UPPER MANGAWHERO AND TRIBUTARIES

Flooding and Erosion Risks at Ohakune

horizons regional council

July 2015

Author
Peter Blackwood
Manager Investigations and Design

Acknowledgements to
Allan Cook, Group Manager Operations
Jeremy Cumming, Senior Engineering Officer
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Peter Hurn, Senior Survey Technician
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Front Cover Photograph
Park Avenue Dam Impoundment at Normal Water Levels
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CONTACT	**24hr Freephone 0508 800 800**		**help@horizons.govt.nz**		**www.horizons.govt.nz**
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POSTAL ADDRESS	Horizons Regional Council, Private Bag 11025, Manawatu Mail Centre, Palmerston North 4442 | **F** 06 9522 929				

EXECUTIVE SUMMARY

NB: Executive summary to be completed upon report being confirmed as final.

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1. Introduction

1.1 Objective

The purpose of this report is to provide the key information for the assessment of flood mitigation options for the township of Ohakune and environs immediately downstream.

The flood mitigation options may include both structural (stopbanks, flood walls, river works) and planning components (zoning of land for uses commensurate with flood risk, minimum floor levels, flood warning and preparedness).

1.2 Background

Horizons Regional Council (HRC) in June 2014 completed a report entitled "Non-Scheme Rivers Investigation Prioritising Future Studies", June 2014, P. L. Blackwood, Horizons Regional Council. This report addressed the flooding and erosion risks to the wider community posed by those rivers and streams within the Region that are currently not managed within a scheme. The report further prioritised the studies that were appropriate, in order to maximise the benefit obtained from the Non-Scheme Rivers Investigation Programme.

The 2014 report investigated a total of 72 rivers and streams, of which 28 were given priority rankings, with six of these assessed as having a "High" priority. The Upper Mangawhero River and its tributaries were assessed as one of the "High" priority rivers and were reported as:

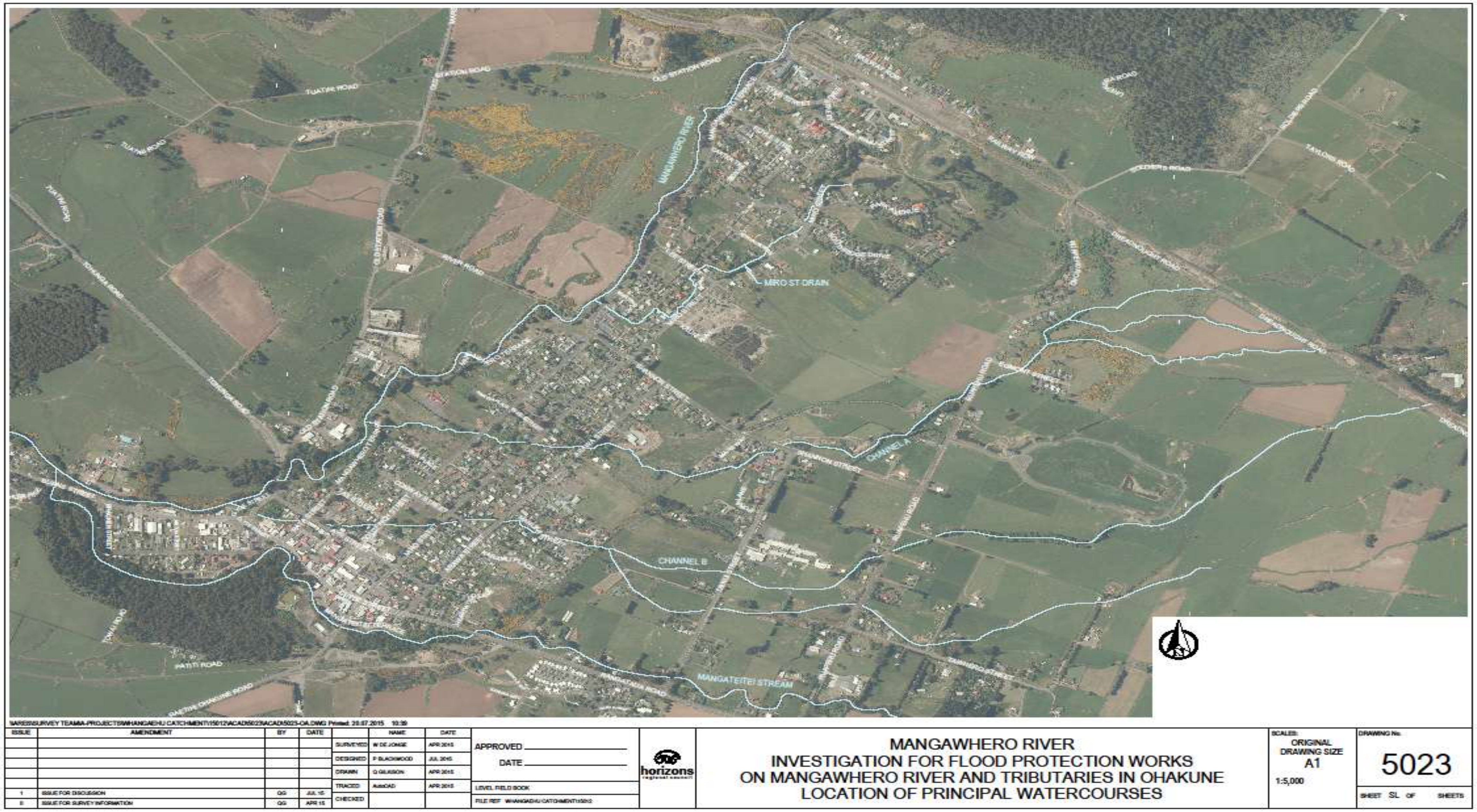
"***Rank 1 – Upper Mangawhero River & Tributaries.*** *At 19 Total Problem Points this river system is well clear of the other rivers and streams. Investigations will need to address flooding, erosion and willow congestion; with obvious risks to the community. Several studies already completed will feed well into the determination of an action plan*."

Consequently, the investigation of the Upper Mangawhero and tributaries was programmed for investigation in the 2014-15 Annual Plan.

Ohakune Township is largely bounded by the Upper Mangawhero River to the west and north-west and the Mangateitei Stream to the south. In addition, there are three streams that traverse the town, named Miro Street Drain, Channel A (Korokoio Stream) and Channel B in this report. The latter four streams are all tributaries of the Mangawhero River. Their location is shown in Figure 1.1.

All of these streams flow of the south-western flanks of the slopes of Mount Ruapehu and have periodically caused flooding in the township. All five of these watercourses are steep mountain watercourses. However, in the Mangateitei Stream the flooding risks are minor and erosion risks largely already addressed.

Figure 1.1: Location of principal rivers and streams through Ohakune



The most recent flooding of any consequence occurred on the 15 October 2013. During this flood three houses flooded in Arawa Road, a very near miss, and there are reports of water entering other houses. Assessment of the available records of flood flows and flooding depths adjacent to watercourses suggests this flood was likely between 4% AEP (1 in 25 year) and 2% AEP (1 in 50 year) in the Mangawhero River and Channels A and B. This flood was a "very near miss" for large parts of Ohakune Township.

Several studies proposing flood mitigation options have been conducted over the years, the most recent being several reports produced by John Philpott & Associates Ltd, Consulting Engineers. However, apart from some ongoing, mainly voluntary channel clearing, none of the main mitigation options have been implemented. The "very near miss" in 2013 demonstrates the need to take decisive actions in addressing mitigation options.

Previous studies have been based on significantly lower design flood estimates. However a review of design flood flows in 2014 showed previous estimates were too low (caused in part by information gained in the 2013 flood). This has significantly increased the challenge to find manageable solutions.

1.3 Scope of Work

This study aims at:

1. Clearly identifying and describing the flooding and erosion risks to Ohakune and environs immediately downstream.
2. Determining the most appropriate method of mitigating the flooding and erosion risks for Ohakune Township.
3. Assessing the method and cost of also managing the Mangawhero River between State Highway 49 and the Raetihi-Ohakune Road.
4. Assessing the relative priorities for these works and determining an construction programme.
5. Determining a strategy for implementing these works. This will follow once consultation has proceeded on the report recommendations.

1.4 Datums

The design levels applied in the investigations are in terms of Moturiki Datum.

2. Hydrology

2.1 Records of Annual Maxima

Flood frequency estimates derived for the hydraulic modelling produced by HydroTasmania Consulting Ltd in July 2010 were:

1% AEP (1 in 100 year)	95 cumecs
0.5% AEP (1 in 200 year)	106 cumecs

However, these estimates appear low and could only be reproduced in a rainfall-runoff model by applying loss parameters below those observed in nine calibration events. Thus, the flood frequency analysis was reviewed in 2014.

Flood flow records are available at three sites as follows:

Mangawhero at Burns Street:	1975-1981
Mangawhero at Hagleys:	1999-2006 and 2013
Mangawhero at Pakihi:	2007-2012 (and to date)

The catchment area of the first two sites is 72 square kilometres and the Pakihi Site 139 square kilometres. A frequency analysis for the Mangawhero at Hagleys location, carried out in 2014, used the combined data from the three sites. The data from the Pakihi site was transposed by the ratio of the catchment areas to the power of 0.8. It could be argued that this excessively reduces the recorded flow at Pakihi, as for both sites the most intense rainfall on Mount Ruapehu is included at that particular site. However, this adds uncertainty and thus, conventional methodology has been applied.

Another complexity is that the flood peak assessment for several years has changed (generally minorly) since the revised frequency assessment. However, the concluded flood frequency analysis is fine, though it does appear that the concluded values are not over-estimates.

The current annual maxima are presented in Table 2.1.

Table 2.1: Mangawhero River annual maxima 1957-2013

YEAR	DISCHARGE (CUMECS)	RANK	YEAR	DISCHARGE (CUMECS)	RANK
1975	122.4	2	2003	49.3	13
1976	105.6	3	2004	72.1	6
1977	57.2	11	2005	24.3	22
1978	61.1	8	2006	57.5	9
1979	93.1	4	2007	48.3	14
1980	87.7	5	2008	42.2	18
1981	57.0	12	2009	27.9	21
1999	57.3	10	2010	42.6	17
2000	67.1	7	2011	32.8	20
2001	46.2	16	2012	33.7	19
2002	47.4	15	2013	150	1

2.2 Flood Analysis Methodology

At-site flood frequency analysis was applied to the combined series of 22 annual maxima.

A L-Moments extreme value statistical fitting methodology was applied to the continuous series for both the Extreme Value Type One (EV1) and General Extreme Value (GEV) distributions – the latter resulted in an Extreme Value Type Two (EV2) distribution (though close to EV1). The Log Pearson Type 3 (LP3) frequency distribution was also applied.

2.3 Flood Frequency Estimates

The calculated flood frequency estimates are presented in Table 2.2.

Table 2.2: Mangawhero at Hagleys flood frequency estimates (cumecs)

RETURN PERIOD (YEARS)		EV1	GEV	LP3
T	Y_T	Q_{T1}	Q_{T2}	Q_{T3}
1.5	-0.0940	38.8	38.6	-
2	0.3665	50.1	49.7	48.5
2.33	0.5786	55.3	54.8	-
5	1.4999	77.7	77.3	77.2
10	2.2504	96.1	96.0	97.5
20	2.9702	114	114	
25	3.3843	119	120	124
50	3.9019	136	138	145
100	4.6001	153	157	166
200	5.2958	170	176	188

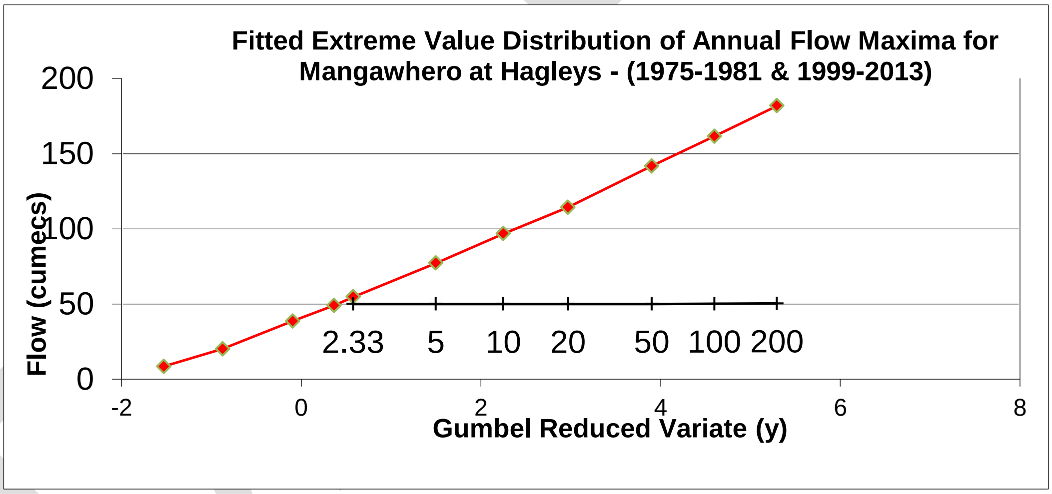
2.4 Design Flood Frequency Estimates

The GEV and LP3 distributions fit the data better and are consistent with regional trends. Consequently, equal weighting has been applied to these two analyses to produce the design flood frequency estimates in Table 2.3 and Figure 2.1.

Table 2.3: Mangawhero at Hagleys design flood frequency estimates

RETURN PERIOD (YEARS)	PROBABILITY (%)	DISCHARGE (CUMECS)	Y VARIATE
1.5	67	39	-0.0940
2	50	49	0.3665
2.33	43	55	0.5786
5	20	77	1.4999
10	10	97	2.2504
20	5	114	2.9702
25	4	122	3.1985
50	2	142	3.9019
100	1	162	4.6001
200	0.5	182	5.2958

Figure 2.1: Mangawhero at Hagleys design flood frequency estimates



2.5 Tributary Channels

As there are no recorders on Miro Street Drain it was necessary to apply the following methods to assess flooding depths and culvert performance.

- Application of the HydroTasmania Consulting Ltd (now Entura) computer model. This is a combined hydrologic-hydraulic model - refer Section 3.
- Extraction of design flows at specific locations of interest.
- Parametric hydrologic design methods, applying HIRDS Version 3 rainfall and catchment characteristics (area, shape, slope, cover, infiltration).

This gave the following estimates. There is a good deal of corroboration here and the Entura estimates were generally applied – except for the potential Egmont Dam option (where there is no Entura estimate).

Miro Street Drain at Park Avenue Dam (Catchment 108 Hectares)

Parametric 1% AEP Inflow	4.1 cumecs
Parametric 0.5% AEP Inflow	4.6 cumecs

These flows were routed through the Park Avenue Dam to produce:

0.5% AEP Dam Outflow (dam unblocked)	3.5 cumecs
0.5% AEP Dam Outflow (50% blocked)	2.1 cumecs
Entura 0.5% AEP Dam Outflow	2.5 cumecs

This estimate falls between the 0 and 50% blocked and is a reasonable design flow, both for the assessment of dam outflows to the Miro Street Drain and peak level of 598.53 m (Moturiki Datum). The dam outlet can be modified.

Miro Street Drain at Mangawhero Terrace

Entura 0.5% AEP Flow	3.4 cumecs

Catchment A (Korokoio Stream) at Shannon Street (Catchment 890 Hectares)

Parametric 1% AEP Inflow	24.4 cumecs
Parametric 0.5% AEP Inflow	27.7 cumecs
Entura 0.5% AEP Flow	28.0 cumecs

Catchment B at Manuka Street (Catchment 249 Hectares)

Parametric 1% AEP Inflow	7.3 cumecs
Parametric 0.5% AEP Inflow	8.3 cumecs
Entura 0.5% AEP Flow	7.6 cumecs.

3. Hydraulic Modelling

The hydrologic and hydraulic analysis and computer modelling has been conducted by HydroTasmania Consulting Ltd (Entura).

The hydraulic modelling encompasses Ohakune Township and the surrounding rural and semi-rural areas affected by flooding. The modelling involved developing a hydrologic and MIKE FLOOD URBAN hydraulic model. This software package combines the MIKE11 1D, MIKE URBAN 1D and MIKE21 2D software packages into a single model, where the significant river channels were modelled using MIKE11 cross-sections. Stormwater drainage was modelled using MIKE URBAN (MOUSE computational engine) and overland flow is modelled using MIKE21. The model was developed by coupling river channels to overland flow, and stormwater drainage to both the river channels and the MIKE21 grid.

Three hydraulic models were developed, with the models extending from approximately 100 m upstream of the North Island Main Trunk Railway Line to Rangataua Road (SH49) in Ohakune Township. The models include the Mangawhero River, tributaries passing through the town, and the existing stormwater drainage network.

A single detailed MIKE URBAN model (Model B) was set-up linking the underground stormwater drainage, MIKE11 channels and a fine scale 5 m MIKE21 grid representing floodplain levels.

Two separate coarser 10 m grid MIKE21 models (Models A & C) were set-up to represent the rural areas and run separately from the MIKE URBAN model.

Models were coherently linked.

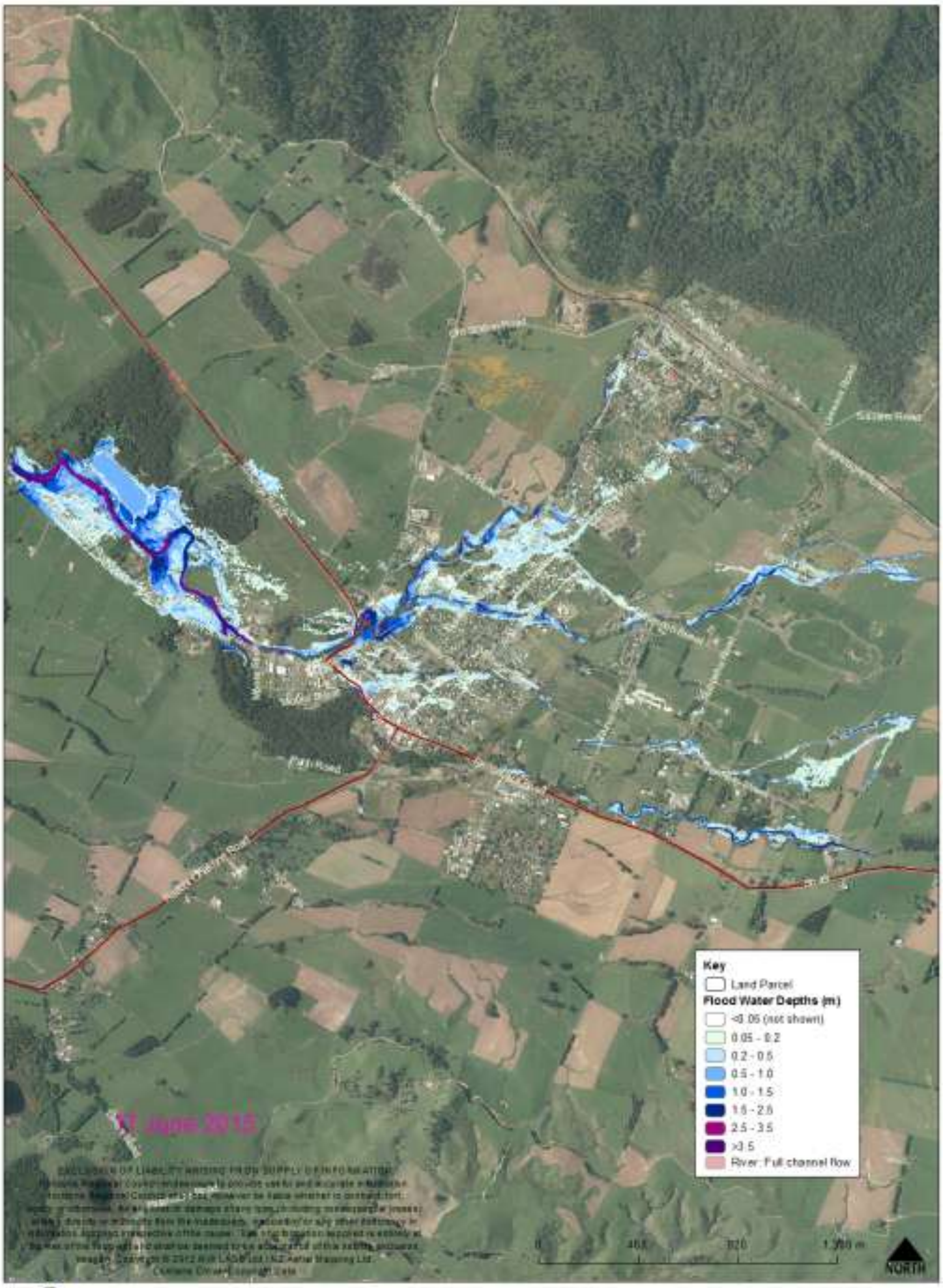
Full details on this task are presented in the two reports entitled:

- "*Ohakune Township Flood Modelling Study Report*", 22 July 2010, HydroTasmania Consulting Ltd.
- "*Ohakune Township Flood Modelling Addendum Study Report*", 2 June 2015, Entura.

4. Design Flood Levels

The models were applied to run the 2% AEP (1 in 50 year), 1% AEP (1 in 100 year) and 0.5% AEP (1 in 200 year) flood events. Storm durations considered were 20 minute, 30 minute, 1 hour, 2 hour, 6 hour, 12 hour and 24 hour. The critical storm duration was 6 hours.

The 0.5% AEP flood map is presented on the following page.



