NZ TRANSPORT AGENCY
WAKA KOTAHI

Peka Peka to North Ōtaki Expressway
Assessment of Hydraulic Effects for Major Watercourse Crossings

Quality Assurance Statement

Project Manager: Ulvi Salayev (NZTA)

Prepared by: H W Smith and M G Webby

Reviewed by: M Devgun

Approved for issue by: T Coulman

Revision Schedule

Rev. No	Date	Description	Prepared by	Reviewed by	Approved by
1	11/2012	Assessment of effects for Waitohu and Mangaone Streams and floodplains updated following completion of their respective detailed investigation reports.	M G Webby	M Devgun	T Coulman
2	1/2013	External peer review, EPA completeness check and GWRC review comments addressed	M G Webby	A Nicholls	T Coulman

NZ Transport Agency

Contents

List of Abbreviations

AEE	Assessment of Environmental Effects
AEP	Annual Exceedance Probability
CC	Climate change
DS	Downstream
GWRC	Greater Wellington Regional Council
KCDC	Kāpiti Coast District Council
LiDAR	Light Detection and Ranging[1]
MfE	Ministry for the Environment
MSL	Mean Sea Level
NIMT	North Island Main Trunk (railway)
NZTA	New Zealand Transport Agency
NZVD	New Zealand Vertical Datum
PP2O	Peka Peka to North Ōtaki
RMA	Resource Management Act
RoNS	Roads of National Significance
SAR	Scheme Assessment Report
SH1	State Highway 1
TRB	True right bank (as viewed looking downstream in direction of river or stream flow)
US	Upstream

[1] This is an airborne laser remote sensing technology used for the measurement of detailed and accurate topographic survey data.

1. Executive Summary

1.1 Introduction

This report provides an overview of an assessment of flood hazard (hydraulic) effects for major watercourses crossed by the proposed Peka Peka to North Ōtaki Expressway ("Expressway"). The major watercourses covered by this report (from north to south) are:

- the Waitohu Stream and floodplain;
- the Mangapouri Stream;
- the Ōtaki River;
- the Ōtaki River floodplain; and
- the Mangaone Stream and floodplain.

1.2 Principle of Hydraulic Neutrality

An elevated transport link (such as the proposed Expressway) constructed across the floodplain or alluvial fan associated with a watercourse interferes with the natural drainage functions of these topographic features. Adequate provision must therefore be made for relief measures within an elevated link to allow the safe passage of floodwaters through it or over it.

A fundamental principle which has been applied consistently with respect to the treatment of individual watercourse crossings on the Expressway is that of hydraulic neutrality[2]. What this means is that the impact of flood hazards from the Expressway should in general be no worse than in the current situation. This objective can sometimes be extremely difficult to achieve while still maintaining the required level of service for the Expressway. Where it has not been possible to achieve this desired objective, a fall-back position has been adopted whereby flood hazards that have been made worse are kept away from residential properties and instead redirected towards uninhabited rural areas.[3]

In the context of the proposed Expressway, the principle of hydraulic neutrality has generally been achieved by preserving existing drainage paths across floodplains and alluvial fans with inclusion of appropriately sized culverts with adequate flow capacity. Bridges have also been designed with sufficiently long spans so as not to constrict the main watercourse that they cross and with adequate freeboard above the design flood level.

1.3 Conclusions for Waitohu Stream and Floodplain Crossing

The proposed bridge crossing of the Waitohu Stream is located near the beginning of a zone of geomorphic instability (Williams, 2004) caused by a change in streambed slope. The 75m bridge span provides ample

[2] Hydraulic neutrality can relate to either compensating for loss of flood storage due to development or managing the difference between pre-development and post-development, particularly due to interruption of overland flow paths.
[3] In discussions with GWRC and KCDC, their preferred position is that complete hydraulic neutrality should be achieved if possible.

fairway width for future potential lateral migration of the active stream channel and sediment deposition induced by this geomorphologic instability. The active stream channel is monitored by GWRC in response to natural river processes including channel migration and sediment aggradation with gravel mining within strict volume limits licensed on an on-demand basis.

The effects of the Expressway with the 75m long bridge crossing of the Waitohu Stream and floodplain and the large culverts incorporated in the bridge approach embankments are minimal and acceptable:

- the extent of flood inundation upstream and downstream is very similar to that for the existing situation;
- flood levels across the flood plain and in the main stream channel immediately upstream of the Expressway are increased relative to those in the existing situation but the increased levels extend no more than 100m upstream due to the steepness of the floodplain slope;
- the duration of flood inundation across the floodplain is not exacerbated; and
- flow velocities across the floodplain are not made any worse with the large culverts in the bridge approach embankments providing continuity for existing overland flow paths.

SH1 is presently overtopped at the location of the Greenwood sub-catchment culvert by floods smaller than a 5% AEP flood adjusted for the effects of possible future climate change. There is minimal flood storage volume upstream of the culvert system so that there is negligible attenuation of peak flows past the culverts.

Because the vertical alignment of the Expressway is required to transition into the existing vertical alignment of SH1 immediately to the north of the Greenwood sub-catchment culvert, the recommended 4m wide by 1.5m high box culvert under the Expressway only just eliminates the occurrence of road overtopping for the 5% AEP flood adjusted for the effects of possible future climate change and satisfies the design freeboard standard. It does not make downstream flood inundation any worse than it would be in the existing situation. The 1% AEP flood adjusted for the effects of possible future climate change in the Greenwood sub-catchment would overtop the Expressway over about a 70m width at a very shallow depth to the north of the Greenwood sub-catchment culvert.

The recommended size for the Greenwood sub-catchment culvert would enable the flood risk at this location to be reduced in the future by requiring only the road level to be raised.

1.4 Conclusions for Mangapouri Stream Crossing

With the proposed mitigation measures outlined in Section 6.1 in place, the effects of the Expressway crossing of the Mangapouri Stream would be as follows:

- Flood levels in the primary storage basin on the Mangapouri Stream would be marginally lower (0.04m) than those in the existing situation for all except the 0.5% AEP and 0.2% AEP floods adjusted for possible climate change effects to 2090. In the case of the former flood, the increased flood level would be only marginally higher (0.02m). In the case of the latter flood, the increase in flood level relative to the existing situation would be up to 0.12m. However, it is important to note that in an extremely rare flood of this magnitude (0.2% AEP) and even lesser floods, there would be widespread flood inundation through Ōtaki

Township due to flood breakout from natural stream channels and surface runoff exceeding the capacity of the piped stormwater drainage system.

