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Memorandum

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Subject	**Adedendum to the Pinehaven Stream and Culvert FHA Reports**	**Project Name**	Pinehaven Stream Improvements
Attention	Josie Burrows, GWRC James Beban, UHCC	**Project No.**	IZ089000
From	Peter Kinley		
Date	November 27, 2019		
Copies to	Michael Law (BECA), Elliot Tuck (BECA),Tristan Reynard (WWL), Angela Penfold (WWL)		

1. Introduction

Following the issue of the Flood Hazard Assessment Report (FHA) in September 2019 Jacobs have used the hydraulic model for the Pinehaven catchment to:

- Reassess the effect of climate change on rainfall depths in accordance with the IPCC Fifth Assessment (AR5) and to a projected 2120 timeframe.
- Investigate the effects of interim scenarios where the upgraded culverts (at Pinehaven Road and Sunbrae Drive) are installed before the main stream channel upgrades. The three interim scenarios are:
    - Pinehaven Road culvert only
    - Sunbrae Drive culvert only
    - Pinehaven Road culvert and Sunbrae Drive culvert only

The updated assessment of climate change was driven by new guidance from the Ministry for the Environment (MfE, September 2018). We consider that the Representative Concentration Pathway 4.5 (RCP4.5) emissions curve from AR5 is appropriate and have adopted a planning horizon of 2120 to determine that the allowance for climate change required by the new MfE guidelines is a 20% increase in extreme event rainfall depth, compared to the 16% allowance used in the FHAs. We determined this in two ways:

1. We confirmed the requirements of Wellington Water Ltd.'s Regional Specification for Water Services, which are for a 20% increase in extreme rainfall
2. We used rainfall data from HIRDS version 4 to calculate/extrapolate the allowance.

The values we calculated from HIRDS version 4 were lower than the Wellington Water requirements; therefore, we chose the more conservative value.

The interim scenarios have been re-modelled in response to a request for further information under section 92 of the Resource Management Act with respect to the Pinehaven Road and Sunbrae Drive culvert resource consent applications.

Figures showing the flood extents for the various scenarios modelled are included as Appendix A to this Addendum.

2. Results from the Remodelling

2.1 Climate change

The hydraulic model of the design scenario (i.e. with the proposed stream improvement works in place) has been re-run with the 25-year flood event (4% AEP) and the 100-year flood event (1% AEP), both with a 20% allowance for the effect of climate change. The water levels for the "20% increase" and the "16% increase" have been compared. An assessment of the reaches where works are proposed has been undertaken and the remodelling shows:

For the 25-year flood event (4% AEP) the maximum increase in water level is 0.03m and the median increase is 0.02m. 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 0.11m and the median increase is 0.03m. 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.

The number of floors within the extent of the 100-year flood event (1% AEP) for the two climate change scenarios for the base model network and the proposed design are shown in Table 2-1.

Table 2-1: Effect of Updated Climate Change Guidelines on Floor Flooding

Scenario		Floors within the 100-year flood event (1% AEP) floodplain		
Network	**Climate Change**	**Habitable**	**Non-habitable**	**Total**
Base	16%	64	16	80
Design	16%	16	7	23
Base	20%	78	31	109
Design	20%	16	7	23

The numbers above differ from the numbers reported in the FHA. The change results from buildings on the eastern side of Blue Mountains Road being excluded, which was done because it was found that the proposed works do not have a significant effect in this area.

2.2 Interim Culvert Scenarios

The base model has been updated to create scenarios representing the effect of:

- The upgraded Pinehaven Road culvert only
- The upgraded Sunbrae Drive culvert only
- The upgraded Pinehaven Road culvert and Sunbrae Drive culvert only.

The base model has been re-run with the 25-year (4% AEP) and 100-year (1% AEP) flood events, both with 20% allowance for climate change. The three interim culvert scenarios with the 25-year and 100-year storm event, with a 20% allowance for climate change have been run and a comparison of the effects on peak water levels, changes in velocity, floors within the floodplain and culvert performance has been undertaken.

2.2.1 Peak Water Levels in the Main Channel

The remodelling shows there are changes in peak water levels for all three interim culvert scenarios compared to the base case. The results are summarised in Table 2-2 and Table 2-3.

Table 2-2: Change in peak water levels for three culvert configurations for the 4% AEP flood event with 20% climate change in the four channel reaches where upgrade works are proposed

Reach	Change in Water Level for each Network Scenario compared to base case (m)								
	Pinehaven Road Culvert Only			Sunbrae Drive Culvert Only			Pinehaven Road and Sunbrae Drive Culvert Only		
	Min	Max	Median	Min	Max	Median	Min	Max	Median
Pinehaven Reserve to Pinehaven Road	-0.75	0.14	-0.01	0.00	0.00	0.00	-0.70	0.02	-0.03
Pinehaven Road to Sunbrae Drive	-0.07	0.05	0.00	-0.74	0.00	-0.05	-0.74	0.04	-0.07
Sunbrae Drive to Bypass Inlet	0.00	0.00	0.00	-0.05	0.14	0.00	-0.05	0.14	0.00
Lower Pinehaven	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2-3 Change in peak water levels for three culvert configurations for the 1% AEP flood event with 20% climate change in the four channel reaches where upgrade works are proposed