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Ohakune Township Flood Depths in a 0.5% AEP (1 in 200 year) Flood

5. Identified Flooding Problems

Several parts of Ohakune Township are vulnerable to flooding. This was demonstrated in the medium flood of 15 October 2013. During this flood three houses flooded in Arawa Road, there was a very near miss at another house there, with water rushing past at deck level (with just glass sliding doors between Channel A and the house interior). There are reports of water entering other houses. Assessment of the available records of flood flows and flooding depths adjacent to watercourses suggests this flood was likely between 4% AEP (1 in 25 year) and 2% AEP (1 in 50 year) in the Mangawhero River and Channels A and B. This flood was a “very near miss” for large parts of Ohakune Township.

The following maps present the 0.5% AEP flood depths for various vulnerable portions of the town.

Figure 5.1: Miro Street and Arawa Street flooding from Channel A

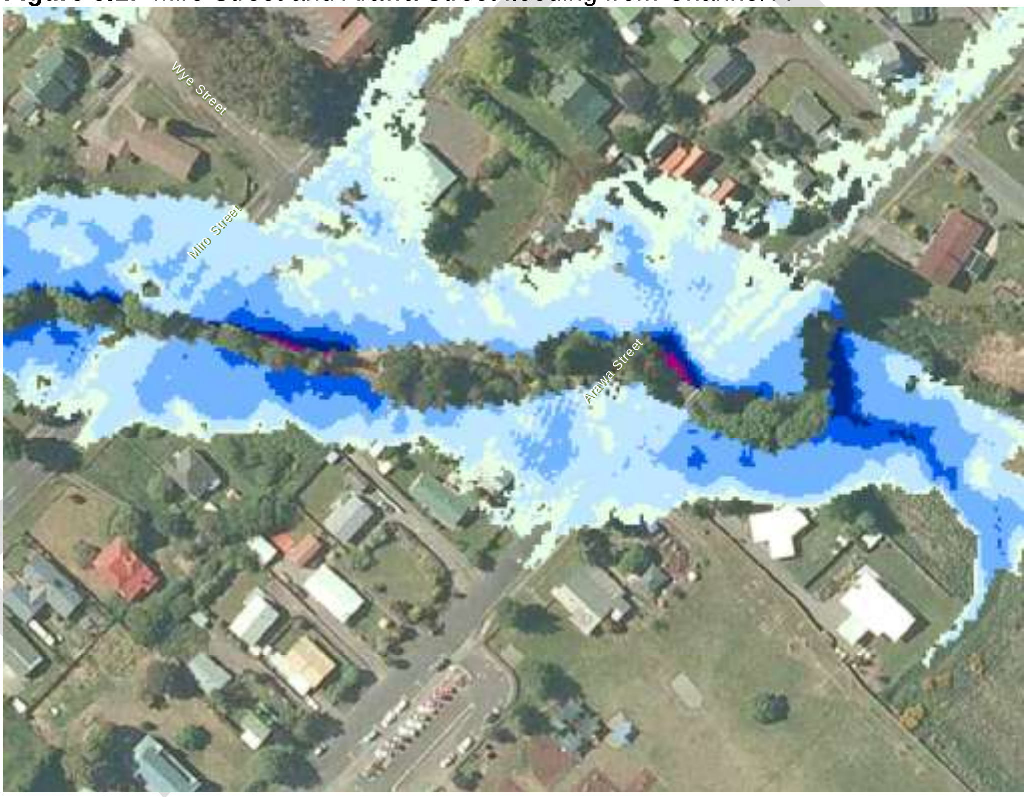


Figure 5.2: Flooding from Lower Miro Street Drain and Mangawhero River

Figure 5.3: Ti Kouka Place and Conway Street flooding from Channel A and Mangawhero River

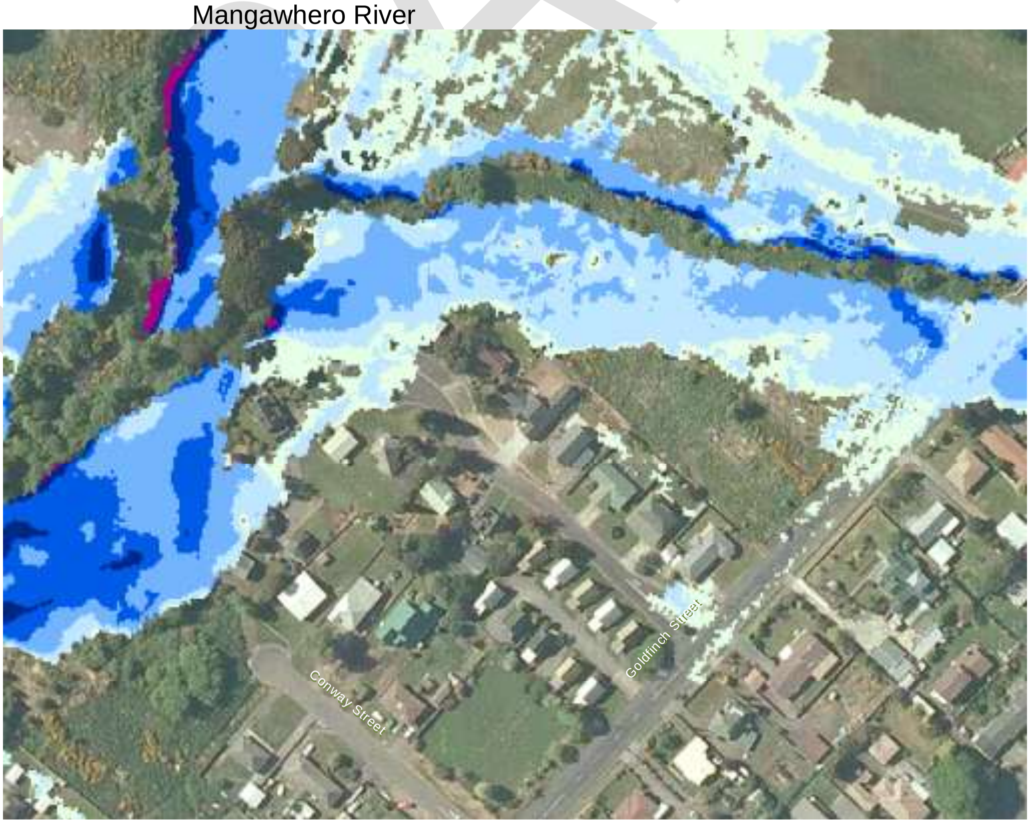
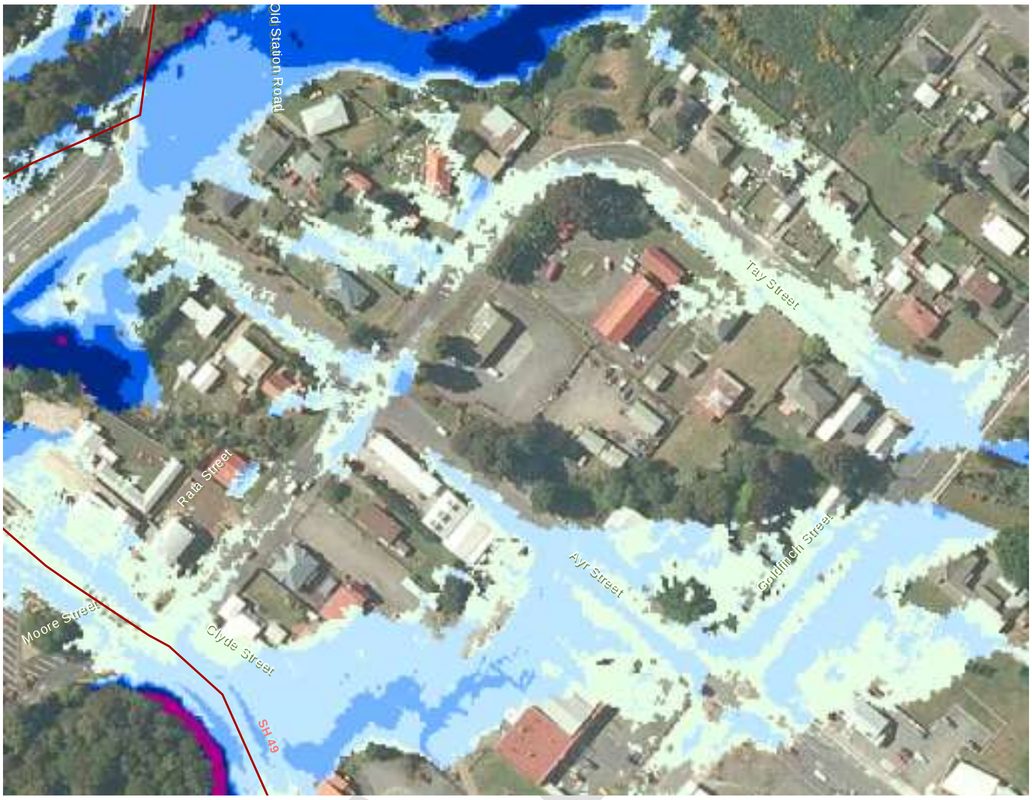


Figure 5.4: Ayr, Rata and Tay Streets and CBD flooding mainly from Channel B overflows



As the flood maps show, flood risks exist in some cases well away from the principal watercourse, due to upstream breakouts. This is particularly evident in Figure 5.4 above; with the majority of the flooding caused by various overflows from Channel B. There are a number of generic factors causing flood risks in Ohakune. The principal ones are:

- Considerably inadequate culvert sizes. Almost all the culverts are significantly undersized. The main exception is culverts in the Miro Street Drain, where peak flows are retarded due to the construction of the Park Avenue Dam;
- Inadequate channel sizes with vegetation infestation significantly increasing risks. The vegetation management report prepared by Jeremy Cumming, Senior Engineering Officer, Horizons Regional Council is contained in Appendix B and states "*Channel size varied enormously within even a short 100 m length and it was almost invariably due to the types of vegetation that had established on either one or both banks*";
- Overflows of streams at sharp bends; and
- Construction of houses, motels and commercial buildings too close to and/or with inadequate floor levels above the various mountain streams. This shows the importance of wise planning decisions for subdivisions and individual building approvals.

5.1 Mangawhero River

The 0.5% AEP flood map in Section 4 shows that in general the Mangawhero River is slightly incised and only affects a few areas upstream of SH49. However, downstream of SH49 there are numerous houses and properties adjoining Burns Road that flood or nearly flood – refer Appendix C.

Mangawhero Bend

Just upstream of the Mangawhero Terrace-Goldfinch Streets intersection, the Mangawhero River takes a very sharp right bend of slightly over 90 degrees (refer photo 5.1 below). The estimated super-elevation on this bend in the 0.5% AEP flood is 0.35 m. This is based on modified formula of Chow (1959):

- ***$\Delta H = 0.5 * v^{\wedge 2} * b /(g * r)$***

Where:

- ***ΔH is the super-elevation (m)***
- ***0.5 is a correction co-efficient found suitable for New Zealand rivers as applied on the Waipaoa River by Webby (2002) and Whakatane River by Wallace (2006) and following the recommendations of the USACE (1994).***
- ***v is the mean section velocity (m/s)***
- ***b is the main flow width (m)***
- ***g is the gravitational constant ($9.81 m/s^{\wedge 2}$)***
- ***r is the bend radius (m).***

This gives a combined level of 591.45 m at the apex of the bend, very similar to the Entura value of 591.40 m. The animation of the Entura model clearly shows water exiting the bend near the apex and flowing across Mangawhero Terrace.

Photo 5.1: Sharp bend on Mangawhero River where outflows can occur

Channel Adjacent to Conway–Ti Kouka Streets and Factory at 4 Old Station Road

The 0.5% AEP flood map shows the factory at 4 Old Station Road surrounded by flood waters and water entering houses at the rear of the Conway Street-Ti Kouka Streets area. Since this model was developed the channel form has changed at this location-mainly during the flood of 15 October 2013. The river has avulsed into a new channel towards the right bank and the left bank channel is currently largely dry during low flow periods. Felled trees have been left in this old channel. These are to be removed and it kept as an overflow channel. Ruapehu District Council has recently received consent to armour the right bank with riprap to protect an erosion risk near the factory.

A detailed assessment of river levels through this reach has been carried out to assess the risk to the factory in the 0.5% AEP flood. The following levels refer to the cross-section 3, which coincidentally is adjacent to the factory.

0.5% AEP Level Model XS 24/4/2002	580.75 m
0.5% AEP Level XS 22/4/2015	580.61 m
0.5% AEP Level XS 22/4/2015 Cleared Left Channel	580.5 m
Factory Floor Levels	580.70-580.78 m.

Therefore, based on the position of the channel in 2002 the factory had a marginal flood risk, with water likely to have just entered the concrete floor. The factory floor levels are now just above the 0.5% AEP flood level, more so if both channels are kept open. The factory does not quite have the required freeboard of 0.3 m for industrial buildings, but does not warrant specific protection and channel management should focus on keeping both channels open.

Note water is still likely to enter some houses in the Conway-Ti Kouka area. However, with the current channel arrangement and the channel management referenced above levels should drop – though flood mitigation works are definitely warranted.

Burns Street

There are almost 30 houses or other habitable buildings in Burns Street that may be flooded or surrounded by floodwaters in a 0.5% AEP flood from the Mangawhero River. Maps showing typical depths of water around these buildings (it will of course vary around the building) are shown in Appendix C. The maximum depth of water besides a building shown is 630 mm, which is marginal for safe wading egress. Most of the buildings will have safe egress.

The depths of water inside the houses are unknown, as the height of the floor above adjacent ground level has not been recorded. However, one assumption might be that on average the buildings are 250 mm above ground level, in which case around 18 would flood above floor level.

This flooding is difficult to mitigate, though channel management will help. An upstream dam is considered later in this report (Section 7.3) and that would lower flood levels – though the cost may be prohibitive.

5.2 Miro Street Drain

The 0.5% AEP flood map in Section 4 and Figure 5.2 shows that there are significant outflows from the Miro Street Drain in the vicinity of the motels by Shannon Street. The outflows are caused by inadequate channel capacity aggravated by the sharp right hand bend upstream of the motels. The flooding is not caused by the 4.0 m x 1.5 m culvert at Mangawhero Terrace. This culvert has surplus capacity and acts under downstream control.

Park Avenue Dam

To accurately assess the flood risks in Miro Street Drain requires first an assessment of the existing Park Avenue Dam operation (efer figure 5.5 below). Whilst 4.6 cumecs enter this impoundment in the 0.5% AEP flood, the dam attenuates the outflows to around 2.5 cumecs (refer Section 2.5) and could be throttled to 2.0 cumecs (refer figure 5.6).

Figure 5.5: Park Avenue Dam on Miro Street Drain

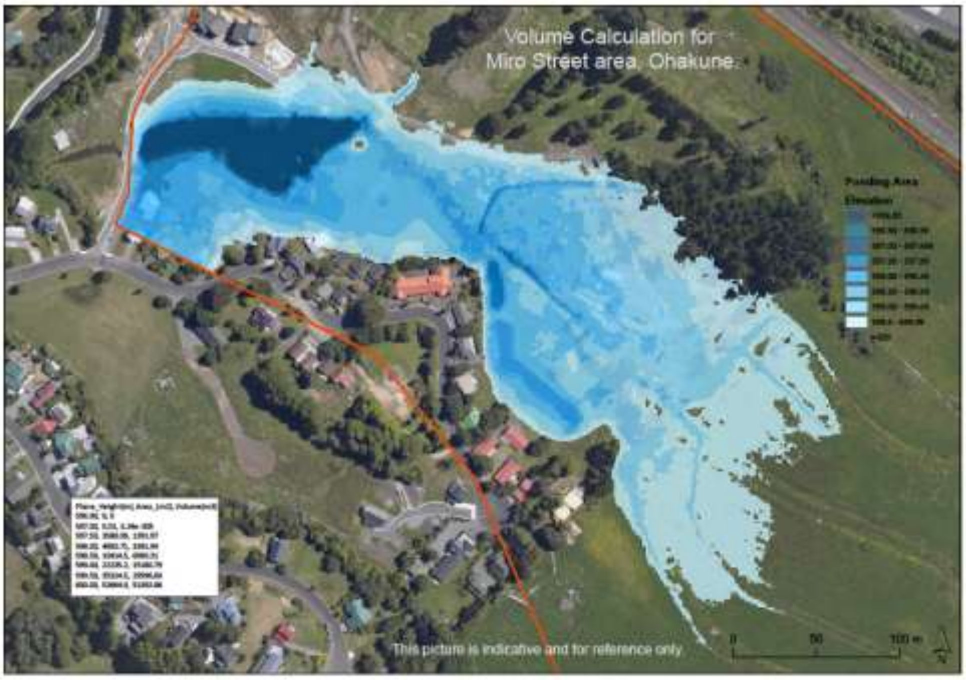
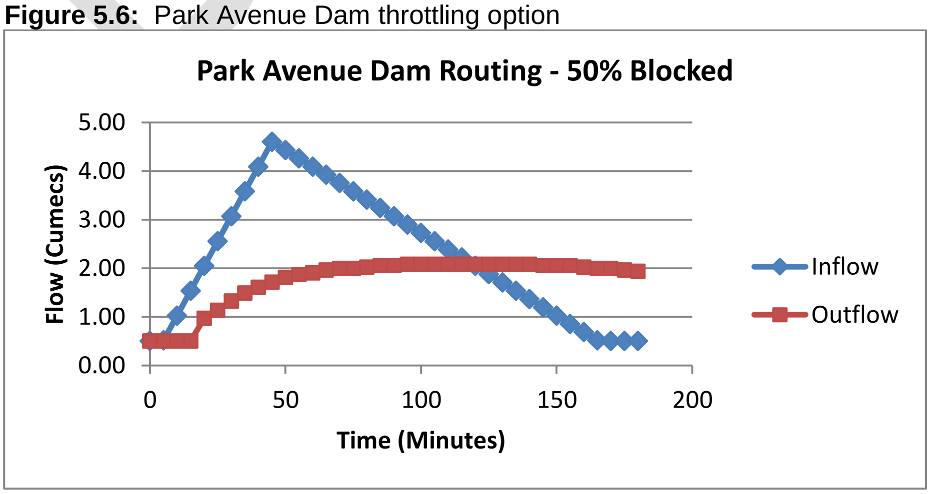


Figure 5.6: Park Avenue Dam throttling option



Increasing the dam attenuation to reduce outflows to 2.0 cumecs requires an increase in peak impoundment level from 598.52 (Entura modelling) to around 598.65 m. This will not be quite sufficient to cause the dam to overtop. However, it will add to the flooding of an adjoining house (refer photo 5.2) that has a floor level of 598.40 m. Apparently, this house has previously flooded and will require some form of a ring bank. No other houses in the vicinity are forecast to flood.

Photo 5.2: Park Avenue Dam (at right) and floodable house

Miro Street Drain Channel, Culverts and Bridges

Miro Street Drain has numerous culvert and bridge crossings. Most of the culverts are 1200 mm diameter concrete pipes, though there are some variations on this. The assessment of their capability below is based on the existing Miro Street Dam outflow capacity of 2.5 cumecs in the 0.5% AEP flood. The assessed capacities and channel capacity currently available prior to flooding adjacent roads or properties are:

Miro Road Crossing:	4.4 cumecs (1200 mm diameter, Hw 2.7 m)
Willow Lane:	4.4 cumecs (1200 mm diameter, Hw 2.7 m)
Opp Wineberry Lane:	4.0 cumecs (1200 mm diameter, Hw 2.4 m)
Kowhai Heights:	3.7 cumecs (1100 mm diameter, Hw 2.6 m)
139 Miro Street:	2.2 cumecs channel capacity (1.7 m wide x 1 m high)
139 Miro Street:	4.9 cumecs (Bridge 1.7 m wide x 1.9 m high)
131 Miro Street:	0.64 cumecs (severely congested 0.4 m wide)
131 Miro Street:	2.2 cumecs (Bridge 1.7 m wide x 1 m high)
Lee Street:	3.2 cumecs (1200 mm, Hw 1.8 m, badly congested)
121 Miro Street:	3.2 cumecs (1200 mm, Hw 1.8 m, badly congested)
119 Miro Street:	2.5 cumecs (Bridge 2 m wide x 1.0 m high, reduced by 10% for sewer crossings)

111 Miro Street:	3.0 cumecs (Bridge, cross-section 1.2 m base, 2.7 m bridge, height 0.95 m, 500 mm freeboard to house)
Martin Place:	Several small bridges very low capacity, will overtop
9B Shannon Street	Bridge with high waterway capacity, not assessed
Mangawhero Terrace	>4 cumecs (4.0 m wide x 1.5 m high culvert).

Thus, with the exception of the bridges at 131 and 139 Miro Street (2.2 cumecs each) and the bridges adjoining Martin Place (low capacity) all the crossings will pass the 0.5% AEP flood. The bridges at 131 and Miro Street are close to capacity and can be improved readily.

There is a large variation in channel capacity, almost totally related to whether vegetation has been cleared. This has a significant impact on flood overflows. (refer Section 7.2).

At 2 Martin Place the house is both close to the Miro Street Drain and very low-lying (refer photo 5.3). Strong planning rules will need to be implemented to prevent these flooding problems and risks recurring.

Photo 5.3: Low-lying house close to Miro Street Drain

5.3 Channel A (Korokoio Stream)

Channel A is the largest waterway passing through the centre of Ohakune Township. The 0.5% AEP flood of 28 cumecs at Shannon Street is a large flow conveyed on steep grades. This stream has the capacity to cause severe flood problems. Included in reports of the flooding experienced from Channel A in the 15 October 2013 flood was:

- Flow across the rear of the properties in Egmont Street – though this may have been caused by a tributary of Channel A.

- Ponding at the Ruapehu Street culvert, with flows flowing across the road around both ends of the culvert.
- Significant overflows at the Shannon Street culvert with flood depths of almost to the knees (400 mm - Mr Steve Adams eyewitness account). Water was surging a car stalled in the floodwaters. The estimated flow through the culvert and across Shannon Street was 20 cumecs.
- Significant outflows on the true right at Arawa Street culvert. This flooded 3 A-Frame houses at 59 Arawa Street and can be shut off by a floodwall.
- Floodwaters reached the deck level of 57 Arawa Road. With a further small rise they would only be separated from the interior of the house by glass doors. The fire brigade checked on the residents and safe egress is available. However, a larger flood at night would be an unpleasant experience.
- There are reports of a flooded house in Ti Kouka Street, most likely from Channel A floodwaters.