- The flood levels in the primary flood storage basin currently affect a number of houses within the area of the basin either by exceeding floor levels or being within 0.5m of floor levels. In terms of the former criterion, the number of affected houses with the Expressway would be slightly lower than in the existing situation for the smaller floods considered (six in the case of the 1% AEP flood adjusted for possible future climate changes effects in the proposed situation compared to eight in the existing situation). However the number of affected houses would be the same (eight) for the 0.5% AEP flood and increased by one (ten) for the 0.2% AEP flood (both floods also adjusted for possible future climate change effects).
- Where the predicted flood level for the 0.5% AEP flood adjusted for possible future climate change effects exceeds house floor levels in the primary flood storage basin with the Expressway, the 0.02m increase in floor level inundation would be very small in a relative sense for six of the affected properties as the predicted inundation depths in the existing situation are already large (0.27-0.94m). For the other affected houses, the relative increases in floor level inundation with the Expressway would be much larger as the predicted inundation depths in the existing situation are very low (less than 0.05m) although the actual increases would remain low in the proposed situation (less than 0.07m). We would expect the resulting flood damage costs to be similar in the case of each affected house between the existing and proposed situations[4].
- Where the predicted flood level for the 0.2% AEP flood adjusted for possible future climate change effects exceeds house floor levels in the primary flood storage basin with the Expressway, the 0.12m increase in floor level inundation would be modest in a relative sense for six of the affected properties as the predicted inundation depths in the existing situation are already large (0.31-0.98m). For the other affected houses, the relative increases in floor level inundation with the Expressway would be more significant as the predicted inundation depths in the existing situation are low. The inundation depths would increase from less than 0.00-0.09m in the existing situation to 0.06-0.21m in the proposed situation. We would expect the resulting flood damage costs to be similar for the six houses where the relative increases in floor level inundation are modest and slightly greater for the other houses where the relative increases in floor level inundation are more significant.
- Flood levels within the Pare-o-Matangi Reserve storage basin area (upstream of the SH1 culvert) would be 0.03-0.07m higher for some of the intermediate sized floods considered (2% AEP flood up to the 1% AEP floods adjusted for possible climate change effects to 2090). However this would only impact on the same number of buildings as at present (excluding those houses which need to be acquired for the Expressway). The existing flood inundation risk for these floods will be mitigated by landscaping the Pare-o-Matangi Reserve to form a low bund around the perimeter of the affected properties on the corner of the existing SH1 and Rahui Road. Flood levels within the Pare-o-Matangi Reserve storage basin area would be only 0.01-0.02m higher for the 5% AEP flood and the two largest floods considered (0.5% and 0.2% AEP floods adjusted for possible climate change effects to 2090).

In summary then, the effects of the Expressway crossing of the Mangapouri Stream and its ancillary features are minimal and acceptable. In very rare floods such as the 0.5% AEP and 0.2% AEP floods adjusted for

[4] Flood damage costs for inundated buildings are typically expressed in terms of different floor level inundation depth bands, e.g. -0.1 to 0m, 0 to 0.05m, 0.05 to 0.5m and 0.5 to 2.0m.

possible change effects to 2090 where the effects would be slightly greater than in the existing situation (but with the same number of properties affected), there would be widespread flood inundation elsewhere through Ōtaki Township.[5]

1.5 Conclusions for Ōtaki River Crossing

The long span of the twin parallel bridges forming the Expressway crossing of the Ōtaki River means that flood flows in the river would not be constricted and that there would be no backwater effect extending upstream as occurs presently with the existing SH1 bridge. The wide spacing of the piers on each of the two bridges (the piers on both bridges would be aligned) and minimal number of piers would result in very low pier head losses so that flood levels in the main river channel would be only marginally higher than in the existing situation for the same flood magnitude. Due to the hydraulic steepness of the river, these marginally higher flood levels would only extend a very short distance upstream.

The backfilling process for the off-channel storage basin occupied by the Stresscrete concrete factory would be unaffected by the northern approach embankment to the twin bridges crossing the Ōtaki River. However the effect of the approach embankment bisecting the off-channel storage basin would be to cause peak flood levels within the basin to be 0.4m higher on the downstream side of the embankment (but very similar in magnitude to the peak level in the existing situation) and lower on the upstream side in a 0.2% AEP flood. The reverse would be true in a larger 0.2% AEP flood adjusted for possible future climate change effects to 2090 with higher peak flood levels on the upstream side of the approach embankment and lower on the downstream side. In the latter flood, the upstream flood levels in the basin would be about 0.3m higher than in the existing situation meaning that the depth of stopbank overtopping would be 0.3m greater in the Expressway situation over a distance of about 200m upstream of the bridge approach embankment for the Expressway.

In summary, the effects of the proposed PP2O Expressway crossing of the Ōtaki River on flood levels in the Ōtaki River and within the off-channel storage basin occupied by the concrete factory will be minimal and acceptable.

---

[5] It is acknowledged that the approach used here for assessing the hydraulic (flood hazard) effects of the Expressway on houses in the primary flood storage basin on the Mangapouri Stream, whether these effects are acceptable and whether mitigation is required, differs slightly from the approach used in other locations and in the companion report assessing the stormwater effects of the Project (Coles and Bird, 2013).

Because the primary flood storage basin on the Mangapouri Stream is a dedicated flood storage facility designed to relieve flood risks downstream through Ōtaki Township, it has been treated as a special case. A wider range of floods other than the 1% AEP flood adjusted for possible future climate change effects has been considered. Since the flood effects are predicted to be slightly reduced in the case of the 1% AEP flood adjusted for possible future climate change effects and slightly worse in the case of the rarer 0.5% and 0.2% AEP floods also adjusted for possible future climate change effects (flood level increases of 0.02m and 0.12m respectively) with widespread flooding elsewhere through Ōtaki Township, the effects of the Project are considered to be minimal and acceptable and that, therefore, no additional mitigation is required.

For the "Assessment of Stormwater Effects" report (Coles and Bird, 2013), the standard flood test applied throughout the Project area has been the 1% AEP flood adjusted for possible future climate change effects. In the case of the affected farm shed within the Gear / Settlement Heights flood ponding area (see Figures 22 and 23 in Coles and Bird (2013)), the increase in flood level due to the Expressway is 0.3m. Due to the higher probability of occurrence of the 1% AEP flood adjusted for possible future climate change effects compared to the 0.5% and 0.2% AEP floods and the significantly greater increase in depth of flood inundation for this affected farm shed, exploring mitigation with the affected landowner in this particular case is recommended.

