Holwerda Wetland Culvert Upgrade Options Report

Bay of Plenty Regional Council
Operations Publication 2014/01

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NEW ZEALAND

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Cover Photo: Photographer Braden Rowson

Acknowledgements

Thanks to Raoul Fernandes, Mark James and Peter West for assistance with the model and technical review.

Executive summary

This report provides the modelling results for different culvert options at both a downstream and upstream intake location of the Holwerda Wetland.

The wetland is separated from the Uretara Stream by an existing stopbank created to reclaim the land. A 600 mm diameter culvert connecting the Holwerda Wetland to the Uretara Stream near the mouth of the stream is currently limiting the amount of water entering and exiting the wetland and consequently the restoration of the wetland to saltmarsh. Erosion at both the stream end and wetland end of the culvert is also a problem.

A culvert upgrade has been proposed to increase the flows into and out of the wetland and reduce erosion on both the wetland and stream sides. An upstream culvert has been investigated with the aim to further increase the volumes of water entering the wetland and potentially provide a freshwater input to the wetland.

The desired primary outcome of the culvert upgrade is to get as close to natural flooding and tidal inundation as possible without removing the stopbank.

This report recommends the replacement of the downstream culvert with two 1200 mm diameter culverts to increase the volumes entering and exiting the wetland. Modelling up to 8 x 1200 mm diameter culverts showed that with more culvert barrels, more water entered and exited the wetland, but the larger numbers of culverts are not cost effective. There was minimal difference in water levels in the wetland whether there was an upstream culvert present or not; a lowering of the upstream culvert invert levels and channel works in the wetland may increase the water levels.

Contents

Tables and figures

Part 1: Background

The Holwerda Wetland property is an historic reclamation (Figure 1 and 2) near the mouth of the Uretara Stream, Katikati.

Figure 1 Uretara Stream, Katikati.

Figure 2 Holwerda Wetland, Katikati.

Until six years ago the reclaimed land was kept dry via the existing 600 mm culvert with floodgate (Figures 3-5). The location of the culvert is shown in Figure 2 with the top yellow dot. The current owner has removed the floodgate to restore tidal inundation and allow the area to revert back to native saltmarsh. Full tidal inundation of the wetland doesn't happen and the flow through the culvert creates significant scouring and eddying on both sides of the culvert. The wetland area is not capable of completely filling as the tide turns before it has reached capacity and then starts flowing out.

Figure 3 Downstream culvert on stream side of stopbank.

Figure 4 View from stopbank to stream.

Figure 5 Downstream culvert on wetland side of stopbank.

There is a small stopbank between the Uretara Stream and the site which is approximately 1.5 - 2 m higher than the paddock level. Approximately half the site is covered with either mud or brackish/salt tolerant species such as rushes and Bachelor's Buttons. The remaining area has low pasture value due to its high water table but requires more inundation to restore it to mud or brackish/salt tolerant species. The stopbank is part of a walkway so the removal of the stopbank is not an option.

The saltwater wedge in the stream has not been measured at low tide but the apex of the saltwater wedge is at the State Highway 2 Bridge (shown near the bottom left of the Figure 1) for a spring high tide. There is some freshwater input to the wetland in the south east corner from natural springs and storm water. The whole area is to be enhanced with machinery with the aim of creating potential native fish spawning and habitat areas. For the current high water table area, re-vegetation will be primarily natural but drier margins that would otherwise grow weeds are likely to be planted in appropriate native species.

Suggestions for replacement of the existing culvert include one or more larger culverts or a footbridge at the downstream location and the installation of second culvert at the upstream end of the wetland (location shown in Figure 1) which may provide large volumes of freshwater through the wetland system at high tide and flood events. Flood events were not modelled. There are concerns about the possible establishment of mangroves in the wetland from mangrove propagules entering the wetland via the channel/culvert. Options for preventing the growth of mangroves in the wetland are mangrove exclusion grates (requiring cleaning) or removal of the mangroves if they start to establish themselves.

The primary outcome that is required from the "culvert upgrade" project is to get as close to natural flooding and tidal inundation as possible without removing the stopbank.

Secondary requirements include:

- Prevent/reduce scouring currently happening at the culvert,
- Provision of freshwater into the wetland to allow variable salinity,
- Prevent mangroves establishing in the wetland.

Variable salinity and the prevention of mangroves in the wetland are not covered in this report.

Part 2: Hydraulic modelling

A model for the Holwerda Wetland was constructed using DHI's MIKE FLOOD software package. MIKE FLOOD is a 1D/2D coupled floodplain model and is appropriate to simulate the spread of water across the wetland. Variable salinity caused by mixing of freshwater was not considered in this analysis.

2.1 Model setup

MIKE FLOOD has two components: MIKE 11 (1D) and MIKE 21 (2D). The MIKE 11 network has been coupled to the MIKE 21 network using a lateral link coupling. The wetland and other floodplains in the area were represented by MIKE 21. For MIKE 21 the 2 m x 2 m DEM (Digital Elevation Model) was resampled to 10 m x 10 m cells. MIKE 11 was used to represent the three channels used in the model:

- The Uretara Stream from chainage 0 to 2239 m with the State Highway 2 Bridge over the Uretara Stream at chainage 0,
- A 73 m downstream connection from the wetland to the stream through the stopbank,
- A 35 m upstream connection from the stream to the wetland.

Adjustments to the model were made to best represent the wetland. Land cells next to Uretara Stream were blocked out to prevent double counting of the storage and at the northern portion of the wetland the stopbank was designated as land cells to prevent overtopping.

Both river left and river right have sections that use external files. The external files were obtained by selecting elevation values on the stopbank using LIDAR.

2.2 Wetland characteristics

The area of the wetland was estimated at 14.7 hectares using ArcMap 10.1. The DEM in Figure 6 shows the relative elevations in a map form.

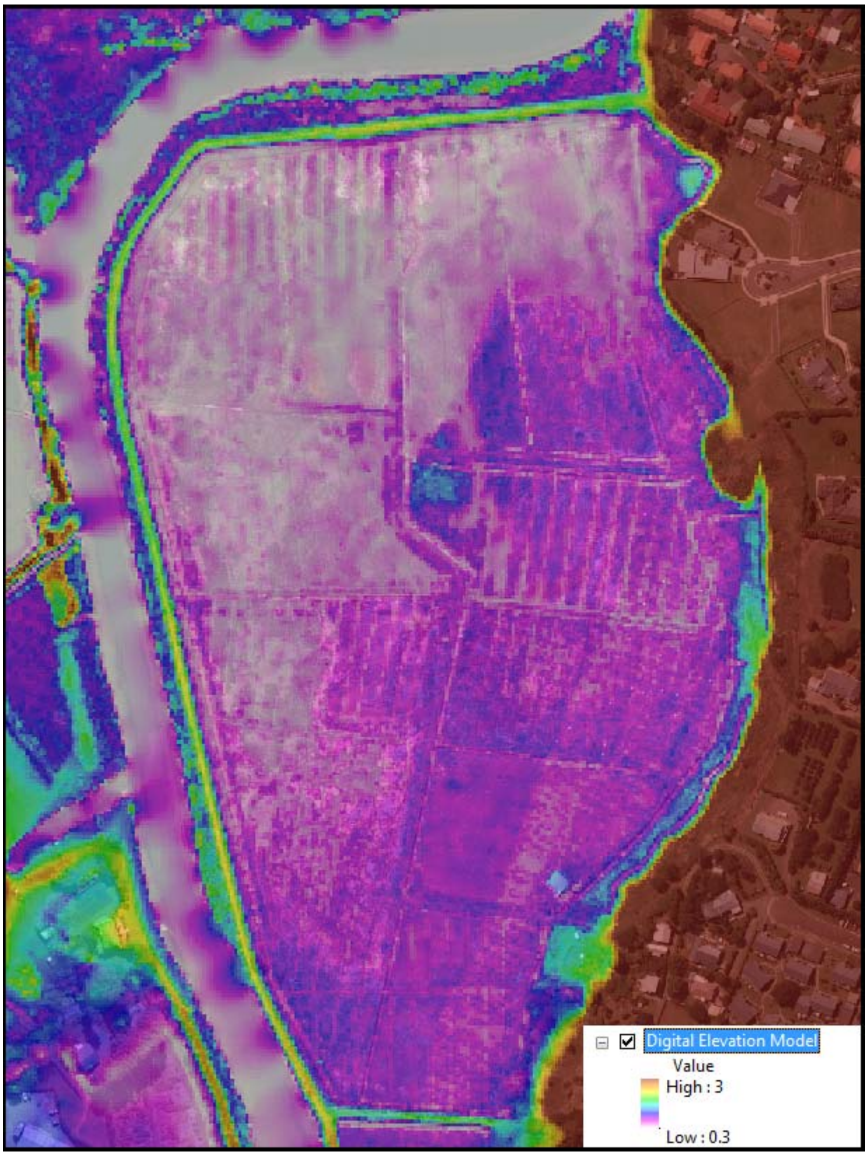

Figure 6 *Digital Elevation Model showing the topography of the Holwerda Wetland.*

2.3 Boundary conditions

The sea level boundary condition for the downstream culvert was three months of tidal data from 1 January 2013 to 1 April 2013 for the Site 14212 Tauranga Harbour at Kotuku Reserve from the Tideda software. The high tide level for the selected three months of tidal records used in this analysis varied from 0.6 m to 1.2 m (Moturiki 1953).

A river flow boundary condition was also required. As there was no daily flow available for the Uretara Stream, a transposed specific annual mean flow of 1.2 m^3/s from the Tuapiro Gauge nearby was used as the boundary condition. Note: the river flows were modelled as continuous constant flows over the three months (not peak flows).

2.4 Cross sections

The cross section for where the culverts pass through the stopbank was set at 10 m wide to ensure all scenarios (including the 8 x 1200 mm diameter culverts option) all fitted into the cross section.

Cross sections for the length of the Uretara Stream between the proposed upstream culvert site and downstream culvert were taken from the Uretara Stream Capacity Review (Medwin, 2006/07).

2.5 Culverts

For the investigation into a suitable culvert capacity, the number of culvert barrels at the downstream location varied from 1 to 8 and from 0 to 4 at the upstream location. Culvert diameters used in the simulation scenarios for the model were 600 mm for the existing scenario and multiples of 1200 mm for other scenarios. The inverts for the downstream culvert were -0.75 (river side) and -0.79 (wetland side) and the upstream culvert inverts were 0.04 (river side) and 0.00 m (wetland side).

The nine different culvert options are shown in Table 1. Note that Option 1 represents the existing situation of one downstream culvert of 600 mm diameter.

Table 1 List of simulations run with culvert diameter and inverts.