In the 0.5% AEP flood almost all the properties in Egmont Street will experience flooding. This is caused by flows from Channel A jumping out into relic channels (with the main channel located to the western end of the Egmont Street, beyond the houses). The depths of flooding are presented in a map in Appendix C. Generally, flooding depths do not exceed 300 mm, though around eight houses will have water flowing completely around them or underneath. Safe egress will be available.

Flooding at the Shannon Street culvert is mainly caused by the inadequate culvert size.

The flooding at Arawa Street is due to the combination of the inadequate culvert size and very low channel capacity upstream, causing overflows on the outside of the right hand bend. Section 7.3 presents further details on the channel capacity limitations.

Channel A has four principal culvert crossings through Ohakune Township (excluding consideration of the Ruapehu Street culvert on the outer limits of the town). Most of the culverts are around 2.4 m concrete box culverts, though there are some minor variations on this. The assessment of their capability below is relative to the assessed flow at Shannon Street of 28 cumecs in the 0.5% AEP flood (increasing to 29 cumecs before Arawa Street). The assessed capacities and channel capacity currently available prior to flooding adjacent roads or properties are:

Shannon Street:	18 cumecs (arch 2.0 m wide x 2.6 high, Hw 3.3 m)
Shannon Street:	29 cumecs channel capacity (3 m wide x 2.4 m deep)
Arawa Road:	18.7 cumecs (2.4 m square box culvert, Hw 2.65 m)

Arawa Road:	approximately 10 cumecs Channel capacity
Miro Street:	18.6 cumecs (arch 2.4 m wide x 2.4m high, Hw 2.7 m)
Goldfinch Street:	21.7 cumecs (2.6 m wide x 2.48 m high, Hw 3.15 m, includes 10% reduction caused by pipe upstream).

Thus, whilst channel clearing is essential, the culverts are too small and several options require consideration.

5.4 Channel B

Channel B enters Ohakune Township via a large box culvert just east of Manuka Street. The box culvert size of 1.77 m wide x 5.25 m long permits has a capacity of 11.5 cumecs, easily permitting passage of all of the 0.5% AEP flood flow of 7.6 cumecs. However, downstream of this the culverts are almost all too small.

The main reports on the flooding experienced from Channel B in the 15 October 2013 flood Channel A were:

1. Significant overflows down Manuka Street. These have been assessed at around 3.3 cumecs.
2. Flooding of 40 Arawa Street, this has since been raised to 0.3 m above road level.
3. Flooding of the steps at 34 Miro Street to 0.5 m below floor level. This was from overflows upstream at Conway Street.

At Arawa Street the channel requires an improved left bank culvert entry at the sharp right hand bend.

The Miro Street culvert has a high theoretical capacity but is prone to blockage due to the sharp left hand bend and vegetation. The inlet entry is poor, also due to a sharp bend, and a floodwall could be built along the left bank to retain floodwaters in the channel. As reported above, the general flooding in this area in 2013 was due to upstream overflows at Conway Street.

The assessed capacities and channel capacity currently available prior to flooding adjacent roads or properties are:

Manuka Street (1):	3.1 cumecs (arch 1.4 m wide x 0.9 m high, Hw 1.7 m)
Manuka Street (2):	3.1 cumecs (arch 1.4 m wide x 0.9 m high, Hw 1.7 m)
Manuka Street:	4.1 cumecs channel capacity (1 m wide with overbank width 4 m x 1.5 m deep, 500 mm freeboard to house; typical capacity of Channel B)
Arawa Street:	>3.1 cumecs (arch 1.4 m wide x 1.0 m high, Hw 2.85 m)
Conway Street:	5.8 cumecs (1.4 m wide x 1.1 m high box, Hw 2.5 m)
Miro Street:	6.7 cumecs (1.5 m wide x 1.2 m high box, Hw 2.5 m)
Goldfinch Street:	4.0 cumecs (arch -/9 m wide x 1.3 m high, Hw 2.35 m)
21 Ayr Street:	4.5 cumecs (circular 1.2 m diameter, Hw 2.8 m)
Ayr to Rata Street:	8.7 cumecs (circular 1.8 m diameter, Hw 2.5 m, some 53 m long)
SH49:	4.2 cumecs (circular 1.1 m diameter, Hw approx. 3.3 m).

Conclusions on Culvert Capacities Channel B:

1. Capacity of all culverts is at least 3.1 cumecs (two are exactly that and one slightly more).
2. A channel maintained clear of excessive vegetation and with some minor improvements should be able to convey around 4 cumecs.
3. However, the 0.5% AEP flow is now increased to 7.6 cumecs, so 4.5 cumecs require diversion, if culverts are not upgraded.
4. Three of the culverts pass 4 cumecs or slightly more and three significantly greater. Possibly design flows could be increased to 4.0 cumecs, but would require the channel improvements – as demonstrated by 30 year flood 15 October 2013, that flooded properties (but not houses).
5. In any case the diversion option has previously been shown to be likely to be cheaper.

5.5 Mangateitei Stream

There are no identified areas that flood in a 0.5% AEP flood adjacent to housing and no flooding problems were evident during this investigation.

6. Channel Management Problems and Recommended Works

Channel management is fully reported in Appendix B. This appendix divides the problems and recommended works into the various watercourses. The following summarises the information in Appendix B.

6.1 Mangawhero River

Of particular note in Appendix B is the advice on channel management below SH49. The key points being:

1. The channel downstream of SH49 to 64 Burns Street is wide, deep (3 m) and relatively straight, with little channel constriction.
2. Downstream of 64 Burns Street, the gradient markedly drops from around 1.7% above to 0.8% and the channel becomes more winding. Gravel transported from Mount Ruapehu has dropped out in deposits that are affecting mainly channel stability, but also to a lesser degree flood levels (refer photo 6.1 below).
3. Thus gravel management is important. There are gravel build-ups on six beaches and three of these require removal of gravel at 750 m^3 or more.
4. Management of willows and poplars is also important to both remove obstructions and layer and strengthen vegetative protection works.
5. Any management programme should also include the large drain running from the north-west side of Mangawhero River Road.
6. Upstream of SH49 to the Shannon Street footbridge, the management of the willow prior to 2011 was based around spraying the younger growth and cutting and chipping the older trees. Today that younger vegetation is out of spraying reach and control would be achieved by cutting, pasting stumps and chipping the biomass.

Photo 6.1: Gravel beach at rear of photo and erosion on Mangawhero River 2 km downstream of Ohakune

Retention of Old Left Channel near Ti Kouka and Conway Streets

The old left bank channel near Ti Kouka and Conway Streets is to be cleared of surplus vegetation and the inlet reinstated. This is largely being done by Ruapehu District Council under their resource consent. The Mangawhero Stream has avulsed into a shortened alignment. This will cause increased velocities and scour. This new alignment was accepted, as it will convey greater flow than before due to the increased slope (through shortening). It is also important to retain the old left channel in order to reduce flood risk to a nearby factory. The works are:

1. Vegetation clearance, in particular a large pine tree and maintenance to the existing rock riprap at the downstream end of the reach.
2. Remove the trees felled and dumped in the old left channel.
3. Trimming of the scoured right bank, excavation of rocks and gravels from the left bank (above water level) and armouring a 40 m length with either large riverbed rocks or imported.
4. Partially remove the build-up of rocks and gravels deposited at the entrance to the old left channel. The aim is the formation of a 10 m wide channel there with the bed level 500 mm above the adjacent water level.

Vegetation/Channel Maintenance.

With the assumption that the channel clearing works described above take place progressively over a period of say 5 years, maintenance of the completed work will begin, in a minor way, from Year 2.

Most owners of private dwellings, once they have understood the big picture goals, will adjust their garden design and maintenance to accommodate the "wider channel approach". In this respect it is not envisaged that annual maintenance will be a big ticket item.

However, there are a number of empty sections, commercial premises and land in crown and local government ownership, where ongoing maintenance will be required. The same can be said for the pastoral land downstream of the SH49 Bridge.

Once the initial clearing work has been achieved it is anticipated that there will be an ongoing need for knapsack spraying, minor planting (to stabilise banks either side of new culvert approaches and to reinforce the vegetation on sharp bends etc.) and small amounts of clearing work as required.

6.2 Miro Street Drain

There is a large variation in channel capacity in Miro Street Drain, almost totally related to whether the vegetation has been cleared. It is understood that a volunteer group progressively clear some of the Miro Street Drain, with some funding for materials from Ruapehu District Council. This clearing has produced a great result, with the stream capacity optimised and seemingly capable of carrying the 0.5% AEP flood. Refer following photos.

Photos 6.2 & 6.3: Cleared sections of Miro Street Drain

However, there are some severely congested sections of the drain and the 0.5% AEP flood map in Section 4 shows significant overflow travelling down the road. There is also a sizable area of flooding on the eastern side of Miro Street upstream of Kowhai Heights.

There is an extensive vegetation problem at 130/131 Miro Street with numerous Lawson Cypress on both banks, with roots congesting the channel and acting as grade controls (refer photos 6.4 and 6.5).

In the lower reaches of the stream, adjacent to Martin Place, there are significant obstruction to flow including the previously referenced bridges, a retaining structure for a shrub and a very large pile of vegetation (refer photo 6.6).

Photos 6.4 & 6.5: Congested sections of Miro Street Drain note severe restriction created by large tree

Photo 6.6: Congested section of Miro Stream note very large vegetation rubbish heap

6.3 Channel A (Korokoio Stream)

Behind Egmont Street the two stream channels there are both severely congested with mature willow. Removal of this would reduce flooding in that vicinity.

In the reach from Ruapehu Street to Shannon Street there is heavy willow congestion and also at Maire Way. However, there has been a good job of clearing the channel immediately downstream of Shannon Road, adjacent to the motels at 55A-59 Tainui Street (refer photo 6.7 below)

Photo 6.7: 0.5% AEP capacity in Channel A downstream of Shannon Street

The flooding at Arawa Street is due to the combination of the inadequate culvert size and very low channel capacity upstream, causing overflows on the outside of the right hand bend (refer photo 6.8). This section of the channel has a large number of willows, with the roots acting as grade controls, elevating flood waters and encouraging outflows. Channel A reverses direction twice in the reach upstream of the Arawa Street culvert, with further congestion immediately upstream of the culvert.

Photo 6.8: Low channel capacity in Channel A upstream of Arawa Street in total contrast to photo 6.7 (located 500 m upstream)

Between Miro Street and Goldfinch Street there are three unoccupied titles with partially cleared willow in the shallow channel.

The Ohakune Club title and the large paddock downstream both have willow in the channel that needs removing and below here the Barberry and native shrubs on both banks upstream of the walking track bridge need to be removed.

6.4 Channel B

Starting at the urban/rural divide at the top end of Manuka Street the watercourse is set between the two arms of the 'Y' section road. The open channel has been planted on both banks to water level with native shrubs and this need to be re-sited 750 mm back from the water to provide an unrestricted space for flood waters.

From 6 Manuka Street through five properties to Arawa Street the channel is mostly clear with only minor vegetation needing to be removed.

The channel becomes deeper through the three Conway Street properties and access to the dense native/exotic vegetation could be difficult.

The land between Miro and Goldfinch Streets is open space amenity parkland and the channel flows under a eucalypt canopy with native regrowth on the stream sides. Recent channel clearing has been undertaken by Ruapehu District Council over part of the total length, but it needs to be completed.

The channel now becomes quite incised (3 m wide) at the rear of the ski chalets on 16 Tay Street. It is only the native regrowth on the lower banks that needs to be removed.

There is an extensive problem between 17 and 25 Ayr Street (five properties) where the open channel has had little or no management for 20 years. The deep well-formed channel has been used by vegetation fly tippers for years and the section in front of the tyre retailer is 50% blocked with debris. Blackberry, native regrowth, bamboo and willow occupy the remaining 50%. It is particularly important that this should be cleared because the flow enters the long culvert at No. 12 to exit after 60 m at the Church of England property on Rata Street. The risk of culvert blockage is significant.

The channel is 4-5 m deep behind 6–10 Ayr Street with only the lower banks needing to be cleared of native regrowth. It then flows through a short stretch of low lying land (mown pasture) adjacent to the State Highway before its confluence with the Mangawhero.

6.5 Mangateitei Stream

As there were no identified flooding problems the channel management of the Mangateitei has not been assessed. It has included minor works in past years, including designed rock riprap protection constructed in Moore Street.

7. Flood Mitigation Options – Stopbanks and Floodwalls

A coherent set of flood mitigation options has been prepared, outlined in the following sections. All options presented are to contain the 0.5% AEP (1 in 200 year) flood. This standard of protection was selected as:

1. This would provide for a 1% AEP standard of protection with forecast climate change (average forecast scenario) over the next 40 to 50 years; and
2. The marginal cost of 0.5% AEP is very little above that for a 1% AEP standard. This is due to the fact that all options would include the same physical features of a floodway, culverts, stopbanks and floodwalls. The marginal cost in increasing the size of the flood protections is relatively small.

The assessments in Sections 5 and 6 shows that currently the various waterways cannot carry anywhere near this standard (except for the Mangateitei Stream). The current standard of flood protection varies between the 2.5% and 5% (20 to 40 year) level.

Generally freeboard is 500 mm. The proposed works are shown on Plan Set Number 5023 in Appendix A.

7.1 Mangawhero River

Mangawhero Bend Stopbank

The proposed stopbank extends the existing stopbank by almost 60 metres to a new length of 100 metres. It would extend upstream to finish near the Mangawhero River footbridge and downstream to just short of the large trees. This will cut off the overflows that can currently overflow this bend due to super-elevation.

The existing stopbank at Mangawhero Bend would be raised by 0.4m at the bend apex (from 591.5m to 591.9m) and widened. Peak stopbank height would increase to 1.5m.

The stopbank upgrade has been designed with a 3m wide crest and 2:1 batters. Total earthworks volumes are around 440 cubic metres.

Fill material for the stopbanks will have to be imported to ensure good quality material is used in the new stopbank construction.

Also included in the estimates are 100 t of rock riprap protection to add to the existing rock.

Conway Street to Ti Kouka Place Stopbank and Floodwalls

The houses at the rear of Conway Street and Ti Kouka Place can be protected by:

1. A 92 m long stopbank starting downstream of Conway Street through to near 21 Ti Kouka Place. The stopbank would have an average height of around 1.4 m.
2. A 192 m wooden floodwall extending between 21 and 10 Ti Kouka Place. The floodwall would have an average height of just over 0.6 m.

The stopbank has been designed with a 3 m wide crest and 2:1 batters. Total earthworks volumes are around 1,900 cubic metres. Detailed site survey at the time of construction is likely to reduce these quantities slightly.

Wooden floodwalls have been selected, as they are cheaper, easier to install and have more certain overturning and sliding stability than concrete floodwalls. Concrete floodwalls can be used and provide robust safety factors, but this is difficult on what are generally very constricted sites. The wooden wall is expected to have a life-time of at least 40 years and is expected to be adequate for the likely floodwater velocities.

Fill material for the stopbanks will have to be imported to ensure good quality material is used in the new stopbank construction.

7.2 Miro Street Drain

Mangawhero to Martin Place Floodwalls and Stopbanks

Outflows on both banks are likely to occur in floods of around 2-4% AEP 1 in (25 to 50 years). Left bank overflows are the more serious as they will flow across Shannon Street and flood the Shannon Street area and progressively into the surrounding streets. Right bank overflows will flood surrounding houses in Martin Place, including one very low-lying house immediately adjacent to the stream.

The stopbanks and floodwalls have been designed with a lesser 400 mm freeboard as there is a proposed lower section of concrete wall (with 250 mm freeboard) over a 10 m length at Mangawhero Terrace at the Miro Street Drain culvert.

There is an existing stopbank on the left bank, but it is too low and will require raising by an average of 440 mm over a 75 m length. Peak stopbank height would increase be 1.3 m.

As space is congested and the stopbank is not high the upgrade has been designed with a 2 m wide crest and 2:1 batters.

Total earthworks volumes are around 730 cubic metres.

Fill material for the stopbanks will have to be imported to ensure good quality material is used in the new stopbank construction.

Also included are 124 m of wooden floodwall on the left bank at an average height of 430 mm and 179 m of wooden floodwall on the right bank at an average height of 720 mm. Wooden floodwalls have been selected for the same reasons as in Section 6.1.

Finally, there is the 10 m long concrete floodwall to be connected into the existing culvert headwall structure. It is relatively low at a maximum increase in height of 220 mm.

Park Avenue Dam Ringbank

The floor of the house immediately adjacent to the Park Avenue Dam has already flooded and is vulnerable to recurring flooding. The floor of the other houses nearby are above potential flood levels, with the dam embankment (Park Avenue Road) commencing to overtop at around 598.7 m and the houses above the 600 m level. However, some may have water around the house exterior. A plan of the proposed ringbank alignment is not included, as it will require discussion with the landowners in the area to optimise and ownership of the land is complex – but not so much as to rule out protection of the house.

The proposed stopbank alignment would have mean height of 680 mm over a 75 m length. In order to carefully landscape the stopbank into the parklike surroundings it has been designed with a 3 m wide crest and 4:1 batters.

Total earthworks volumes are again around 730 cubic metres. In addition, a small road hump has been designed to contain spillway flows. This will be quite low and initial discussions with residents were favourable – it would lower undesirable traffic speeds.

7.3 Channel A (Korokoio Stream)

Options

The capacities of the culverts in Channel A are only around 18 to 21.7 cumecs. This is well below the 0.5% AEP flow of 28 cumecs. Thus, minor culvert modifications, such as improved entrances, will not be capable of providing the required design capacities. There are two principal options for Channel A as follows:

1. Investigate a detention dam.
2. Upgrade the culverts and channel.

Egmont Dam

Options for cost-effective flood detention on Channel A are very limited; principally because the prevailing land slope is steep and storage would be small. The best site appeared to be at a location slightly over 200 m east of Egmont Street (refer figure 7.1).

A full hydraulic analysis was conducted on this site, based on the design flows and storage-area data computed by Environmental Information Section staff. The peak inflows were determined from the Entura modelling at 22.1 cumecs – this was corroborated by comparison with parametric assessments for the 736 ha catchment.

After optimisation of the dam location, low flow culvert invert level and size the following parameters were produced:

Design Event:	0.5% AEP (1 in 200 year) flood
Peak Inflow:	22.1 cumecs

Option I – 2 m wide x 1.3 m high Culvert

Peak Outflow:	15.6 cumecs
Reduction in Peak:	6.5 cumecs
Peak Height:	5.6 m
Peak Volume:	37,400 m^3

Option II – 1.5 m square Box Culvert

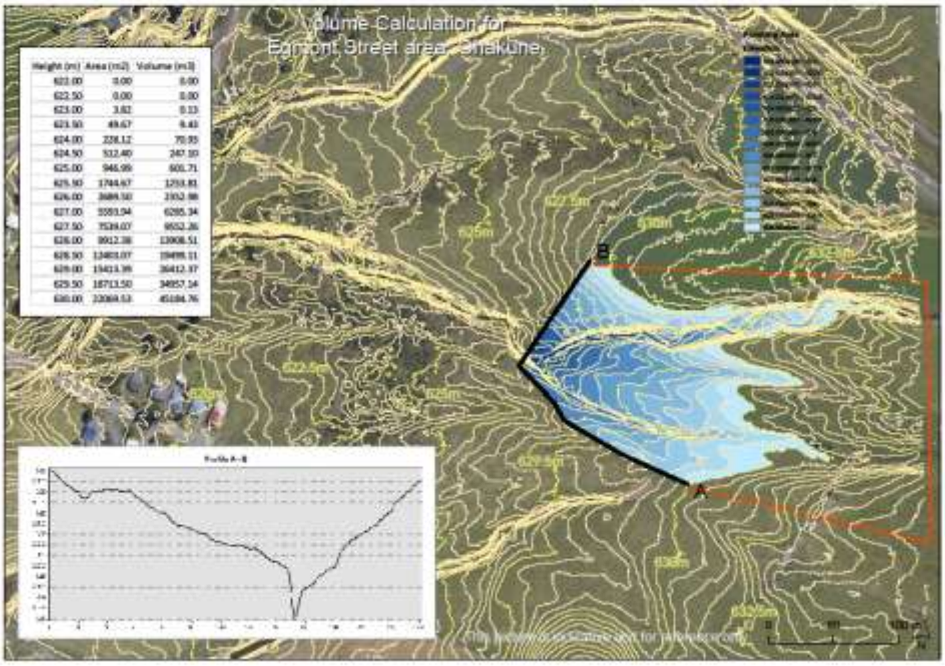
Peak Outflow:	14.1 cumecs
Reduction in Peak:	8.0 cumecs
Peak Height:	6.1 m
Peak Volume:	48,400 m^3

Thus, these dams can get close to meeting the requirements. However, the proposed dam height for Option II is higher than our initial recommendations for the volcanic terrain (even with imported fill), though it could be constructed. Estimates have been prepared for Option I and involve the following quantities:

Earthworks:	15,000 m^3
Batter Slope:	3:1
Base Culvert:	2 m wide x 1.3 m high x 50 m long
Cut-off Wall at Culvert:	20 m wide x 5 m deep
Spillway:	150 m long x 30 m wide
Spillway Lining:	Enkamat
Rock Protection at Toe:	280 t.

A secondary benefit of the Egmont Dam option is that it will reduce the flooding in the Burns Street area to some degree. Thus, whilst this option is significantly more expensive (refer Section 8), it does produce this benefit.