Reach	Change in Water Level for each Network Scenario compared to base case (m)								
	Pinehaven Road Culvert Only			Sunbrae Drive Culvert Only			Pinehaven Road and Sunbrae Drive Culvert Only		
	Min	Max	Median	Min	Max	Median	Min	Max	Median
Pinehaven Reserve to Pinehaven Road	-0.78	0.10	-0.02	0.00	0.00	0.00	-0.75	0.02	-0.03
Pinehaven Road to Sunbrae Drive	-0.09	0.05	0.00	-0.62	0.00	-0.06	-0.62	0.03	-0.08
Sunbrae Drive to Bypass Inlet	0.00	0.01	0.00	-0.04	0.15	-0.01	-0.04	0.15	0.00
Lower Pinehaven	0.00	0.02	0.01	-0.01	0.00	-0.01	0.00	0.01	0.00

In Table 2-2 and Table 2-3 negative values show decreases in peak water level for the proposed network configuration when compared to the base network, which is an improvement. Conversely, positive values show increases in peak water levels.

Minimum values (in the “Min” columns) show either the largest decrease in peak water level or the smallest increase. Maximum values (in the “Max” columns) show either the largest increase in peak water level or smallest decrease.

Increases in peak water level occur:

- In the reaches immediately upstream and downstream of the Pinehaven Road culvert for both interim network scenarios that include an upgraded Pinehaven Road culvert.

The largest increases in peak water level occur with only the Pinehaven Road culvert upgraded; including the Sunbrae Drive culvert reduces the magnitude of the increases.

  - With only the Pinehaven Road culvert in place the peak water level upstream of Pinehaven Road increases by up to +0.14m in the 4% AEP flood event and by up to +0.10m in the 1% AEP flood event. Downstream of Pinehaven Road the peak water level increases by up to +0.05m in both the 4% AEP flood event and the 1% AEP flood event.
  - With both the Pinehaven Road culvert and the Sunbrae Drive culvert in place the increase in peak water level upstream of Pinehaven Road is reduced to 0.02m in both events. Downstream of Pinehaven Road the peak water level increases by up to +0.04m and +0.03m in the 4% AEP flood event and 1% AEP flood event respectively.

- In the reach immediately downstream of the Sunbrae Drive culvert for both interim network scenarios that include an upgraded Sunbrae Drive culvert.

  - The increases in peak water level in this reach are not influenced by the Pinehaven Road culvert.
  - The peak water level downstream of Sunbrae Drive increases by up to +0.14m in the 4% AEP flood event and by up to +0.15m in the 1% AEP flood event.

The channel downstream of the bypass inlet is not affected in any of the interim culvert scenarios as all the changes to peak water level are within the range of a -0.01m decrease to a +0.02m increase.

In the other three reaches (Pinehaven Reserve to Pinehaven Road, Pinehaven Road to Sunbrae Drive, and Sunbrae Drive to the Bypass Inlet) the interim culvert scenarios result in changes to the median peak water level of between -0.08m and +0.01m and reductions to the peak water level of up to -0.78m. Increases to the peak water level are +0.05m or less, except at:

- Pinehaven Road for the Pinehaven Road culvert only scenario, where the maximum increase is +0.14m for the 4% AEP flood event and +0.10m for the 1% AEP flood event.
- Sunbrae Drive for the Sunbrae Drive culvert only and the Pinehaven Road and Sunbrae Drive culverts only scenarios, where the maximum increase is +0.14m for the 4% AEP flood event and +0.15m for the 1% AEP flood event.

Increases in peak water level downstream of the culverts result from the increased ability of the upgraded culverts to convey flow. Increases in peak water level upstream of the culverts result from the additional head required to drive the increased velocities in the culvert.

2.2.2 Peak Velocities

The culverts do not change the median velocity in the reaches where works are proposed. The effect of the interim culverts on velocities is shown in Table 2-4.

Constructing only the Pinehaven Road culvert increases velocities in the culvert barrel by up to 0.88m/s for the 25-year event and by up to 1.27m/s for the 100-year event. Installation of scour protection at

the downstream end of the culvert reduces the maximum velocities in the channel by up -0.40m/s. The effects elsewhere in the area of the works are minor.

Constructing only the Sunbrae Drive culvert decreases velocities in the culvert barrel by up to -1.96m/s for the 25-year event and by up to -1.55m/s for the 100-year event. Increases in maximum velocity of up to +0.32m/s occur upstream and downstream of the culvert due to the smoother flow through the culvert. The effects elsewhere in the area of the works are minor.

Constructing both culverts has a similar effect on the change in maximum velocities at the affected areas individually. That is to say, for the interim scenario where both culverts are installed, the effects at Pinehaven Road are similar to when only the Pinehaven Road culvert is installed, and the effects at Sunbrae Drive are similar to when only the Sunbrae Drive culvert is installed, for both the 25-year and 100-year event.