1.6 Conclusions for Ōtaki River Floodplain Crossing

On balance the effects of the Expressway on stopbank overtopping flows flowing over the Ōtaki River floodplain will be minimal and with, the mitigation measures outlined in Section 6.3 implemented, acceptable. In particular the impact on populated areas will generally be no worse than in the existing situation as any differences in peak flood depths and flow velocities are within the accuracy of the computational hydraulic model predictions. The effects of the Expressway will only be greater in uninhabited areas used for pastoral purposes. The effects will also be temporary and extremely rare due to the very low annual exceedance probability of Ōtaki River floods which would overtop the existing protective stopbank system.

1.7 Conclusions for Mangaone Stream and Floodplain Crossing

Whereas flood ponding occurs upstream of the slightly elevated NIMT railway line in the existing situation, flood ponding will be transferred to upstream of the Expressway and the local link road in the proposed situation. However, this flood ponding will only be likely to occur on average once every five to ten years and will also be temporary, lasting no more than a few hours. It will also not impact of people or property significantly as the inundated land is used for pastoral purposes and is not inhabited.

Overland flow paths along the northern edge of the alluvial fan and along School Road which result in overtopping of SH1 in significant flood events will be eliminated. The downstream extensions of these flow paths to the west of SH1 beyond the intersection of Te Waka Road with SH1 (northern breakout flow path) and through the south end of Te Horo Village will also be eliminated.

The culvert systems on the main stream channel and on the Mangaone Overflow in the proposed situation will cause a slight redistribution of the peak flow volumes between the main stream channel and the Mangaone Overflow in the case of the design 1% AEP flood adjusted for possible climate change effects to 2090. However the total peak flow volume between the two primary watercourses will be slightly reduced.

Downstream (to the west) of SH1, much of To Horo Village and beyond will be inundated by the design 1% AEP flood adjusted for possible climate change effects to 2090. However the predicted peak flood depth and flow velocity differences between the existing and proposed situations across much the inundated area are within the level of accuracy of the MIKEFLOOD model. In other words no effective change in peak flood depths and velocities is predicted over most of the inundated area west of SH1.

Peak flood depths and flow velocities over a nominal 100m wide strip to the south of Te Horo Beach Road and west of SH1 (which passes through a mixed residential and retail part of Te Horo Village) will be slightly reduced in the proposed situation compared to the corresponding values in the existing situation (see Figures 6-21 and 6-23).

The footprint of the western approach embankment to the local link road overbridges will block out part of the effective width of the Lucinsky Overflow in the proposed situation. As a result the peak flood discharge along the Lucinsky Overflow is predicted to be reduced from $3.5m^3/s$ in the existing situation to $0.7m^3/s$ in the proposed situation. However this conclusion could be affected by possible vegetation induced errors[6] in the LiDAR sourced topographic data used to form the digital terrain model defining the floodplain geometry for the MIKEFLOOD computational hydraulic model. If necessary hydraulic neutrality in the proposed situation can be restored by lowering a section of the low stopbank along the right bank of the main stream channel to form a dedicated connection with the dry culvert through the approach embankment to the local link road overbridge.

In summary then, with the proposed mitigation measures outlined in Section 7.5 in place, the effects of the Expressway crossing of the Mangaone Stream and alluvial fan would be minimal and acceptable.

[6] These possible vegetation induced errors are only a very localised issue. The height accuracy of the LiDAR sourced topographic data in areas of open land cover only was checked against a set of surveyed ground points. The standard deviation between the LiDAR derived levels and the ground surveyed levels was ± 0.04m.

2. Introduction

2.1 Purpose of Report

This report provides an overview of an assessment of flood hazard (hydraulic) effects for major watercourses crossed by the proposed Peka Peka to North Ōtaki Expressway ("Expressway"). The major watercourses covered by this report include:

- the Waitohu Stream and floodplain;
- the Mangapouri Stream;
- the Ōtaki River;
- the Ōtaki River floodplain; and
- the Mangaone Stream and floodplain.

The location of these watercourses in relation to the Expressway is illustrated in Figure 2-1.

Figure 2-1 Location of Major Watercourses in relation to the Peka Peka to North Ōtaki Expressway

This overview report is complemented by a series of detailed investigation reports as follows:

- "Peka Peka to North Ōtaki Expressway, Detailed Investigations for Expressway Crossing of Mangapouri Stream" (Smith and Webby, 2013a)
- "Peka Peka to North Ōtaki Expressway, Hydraulic Investigations for Expressway Crossing of Ōtaki River and Floodplain" (Smith and Webby, 2013b)
- "Peka Peka to North Ōtaki Expressway, Hydraulic Investigations for Expressway Crossing of Waitohu Stream and Floodplain" (Smith and Webby, 2013c)
- "Peka Peka to North Ōtaki Expressway, Hydraulic Investigations for Expressway Crossing of Mangaone Stream and Floodplain" (Smith and Webby, 2013d)

The assessment of flood hazard (hydraulic) effects of other minor watercourses crossed by the Expressway is covered by another companion report:

- "Peka Peka to North Ōtaki Expressway, Assessment of Stormwater Effects" (Coles and Bird, 2012).

The companion report includes a comprehensive summary of also culverts and bridges along the Expressway which incorporates the results of the assessment of flood hazard (hydraulic) effects for the major watercourse crossings presented in this overview report.

2.2 Topographic Data

Topographic data for the general area of these investigations was obtained from LiDAR data provided by KCDC. The LiDAR data was collected in July and August 2010 over a 255km^2 area of the Kāpiti Coast. The height accuracy of the data in areas of open land cover only was checked against a set of surveyed ground points. The standard deviation between the LiDAR derived levels and the ground surveyed levels was ± 0.04m.

2.3 Level Datum

Since flood levels in a river or stream near the outlet to the sea are affected by sea levels, Greater Wellington Regional Council (GWRC) consistently uses the Mean Sea Level Wellington (1953) level datum for their flood hazard investigations and flood protection works design. The investigations described in this report have made use of stream cross-section and culvert level information sourced from GWRC which is expressed in terms of this mean sea level datum. To ensure consistency with GWRC publications and information, these investigations have used the same level datum to evaluate flood levels along all watercourses for both the existing situation and for the Expressway situation.

Existing ground levels from LiDAR data and construction levels for the Expressway on the other hand are expressed in terms of the NZ Vertical Datum (2009). It has therefore been necessary to translate between the two level data when specifying design flood levels and road design levels at key stream / river crossing locations.

Throughout this report, flood levels are generally expressed in terms of Mean Sea Level (MSL) Wellington (1953) datum. To adjust these levels to be in terms of NZ Vertical Datum (2009), 0.44m needs to be subtracted. Conversely to adjust levels in NZ Vertical Datum (2009) to be in terms of MSL Wellington Datum, 0.44m needs to be added.

