Pinehaven Structural Works - Technical Review - Flooding

Peer Review

Prepared for Greater Wellington Regional Council
Prepared by Beca Limited

21 November 2019

make everyday better.

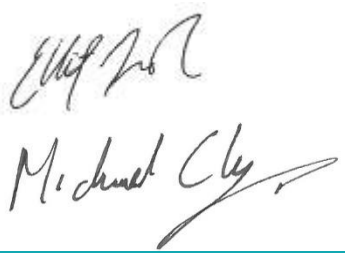
Creative people together transforming our world

Contents

Revision History

Revision Nº	Prepared By	Description	Date
1.0	**Michael Law**	Draft for Modeller comment	11 November 2019
2.2	**Michael Law**	Reviewer response to Modeller comments	21 November 2019

Document Acceptance

Action	Name	Signed	Date
Prepared by	**Elliot Tuck and Michael Law**		21 November 2019
Reviewed by	**Michael Law**		21 November 2019
Approved by	**Michael Law**		21 November 2019
on behalf of	Beca Limited		

1 General information

This document summarises our review of the 2019 flood model for the Pinehaven catchment in Upper Hutt. The review process should not be considered complete until any issues identified have been suitably addressed and closed by the reviewer (See sections 4 to 7).

The model may be updated as part of an ongoing process of model use, improvement and review through the project.

2 The scope of our review

We have been provided a hydraulic model, developed by Jacobs (summary information in Figure 2-1). The hydraulic flood model and associated hydrological model were originally developed by Sinclair Knight Merz and MWH respectively between 2008 and 2010 for Greater Wellington Regional Council's (GWRC) Flood Management Plan for Pinehaven. The models were audited in 2015[1] by Beca for GWRC.

Our scope is to review the current version of the hydraulic flood model and associated information. We have undertaken a review of the model assumptions, the model logic and the results based on the information provided. We have not undertaken a review of the hydrological model used to provide the input hydrographs to the hydraulic model, as this was not part of the scope. The focus has been on the modelling of the stream between Pinehaven Reserve and the Bypass Weir as this is the reach subject to the proposed works. The review has not revisited the hydraulic modelling of catchment upstream of Pinehaven Reserve.

Figure 2-1 Review information

Job name	**Pinehaven Structural Works - Technical Review - Flooding**
Model description and purpose	The model is a 2-way coupled (MIKE11 and MIKE21) model adapted to represent the proposed stream works in Pinehaven Stream. The model was previously constructed to quantify flood risk in the catchment.
Model developed by	Jacobs
Modeller's name(s)	Peter Kinley and Jarad Sinni
Reviewer's name(s)	Michael Law and Elliot Tuck
Review date	11 November 2019
Model software/platform and file	Hydraulic flood model - MIKE by DHI
Key features	• Pinehaven Stream and instream structures represented in 1D • Floodplain represented in 2D, developed using LiDAR
Model report file name & date	Pinehaven Stream Improvements, Flood Hazard Assessment, written by Jacobs for Wellington Water Ltd. 19 September 2019.

[1] ***Pinehaven Stream – Flood Mapping Audit,*** Beca Ltd for GWRC. 13 July 2015 (Beca 2015)

3 Our review methodology

Our model review rating scheme provides a standardised approach to our review and makes it clear where action is required (Figure 3-1). This also allows us to suggest areas for more general improvement; these can be addressed as part of this work or incorporated into similar models in the future.

Our rating scheme assigns a score of 0-3 for each item reviewed.

- Scores of 0 and 1 are generally for information only and are unlikely to impact the modelling outcomes.
- A score of 2 is classed as a major issue. However, one which could be accepted if addressed or if more detail is provided. The issue may be closed and be considered fit for use for this project, even though an un-resolved issue remains.
- A score of 3 is a fatal flaw that is likely to require a reasonable amount of investigation/rework to be accepted or may invalidate the model findings.

Figure 3-1 Review framework

Description	Review Rating	Fit for use[2]
No issue: The element or parameter being reviewed is modelled acceptably	**0**	**Yes**
Minor issue: There is an issue, but it is unlikely to significantly affect model results.	**1**	**Yes**
Major issue: Failure to resolve the issue compromises the model and should be rectified but may be resolved by explanation or acceptance of model limitations.	**2**	**Yes, No or Review.** *Issue may be closed or remain open*
Fatal flaw: Failure to resolve this issue severely compromises the model and should be rectified before the model is accepted.	**3**	**No**

The review is tabulated in Section 4 and includes room for the Modeller to respond to the Reviewer's comments, and for the Reviewer to close out each issue.

[2] The 'fit for use' categorisation refers to the use of the model for the stream works project only, and does not reflect its suitability for other purposes or future modelling.

4 Model review

4.1 Information Received

The following information has also been received from the modeller

- Catchment shapefile: Lidar_Catchments_Pinehaven_Backup.shp
- Reports:
  - ***Pinehaven Stream Improvements, Flood Modelling Draft Flood Modelling Report***. Jacobs for Wellington Water Ltd, December 2017 (Jacobs 2017).
  - ***Pinehaven Stream Improvements, Flood Hazard Assessment***. Jacobs for Wellington Water Ltd, September 2019 (Jacobs 2019a).
- Memorandum
  - ***Addendum to the Pinehaven Stream Improvement Works, Pinehaven Road Culvert and Sunbrae Drive Culvert Flood Hazard Assessment Reports – DRAFT.*** From Peter Kinley (Jacobs) to Josie Burrows (GWRC), James Beban (UHCC), and Mike Law (BECA). 14 November 2019. (Jacobs 2019b)
- Response to draft review culverts; ***Jacobs Response to Beca Modelling Review Draft Report - 13-11-2019.xlsx***, emailed to Josie Burrows (GWRC), James Beban (UHCC), and Mike Law (BECA) by Helen Anderson (Jacobs). 13 November 2019.
- MIKE model files listed in Figure 4-1,

Figure 4-1 Model files

Model	Mike 11	Mike 21	Results
U2_0 Base Case	• Pinehaven_U2_0_Q25_CC.sim • Pinehaven_U2_0_Q100_CC.sim • Pinehaven_U2_HB.hd11 • U2_Q25CC_CC_2hr_HB.bnd11 • U2_Q100CC_2hr_HB.bnd11 • Pinehaven_U2_0.nwk11 • Pinehaven_U2_0.xns11 • Final_Q25_CC_2hr.dfs0 • Final_Q100CC_CE_2hr.dfs0	• Pinehaven_U2_0_Q25_CC.m21 • Pinehaven_U2_0_Q100_CC.m21 • DD_GWRC_TrA_2m_NZMG_Clip4.dfs2 (A number of versions delivered but this appears to be the one used) • InitialDD_GWRC_TrA_2m_NZMG_Clip4.dfs2 (A number of versions delivered but this appears to be the one used) • Pinehaven_NZMGClip_2m_resistance1.dfs2	• Pinehaven_U2_0_SurvBypassWeir_6.4mLength_Q25_CC.dfs2 • Pinehaven_U2_0_SurvBypassWeir_6.4mLength_Q25_CC.re11 • Pinehaven_U2_0_SurvBypassWeir_6.4mLength_Q25_CCHDAdd.res11 • Pinehaven_U2_0_SurvBypassWeir6.4m_Q100_CC.dfs2 • Pinehaven_U2_0_SurvBypassWeir6.4m_Q100_CC.res11 • Pinehaven_U2_0_SurvBypassWeir6.4m_Q100_CCHDAdd.res11

