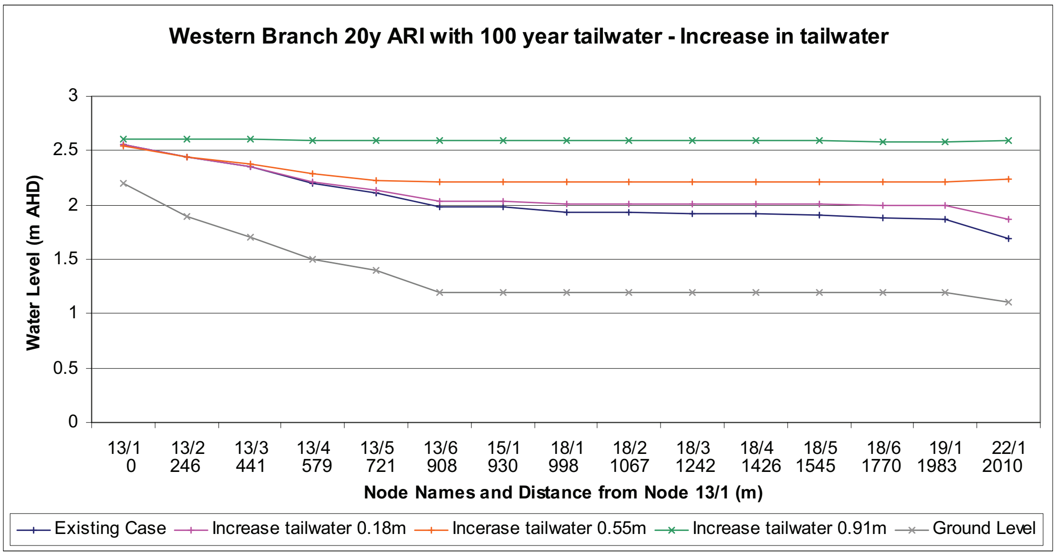


Graph 4. Scenario 2, Effect of Increased Rainfall Intensity on Western Branch

The effect of increased rainfall intensities can be summarised as:

- The effect of a 10% increase in rainfall intensity, is an increase of flood levels by an average of 0.05 m;
- The effect of a 20% increase in rainfall intensity, is an increase of flood levels by an average of 0.1 m. The greatest increase is 0.15 m at node 13/3; and
- The effect of a 30% increase in rainfall intensity, is an increase of flood levels by an average of 0.16 m. The greatest increase is 0.21 m at node 13/3.

Graph 5 shows the effect of an increasing tailwater along the western branch of the model in Scenario 2. The results indicate that the flood levels are dictated by the tailwater levels, increasing by up to 0.71 m.

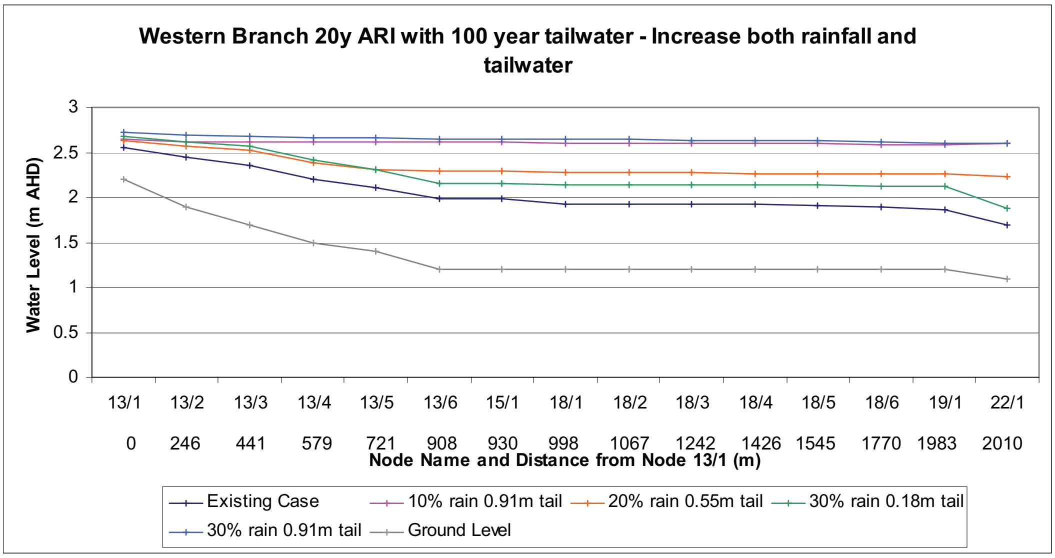


Graph 5. Scenario 2, Effect of Increased Tailwater on Western Branch

The effect of increased tailwater for the various tailwater levels is summarised as:

- The effect of a 0.18 m tailwater increase is an increase in flood levels south of and including node 13/6 by 0.05 to 0.12 m;
- The effect of a 0.55 m tailwater increase is an increase in flood levels south of and including node 13/4 by 0.09 to 0.34 m; and
- The effect of a 0.91 m tailwater increase is an increase in flood levels for the length of the western branch by 0.06 to 0.71 m.

Graph 6 shows the effect of a combination of joint occurrences where there is both increased rainfall and increased tailwater. The flood levels increase up to 0.74 m.



Graph 6. Scenario 2, Effect of Increasing both Rainfall Intensity and Tailwater Levels on Western Branch

The effect on the flood levels in the various scenarios is summarised below:

- 10% rain 0.91 m tail: Increase in flood levels south of (and including) node 13/4 by 0.41 to 0.72 m. Upstream of node 13/4, flood levels increase from 0.09 to 0.27 m;
- 20% rain 0.55 m tail: Increase in flood levels south of (and including) node 13/6 by 0.30 to 0.54 m. Upstream of node 13/6, flood levels increase by 0.08 to 0.20 m;
- 30% rain 0.18 m tail: Increase in flood levels along the drainage channel by an average of 0.20 m, the greatest increase of 0.25 m at node 19/1; and
- 30% rain 0.91 m tail: Increase in flood levels south of (and including) node 13/4 by 0.46 to 0.74 m. Upstream of node 13/4, flood levels increase from 0.17 to 0.32 m.

Table 1 is a summary of water levels on the western branch for the scenarios that were modelled.

Table 1. Summary of Water Levels for Western Branch

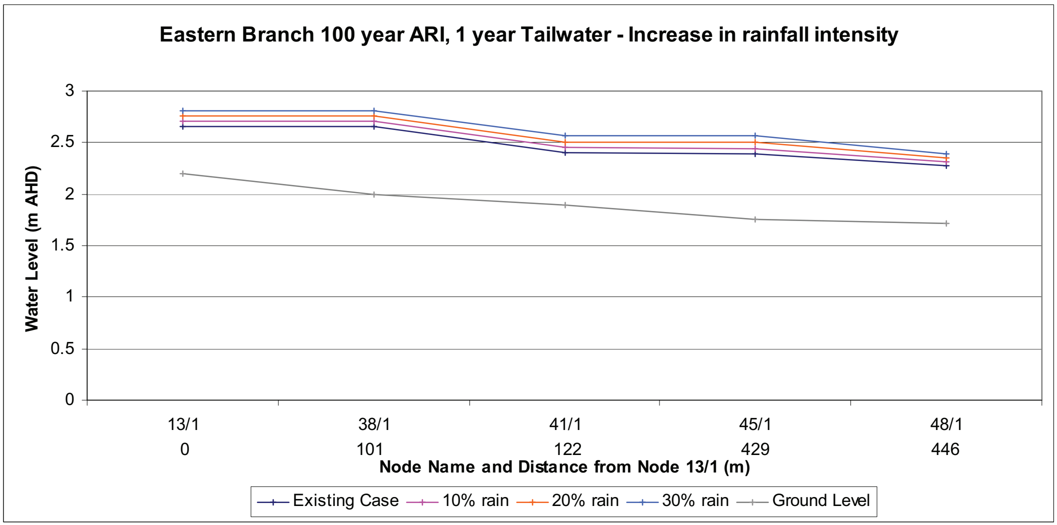
Sea Level Rise	+0.0m				+0.18m				+0.55m				+0.91m			
Node	19/1	18/3	13/6	13/3	19/1	18/3	13/6	13/3	19/1	18/3	13/6	13/3	19/1	18/3	13/6	13/3
Existing Hydrograph 100y rain	1.95	2.02	2.12	2.55	1.95	2.02	2.12	2.55	2.08	2.1	2.13	2.55	2.23	2.25	2.27	2.55
100y rain 10%	2.05	2.10	2.16	2.61									2.27	2.30	2.33	2.62
100y rain 20%	2.13	2.17	2.21	2.67					2.20	2.23	2.27	2.67				
100y rain 30%	2.19	2.24	2.29	2.73	2.20	2.24	2.29	2.73					2.35	2.41	2.45	2.73
Existing Hydrograph 20y rain	1.87	1.92	1.99	2.35	1.99	2.01	2.04	2.35	2.21	2.21	2.21	2.38	2.58	2.59	2.6	2.6
20y rain 10%	1.92	1.98	2.05	2.41									2.59	2.60	2.61	2.62
20y rain 20%	1.97	2.02	2.10	2.51					2.26	2.27	2.29	2.52				
20y rain 30%	2.03	2.07	2.13	2.56	2.12	2.14	2.15	2.56					2.61	2.64	2.65	2.67

3.2 EASTERN BRANCH

3.2.1 Scenario 1 – 100 year ARI Rainfall Intensity Combined with 1 year ARI Baywater Level

Graph 7 shows the effect of an increasing rainfall intensity through the long-section profile of the eastern branch from nodes 13/1 (uppermost node in the drainage channel) to 48/1 (southern-most node which is directly adjacent to the proposed development). Results for the eastern branch of the model are over a shorter distance than those displayed for the western branch, as the eastern branch of the model is primarily along the established retirement villages.

Graph 7 shows the effect of an increase in rainfall intensity. In the high climate change scenario, flood levels increase by an average of 0.15 m.

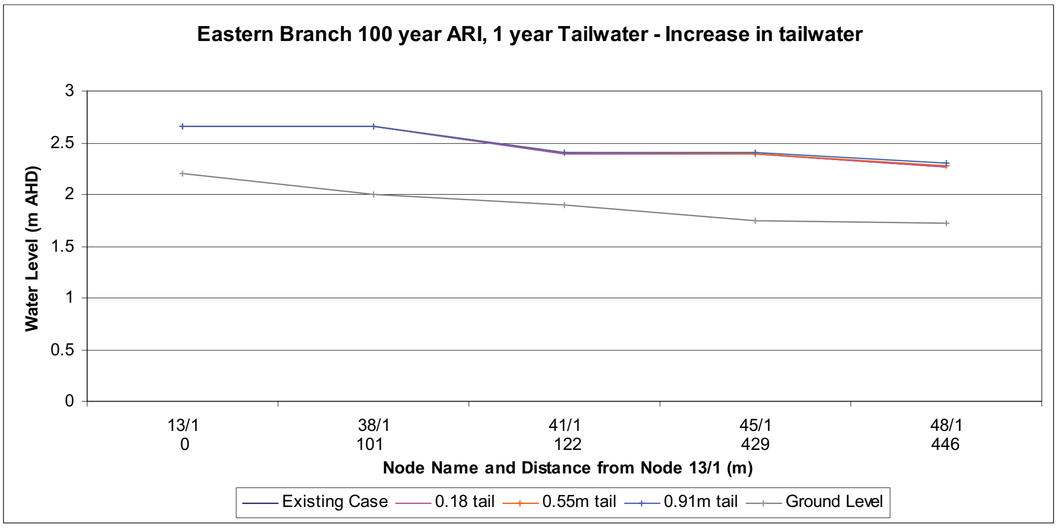


Graph 7. Scenario 1, Effect of Increased Rainfall on Eastern Branch

The effect of increased rainfall intensities can be summarised below:

- The effect of a 10% increase in rainfall intensity is an increase of flood levels by an average of 0.05 m;
- The effect of a 20% increase in rainfall intensity is an increase of flood levels by an average of 0.10 m; and
- The effect of a 30% increase in rainfall intensity is an increase of flood levels by an average of 0.15 m.

Graph 8 shows the effect of an increasing tailwater along the eastern branch of the model. The increase in tailwater has little effect on the eastern branch, the largest increase is by 0.06 m in the high climate change scenario.

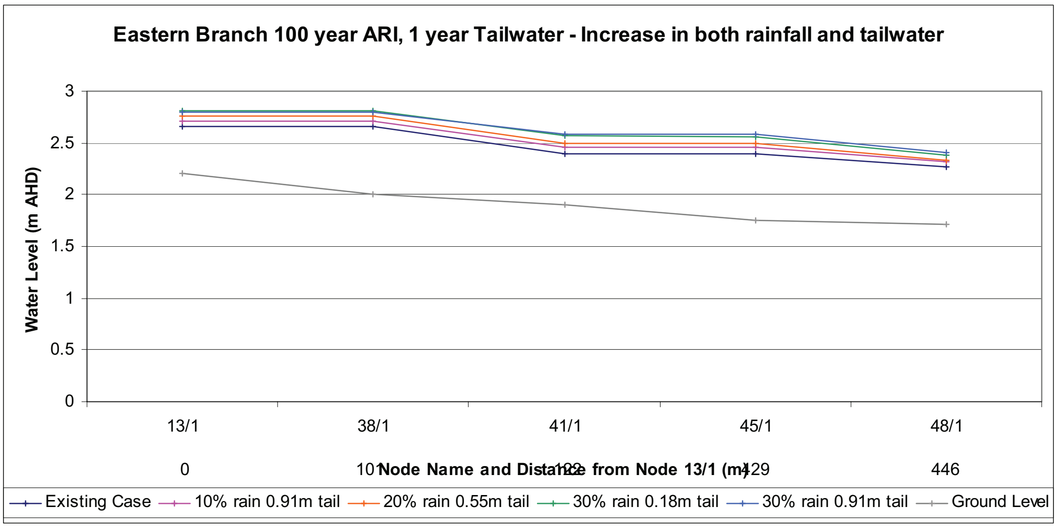


Graph 8. Scenario 1, Effect of Increased Tailwater on Eastern Branch

The effect of increased tailwater is summarised below:

- The 0.18 m and 0.55 m increases in tailwater do not affect flood levels on the eastern branch within proposed development; and
- The effect of a 0.91 m tailwater increase is an increase in flood levels on the north-eastern edge of the development by an average of 0.01 m, the greatest increase is by 0.06 m at node 48/1.

Graph 9 shows the effect of a combination of joint occurrences where there is both increased rainfall and increased tailwater. As there is very little tidal influence on the flood levels on the eastern branch, the results of the combined climate change affects is dominated by the increase in rainfall intensity. Increasing the rainfall intensity and tailwater level resulted in increased flood levels across the development by an average of 0.16 m under the high climate change scenario.



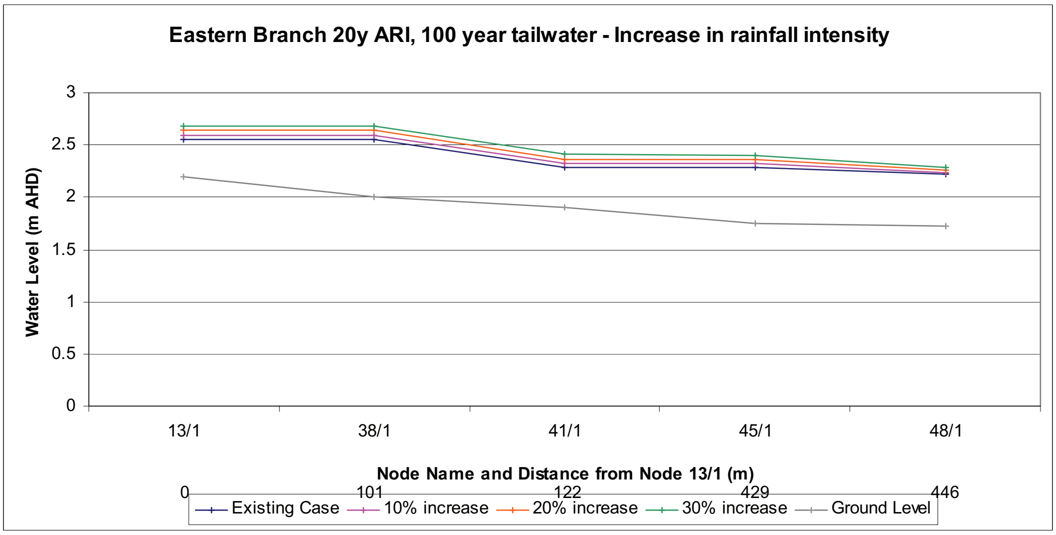
Graph 9. Scenario 1, Effect of Increasing both Rainfall Intensity and Tailwater on Eastern Branch

The effect on the flood levels in the various scenarios is summarised below:

- 10% rain 0.91 m tail: Increase in flood levels by an average of 0.05 m;
- 20% rain 0.55 m tail: Increase in flood levels by an average of 0.10 m;
- 30% rain 0.18 m tail: Increase in flood levels by an average of 0.15 m; and
- 30% rain 0.91 m tail: Increase in flood levels by an average of 0.16 m.

3.2.2 Scenario 2 – 20 year ARI Rainfall Intensity Combined with 100 year ARI Baywater Level

Graph 10 shows the effect of an increasing rainfall intensity on the eastern branch for Scenario 2. The results illustrate an increase in flood levels across the development by an average of 0.12 m under the highest increase in rainfall intensity.