2.4 Flood Magnitudes and Climate Change Effects

In this report, flood magnitudes are identified by reference to their annual exceedance probability (AEP). This is a statistical measure of how large a flood is and is generally based on a flood frequency analysis of the annual flood maxima series for a continuous measured flow record from a hydrological gauging station (such as on the Ōtaki River, the Waitohu Stream and the Mangaone Stream). For example a 1% (1 in 100) AEP flood is one that would be exceeded on average once every 100 years over a very long period of time (much longer than 100 years).

For bridges and culvert structures on routes of major importance such as the proposed Expressway, the 1% AEP flood (adjusted for the effects of possible climate change over the projected lifetime of the structures) is specified as the Serviceability Limit State Flood by the NZ Transport Agency's *Bridge Manual* (Transit NZ, 2003). The *Bridge Manual* requires bridges and culvert structures to remain serviceable during the passage of a flood of this magnitude.

GWRC have recommended that consideration be given to evaluating the effects of an over-design flood such as one 1.5 times the magnitude of the 1% AEP flood adjusted for possible future climate change effects. While this may be appropriate for very small catchments, it is not necessarily appropriate for large catchments.

For the Ōtaki River, extrapolation of the flood frequency data from McKerchar (2009) in Table 2-1 (which has considerable uncertainty) indicates that a flood 1.5 times the magnitude of the 1% AEP flood adjusted for possible future climate change effects could have an annual exceedance probability in the order of 0.02% (1 in 5,000). This exceeds the Ultimate Limit State design flood standard required for bridges on routes of major importance by the *Bridge Manual* (Transit NZ, 2003) which they are only required to survive without catastrophic failure (the bridge approaches may well be washed but the structure itself is required to survive). A flood of such magnitude is also well in excess of the current design standard for the Chrystall's Bend stopbank providing flood protection to Ōtaki Township. It would almost certainly result in breaching of the stopbank as a consequence of overtopping.

For the smaller Mangaone and Mangapouri Catchments, a flood 1.5 times the magnitude of the 1% AEP flood adjusted for possible future climate change effects could have an annual exceedance probability in the order of 0.04% (1 in 2,500). In the context of the Expressway crossings of the floodplains associated with the streams draining these catchments, a flood of such magnitude would be likely to cause broad scale flood inundation across the whole of each floodplain. A number of the assumptions inherent in the computational hydraulic models developed to predict the extent of flood inundation would also be invalid for a flood of such size.

Based on an analysis of the measured stream flow record for the Waitohu Stream, a flood 1.5 times the magnitude of the 1% AEP flood adjusted for possible future climate change effects for the Waitohu Catchment could have an annual exceedance probability in the order of 0.05% (1 in 2,000). However, for consistency with previous flood hazard investigations by GWRC, the flood estimates used for the assessment of flood hazard effects for the Expressway crossing of the Waitohu Stream and floodplain were instead based on the predictions of a rainfall / runoff model which are even more conservative than those derived from a frequency analysis of the annual flood maxima series extracted from the measured stream flow record. To use an over-design flood of 1.5 times the magnitude of the 1% AEP flood adjusted for possible future climate change effects based on this approach would be extremely conservative. As with the Mangaone and Mangapouri Stream floodplains, a flood of such magnitude would almost certainly result in broad scale inundation across the floodplain and render a number of the assumptions inherent in the computational hydraulic model developed to predict the extent of flood inundation invalid.

For these reasons we have considered over-design floods of lesser magnitude for the major watercourses covered by this flood hazard effects assessment. The selected over-design floods in each case have been related to a statistical probability of occurrence.

The floods of interest with respect to the Ōtaki River were the 1%, 0.5% and 0.2% AEP floods while those of interest to the Waitohu Stream and the Mangaone Stream were the 1% and 0.5% AEP floods. Because of the uniqueness of the situation in the Mangapouri Stream, a much wider range of flood magnitudes was considered from the mean annual flood (with a 1 in 2.33 or 42.9% AEP) up the 0.2% AEP flood.

The flood estimates for the 1%, 0.5% and 0.2% AEP floods for each of the watercourses considered were adjusted for the effects of possible future climate change to 2090 based on a mid-range estimate for increased average temperature and hence rainfall for the Wellington and Manawatu regions from the MfE (2010) Guidelines. The timeframe for consideration of climate change effects reflects the projected design life of the required bridge and culvert structures over the watercourses.

2.5 Summary Details of Computational Hydraulic Models

The assessment of flood hazard (hydraulic) effects for the major watercourses used a computational hydraulic modelling approach. Table 2-1 summarises key details regarding the computational hydraulic model used for each watercourse.

Further details of the calibration checks undertaken for each model are given in the detailed investigation reports listed in Section 2.1.

Table 2-1 Summary details of computational hydraulic models used for assessments of flood hazard effects

Watercourse	Type of Model	Origin	Details of Calibration / Verification	Basis for Hydrological Inputs	Potential for Blockages
Waitohu Stream and Floodplain	MIKEFLOOD (coupled 1d/2d)	Existing GWRC MIKE11 1d model extended and adapted to be a MIKEFLOOD model	Calibration checked against flood level data from February 2004 flood Model predictions for 1% AEP flood + CC checked against original model predictions	Flood hydrograph predictions of Harkness's (2003) rainfall / runoff model	Partial blockage of Greenwood sub-catchment culvert Debris raft on bridge
Mangapouri Stream	MIKE11 (1d storage routing model)	New model specifically developed for this investigation	Qualitative calibration against single anecdotal flood level from 28 October 1998 flood event	Scaled using regional hydrological characteristics	Partial blockage of County Road or old NIMT railway culverts
Ōtaki River and Floodplain	MIKEFLOOD (coupled 1d/2d)	Updated GWRC model – 2d MIKE21 component correctly geo-referenced to NZ Transverse Mercator projection	Not independently calibrated Original MIKE11 model calibrated against March 1990 flood (5% AEP) Model verified with 2006 cross-section data against single inferred level upstream of rail bridge from January 2005 flood	Based on GWRC (2007)report	Debris raft on bridge
Mangaone Stream and Floodplain	MIKEFLOOD (coupled 1d/2d)	MIKE11 / MIKE21 parts of model u/s of SH1 new MIKE11 part of model d/s of SH1 truncated version of MWH (2002b) model MIKE21 model d/d of SH1 new	Pattern of flood inundation predicted by model for 28 October 1998 flood checked against aerial photos of apparent flood extent	Scaled by catchment area from u/s Ratanui gauging station and adjusted for floodplain attenuation effects	Partial blockage of local link road culverts and School Road drain culvert

3. General Description of Expressway Project

3.1 Peka Peka to North Ōtaki Expressway

The Wellington Northern Corridor RoNS runs from Wellington Airport to Levin. The Peka Peka to North Ōtaki Expressway Project (Project) is one of eight sections of the Wellington Northern Corridor RoNS. The location of the Expressway within the Kāpiti Expressway Corridor is illustrated in Figure 3-1 below.