Model	Mike 11	Mike 21	Results
Detailed Design Rev7 (50 BMR Flood wall removed)	• Pinehaven_DetDesign_Iteration7_Q25_CC_0.sim • Pinehaven_DetDesign_Iteration7_Q100_CC_0.sim • Pinehaven_PrelimDesign_PVR04_STAGE2_HB_0.hd11 • UG1_PVR04_STAGE2_Q25CC_CC_2hr_HB.bnd11 • UG1_PVR04_STAGE2_Q100CC_CC_2hr_HB.bnd11 • Pinehaven_DetDesign_Iteration7_0.xns • Pinehaven_DetDesign_Iteration7_0.nwk11 • Final_Q25_CC_2hr.dfs0 • Final_Q100CC_CE_2hr.dfs0	• Pinehaven_DetDesign_Iteration7_Q25_CC_0.m21 • Pinehaven_DetDesign_Iteration7_Q100_CC_0.m21 • Bathy_DetDes_Wall50BlueMtRemoved_2m_NZMG_0.dfs2 • Initial_DetDes_Wall50BlueMtRemoved_2m_NZMG_0.dfs2	• Pinehaven_DetDesign_Iteration7_Q25_CC_0.dfs2 • Pinehaven_DetDesign_Iteration7_Q25_CC_0.res11 • Pinehaven_DetDesign_Iteration7_Q25_CC_0HDAdd.res11 • Pinehaven_DetDesign_Iteration7_Q100_CC_0.dfs2 • Pinehaven_DetDesign_Iteration7_Q100_CC_0res11 • Pinehaven_DetDesign_Iteration7_Q100_CC_0HDAdd.res11

4.2 Hydrological Model

The hydrological modelling for the Pinehaven model was developed outside of Mike by DHI using Hydstra software in 2008[3]. Jacobs informed us that the hydrological model has not changed since the models were reviewed in 2015. Therefore, this section of the review relating to the hydrological modelling underlying the hydraulic flood model review is truncated, and does not differ substantially from the 2015 model and mapping review.

[3] ***Pinehaven Stream Flood Hydrology***, report prepared by MWH for Greater Wellington Regional Council. 4 November 2008

Figure 4-2 Hydrological model review

Item Checked	Findings & Comments	Modeller's response	Reviewer close out comments	Rating	Fit for use
Software	The hydrological modelling was undertaken using Hydstra software. Hydstra is a standard software package that incorporates a catchment runoff model. It was appropriate for this level of analysis at the time of model development. However, the original model files are not available and so the hydrological modelling cannot be updated to reflect updates in rainfall inputs, allowances for climate change and changes in rainfall-runoff modelling techniques. Future hydrological modelling could be undertaken within the MIKE software.	Acknowledged that Hydstra approach appropriate for time of model development. In consultation with Wellington Water, hydrological modelling not revised to retain consistency with previous modelling. The original model files are understood to sit with GWRC, and Jacobs do not know if they can be made available. While future hydrological modelling could be undertaken outside HYDSTRA, this is a decision that would affect future projects and the review suggested is not necessary at this point.	The reviewer's understanding is that the location of the model files is not known. The hydrological modelling should be updated when resources allow, but OK for this project. **CLOSED**	**2**	**Yes**
Rainfall inputs	As noted above, no rainfall files were delivered for review. Therefore, there is no opportunity to update rainfall inputs to reflect data collected over the last ten years. Though probably not likely to result in a major adjustment of design rainfall, it would be prudent to update the rainfall inputs to the hydrological modelling.	For consistency with modelling used to support plan change and public consultation, hydrology used in preliminary modelling not updated for design modelling, in consultation with Wellington Water.		**2**	**Yes**

Item Checked	Findings & Comments	Modeller's response	Reviewer close out comments	Rating	Fit for use
Climate change	As with the rest of the hydrological modelling, the allowance for climate change has not been updated since the models were reviewed in 2015. At that time, the flow hydrograph inputs to the hydraulic flood model were increased by 16% in line with the 2008 guidance from Ministry for Environment (MfE). This was in the model provided to Beca for this review. MfE updated the climate change guidance in 2018, and this update has not been included directly in the modelling being reviewed. However, discussions with Jacobs' modellers propose to update the modelling sing a 20% increase in flows. We have discussed with GWRC and agreed that it is appropriate for this study.	In response to s92 request, 2120 climate change factor of 20% agreed with GWRC and WW. Models have been reassessed with 20% climate change factor and addendum to main works and culvert FHAs is being prepared to summarise differences between 16% and 20% climate change factors.	Jacobs provided an addendum memo dated 14 November that included a summary of the effects of increasing the climate change allowance. The memo has been reviewed. It reports there is no increase in "habitable floor polygons" inundated in the 'with culvert and stream works' modelled scenario when the climate change allowance is increased from +16% to +20%. While the results reported in the addendum are in line with what might be expected, Beca has not reviewed the model run files used to generate the results reported in the addendum. **CLOSED**	**1**	**Yes**
Catchments	Figure 4-3 shows the catchments used in the hydrological modelling. The catchments range from 0.735km² to 0.1397km². Catchments of this size are large for a detailed design model, but given the lack of detail in the hydraulic model (e.g. no stormwater pipe network) these are appropriate. Based on the 2D surface supplied with the model they appear to be delineated appropriately.	Findings and comments on catchment size acknowledged. Agreement with appropriateness of catchment size and delineation, based on resolution and detail of base model.	**CLOSED**	**1**	**Yes**

Item Checked	Findings & Comments	Modeller's response	Reviewer close out comments	Rating	Fit for use
Summary	The issues with the hydrological modelling identified in the 2015 model review persist. The hydrological model has not been updated, and allowances for climate change have been (and are being) made by factoring the output flow hydrographs rather than updating the hydrological model and inputs. Though the hydrographs used as inputs for the hydraulic flood model are still acceptable for the current stream works project, we recommend that the hydrological modelling should be updated either as part of this project or in the next couple of years. This is for the following reasons: • The hydrological modelling is ten years old, and does not account for additional rainfall records, changes in recommended allowances for climate change, and updates to hydrological methods. • The original hydrological model files are not available. • The hydrological modelling could be incorporated within the MIKE hydraulic flood model	Acknowledged that Hydstra approach appropriate for time of model development. In consultation with Wellington Water, hydrological modelling not revised to retain consistency with previous modelling. Support the recommendation to update the hydrological modelling in the next couple of years.	As per previous comments, issue closed but recommendation that the hydrological model is updated when resources allow. **CLOSED**	**2**	**Yes**