Table 2-4: Culvert Scenario Velocity Results

	Scenario					
	25-year			100-year		
	Pinehaven Road culvert only	Sunbrae Drive culvert only	Pinehaven Road and Sunbrae Drive culvert only	Pinehaven Road culvert only	Sunbrae Drive culvert only	Pinehaven Road and Sunbrae Drive culvert only
Greatest Increase in Maximum Velocity	+0.88m/s	+0.31m/s	+0.88m/s	+1.27m/s	+0.32m/s	+1.30m/s
Change in Median Velocity	0.00m/s					

2.2.3 Flooding and Floors

The number of floors within the extent of the 100-year flood event (1% AEP) for the two climate change scenarios for the base network and the proposed design are shown in Table 2-5.

Table 2-5: Effect of Culvert Upgrades on Floor Flooding

Scenario		Floors within the 100-year flood event (1% AEP) floodplain				
Network	**Climate Change**	**Habitable**	**Non-habitable**	**Total**	**New[1,3] Habitable**	**New[1,3] Non-habitable**
Base	20%	78	31	109	N/A	N/A
Pinehaven Road Culvert only	20%	≤77	≤31	≤108	0	0
Sunbrae Drive Culvert only	20%	71	27	98	2[2]	1[2]
Pinehaven Road culvert and Sunbrae Drive culvert	20%	70	27	97	2[2]	1[2]
Design	20%	16	7	23	0	0

Table 2-5 Notes:

1. New Habitable Floors and New Non-Habitable Floors are floors that are affected by the culvert upgrades. These are floors that are not within the 100-year flood event (1% AEP) floodplain in the Base scenario and are within it for the culvert scenario. i.e. the culvert upgrade brings the building into the floodplain.
2. The New Habitable floors are both on the Silverstream Reform Church property. The new Non-habitable floor is a garage at 1 Tapestry Grove.
3. We note that there are several methods for mitigating the increased water levels downstream. For the Sunbrae Drive culvert we propose to restrict the flow into the culvert to pre-upgrade rates by installing a temporary steel plate across part of the inlet. This steel plate would be removed once the channel upgrades downstream were in place. We request that conditions around the design of the steel plate, its maintenance and the timing of its removal are included in the consent.

2.2.4 Performance of Culverts at Pinehaven Road and Sunbrae Drive

The effect of the interim culvert scenarios on water levels for the 25-year (4% AEP) flood event and the 100-year (1% AEP) flood event, both including a 20% allowance for climate change, at the culverts' inlets is shown in Table 2-6 and Table 2-7.

Table 2-6: Culvert Inlet Peak Water Levels for the 4% AEP flood event with 20% allowance for climate change

Culvert Location		Pinehaven Road	Sunbrae Road
Culvert Soffit Level (design) (m RL)		55.16	51.23
Headwall Level (design) (m RL)		56.90	51.94
Network	**Parameter**	**Pinehaven Road**	**Sunbrae Road**
Baseline	Water Level (m RL)	55.83	52.56
	Freeboard (m)	Not Assessed	Not Assessed
Pinehaven Road culvert only	Water Level (m RL)	55.08	52.56
	Freeboard (m)	1.82	Not Assessed
Sunbrae Drive culvert only	Water Level (m RL)	55.83	51.58
	Freeboard (m)	Not Assessed	0.36
Pinehaven Road culvert and Sunbrae Drive culvert only	Water Level (m RL)	55.13	51.58
	Freeboard (m)	1.77	0.36
Design	Water Level (m RL)	55.07	51.29
	Freeboard (m)	1.83	0.65

Table 2-7: Culvert Inlet Peak Water Levels for the 1% AEP flood event with 20% allowance for climate change