<table>
<tr><th rowspan="2">Option #</th><th colspan="2">Downstream</th><th colspan="2">Upstream</th></tr>
<tr><th>Culvert diameter</th><th>Invert levels</th><th>Culvert size</th><th>Invert levels</th></tr>
<tr><td>Existing</td><td>1 x 600 mm</td><td rowspan="9">-0.79 m and
-0.75 m</td><td rowspan="7">N/A</td><td rowspan="7">N/A</td></tr>
<tr><td>1</td><td>1 x 1200 mm</td></tr>
<tr><td>2</td><td>2 x 1200 mm</td></tr>
<tr><td>3</td><td>3 x 1200 mm</td></tr>
<tr><td>4</td><td>4 x 1200 mm</td></tr>
<tr><td>5</td><td>6 x 1200 mm</td></tr>
<tr><td>6</td><td>8 x 1200 mm</td></tr>
<tr><td>7</td><td>2 x 1200 mm</td><td>1 x 1200 mm</td><td rowspan="2">0.04 m and
0.00 m</td></tr>
<tr><td>8</td><td>4 x 1200 mm</td><td>4 x 1200 mm</td></tr>
</table>

2.6 Assumptions

The following assumptions were used with the model:

- The wetland was dry to start with,
- The topography of the wetland was determined using resampled data. The data came from gis_raster.BOP.DEM_BOPRegion_2M,
- Surveyed cross sections used in the Uretara Stream from 2006 are still valid,
- Tidal inputs were based on three months of real data extracted from Tideda at Site 14212 Tauranga Harbour at Kotuku Reserve,
- Estimate of invert levels was from a survey on site and comparison with tide charts,

- Constant river flow within the Uretara Stream throughout the three month period of 1.2 m^3/s from Taupiro Gauge as per section 2.3,
- Mannings n = 0.033 for the 1D model in the stream channels,
- Mannings n = 0.1 for the 2D model in the wetland,
- The datum used for the levels was Moturiki 1953.

Part 3: Results

3.1 Mike results

3.1.1 Water level

Figure 7 shows the water levels for the peak tide from the three months of simulated tide data. For each of the scenarios, the water levels at a point by the downstream culvert inside the wetland are compared against the high tide level on the Uretara Stream side of the culvert downstream of the wetland. Figure 8 shows a zoomed in section of the peak tide.

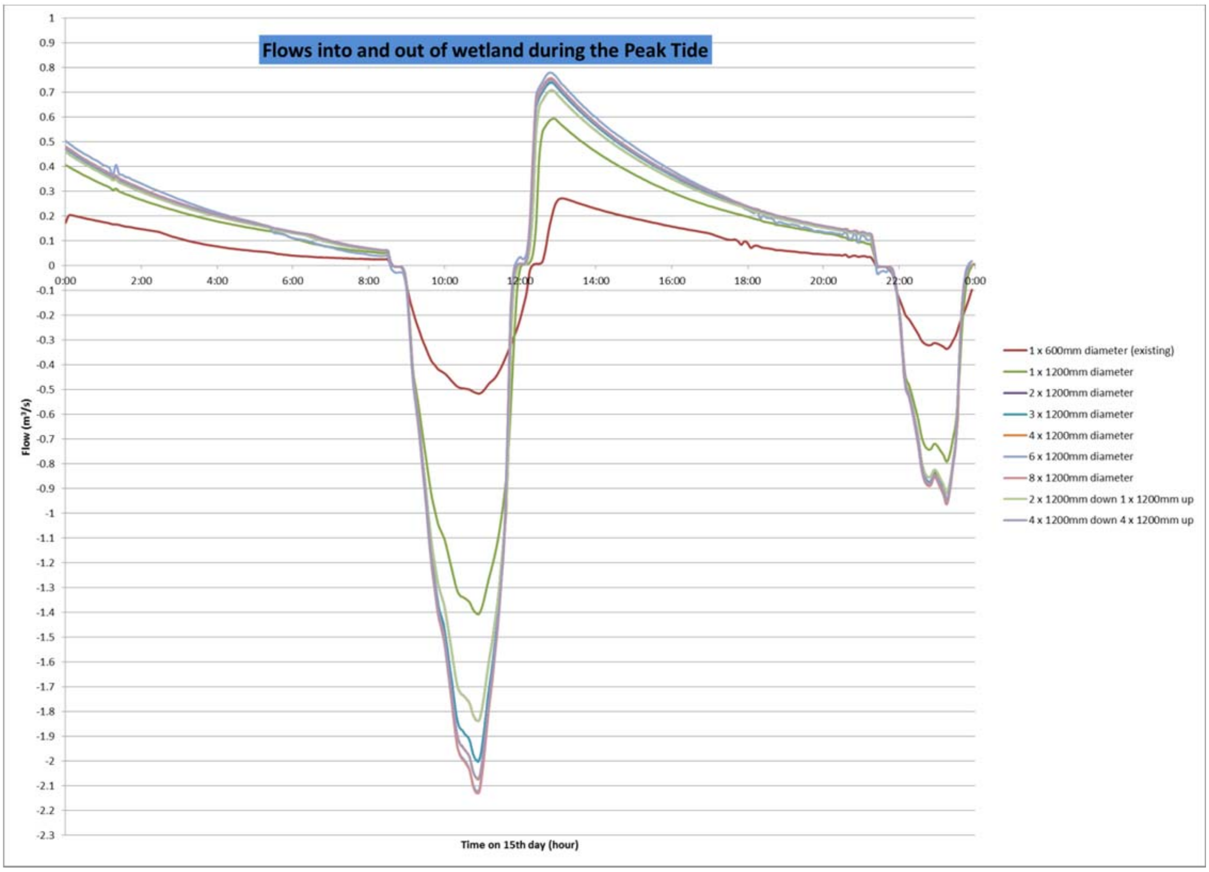

Figure 7 Water levels for the peak tide on 15 January 2014.

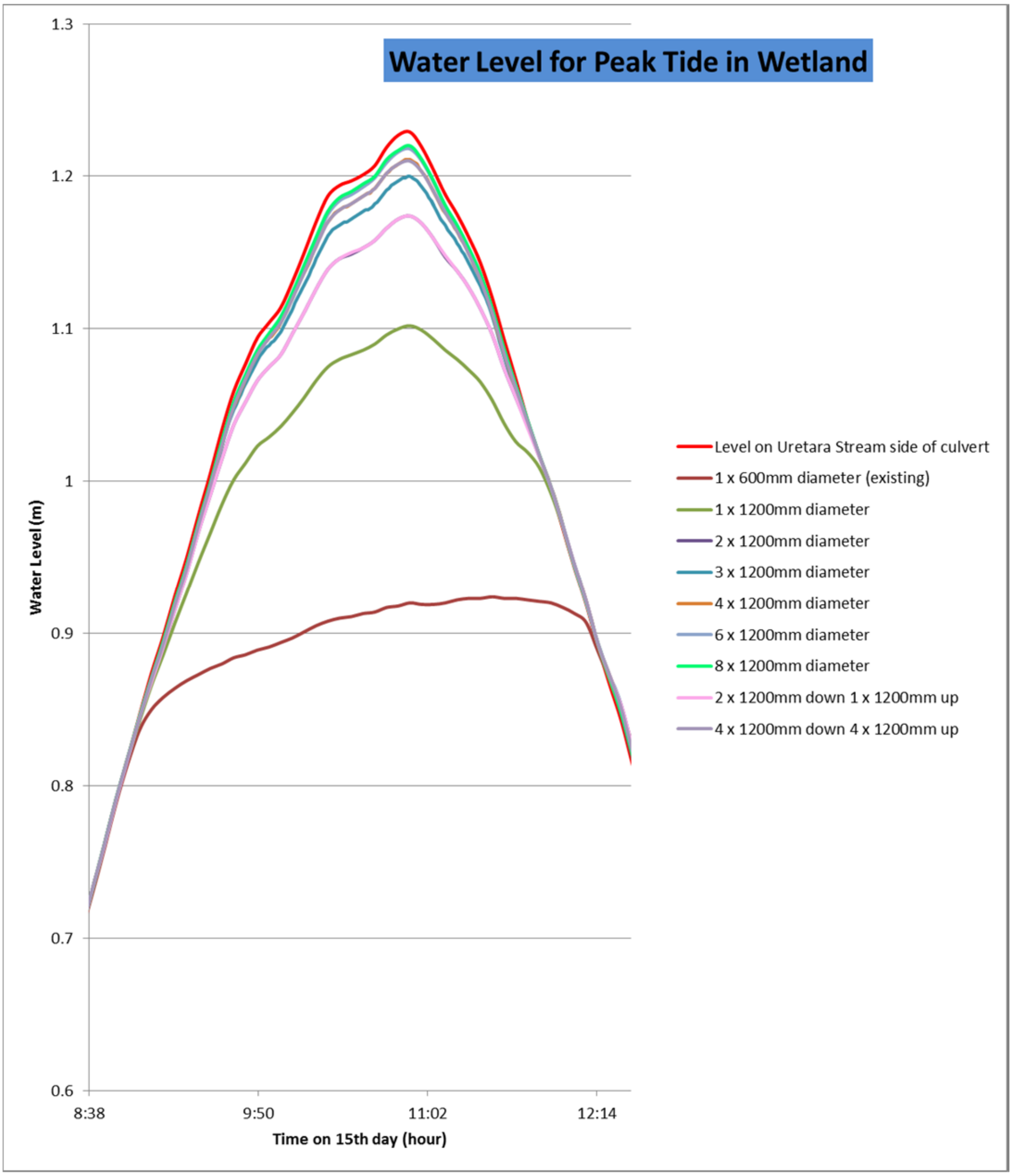

Figure 8 Water level for peak tide on 15 January 2014 (zoomed in).

Table 2 shows the difference in the wetland water level against the peak tide for each of the scenarios. With the existing 600 mm culvert there is a difference of 0.31 m between the peak high tide and the wetland peak water level and also a 35 minute time lag. The other scenarios show no time lag and reduced differences between water level and peak high tide ranging from 0.01 m to 0.13 m. The smallest difference between peak tide and wetland water level is for the 6 x 1200 mm diameter and 8 x 1200 m diameter culvert options with a difference of 0.01 m.

Table 2 Peak high and wetland water level.