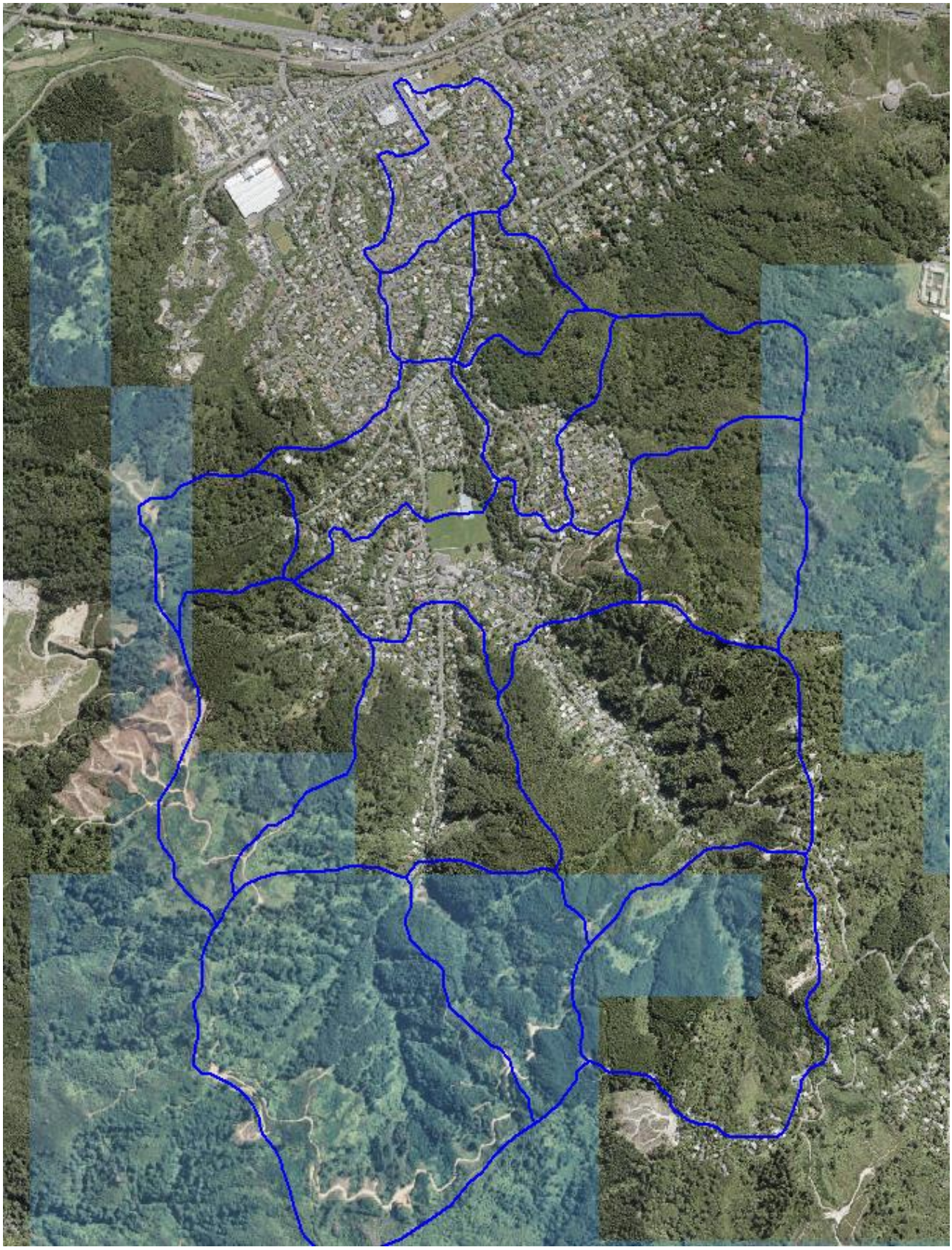


Figure 4-3 Hydrological catchments

4.3 Hydraulic Model

The hydraulic flood model has been built within MIKE by DHI software, with MIKE21 (2D) and MIKE11 (1D) elements. The review considers the MIKE21 elements first, then MIKE11 and finally the results

Item Checked	Findings & Comments	Modeller's response	Reviewer close out comments	Rating	Fit for use
MIKE21					
Grid/Mesh	• Model includes two gridded surfaces; representing Base (pre) and Design (post) proposed stream works • Model updated with 2013 LiDAR • The model uses a grid of 2x2 m. This is an appropriate level of detail, and more refined than the 5x5 m grid reviewed in 2015. • The extent of the grid is such that the flood plain is covered. This is confirmed by the 100-year ARI results showing that that no water is glass-walling at the edges of the grid. • The Pinehaven Stream between Pinehaven Reserve and Whitemans Rd has been blocked out of the grid where M11 is present to prevent double counting. • The blocking out has been increased in areas of stream widening (this matches changes to the M11 cross-sections) as indicated by the red areas in Figure 4-4. • The stream centreline and mesh blockout at 28 Blue Mountains Rd between the Design model and Base model is slightly different.	Agreement with findings and comments noted.	**CLOSED**	**0**	**Yes**

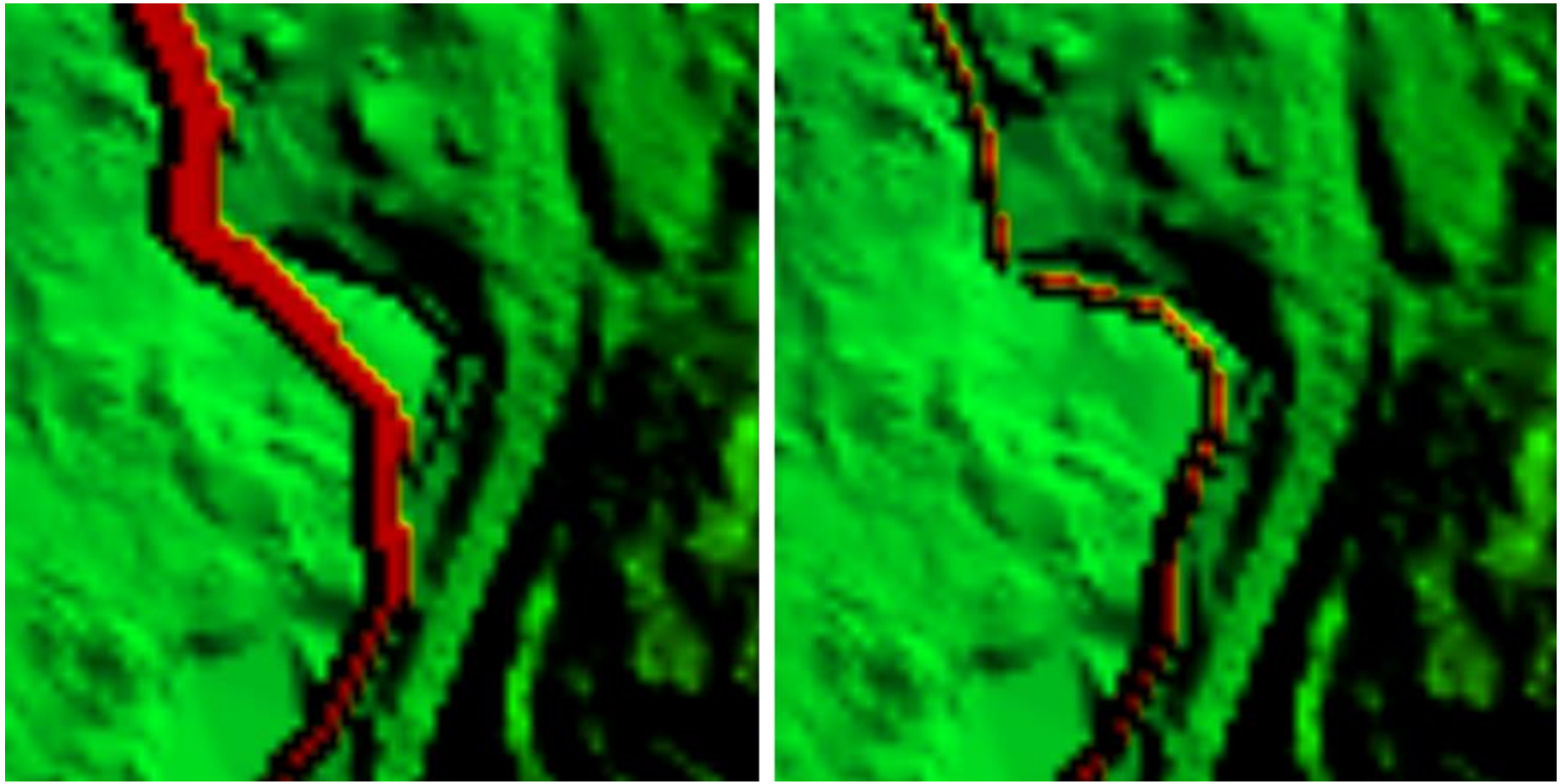


Figure 4-4 Changes to DEM – Design model on the left and Base model on the right

Item Checked	Findings & Comments	Modeller's response	Reviewer close out comments	Rating	Fit for use
MIKE21 (continued)					
Roughness	A resistance map has been used for both models. Roads = 50 / 0.020n Parks = 28.57 /.035n Bush = 6.67 / 0.150n Residential = 10 / 0.100n These resistance values are appropriate	Agreement with findings and comments noted.	**CLOSED**	**0**	**Yes**
Flood/Drying	Drying = 0.01 Flooding = 0.02.	Agreement with findings and comments noted.	**CLOSED**	**0**	**Yes**
Timestep	0.5 second	Agreement with findings and comments noted.	**CLOSED**	**0**	**Yes**
Initial Surface elevation	This looks appropriate, but the origin of the initial surface should be noted.	Agreement with findings and comments noted.	**CLOSED**	1	Yes
MIKE 11					
Runoff input	See review of hydrological inputs above. Catchment runoff hydrographs have been applied directly to the stream (MIKE11) at the locations listed in Figure 4-5. Where appropriate the catchments, or portions of, have been distributed along a length of channel or as a point source. This is standard practice but may not account for network discharges and local topography. Has the proportioning considered overland flow paths and/or pipe network discharges?	See comments on review of hydrology above. Allocation of loads to the network has not been changed from the previous model. The design may have an effect on the allocations, but any effect will not be significant or measurable.	Reviewer agrees that allocation of loads is not likely to have a material effect on the relative effect of the proposed stream works given that the design events are greater than the expected capacity of the stormwater network. **CLOSED**	**1**	**Yes**