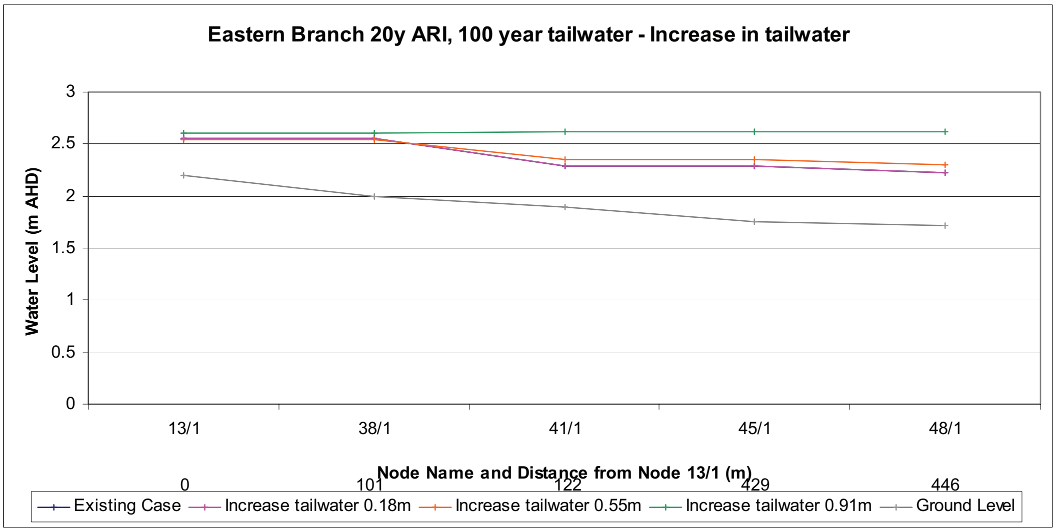


Graph 10. Scenario 2, Effect of Increased Rainfall on Eastern Branch

The effect of increased rainfall intensities can be summarised as:

- The effect of a 10% increase in rainfall intensity, is an increase of flood levels by an average of 0.04 m;
- The effect of a 20% increase in rainfall intensity, is an increase of flood levels by an average of 0.08 m; and
- The effect of a 30% increase in rainfall intensity, is an increase of flood levels by an average of 0.12 m.

Graph 11 shows the effect of an increasing tailwater along the eastern branch of the model in Scenario 2. Increasing the tailwater level resulted in increased flood levels across the development by a maximum of 0.40 m.

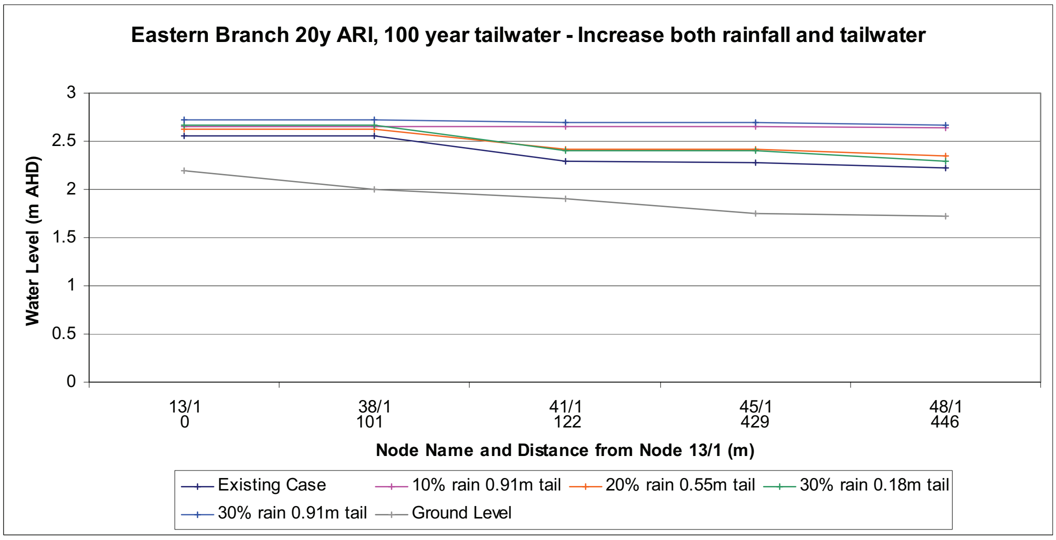


Graph 11. Scenario 2, Effect of Increased Tailwater on Eastern Branch

The effect of increased tailwater for the various tailwaters is summarised as:

- The effect of a 0.18 m tailwater increase has no effect on flood levels on the north-eastern side of the proposed development;
- The effect of a 0.55 m tailwater increase is an increase in flood levels from node 41/1 to 48/2 by 0.06-0.08 m; and
- The effect of a 0.91 m tailwater increase is an increase in flood levels along the selected nodes from 0.06 to 0.40 m.

Graph 12 shows the effect of a combination of joint occurrences where there is both increased rainfall and increased tailwater. Increasing the rainfall intensity and tailwater level resulted in increased flood levels across the development by up to 0.44 m.



Graph 12. Scenario 2, Effect of Increasing both Rainfall Intensity and Tailwater on Eastern Branch

The effect on the flood levels in the various scenarios is summarised below:

- 10% rain 0.91 m tail: Increase in flood levels by 0.10 to 0.41 m;
- 20% rain 0.55 m tail: Increase in flood levels by 0.08 to 0.14 m;
- 30% rain 0.18 m tail: Increase in flood levels by an average of 0.12 m; and
- 30% rain 0.91 m tail: Increase in flood levels by 0.17 to 0.44 m.

Table 2 is a summary of water levels on the eastern branch for the scenarios that were modelled. Node 8/1 was not included in the modelling results presented in Graphs 7-12, but is on the south eastern edge of the proposed development.

Table 2. Summary of Water Levels for Eastern Branch

Sea Level Rise	+0.0m			+0.18m			+0.55m			+0.91m		
Node	8/1	48/1	13/1	8/1	48/1	13/1	8/1	48/1	13/1	8/1	48/1	13/1
Existing Hydrograph 100y rain	2.59	2.27	2.66	2.63	2.27	2.66	2.65	2.28	2.66	2.65	2.3	2.66
100y rain 10%	2.63	2.31	2.71							2.69	2.32	2.71
100y rain 20%	2.67	2.35	2.76				2.71	2.34	2.76			
100y rain 30%	2.74	2.39	2.81	2.76	2.39	2.81				2.77	2.41	2.80
Existing Hydrograph 20y rain	2.49	2.22	2.55	2.58	2.22	2.55	2.61	2.3	2.55	2.68	2.62	2.61
20y rain 10%	2.54	2.24	2.59							2.68	2.63	2.65
20y rain 20%	2.61	2.26	2.64				2.60	2.34	2.63			
20y rain 30%	2.63	2.29	2.68	2.58	2.29	2.67				2.68	2.66	2.72

4. DISCUSSION AND CONCLUSIONS

The Draft Water Management Report for Myall River Downs (2006) recommended that roads be designed at 300 mm above the 100 year ARI flood level and floor levels set at 500 mm above the 100 year ARI flood level. Results from the climate change sensitivity analysis show an increase in flood levels by greater than 300 mm and 500 mm as per the modelled events presented in **Table 3**. The combination of increased flood levels from both scenarios 1 and 2 are presented in Figures 22 and 23 for the highest level of climate change (30% increase in rainfall combined with a 0.91 m increase in sea level) and moderate climate change (20% increase in rainfall combined with 0.55 m increase in sea level).

Table 3. Events Causing Flood Level Increases Greater than 300 mm and 500 mm in the 100 year ARI event

	Scenario 1 **100 year ARI, 1 year Tailwater**	**Scenario 2** **20-year ARI, 100 year Tailwater**	**Combination of Maximum Levels from Scenarios 1 and 2**
Greater than 300mm increase	0.91 m increase tailwater, with rainfall intensity increase of 10% or above	0.55 m increase tailwater, with and without rainfall intensity increases 0.91 m increase tailwater, with and without rainfall intensity increases	Max water levels, scenarios 1 and 2 medium level climate change (20% increase rainfall, 0.55 m increase in tailwater) Max water levels, scenarios 1 and 2 high level climate change (30% increase rainfall, 0.91 m increase in tailwater)
Greater than 500mm increase	Nil	0.91 m increase tailwater with and without rainfall increases	Max water levels, scenarios 1 and 2 high level climate change (30% increase rainfall, 0.91 m increase in tailwater)

From the results in **Table 3**, the effect of increasing the high tailwater in Scenario 2 caused a greater increase in flood levels for the proposed development than the effect of increasing the rainfall intensity.

The low level of tailwater increase (0.18 m) did not increase flood levels by greater than 300 mm on the proposed development for either of the scenarios, nor did the increase in rainfall intensity by 10-30% (in isolation of tailwater increase).

As Scenario 1 has a low tailwater (1 year ARI), increasing the tailwater by 0.18-0.91 m did not have as much as an effect as the same level of increase in Scenario 2.

Flood levels in Scenario 1 were increased by greater than 300 mm but less than 500 mm in the occurrence of a high level of climate change in sea levels coupled with an increase in rainfall intensity of 10% or above.

Flood levels in Scenario 2 increased by greater than 300 mm with a medium level increase in tailwater. Flood levels increased by greater than 500 mm with a high level increase in tailwater.

The climate change sensitivity analysis shows that the dominant factor in flooding at the proposed development is the receiving bay water level.

Figures 22 and **23** were compared to Figure 4 of the Draft Water Management Report 2006. Figure 4 from the 2006 report illustrated the higher water level at each node from both Scenarios 1 and 2, representing the resultant 100 year ARI water levels. The comparison found that under a medium level of climate change (i.e. +0.55 m tailwater with 20% rainfall), the flood levels without climate change are predicted to increase by less than 300 mm, which is less than the freeboard to road surface levels.

Under a low level of climate change, road inundation and flooding of habitable floors would not occur with the recommended freeboards stated earlier.

A high level of climate change (i.e. +0.91 m tailwater with 30% rainfall) would cause an increase in flood levels ranging from 140 mm at the upstream site boundary to 660 mm at the lower end of the site. Increases above 300 mm would inundate roads and affect evacuation procedures, however habitable floor levels would be a further 200 mm above this level. Increases above 500 mm would cause flooding of habitable floors set at 500 mm above the predicted flood levels without climate change, which would cause damage to properties.

Hence, for housing within the development to accommodate the most extreme level of climate change assessed (i.e. +0.91 m tailwater with 30% increased rainfall), it would require an increase of freeboard for the floor levels from the current value of 500 mm to 660 mm for lower lying areas.

In conclusion, we recommend an additional 150 mm of freeboard (i.e. 650 mm total) for habitable floors in areas where the 100 year ARI flood level was predicted to be RL 2.3 m AHD or below without climate change. In higher areas, where the flood level was predicted to be RL 2.4 m AHD or above, the predicted maximum increase was approximately 300 mm or less, which would be accommodated by the respective road and floor freeboards.

Please do not hesitate to contact either Mark Tooker or myself should you require anything further.

Regards,
WorleyParsons

Fiona COE
Executive Engineeer, Urban Infrastructure

Figure 1. Model Layout with Node Names

Figure 2. Peak Water Levels, Scenario 1 Increase in Rainfall Hydrograph 10%

Figure 3. Peak Water Levels, Scenario 1
Increase in Rainfall Hydrograph 20%

Figure 4. Peak Water Levels, Scenario 1
Increase in Rainfall Hydrograph 30%

Figure 5. Peak Water Levels Scenario 1
Increase in Tailwater 0.18 m

Figure 6. Peak Water Levels, Scenario 1
Increase in Tailwater 0.55 m

Figure 7. Peak Water Levels, Scenario 1 Increase in Tailwater 0.91 m

Figure 8. Peak Water Levels, Scenario 1
Increase in Rainfall 10%
Increase in Tailwater 0.91 m

Figure 9. Peak Water Levels, Scenario 1
Increase in Rainfall 20%
Increase in Tailwater 0.55 m

Figure 10. Peak Water Levels, Scenario 1
Increase in Rainfall 30%
Increase in Tailwater 0.18 m

Figure 11. Peak Water Levels, Scenario 1
Increase in Rainfall 30%
Increase in Tailwater 0.91 m

Figure 12. Peak Water Levels, Scenario 2
Increase in Rainfall Hydrograph 10%

Figure 13. Peak Water Levels, Scenario 2 Increase in Rainfall Hydrograph 20%

Figure 14. Peak Water Levels, Scenario 2
Increase in Rainfall Hydrograph 30%

Figure 15. Peak Water Levels, Scenario 2 Increase in Tailwater 0.18 m

Figure 16. Peak Water Levels, Scenario 2
Increase in Tailwater 0.55 m

Figure 17. Peak Water Levels, Scenario 2
Increase in Tailwater 0.91 m

Figure 18. Peak Water Levels, Scenario 2
Increase in Rainfall 10%
Increase in Tailwater 0.91 m

Figure 19. Peak Water Levels, Scenario 2
Increase in Rainfall 20%
Increase in Tailwater 0.55 m

Figure 20. Peak Water Levels, Scenario 2
Increase in Rainfall 30%
Increase in Tailwater 0.18 m

Figure 21. Peak Water Levels, Scenario 2
Increase in Rainfall 30%
Increase in Tailwater 0.91 m

Figure 22. Maximum Peak Water Levels,
Combination of Scenarios 1 and 2
Increase in Rainfall 20% and Increase in Tailwater 0.55 m

Figure 23. Maximum Peak Water Levels, Combination of Scenarios 1 and 2 Increase in Rainfall 30% and Increase in Tailwater 0.91 m

Appendix 3 - WorleyParsons' Response to BMT WBM Review of Draft Water Management Strategy (3rd March 2009)

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Crighton Properties Pty Ltd
PO Box 3369
Tuggerah NSW 2259

Attention Peter Childs

Dear Peter,

MYALL RIVER DOWNS, TEA GARDENS - RESPONSE TO REVIEW OF FLOODING, STORMWATER AND GROUNDWATER ASSESSMENTS

We are writing in response to the letter from Mark Wainwright of BMT WBM, which reviewed the flooding, stormwater and groundwater assessments (dated 22/09/08) for Myall River Downs, Tea Gardens. The flooding and stormwater assessments that were reviewed by BMT WBM were prepared by WorleyParsons - *Myall River Downs Water Management Report July 2006 (issued by Patterson Britton and Partners, now WorleyParsons)* and a subsequent letter (11/8/08) which addressed the Document *Practical Consideration of Climate Change (DECC, 2007).* Groundwater assessments were prepared by Parsons Brinkerhoff and will not be responded to by WorleyParsons.

A conference call was held between Mark Tooker, Jenny Robertson, Mark Wainwright and myself on 7th November, 2008 whereby each of the 46 points relating to flooding and groundwater within the letter were reviewed and where necessary, we agreed upon information to be provided to Council for further clarification. From herein we have provided a summary of our discussion on each of the point, and, where relevant, we have also provided additional information.

1. It is understood that the hydrologic and hydraulic models for the site were developed utilising the MOUSE software. The MOUSE models were not provided for review and therefore our comments are based specifically on the model inputs and outputs, and data provided in the WP reports.

No action required.

2. The local catchments for the flooding assessment were assessed by WP and are presented in Figure 2 within their 2006 report. The MOUSE model developed included consideration of both internal and external site catchments. The estimated subcatchment areas, extents and model configuration appear reasonable from the provided data.

No action required.

3. Design rainfall IFD data were adopted from Tea Gardens for the site and this is considered to be appropriate.

No action required.

4. *The hydrologic parameters adopted within the MOUSE models for the existing and developed scenarios were the default model parameters. Without additional site specific data, this appears to be a reasonable approach for the existing scenario. Although, it is considered that the adopted parameters for the developed scenario may warrant further consideration. The adopted parameters assume a large infiltration soil type. Following development it is considered likely that infiltration may be reduced within the developed areas due to different soil characteristics, filling and compaction of the imported soils and this may warrant adoption of parameters more representative of a lower infiltration capacity soil for the developed scenario.*

Hydrologic modelling results were reviewed to confirm that the generated flows were appropriate, these were checked against Rational Method calculations for individual subcatchments to confirm they were within the acceptable range. Hence it is considered that the infiltration rates are reasonable and this was agreed to by WBM BMT.

5. The peak flows estimated by the MOUSE model were checked by WP against Rational Method estimates for a selection of the modelled sub-catchments and assessed to be reasonable. This is considered to be a reasonable approach for checking model estimates. It is considered that a comparison of the MOUSE and Rational Method estimated peak flows at the catchment outlet should also be undertaken and presented within the report.

The comparison of the MOUSE model results with Rational Method calculations at the catchment outlet would not be relevant considering the storage effect of the proposed measures. Hence, comparisons of MOUSE and the rational method were only undertaken for a selection of individual subcatchments. This was considered reasonable by WBM BMT.

6. The WP report does not include a summary of estimated 20yr and 100yr ARI flows at key locations along the main watercourses within the site for both the existing and developed conditions. Peak flows are presented in the Appendix A of the WP report for individual sub-catchments, but cumulative flows at critical locations along the eastern and western branches were not provided. Critical locations would include culverts/road crossings and discharge points from the site into the adjacent wetlands. It is considered that this information should be provided within the report.

Peak flows at critical locations are provided in **Table 1** and also on Figure 1, attached.

Table 1 Cumulative Flows for Scenarios 1 and 2

Node References	Description	Scenario 1 100-year ARI Rainfall, 1-year ARI Tailwater		Scenario 2 20-year ARI Rainfall, 100-year ARI Tailwater	
		Min	Max	Min	Max
9/1 to 12/1	3x1500Wx450H RCBCs discharge to wetland from approved development	0.00	4.52	-0.01	3.98
Western Branch					
2/1 to 5/1	3x1500Wx450H RCBCs from wetland to swale	-1.35	7.02	-1.12	6.26
13/3	Western branch	0.00	11.75	0.00	8.08
15/1 to 18/1	3x1500Wx450H RCBCs at road crossing on western branch	-1.41	2.62	-1.73	1.94
19/1 to 22/1	3x1500Wx450H RCBCs at southern most road crossing on western branch, discharge to wetland	0.00	4.59	-0.85	3.78
Eastern Branch					
38/1 to 41/1	1x1800Wx600H RCBC at northern most road crossing on eastern branch	0.00	1.40	0.00	1.03
45/1 to 48/1	2x1800Wx600H RCBCs at road crossing on eastern branch	0.00	2.46	0.00	1.70
51/1 to 54/1	3x1800Wx600H RCBCs at road crossing on eastern branch	0.00	4.42	-0.04	3.58
23/1 to 26/1	3x1200Wx450H RCBCs at road crossing on eastern branch, discharge to wetland	0.00	4.48	-0.03	3.81
54/5 to 54/6	Discharge to wetland	-1.55	6.43	-6.96	5.60

7. The model boundary conditions included two joint probability scenarios. The first scenario included consideration of a 100-year ARI catchment event combined with a 1-year ARI receiving water event (RL 1.26 m AHD). The second scenario included consideration of a 20-year ARI catchment event combined with a 100-year ARI (RL 1.69 m AHD) receiving water level. These boundary condition scenarios were based upon earlier estimates in the Port Stephens Flood Study (Manly Hydraulic Laboratory, 1997) and these are appropriate for the site (for standard practice in 2006)

No action required.