Option	Scenarios by culvert diameter	Peak water level	Time	Difference between peak tide and wetland water level (m)	Peak high tide (m) downstream of wetland	Time of peak high tide
Existing	1 x 600 mm	0.92	11:30:00 am	0.31	1.229	10:54:59 am
1	1 x 1200 mm	1.102	10:54:59 am	0.13	1.229	
2	2 x 1200 mm	1.174	10:54:59 am	0.06	1.229	
3	3 x 1200 mm	1.2	10:54:59 am	0.03	1.229	
4	4 x 1200 mm	1.211	10:54:59 am	0.02	1.229	
5	6 x 1200 mm	1.218	10:54:59 am	0.01	1.229	
6	8 x 1200 mm	1.22	10:54:59 am	0.01	1.229	
7	2 x 1200 mm down, 1 x 1200 mm up	1.174	10:54:59 am	0.06	1.229	
8	4 x 1200 mm down, 4 x 1200 mm up	1.21	10:54:59 am	0.02	1.229	

The addition of upstream culverts has no effect on difference in water level for the wetland for all scenarios with the same number of downstream culverts. For example, both the 2 x 1200 mm culverts and the 2 x 1200 mm down/1 x 1200 mm up culverts have a peak water level 0.06 m lower than the peak high tide. The 4 x 1200 mm culverts and the 4 x 1200 mm down/4 x 1200 mm up culverts have a peak water level 0.02 lower than the peak high tide.

3.1.2 Culvert discharge

Table 3 shows the flows into and out of the wetland during the peak tide.

Table 3 Peak flows into and out of the wetland.

Option	Culvert diameter	Peak flow (Into wetland - m^3/s)	Peak flow (Out of wetland - m^3/s)
Existing	1 x 600 mm	0.517	0.271
1	1 x 1200 mm	1.405	0.592
2	2 x 1200 mm	1.835	0.707
3	3 x 1200 mm	2.003	0.738
4	4 x 1200 mm	2.075	0.749
5	6 x 1200 mm	2.119	0.777
6	8 x 1200 mm	2.128	0.756
7	2 x 1200 mm down, 1 x 1200 mm up	1.835	0.706
8	4 x 1200 mm down, 4 x 1200 mm up	2.066	0.748

The discharges through the culverts at peak tide are shown in Figure 9. The positive flows are in the direction from the wetland and into the stream and the negative flows are into the wetland from the stream. The flow increases with the number of culvert barrels and the 8 x 1200 mm downstream culvert option has the highest flow into the wetland whereas the 6 x 1200 mm downstream culvert option has the highest flow out of the wetland.

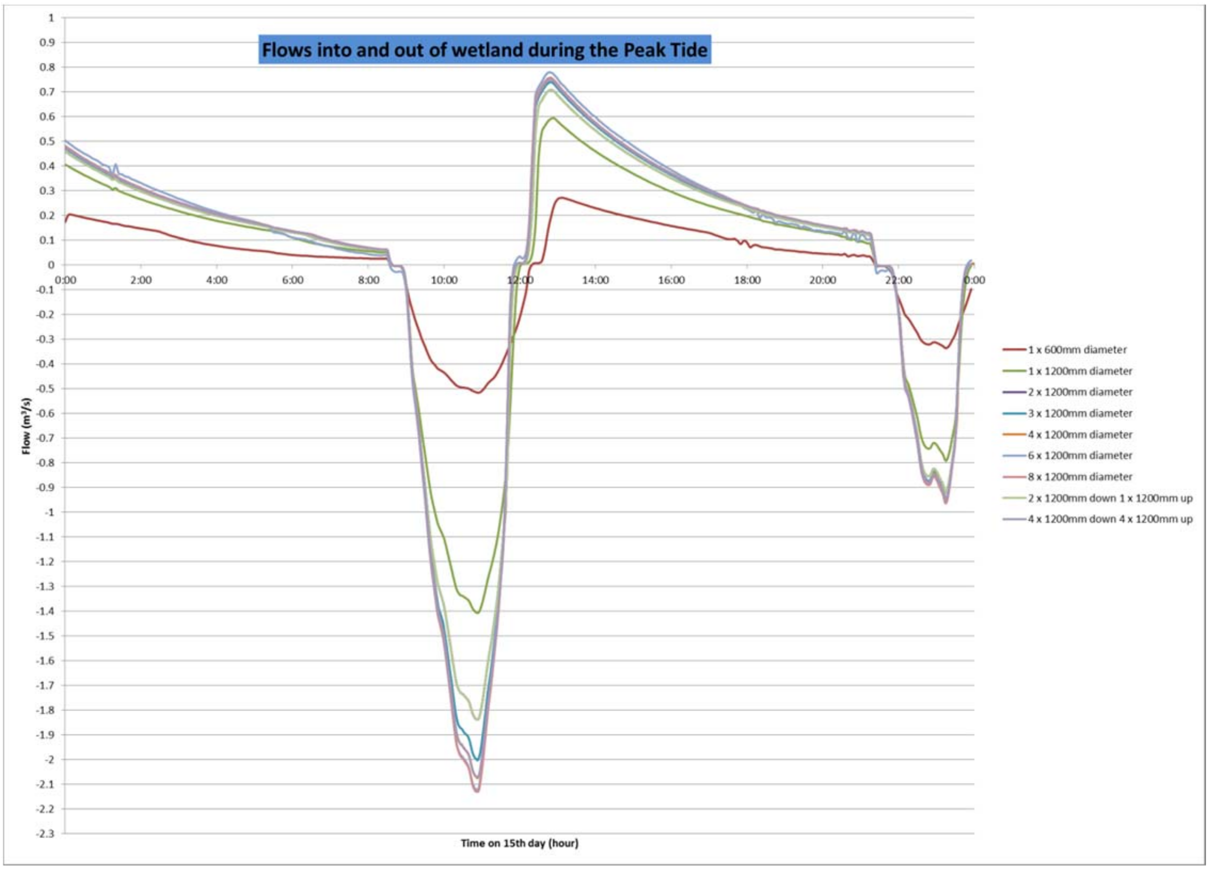

Figure 9 Flows into and out of wetland for peak tide.

3.1.3 Culvert velocity

The peak velocities through the culvert into and out of the wetland for the peak tide over the three month period are shown in Table 4.

Table 4 Peak velocities for the peak tide.

Option	Culvert diameter	Peak velocity (m/s into wetland)	Peak velocity (m/s out of wetland)
Existing	1 x 600 mm	1.826	1.293
1	1 x 1200 mm	1.243	1.349
2	2 x 1200 mm	0.812	0.764
3	3 x 1200 mm	0.591	0.554
4	4 x 1200 mm	0.459	0.429
5	6 x 1200 mm	0.312	0.219
6	8 x 1200 mm	0.236	0.219
7	2 x 1200 mm down, 1 x 1200 mm up	0.811	0.763
8	4 x 1200 mm down, 4 x 1200 mm up	0.457	0.428

The velocities in the culvert decrease with the increase in the number of culvert barrels. The smallest velocities through the culvert into and out of the wetland are for the 8 x 1200 mm barrel option.

Figure 10 shows the velocities for all the scenarios over the 24 hour period that includes the peak tide. The velocity given is the overall velocity for the culvert e.g. the combined velocity for multiple barrel culverts.

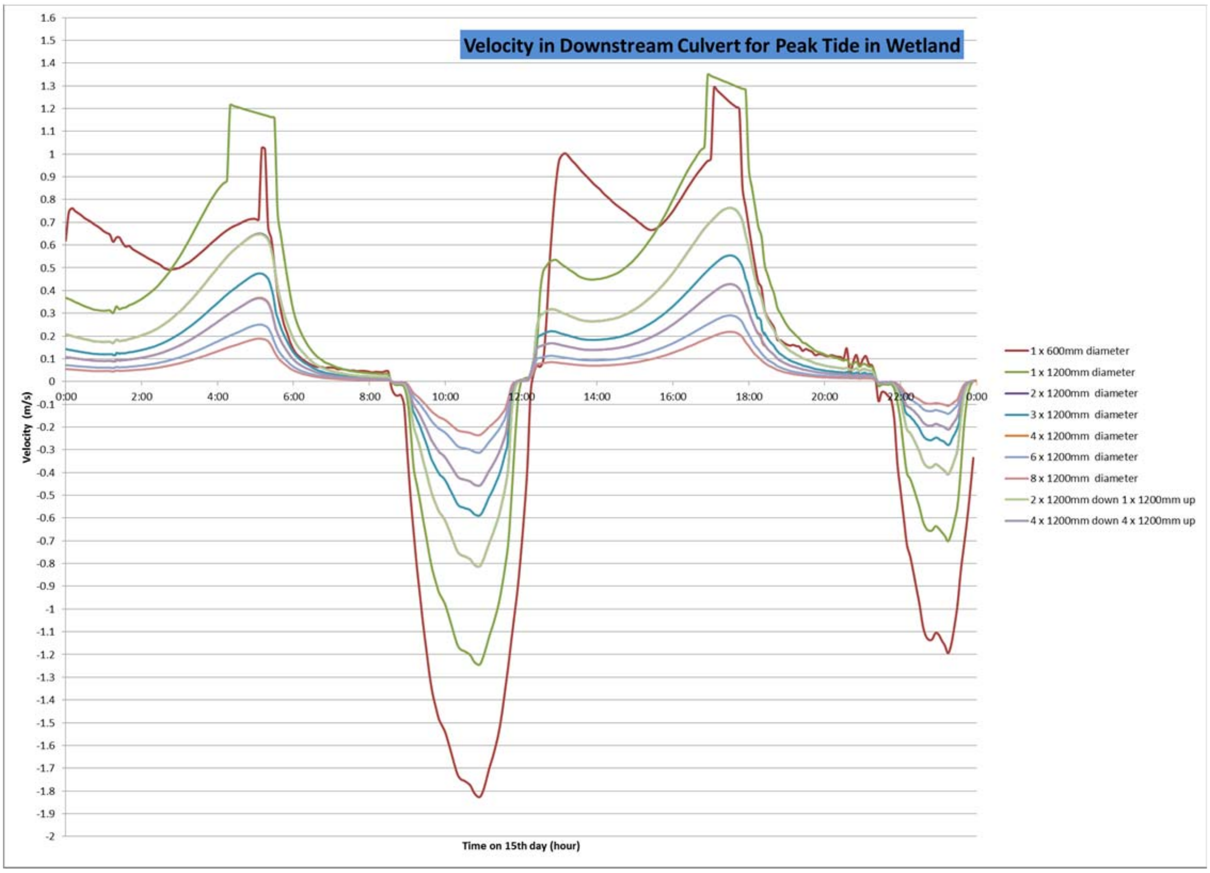

Figure 10 Velocity in downstream culvert.

3.2 Floodmaps

Floodmaps were produced using the waterRIDE™ software package. The floodmaps show an increase in inundation of the wetland and an increase in depth relative to the existing scenario of the 600 mm diameter culvert. Figures 11 to 19 show the coverage of the wetland for the peak tide for each of the scenarios. The depth scale is the same for each scenario. Appendix 1 has full page images of the floodmaps. Note the scale is the same for each floodmap.