Figure 7.1: Possible Egmont Dam



Culvert Upgrades

All four principal culverts (Shannon Street, Arawa Street, Miro Street and Goldfinch Street) can be upgraded to pass the 0.5% AEP flow by installation of supplementary 2 m x 2 m concrete box culverts. There is room to do this at each site, but there will be some minor cost in demolition of existing wingwalls. Refer photos 7.1 and 7.2 for the Miro Street upgrade site, typical of the four culvert sites.

Photo 7.1: Channel A culvert upgrade location at Miro Street

Photo 7.2: Channel A culvert upgrade location at Miro Street

Arawa Street Floodwall

As advised in Section 5.3 the flooding at 59 Arawa Street can be mitigated by installation of a floodwall to prevent overflows. The floodwall would be up to 40 m long (detailed site survey may reduce this) and 0.6 m high.

7.4 Channel B

Options

The current effective capacity Channel B culvert system is 3.1 cumecs, well short of the 0.5% AEP flow of 7.6 cumecs. Thus again, minor culvert modifications, such as improved entrances, will not be capable of providing the required design capacities.

1. Construct a floodway from the box culvert upstream of Manuka Street to the Mangateitei Stream at SH49 (Rangataua Road). This would still require ongoing channel maintenance.
2. Upgrade the culverts and channel.

Floodway

The floodway must be capable of passing 4.5 cumecs. The proposed floodway centreline is shown in the plans in Appendix B. It has been carefully located to minimise effects on the landowners involved. There is a raised area of land near SH49 that potentially could be a house site and the contingency plan would be to pipe the floodway through here. However, it is uncertain what is planned here and earthworks from the floodway excavation could be placed to form a building platform on land to the north-east of the existing house. Consultation should be initiated with the three affected landowners.

The floodway would be around 400 m long, with the invert level dropping from 592.75 m at the Manuka Street end to 591.0 m at the Mangateitei Stream – a grade of 0.44%. The box culvert inlet is an ideal location to divert the water requiring only minor diversion works. The floodway would have an invert 10 m wide with 2:1 batters each side. In the 0.5% AEP flood the 4.5 cumecs diverted would flow at just under 1 m/s at a depth of just under 0.5 m. The earthworks volume involved is 15,000 cubic metres.

There are two sewer manholes located near the proposed alignment. The plans of these have been inspected and it appears that the sewer line will not be a formidable obstruction and grades and dimensions can be adjusted to fit the service.

A total of 140 t of rock protection will be required at the entry to the Mangateitei Stream.

An important consideration is to ensure that diversion of 4.5 cumecs to the Mangateitei Stream does not increase flood risks there. The increase in flood levels is minor at less than 100 mm.

The approximate location of the floodway is shown in photos 7.3 and 7.4.

Photo 7.3: Downstream end of proposed Channel B diversion floodway to right of photo

Photo 7.4: Proposed Channel B diversion floodway looking upstream

Culvert Replacements and Upgrades

There are eight culverts that require upgrading. Not all of these have sufficient space to locate a supplementary culvert. Therefore, at this stage five replacement culverts and three supplementary culverts have been sized to carry the 0.5% AEP flow of 7.6 cumecs as follows:

Manuka Street (1):	Supplementary 1.5 m wide x 1 m high box culvert
Manuka Street (2):	Supplementary 1.5 m wide x 1 m high box culvert
Arawa Street:	Replacement 2 m wide x 1 m high box culvert
Conway Street:	Replacement 2 m wide x 1.5 m box culvert
Miro Street:	Replacement 2 m wide x 1 m high box culvert
Goldfinch Street:	Replacement 2 m wide x 1.5 m high box culvert
21 Ayr Street:	Replacement 1.8 m diameter culvert
Ayr to Rata Street:	Adequate existing capacity
SH49:	Supplementary 1.2 m diameter culvert.

8. Cost Estimates

Cost estimates have been prepared for all options. They include:

- The expected construction cost based on current rates;
- The appropriate contingencies allowance. This ranges 15 to 20 percent of the construction cost estimate - depending on the certainty of the design and possible ancillary costs;
- Engineering at 7.5% of the construction cost estimate; and
- Estimated land purchase or easements.

Estimates have been carried out for the 0.5% AEP level of flood protection as follows:

8.1 Mangawhero River

Mangawhero Bend Stopbank	$ 22,100
Conway to Ti Kouka St Stopbank & Floodwalls	$ 185,600
Mangawhero Vegetation above SH49	$ 31,500
Mangawhero Vegetation below SH49	$ 29,700
Total	**$ 268,900**

8.2 Miro Street Drain

Park Avenue Dam Ringbank	$ 37,100
Lower Miro Street Drain Stopbank & Floodwalls	$ 202,200
Miro St Drain Vegetation	$ 22,400
Total	**$ 261,700**

8.3 Channel A

Option A

Four Supplementary Culverts	$ 462,900
Arawa Street Floodwall	$ 22,000
Channel A Vegetation	$ 42,900
Total	**$ 527,800**

Option B

Egmont Dam*	$1,013,800
Arawa Street Floodwall	$ 22,000
Channel A Vegetation	$ 42,900
Total	**$1,078,700**

** Note Egmont Dam cost does not include land purchase or easements*

8.4 Channel B

Option A	
Floodway	$ 318,500
Channel B Vegetation	$ 21,400
Total	**$ 339,900**

Option B	
Eight Culvert Upgrades	$ 984,600
Channel B Vegetation	$ 21,400
Total	**$ 1,006,000**

8.5 Upgrade Total

Mangawhero River	$ 268,900
Miro Street Drain	$ 261,700
Channel A Option A	$ 527,800
Channel B Option A	$ 339,900
Total	**$ 1,398,300**
Total (Rounded)	**$1.4 Million**

8.6 Ongoing Channel Maintenance

With the assumption that the channel clearing works described above take place progressively over a period of say 5 years, maintenance of the completed work will begin, in a minor way, from Year 2.

Total Annual Channel Maintenance **$22,500**

8.7 Ongoing Asset Maintenance

These works are expected to require very minor maintenance in the initial years. The upgraded culverts should require less maintenance than the existing assets, as the capacity is improved. Some maintenance of the flood protection may be required following floods. This has not been costed.

9. Recommended Implementation Programme

The recommend implantation is based on the following considerations:

- The magnitude of current flood risks. Whilst houses flooded from Channels A and B in the October 2013, a significant number of houses will flood from Miro Street Drain once a slightly larger flood (around 2% AEP) occurs. There are significant outflows from the Miro Street Drain in the vicinity of the motels by Shannon Street that will flood Shannon Street through to Mangawhero Terrace and surrounding streets.
- There are cost savings in constructing the nearby Mangawhero bend stopbank concurrently.
- There will be significant flooding in the CBD in a large flood in Channel B, that would have a serious impact on the town. The floodway is the only viable option and steps need to be taken to enable this option.
- The next biggest risk is clearly mitigating the impacts of the high flows that can travel down Channel A.
- The highest priority in the vegetation works is to clear the lower Mangawhero to reduce flood risks in Burns Street.

Year One:

Mangawhero Bend Stopbank	$ 22,100
Park Avenue Ringbank	$ 37,100
Lower Miro Street Drain Protection	$ 202,200
Mangawhero River Vegetation below SH49	$ 29,700
Total	**$ 291,100**

Year Two:

Channel B Floodway	$ 318,500
Channel A Vegetation	$ 42,900
Total	**$ 361,400**

Year Three:

Channel A Arawa, Miro, Shannon Culverts	$ 344,100
Arawa Street Floodwall	$ 22,000
Mangawhero River Vegetation above SH49	$ 31,500
Total	**$ 397,600**

Year Four:

Conway-Ti Kouka Stopbank & Floodwalls	$ 185,600
Miro Street Drain	$ 22,400
Total	**$ 208,000**

Year Five:

Goldfinch Culvert	$ 118,800
Channel B Vegetation	$ 21,400
Total	**$ 140,200**

GRAND TOTAL **$1,398,300**

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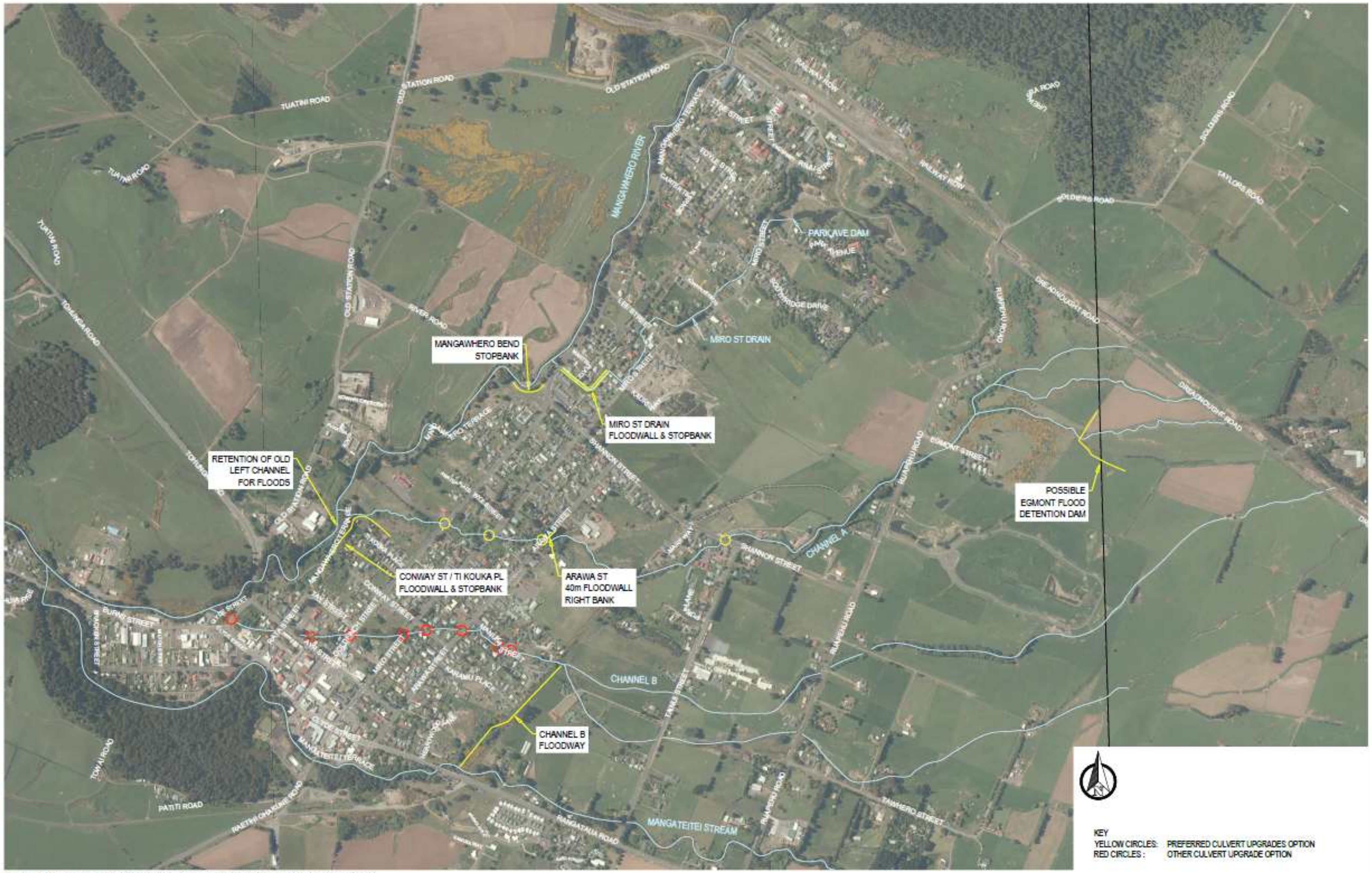
APPENDIX A

Flood Mitigation Options Plans



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ISSUE	AMENDMENT	BY	DATE		NAME	DATE
				SURVEYED	W DE JONGE	APR 2015
				DESIGNED	P BLACKWOOD	JUL 2015
				DRAWN	Q GILKISON	APR 2015
				TRACED	AutoCAD	APR 2015
1	ISSUE FOR DISCUSSION	QG	JUL 15	CHECKED		
0	ISSUE FOR SURVEY INFORMATION	QG	APR 15			

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LEVEL FIELD BOOK

FILE REF WHANGAEHU CATCHMENT\15012

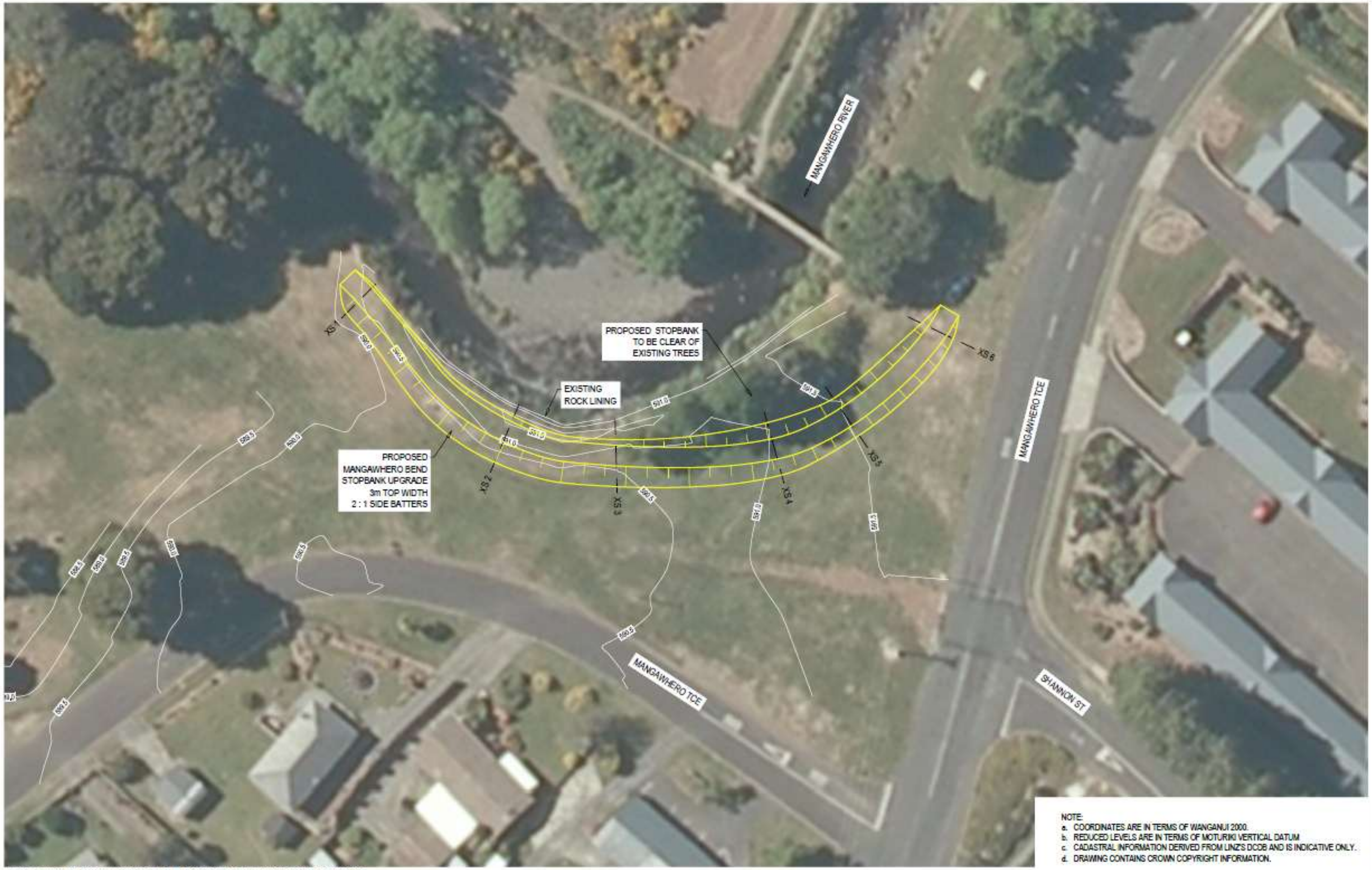
horizons regional council

MANGAWHERO RIVER
INVESTIGATION FOR FLOOD PROTECTION WORKS
ON MANGAWHERO RIVER AND TRIBUTARIES IN OHAKUNE
OHAKUNE FLOOD MITIGATION OPTIONS LAYOUT

SCALES: ORIGINAL DRAWING SIZE A1
1:5,000

DRAWING No. 5023

SHEET OA OF SHEETS



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c. CADASTRAL INFORMATION DERIVED FROM LINZ'S DCDB AND IS INDICATIVE ONLY.
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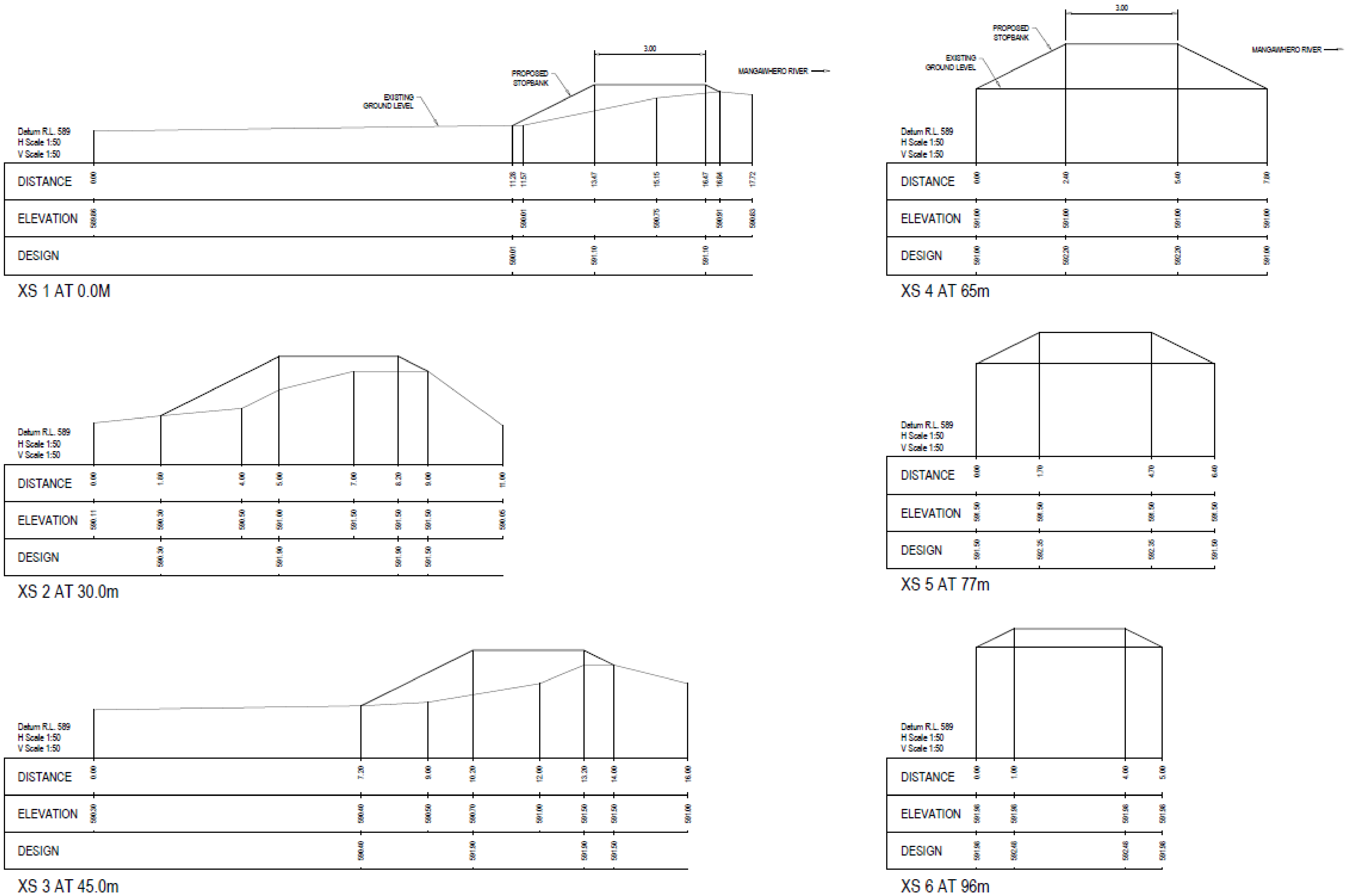
horizons regional council

MANGAWHERO RIVER
INVESTIGATION FOR FLOOD PROTECTION WORKS ON MANGAWHERO RIVER AND TRIBUTARIES IN OHAKUNE
PROPOSED MANGAWHERO BEND STOPBANK UPGRADE

SCALES: ORIGINAL DRAWING SIZE A1
1:250

DRAWING No. 5023

SHEET 2-1 OF SHEETS



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horizons regional council

MANGAWHERO RIVER
INVESTIGATION FOR FLOOD PROTECTION WORKS ON MANGAWHERO RIVER AND TRIBUTARIES IN OHAKUNE
MANGAWHERO TCE SITE : PROPOSED CROSS SECTIONS

SCALES: ORIGINAL DRAWING SIZE A1

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SHEET 2-2 OF SHEETS

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ISSUE	AMENDMENT	BY	DATE
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LEVEL FIELD BOOK

FILE REF: WHANGAEHU CATCHMENT\15012

horizons regional council

MANGAWHERO RIVER
INVESTIGATION FOR FLOOD PROTECTION WORKS ON MANGAWHERO RIVER AND TRIBUTARIES IN OHAKUNE
PROPOSED CONWAY ST & TI KOUKA PL FLOOD PROTECTION

SCALES:
ORIGINAL DRAWING SIZE A1
1:400

DRAWING No.
5023

SHEET 4-1 OF SHEETS

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e. PLAN SHOWS MAXIMUM LIKELY EXTENT OF WORKS. FURTHER HYDRAULIC MODELING IS EXPECTED TO SHORTEN UPSTREAM END BY APPROXIMATELY 30 METRES.