Item Checked	Findings & Comments	Modeller's response	Reviewer close out comments	Rating	Fit for use
Other boundary conditions	Downstream boundary conditions have been applied to Hull Creek (at both eastern and western ends). One is a Q/H table and the other a fixed water level (44.22mRl). What event does the fixed water level represent, and please state whether the model results in the stream works reach are sensitive to the downstream boundary conditions.	Due to the steepness of the catchment and distance from the downstream extent to the project reach, the model results within the project reach are not expected to be sensitive to the downstream boundary conditions. The variability of water levels in the Hulls Creek branch was checked and found to vary by up to 5mm for the events studied, with a median value of 2mm. This is within the limits that the software can predict water levels and shows the model is not sensitive to the boundary condition at Hulls Creek.	The reviewer agrees with the modeller's response. CLOSED	**1**	**Yes**

	Boundary Description	Boundary Type	Branch Name	Chainage	Chainage	Gate ID	Boundary ID
1	Open	Q-h	HULL_CREEK	1078	0		Dummy_Boundary
2	Open	Water Level	HULL_CREEK	0	0		Dummy_Boundary
3	Open	Inflow	ELMSLIE_RD	0	0		Catchment_A
4	Distributed Source	Inflow	ELMSLIE_RD	0	853		Catchment_F
5	Point Source	Inflow	ELMSLIE_RD	994	0		1/3_Catchment_H
6	Open	Inflow	JOCELYN_CRES	0	0		Catchment_E
7	Point Source	Inflow	JOCELYN_CRES	334	0		1/3_Catchment_H
8	Point Source	Inflow	JOCELYN_CRES	522	0		1/3_Catchment_H
9	Open	Inflow	WYNDHAM_RD	0	0		Catchment_I
10	Open	Inflow	FENDALTON_CRE	0	0		Catchment_G
11	Distributed Source	Inflow	FENDALTON_CRE	117	296		Catchment_K
12	Distributed Source	Inflow	FENDALTON_CRE	340	680		Catchment_L
13	Open	Inflow	PINEHAVEN	0	0		Catchment_B
14	Open	Inflow	UPPER_PINEHAVE	0	0		Catchment_C
15	Distributed Source	Inflow	PINEHAVEN	135	1029		Catchment_D
16	Distributed Source	Inflow	PINEHAVEN	1365	1866		1/2_Catchment_J
17	Distributed Source	Inflow	PINEHAVEN	1949	2426		Catchment_M
18	Point Source	Inflow	PINEHAVEN	2432	0		Catchment_N
19	Point Source	Inflow	PINEHAVEN	2599	0		1/4_Catchment_O
20	Point Source	Inflow	PINEHAVEN	2734	0		1/4_Catchment_O
21	Point Source	Inflow	LOWER_PINEHAV	64	0		1/4_Catchment_O
22	Point Source	Inflow	LOWER_PINEHAV	268	0		1/4_Catchment_O
23	Distributed Source	Inflow	WYNDHAM_RD	130	771		1/2_Catchment_J

Figure 4-5 Hydrograph input locations

Item Checked	Findings & Comments	Modeller's response	Reviewer close out comments	Rating	Fit for use
Cross-sections	• Design drawings of the proposed cross-section have not been received and therefore we cannot comment on the representation of these in the model. We are limited to comparing the design cross sections to those in the Base case model. • The stream works detailed in the *Pinehaven Stream Improvements* report appear in model chainages Ch 1488 – 1604 inclusive; and Ch 1838 – 2430 inclusive (2017 12d design). An example is shown in Figure 4-6 for cross-section 1496. • The lower ~200mm of channel has been left the same as the Base model representing no modification to this portion of the cross-section • The design cross-sections contain vertical walls (approx1.5m high). Note that if these can't be achieved due to stability etc any changes to the side slopes would need to be re-modelled as it may result in a loss in conveyance.	Additional survey was collected to update the quantity and resolution of stream cross-sections from what was represented in the preliminary models. Proposed cross-sections included reference to updated survey information where applicable. In vertical cross sections, up to a 2-inch per row of blocks may be integrated into the proposed design. Following completion of final design of the block walls, if a batter is proposed, a check will be performed on all cross sections to confirm that the effective flow area is not decreased (it is noted this may extend top of bank extents by a nominal amount).	We agree with the modeller's response. Checks should be made to the final design cross-sections to confirm that the hydraulic performance meets the performance of the reviewed model. **CLOSED**	1	Yes

Item Checked	Findings & Comments	Modeller's response	Reviewer close out comments	Rating	Fit for use
Roughness	• The edges of some design cross-sections have had roughness increased to represent walls, though the material is not stated. Ch1838-1847 has High/low roughness zones, whereas CH.1854-1883 does not. Without a set of drawings/design can't comment if these are appropriate. • 0.035n Global roughness in both models Fresh plains (extensions of the channel below the bank level to accommodate 'fresh flows') / planted benches appear to have been created in some of the design cross-sections, including cross-section 1854 (Figure 4-7). If they are to be planted, then no account has been taken of the change in model roughness. Modeller to confirm whether changes in roughness have been, or need to be, made.	Comments acknowledged. Where roughness was used to represent existing private bridges, walls or other structures in the model, appropriateness of the roughness factors were confirmed with Wellington Water. It is expected that the final planting plan and recommended maintenance practices will be consistent with roughness factors used in the model in 'fresh plains' areas below the proposed top of bank and that changes to roughness represented in the model will not be required. The roughness values used were reviewed internally and with our client to confirm they are appropriate.	The channel roughness factor used are appropriate for the stage of design. The modeller should confirm that the appropriate roughness is used when the "final planting plan and recommended maintenance practices" are confirmed. **CLOSED**	**2**	**Yes**

Item Checked	Findings & Comments	Modeller's response	Reviewer close out comments	Rating	Fit for use
Stream works					
Culverts	• A replacement culvert is included in the design model at Pinehaven Rd 4.05m x 1.81m (existing is 2.96m x 1.54m). Inlet loss applied but we can't confirm if this is correct without inlet details. • A new culvert at Sunbrae Dr has been included as 6 m x 1.5m (existing is 1.785m dia). Again, the appropriateness of the inlet loss is to be confirmed. • If the culverts are to have natural bed materials (to facilitate fish passage) then the roughness should be increased on the base? Modeller to confirm	The replacement culvert at Pinehaven Road is 4.0m x 2.5m (including 700mm embedment) and the replacement culvert for Sunbrae Drive is 6.0m x 2.0m (including 500mm of embedment). Inlet losses have been adopted from the previous modelling. As the design is likely to improve inlet efficiency the parameter values adopted are likely to be conservative. The roughness values used were reviewed internally and with our client to confirm they are appropriate.	We note the Modeller's response that the culverts are embedded which confirms the sizing. However, the modelled culverts in both the Base and Design cases have bed roughness of n=0.015, which is low for a gravel bed through a culvert. Manuals and experience suggest a higher n value for channels described as 'gravel bed with sides of formed concrete'. We note that the culverts are wide in relation to the height, and so the bed material is a significant component of the total roughness. If absolute flood levels are required, then this issue remains **OPEN**.	**2**	**See comment**
Bridges	Bridges in the model have been modelled as culverts. Given their scale this is appropriate.	Noted; agreement with comment.	**CLOSED**	**0**	**Yes**
Other structures	The modelling of the bypass weir has been updated since 2015 review. In speaking with Jacobs, the weir length has been adjusted to account for actual length and then adjusted for effective length. Doesn't change between Base and Design models	Noted, agreement with comment. No changes have been made to the bypass weir between the (updated) Base and Design models.	**CLOSED**	**0**	**Yes**