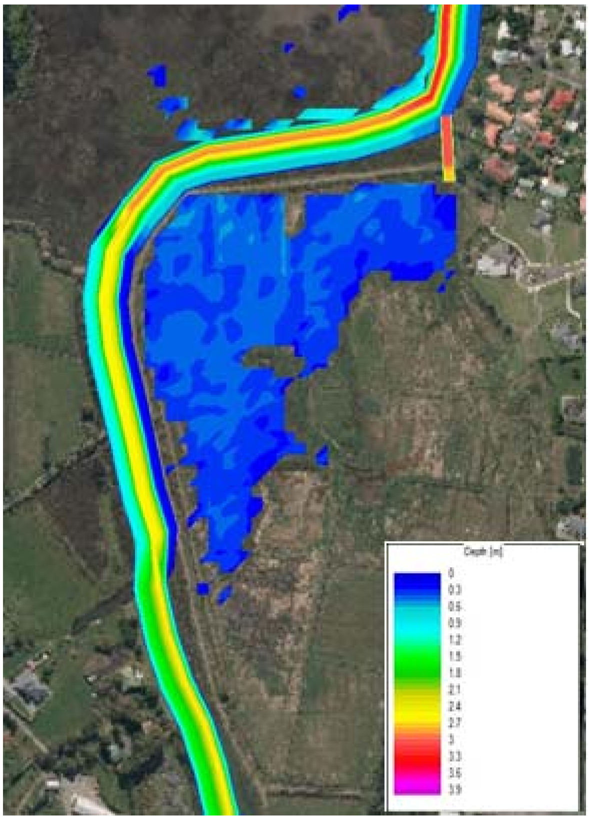

Figure 11 1 x 600 mm diameter culvert.

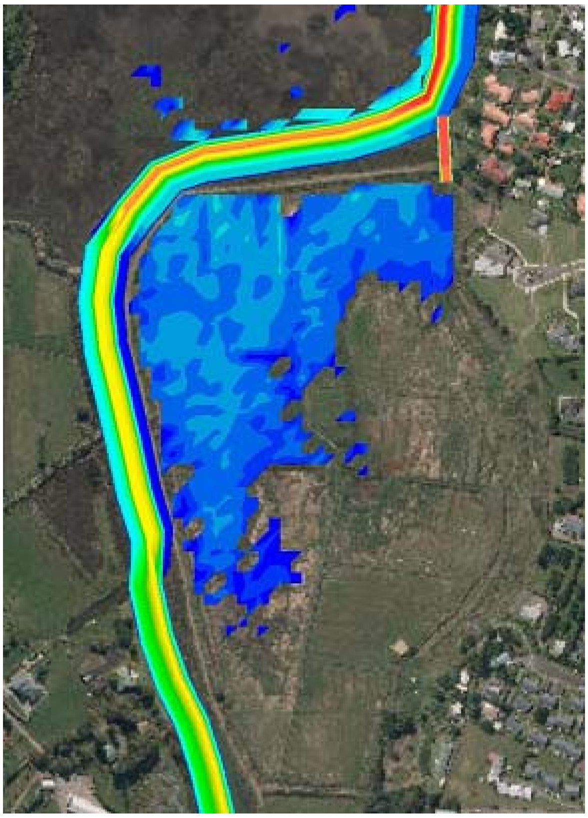

Figure12 1 x 1200 mm diameter culvert.

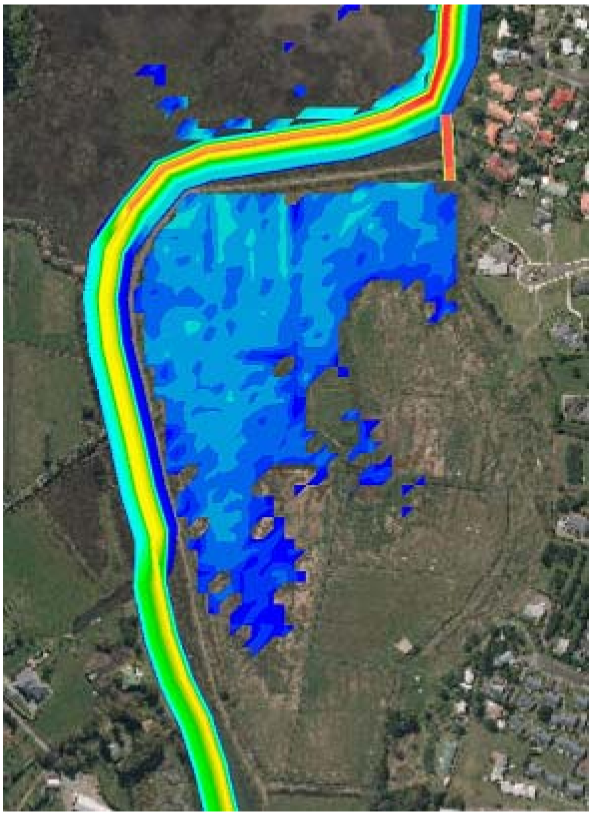

Figure13 2 x 1200 mm diameter culverts.

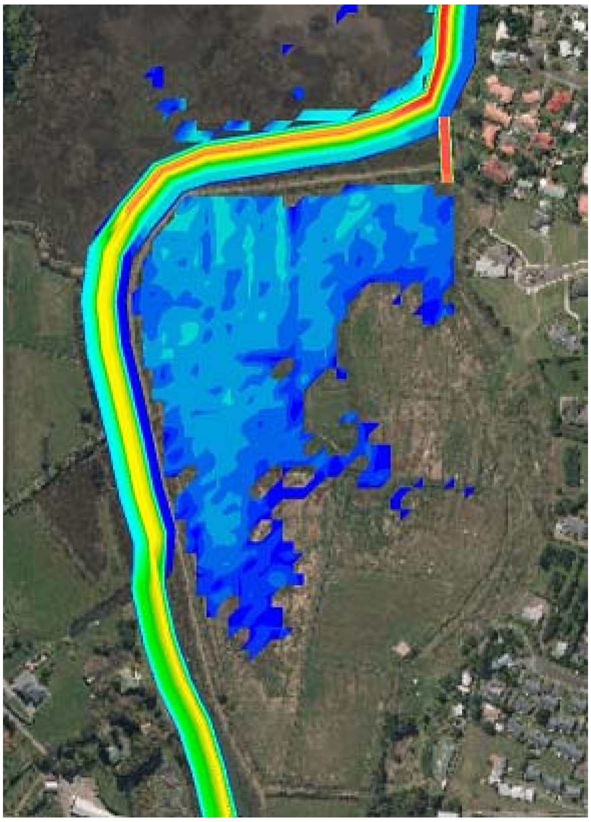

Figure 14 3 x 1200 mm diameter culverts.

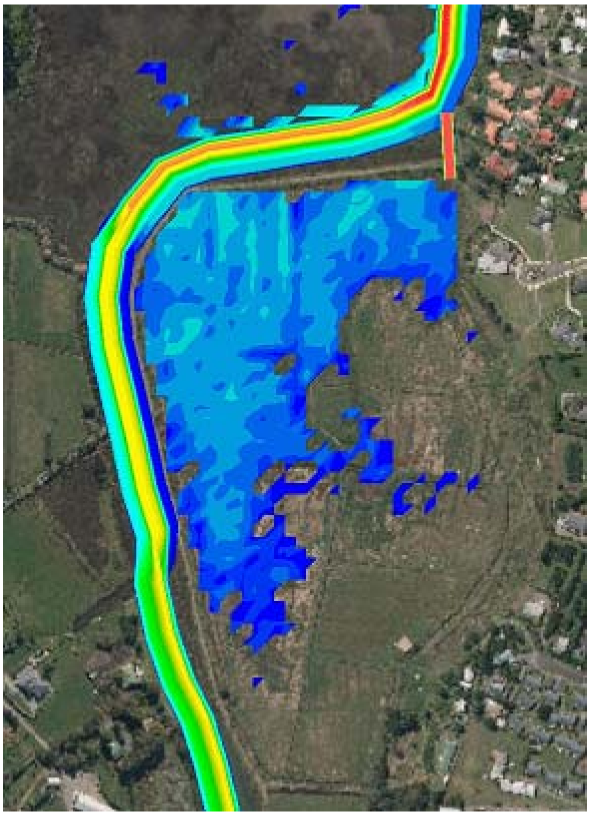

Figure 15 4 x 1200 mm diameter culverts.

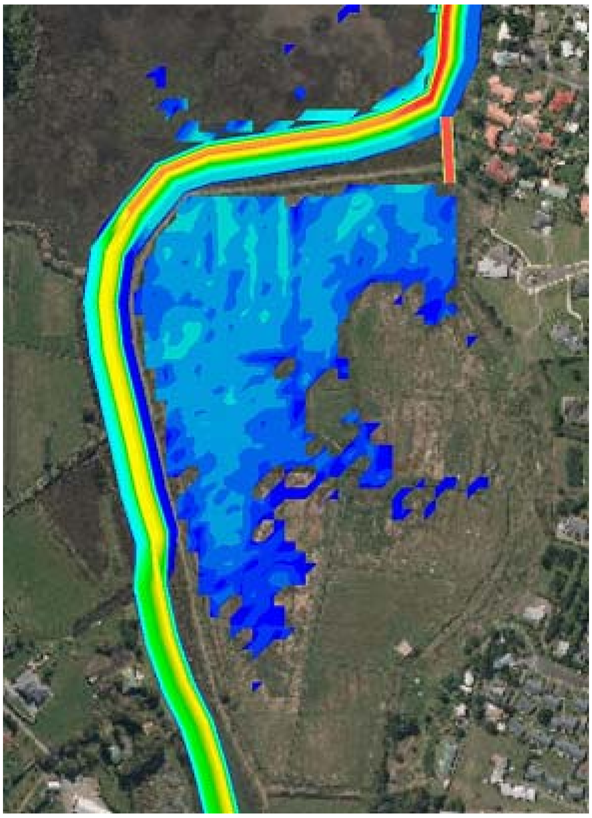

Figure 16 6 x 1200 mm diameter culverts.