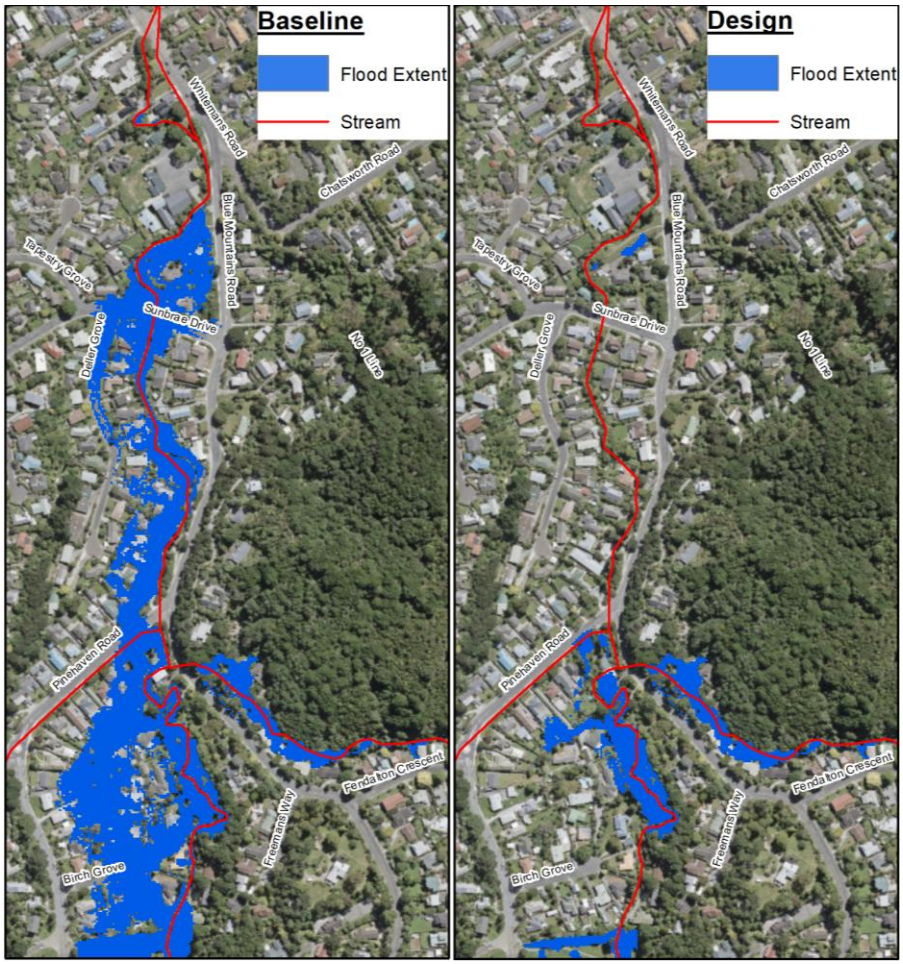
Culvert Location		Pinehaven Road	Sunbrae Road
Culvert Soffit Level (design) (m RL)		55.16	51.23
Headwall Level (design) (m RL)		56.90	51.94
Network	**Parameter**	**Pinehaven Road**	**Sunbrae Road**
Baseline	Water Level (m RL)	55.99	52.61
	Freeboard (m)	Not Assessed	Not Assessed
Pinehaven Road culvert only	Water Level (m RL)	55.24	52.63
	Freeboard (m)	1.66	Not Assessed
Sunbrae Drive culvert only	Water Level (m RL)	56.02	51.77
	Freeboard (m)	Not Assessed	0.17
Pinehaven Road culvert and Sunbrae Drive culvert only	Water Level (m RL)	55.27	51.77
	Freeboard (m)	1.63	0.17
Design	Water Level (m RL)	55.22	51.39
	Freeboard (m)	1.68	0.55

The Pinehaven Road culvert is not surcharged in the 4% AEP flood event. It meets the requirement of at least 0.50m of freeboard from the peak water surface elevation to the top of the headwall for all the relevant interim culvert scenarios and for the design scenario. In the 1% AEP event the Pinehaven Road culvert is surcharged by 0.08m with only the Pinehaven Road culvert in place and by 0.11m with both the Pinehaven Road and Sunbrae Drive culverts in place, which is reduced to 0.06m with the design in place. The freeboard requirements of at least 0.50m is met for all relevant interim culvert scenarios for the 1% AEP flood event.

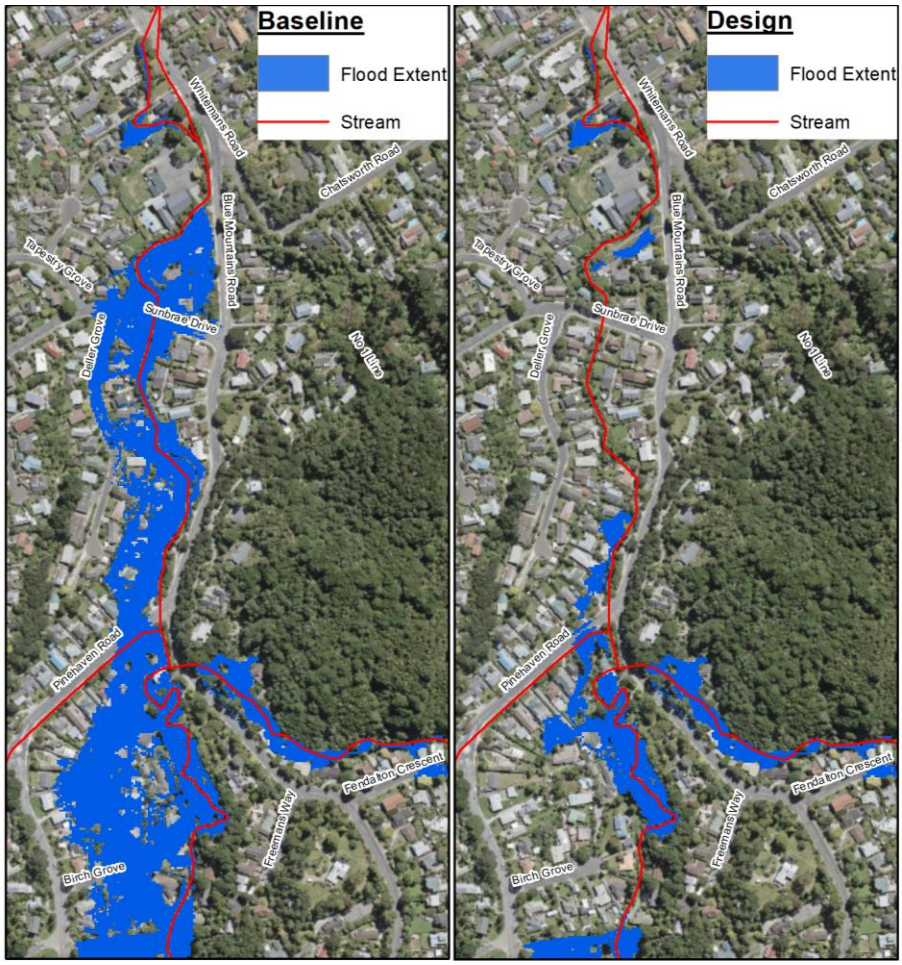
The Sunbrae Drive culvert is surcharged by 0.35m for the relevant interim culvert scenarios in the 4% AEP flood event. With the design in place the surcharge is reduced to 0.06m in the 4% AEP flood event. It does not meet the requirement of at least 0.50m of freeboard from the peak water surface elevation to the top of the headwall for the relevant interim culvert scenarios. The quantity achieved for the design scenario is 0.65m, which meets the freeboard requirement. In the 1% AEP event the culvert is surcharged by 0.54m for the relevant interim culvert scenarios, which is reduced to 0.16m with the design in place. The freeboard requirements of at least 0.50m is not met for any of the relevant interim culvert scenarios for the 1% AEP flood event; 0.55m of freeboard is achieved for the design scenario, which meets the requirement.