8. The WP reports do not present existing scenario design flood level estimates for the site. The modelling appears to have focused on developed scenario flooding and ensuring that these flows can be accommodated within proposed drainage corridors. The assessment of the existing flood levels is important to satisfy Council's LES assessment requirement that the proposed development would not have an impact on upstream/adjacent development during the 1% AEP design event and an extreme event.

Existing flood behaviour has not been modelled due to the likely impacts being limited to the development site. An existing conditions model was not created, however a qualitative assessment of the likely upstream impacts was undertaken.

The surface level of the lots of the industrial area which back on to the proposed development is approximately RL 3.75 m AHD. The industrial area would drain into the channel and basin at the northern boundary of the proposed development, which would have an invert of approximately RL

2.60 m AHD. The proposed channel would continue in south then bifurcate at node 13/1 (RL 2.20 m AHD). The proposed development in the vicinity of the upstream site boundary includes:

- A wide flowpath for flood conveyance, and
- Creation of a new wetland (including excavation).

Therefore it was considered that the development would not negatively impact on flooding in the industrial land.

In addition to the above information, Figure 3-6, *100-year ARI Flood Envelope* from the Parsons Brinckerhoff LES (Volume 2, October 2003) has been reviewed. It shows the flood level at the boundary of the industrial estate under existing conditions as RL 3.35 m AHD. It also shows that under existing conditions, the 100-year ARI flood level does not extend from Myall River Downs into the industrial estate.

WorleyParsons' MOUSE model for the proposed development predicts a flood level of RL 2.93 m AHD at the boundary to the industrial estate. Although comparison of flood levels which have been generated from different software is not generally recommended, as the difference in flood levels for the two scenarios is 0.42 m, WorleyParsons is confident that the proposed development would not be creating additional flooding problems upstream of the subject site.

9. *Estimated 20yr and 100yr flood levels are provided in the 2006 and 2008 WP reports. For the purposes of this assessment it has been assumed that the predicted flood levels presented in the 2008 report supersede the modelling results in the 2006 report. Although, we understand that the methodology applied to build the 2006 report flood models was adopted for the 2008 report with only the design rainfall input and downstream boundary conditions modified.*

The 2008 report provides supplementary information to the 2006 report. The 2008 modelling was based on the model used for the 2006 report, with changes to the rainfall intensities and tail water conditions. The base case (without changes to rainfall intensity or tail water conditions) flood levels for the proposed development (from the 2006 report) did not change, but were compared with the climate change scenarios in the 2008 report. No action required.

10. Figures were provided in the 2008 report showing the estimated flood levels for the various climate change scenarios. The image resolution of these figures was low and values presented were illegible. Comments in this review are based upon the longitudinal flood profiles provided in the 2008 report which have been considered with the MOUSE node layout provided in Figure 1 of the 2006 report. It was assumed that the MOUSE node layout was the same for both the 2006 and 2008 models.

The model and node layout in MOUSE was the same for both the 2006 and 2008 models. No action required.

11. Additional modelling was undertaken by WP to consider the recommendations of DECC in their guideline document "Practical Consideration of Climate Change, 2007." Consideration of these recommendations resulted in the receiving water level boundary conditions and rainfall *intensities being increased and the models revised. WP prepared additional model runs for both the 20-year and 100-year ARI scenarios to consider the impacts of climate change on the 2006 estimated flood levels within the site. The additional scenarios modelled for the 20-year and 100-year ARI design events included:*

- *Existing rainfall intensities, 0.18 m, 0.55 m and 0.91 m increase in receiving water boundary condition;*
- *10%, 20% and 30% increase in rainfall intensities, existing receiving water boundary condition;*
- *10% increase in rainfall intensity, 0.91 m increase in receiving water boundary condition;*
- *20% increase in rainfall intensity, 0.55 m increase in receiving water boundary condition;*
- *30% increase in rainfall intensity, 0.18 m increase in receiving water boundary condition; and*
- *30% increase in rainfall intensity, 0.91 m increase in receiving water boundary condition.*

It is considered that the additional combinations of climate change scenarios modelled by WP satisfies the intent of the DECC guideline recommendations.

No action required.

12.WP concluded that the most dominant factor for flooding associated with the simulated climate change scenarios within the site was the elevated downstream water level boundary condition. Increased rainfall intensities only had a minor impact on estimated flood levels in the upper most reaches of the site for these scenarios. These conclusions seem reasonable.

No action required.

13. WP has proposed revision of the freeboard requirements for the site based on the most extreme level of climate change assessed (30% increase in rainfall intensity, 0.91m increase in the downstream water level boundary condition (100yr ARI receiving water level)). WP has recommended that the minimum flood planning level (minimum floor level) be set approximately equivalent to the estimated flood levels for the most extreme climate change scenario modelled in the lower reaches of the floodways. In the upper reaches where the predicted increase in flood level was less than 300mm WP has recommended that the previous freeboard and flood planning levels be adopted. It is our understanding that in addition to potential climate change impacts, freeboard includes allowance for factors including uncertainties with the modelling approach / input data, local factors and future floodplain modifications. Based on the WP flood level estimates, it is our opinion that the minimum floor level requirement should be increased by significantly more than has been recommended to allow for these additional uncertainties. The magnitude of the additional freeboard required would need to be confirmed by Council in accordance with their flood planning policy.

Adoption of a worst case scenario for sea level rise over the next 100 years given the uncertainty in the prediction and the complexity of the process represents an inefficient use of resources and an unnecessary burden on the community.

Adaptive environmental management is an approach which balances the risk and environmental/social costs to the community. The risk associated with sea level rise is the potential for increased flood levels and therefore a potential for increased flood damages if residential floor levels are inundated. The social and economic costs of increasing habitable floor levels is the increased costs to fill the land mass or raise the dwellings while the social cost is a reduced amenity if the houses are raised above the ground level or with filling, the development provides a reduced visual and recreational amenity with respect to the drainage corridors and surrounding land.

The DECC Climate change guidelines do not recommend adoption of the worst case sea level rise, rather it adopts an adaptive environmental management approach which requires a sensitivity assessment of the risk by reviewing the impact of the range of sea level rise predictions.

The most adaptive environmental management approach for this risk is to set the habitable floor levels using the most likely sea level rise prediction and ensure that even with the worst case sea level rise, the increase in flood levels is accommodated readily within the freeboard allowance. In this way the flood damages are not increased and additional social and economic costs are not incurred for the community. This would provide the best use of resources while appropriately managing risk. This is the approach taken in the WP recommendation for habitable floor levels

The flood level and associated flood planning level could be reviewed every 10 years (i.e. 10 times in a 100-year planning period) to ensure adopted floor levels are appropriate.

Climate change modelling show that under a medium level of climate change (i.e. +0.55 m tailwater with 20% rainfall), the flood levels are predicted to increase by less than 300 mm, which is less than the freeboard to road surface levels.

A high level of climate change (i.e. +0.91 m tailwater with 30% rainfall) would cause an increase in flood levels ranging from 140 mm at the upstream site boundary to 660 mm at the lower end of the site. Increases above 300 mm would inundate roads and affect evacuation procedures, however habitable floor levels would be a further 200 mm above this level. Increases above 500 mm would cause flooding of habitable floors set at 500 mm above the predicted flood levels without climate change, which would cause damage to properties.

Hence, for housing within the development to accommodate the most extreme level of climate change assessed (i.e. +0.91 m tailwater with 30% increased rainfall), it would require an increase of freeboard for the floor levels from the current value of 500 mm to 660 mm for lower lying areas.

In conclusion, we recommend an additional 150 mm of freeboard (i.e. 650 mm total) for habitable floors in areas where the 100 year ARI flood level was predicted to be RL 2.3 m AHD or below (based on the results presented in Figure 4 of the 2006 report). In areas of higher elevation, where the flood level was predicted to be RL 2.4 m AHD or above, the predicted maximum increase was approximately 300 mm or less, which would be accommodated by the respective road and floor freeboards.

14. The flood management strategy includes a proposal to excavate along the key drainage pathways by up to 2m to reduce flood levels and reduce the extent of filling required in the lower *sections of the site. Based on the revised design scenario modelling results that incorporate climate change considerations, it is expected that additional excavation would have minimal impact on reducing flood planning levels which are dominated by the receiving water level. It is considered that the proposal to excavate may have impacts on the groundwater flow/quality and the performance of any stormwater quality measures provided in the excavated channel.*

Potentially, excavation could be up to 3 m in areas where permanent storage for constructed wetlands is to be formed below the base of the channel. The wetlands themselves are to be 1 m in depth.

The effect of excavation on groundwater flow quality should be commented upon by a groundwater specialist. We do not anticipate the groundwater would affect the performance of stormwater quality treatment measures.

15. It is unclear if in principle approval from DWE to excavate within a watercourse under the Water Management Act has been received. This will be important to ensure the proposed flood and water quality management strategies incorporating excavation of the watercourses are achievable.

Discussions are ongoing with DWE.

16. Limited information is provided in the report regarding the dimensions of the modelled channels. Depths and side slopes are provided, but no details on the modelled widths are provided. The report indicates that 'channel widths were estimated from the masterplan'. It is considered that this information should be provided in the report.

Channel dimensions for the model are provided in **Appendix A**. It is further noted that masterplanning is preliminary, but the channels widths must comply with the requirements dictated by flood modelling.

17. Constructed wetlands are proposed to be formed within the invert of the main channel. The constructed wetlands were modelled in MUSIC with a 1m deep permanent storage and 0.3m deep extended detention storage. Based on Diagram 2.4 presented in the WP report, it appears that provision of the constructed wetlands within the main channel has not been incorporated into the hydraulic models.

The 1 m deep permanent storage in the constructed wetlands would be provided below what we have modelled as the invert of the channel (i.e. the what is shown as the ground level in the hydraulic model would be the still water level of the wetlands). WorleyParsons has incorporated the extended detention as a part of this review, the revised levels are given in the **Table 2**, and also displayed in Figure 2 (attached).

Table 2 Change to WL from Incorporation of Extended Detention in Hydraulic Model

	20y ARI rain		100y ARI rain		Max Results		
Node	2006	Nov-08	2006	Nov-08	Max 2006	Max Nov 2008	Nov 2008 -2006
1/1	2.85	2.870	2.91	2.93	2.91	2.93	0.03
13/1	2.55	2.49	2.66	2.68	2.66	2.68	0.02
13/2	2.44	2.482	2.61	2.63	2.61	2.63	0.02
13/3	2.35	2.411	2.55	2.57	2.55	2.57	0.03
13/4	2.20	2.240	2.39	2.41	2.39	2.41	0.02
13/5	2.11	2.128	2.29	2.30	2.29	2.30	0.01
13/6	1.99	1.998	2.12	2.13	2.12	2.13	0.01
5/1	1.96	1.981	2.08	2.12	2.08	2.12	0.04
15/1	1.99	1.997	2.12	2.13	2.12	2.13	0.01
18/1	1.93	1.944	2.03	2.05	2.03	2.05	0.03
18/2	1.93	1.943	2.02	2.05	2.02	2.05	0.02
18/3	1.92	1.939	2.02	2.04	2.02	2.04	0.02
18/4	1.92	1.931	2.00	2.03	2.00	2.03	0.02
6/1	1.92	1.931	2.00	2.03	2.00	2.03	0.02
18/5	1.91	1.927	2.00	2.02	2.00	2.02	0.02
7/1	2.19	2.190	2.25	2.25	2.25	2.25	0.00
18/6	1.89	1.901	1.97	1.99	1.97	1.99	0.03
19/1	1.87	1.879	1.95	1.97	1.95	1.97	0.03
22/1	1.69	1.693	1.28	1.28	1.69	1.69	0.00
38/1	2.55	2.562	2.66	2.68	2.66	2.68	0.02
41/1	2.29	2.304	2.40	2.41	2.40	2.41	0.01
45/1	2.28	2.300	2.39	2.41	2.39	2.41	0.01
48/1	2.22	2.228	2.27	2.28	2.27	2.28	0.01

Table 2 shows that the incorporation of extended detention through the model increases the water level by an average of 0.02 m. The level of increase ranges from 0.00 to 0.04 m.

The increased flood levels under climate change scenario modelling are likely to be similar with modelled results to be provided at a later date.

Long sections of the revised model are provided in **Appendix A**.

18. The drainage concept outlined in the 2006/2008 WP reports includes eastern and western branch lines that each commence at the north-eastern corner of the site. The western branch is aligned with an existing constructed drain that is proposed to be bifurcated just upstream of a former sand mine pit. A minor branch connects the main western branch to the sand mine pit. It appears that flow will initially be diverted to the former sand mine pit. Based on estimates in the LES, the sand mine pit has a capacity of approximately 300ML. Diversion of runoff into the former sand mine pit may impact on environmental flows to the adjacent wetlands. It is unclear if the harvestable rights for the catchment and potential impacts of the storage on environmental flows to the receiving wetlands have been assessed.

A site visit has confirmed that the existing drainage through the site does not discharge to the sand mine pit other than in severe events. As such, the low flow (minor) channel in the proposed development (as described above) would not have a direct connection with the sand mine pit, however, major flows would be directed to the former sand mine pit for attenuation.

The design of the interaction of the channels, proposed sandmine pit waterbody and low/high runoff rates would ensure that the existing environmental flows to wetlands were maintained. This would be achieved with appropriate flow diversion structures in the channels. No action required.

19. The WP reports have focused on the impacts on flood levels within the site following development. Impacts on existing adjacent upstream developments (e.g. industrial development, retirement village) were not assessed within the report.

Refer to comment on point 8.

20. The MUSIC program was applied to assess stormwater quality for the existing and future development scenarios. This program is considered to be the most appropriate currently available program for this type of assessment.

No action required.

21.The Developed (With Treatment) scenario aimed to achieve a no-net increase in annual pollutant loads discharged to the existing wetlands located to the south and west of the site. In addition to the strategy aimed to achieve the objective to reduce post development pollutant loads of TSS, TP and TN discharging the site by 80%, 45% and 45% respectively. The no-net increase and the 80/45/45 reduction objectives are consistent with current best practice and the objectives in Council's "Tea Gardens, Hawks Nest and Buladelah SMP."

No action required.

22. Flow targets to manage stream erosion and wetland hydrology (which was identified as being important to the Wallum Froglet habitat in the wetlands) are not proposed for the site. It is considered that flow objectives and targets should be set to address Council's requirement that 'discharge patterns are maintained' under developed conditions. This is considered to be particularly important for this site due to the apparent ecological sensitivity of the receiving wetlands.

In regard to the comment on stream erosion, given the extremely flat grades and series of wetlands, an environment of deposition rather than erosion is present and hence a stream erosion analysis is considered unwarranted.

In response to the issue of hydrology, environmental flows that discharge to the eastern corridor will be maintained. The flow regime to the west of the sand mine will also be maintained following development (see comment response to comment 18). The structures to ensure environmental flows are maintained would be designed in a more detailed study.

The annual flows along the eastern corridor to the Wallum Froglet habitat, were calculated utilising the MUSIC models. The models were configured to direct the external catchments along the eastern drainage corridor. Flows from the external catchments and also catchments B1 to B6 (inclusive) combine to produce an annual flow of 407.5 ML for the existing scenario and 397.4 ML for the developed scenario. Hence, the proposed development would maintain the existing flows through the habitat, and based on the MUSIC modelling, flows in the proposed development would not be significantly different to those in the existing scenario.

23. The impact of elevated receiving water levels on the ability of the ecology of the wetlands to adapt to climate change is also considered to be an important issue requiring consideration for this site. Following development, the reduced buffer width to the wetlands may limit the potential for migration of wetland habitats. This ultimately may be more significant to the long-term survival potential of wetland flora/fauna at this site than immediate hydrologic changes due to development.

It is possible that wetlands may migrate inland under elevated sea level conditions. However, this would depend on many variables such as soil conditions, surface slopes and the interaction between seawater and groundwater and is too complex to predict (*pers comm* Geoff Winning, Hunter Wetlands Research). It is recommended that a buffer area is retained, as per the current proposal.

24.Rainfall data were sourced from the Bureau of Meteorology pluviograph at Williamtown. This site is the nearest BoM pluviograph with a long term record and it is considered to be the best available site to use for modelling near Tea Gardens. It was estimated that the average annual rainfall for the site based on a nearby daily rainfall station located at Hawks Nest Forster is 1356 mm. Adoption of 6-minute time step data from the Williamtown station as representative of the site appears to be a reasonable approach due to the lack of nearby pluviographs.

No action required.

25. A one year period of rainfall data from the Williamtown station was adopted for the MUSIC models. It is considered that this short period is insufficient for simulating a range of event durations and intensities likely to be experienced at this site. A five year minimum modelling period is considered more appropriate for simulating longer term conditions. The adopted modelling period should include a sample of wet, dry and average rainfall years.