Item Checked	Findings & Comments	Modeller's response	Reviewer close out comments	Rating	Fit for use
Initial water level/flow	Initial water depths remain the same between the two models	Noted; agreement with comment.	**CLOSED**	**0**	**Yes**
MIKE Flood					
Lateral coupling	Coupling is the same between base and design models using default setting. A combination of left and right (or both) coupling depending on the location. All seems appropriate.	Noted; agreement with comment.	**CLOSED**	**0**	**Yes**
Coupling parameters	Default figures have been used	Noted; agreement with comment.	**CLOSED**	**0**	**Yes**

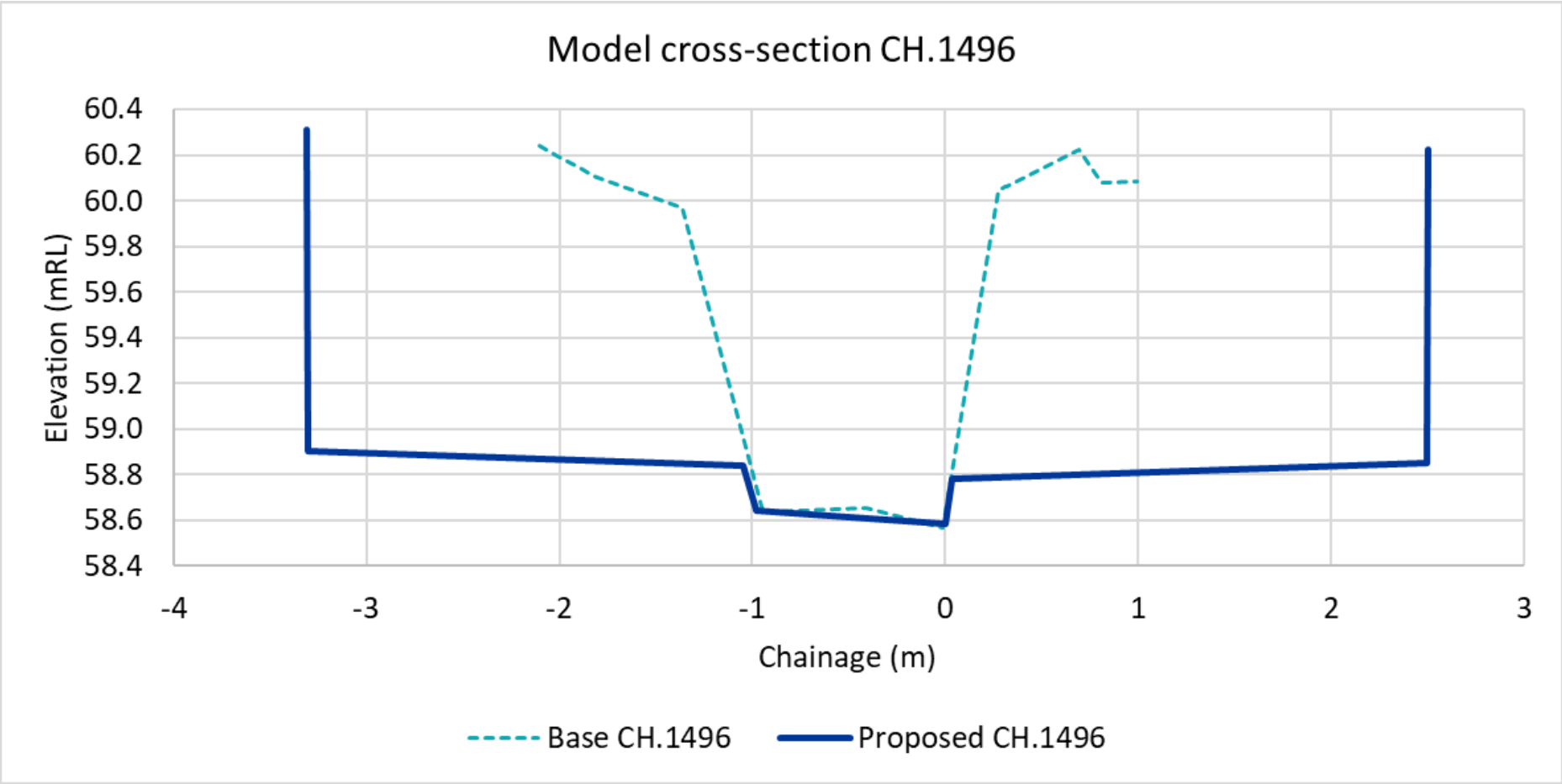


Figure 4-6 Cross-section 1496

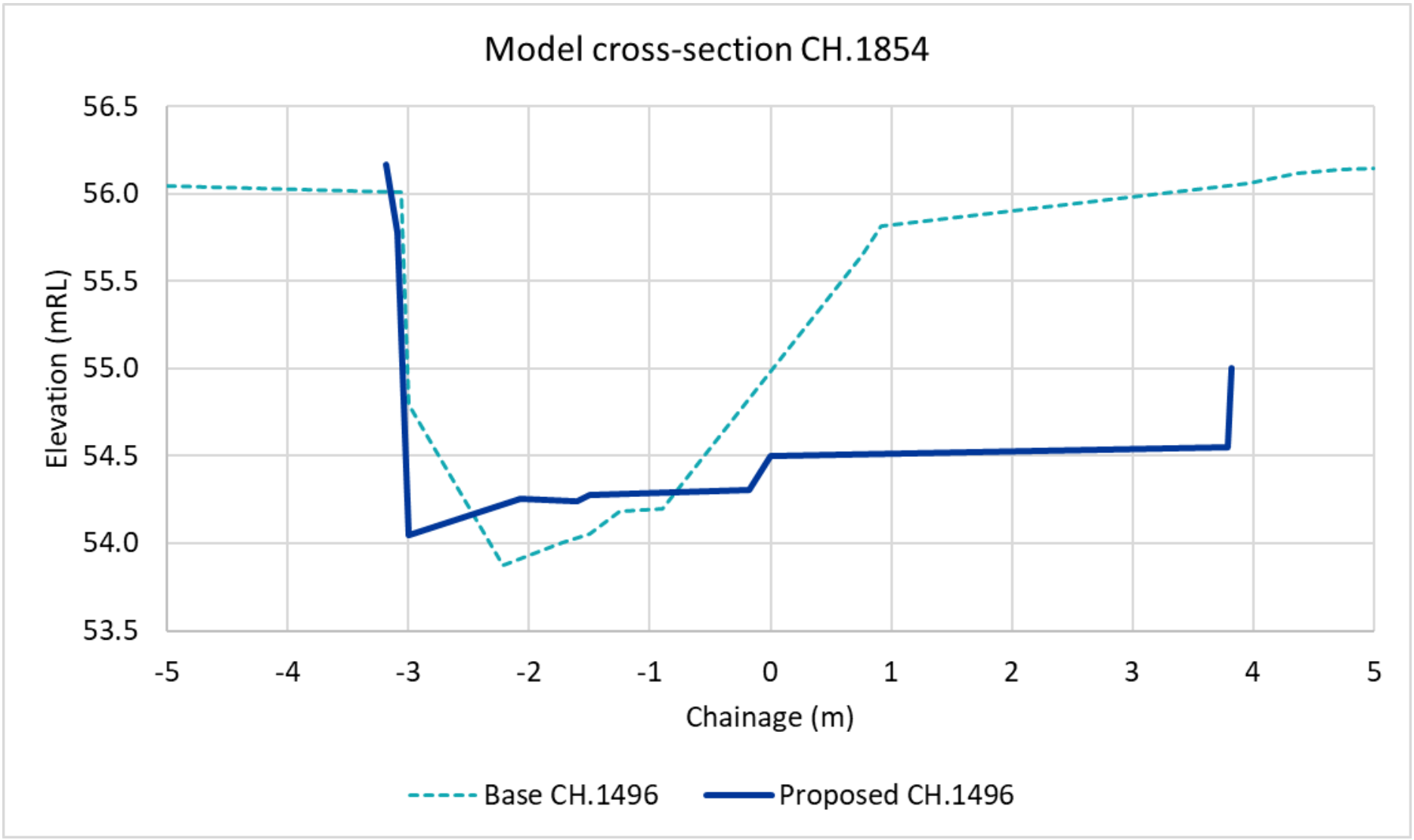


Figure 4-7 Cross-section 1854

4.4 Results

We note that there is a significant reduction in flooding downstream of Pinehaven reserve.

Item Checked	Findings & Comments	Modeller's response	Reviewer close out comments	Rating	Fit for use
Blockage testing	No blockage testing appears to have been undertaken. It would be appropriate to test the sensitivity of the existing Base case culverts/bridges and Design culverts to blockage. This could be done using a method such as developed for ARR that accounts for the availability and mobility of debris, and the size of the culvert in setting an appropriate amount of blockage to model.	Blockage assessments for the base scenario and for the Pinehaven Road and Sunbrae Drive culverts were completed and results can be provided, however there have been changes to the design since this blockage analysis was completed and we have not assessed whether the findings are still valid. A blockage assessment for the design will be provided once it is complete.	This issue is not expected to adversely affect the relative effects of the stream works, and so does not materially affect the 'fit for use' categorisation. However, the Reviewer notes that testing is ongoing and so the issue will remain open until that is completed. **OPEN**	**2**	**Yes**
MIKE11 Water levels	The HGL plot in Figure 4-8 and Figure 4-9 shows that the 100-year ARI event water levels are reduced in most stretches of the stream due to the stream widening and larger culverts. Two sections have increased in water level. • The piped section in and upstream of Pinehaven Reserve. This is unexpected, as we assumed that there were no changes in this reach and do not expect it to be affected by the stream works. Is the modeller able to explain this? • A short section at Ch.1600. Near 2A Freemans Way (as stated in the executive summary of the Flood Hazard Assessment report)	The piped section in Pinehaven Reserve was not checked because it is outside the area of main channel works. Differences in water level do not affect containment within the channel (as this is a piped section) or habitable floor flooding (as the area is a reserve). Near 2A Freemans Way there are no channel works proposed. The differences are thought to be due to a combination of channel works upstream directing more flow into this reach instead of entering the Birch Grove area and a slight change in timing of the flood peak.	Uncertainty over the cause of the raised water levels through the reserve is not expected to adversely affect the relative effects of the stream works, and so does not materially affect the 'fit for use' categorisation. However, the Reviewer notes that the issue is not resolved and so the issue will remain open **OPEN**	**2**	**Yes**
MIKE21	Downstream of Pinehaven reserve there is a significant reduction in flood levels. These are replicated in both the M11 water levels and the M21 results (Figure 4-10).	Noted; agreement with comment.	**CLOSED**	**0**	**Yes**