Appendix A. Flood extents for different design scenarios

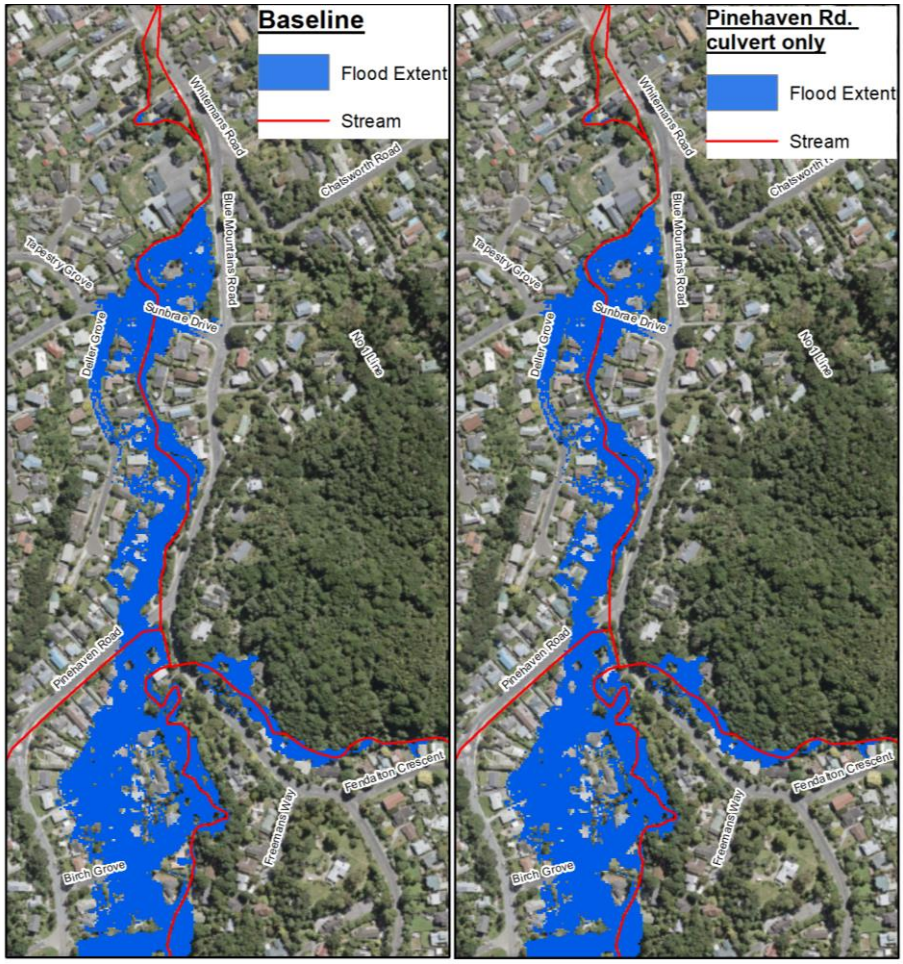
A.1 Effect of the proposed works on the extent of flooding within the project area for the 4% AEP flood (including 20% climate change allowance)