The New Zealand Transport Agency (NZTA) proposes to designate land and obtain the resource consents to construct, operate and maintain the Expressway. The Project extends from Te Kowhai Road in the south to Taylors Road just north of Ōtaki, an approximate distance of 13km.

The Expressway will provide for two lanes of traffic in each direction. Connections to local roads, new local roads and access points over the Expressway to maintain safe connectivity between the western and eastern sides of the Expressway are also proposed as part of the Project. There is an additional crossing of the Ōtaki River (comprised of two parallel two-lane bridges) proposed as part of the Project, along with crossings of other watercourses throughout the Project length.

On completion, it is proposed that the Expressway becomes State Highway 1 (SH1) and that the existing State Highway 1 between Peka Peka and North Ōtaki becomes a local road, allowing for the separation of local and expressway traffic.

Figure 3-1 Location of Peka Peka to North Ōtaki Expressway within the Wellington Northern Corridor RoNS

3.2 Realignment of North Island Main Trunk Railway Line

KiwiRail proposes to designate land in the Kāpiti Coast District Plan for the construction, operation and maintenance of a realigned section of the North Island Main Trunk (NIMT) Railway through Ōtaki. This realignment of this section of the railway line is required to facilitate construction of the Expressway.

4. Existing Environment from Flood Hazard Perspective

4.1 Waitohu Stream and Floodplain

The Waitohu Stream lies to the north of Ōtaki Township and the Ōtaki River. The Waitohu Stream and its tributaries drain a 53km^2 catchment on the steeply sloping western side of the Tararua Ranges. After the stream flows out of the foothills, it meanders across the coastal plain for a distance of about 7 km before exiting into the sea north of Ōtaki Beach Village. The average channel slope of 13.3% makes the stream extremely steep hydraulically.

Figure 4-1 shows a topographic relief map of the Waitohu Stream and floodplain area in the vicinity of the Expressway crossing. The map highlights the natural drainage paths across the floodplain surface beyond the foothills. The route of the Expressway has been overlaid on the map in Figure 4-1.

The slope of the Waitohu Stream reduces significantly at about the location of the existing SH1 bridge causing this location and downstream to be a zone of lateral channel instability and sediment aggradation. For river management purposes, GWRC have established a 75m fairway width for the stream downstream of the SH1 Bridge to allow for possible further changes in channel alignment occurring in response to channel migration and sediment deposition during extreme flood events. GWRC also monitor streambed aggradation due to sediment deposition over time and allow gravel extraction to occur on an on-demand basis within strict limits on the volume of gravel material able to be mined.

The Expressway crosses the Waitohu Stream about 260m downstream of the existing SH1 bridge within the zone of lateral channel instability and sediment aggradation. The Expressway bridge has been detailed with a minimum span length of 75m to accommodate this zone and GWRC's design alignment for the stream. The piers of the Expressway bridge will be located outside of the existing main flow channel of the stream so as not to interfere with normal flows in the stream. This means the bridge will require three spans of about 25m each.

One other significant issue for the Expressway crossing of the Waitohu Stream is the very extensive area of flood inundation that occurs on the north side of the stream crossing and to a lesser degree on the south side. This is illustrated in Figure 4-2a for the flood resulting from a 2 hour duration 1% annual exceedance probability (AEP) rainfall event over the catchment. The flood inundation on the north side of the stream crossing is due to a combination of surface runoff sourced from the adjacent Greenwood sub-catchment and flood breakout along the right bank of the main channel upstream of the existing SH1 bridge while the flood inundation on the south side of the stream occurs as a result of flood breakout along the left bank of the main stream channel upstream of the existing SH1 bridge. The breakout of floodwaters along both banks upstream of the existing SH1 bridge is caused by a number of contributing factors:

- the restricted waterway area of the existing SH1 bridge;
- the location of the bridge immediately downstream of a sharp bend; and
- the very low bank heights on either side of the active stream channel upstream of the bridge.