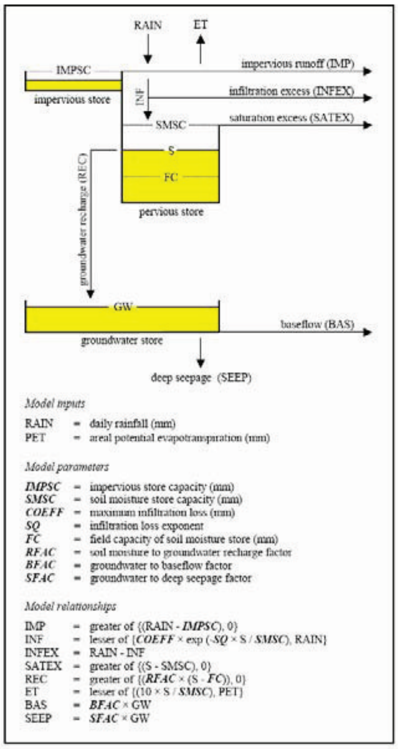
WorleyParsons has also run the MUSIC models with the five year period of rainfall data from 1/7/1959 to 31/6/1964 from the Williamtown station. The average rainfall for this period is 1326 mm/yr (Hawkes Nest is 1356 mm/yr, the previous modelled 1yr period was 1400 mm/yr). The rainfall input is from the Williamtown station, the dataset contains the highest recorded rainfall over a five-year period for the Williamtown station. As such, this is the most appropriate dataset to represent a 5-year period at Tea Gardens. The results are reported in response to items 37, 39 and 40.

26. Potential evapotranspiration data were sourced for the site from BoM data for Tea Gardens. The adopted values presented in the report are considered to be appropriate.

No action required

27. The rainfall-runoff parameters adopted in the MUSIC models were modified from the default values. It is considered that the adopted parameters may not appropriately represent the existing site hydrology. Although the estimated Cv of 0.21 for the site appears appropriate for the site characteristics, it is considered that the distribution of surface runoff and base flow that comprise the *total runoff for the site may not be reflective of the existing catchment conditions. It is considered that further justification for modifying the default rainfall-runoff parameters should be provided.*

The following diagram has been taken from the MUSIC v3.0.1 manual and represents the rainfall-runoff processes that occur through MUSIC.



MUSIC provides default parameters of soil storage capacity and field capacity which represent Brisbane soil conditions. Appendix A of the MUSIC manual (v3, 2005) presents typical values of the soil storage and field capacities for the Australian capital cities. The values adopted in the model are within the range presented for Sydney and Brisbane.

In the 2006 model, the daily deep seepage rate was increased from zero to one percent to acknowledge the recharge process which occurs on-site.

Further work on the groundwater mechanisms in the area may provide results indicating water loss to a deep groundwater store. As there is some uncertainty surrounding this issue, additional modelling was undertaken in order to quantify pollutant loads that are lost through the following mechanisms:

- Deep seepage losses from the groundwater store in both the existing and developed scenarios; and
- Seepage loss from infiltration basins in the developed scenario (infiltration basins were the only nodes to have seepage losses).

The additional modelling incorporated 0 % infiltration from the source nodes into deep seepage for both the existing and developed scenarios and a 0 mm/hr seepage in the infiltration basins modelled in the developed scenario (and other changes to the MUSIC models as listed throughout this letter).

The additional pollutant load in the water 'lost' to groundwater was determined by calculating the difference in flows (ML/yr) in both the 'with seepage' and 'without seepage' models for both existing and developed scenarios. This additional flow was then multiplied by the EMC values published by Duncan et al, for the dry weather concentrations of a Forest/Natural land-use. This approximates the expected characteristics of groundwater flows.

Unexpectedly, the results from MUSIC modelling based on the 1 year of rainfall data originally adopted indicate that there would need to be additional treatment, while the 5 year data set predicted no additional treatment required. Section 3.7.3 of Patterson Britton and Partners 2006 report states that infiltration areas of 25m^2 are to be located on each of the residential lots. Based on the 1 year of rainfall data used in the 2006 report, the infiltration areas would need to increase to 34m^2 through the majority of lots (all areas through the A-series of subcatchments). Infiltration areas through the B-series of subcatchments range from 20m^2 to 42m^2 and in C1 and C2 are 49 m^2 and 67 m^2 respectively.

Modifications (as summarised below and explained throughout the report) to the existing model result in an increase to the Cv from 0.21 to 0.30 (with 1% seepage) or an increase to 0.34 (no seepage). The Cv remains the same value for either 4% or 5% baseflow.

- 5-year rainfall period.
- The external catchments shown in Figure 2 of the 2006 report as 1/1_2, 1/1_4, 1/1_48, 1/1_3, 1/1_6 and 1/1_49 were incorporated into the existing model, as 25.34 ha of forested area (0% impervious) and 19.76 ha of industrial area (80% impervious). The external subcatchments were routed through subcatchment B1.
- Subcatchments A11, A16 and A19 were changed to have 10% forested area, 30% of the forested area was modelled as impervious to reflect the impervious nature of the waterbodies;
- Subcatchment A20 was changed to have 30% of the forested area as impervious (the previous model had 0% impervious).
- Subcatchments B2 and B3 were updated to have 20% impervious forested area and subcatchment B6 was updated to be 30% impervious (the previous model had 0% impervious for each catchment);
- Subcatchment A13 was changed to be 50% impervious (this is considered appropriate as the sand mine is partially full with rainwater), the previous model had 0% impervious; and
- In reviewing the subcatchments it was noted that the labels on Figure 5 of the 2006 report are incorrect. Figure 5 shows what is modelled and reported in the tables as D3, labelled as D1, and the subcatchment modelled as D1 incorporated into A13 (which is shown as 17.58 ha in size rather than 14.38 ha). We have re-issued Figure 5 (labelled Figure 3 for this document) with the correct labelling. The forested % of these catchments were also reviewed, with D2 set as 5% forested and D3 set as 0% forested.

The MUSIC model for the developed scenario was also updated to include the following:

- Trunk drainage catchments were modified to be 50% impervious, to incorporate the impervious nature of the permanent wetlands; and
- The impervious fraction of Subcatchment A13 was increased to 70%.
- The developed model was updated to have an impervious threshold of 1.7 mm.

In conclusion, the updated model with 5 year rainfall data, which restores the daily deep seepage rate to the default value 0% and infiltration rate to 0 mm/hr, shows that the treatment specified in the 2006 report is adequate.

28. The rainfall-runoff parameters adopted in MUSIC were estimated using one year of rainfall data. Estimating the pervious area parameters using a longer period (say five years minimum) with a mix of wet and dry years and a larger number of rainfall periods is considered to be more appropriate to ensure that the derived parameters are not based on a relatively small number of rainfall events. It is recommended that the estimated pervious area parameters be verified using a longer rainfall period to ensure that runoff from pervious surfaces is not overestimated for the existing scenario.

As explained in point 25, a five year period from 1/7/1959 to 30/6/1964 has now also been analysed, results are presented in response to items 37, 39 and 40. No further action required

29. An impervious threshold of 2.5mm has been adopted for impervious surfaces. This value appears slightly higher than typical practice. It is considered that a maximum value of 1.5mm would be more appropriate.

WorleyParsons has calculated the impervious threshold value based on a composite of various impervious surfaces, as listed below:

- Threshold for both road surfaces and paved areas of 2.5mm; and
- Threshold for roofs of 1mm.

Crighton Properties have advised that a typical lot would be 600 m^2 in area. A typical 3-bedroom single storey development is in the order of 250 m^2. Based on the assumption within MUSIC that the lots are 60% impervious, the lots would be comprised of 250 m^2 of roof area and 110 m^2 of paved surface. This equates to an impervious threshold of 1.5 mm for lot areas. In an urban environment of 80% lots and 20% road, the threshold increases to 1.7mm. The developed model was updated to have an impervious threshold of 1.7 mm.

The impervious threshold for the existing model has not changed from 2.5 mm for road surfaces, however, in areas containing a waterbody, the impervious threshold has been set to 0 mm.

In conclusion, the model representing the developed scenario has been updated to incorporate an impervious threshold of 1.7 mm., WP considers the impervious threshold in the existing scenario to be appropriate.

30. It appears that a model time step of 6 minutes was adopted for the models and this would be appropriate. Confirmation of the adopted time step interval should be provided.

We confirm that a six-minute time step was adopted.

31. Stormwater pollutant concentration parameters input to MUSIC were adopted from Stormwater Flow and Quality and the Effectiveness of Non-proprietary Stormwater Treatment Measures (Fletcher et al, 2004). Values are presented in the report and these appear to be the adopted storm flow concentrations. Adopted concentration parameters for base flow should also be provided in the report.

Baseflow parameters from *Fletcher et al, 2004* are provided in **Table 3**.

Table 3 Baseflow parameters used for the MUSIC modelling

	Pollutant Concentration *(mg/L)*		
	Suspended Solids	**Total Phosphorus**	**Total Nitrogen**
Land-use	*Dry weather concentration*		
Source Values			
Forested	6	0.03	0.3
General Urban	16	0.14	1.3
Rural	14	0.06	0.9
Local Existing Land Use			
Forested	6	0.03	0.3
Rural	14	0.06	0.9
Post-Developed Land Use			
Residential/ Industrial/ Eco-resort	16	0.14	1.3
Trunk Drainage	6	0.03	0.3
Open Space / Parkland/ Lake	14	0.06	0.9

32. The previous land uses (pine forest plantation, sand mining, waste disposal facility) within the site appear to have contributed to higher than typical concentrations of TP and TN in the groundwater (based on limited monitoring undertaken). Groundwater quality monitoring undertaken for the LES indicated the presence of elevated organic nitrogen concentrations which were attributed to past land uses. Although further monitoring data would be required to confirm, it is considered that the adopted TN and TP storm flow and base flow concentrations for modelling may be lower than the existing site conditions. Therefore the adopted concentrations for the existing scenario model may be conservative and this is considered to be a reasonable approach.

No action required.

33. The existing scenario model includes a number of sub-catchments within the site boundary comprising a total area of 202 ha. The estimated total catchment area within the site appears to be reasonable.

No action required.

34. Sub-catchments for the MUSIC modelling (which differ from the flooding assessment sub-catchments) are shown on Figure 5 (Catchment Plan) within the 2006 WP report. The configuration of the sub-catchments within the site appears reasonable. It is considered that the catchment plan should also include the sub-catchments in the forested area to the north of the site to appropriately simulate the on-line constructed wetlands that form a component of the developed (with measures) scenario.

The external catchments shown in Figure 2 of the 2006 report as 1/1_2, 1/1_4, 1/1_48, 1/1_3, 1/1_6 and 1/1_49 were incorporated into the existing model, as 25.34 ha of forested area (0% impervious) and 19.76 ha of industrial area (80% impervious). The external subcatchments were routed through subcatchment B1. Refer to the results in **Table 7**.

35. The modelled effective impervious proportion for the existing site was approximately 2%. This estimate appears to be reasonable based on the observed conditions of the site.

No action required.

36. The existing site was modelled as a combination of rural and forest source nodes. The proportion of forested area in each sub-catchment was estimated from aerial photography and these values are presented in T.3.5 in the report. It is our opinion that the adopted forested area proportions for some of the sub-catchments (primarily those south of the former sand mine) may be underestimated and there appears to be some inconsistency between sub-catchments (e.g. Sub-catchments D1 and D3). It is also considered that the adopted land uses along the drainage corridor should be similar between the existing and developed scenarios.

In response to the proportion of forested area within the subcatchments, from the review of the percentage breakdown of rural and forested area through the subcatchments, the following modifications were made to the MUSIC model:

- Subcatchments A11, A16 and A19 were changed to have 10% forested area, 30% of the forested area was modelled as impervious to reflect the impervious nature of the waterbodies;
- Subcatchment A20 was changed to have 30% of the forested area as impervious (the previous model had 0% impervious).
- Subcatchments B2 and B3 were updated to have 20% impervious forested area and subcatchment B6 was updated to be 30% impervious (the previous model had 0% impervious for each catchment);
- Subcatchment A13 was changed to be 50% impervious (this is considered appropriate as the sand mine is partially full with rainwater), the previous model had 0% impervious; and

- In reviewing the subcatchments it was noted that the labels on Figure 5 of the 2006 report are incorrect. Figure 5 shows what is modelled and reported in the tables as D3, labelled as D1, and the subcatchment modelled as D1 incorporated into A13 (which is shown as 17.58 ha in size rather than 14.38 ha). We have re-issued Figure 5 (labelled Figure 3 for this document) with the correct labelling. The forested % of these catchments were also reviewed, with D2 set as 5% forested and D3 set as 0% forested.

With regard to the adopted land uses along the drainage corridor and the differences between the existing and developed scenarios, the condition of the drainage corridor would change in the proposed scenario. The removal of cattle will improve the quality of runoff through the subcatchments, particularly in the area of the existing channel north of subcatchment A9.

Through the lower reaches of the site where the drainage corridor is in good condition, the functional riparian corridor will be widened.

37. The estimated existing average annual loads of TSS, TP and TN presented in T.3.6 within the report appear to be within the appropriate range for the existing site conditions. Although, it is considered that the recommended modifications to the existing scenario MUSIC model described above be undertaken to ensure that both the hydrology and pollutant concentration inputs are reasonable as these form the basis for the developed scenario models.

Pollutant loads from the revised MUSIC model for the existing scenario are presented in **Table 4**, incorporating the additions for groundwater-based pollutant loads. These are compared with the proposed loads in points 39 and 40.

Table 4 Annual Pollutant Export Loads (Existing State)

Scenario	Pollutant Load (kg/y)		
	Total Suspended Solids	Total Phosphorus	Total Nitrogen
Existing State (with 1% seepage)	60,900	144	1,400
Flow lost through seepage: 102 ML/y			
Existing State (incorporation of additional flows and pollutants generated from seepage)	61,512	147.1	1,430.6

38. The developed site was modelled adopting land use descriptions including trunk drainage, residential, lake, park, marina, eco-resort. The stormwater pollutant concentration parameters adopted for each of these land uses are presented in T.3.4 and these are considered appropriate.

No action required.

39. The total modelled effective impervious proportion for the developed site was approximately 45%. The adopted impervious fractions for each sub-catchment are presented in T.3.7 within the report and these typically appear to be slightly high (which is a conservative and therefore a *reasonable approach). It is considered that the sub-catchment imperviousness in Sub-catchment A13 (Lake) should be increased to allow for direct rainfall on the relatively large lake surface area. It is also considered reasonable to allow for a 20% 'impervious' proportion in the drainage corridors to allow for direct rainfall on the significant areas of wetland proposed.*

The MUSIC model for the developed scenario has been updated to include the following:

- Trunk drainage catchments were modified to be 50% impervious, to incorporate the impervious nature of the permanent wetlands; and
- The impervious fraction of Subcatchment A13 was increased to 70%.

Pollutant loads from the revised MUSIC model are presented in Error! Not a valid bookmark self-reference..

Table 5 Annual Pollutant Export Loads (Developed State)

Scenario	Pollutant Load (kg/y)		
	Total Suspended Solids	Total Phosphorus	Total Nitrogen
Developed State (No Treatment)	196,000	371	3,090
Flow lost through seepage: 60 ML/y			
Developed State (No Treatment, incorporation of flows lost through seepage)	196,360	372.8	3,108

40. The estimated existing average annual loads of TSS, TP and TN presented in T.3.8 within the report are considered to be within reasonable bounds for the developed site conditions. Although, it is considered that the recommended modifications to the developed scenario MUSIC model described above be undertaken to confirm that both the hydrology and pollutant concentration inputs are reasonable.

Pollutant loads from the revised MUSIC model are presented in **Table 6** and **Table 7**.

Table 6 Annual Pollutant Export Loads (Developed State)

Scenario	Pollutant Load (kg/y)		
	Total Suspended Solids	Total Phosphorus	Total Nitrogen
Developed State (with treatment)	20,300	94.6	1,180
Flow lost through seepage: 810 ML/y			
Developed State (with Treatment, incorporation of flows lost through seepage)	25,160	118.9	1,423

Table 7 Summary of Annual Pollutant Export Loads.

Scenario	Pollutant Load (kg/y)		
	Total Suspended Solids	Total Phosphorus	Total Nitrogen
Existing State	61,512	147.1	1,430.6
Developed State (No treatment)	196,360	372.8	3,108
Developed State (With Treatment)	25,160	118.9	1,423

NB All scenarios presented in Table 7 incorporate pollutants from flows lost to seepage.

41. Infiltration measures were simulated (as bioretention measures in MUSIC) to manage stormwater from future residential lots and public streets. The infiltration measures were simulated adopting a seepage loss of 54mm/hr and this has resulted in approximately 75% of surface runoff and base flow generated by the source nodes being 'lost' from the modelled system through infiltration. In addition to losing flow volume, the pollutant loads conveyed within this flow are also lost. The modelled flow for the existing scenario is approximately 580ML/yr and the developed (with treatment) scenario is approximately 365ML/yr. It is unlikely that the total runoff volume for the developed scenario can be reduced below existing conditions for the indicated water management strategy.

WorleyParsons agreed with BMT WBM that MUSIC simulates the initial filtration of the runoff to soil and provides a simplistic analysis of baseflow. However, it is considered that infiltration provides a key part of the water management strategy. The existing wetlands are supported by acid groundwater percolated through in-situ peat layers (*pers comm* Geoff Winning, Hunter Wetlands Research), therefore the infiltration is to be promoted under developed conditions to maintain this regime.

Through the update of the MUSIC models, the flow for the existing scenario is 998 ML/y and the developed (with treatment) scenario is 870 ML/y.

Although there is no model for ground water quality on the site, an investigation by Hunter Wetlands Research "Effect of Stormwater Basins on Water Quality in Frog Habitat in the Vicinity of Myall River Downs, Tea Gardens" (2008) was undertaken to determine the effect of the already constructed stormwater basins (constructed in 2000) at Myall River Downs and the adjoining Tea Gardens Grange. The investigation addressed concerns from Great Lakes Council that a further basin to be constructed for an aged-care facility at Myall River Downs may adversely affect nearby Wallum Frog habitat. The existing basins do not discharge surface water into the identified Wallum Frog habitat, and as such, the report addressed whether infiltration to groundwater from the basins affect groundwater or its surface water expression in the frog habitat. The report concluded that:

"Overall, the data indicate no evident impact on water quality within the Wallum Frog habitat area or other remnant habitat areas of water infiltrating into these areas from constructed stormwater basins.