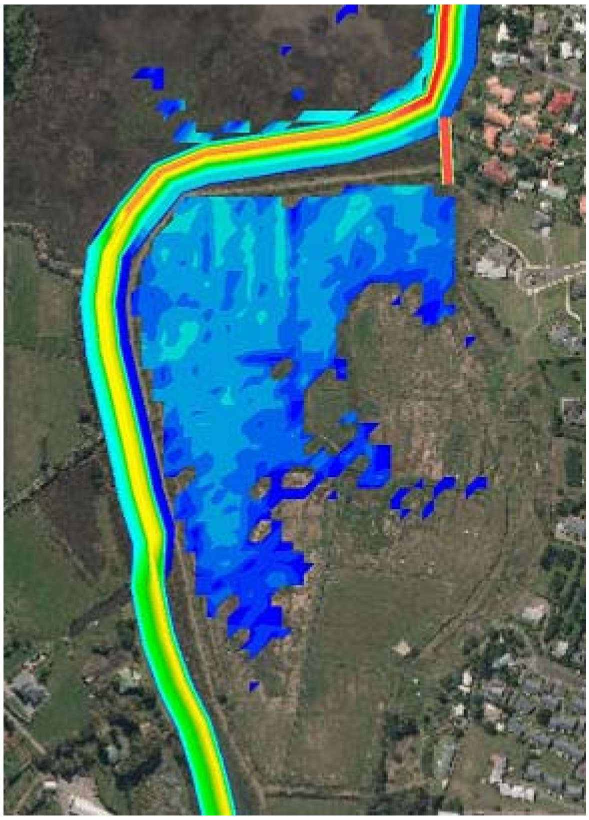

Figure17 8 x 1200 mm diameter culverts.

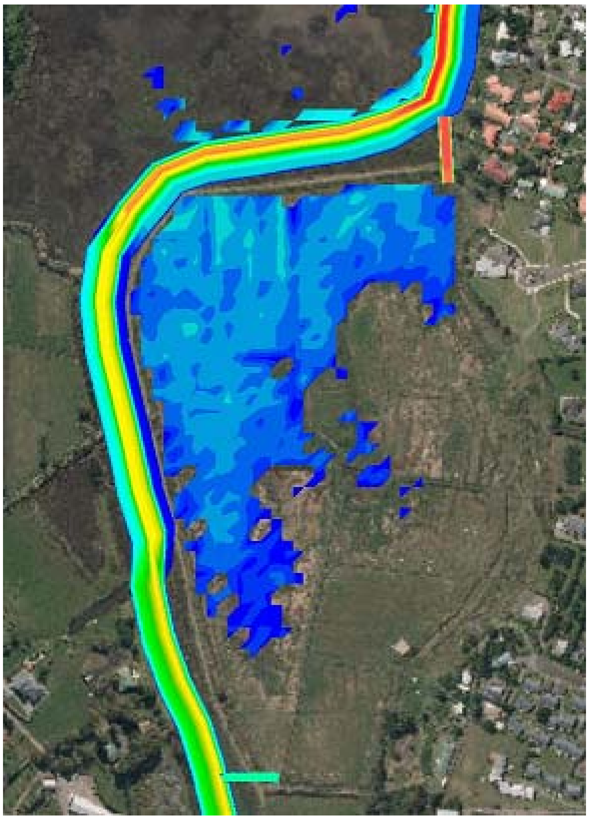

Figure 18 2 x 1200 mm diameter culverts downstream 1 x 1200 mm diameter culvert upstream.

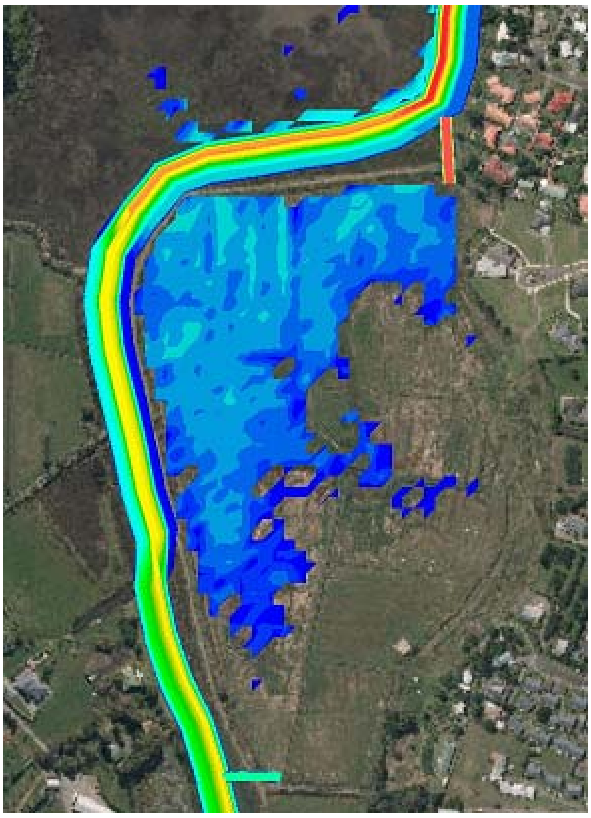

Figure 19 4 x 1200 mm diameter culverts downstream 4 x 1200 mm diameter culverts upstream.

3.3 Discussion

Increasing the diameter of the downstream culvert from 600 mm to 1200 mm removes a restriction. The peak wetland water level and peak discharge through the culvert increases as the number of culvert barrels are added. The velocities through the culvert decreases with the increase in number of culvert barrels.

The model shows no difference in peak water level and minimal difference for peak discharge with the addition of extra culverts upstream to the same downstream culverts. The upstream culvert invert of 0.00 m may be restrictive on the amount of water entering the wetland from the upstream end. Further work could be completed to determine the effect of a lowered upstream invert but the configuration of the network of channels within the wetland would be needed. Lower high tides will give less water into and out of the wetland.

The floodmaps for the culvert scenarios investigated show an increase in coverage from the existing situation but the increase in coverage is limited. Excavation works in the form of extra channels within the wetland could increase the amount of water to the eastern side of the wetland.

Of the scenarios investigated the best option is the 8 x 1200 mm downstream culverts as it gives the greatest increase in water level and the smallest velocities through the culverts. But eight culverts is expensive so when the cost is taken into account the best option may be the 2 x 1200 mm downstream culverts.

Part 4: Conclusions and recommendations

4.1 Conclusions

- The existing 600 mm diameter culvert is restricting the flow of water into and out of the wetland,
- An increase in the size and number of culverts increases the peak water level and inundation within the wetland,
- The scenarios with the extra upstream culverts showed no difference in peak water level compared to scenarios with the same downstream culverts and no upstream culverts for the tidal situation,
- Flood flows were not modelled for the river. Flood flows in the Uretara Stream will increase water levels in the wetland. If this creates problems in the wetland then flapgates can be installed,
- The 8 x 1200 mm downstream culverts option gives the best performance but due to the cost issues, the 2 x 1200 mm downstream culvert option provides a similar overall performance. The 2 x 1200 mm diameter culvert is the preferred option.

4.2 Recommendations

- The existing downstream 600 mm diameter culvert is replaced with a 2 x 1200 mm diameter culvert,
- The culvert should include headwall structures to provide greater hydraulic efficiency for water entry and exit,
- The culvert barrels should be installed so the inverts always have water present to aid fish passage. The current invert level of -0.8 m is a suitable level.

Part 5: References

Medwin, R. (2006/07). *Uretara Stream Capacity Review.* Whakatane: Environment Bay of Plenty.

Appendices

Appendix 1 - Floodmaps

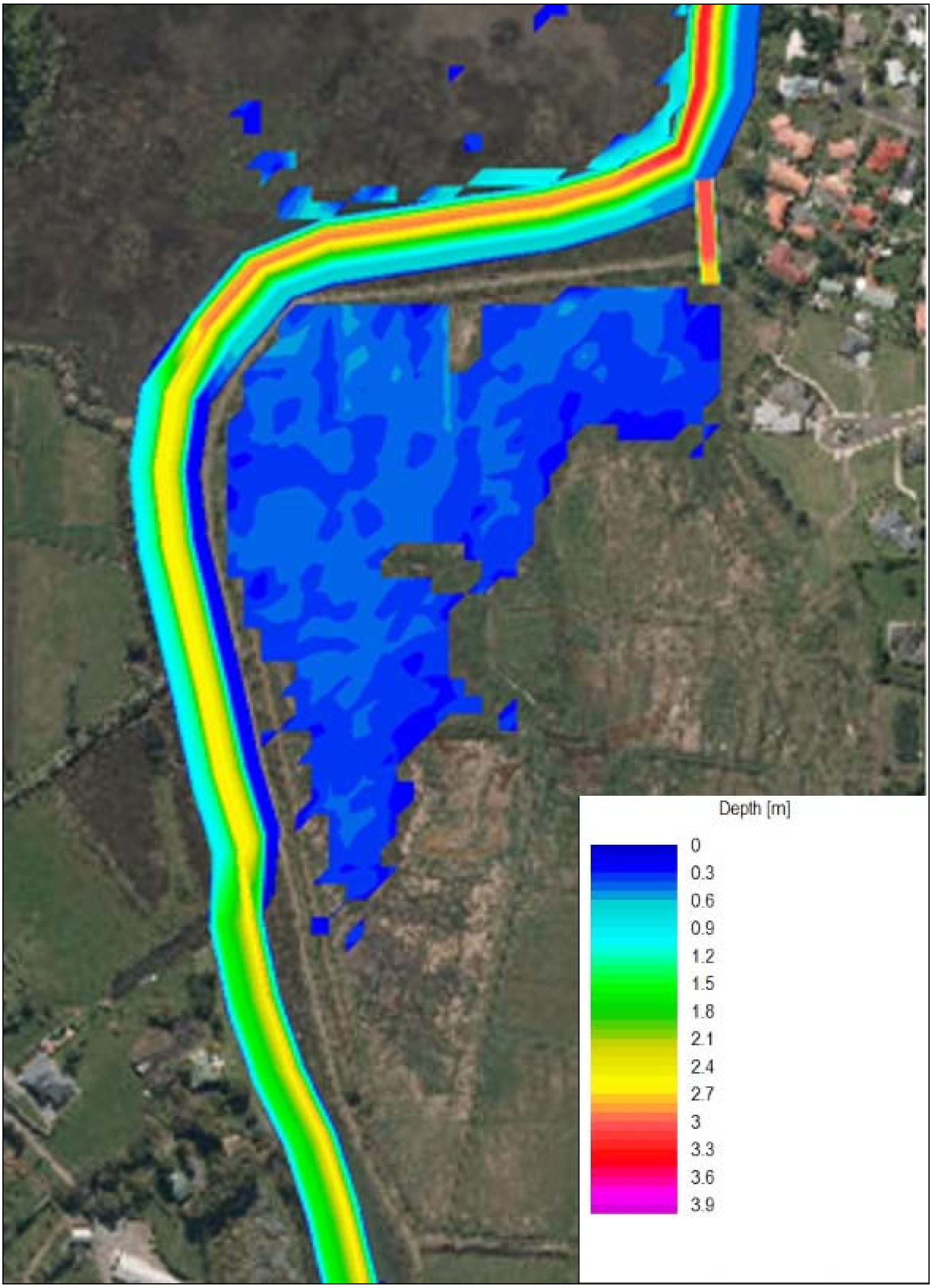

Figure 20 Existing 600 mm diameter culvert.