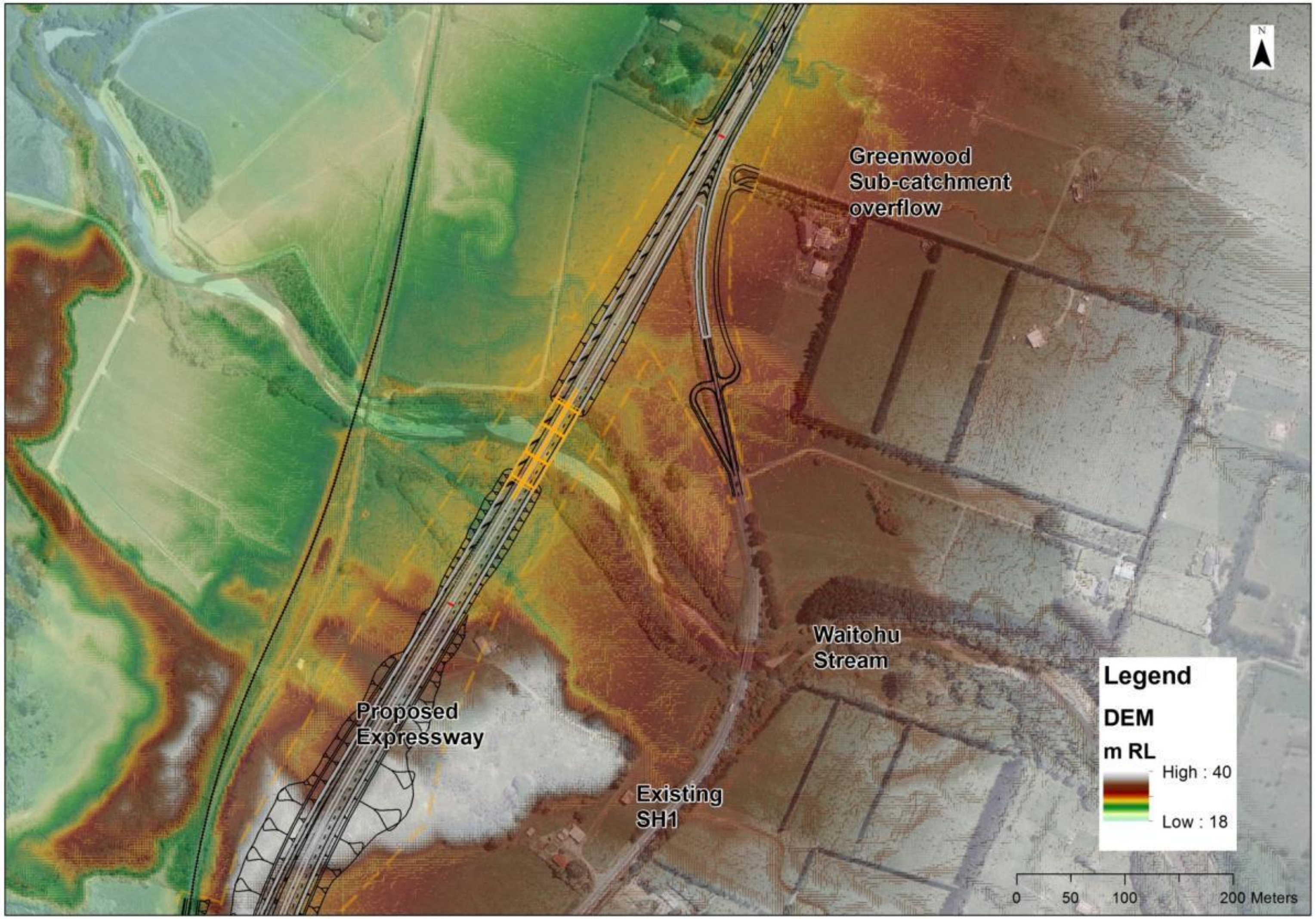

Figure 4-1 Topographic relief map of Waitohu Stream and floodplain area with route of proposed Expressway superimposed

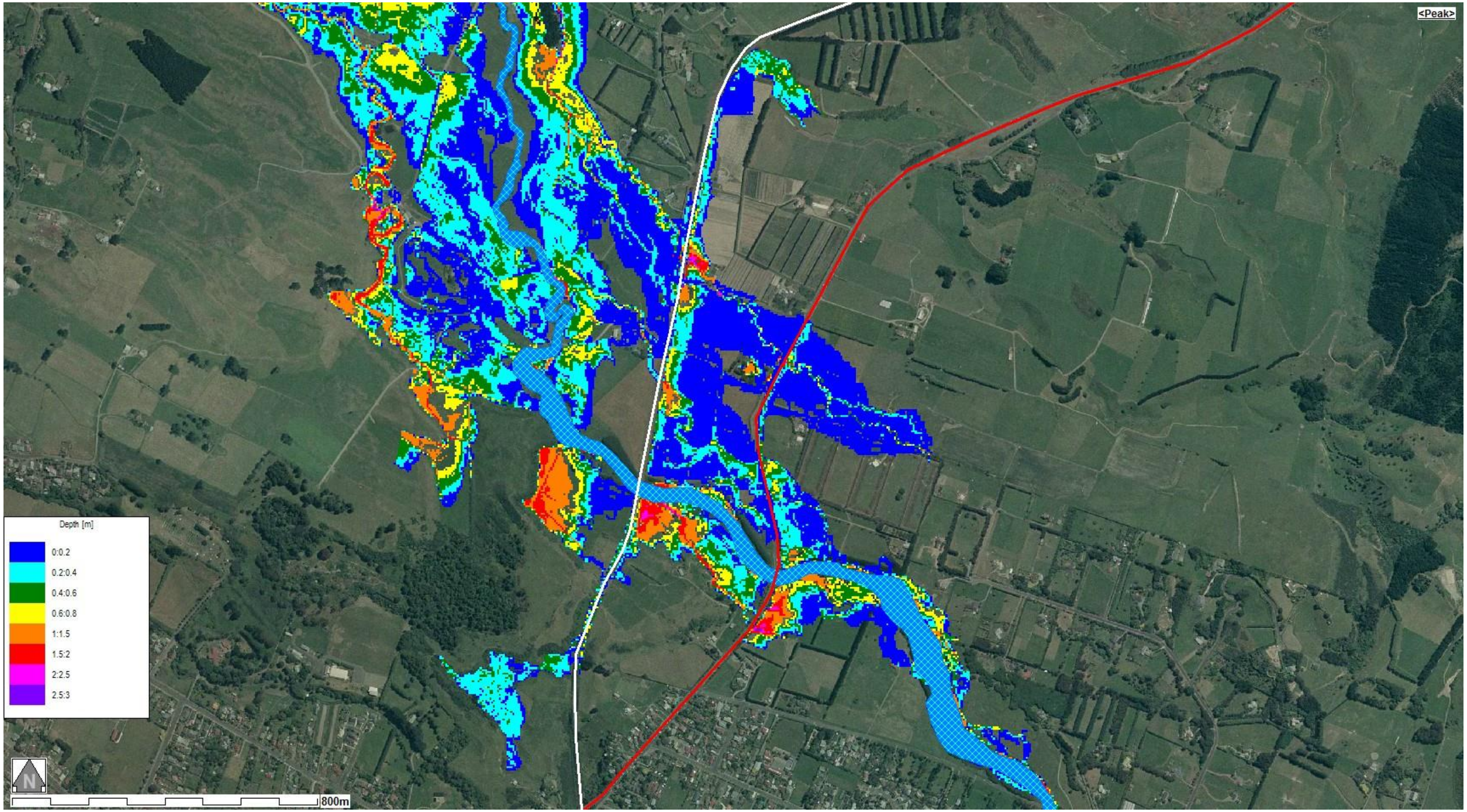

Figure 4-2a Predicted flood depths across Waitohu Stream alluvial fan and floodplain in existing situation for 1% AEP flood (based on 2 hour duration 1% AEP rainstorm) adjusted for possible future climate change effects to 2090 (red line is existing SH1, white line is NIMT railway)