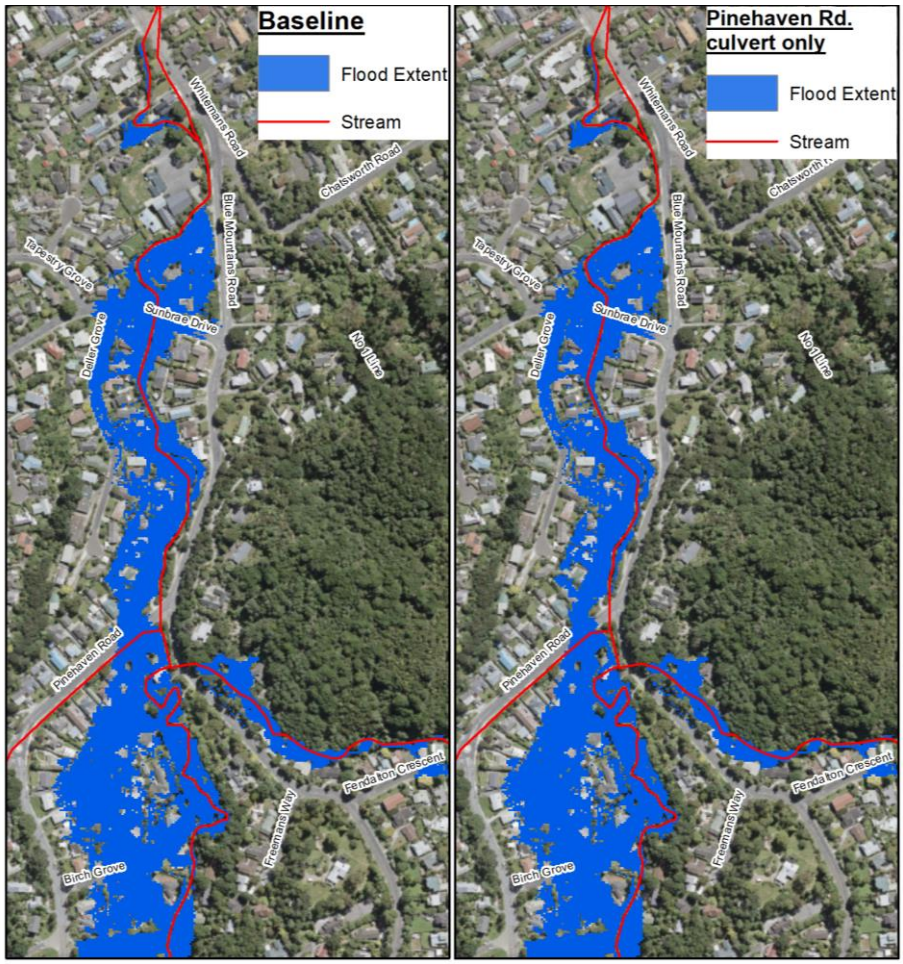
A.2 Effect of the proposed works on the extent of flooding within the project area for the 1% AEP flood (including 20% climate change allowance)



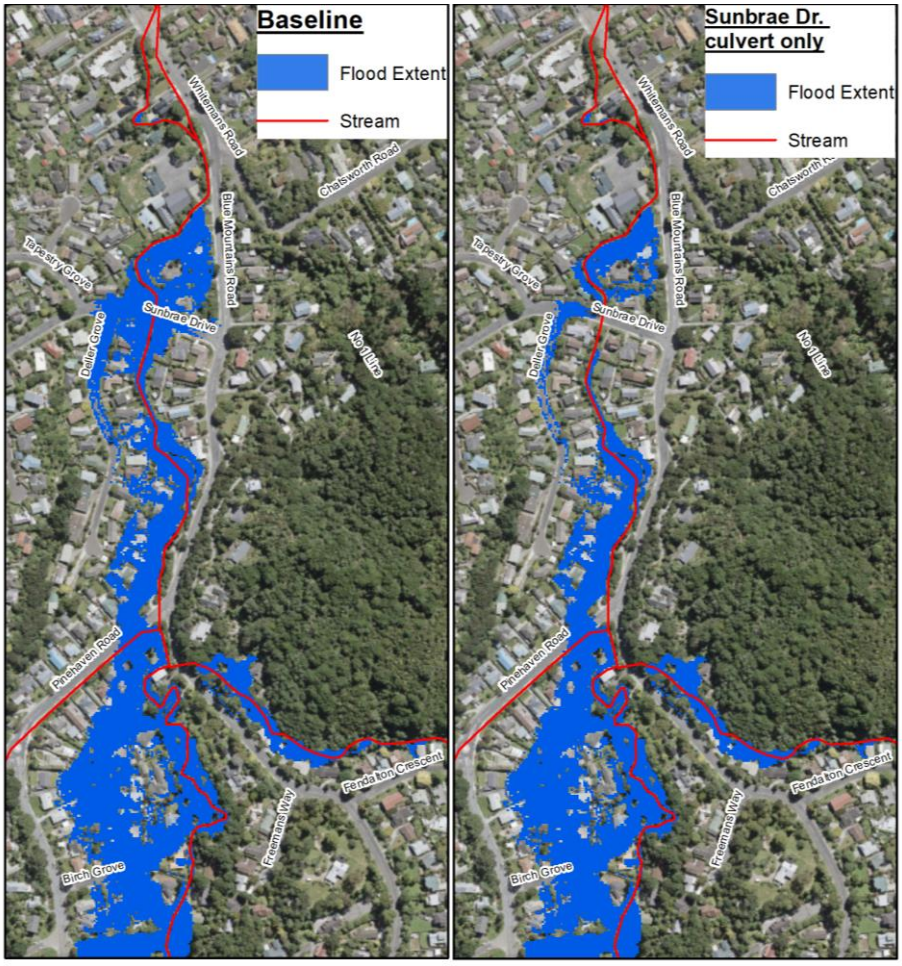
A.3 Effect of the replacement of Pinehaven Road culvert only on the extent of flooding within the project area for the 4% AEP flood (including 20% climate change allowance)