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ISSUE	AMENDMENT	BY	DATE
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horizons regional council

MANGAWHERO RIVER
INVESTIGATION FOR FLOOD PROTECTION WORKS ON MANGAWHERO RIVER AND TRIBUTARIES IN OHAKUNE
PROPOSED LOWER MIRO STREET DRAIN FLOOD PROTECTION

SCALES: ORIGINAL DRAWING SIZE A1
1:250

DRAWING No. 5023

SHEET 3-1 OF SHEETS

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LEVEL FIELD BOOK

FILE REF

horizons regional council

MANGAWHERO RIVER
INVESTIGATION SURVEY FOR FLOOD PROTECTION WORKS ON MANGAWHERO RIVER AND TRIBUTARIES IN OHAKUNE
SITE SURVEY : PARK AVENUE SITE

SCALES: ORIGINAL DRAWING SIZE A1
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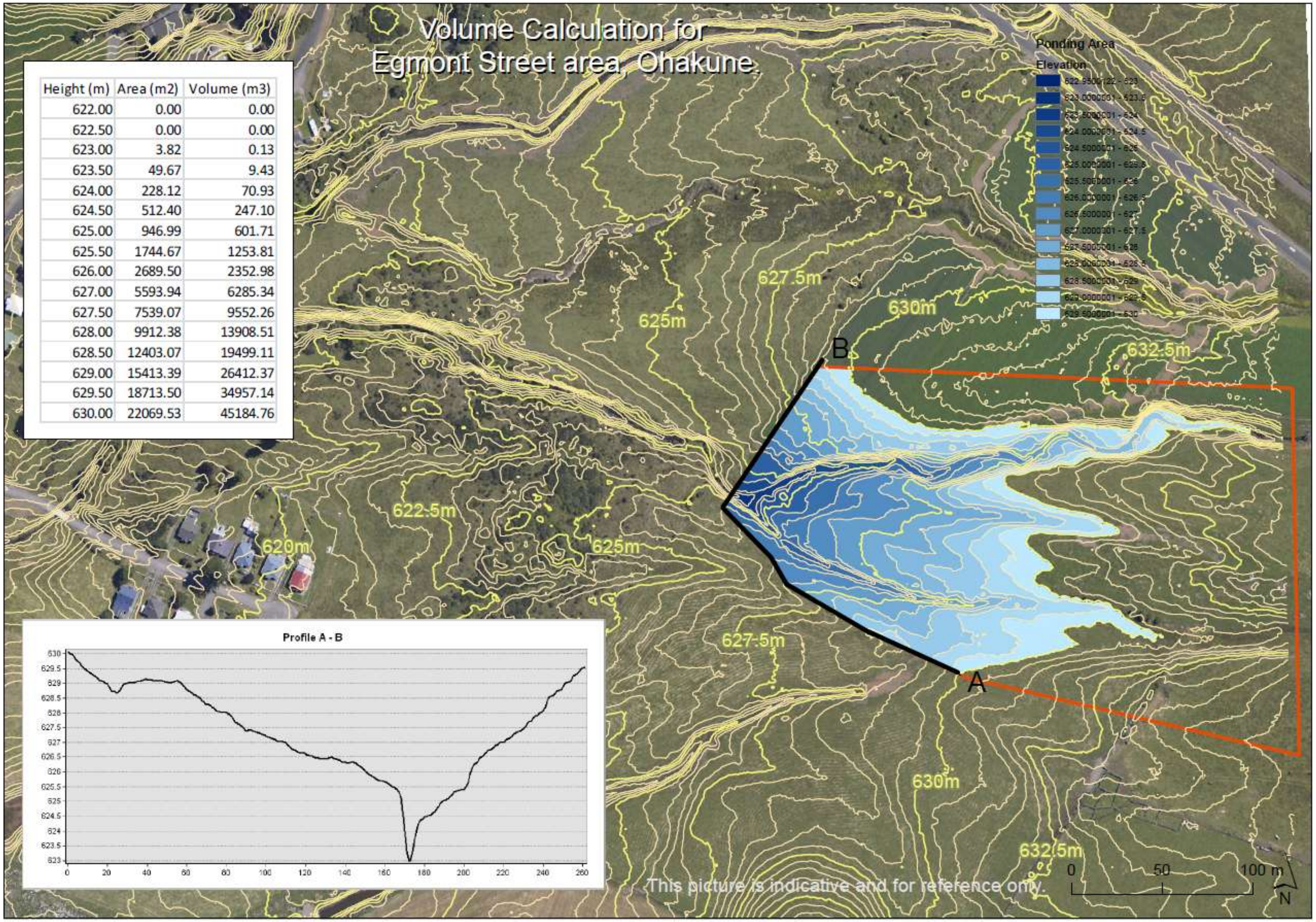
SHEET OF SHEETS



Height (m)	Area (m2)	Volume (m3)
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622.50	0.00	0.00
623.00	3.82	0.13
623.50	49.67	9.43
624.00	228.12	70.93
624.50	512.40	247.10
625.00	946.99	601.71
625.50	1744.67	1253.81
626.00	2689.50	2352.98
627.00	5593.94	6285.34
627.50	7539.07	9552.26
628.00	9912.38	13908.51
628.50	12403.07	19499.11
629.00	15413.39	26412.37
629.50	18713.50	34957.14
630.00	22069.53	45184.76

NOTE:

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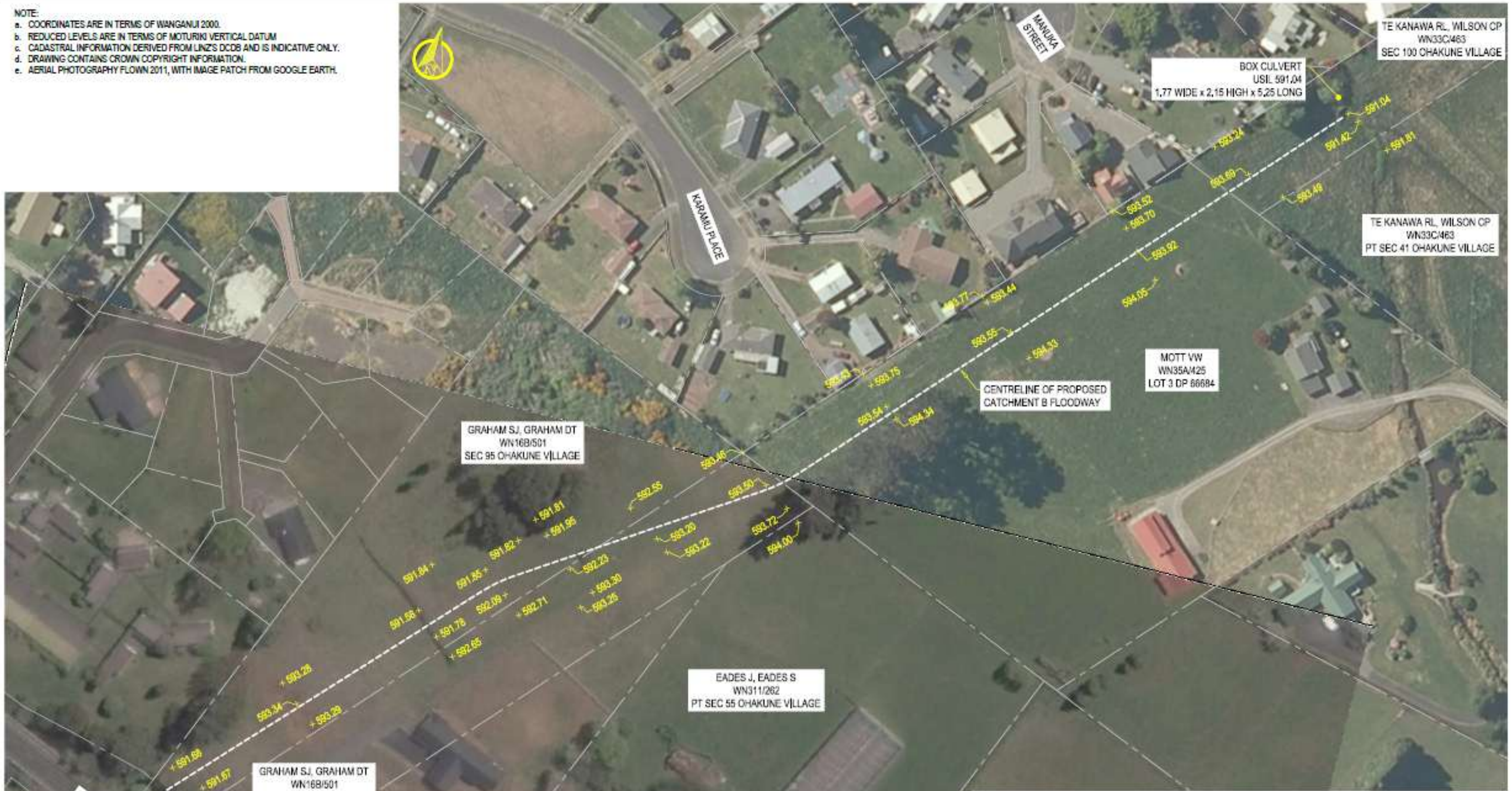

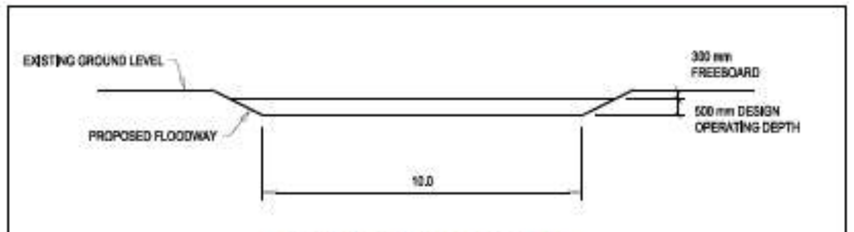

TYPICAL CROSS SECTION

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ISSUE	AMENDMENT	BY	DATE
0	ISSUE FOR SURVEY INFORMATION	QG	JUN 15

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LEVEL FIELD BOOK

FILE REF WHANGAEHU CATCHMENT\15012

horizons regional council

MANGAWHERO RIVER
INVESTIGATION FOR FLOOD PROTECTION WORKS ON MANGAWHERO RIVER AND TRIBUTARIES IN OHAKUNE
CENTRELINE OF PROPOSED CATCHMENT B FLOODWAY

SCALES: ORIGINAL DRAWING SIZE A1

1:500

DRAWING No. 5023

SHEET 1-1 OF SHEETS

APPENDIX B

Vegetation Report & Plans

horizons regional council

MEMORANDUM

FILE: PRD 03 07

DATE: 30 June 2015

TO: Peter Blackwood

FROM: Jeremy Cumming

SUBJECT: **OHAKUNE FLOOD RISK INVESTIGATIONS**

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1. **Introduction**

This report is designed to be appended to an all encompassing investigation by Horizons Regional Council (Operations) into flood risk and mitigation options in the township of Ohakune.

2.0 **Scope**

The following watercourses were investigated.

a. Miro St Drain
Park Avenue dam outlet (1807946/5635443) to the confluence with the Mangawhero River (1807234/5635048).

b. Channel A (as described in the substantive report) from the junction of two tributaries 100 m north of Egmont Street (1808431/5634865) to the confluence with the Mangawhero River (1806614/5634603).

c. Channel B (as described in the substantive report) from the urban boundary at the end of Manuka Street (1807228/5634191) to the confluence with the Mangawhero River (1806230/5634372).

d. Mangawhero River from the footbridge at the end of Shannon St (1807194/5634995) to the SH 49 road bridge.

e. Mangawhero River from the SH 49 road bridge to the Raetihi/Ohakune road bridge (1801835/5633787).

With the exception of the Miro Street Drain these water courses arise further afield but it is only the part through the urban environment which is relevant to this exercise.

3.0 **Inspection Dates**

All inspections were completed over the period 6 June to 17 June.

4.0 **Vegetation Parameters**

For the purpose of this report any vegetation from the crest of the left bank, through the flowing channel to the crest of the right bank was considered when assessing its effect on flood flows.

4.1 General observations

Channel size varied enormously within even a 100m distance and that was almost invariably due to the types of vegetation that had established on either one or both banks. Narrow confined channels such as that in the Miro St Drain above Wineberry Lane were almost always densely vegetated with low growing shrubs eg carex grasses, flax, lily, Astelia, rushes, tussocks and sedges.

It was found that both channel width and depth had been reduced by vegetation encroachment, in the latter case as a consequence of root systems trapping silts and encouraging progressive bed raising.

Where channel size was compromised by fern type vegetation then an allowance was made for removing, spraying or mulching at least one bank to encourage the loosening of silts.

Conversely at deeply incised channels (Channel B below Goldfinch Street) it was acceptable to leave bigger specimen trees within the wider channel.

Where a channel sharply changed direction, there was a greater emphasis in costing the removal of all vegetation apart from ferns on the outside bend.

In places channel capacity was minimal on account of willow roots growing across/under the bed, causing a build-up of silts and vegetation behind the obstruction, resulting in waters spilling, even in a minor flood. An example is at Channel A above Arawa Street where in addition to removing trees, mechanical deepening of the channel is recommended. However apart from small localised obstructions, mechanical clearing of the channel has not been costed.

4.2 Sectional description of vegetation

4.2.1 Miro St Drain

Above the Miro Street culvert there is a dense canopy of Cypress and Banksia trees but the channel is largely free of lower vegetation. Below the culvert, down to Kowhai Heights the channel is mainly clear of trees and shrubs but extensive flax plantings have contributed to channel narrowing.

There is an extensive problem at 130/131 Miro Street with numerous Lawson Cypress, on both banks, with roots acting as grade control for 100 m. The problem is exacerbated with the three downstream properties extensively vegetated with low shrubs, willow, barberry and cotoneaster.

At the downstream end of the Lee Street culvert a large willow stump restricts flow but the channel is largely clear of taller vegetation until 119 Miro Street. However numerous flax plantings are contributing to a narrow channel.

Numbers 115,117 and 119 Miro Street have both banks planted with native vegetation, prunus and cotoneaster that need removing.

The drain now goes down the side of 111 Miro Street to the rear of four properties on Martin Place, all of which are planted on the left bank with native shrubs, again restricting channel size.

Behind the Shannon Street Motels the small stopbank is free of vegetation but flax on the right bank needs to be removed.

4.2.2 Channel A

Behind Egmont Street the two channels that join are both severely congested with mature willow (250 m plus 90 m). Both have been priced for clearing and debris burning. This will reduce the risk of blockage upstream of the culvert meaning flows are more likely to be retained within the channel.

Although not inspected, the channel through 101 Ruapehu Road looks heavily congested with willow and together with the willows on two Shannon Street properties, have been priced for removal.

The channel alongside motel units on 55A/59 Tainui Street has recently been cleared of vegetation but there are larger willows remaining in each of the Maire Way sections that should be removed.

The paddock accessed from 64-66 Arawa Street has a number of large willow within the channel that are acting as a grade control and the channel capacity is almost non existent. Undoubtedly this is contributing to the problems at the Arawa Street culvert.

Channel A reverses direction twice within the section at 62 Arawa Street, which is congested with willow growth immediately above the Arawa Street culvert.

The two properties downstream of the culvert have well managed gardens but both need native and exotic vegetation cut back from the immediate banks. Downstream of the path between Arawa and Miro Streets the land is untitled waste ground with a cover of Broom, Blackberry and Privet on both banks.

Between Miro Street and Goldfinch Street there are three unoccupied titles with partially cleared willow in the shallow channel.

The Ohakune Club title and the large paddock downstream both have willow in the channel that needs removing and below here the Barberry and native shrubs on both banks upstream of the walking track bridge need to be removed.

4.2.3 Channel B

Starting at the urban/rural divide at the top end of Manuka Street the watercourse is set between the two arms of the ‘Y’ section road. The open channel has been planted on both banks to water level with native shrubs and these need to be resited 750 mm back from the water to provide an unrestricted space for flood waters.

From 6 Manuka Street through five properties to Arawa Street the channel is mostly clear with only minor vegetation needing to be removed.

The channel becomes deeper through the three Conway Street properties and access to the dense native/exotic vegetation could be difficult.

The land between Miro and Goldfinch Streets is open space amenity parkland and the channel flows under a eucalypt canopy with native regrowth on the stream sides. Recent channel clearing has been undertaken by RuDC over part of the total length, but it needs to be completed.

The channel now becomes quite incised (3 m wide) at the rear of the ski chalets on 16 Tay Street. It is only the native regrowth on the lower banks that needs to be removed.

There is an extensive problem between 17 and 25 Ayr Street (five properties) where the open channel has had little or no management for 20 years. The deep well- formed channel has been used by vegetation fly tippers for years and the section in front of the tyre retailer is 50% blocked with debris. Blackberry, native regrowth, bamboo and willow occupy the remaining 50%. It is particularly important that this should be cleared because the flow enters the long culvert at No. 12 to exit after 60 m at the Church of England property on Rata Street. The risk of culvert blockage is significant.

The channel is 4-5 m deep behind 6 – 10 Ayr Street with only the lower banks needing to be cleared of native regrowth. It then flows through a short stretch of low lying land (mown pasture) adjacent to the State Highway before its confluence with the Mangawhero.

4.2.4 Mangawhero River above SH 49 (to Shannon Street footbridge)

The vegetation here has been the subject of a number of previous reports (ref. John Philpott and Associates Ltd "Ohakune Flood Control – Works and Estimated Costs" – August 2011), but can be summarised as: mixed aged willow on both banks and on the wider gravel deposits.

Management of the willow prior to 2011 was based around spraying the younger growth and cutting and chipping the older trees. Today that younger vegetation is out of spraying reach and control would be achieved by cutting, pasting stumps and chipping the biomass.

4.2.5 Mangawhero River Below SH 49 to the Raetihi/Ohakune Road Bridge

The channel downstream of the SH 49 road bridge as far as 64 Burns Street is wide, deep (3 m) and relatively straight, with the banks covered in young native vegetation that frequently gets swept clean by flood water.

Downstream of 64 Burns Street, the gradient is much reduced (45 m over 5.9 km compared with 40 m in the 2.4km section above SH 49) and the channel course more winding. Gravel readily transported to this point has dropped out in deposits that are having a profound effect on adjacent bank stability.

Willow and poplar plantings by themselves will not arrest bank loss without gravel management, but existing willow could be managed better. Large trees can be removed from the bank edge and some well managed plantings on outside bends could be coppiced to reinvigorate the root mass. Other willow in the wider channel environment could be removed altogether.

5.0 Costs of initial channel clearance

The methodology to be applied and equipment needed falls into two broad categories, depending on whether the work is undertaken in either an urban or rural environment and the suitability of the site for firing waste material.

- The urban environment demands smaller equipment to work in tight locations. Trees and shrubs often have to be lifted out of tight gullies and over property boundaries. Waste material has to be processed on site through a mulch/chipper unit. Few contractors have the skills and suitable equipment and none operate from Ohakune. The closest are likely to be based in either Taupo, Turangi or Wanganui.

- Rural locations permit cheaper methods of operation and disposal of waste products. There are a number of local contractors with a medium sized digger who could handle this work.

5.1 Unit Costs of Work

5.1.1 Urban environment – A daily (8 hour) **unit cost of $2,700** has been derived assuming a three man specialist crew with specialist equipment, transportation, travel and accommodation.

5.1.2 Rural environment - A daily (8 hour) **unit cost of $1,500** has been derived assuming a locally sourced 12 tonne excavator, cross-cutter and transportation.

6.0 Summary of initial vegetation management costs

Applying those unit rates, the estimated cost of initial clearance works in the five watercourses are as follows (details are available):

	Unit A	**Unit B**	**Total**
Miro St Drain	22,382.25		22,382.25
Channel A	21,364.88	21,503.25	42,868.13
Channel B	21,364.88		21,364.88
Mangawhero R above SH 49	28,486.50	3,018.00	31,504.50
Mangawhero R below SH 49	1356.50	28,293.75	29,650.25
	$94,955.00	**$52,815.00**	**$147,770.00**

7.0 Vegetation/channel maintenance.

With the assumption that the channel clearing works described above take place progressively over a period of say 5 years, maintenance of the completed work will begin, in a minor way, from Year 2.

Most owners of private dwellings, once they have understood the big picture goals, will adjust their garden design and maintenance to accommodate the “wider channel approach”. In this respect it is not envisaged that annual maintenance will be a big ticket item.

However there are a number of empty sections, commercial premises and land in crown and local government ownership, where ongoing maintenance will be required. The same can be said for the pastoral land downstream of the SH49 bridge.

Once the initial clearing work has been achieved it is anticipated that there will be an ongoing need for knapsack spraying, minor planting (to stabilise banks either side of new culvert approaches and to reinforce the vegetation on sharp bends etc) and small amounts of clearing work as required.