Indeed, the quality of water within the stormwater basins at the time of sampling was of high quality, comparable to background levels."

Incorporation of pollutant loads from seepage in the infiltration basins and the daily deep seepage rate were also addressed in point 27, and in Tables 4-7.

In conclusion, results from the updated models including the incorporation of pollutant loads which were previously lost to infiltration, show that the water quality objectives for the runoff would still be achieved. No action required.

42. It is considered that the infiltration measure modelling approach has resulted in the discharged pollutant loads being significantly underestimated for the developed (with treatment) scenario. It is considered likely that infiltrated flow would contribute to groundwater recharge to the wetlands/constructed channels and also convey TSS and nutrient loads to the wetlands. Infiltrated flow and pollutant loadings are accounted for in the existing scenario model. To ensure an appropriate comparison between existing and developed scenarios is undertaken, the infiltrated loads (through seepage) under developed conditions should be included in the comparison.

Addressed in response to point 27. Runoff water quality objectives achieved.

43. Constructed wetlands were modelled along the trunk drainage corridors. It is considered that the MUSIC models should be modified to include the runoff and catchment loads from the forested catchment to the north of the development site. It is important when modelling on-line treatment measures that the catchment for the measures is accurate to ensure that hydrologic and catchment loadings are appropriate.

Addressed in response to point 34. No action required.

44. Following excavation, the invert of the eastern and western branch channels is proposed to be lower than the current design 1 yr ARI receiving water level of 1.26m AHD. It is unclear from the WP reports how relatively frequent inundation from marine water (particularly considering predicted climate change impacts) would be managed in the channels, particularly as the channels are proposed also to be utilised as freshwater constructed wetlands to treat stormwater.

Constructed wetlands would be brackish rather than freshwater, where required. This would not affect the ability of the wetlands to function as stormwater quality control measures.

45. A swale was simulated in the developed (with treatment) scenario for Sub-catchment B7. The swale has been modelled with a gradient of 3% which appears high for the site condition. It is also likely that the provision of a swale (secondary treatment) after an infiltration/bioretention measure (tertiary treatment) would provide limited treatment.

It was agreed that this is a minor issue and would have little effect on the rezoning study.

46. Estimated lifecycle costs for the developed with treatment scenario were not provided.

Indicative WSUD maintenance costs, generated from the MUSIC model, are provided in **Table 8**, (default values were adopted for all parameters). The estimated maintenance costs are only indicative and need to be reviewed in light of site specific conditions, the design of the WSUD features, the maintenance techniques to be adopted and how this is integrated into maintenance of other facilities and landscaping on the site. This review will be undertaken at the detailed design phase.

Table 8 Indicative Life Cycle Cost for Developed with Treatment Scenario

Span of Analysis (yrs)	50
Real Discount Rate (%)	5.5
Annual Inflation Rate (%)	2
Base Year for Costing	2006
Life Cycle Cost of Treatment Train ($2006)	$22,765,809
Equivalent Annual Payment Cost of Treatment Train ($2006/annum)	$455,316
Equivalent Annual Payment/kg Total Suspended Solids/annum	$2.57
Equivalent Annual Payment/kg Total Phosphorus/annum	$1,614.48
Equivalent Annual Payment/kg Total Nitrogen/annum	$237.06
Equivalent Annual Payment/kg Gross Pollutant/annum	$8.79

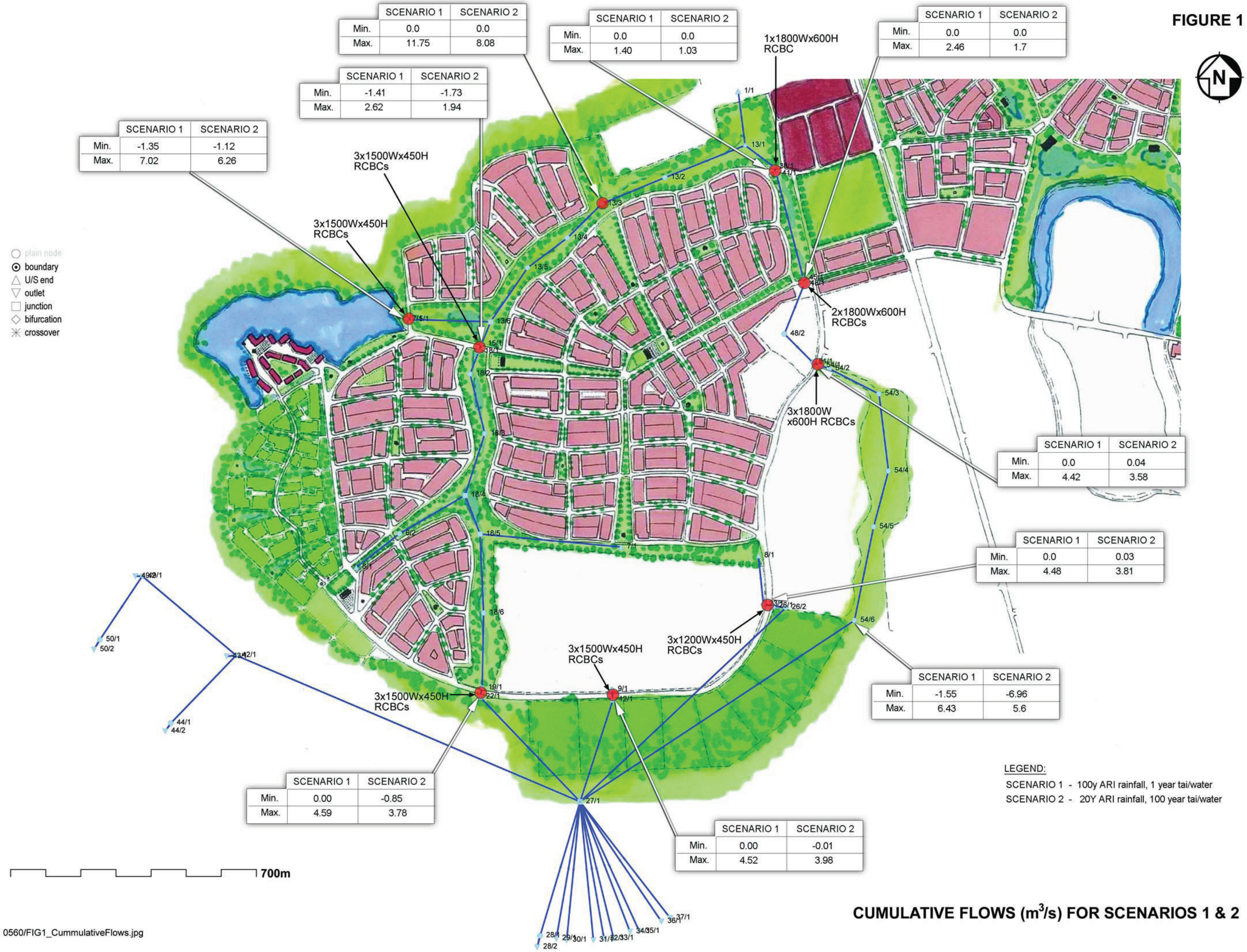
If you have any questions on the issues and responses listed above, please do not hesitate to contact either myself or Mark Tooker on 8456 7200.

Yours faithfully,
WorleyParsons

Fiona COE
Senior Engineer, Urban Infrastructure

FIGURES

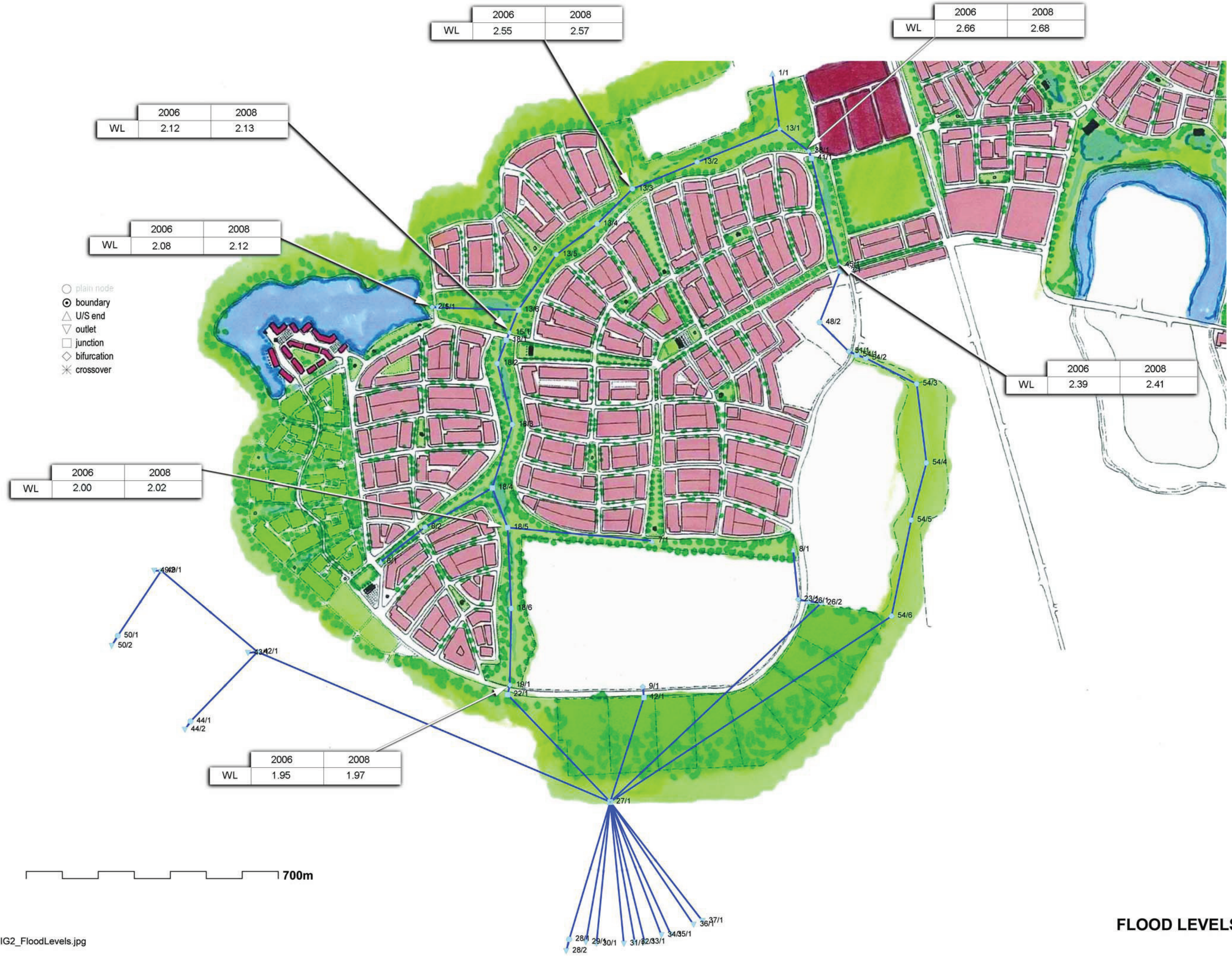
FIGURE 1



CUMULATIVE FLOWS (m^3/s) FOR SCENARIOS 1 & 2

0560/FIG1_CummulativeFlows.jpg

FIGURE 2



FLOOD LEVELS (m AHD)

0560/FIG2_FloodLevels.jpg

FIGURE 3

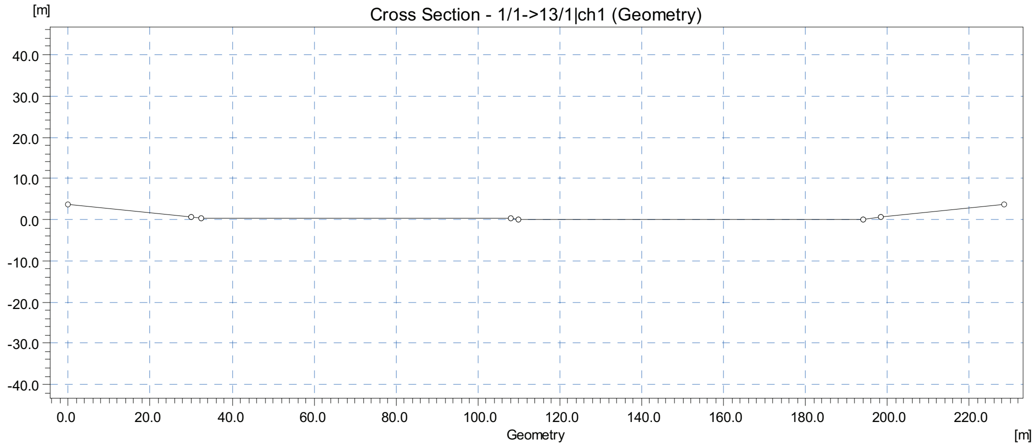
0560/FIG3_CatchmentPlan.jpg

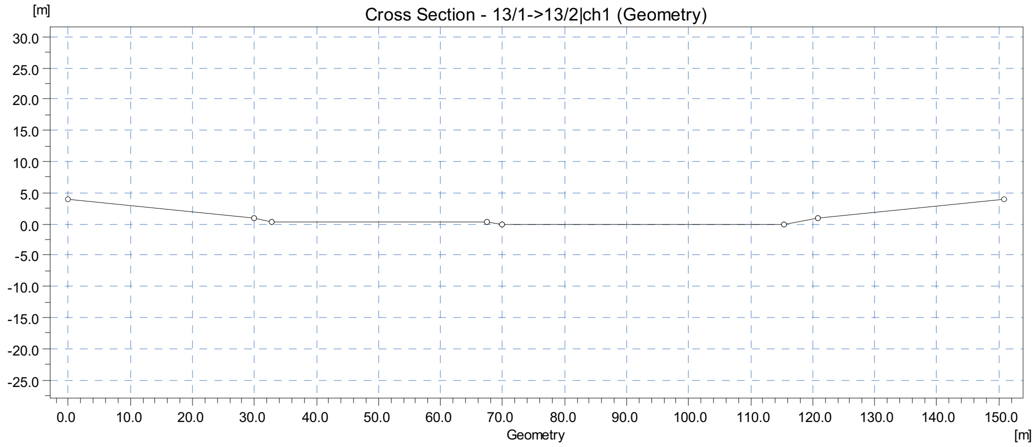
CATCHMENT PLAN

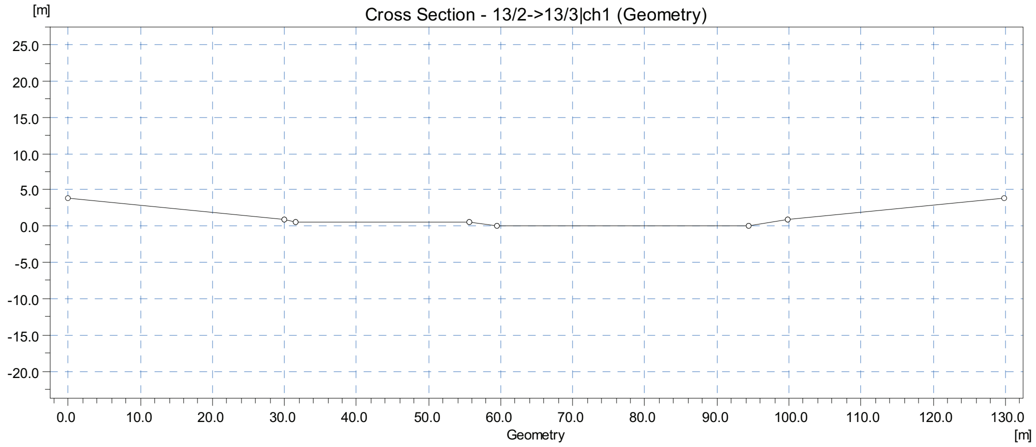
APPENDIX A – ADDITIONAL INFORMATION

16. Limited information is provided in the report regarding the dimensions of the modelled channels. Depths and side slopes are provided, but no details on the modelled widths are provided. The report indicates that 'channel widths were estimated from the masterplan'. It is considered that this information should be provided in the report.

Channel geometry is provided below.