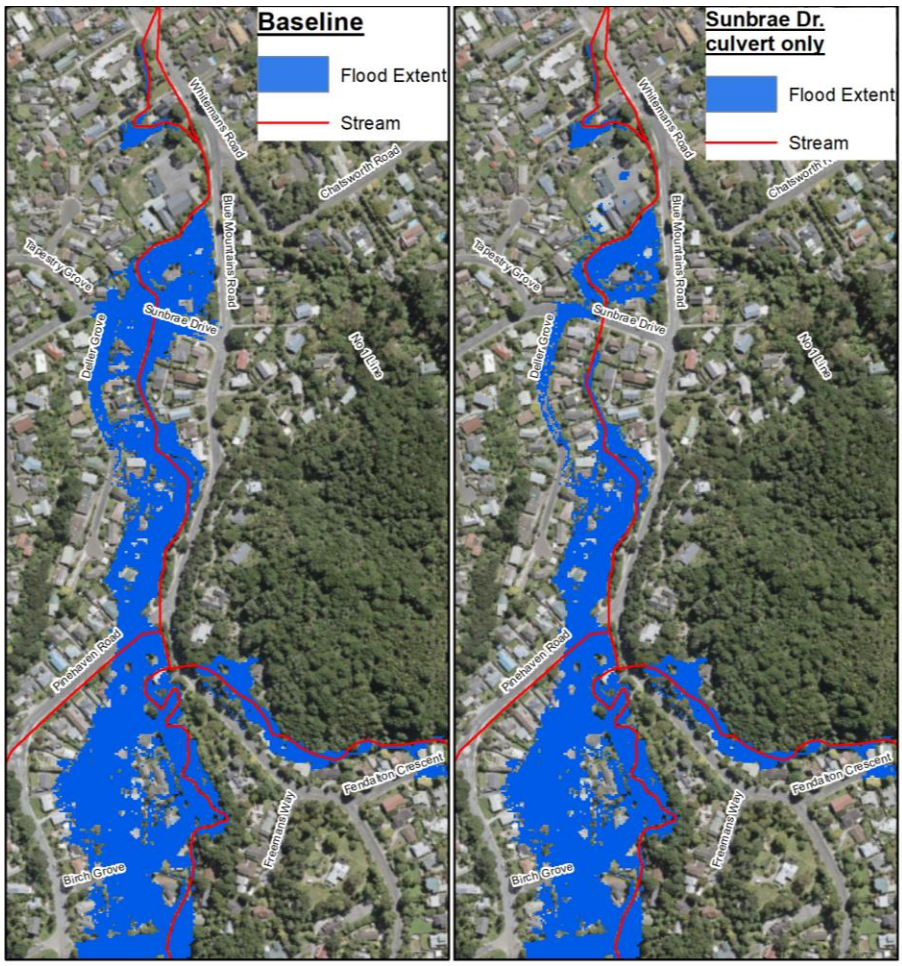
A.4 Effect of the replacement of Pinehaven Road culvert only on the extent of flooding within the project area for the 1% AEP flood (including 20% climate change allowance)