40 hours of knapsack spraying	@ $60.00/hr	2 400
Planting		3 000
3 days of Unit A work	@ $2,700/day	8 100
3 days of Unit B work	@ $1 500/day	4 500
Gravel relocation 3 days dozer work	@ $1500 /day	4 500
Total Annual maintenance		**$22,500**

Cost of Vegetation Works for 5 Drainage Channels at Ohakune

Miro Street Drain

	Unit A
Foot bridge	
3a Park Ave to Miro St	1.00
Culvert under Miro St	
161 Miro St	
2 Willow Lane	
Culvert under Willow Lane	
Cnr Willow Lane/Miro St	0.13
Culvert under Wineberry Lane	
143-149 Miro St	0.13
Culvert under Kowhai Heights	
141 Miro St	0.50
130/131 Miro St	2.00
35 Lee St	0.25
27/29 Lee St	0.50
Culvert under Lee St	
22 Lee St - 123 Miro St	0.75
117/119 Miro St	0.50
115 Miro St	0.75
113 Miro St	
111 Miro St	0.25
6 Martin Place	1.00
4 Martin Place	
2 Martin Pl to Mangawhero Terrace	0.50
Culvert under Mangawhero Terrace	
Unit total	8.25
Unit A value	$2,713
Unit B value	
Total Unit values	$22,382.25

Channel A

	Unit A	Unit B
Split in channel above Egmont St		10.000
Culvert under Egmont St		
Culvert under Ruapehu St		
101 Ruapehu St	1.000	
83 Shannon St	0.500	
75 Shannon St	0.125	0.625
Culvert under Shannon St		
55a/59 Tainui St		
3,7,8,9 Maire Way		1.000
64-66 Arawa St		0.500
62/Crown Arawa St		1.500
Culvert under Arawa St		
57 Arawa St		
57a Arawa St	1.000	
55 Arawa St	1.000	
68 Miro St	0.750	
Road berm	0.250	
Culvert under Miro St		
63 Miro St	0.500	
61a Miro St	0.250	
64-66 Goldfinch St	1.000	
Culvert under Goldfinch St		
71 Goldfinch St		0.625
55 Goldfinch St	0.750	
16 Ti Kouka Place		
Reserve to footbridge	0.750	
Unit total	7.875	14.250
Unit A value	$2,713	
Unit B value		$1,509
Total Unit values	$21,364.88	$21,503.25

Channel B

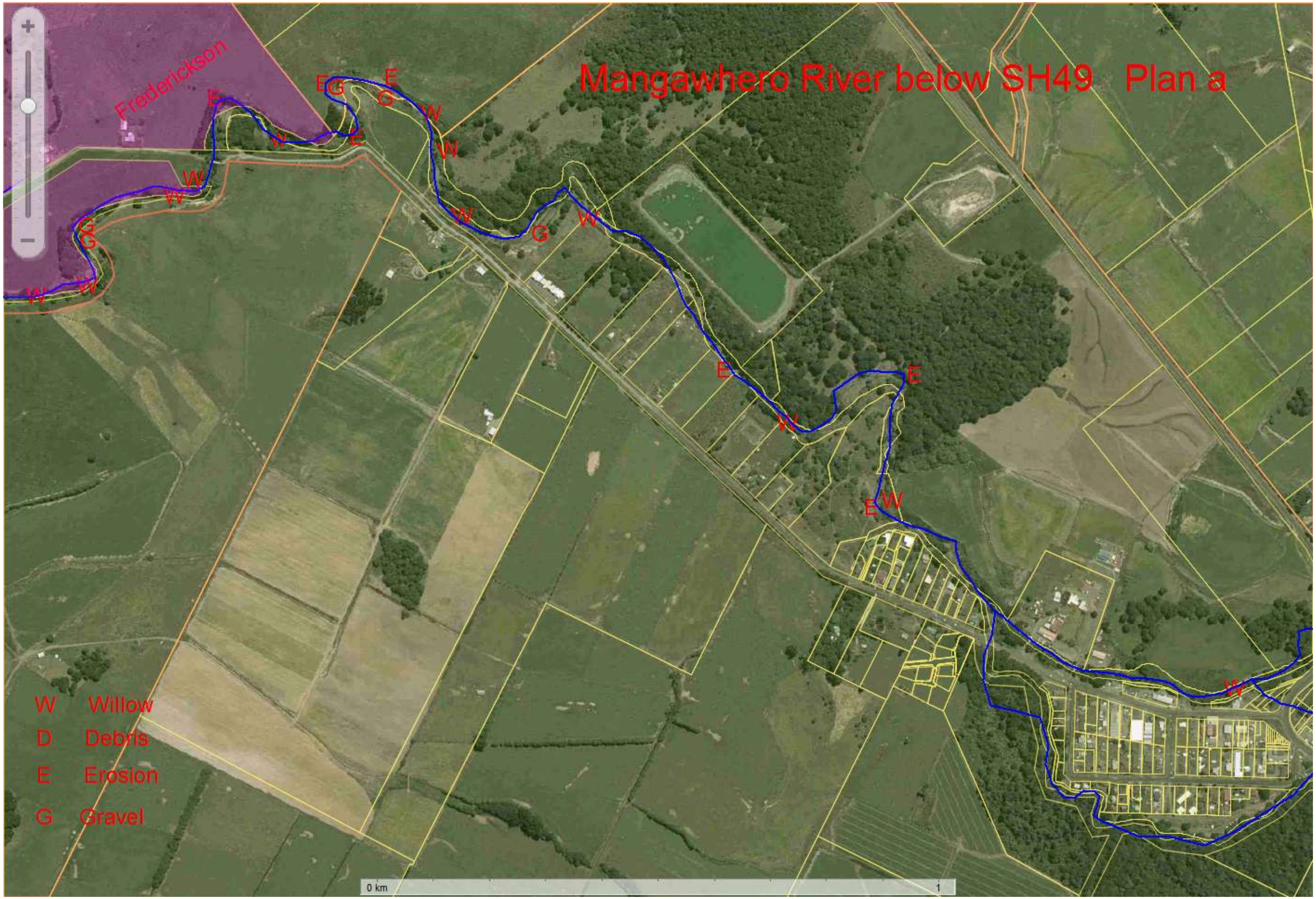
	Unit A
22 Manuka St	0.500
Manuka St central berm	0.750
2-6 Manuka St	0.125
42 Arawa St	
Culvert under Arawa St	
23,25,31 Conway St,36 Miro St	0.500
Culvert under Conway St	
Culvert under Miro St	
Miro St to Goldfinch St	1.000
Culvert under Goldfinch St	
16a,16b,14 Tay St	0.500
25 Ayr St	1.000
17,19,21 Ayr St	1.500
4,10 Rata St,11,13 SH49	2.000
Culvert under SH49	
Bermland to Mangawhero R	
Unit total	7.875
Unit A value	$2,713
Unit B value	
Total Unit values	$21,364.88

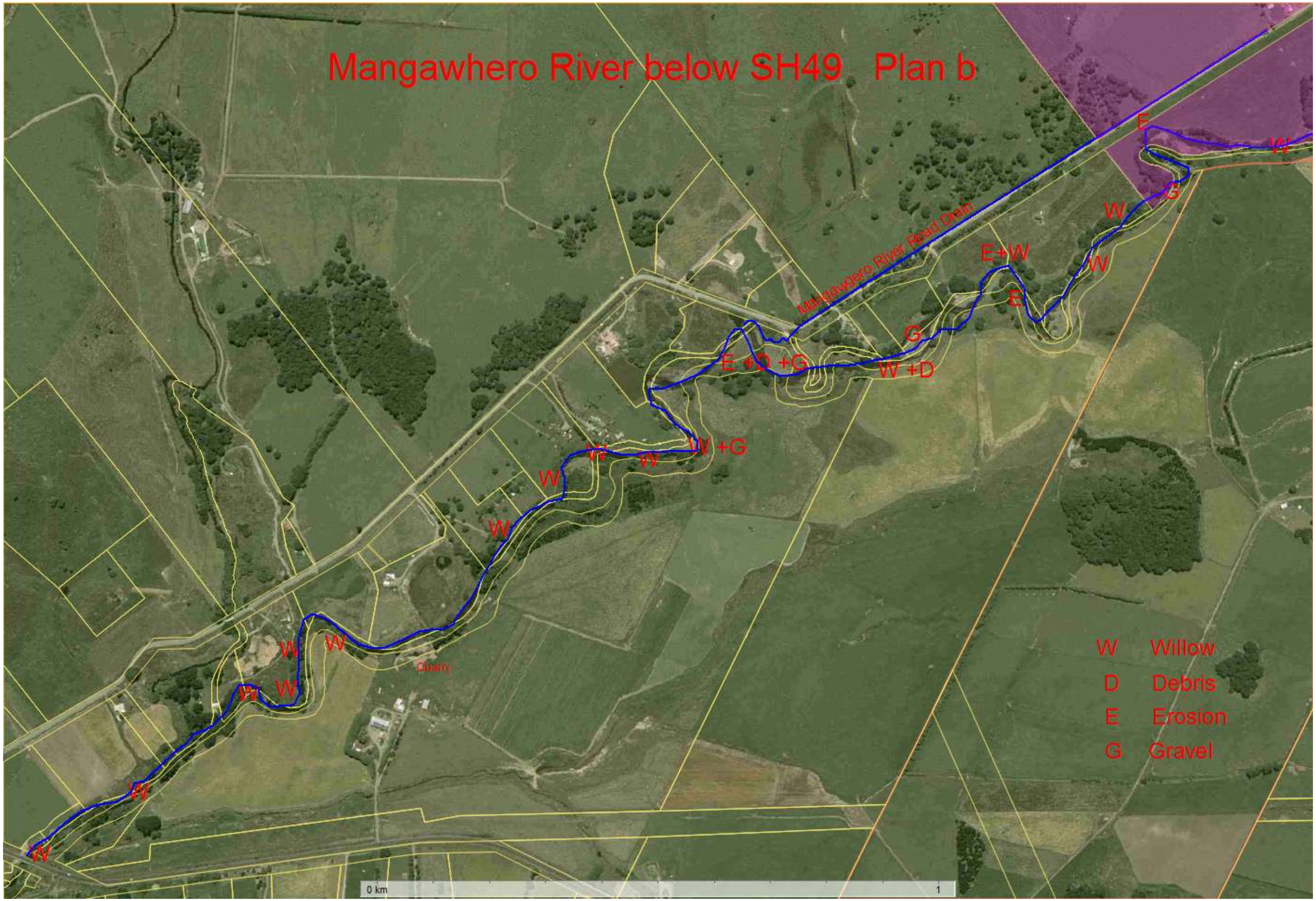
Mangawhero R. above SH49

	Unit A	Unit B
Footbridge at Shannon St to the end of Mangawhero Tce Rd	1.50	
Beach below f/b= 300m^3		
Rope fence to picnic tables	2.50	1.00
Picnic area to Channel A f/b	3.25	
Channel A f/b		
F/b to Beech tree in drain	1.25	1.00
Beech tree to confl. of channels	2.00	
Channel confluence to SH49		
Unit total	10.5	2.00
Unit A value	$2,713	
Unit B value		$1,509
Total Unit values	$28,486.50	$3,018.00

Mangawhero R. below SH 49

	Unit A	Unit B
SH49 bridge to 36 Burns St	0.50	
68 Burns St		0.375
98 Burns St		0.500
128 Burns St		0.125
146/150 Burns St		1.000
Mid channel beach 180m^3		
Public river access to bridge		2.125
Bridge over Burns St		
Frederickson's Property		1.375
2 x LB beaches. 90m^3 + 750m^3		
Fredrickson property to Raetihi Ohakune Road		13.25
Beach at 3464/4755 - 5000m^3		
Beach at 3160/4686 - 1000m^3		
Beach at 3027/4527 - 200m^3		
Unit total	0.50	18.750
Unit A value	$2,713	
Unit B value		$1,509
Total Unit values	$1,356.50	$28,293.75

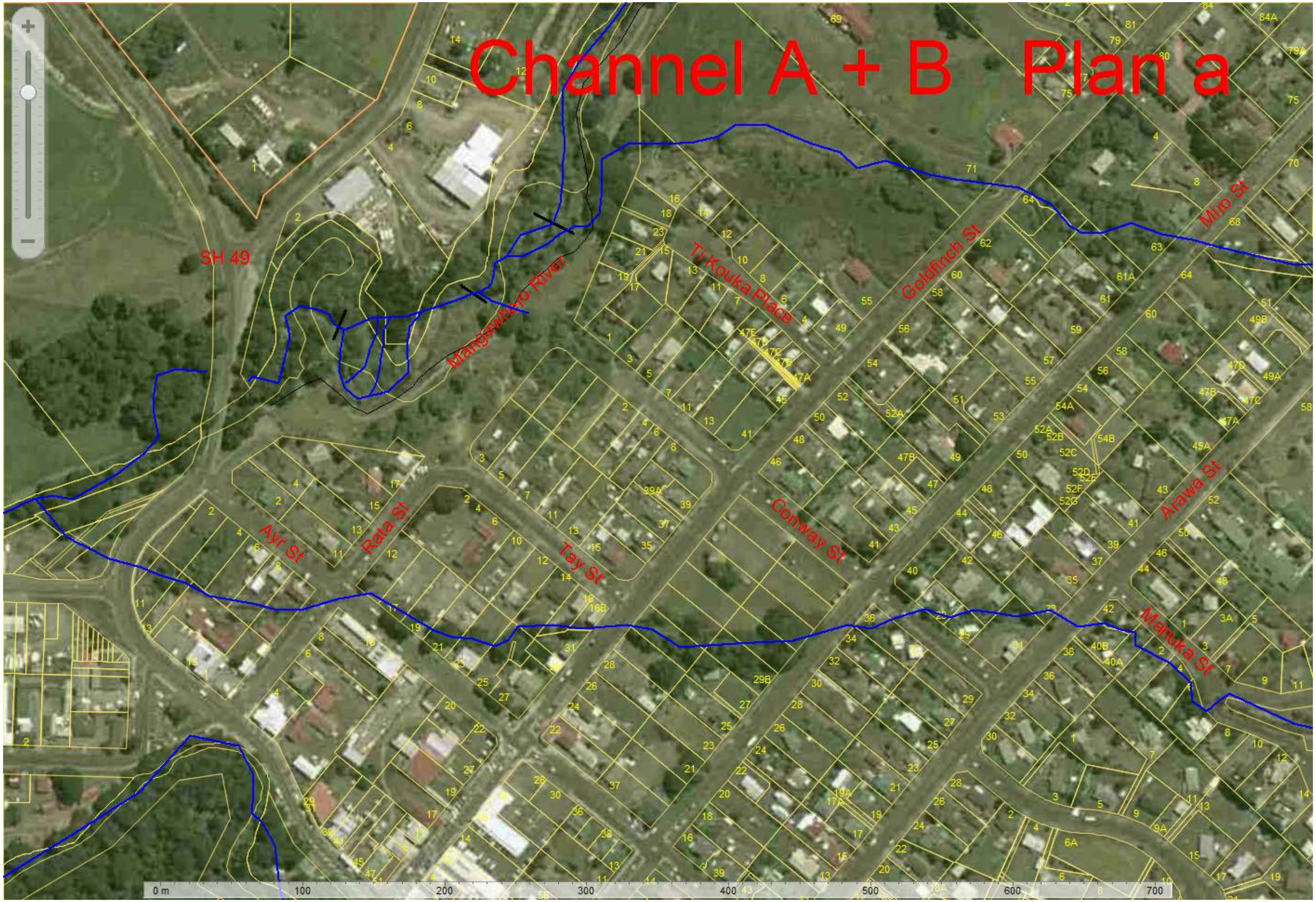

Mangawhero River below SH49   Plan a
Frederickson
W Willow
D Debris
E Erosion
G Gravel
0 km
1



Mangawhero River below SH49   Plan b
Mangawhero River Road Drain
E
W
G
W
E+W
W
E
G
E +D +G
W +D
W +G
W
W
W
W
W
W
W
Quarry
W
W
W
W
W   Willow
D   Debris
E   Erosion
G   Gravel
0 km
1

Mangawhero River- above SH49
Gravel
F/b
Mangawhero Tce
Shannon St
Mangawhero River
Miro St
64-66
SH 49
Ti Kouka Place
Goldfinch St
62/Crown
0 m
100
200
300
400
500
600
700


Miro St Drain
Mangawhero River
Mangawhero Tce
Lee St
Kowhai Heights
Wineberry Lane
Willow Lane
Miro St
Park Ave
Miro Place
0 m
100
200
300
400
500
600


Channel A + B Plan a
SH 49
Mangawhero River
Ti Kouka Place
Goldfinch St
Miro St
Ayr St
Rata St
Tay St
Conway St
Arawa St
Manuka St
0 m
100
200
300
400
500
600
700

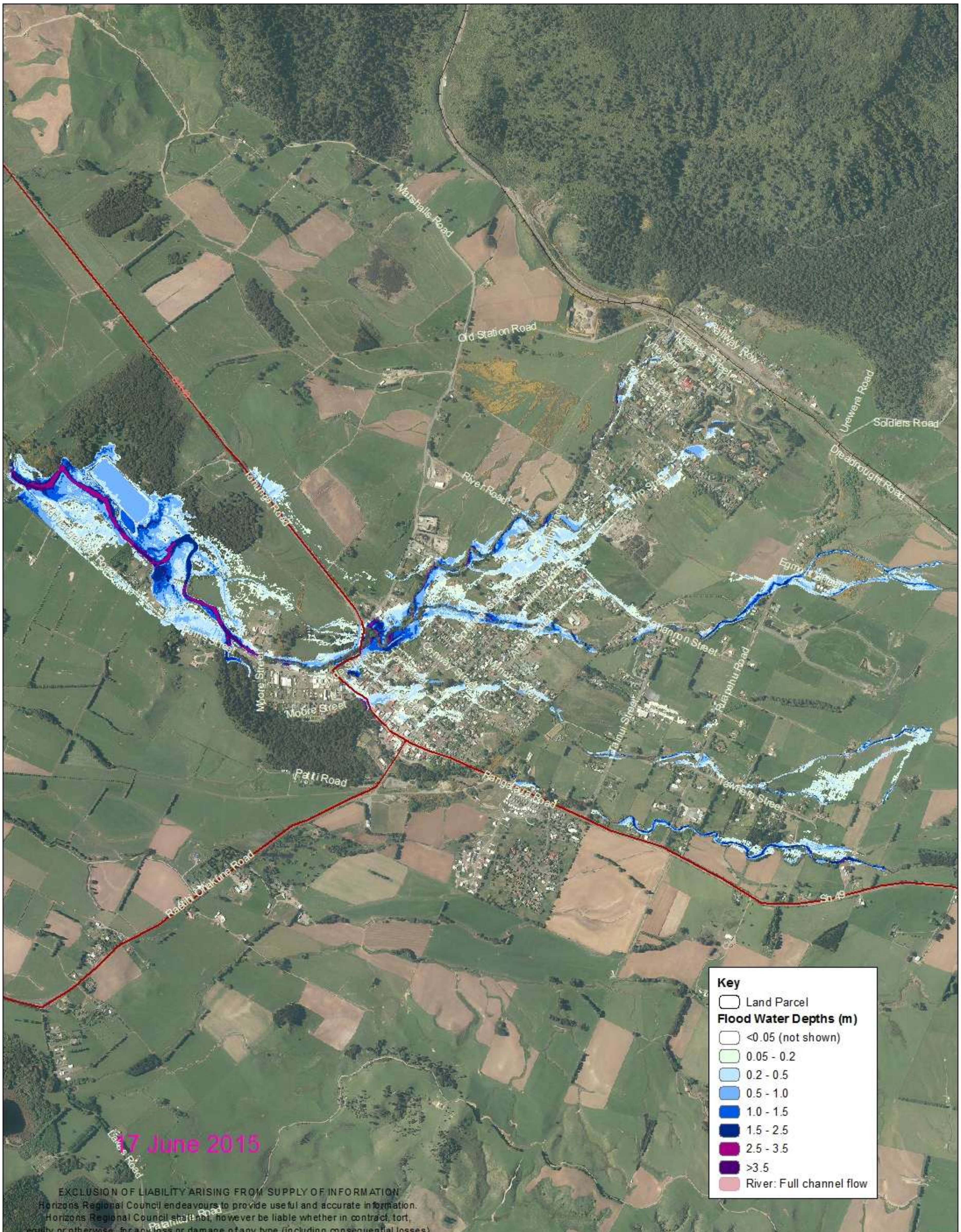
Channel A+B Plan b
Miro St
64-66
62/Crown
Mare Way
Shannon St
Channel A
Arawa St
Tainui St
Manuka St
Channel B
0 m
100
200
300
400
500
600
700


Channel A Plan c
Ruapehu Rd
Egmont St
Shannon St
151
175
126
124
122
120
118
116
114
112
110
108
106
104
102
100
15
17
19
21
23
12
14
16
18
20
22
84
57
59
101
80
65
76
95
75
74
50
83
91
0 m
100
200
300
400
500
600
700