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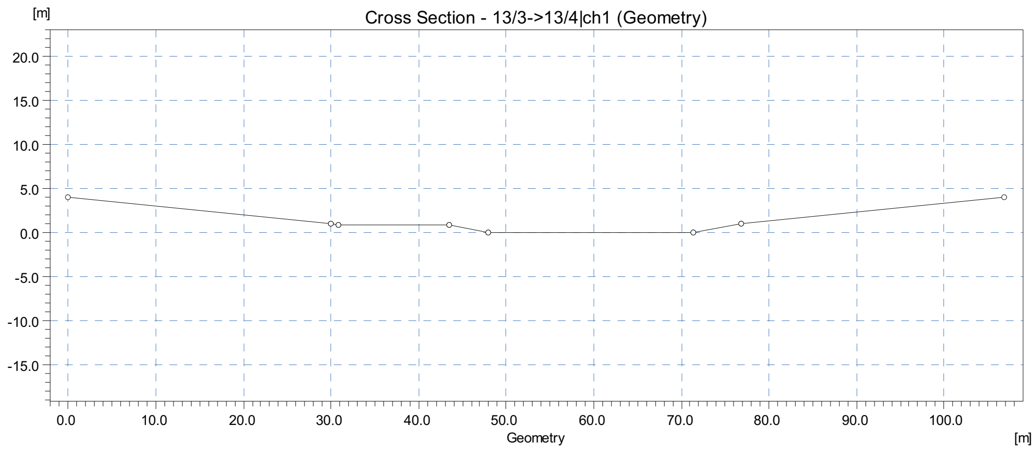
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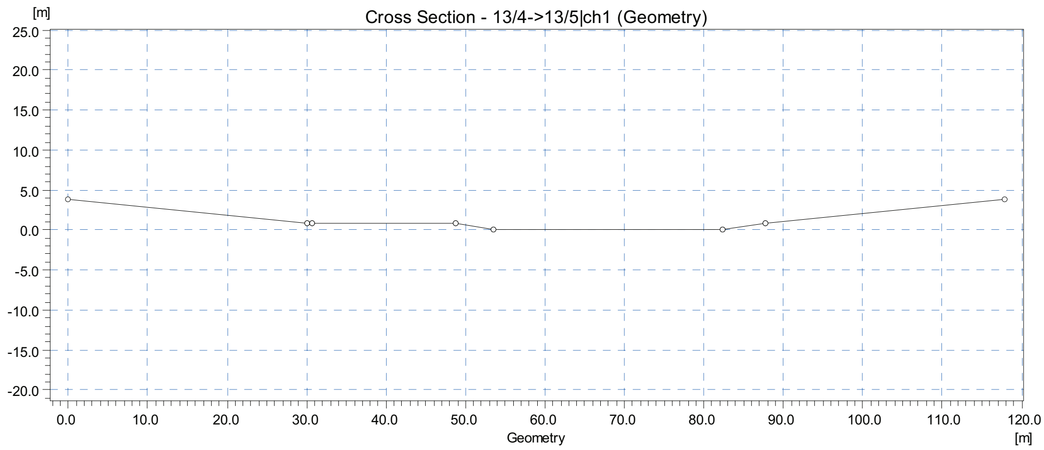
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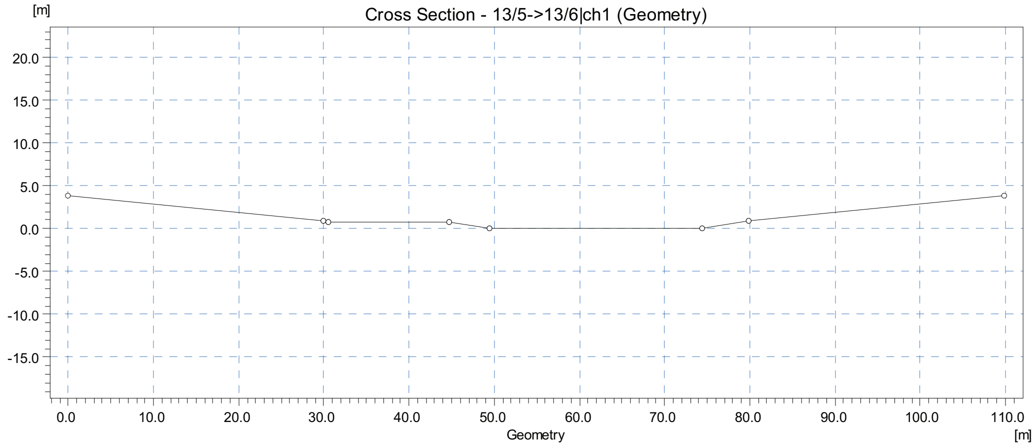
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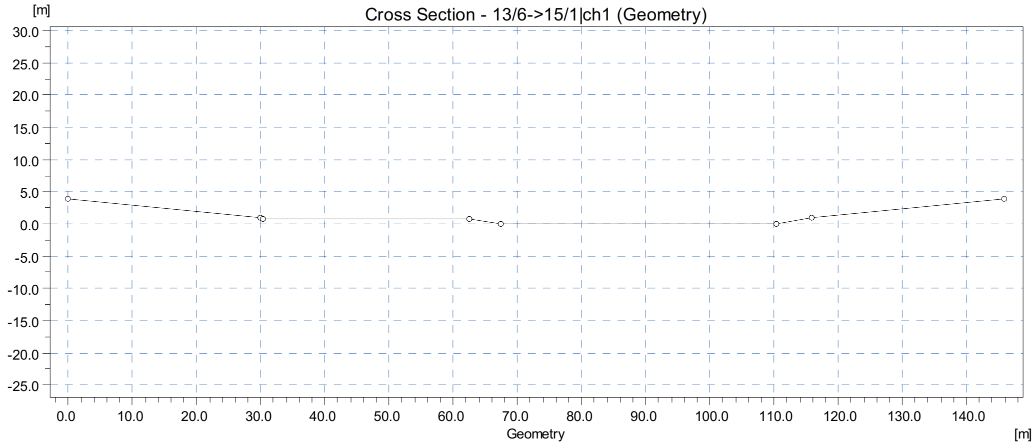
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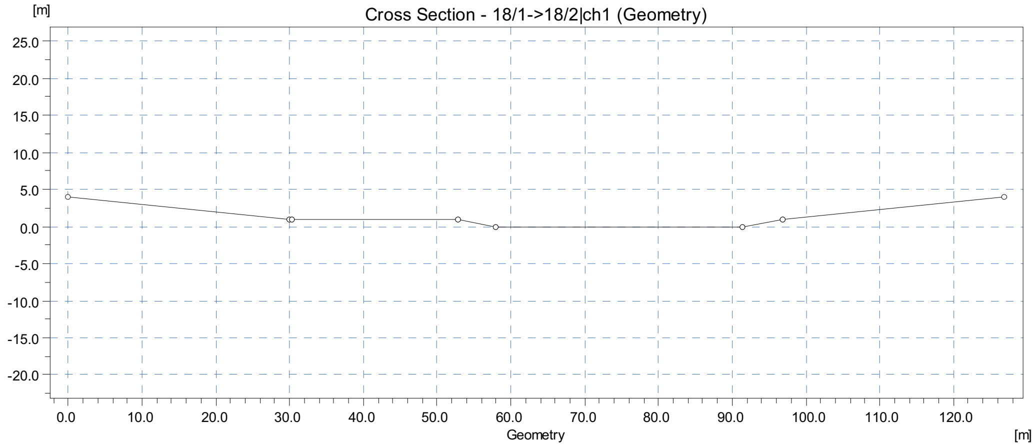
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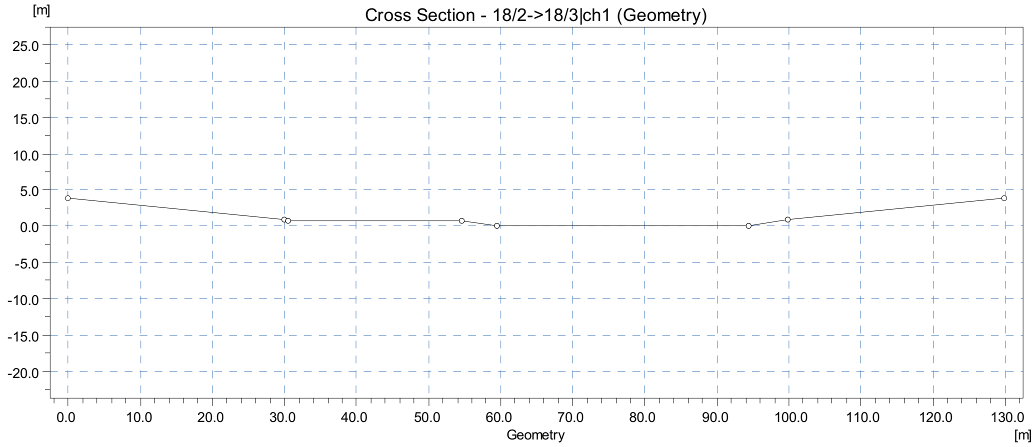
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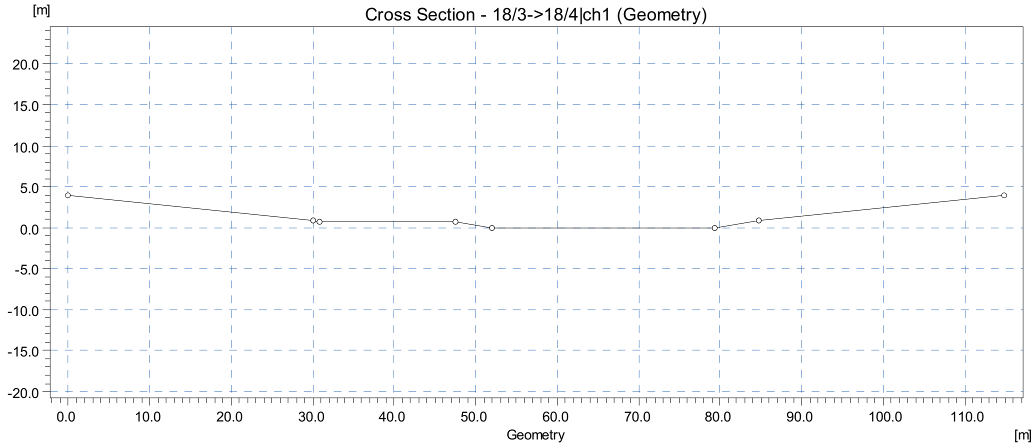
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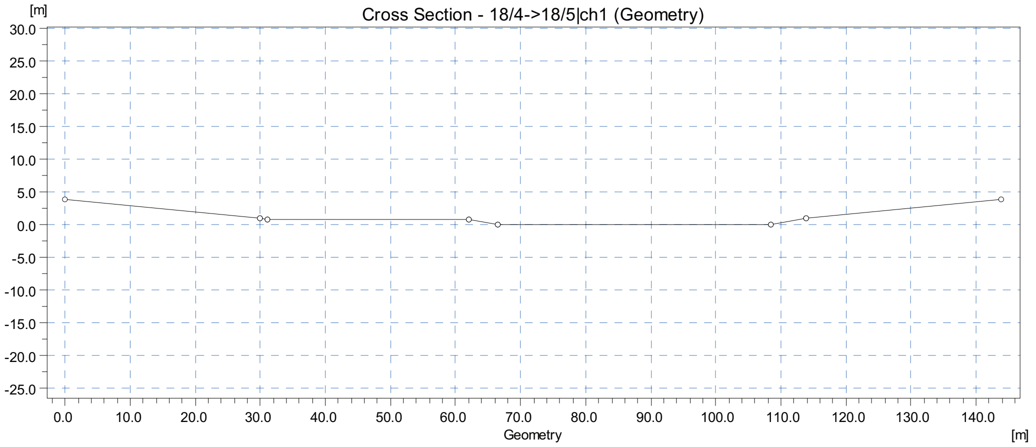
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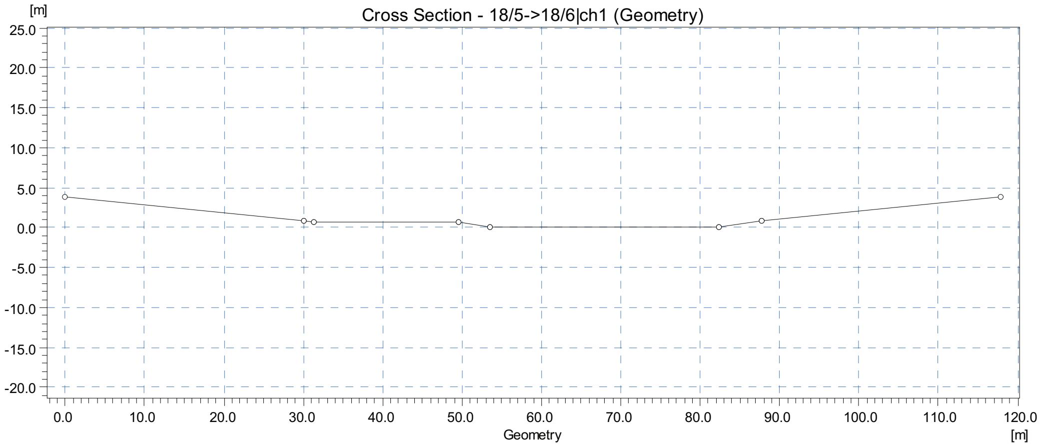
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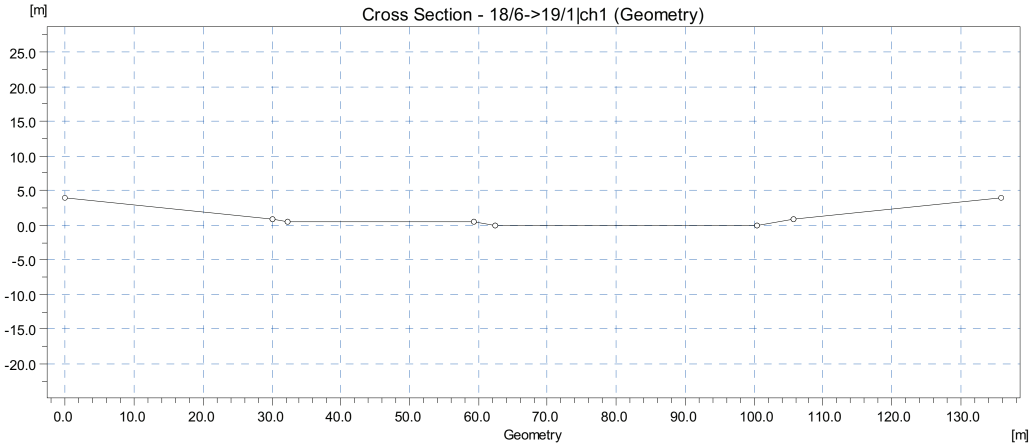
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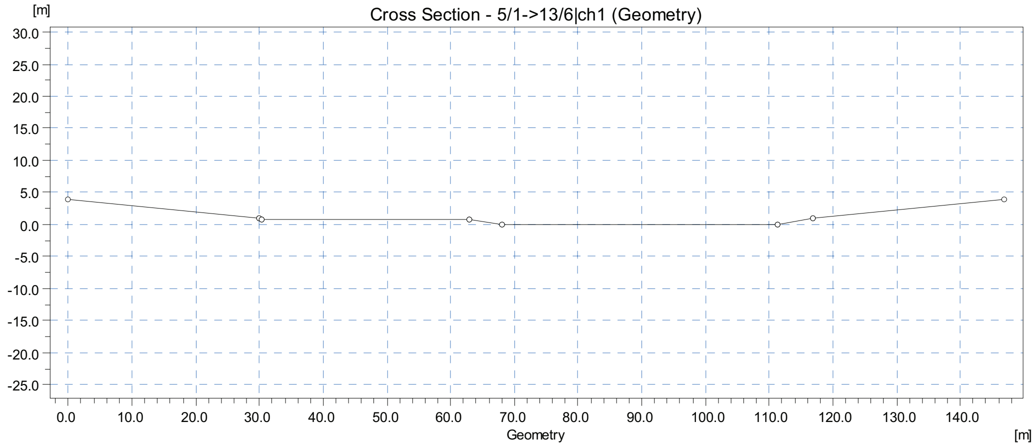
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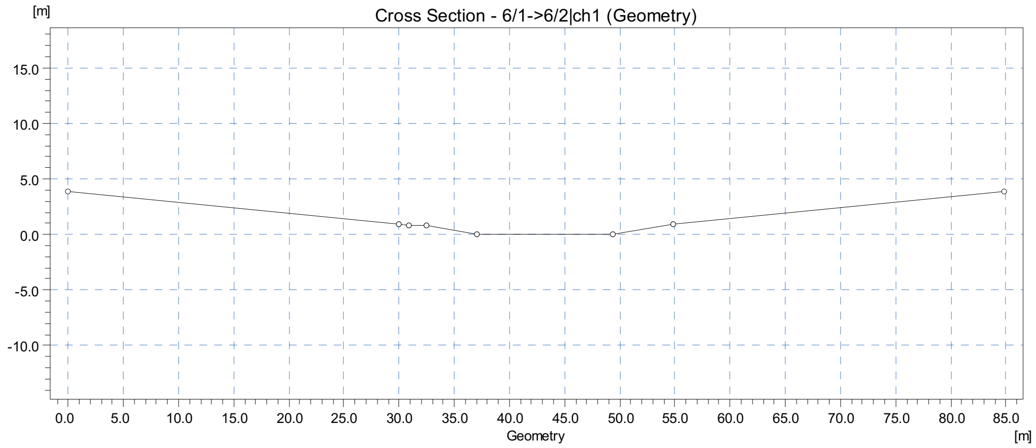
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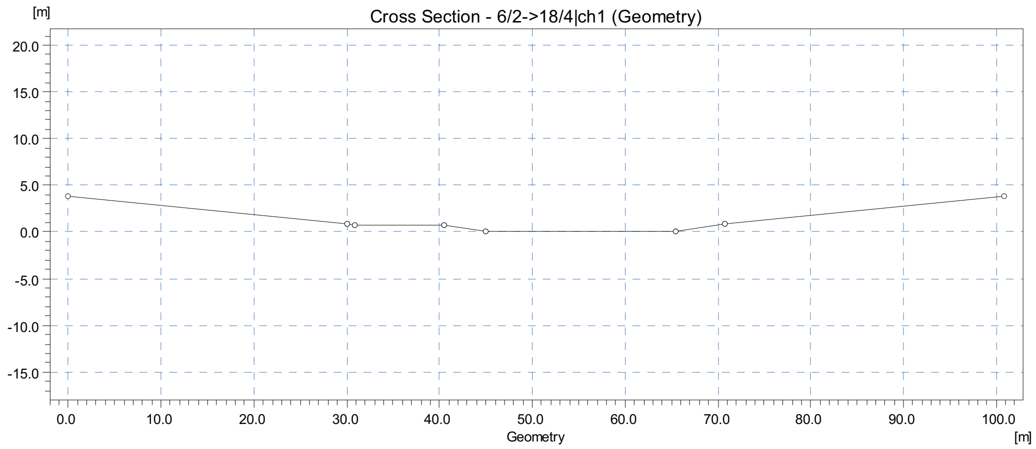
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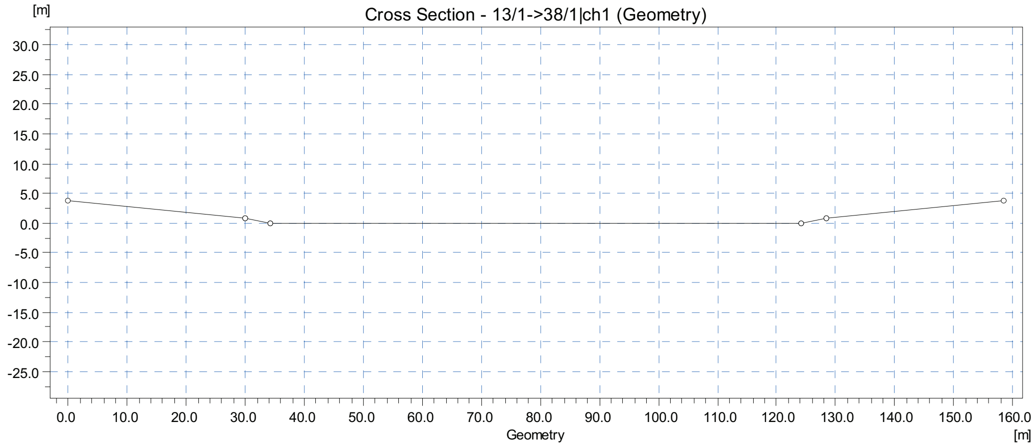
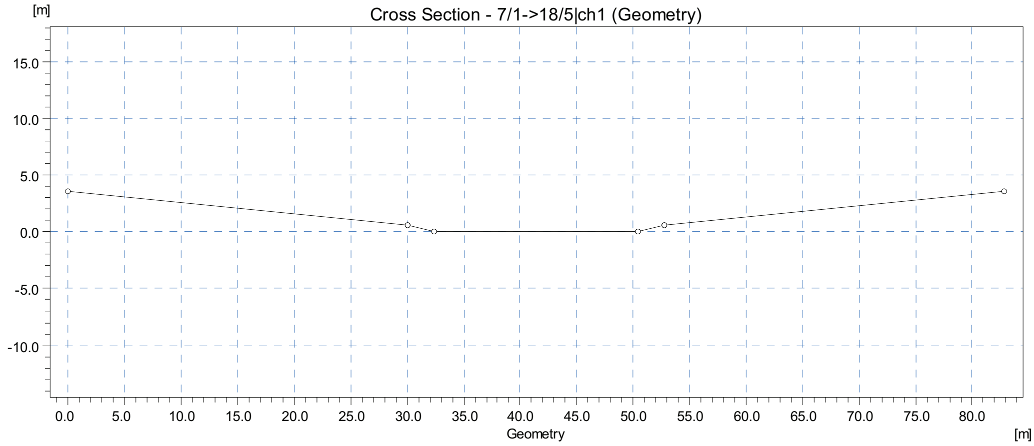
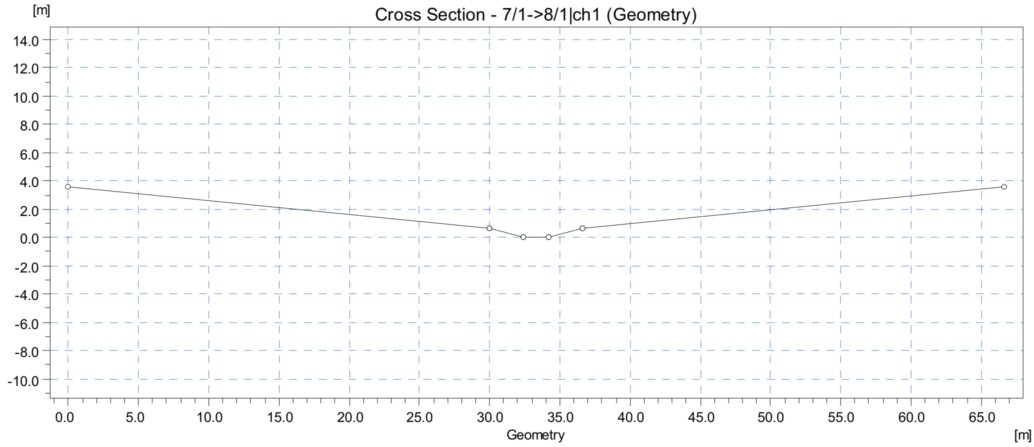
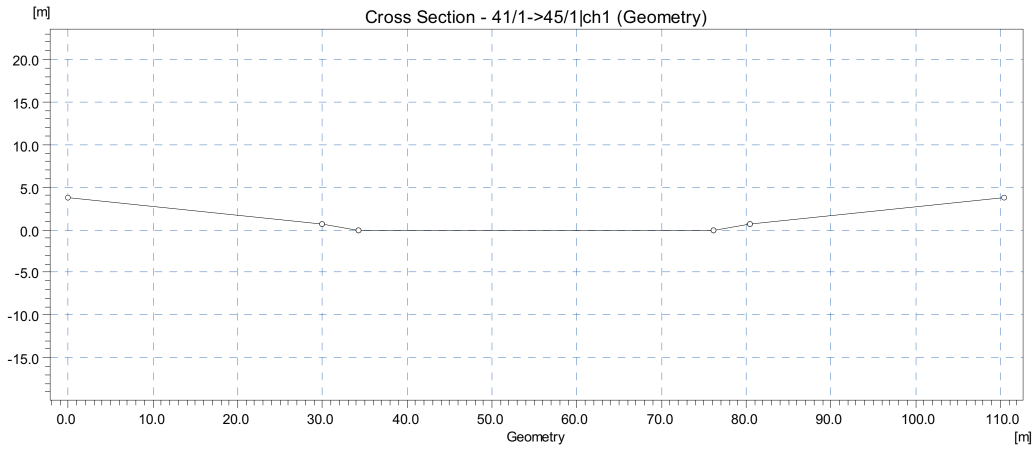
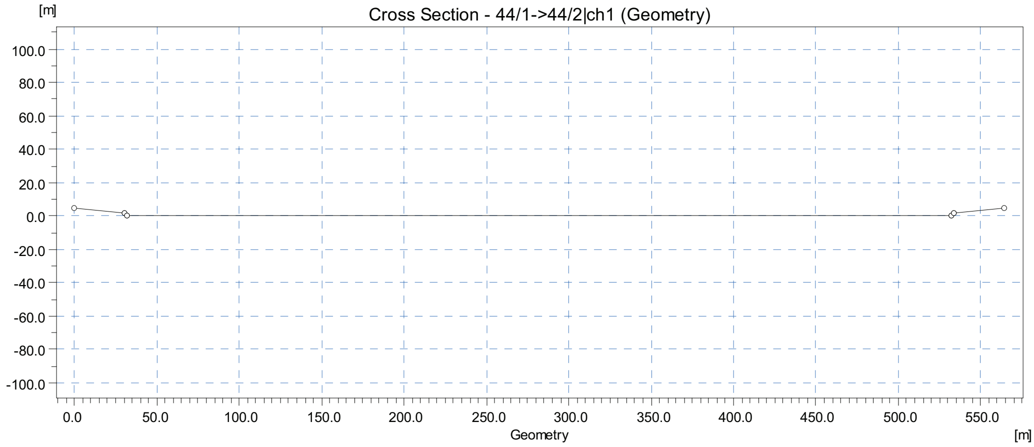