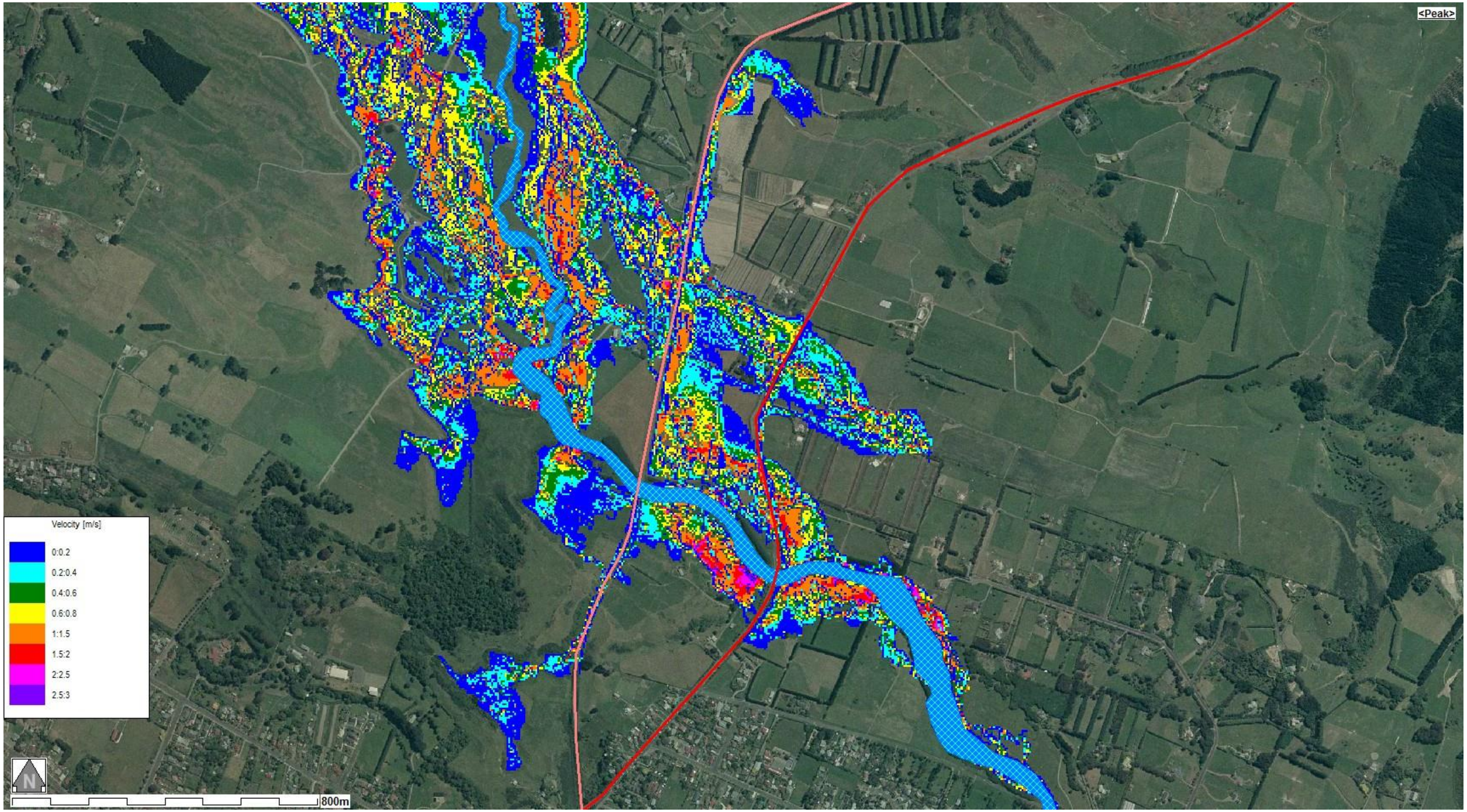

Figure 4-2b Predicted flow velocities across Waitohu Stream alluvial fan and floodplain in existing situation for 1% AEP flood (based on 2 hour duration 1% AEP rainstorm) adjusted for possible future climate change effects to 2090 (red line is existing SH1, pink line is NIMT railway)

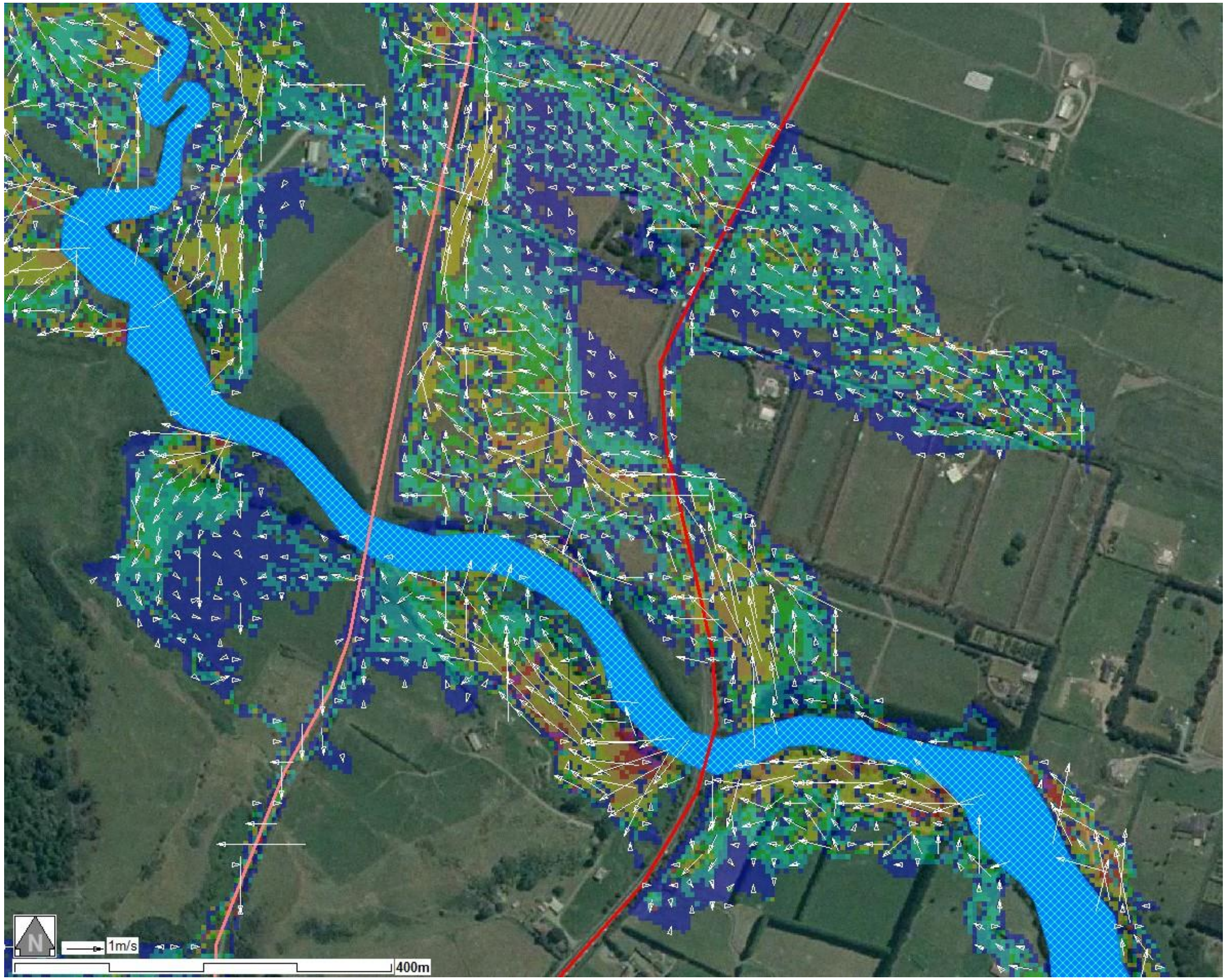

Figure 4-2c Zoomed-in-up section of Figure 4-2b showing directions of overland flow paths past the existing SH1 and NIMT railway crossings of the Waitohu Stream and floodplain (red line is existing SH1, pink line is NIMT railway)