APPENDIX C

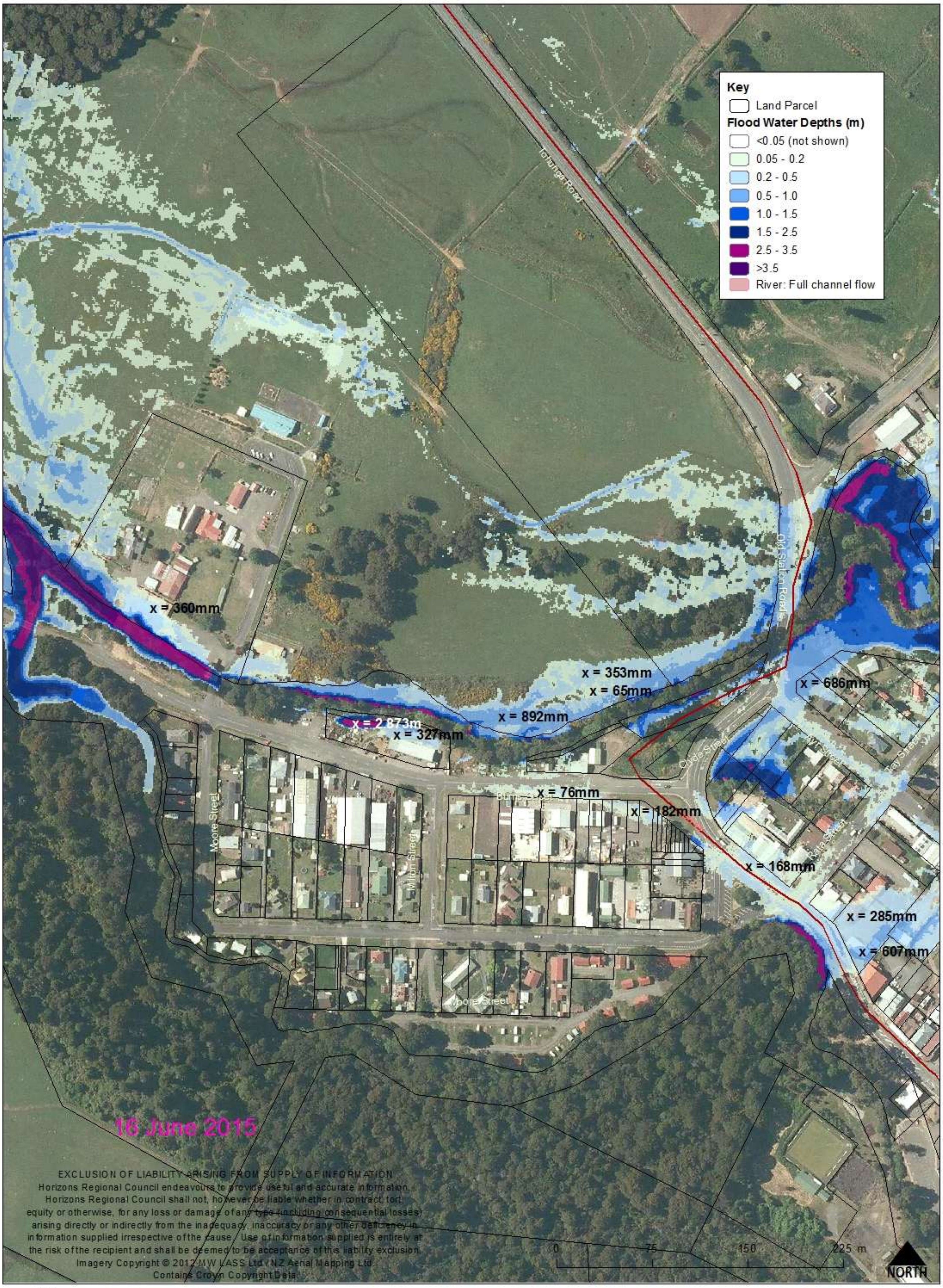
Residual Flood Risks Maps for Burns Street and Egmont Street


x = 131mm
x = 71mm
x = 89mm
Egmont Street
x = 238mm
x = 274mm
x = 164mm
x = 149mm
x = 200mm
x = 241mm
x = 253mm
x = 300mm
x = 146mm
x = 158mm
x = 276mm
x = 106mm
x = 257mm
x = 405mm
x = 401mm
x = 300mm
x = 428mm



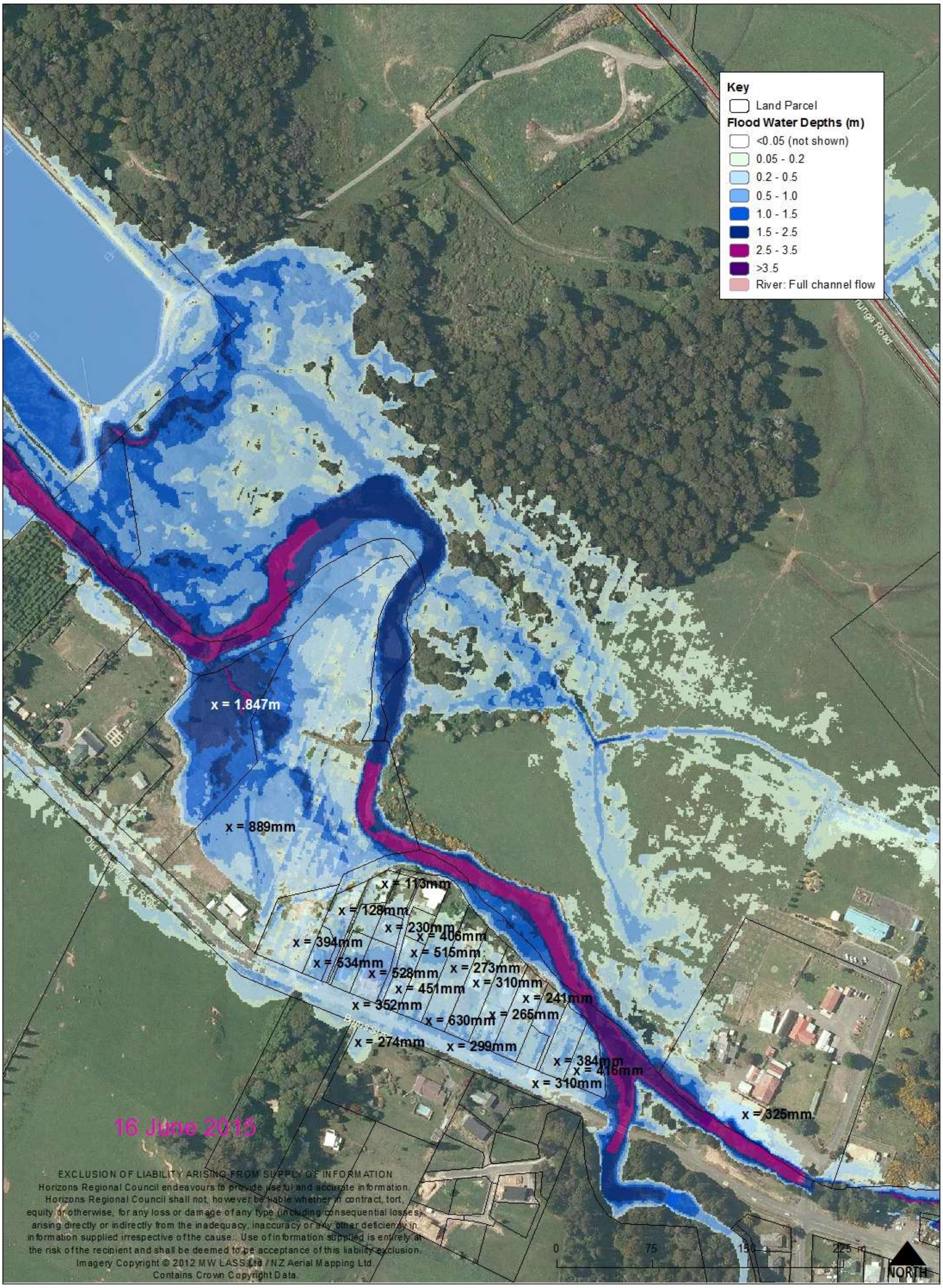
horizons regional council

Ohakune Township Flood Depths in a 0.5% AEP (1 in 200 year) Flood



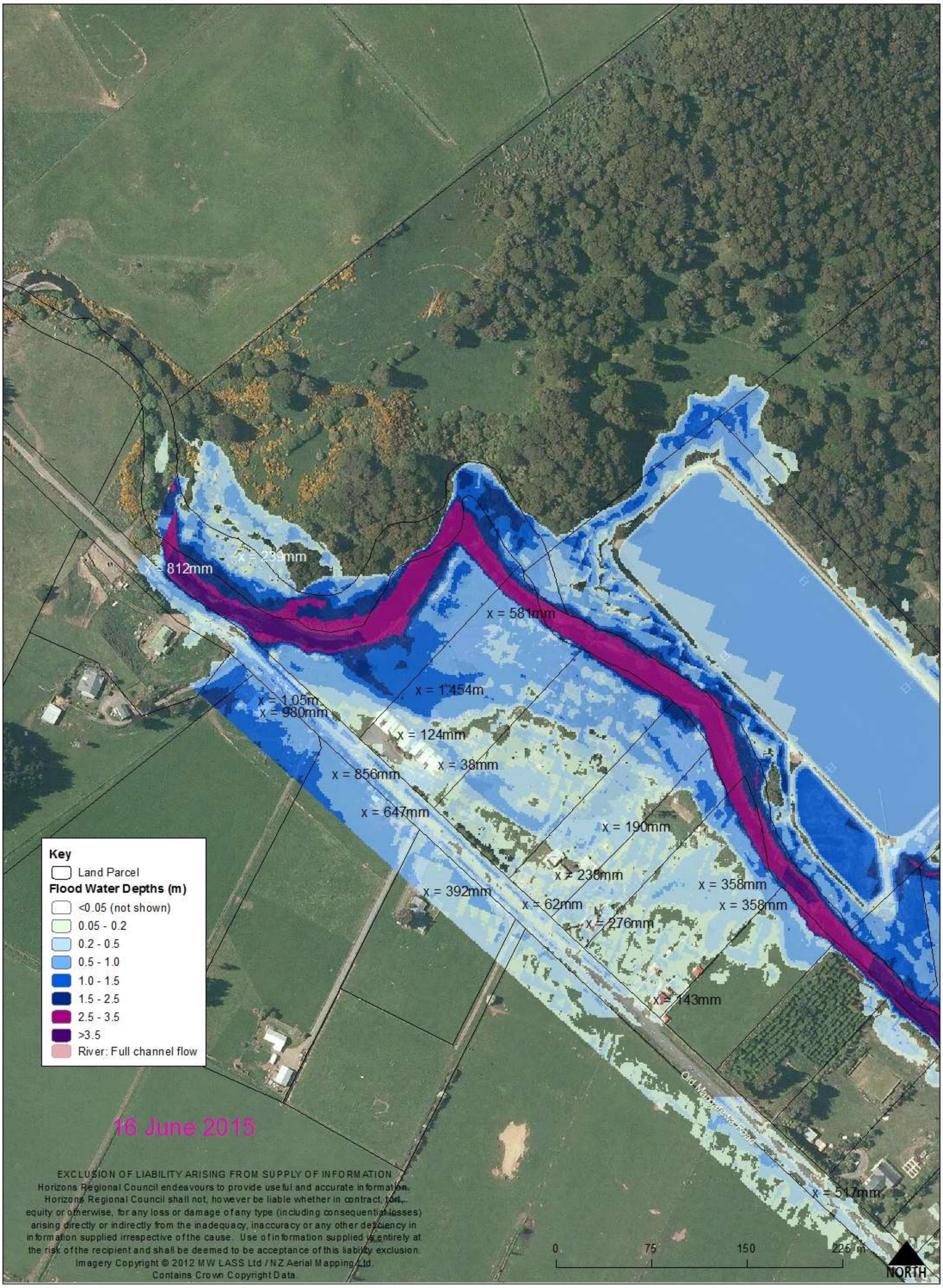
horizons regional council

Ohakune Township Flood Depths - 0.5% AEP Flood, Burns St & Clyde St intersection



horizons regional council

Ohakune Township Flood Depths - 0.5% AEP Flood, Lower Burns St



horizons regional council

Ohakune Township Flood Depths - 0.5% AEP Flood, Upper Burns St

APPENDIX D

Detailed Cost Estimates

Mangawhero Bend Stopbank Costing

Item No.	Item	Quantity	Unit	Rate	Cost
1	Earthworks	440	m^3	25	$ 11,000.00
2	Rock Protection	100	Tonnes	70	$ 7,000.00
	Subtotal				$ 18,000.00
	Contingencies 15%				$ 2,700.00
	Engineering 7.5%				$ 1,350.00
					$ -
	Total				**$ 22,050.00**

Conway St to Ti Kouka St Flood Protection Costing

Item No.	Item	Quantity	Unit	Rate	Cost
1	Mangawhero Stopbank - Left Bank	1900	m^3	30	$ 57,000.00
3	Wooden Flood Wall - East of Ti Kouka St	15	m	400	$ 6,000.00
4	Wooden Flood Wall - West of Ti Kouka St	177	m	500	$ 88,500.00
	Subtotal				$ 151,500.00
	Contingencies 15%				$ 22,725.00
	Engineering 7.5%				$ 11,362.50
					$ -
	Total				**$ 185,587.50**

Park Avenue Dam Stopbank Costing

Item No.	Item	Quantity	Unit	Rate	Cost
1	Earthworks	730	m^3	25	$ 18,250.00
2	Road Hump Sealed 7m Wide	1	LS	12000	$ 12,000.00
	Subtotal				$ 30,250.00
	Contingencies 15%				$ 4,537.50
	Engineering 7.5%				$ 2,268.75
					$ -
	Total				**$ 37,056.25**

Lower Miro Street Drain Stopbank Costing - Updated 14/7/15

Item No.	Item	Quantity	Unit	Rate	Cost
1	Stopbank - Left Bank	730	m^3	30	$ 21,900.00
2	Ramps at Bridge (Left bank)	1	LS	1500	$ 1,500.00
3	Wooden Flood Wall - Left Bank	104	m	400	$ 41,600.00
4	Wooden Flood Wall - Right Bank	179	m	550	$ 98,450.00
5	10m Concrete Flood Wall - Mangawhero Tce	0.8	m^3	2000	$ 1,600.00
	Subtotal				$ 165,050.00
	Contingencies 15%				$ 24,757.50
	Engineering 7.5%				$ 12,378.75
					$ -
	Total				**$ 202,186.25**

Catchment A Culvert Costings

Item No.	Item	Quantity	Unit	Rate	Cost	Cost Subtotal
1.1	Shannon Street S upplementary 2m x 2m Box, 14m long, Supply Onsite	9	Number	3970	$ 35,730.00	
1.2	Shannon St Headwalls & Wingwalls	1	LS	13200	$ 13,200.00	
1.3	Shannon Street Foundation Prep & Culvert Placement	14	m	2200	$ 30,800.00	
1.4	Shannon Street Excavate & Backfilling Embankment 3.3m above Invert	470	m^3	80	$ 37,600.00	$117,330.00
2.1	Arawa Road S upplementary 2m x 2m Box, 9.3m long, Supply Onsite	6	Number	3970	$ 23,820.00	
2.2	Arawa Road Headwalls & Wingwalls	1	LS	13200	$ 13,200.00	
2.3	Arawa Road Foundation Prep & Culvert Placement	9.3	m	2200	$ 20,460.00	
2.4	Arawa Road Excavate & Backfilling Embankment 2.65m above Invert	230	m^3	80	$ 18,400.00	$75,880.00
3.1	Miro St S upplementary 2m x 2m Box, 9.3m long, Supply Onsite	6	Number	3970	$ 23,820.00	
3.2	Miro St Headwalls & Wingwalls	1	LS	13200	$ 13,200.00	
3.3	Miro St Foundation Prep & Culvert Placement	9.3	m	2200	$ 20,460.00	
3.4	Miro St Excavate & Backfilling Embankment 2.7m above Invert	240	m^3	80	$ 19,200.00	$76,680.00
4.1	Goldfinch St S upplementary 2m x 2m Box, 11m long, Supply Onsite	7	Number	3970	$ 27,790.00	
4.2	Goldfinch St Headwalls & Wingwalls	1	LS	13200	$ 13,200.00	
4.3	Goldfinch St Foundation Prep & Culvert Placement	11.0	m	2200	$ 24,200.00	
4.4	Goldfinch St Excavate & Backfilling Embankment 3.15m above Invert	350	m^3	80	$ 28,000.00	$93,190.00
	Subtotal				$ 363,080.00	$ 363,080.00
	Contingencies 20% (Incl Tie Rod Connectors & Grout)				$ 72,616.00	$ 72,616.00
	Engineering 7.5%				$ 27,231.00	$ 27,231.00
					$ -	$ -
	Total				**$ 462,927.00**	**$ 462,927.00**

Arawa Street 40m Floodwall Costing

Item No.	Item	Quantity	Unit	Rate	Cost
1	40m Concrete Flood Wall - Up to 0.6m High	11.2	m^3	1600	$ 17,920.00
	Subtotal				$ 17,920.00
	Contingencies 15%				$ 2,688.00
	Engineering 7.5%				$ 1,344.00
					$ -
	Total				**$ 21,952.00**

Egmont Dam Costings

Item No.	Item	Quantity	Unit	Rate	Cost
1	Establishment	1	LS	15,000	$ 15,000.00
2	Earthworks	15,500	m^3	22.5	$ 348,750.00
3	Cutoff 20m*5m*0.8m	80	m^3	200	$ 16,000.00
4	Spillway Cut into RB (150m x 30m wide)				$ -
4.1	Volume Excavation (110*30*.65)	2200	m^3	15	$ 33,000.00
4.2	Supply & Place Enkamat Lining 30m wide	3300	m^2	19	$ 62,700.00
4.3	Rock Protection at Toe (30m x 5m x 1m)	150	m^3	140	$ 21,000.00
5	Base culvert 2m x 1.3m x 50m long	50			$ -
5.1	Supply & deliver culverts (1.55m long)	33	Number	6700	$ 221,100.00
5.2	Foundation Prep & Culvert Placement (exluding embankment)	50	m	2200	$ 110,000.00
	Subtotal				$ 827,550.00
	Contingencies 15%				$ 124,132.50
	Engineering 7.5%				$ 62,066.25
					$ -
	Total				**$ 1,013,748.75**

Catchment B Floodway Costing

Item No.	Item	Quantity	Unit	Rate	Cost
1	Earthworks	15000	m^3	12	$ 180,000.00
2	Rock Outfall at Mangateitei	140	Tonnes	70	$ 9,800.00
3	Throttle on Upstream Culvert	1	LS	5000	$ 5,000.00
4	Land	1	ha	80000	$ 48,000.00
5	Fencing	1	LS	12000	$ 12,000.00
	Subtotal				$ 254,800.00
	Contingencies 17.5% (incl bypass sewer)				$ 44,590.00
	Engineering 7.5%				$ 19,110.00
					$ -
	Total				**$ 318,500.00**

Catchment B Culvert Costings

Item No.	Item	Quantity	Unit	Rate	Cost	Cost Subtotal
1.1	Manuka St Supplementary (1) 1.5m x 1m Box, 12m long, Supply Onsite	8	Number	3340	$ 26,720.00	
1.2	Manuka St (1) Headwalls & Wingwalls	1	LS	13200	$ 13,200.00	
1.3	Manuka St (1) Foundation Prep & Culvert Placement	12	m	1500	$ 18,000.00	
1.4	Mauka St (1) Excavate & Backfilling Embankment 1.7m above Invert	160	m^3	100	$ 16,000.00	$73,920.00
2.1	Manuka St Supplementary (2) 1.5m x 1m Box, 4.65m long, Supply Onsite	3	Number	3340	$ 10,020.00	
2.2	Manuka St (2) Headwalls & Wingwalls	1	LS	13200	$ 13,200.00	
2.3	Manuka St (2) Foundation Prep & Culvert Placement	4.5	m	1500	$ 6,750.00	
2.4	Manuka St (2) Excavate & Backfilling Embankment 1.7m above Invert	60	m^3	100	$ 6,000.00	$35,970.00
3.1	Arawa Road Replacement 2m x 1m Box, 14m long, Supply Onsite	9	Number	3350	$ 30,150.00	
3.2	Arawa Rd Headwalls & Wingwalls	1	LS	13200	$ 13,200.00	
3.3	Arawa Rd Foundation Prep & Culvert Placement	14	m	2200	$ 30,800.00	
3.4	Arawa Rd Excavate & Backfilling Embankment 2.85m above Invert	380	m^3	80	$ 30,400.00	
3.5	Arawa Rd remove existing Armco 1.4m high x 1m wide	1	LS	5000	$ 5,000.00	$109,550.00
4.1	Conway St Replacement 2m x 1.5m Box, 14m long, Supply Onsite	9	Number	3680	$ 33,120.00	
4.2	Conway St Headwalls & Wingwalls	1	LS	13200	$ 13,200.00	
4.3	Conway St Lay Including Embankment 2.5m above Invert	14	m	2200	$ 30,800.00	
4.4	Conway St Excavate & Backfilling Embankment 2.5m above Invert	310	m^3	80	$ 24,800.00	
4.5	Conway St remove existing Box 1.4m wide x 1m wide	1	LS	5000	$ 5,000.00	$106,920.00
5.1	Miro St Replacement 2m x 1m Box, 15m long, Supply Onsite	10	Number	3350	$ 33,500.00	
5.2	Miro St Headwalls & Wingwalls	1	LS	13200	$ 13,200.00	
5.3	Miro St Foundation Prep & Culvert Placement	15	m	2200	$ 33,000.00	
5.4	Miro St Excavate & Backfilling Embankment 2.8m above Invert	400	m^3	80	$ 32,000.00	
5.5	Miro St remove existing Box 1.5m wide x 1.1m wide	1	LS	5000	$ 5,000.00	$116,700.00
6.1	Goldfinch St Replacement 2m x 1.5m Box, 14m long, Supply Onsite	9	Number	3680	$ 33,120.00	
6.2	Goldfinch St Headwalls & Wingwalls	1	LS	13200	$ 13,200.00	
6.3	Goldfinch St Foundation Prep & Culvert Placement	14	m	2200	$ 30,800.00	
6.4	Goldfinch St Excavate & Backfilling Embankment 2.35m above Invert	290	m^3	80	$ 23,200.00	

6.5	Goldfinch St remove existing Box 0.9m wide x 1.3m wide	1	LS	5000	$ 5,000.00	$105,320.00
7.1	21 Ayr St Replacement 1.8m circular, 4.88m long, Supply Onsite	4.88	m	1905	$ 9,296.40	
7.2	21 Ayr St Headwalls & Wingwalls	1	LS	13200	$ 13,200.00	
7.3	21 Ayr St Foundation Prep & Culvert Placement	4.88	m	1700	$ 8,296.00	
7.4	21 Ayr St Excavate & Backfilling Embankment 2.8m above Invert	130	m^3	80	$ 10,400.00	
7.5	21 Ayr St remove existing 1.2m circular	1	LS	3000	$ 3,000.00	$44,192.40
8.1	SH49 Supplementary 1.2m circular, 30m long, Supply Onsite	31.72	m	850	$ 26,962.00	
8.2	SH49 Headwalls & Wingwalls	1	LS	13200	$ 13,200.00	
8.3	SH49 Foundation Prep & Culvert Placement	30	m	2200	$ 66,000.00	
8.4	SH49 Excavate & Backfilling Embankment 3.3m above Invert	919	m^3	80	$ 73,520.00	$179,682.00
	Subtotal				$ 772,254.40	$ 772,254.40
	Contingencies 20% (Incl Tie Rod Connectors & Grout)				$ 154,450.88	$ 154,450.88
	Engineering 7.5%				$ 57,919.08	$ 57,919.08
					$ -	$ -
	Total				**$ 984,624.36**	**$ 984,624.36**

APPENDIX E

Site Visits Detailed Notes

MEMORANDUM

FILE: PRD 03 07

DATE: 28 April 2015

TO: File Note

FROM: Peter Blackwood

SUBJECT: **OHAKUNE FLOOD INVESTIGATIONS SITES VISIT 20/04/2015**

On 20 April 2015, John Philpott and Peter Blackwood carried out a detailed inspection of the various watercourses through the township of Ohakune (excluding the Mangateitei Stream). This Memorandum documents the site visit findings. Also documented are findings of further site visits on 27 May 2015 with Ruapehu District Council staff, Mr Steve Adams, Contracts Supervisor, Water Services and Anne-Marie Westcott, Environmental Manager, and 4 June 2015 with Jeremy Cumming, Horizons Regional Council Senior Engineering Officer.