Cross Section - 13/1->38/1|ch1 (Geometry)
[m]
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
150.0
160.0
Geometry
[m]


Cross Section - 7/1->18/5|ch1 (Geometry)
[m]
15.0
10.0
5.0
0.0
-5.0
-10.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
Geometry
[m]

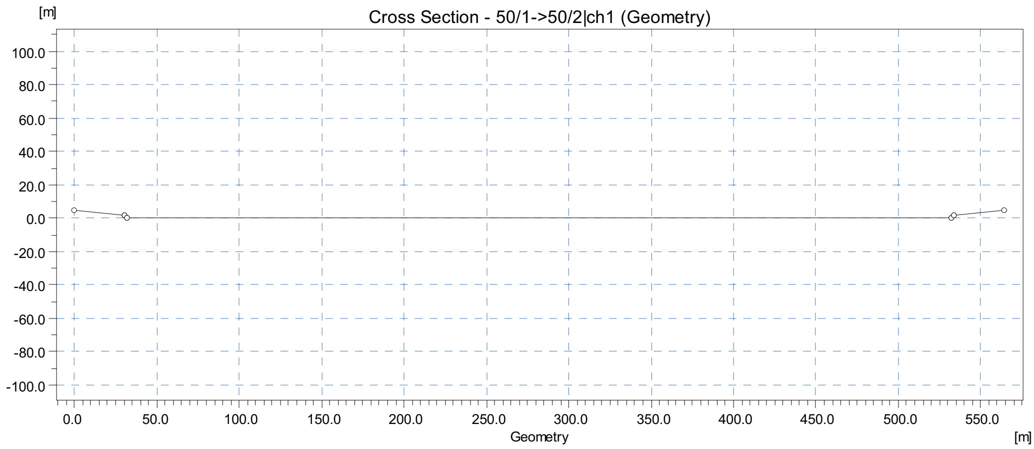

Cross Section - 7/1->8/1|ch1 (Geometry)
[m]
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
Geometry
[m]


Cross Section - 41/1->45/1|ch1 (Geometry)
[m]
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
Geometry
[m]

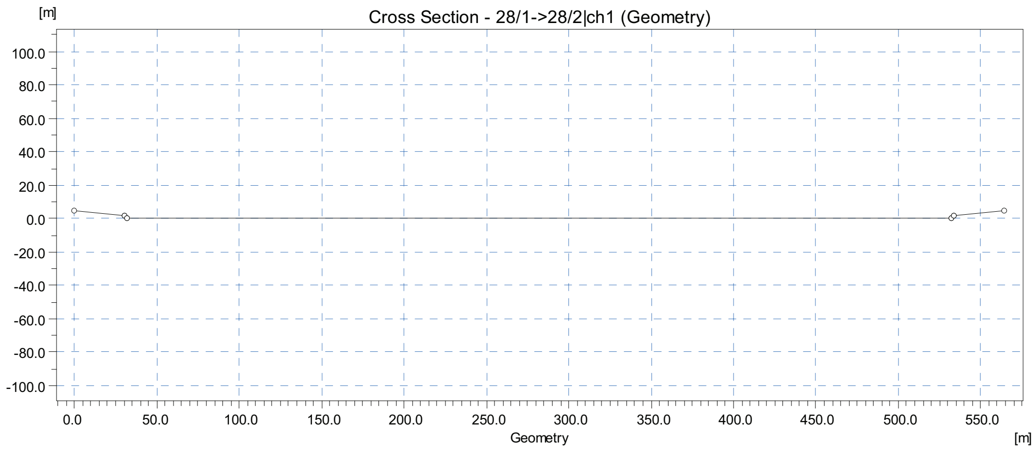
Cross Section - 44/1->44/2|ch1 (Geometry)

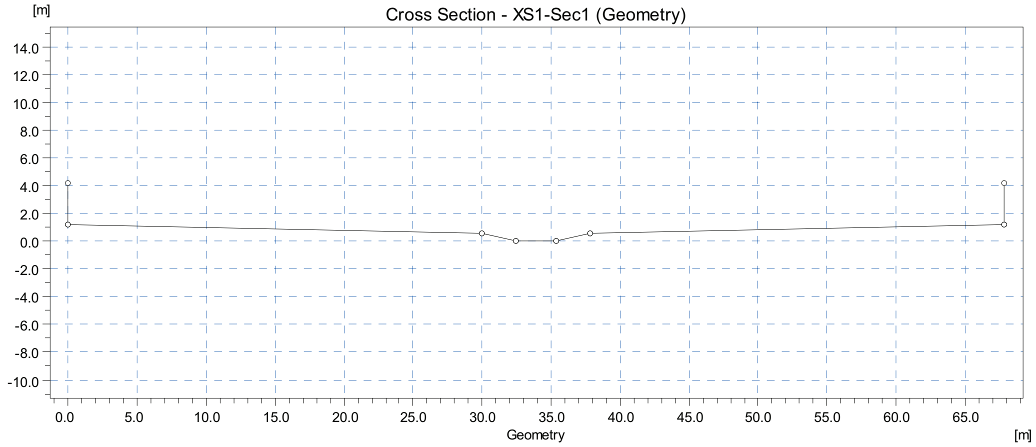


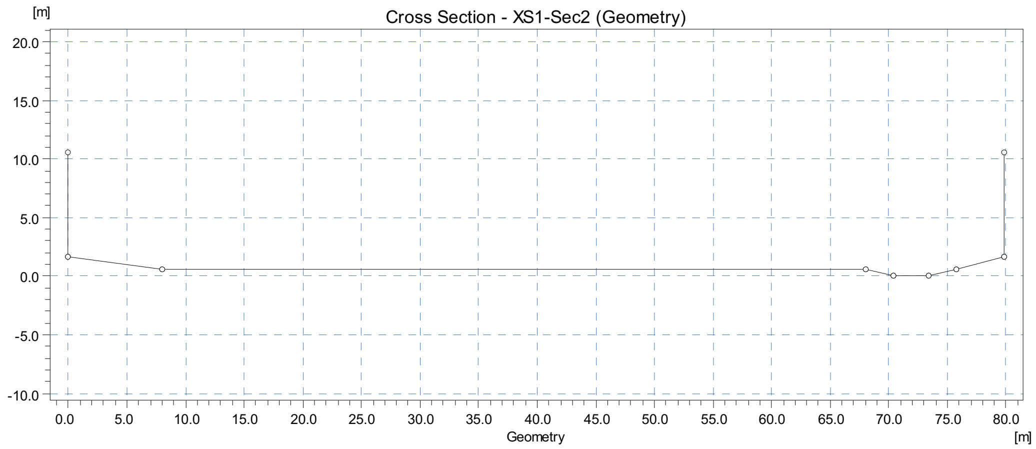
Cross Section - 50/1->50/2|ch1 (Geometry)

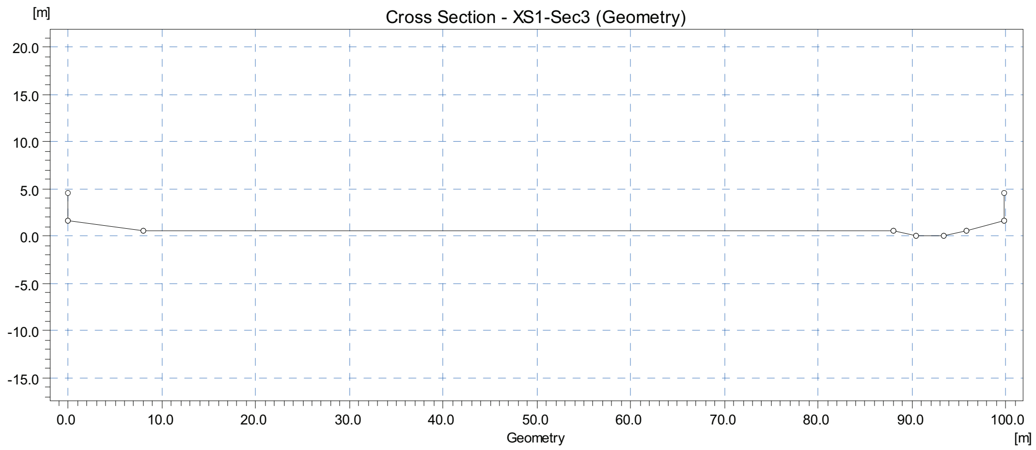


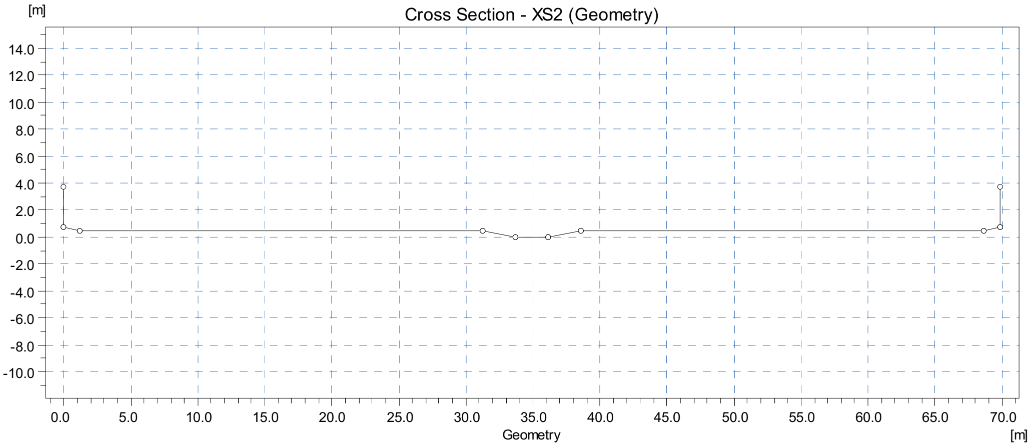
Cross Section - 28/1->28/2|ch1 (Geometry)