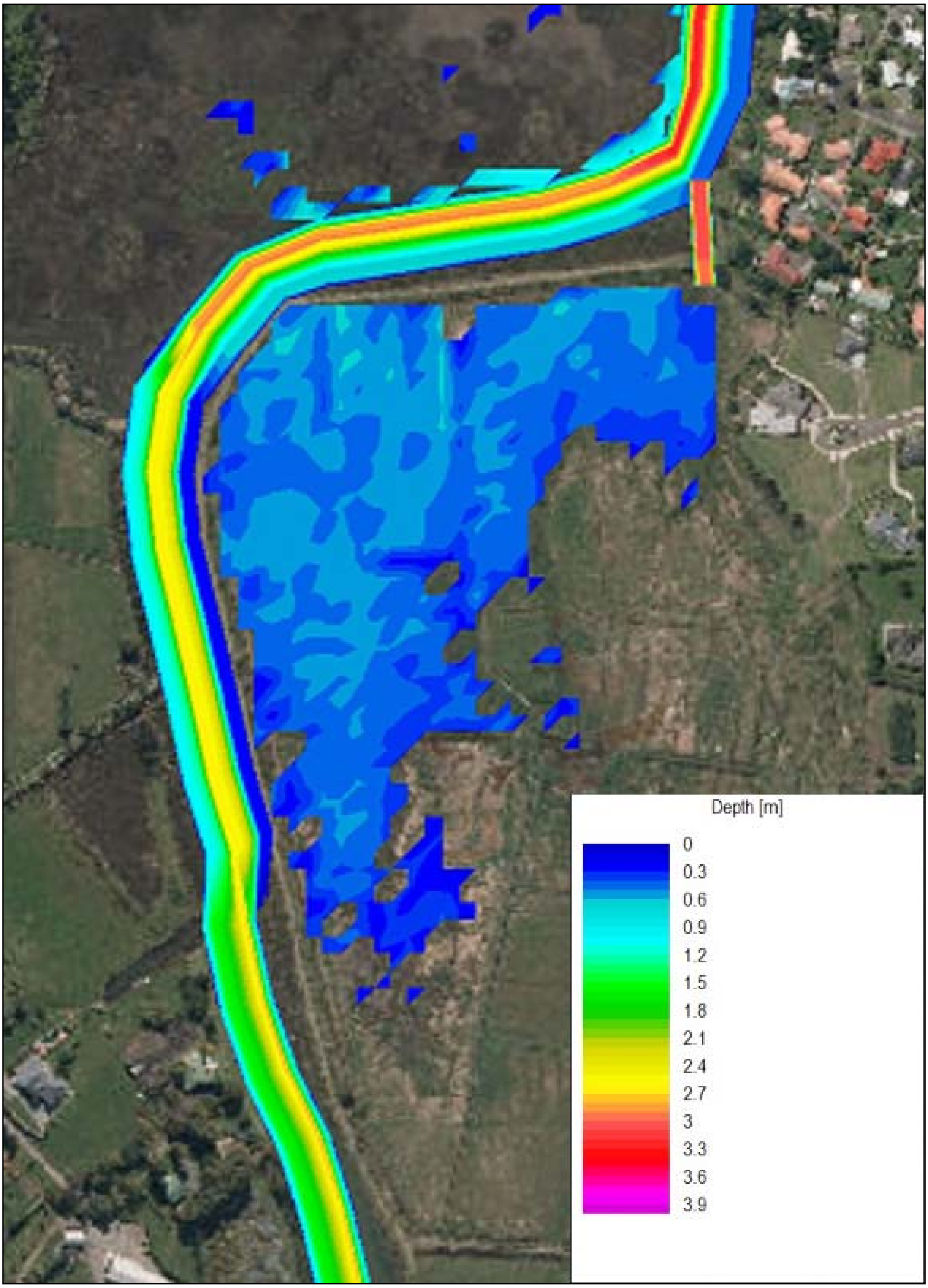

Figure 21 1 x 1200 mm diameter culvert.

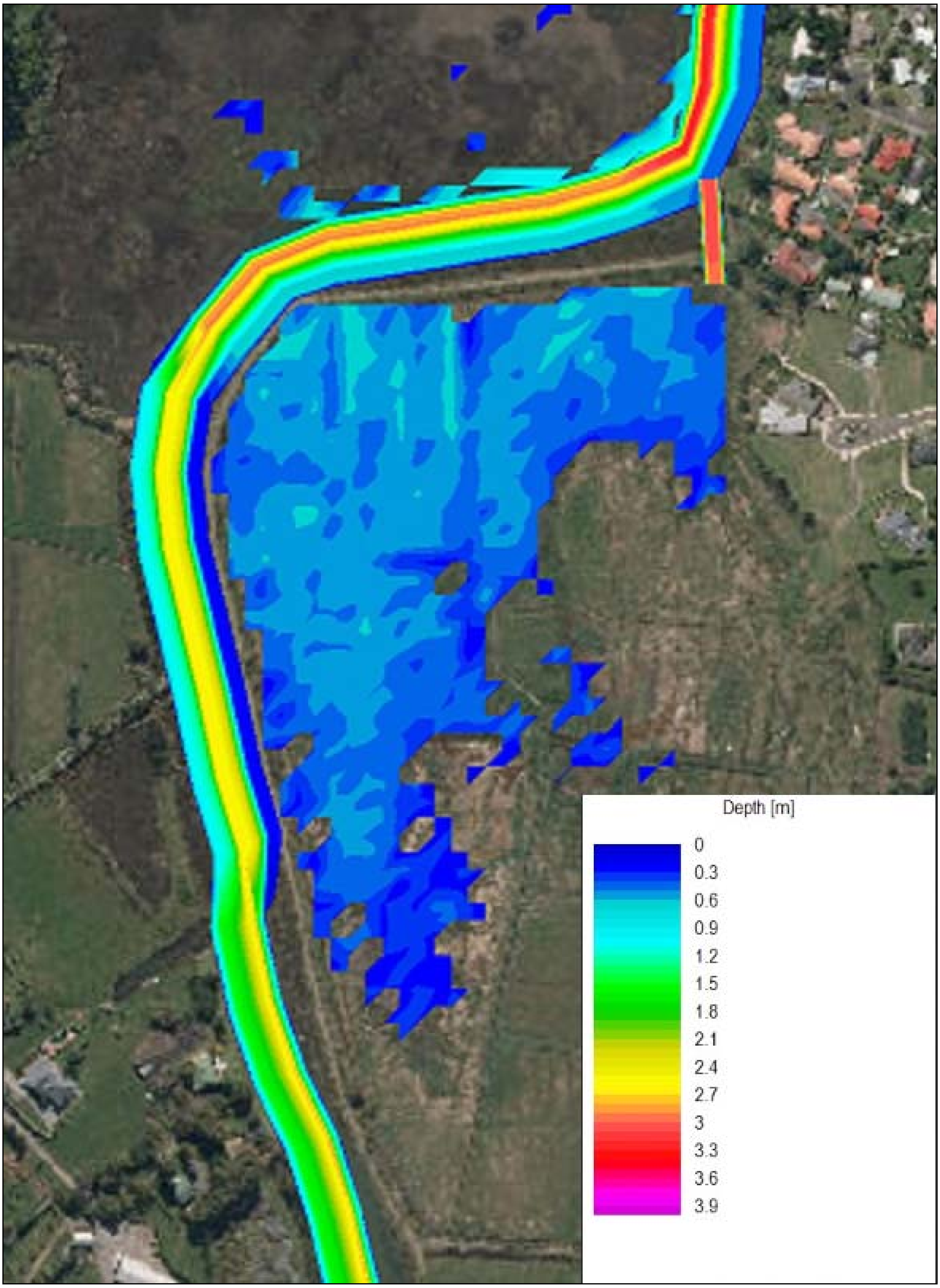

Figure 22 2 x 1200 mm diameter culverts.

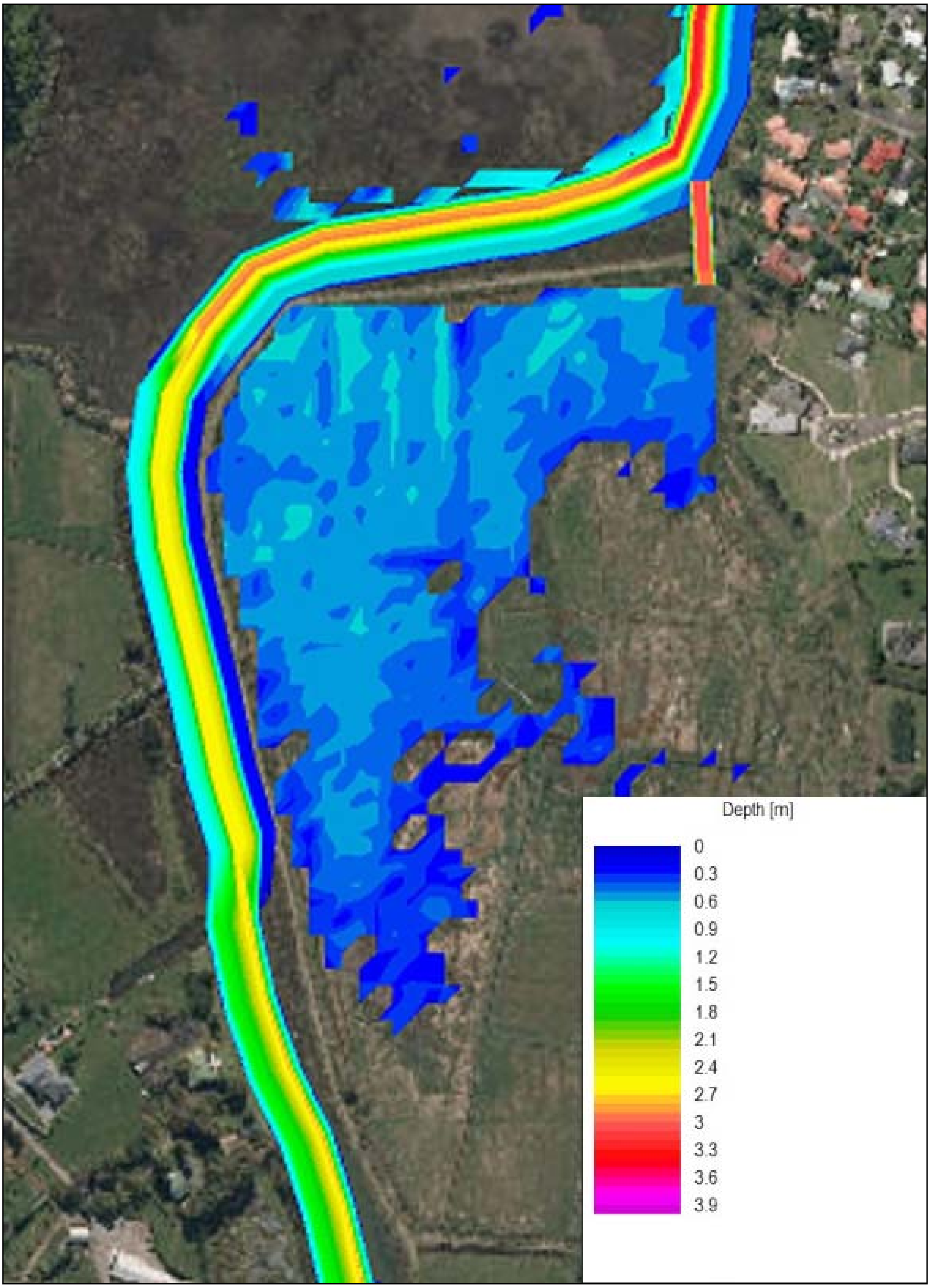

Figure 23 3 x 1200 mm diameter culverts.