1. Park Avenue Dam

Located immediately to the southeast of the Park Avenue Dam is a house (on Lot 1 DP 65744), with the floor level set around 350 mm below the dam crest. During major floods this dam is likely to overtop due the flood size and poor inlet. Floodwaters will also flow around a second house. – also noted in the John Philpott & Associates Ltd report on Ohakune Flood Control, dated August 2011. The inlet might require upgrading and it is likely that a lateral stopbank is required to exclude floodwaters from these houses. Furthermore a small 5.5m long judder bar is required at Par Avenue on the true left bank crossing the road embankment. This should be connected into the stopbank and a small guide bank downstream. The following photographs refer.

Photo 1: Berm area on left bank of Park Avenue Dam. Lowest-lying house obscured to right of photo. Second house that would be surrounded in major floods is in centre of photo. Small lateral stopbank could be landscaped into the berm area.

Photo 2: Poor inlet structure to Park Avenue Dam

Photos 3 & 4: Dam Crest at Park Avenue

2. Miro Street Drain

The inspection covered the length of the Miro Street Drain from Park Avenue to just short of Shannon Street and then the reach to Mangawhero Terrace (where currently considerable overflows can occur) and thence to the outlet at Mangawhero River.

The ponding area immediately upstream of the Miro Street crossing and adjacent to Southridge Drive was noted as being floodable (as in the Philpott 2011 report), with the water extending into property backyards. This is a smaller problem to resolve and will be looked at later in the investigation.

A reasonable amount of clearing has taken place in the upstream end of Miro Street as shown below.

Photos 6 & 7: Recent clearing of Miro Street Drain

However, there is still a reasonable amount of clearing required. The channel upstream of Wineberry Lane is also too narrow – far too small for the design flow of 2.6 cumecs. However, it is reasonably well confined and may not need too much enlargement. Refer to the following photos.

Photos 8 & 9: Congested or narrow portions of Miro Street Drain upstream of Wineberry Lane and 131 Miro Street respectively. Also a water pipe is in the waterway.

At 131 Miro Street there are three obstructions:

1. a large tree in the stream in the stream;
2. a low level bridge; and
3. a water pipe.

These will certainly retard flow and aggravate localised flooding.

Photo 10: Congested channel at 131 Miro Street, with restrictions due to narrow channel, large trees, low level footbridge and water pipe.

Photo 11: Another congested reach in Miro Street Drain.

Mr Mike Ryan of 20 Lee Street reports that in the 15 October 2013 flood, the Miro Street Drain flooded right to the edge of Lee Street but water did not cross it. 23B Lee Street on the upstream side was flooded or very close to flooding. 25 Lee Street is slightly higher in elevation and is likely above flood levels. Mr Ryan also noted that the drain has not been cleared of vegetation for around 4 years. It obviously now does need clearing.

Photos 12 & 13: Restriction to flow caused by small channel, vegetation and access structure downstream of 22 Lee Street. Photo on right is immediately downstream.

Photo 14: Very congested portion of Miro Street Drain at 115 Miro St, kink in the channel and 450mm diameter corrugated pipe. Photo 15: Channel dimensions at 131 Miro Street.

Photo 16: At 113 Miro Street the house floor level is roughly 500mm above the stream bank crest. Freeboard in a 0.5% AEP flood would be small. The culvert crest is around 200mm only below the driveway level.

Photo 17: Possible higher ground return for left bank stopbank at 107 Miro Street

Photos 18 & 19: Obstructions to flow outside 105 Miro Street - Retaining wall for plant, footbridge and 1.5m high green waste pile.

Photo 20: Obstructions to flow and proposed wooden flood wall location adjacent to fence on left bank. Flood wall continues through gap behind green waste to connect into grassed stopbank – in distance.

Photos 21 & 22: Proposed flood wall location. Stopbank is visible photo 22.

Photos 23 & 24: Miro Street Drain Stopbank looking towards Mangawhero Terrace. Note unconsented bridge access to 1A Martin Place.

Photo 25: Low level foot bridge at 6 Martin Place immediately upstream of proposed stopbank and floodwall.

Photo 26: Low-lying house at 2 Martin Place adjacent to Miro Street Drain. A wooden floodwall will have to be constructed through here.

At the downstream and south-western area (true left bank) adjoining the Miro Street Drain there is considerable flooding. There is some on the north-eastern (true right bank) also.

Most of this will be mitigated by construction of wooden floodwalls and minor upgrade of the existing stopbank. However, it seems likely that some back flow from the Mangawhero River is also flowing up the Miro Street Drain via the Mangawhero Terrace Bridge. This then adds to overflows. This will require careful examination of the computer hydraulic modelling.

4. Mangawhero River

The inspection covered the length of the floodable area from Shannon Street to State Highway 49. Also inspected was the Ohakune Wastewater Treatment Plant to confirm flood protection requirements. These are being separately addressed by John Philpott.

Photo 27: Mangawhero Terrace at the downstream end. There is a stopbank location slightly to left of trees, then connecting around the turning circle into higher ground. Upstream end connects into existing bank on Mangawhero River bend and possibly Goldfinch Street

Photo 28: Immediately downstream of Mangawhero Terrace turning circle. The 0.5% AEP flood map indicates there is no stopbank required here. However, there is an overflow path around 60 metres downstream. This may be cut off by the Miro Street Drain stopbank works.

Mangawhero Terrace: Refer photograph 27 showing location of a stopbank to prevent flooding of houses in Mangawhero Terrace. This may not be necessary along the full length of this street. Much of the flooding of the Mangawhero Terrace-Goldfinch Street area is from outflows of the Miro Stream at the motels, though not all the flooding (the modelling shows this). However, there is definitely also a significant amount of super-elevation at the sharp right-hand bend near the Mangawhero Terrace-Goldfinch Street intersection, refer photographs 29 and 30 below (taken later on 25 May 2015).

Photos 29 & 30: Sharp bend on Mangawhero River near Mangawhero Terrace & Goldfinch St intersection.

Factory at 4 Old Station Road: Updated flood maps show this just flooding in 0.5% AEP flood. In the previous version, before flows were corrected, it just missed flooding. However, the Mangawhero has now also avulsed with two channels possible and now the flood levels may be lowered. This will require resurveyed of Cross-Section 3 immediately adjacent to the factory (completed). Flood protection to the factory appears unnecessary in any case (now confirmed).

The 0.5% AEP flood levels under the various scenarios are:

Applying 16/2/10 Cross-Section	580.30 m (matches the Entura Modelling)
Applying the 22/4/15 Cross-Section	580.16 m (0.14 m drop now)
Applying the 22/4/15 Cross-Section LB Cleared	580.05 m (0.25 m drop)
Factory Ground Levels	580.30 - 580.40 m
Factory Floor Levels	580.70 - 580.78 m

Thus, whilst there is flooding around the factory, the floor is around 0.4 m above the 0.5% AEP flood level as under the 16/2/10 survey and is now slightly above 0.5 m above flood levels and with a cleared channel would be 0.65 m above flood levels. Therefore, the flood risk to the factory in the 0.5% AEP flood can be discounted.

Tay Street to Ti Kouka Place: Outflows from the Mangawhero to houses between Tay Street and Ti Kouka Place can be excluded by a stopbank starting near Tay Street and extending to the higher ground on the left bank of the downstream end of Catchment A.

5. Catchment A (Korokoio Stream)

The various box culverts on this stream were examined and dimensions and available headwater depths confirmed. There are various dimensions in the Philpott August 2011 Design Report, HydroTasmania (now Entura) Design Report and those measured by Blackwood/Philpott on 20 April 2015. Generally, I have applied the HydroTasmania dimensions, unless the Blackwood/Philpott figures are obviously more accurate.

Goldfinch Street Culvert (John Philpott # 047)

2.6 m wide x 2.48 m high, Available Hw 3.15 m. 11 m long. There is also a restriction caused by a 200 mm watermain atop a 300 mm support beam some 2 m upstream, with the crest of the watermain some 100 mm below the culvert soffit. This reduces the flow capacity by an estimated 10% to 21.7 cumecs with upstream control governing. No need to head up, as no houses nearby. Refer photo 31 (below).

Miro Street Culvert (# 046)

Arch culvert 2.4 m wide x 2.4 m high. Available Hw 2.7 m. 9 m long.
Capacity by orifice equation 18.6 cumecs. Upstream control governs with 18.6 cumecs the capacity.

Arawa Road Culvert (# 045)

2.4 m wide x 2.4 m high. Available Hw 2.65 m, could increase if needed. 8 m long.
Capacity by orifice equation 18.7 cumecs. Upstream control governs with 18.7 cumecs the capacity. However, of considerable importance is that on 15 October 2013 outflows occurred on the true right around 30 m upstream of Arawa Street and flooded three A-Frame houses. This overflow path must be blocked off by an approximately 1 m high floodwall.

Shannon Street Culvert (# 043 & 044)

Upstream Arch culvert 2.0 m wide x 2.6 m high. Available Hw 3.3 m.
Downstream 2.5 m diameter Armco. Available Hw 3.3 m.
Total length 13 m.
Can carry around 18 cumecs before spilling across Shannon Street.

On 15 October 2013 flood the stream overflowed on the left bank and across the top of the culvert, flowing turbulently (surging) almost to the knees (400 mm deep) of Mr Steve Adams. A car became stuck in the flow, estimated at 20 cumecs. Refer following photos 32 to 34.

Photo 32: Looking downstream from Shannon Street culvert Channel A.

Photos 33 & 34: Shannon Street Culvert crossing showing location of stalled car in 400mm of surging water (Steve Adams standing there) during 15 October 2013 flood.

Ruapehu Street Culvert (# 040)

2.4 m wide x 2.5 m high. Available Hw 2.65 m could increase to 3.25 m. 8 m long. Keep capacity limited by Hw 2.65 m, as want to detain at this stage. Capacity by orifice equation 19.2 cumecs. Upstream control governs with 19.2 cumecs the capacity. Occupant of 22 Egmont Street advised this culvert just overtopped both ends of the crossing (road above culvert is minorly perched) in October 2013 – this concurs well with estimated 20 cumecs at Shannon Street.

Egmont Street Bridge (# 041)

5.0 m wide x 2.0 m high bridge.

6. Catchment B

The various box culverts on this stream were again examined and dimensions and available headwater depths confirmed. Again there are various dimensions in the Philpott August 2011 Design Report, HydroTasmania (now Entura) Design Report and those measured by Blackwood/Philpott on 20 April 2015. Generally, I have applied the HydroTasmania dimensions, unless the Blackwood/Philpott figures are obviously more accurate. I have noted that the HydroTasmania report has erroneously assessed some pipe arch culverts as rectangular culverts – however the minor error involved is not relevant to my investigation.

Manuka Street Channel Capacity

A cross-section recorded at 4 Manuka Street is regarded as typical of the channel capacity of Catchment B. The height from stream invert to adjacent house floor levels is close to 2.0 m. General overbank flow total width is 4 m. At 1.5 m (0.5 m freeboard) the channel capacity is 4.1 cumecs (Mannings N 0.045, slope 0.013).

Manuka Street Culverts (# 069)

To Arch culverts both 1.4 m wide x 0.9 m high, 12m long. Available Hw 1.7 m.
Capacity by orifice equation 3.1 cumecs. Upstream control governs with 3.1 cumecs the capacity.

On 15 October 2013 flood the stream overflowed the top of the culvert, flowing turbulently (some 2004 mm deep (Mr Steve Adams, pers comm). This equates to a flow of 3.34 cumecs.

Arawa Street Culvert (# 070)

Arch culvert 1.4 m wide x 1.0 m high, 14 m long (not 3 m as per JP spreadsheet). Available Hw 2.85 m.

Capacity by orifice equation 4.64 cumecs, but will be less as that would be downstream controlled. Effective capacity at least 3.1 cumecs.

Note that number 40 Arawa Street also flooded in the 15 October 2013 flood. It has since been raised so the floor level is 0.3m above road level. The floor level at 38 Arawa Street is 0.5 m above the road level.

At Arawa Street the Catchment B Drain requires an improved left bank entry top the sharp right hand bend.

Conway Street Culvert (# 071)

Box culvert 1.4 m wide x 1.1 m high, 14 m long. Available Hw 2.5 m.
Capacity by orifice equation 5.8 cumecs. Upstream control governs with 5.8 cumecs the capacity.

However, there is a note by John Philpott that if it heads up above road level would flood an upstream house. Site inspections suggest overflows would flood a low-lying house immediately downstream of the culvert at 24 Conway Street and an A-Frame house upstream at 25 Conway Street.

Miro Street Culvert (# 072)

Box culvert 1.5 m wide x 1.2 m high, 15 m long. Available Hw 2.5 m.
Capacity by orifice equation 6.7 cumecs. Upstream control governs with 6.7 cumecs the capacity.

Mr John King of 34 Miro Street reported that in the 15 October 2013 flood (estimated at around 30 year ARI) his steps flooded to 0.5 m below his floor level. This was from overflows upstream at Conway Street.

The culvert outlet is prone to blockage due to the left hand bend and vegetation and inlet entry is also poor, due to a sharp bend.

John Philpott notes that a floodwall could be built along the left bank to retain floodwaters in the channel.

Goldfinch Street Culvert (# 073)

Pipe arch concrete culvert 0.9 m wide x 1.3 m high, 13 m long. Available Hw 2.35 m.

Capacity by orifice equation 4.0 cumecs. Upstream control governs with 4.0 cumecs the capacity.

21 Ayr Street Culvert (# 074)

Circular culvert crossing 1.2 m in diameter, 3 m long. Available Hw approx. 2.8 m.

Capacity by orifice equation 4.5 cumecs. Upstream control governs with 4.5 cumecs the capacity.

Ayr Street to Rata Street combined culvert crossing (# 075-76)

Circular culvert crossing 1.8m in diameter, 53m long. Available Hw approx. 2.5m.

Capacity by orifice equation 8.7 cumecs. Upstream control governs with 8.7 cumecs the capacity.

SH49 Culvert (# 077-78)

Circular culvert crossing 1.1 m in diameter, 30 m long. Available Hw unknown, but Philpott report advises significant heading up available, our site estimate is 3.3 m.

Capacity by orifice equation 4.2 cumecs. Upstream control governs with 4.2 cumecs the capacity.

Conclusions on Culvert Capacities Catchment B:

1. Capacity all culverts at least 3.1 cumecs (one is exactly that and one slightly more). Therefore agree with John Philpott original assessment that 2 cumecs (of 5.1 cumecs Q200) did require diversion.
2. However Q200 is now 7.6 cumecs, so 4.5 cumecs require diversion.
3. Three of the culverts pass 4 cumecs or slightly more and three significantly greater. Possibly design flows could be increased to 4.0 cumecs, but would require channel improvements – as demonstrated by 30 year flood 15 October 2013 (approx. 4.6 cumecs) that flooded properties (but not houses).
4. In any case the diversion option has already been shown to likely to be cheaper.

7. Miro Street Drain (Cont.)

The headwater depths to Miro Street drain were remeasured by Jeremy Cumming and Peter Blackwood on 4 June 2015 and individual culverts and bridges assessed as follows. The potential stopbanking at the Park Avenue Dam was also reviewed and discussed with My Peter Spittle the owner of the floodable house. This house has been flooded in the past.

Photo 35: Park Avenue Dam and floodable house

Miro St Culvert Crossing (#022)

Circular culvert crossing 1.2 m in diameter, 16 m long. Available Hw approx. 2.7 m.

Capacity 4.4 cumecs (MWD Culvert Chart 4.5.3).

Willow Lane Culvert (#024)

Circular culvert crossing 1.2 m in diameter, 18 m long. Available Hw approx. 2.7 m.

Capacity 4.4 cumecs (MWD Culvert Chart 4.5.3).

Opposite Wineberry Lane Culvert (#026)

Circular culvert crossing 1.2 m in diameter, 6 m long. Available Hw approx. 2.4 m.

Capacity 4.0 cumecs (MWD Culvert Chart 4.5.3).

Kowhai Heights Culvert (#027)

Circular culvert crossing 1.1 m in diameter, 18 m long. Available Hw approx. 2.6 m.

Capacity 3.7 cumecs (orifice equation). Jeremy reported there had been a landowner complaint of dumping downstream of this culvert and it was also evident that the channel needed widening downstream (where it had been constrained).

139 Miro St Channel Capacity

Nominal channel dimensions are 1.7 m wide x 1.0 m high. Assuming slope 1.2% (might be slightly higher), Mannings n 0.050 (average top slightly poor channel) capacity 2.2 cumecs. Above this flow the stream will flood surrounds and in most places will not immediately flood Miro St – but the possibility of this remains.

139 Miro St Bridge

Bridge 1.7 m wide x 1.9 m high. Capacity immediatwly below soffit is 4.9 cumecs.

131 Miro St Bridge (#028)

Bridge 1.7 m wide x 1.0 m high (excluding tree). Capacity immediately below soffit 2.2 cumecs. However, at the bridge the large tree reduces the available channel width to 0.4 m and the capacity drops to 0.64 cumecs.

Mrs Lesley Thompson, very long-time occupant since 1960s, advised October 2013 flood was at bridge level – however it does seem that the flows would have been larger than 0.64 cumecs (though the Park Avenue Dam may have retarded flows markedly in this below design event, but refer to comments at 111 Miro Street below). Mrs Thompson was quite amenable to the tree removal.

There is a a slight rise to the road, so 2.5 cumecs is readily achievable.

Lee Street Culvert (#029)

Circular culvert crossing 1.2 m in diameter, 12 m long. Available Hw approx. 1.8 m.

Capacity 3.2 cumecs (MWD Culvert Chart 4.5.3). Jeremy observed a 160 mm diameter services pipe (sewer?) near the culvert soffit. There are numerous of these crossings. Stream is badly congested through this reach and requires upgrading regardless of the benefit provided by Park Avenue Dam in attenuating flows.

121 Miro Street Culvert (#030)

Circular culvert crossing 1.2 m in diameter, 4 m long. Available Hw approx. 1.8 m.

Capacity 3.2 cumecs (MWD Culvert Chart 4.5.3). Very congested reach.

119 Miro St Bridge (#031)

Bridge 2 m wide x 1.0 m high. Sewer crossings (approx. 100 mm diameter) immediately above (at riverbed level) and below (near soffit) reduce capacity an estimated 10%. Capacity immediately below soffit is 2.5 cumecs. 0.55 m freeboard to Miro Street. Generally, this seems like the usable design capacity.

113 Miro St Culvert

Circular culvert crossing 1.2 m in diameter, Short maybe 4 m long. Available Hw approx. 1.5 m.

Capacity 2.7 cumecs (MWD Culvert Chart 4.5.3).

Summary to Park Avenue Dam to 113 Miro Street

1. Generally capacity of 2.5 cumecs with some berm flooding – agrees with hydraulic model flows.
2. Requires some significant channel clearance to achieve this in congested areas.

Note: Entry to Miro Street Drain of 500 mm diameter Toetoe Lane culvert. This could add say 0.6 cumecs (at 3m/s design velocity, to be subsequently checked by Ruapehu District Council), making the design flow 3.1 cumecs. This new subdivision might need detention of additionally generated flows.

111 Miro Street Bridge (Mr Ron McCullough)

Bridge cross-section 2.7 m wide at soffit, 0.65 m to water level at 1.2 m wide, depth 0.3 m. Capacity 2.0 cumecs. However, at the running board crest level there is still 600 mm freeboard to the house floor. Allowing 100 mm for efflux the capacity at 500 mm freeboard is 3.0 cumecs. Therefore, there is likely adequate freeboard, but the flows from Toetoe Street require assessment.

The landowner, Mr Ron McCullough, advised that flows were close to the bridge soffit in October 2013, suggesting a flow of close to 2.0 cumecs.

8. Catchment B Drain (Cont.)

Photos 36 and 37 following show channel congestion and clearing west of Miro Street.

9. Mangawhero River Downstream Highway

This area was inspected, with Jeremy to estimate vegetation clearance costs and gravel volumes on the various beaches. Refer following photos.

Photo 38: Showing cleared pine plantation, gravel beach (photo rear) and riverbank erosion.

Photo 39: Showing beech tree collapsed into and blocking Mangawhero River