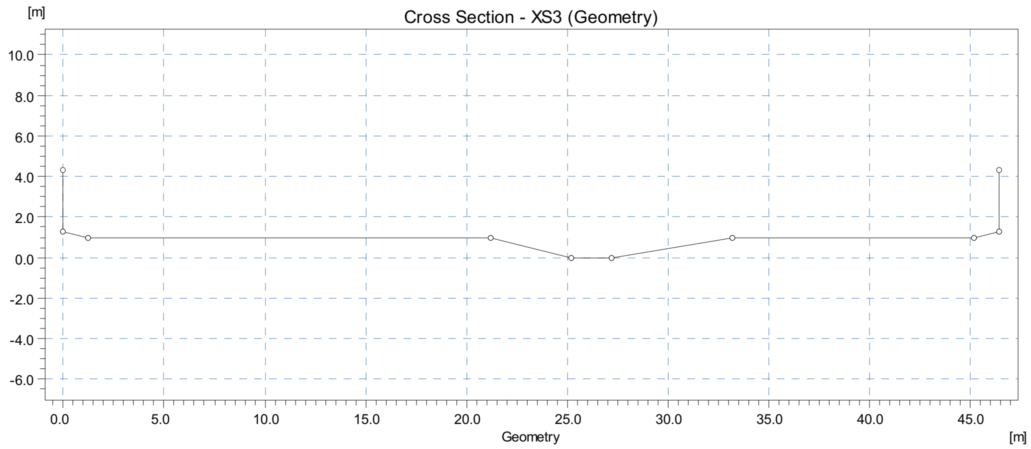


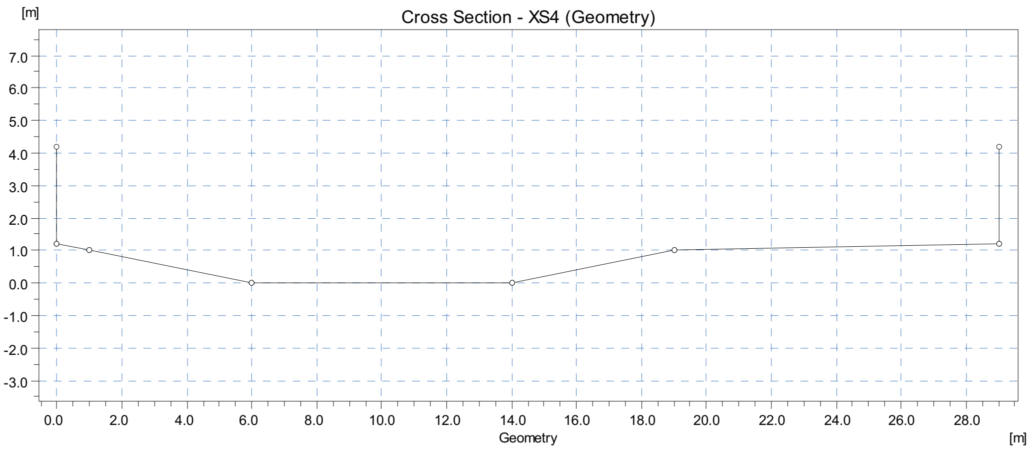

Cross Section - XS1-Sec1 (Geometry)
[m]
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
0.0 5.0 10.0 15.0 20.0 25.0 30.0 35.0 40.0 45.0 50.0 55.0 60.0 65.0
Geometry
[m]

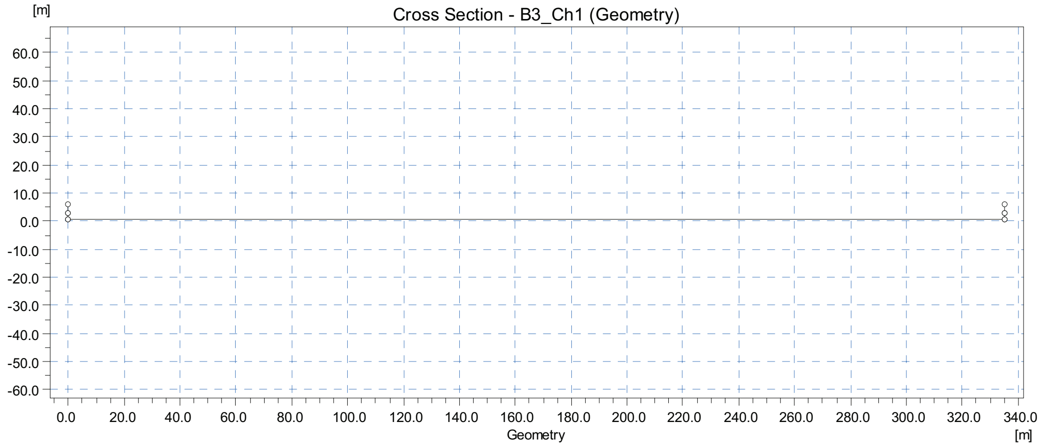

Cross Section - XS1-Sec2 (Geometry)
[m]
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
0.0 5.0 10.0 15.0 20.0 25.0 30.0 35.0 40.0 45.0 50.0 55.0 60.0 65.0 70.0 75.0 80.0
Geometry
[m]

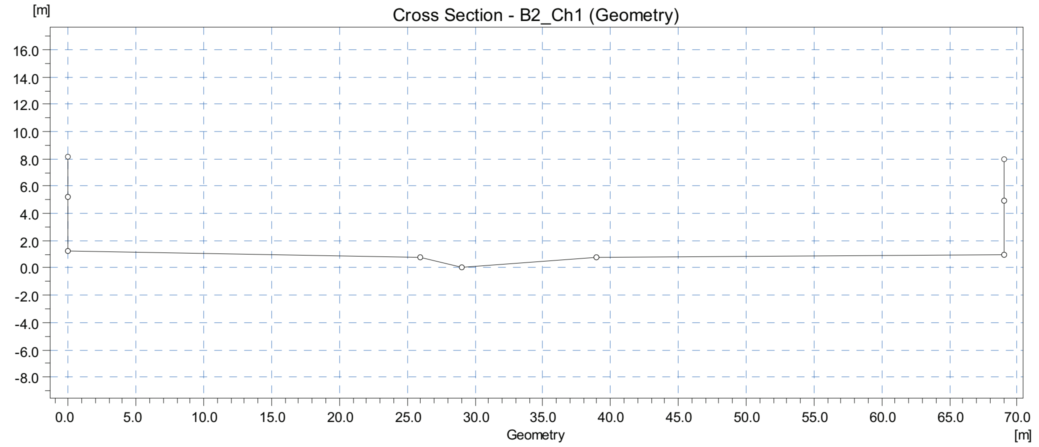

Cross Section - XS1-Sec3 (Geometry)
[m]
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
0.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0
Geometry
[m]


Cross Section - XS2 (Geometry)
[m]
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
Geometry
[m]

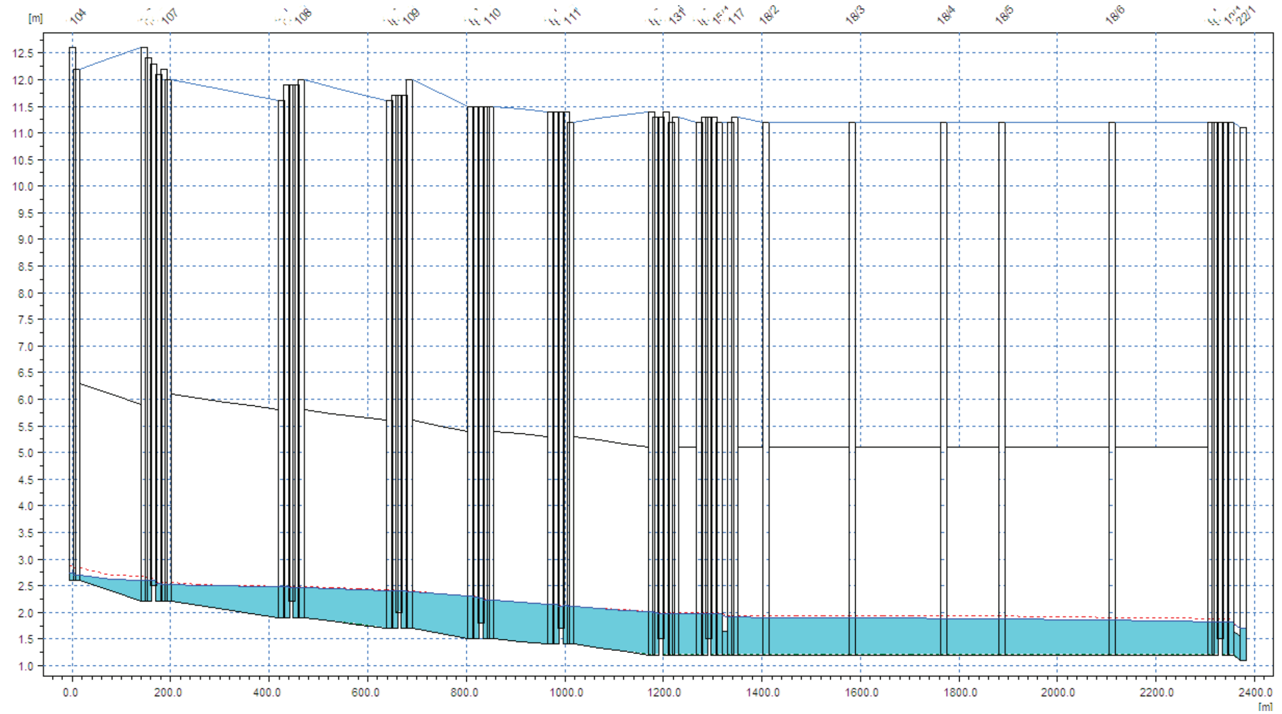

Cross Section - XS3 (Geometry)
[m]
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
Geometry
[m]


Cross Section - XS4 (Geometry)
[m]
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
Geometry
[m]



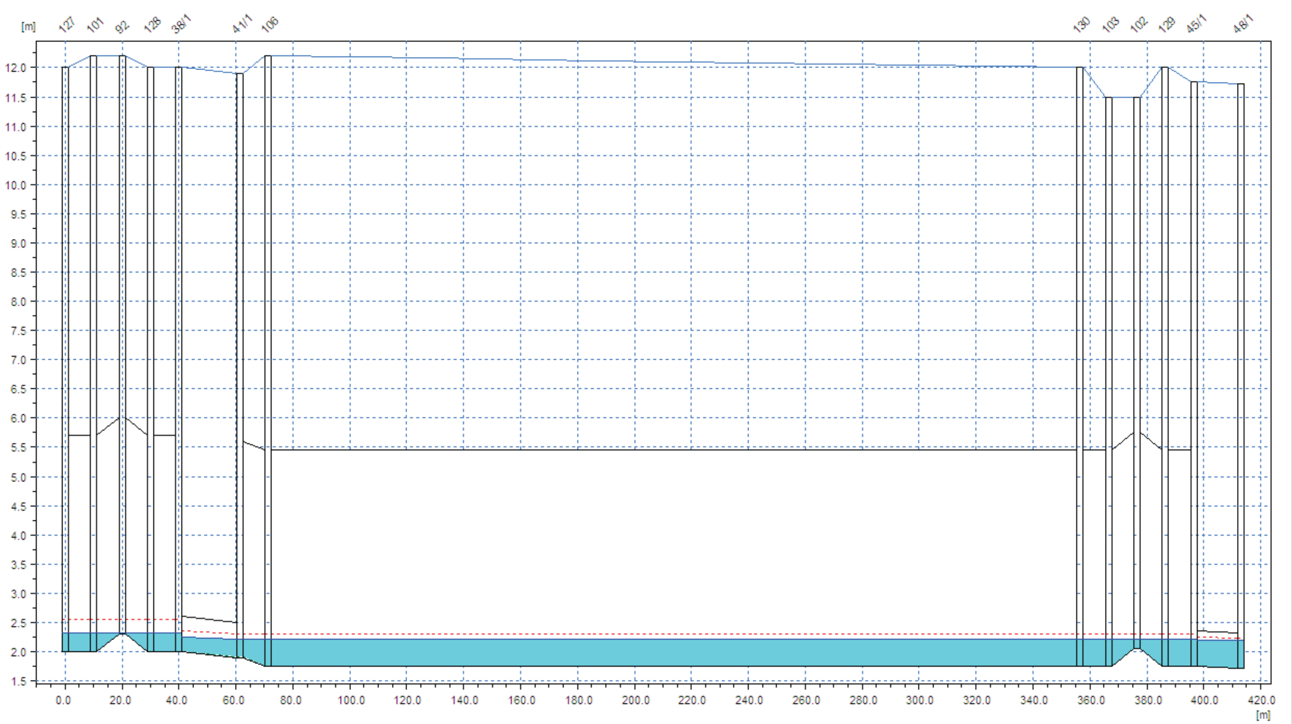


17. Constructed wetlands are proposed to be formed within the invert of the main channel. The constructed wetlands were modelled in MUSIC with a 1m deep permanent storage and 0.3m deep extended detention storage. Based on Diagram 2.4 presented in the WP report, it appears that provision of the constructed wetlands within the main channel has not been incorporated into the hydraulic models.

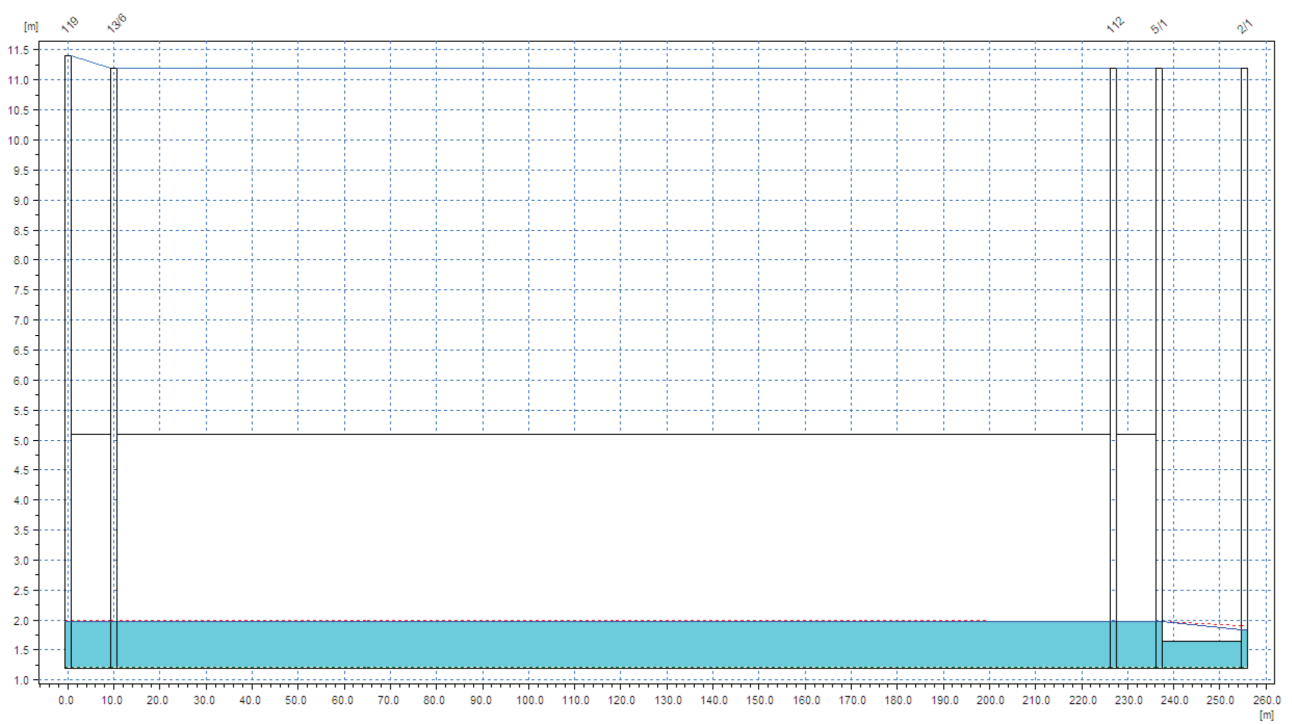


I

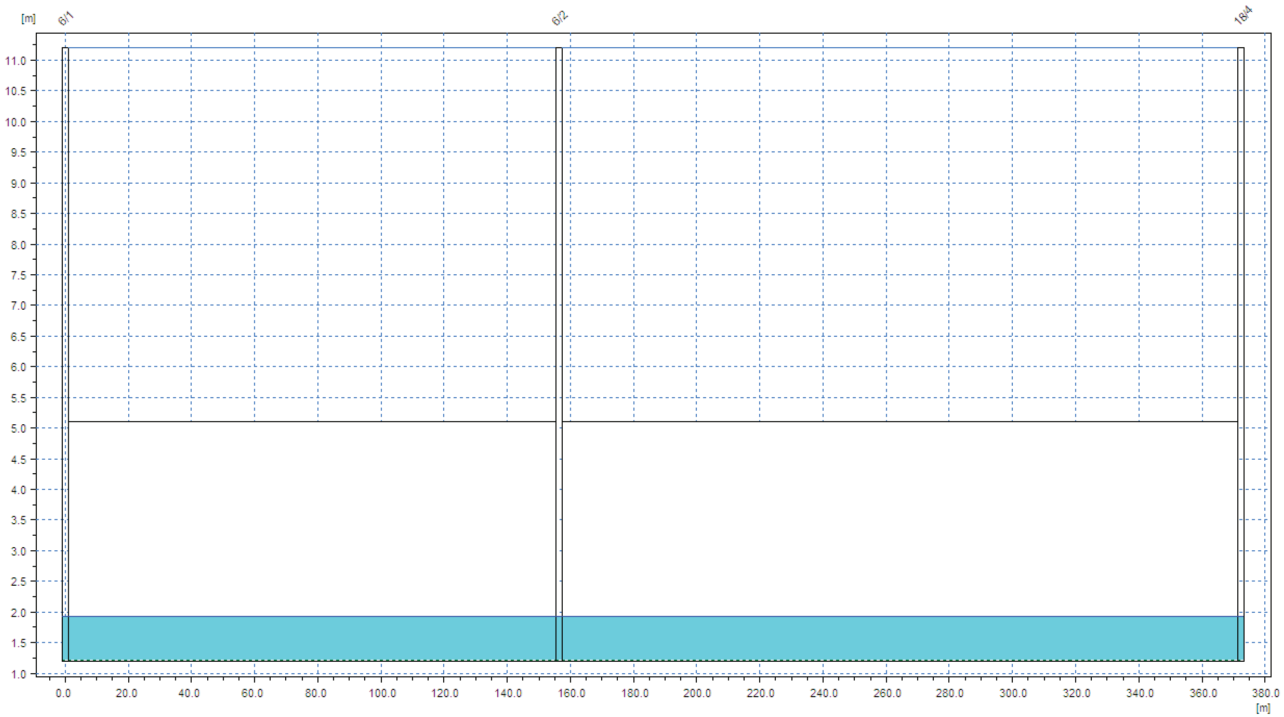
Long section of western branch



Long section eastern branch, nodes 38/1 to 48/1



Long section western branch, nodes 13/6 to 2/1



Long section western branch, nodes 6/1 to 18/4

Appendix 4 - BMT WBM Additional Review of Draft Water Management Strategy (16th December 2010)