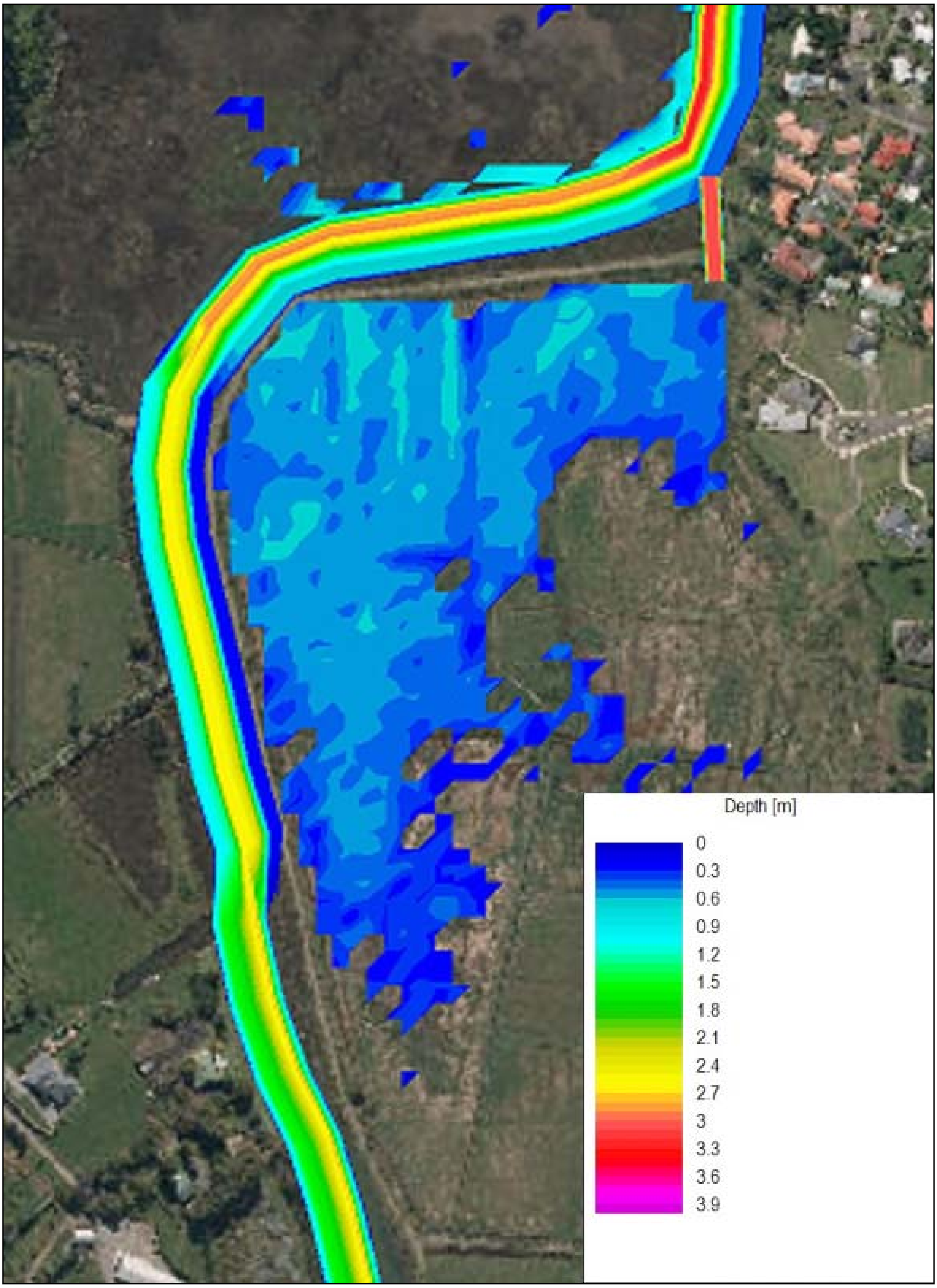

Figure 24 4 x 1200 mm diameter culverts.

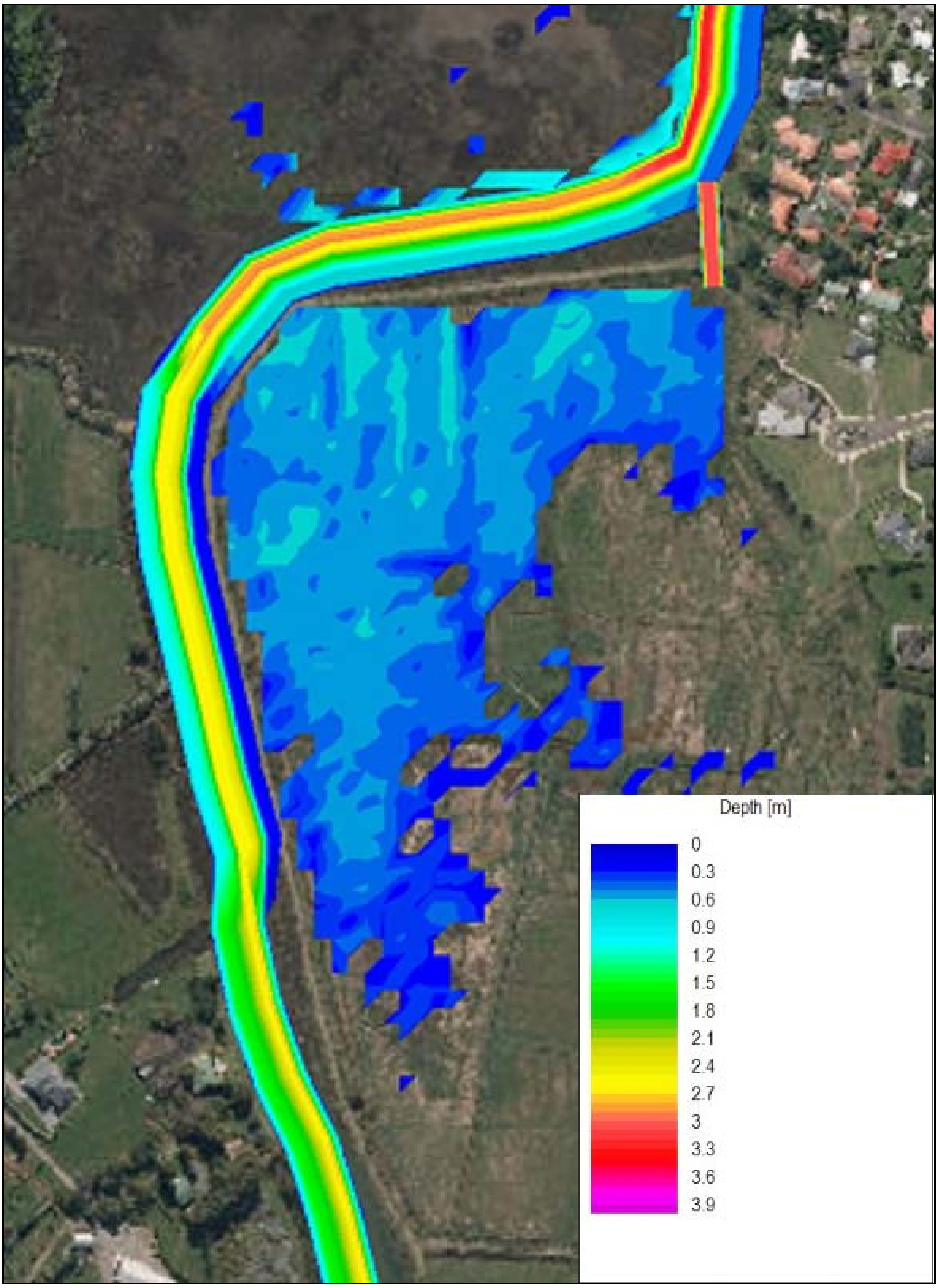

Figure 25 6 x 1200 mm diameter culverts.