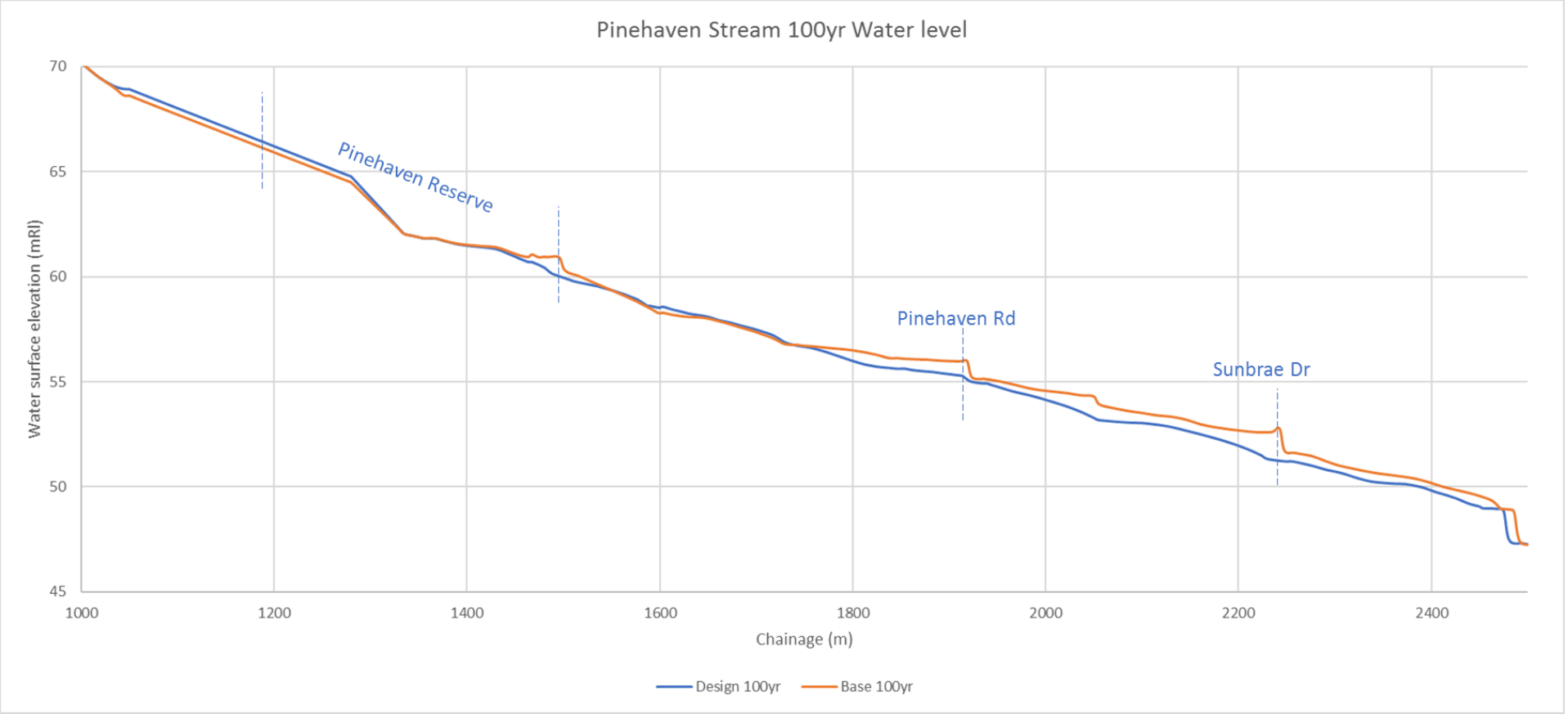


Figure 4-8 100-year ARI long-section

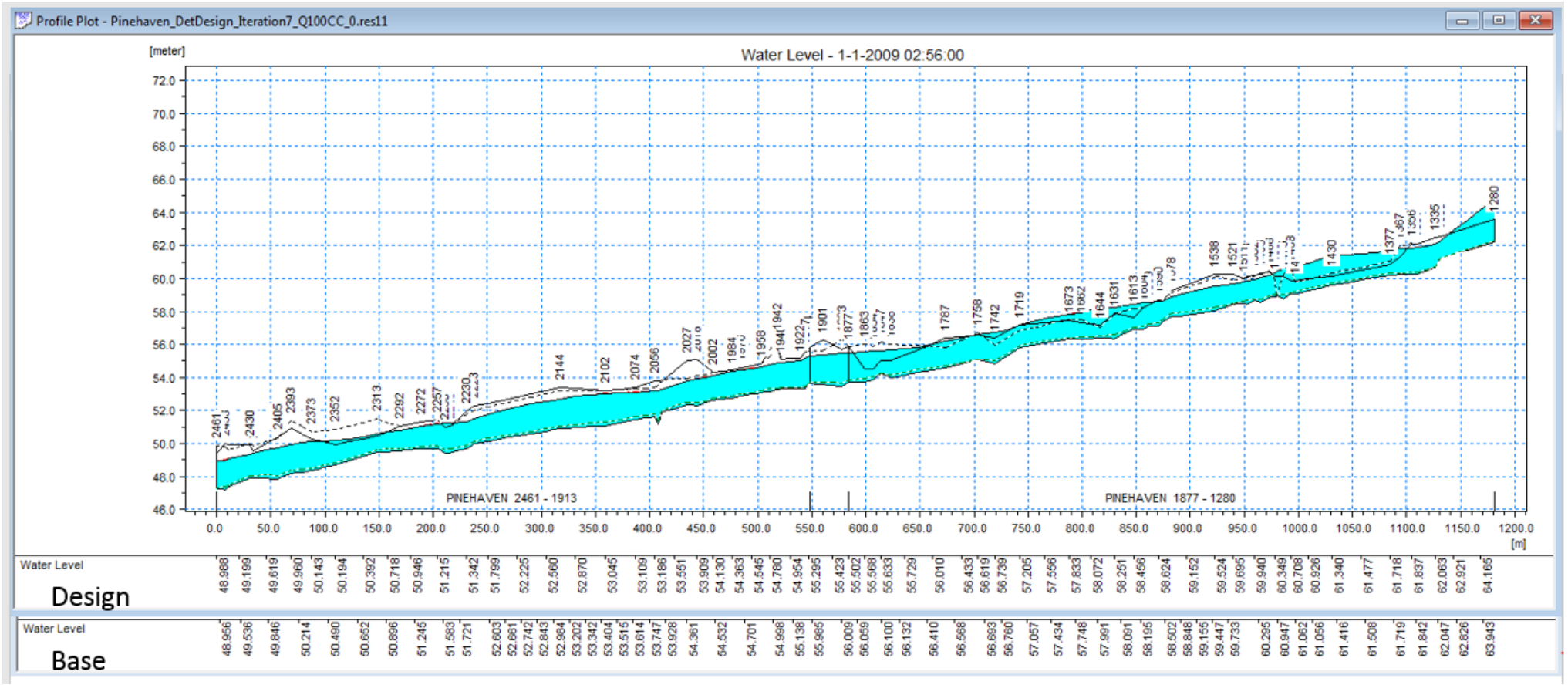


Figure 4-9 100-year ARI hydraulic grade line (Clip from MIKE View)

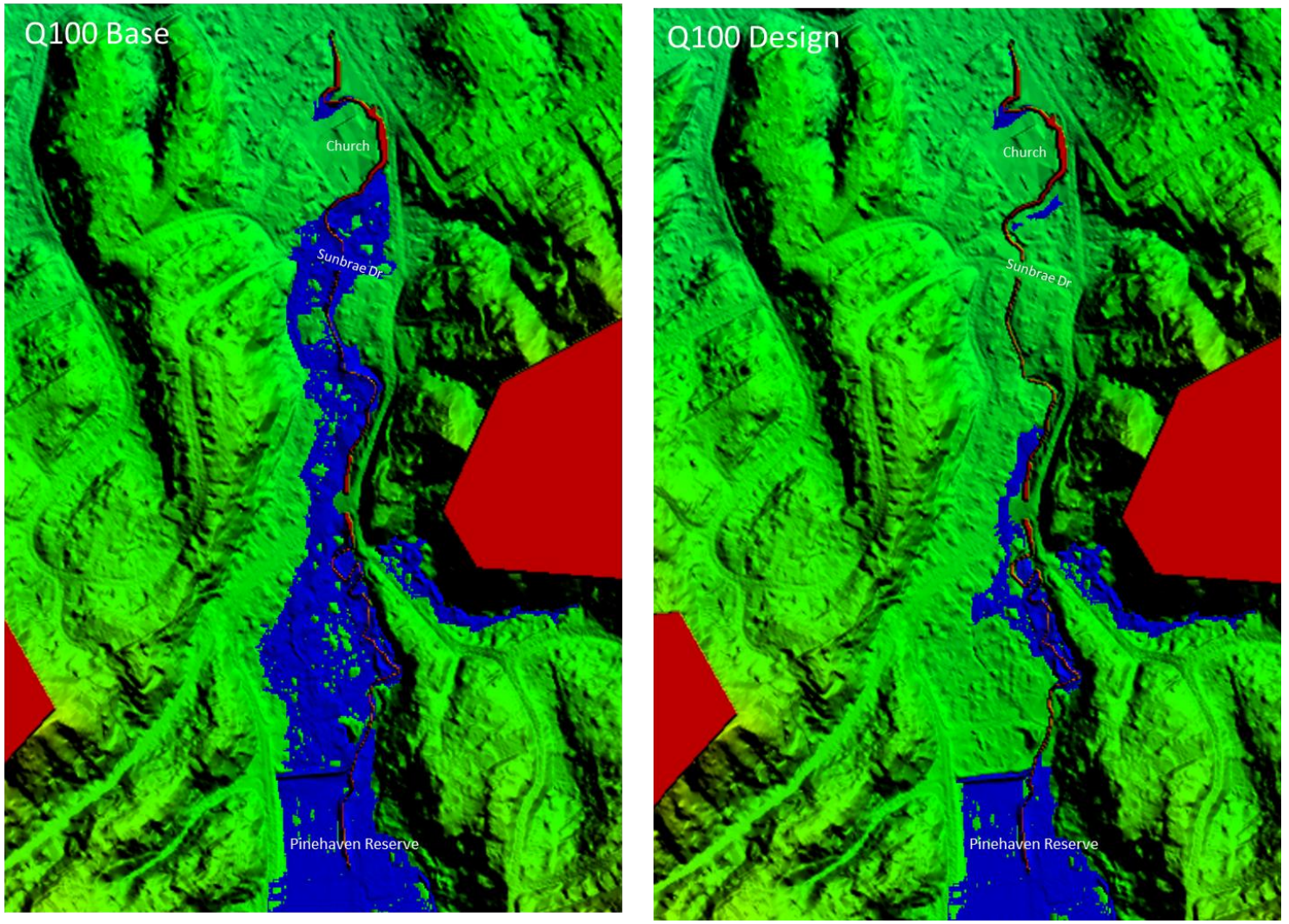


Figure 4-10 100-year ARI MIKE21 (2D) flood extents.

5 Commentary on reports

Beca were provided with three reports to provide background and update information on the recent flood modelling.

5.1 Draft Flood Modelling Report (Jacobs 2017)

This report describes the updates to the 2009/2010 Existing Case Model to incorporate new LiDAR and channel cross-section information, and the modelling of preliminary design options as they were in 2017. We note that the channel cross-sections were only updated for the reach between Pinehaven Reserve and Whitemans Road; the reach that is to be subject to stream widening.