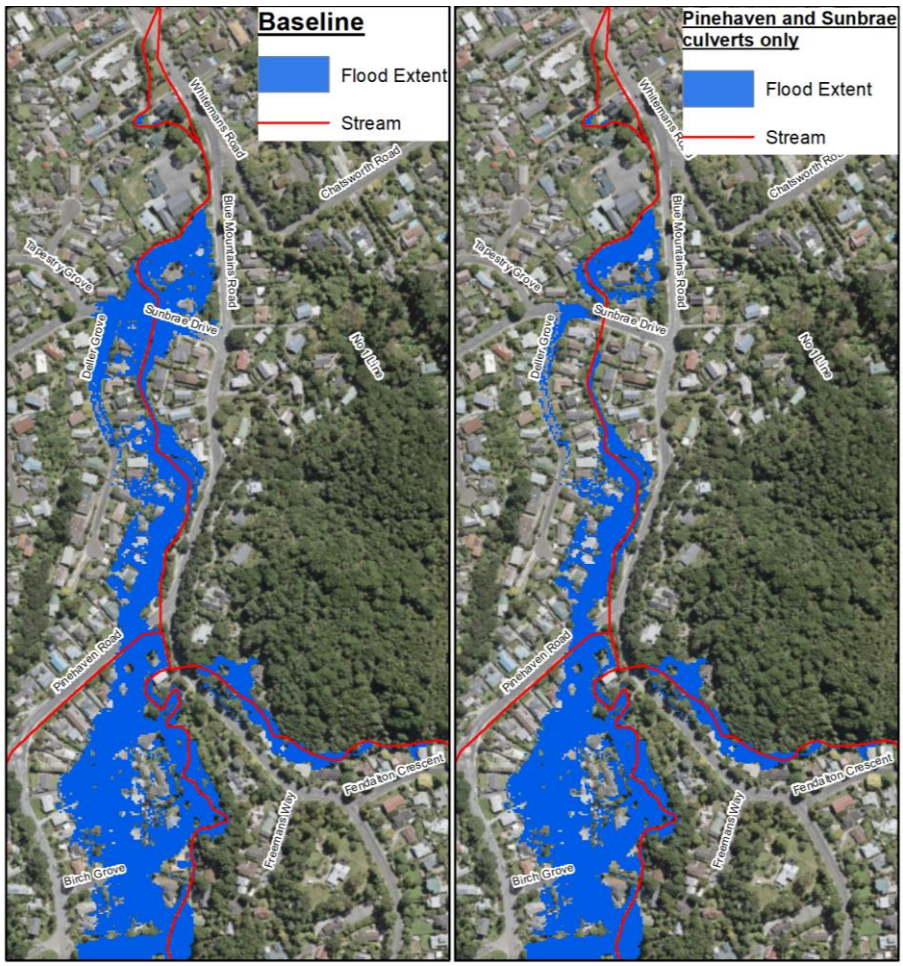
A.5 Effect of the replacement of Sunbrae Drive culvert only on the extent of flooding within the project area for the 4% AEP flood (including 20% climate change allowance)



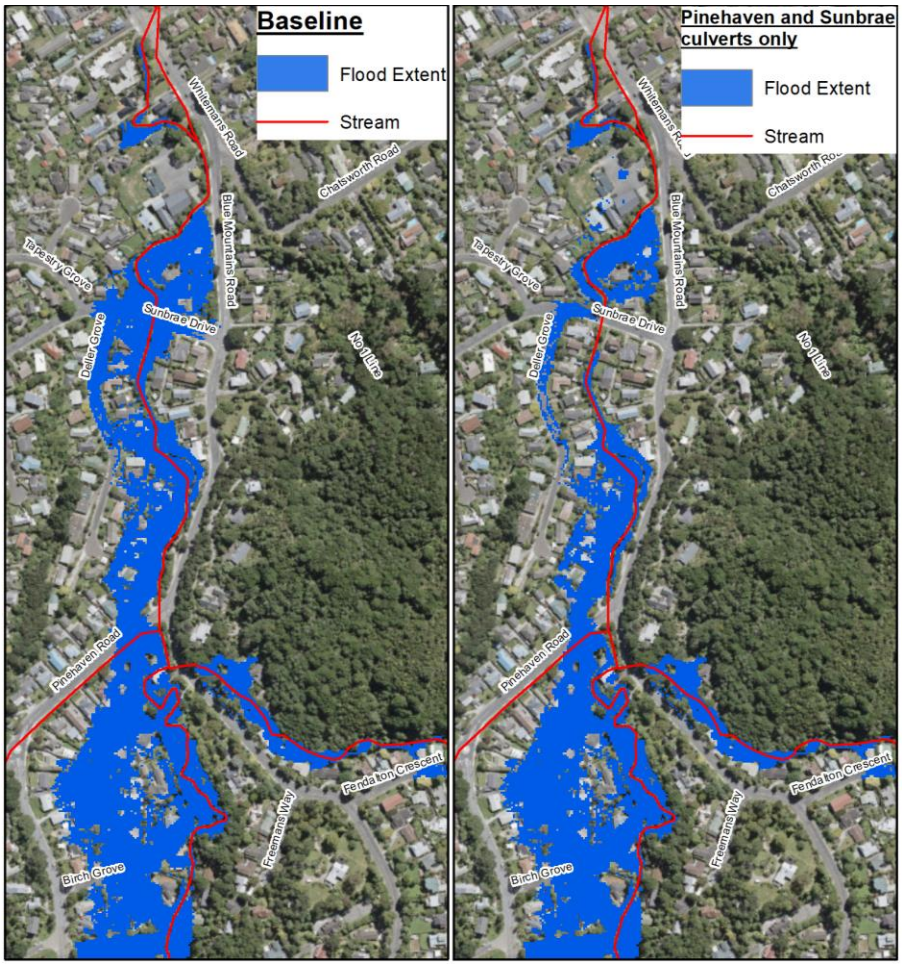
A.6 Effect of the replacement of Sunbrae Drive culvert only on the extent of flooding within the project area for the 1% AEP flood (including 20% climate change allowance)



A.7 Effect of the replacement of Pinehaven Road and Sunbrae Drive culverts only on the extent of flooding within the project area for the 4% AEP flood (including 20% climate change allowance)



A.8 Effect of the replacement of Pinehaven Road and Sunbrae Drive culverts only on the extent of flooding within the project area for the 1% AEP flood (including 20% climate change allowance)



A.9 Change on the extents of flooding for de design scenario within the project area for the 4% AEP flood including 16% (left) and 20% (right) climate change allowance.