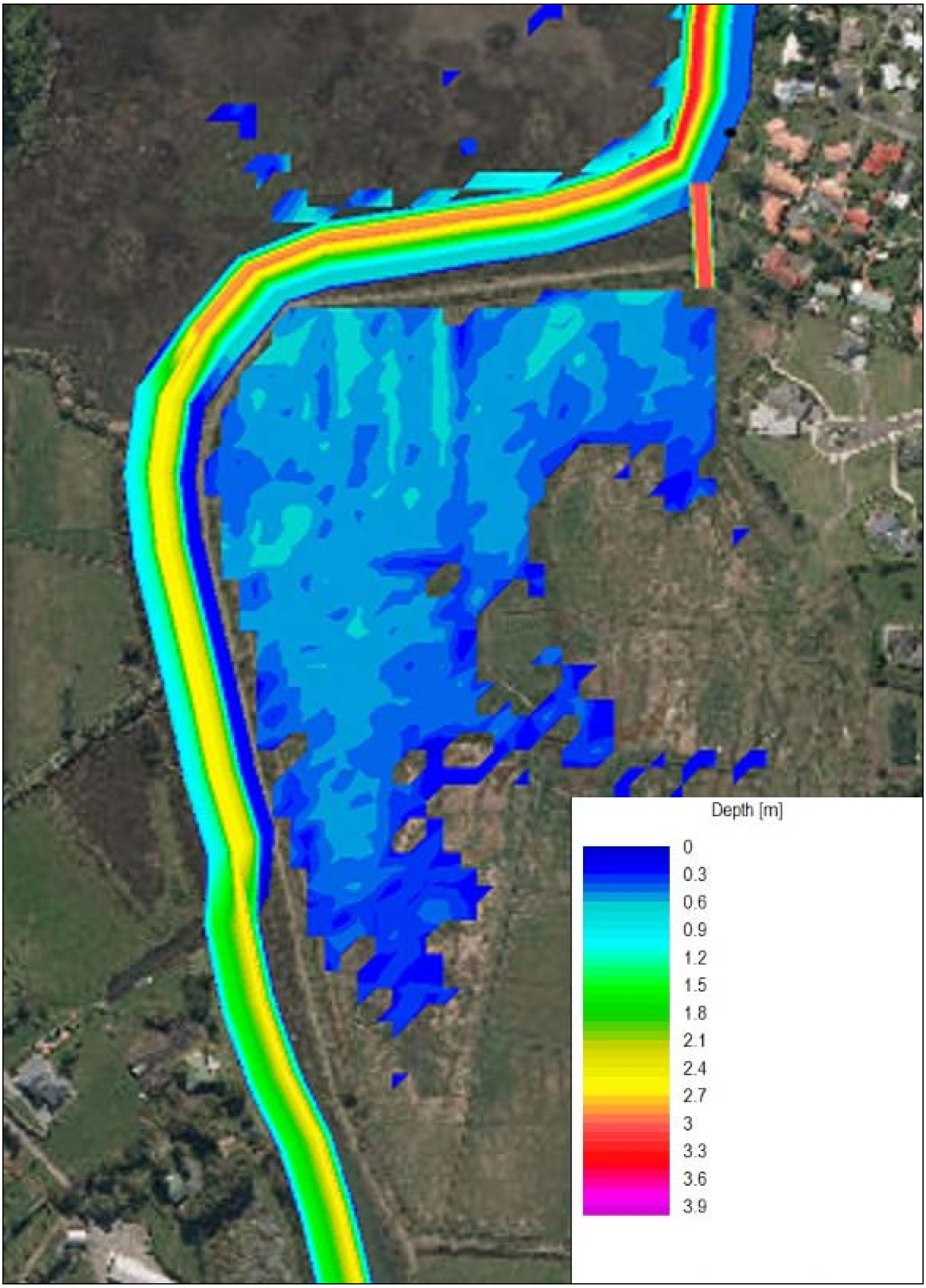

Figure 26 8 x 1200 mm diameter culverts.

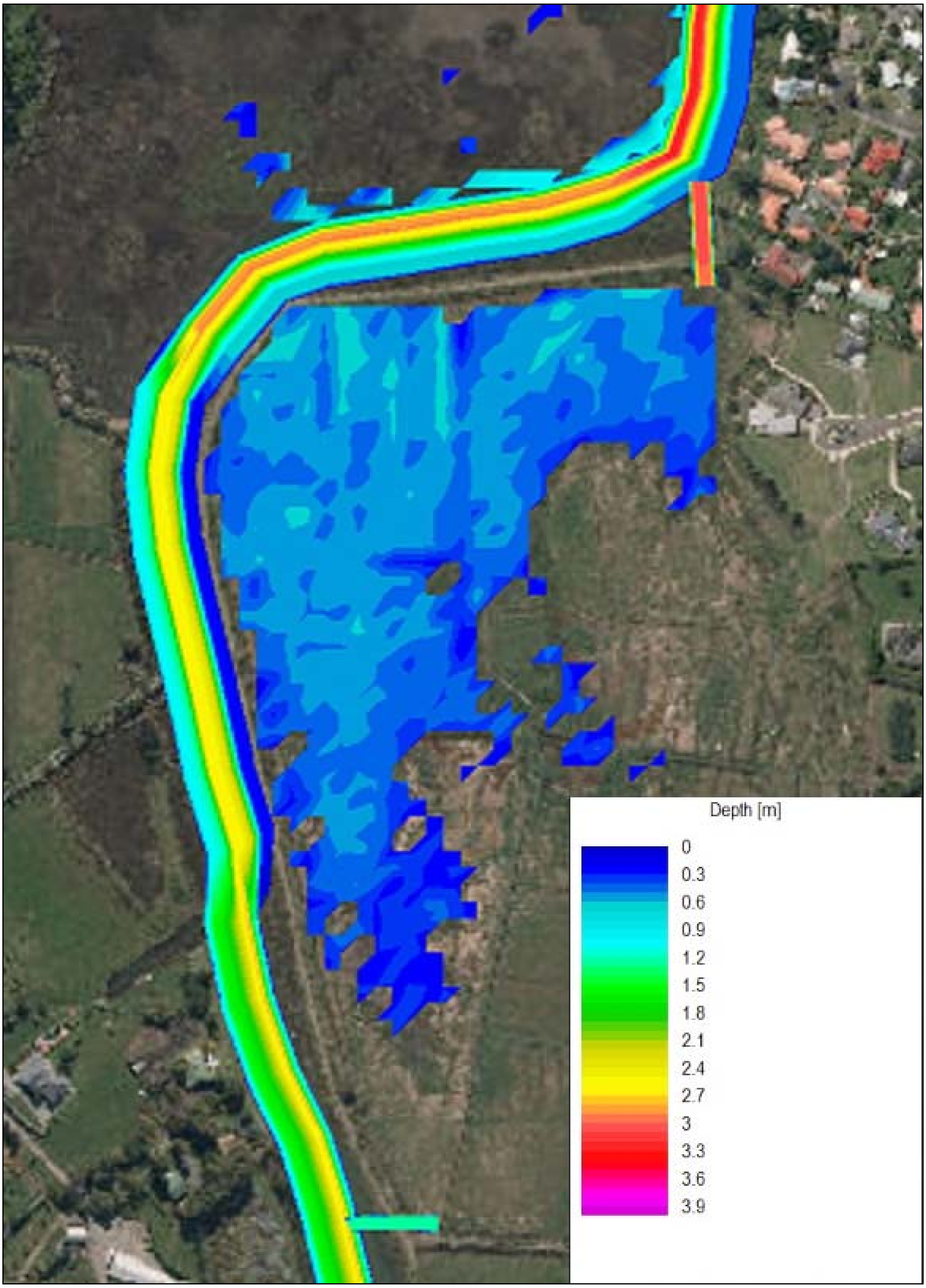

Figure 27 1 x 1200 mm diameter culvert (downstream) 2 x 1200 mm diameter (upstream).

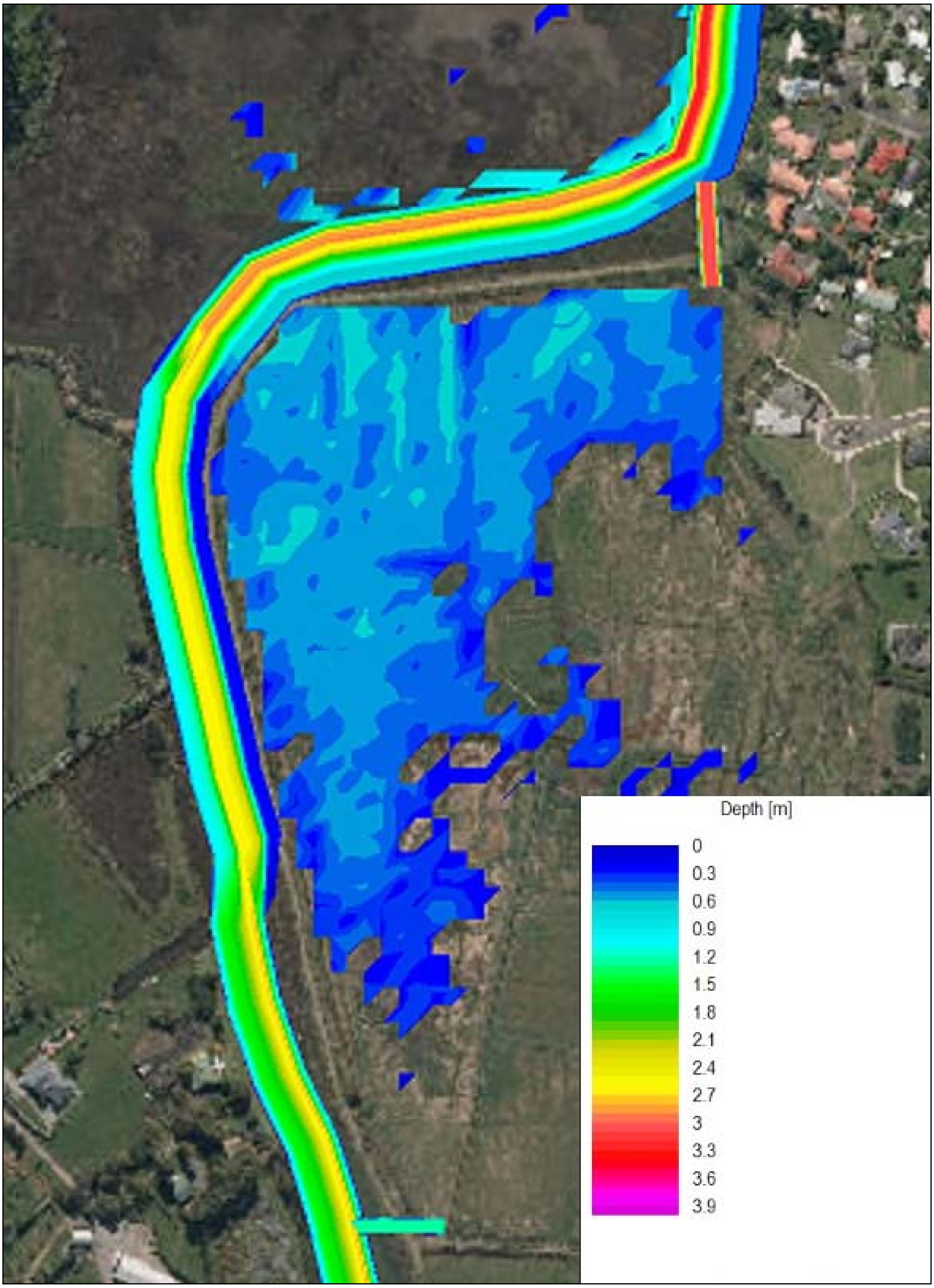

Figure 28 4 x 1200 mm diameter culverts (downstream) 4 x 1200 mm diameter culverts upstream.