The changes to the Existing Case Model are reported to have generally reduced peak flooding depths and levels (and the number of properties affected by flooding), and explained in Section 5 of the report as:

> *"The difference in flooding depths can be explained by two factors. Firstly, the smaller grid size which means the Updated Existing Case Model incorporates increased definition of both low-lying and raised areas. Secondly, the cross-sections from the 2015 survey provided more channel capacity in some locations which reduced the overland flooding."*

We note that:

- The two improvements to model definition are in line with recommendations made in Beca's 2015 audit of the flood modelling and mapping (Beca 2015).
- The report confirms that the hydrological inputs were unchanged from the 2009/2010 Existing Case Model, which meant that the allowance for climate change was based on MfE's 2008 guidance.
- An assessment of freeboard was not included in the report, though it is noted that this is to be carried out at detailed design stage.
- The 2017 preliminary designs for the Pinehaven Road and Sunbrae Drive culverts described in the report are different from the culvert designs presented in 2019.
- The Preliminary Design of channel widening, and replacement road culverts, reduces the number of properties affected by flooding. The modelling described does not consider the effect of modelling the culvert upgrades in isolation.
- Though two years old, the report is flagged as Draft. We assume that a Final version of the report has not been produced.

Though we have not reviewed the 2017 model, the report provides a fair reflection of the updates noted in the 2019 version of the Existing Case Model. We did not note any obvious errors in the report.

5.2 Flood Hazard Assessment Report (Jacobs 2019a)

The Flood Hazard Assessment Report does not describe the changes in the modelling that are described in Jacob 2017. Rather, the report summarises the objectives of the Pinehaven Stream Improvements Project, the proposed works, the results (in terms of flood levels and properties affected by flooding) and an assessment of the effects. This is appropriate for the target audience of the report, but does require the report to reference a current version of the Flood Modelling Report.

We note that the results and effects reported are for the stream improvements including both the channel widening and replacement of road culverts. However, the road culverts are being consented separately, which could result in different effects to the combined works. We raised this with Jacobs at a meeting to kick-off this review process, and it is partially addressed in the Section 5.3.

We did not note any obvious errors in the report.

5.3 Memorandum - Addendum to the Flood Hazard Assessment Report (Jacobs 2019b)

In response to a question raised (during the initial phase of this model review) about the ongoing use of hydrology incorporating MfE's 2008 guidance on allowances for climate change, Jacobs provided a draft addendum to the Flood Hazard Assessment report on 14 November 2019. This related to increasing the catchment flows by +20% rather than +16% to allow for climate change to represent MfE's 2018 updated guidance[4] on climate change. Separately, the addendum also summarises the effects of only upgrading the two road culverts (and not the associated channel improvements), given that these are subject to a separate consent application.

5.3.1 Increase allowance for climate change

A summary of the reported difference in water levels is provided by the following two bullet points from Page 2 of the addendum.

- *"For the 25-year flood event (4% AEP) the maximum increase in water level is 31mm and the median increase is 18mm. The highest increases in peak water level occur immediately upstream of Pinehaven Road. The maximum increase in velocity is 0.07m/s and the median increase is 0.02m/s.*
- *For the 100-year flood event (1% AEP) the maximum increase in water level is 110mm and the median increase is 27mm. The highest increases in peak water level occur at the lower end of the works, from about 20m upstream of the Bypass Inlet and downstream in the Lower Pinehaven Stream reach. The maximum increase in water level occurs at the inlet to the main Pinehaven Stream culvert in Whitemans Road. The maximum increase in velocity is 0.07m/s and the median increase is 0.03m/s."*

While those show the effect of increasing the flows on water levels and velocities, Table 1 on page 3 of the addendum shows that there is no increase in "habitable floor polygons" inundated in the 'with culvert and stream works' modelled scenario when the climate change allowance is increased from +16% to +20%.

While the results reported in the addendum are in line with what might be expected, Beca has not reviewed the model run files used to generate the results reported in the addendum.

5.3.2 Installation of culvert only (no stream works)

Table 2 on page four of the addendum summarises the change in water levels due to installation of the culverts only. Water levels generally increase and at the end of page 8 of the addendum it is acknowledged that the freeboard required for the Sunbrae Drive culvert is not met in the interim (culvert only, no stream works) scenarios. Mitigation for this is proposed in the final paragraph on page 9 of the addendum.

- *"As a result of the projected increase downstream of the Sunbrae Culvert for the interim condition before the stream works are completed, it is recommended to temporarily choke the inlet so the upgraded culvert discharge remains consistent with the base scenario. This will prevent an increase in water surface elevation for the interim condition compared to the base scenario. "*

Recognising that the addendum is a draft version and not all the model runs were completed, the final version of the addendum should include more explanation as to why the water levels increased as a result of the 'culvert only' works. This may be due to increased conveyance through the culverts. But this should be explained and clarified.

As with the updated climate change scenarios, Beca has not reviewed the model run files informing these results.

[4] ***Climate Change Projections for New Zealand – 2nd Edition***, MfE reference 1385. September 2018. https://www.mfe.govt.nz/publications/climate-change/climate-change-projections-new-zealand

6 Our findings

- The model represents a build that was common (and still is in some situations) when the model was built ten years ago. It is a standard grid type model, with reasonably large catchments and no pipe network. If a model were built of the catchment today it would likely have model detail included outside of the stream, including the piped stormwater network. However, that does not mean that the model is not fit for purpose.
- The stream now has a reasonable amount of detail and has been surveyed in critical locations. Changes have been made to the Design model but without the design drawings we cannot say if they have been represented and modelled correctly, and whether sufficient freeboard has been provided to the top of the stream bank.
- The changes to the model do represent a reduction in flood levels within the catchment but only if the design matches that represented by the model.
- We note that the model results do not include freeboard. This is noted in the draft modelling report (Jacobs 2017) and should be recorded on outputs so as to minimise the risk of confusion with other flood extent maps and water levels for the Pinehaven catchment.
- The modeller has provided acceptable responses to most of the issues raised by the draft review (circulated on 11 November 2019). While some issues remain categorised as level 2, most do not prevent the model for being used for this project.
- However, the importance of one issue remains to be confirmed before the model is considered fit for purpose. That issue is the roughness value used in the two culverts, which are embedded in the stream to provide a natural stream bed. The model has a roughness value of n=0.015 for both the Base and Design cases. We would have expected a higher roughness to be used, given that the culverts are wide in relation to the culvert height the natural bed forms most of the wetted perimeter of the channel. While using the same roughness value for both the Base and Design models will allow a comparison of relative flood levels, increasing the roughness value would be expected to increase absolute flood levels.
- The Draft Flood Modelling Report (Jacobs 2017) and Flood Hazard Assessment Report (Jacobs 2019a) provide good descriptions of the modelling undertaken and flooding results. Beyond the issues raised in the model review (Section 4) there are no significant issues raised by the reports
- The Addendum to the Flood Hazard Assessment Report (Jacobs 2019b) addresses an interim solution to accommodating MfE's 2018 guidance on climate change. However, we recommend that the model hydrology is updated when resources allow. Information provided in the addendum acknowledges that the two road culverts are to be consented separately from the other stream works, goes some way to describing the effects of upgrading the culverts in isolation *(additional modelling being undertaken at the time of writing)*.

7 Conclusion

The model is only considered fit for use to describe the relative changes in flood level and confirm a reduction in the number of properties affected by flooding. If absolute flood levels are required, the culvert roughness must be closed out for the model to be fit for use.

Other issues may be addressed at detailed design and as agreed with Greater Wellington Regional Council.

8 Use of this report

This report has been prepared by Beca on the specific instructions of our Client. It is solely for our Client's use for the purpose for which it is intended in accordance with the agreed scope of work. Any use or reliance by any person contrary to the above, to which Beca has not given its prior written consent, is at that person's own risk.

Should you be in any doubt as to the applicability of this report and/or its recommendations for the proposed development as described herein, and/or encounter materials on site that differ from those described herein, it is essential that you discuss these issues with the authors before proceeding with any work based on this document.