The effect of these aspects of the existing SH1 bridge and stream channel is to cause extensive inundation of SH1 across the floodplain by the 1% AEP flood adjusted for possible future climate change effects. SH1 is also predicted to be inundated at the Greenwood sub-catchment culvert location although this is due to the sub-catchment flood resulting from a 2 hour duration 5% AEP rainstorm (adjusted for possible future climate change effects) in combination with the flood resulting from the 1% AEP rainstorm (also adjusted for possible future climate change effects) impacting on the main Waitohu Catchment. Note that, except along the narrow vee-shaped dry channel forming the main drainage path for the Greenwood sub-catchment, the peak flow depths across the inundated area of this sub-catchment are very shallow (< 0.2m). This reflects the very flat nature of the sub-catchment surface. The flood inundation over SH1 is also very wide and shallow.

Peak flow depths across the floodplain as seen in Figure 4-2a are generally predicted to be fairly shallow in most areas, typically less than 0.4m. Along the natural dry channels within the predominant overland flow paths, flow depths are deeper. There are other isolated pockets including in front of the elevated railway track and SH1 where flow depths are also deeper (as much as 2m).

Figures 4-2b and c complement Figure 4-2a.

Figure 4-2b shows peak flow velocities across the floodplain predicted by the MIKEFLOOD model for the 1% AEP flood adjusted for the effects of possible future climate change to 2090. Peak flow velocities across the floodplain are quite high in places (up to 1-1.5m/s and occasionally higher) along the predominant left and right bank flood plain flow paths below the SH1 and NIMT railway bridges. In the Greenwood sub-catchment, the peak flow velocities are typically less than 0.4m/s implying that the shallow floodwaters are, not surprisingly, fairly slow moving.

Figure 4-2c shows a zoomed-in part of Figure 4-2b around the existing SH1 and NIMT railway crossings of the Waitohu Stream and floodplain with velocity vectors superimposed to indicate the directions of overland flow paths. This highlights the predominant flow paths on both the left and right bank floodplains between the SH1 and NIMT railway bridges.

A twin culvert system (one 0.9m diameter culvert and one 1.05m diameter culvert) allows surface runoff from the Greenwood sub-catchment to pass under the existing SH1. The fact that SH1 overflows at this culvert system location in only a 5% AEP flood (adjusted for possible future climate change effects) means that the existing highway is flood prone. This observation is consistent with anecdotal evidence of the highway flooding at this location from time to time.

The extent of flood inundation along the Expressway route for the 1% AEP flood adjusted for possible future climate change effects is approximately 0.9km in length. The Expressway will therefore need to be elevated above the floodplain over at least part of this length although it will also be tied into the existing vertical alignment of the present SH1 north of Taylors Road. Culverts will also need to be provided under the Expressway to provide continuity for existing natural drainage paths as seen in Figure 4-1. This includes an upgrade of the Greenwood sub-catchment culverts system.

Increasing the waterway area of the SH1 bridge is specifically excluded from the scope of the PP2O Project.

4.2 Mangapouri Stream

The Mangapouri Stream is a tributary of the Waitohu Stream. It drains a small catchment of 2.37km^2 in area (to the east of the Expressway) along the northern side of the Ōtaki River floodplain. The catchment upstream of the Expressway is partly rural and partly urban. It includes part of the Ōtaki Racecourse which has been landscaped to direct surface runoff via a drainage system along the northern boundary into the stream. This landscaping has completely altered natural drainage patterns in the area.

The flood capacity of the Mangapouri Stream downstream of the existing SH1 culvert through Ōtaki Township is severely restricted. Consequently the culvert under the NIMT railway line has been deliberately restricted in size in order to throttle downstream flood flows to a magnitude of about 8m^3/s (approximately a 10% annual exceedance probability flood). This forces storm runoff to pond upstream in:

- a primary flood storage basin bounded by the existing NIMT railway embankment / County Road, Rahui Road and the high ground of the Te Manuao Catchment to the north (see Figure 4-3); and
- a secondary flood storage basin within the Pare-o-Matangi Reserve bounded by the existing NIMT railway embankment, Rahui Road to the west of the railway crossing and SH1 (see Figure 4-3 also).

The decision to throttle flood flows in this manner was made previously by Wellington Regional Council and KCDC.

The primary and secondary flood storage basin areas both incorporate a number of houses which would have their floor levels inundated by floodwaters in a large enough flood event in the existing situation[7]. In the case of the primary storage basin, at least three houses would be affected by a flood as small as a 20% AEP flood and at least twelve houses by a 1% AEP flood adjusted for possible future climate change effects to 2090 (Smith and Webby, 2013a). In the case of the secondary storage basin, at least two houses would be affected by a 1% AEP flood and at least five houses would be affected by a 1% AEP flood adjusted for possible future climate change effects to 2090 (Smith and Webby, 2013a).

The drainage system along the northern boundary of the racecourse has only limited capacity so that the estimated area for the Mangapouri Catchment may be overestimated for extreme storm events. Any storm runoff exceeding the capacity of the drainage system would instead flow overland towards an unnamed watercourse draining under the railway line, the railway retail precinct area and SH1 (see Figure 4-4) to a soakage area on the grounds of Ōtaki College.

The 0.316km^2 Te Manuao Catchment on the terrace to the north of the Mangapouri Catchment drains into the Mangapouri Stream via a wetland area to the west of SH1 (see Figure 4-3). The stormwater network in this mainly urban catchment is quite limited in extent (B Fountain (SKM), pers. comm.) with only a single 0.45m diameter outlet pipe under SH1. Any rainfall on the catchment not infiltrating into the ground or captured by the piped drainage system will therefore flow overland towards SH1. Surface runoff reaching SH1 will mostly flow over the road into the Railway Wetland along with the stormwater conveyed by the piped drainage system. However some of the surface runoff may flow down the eastern side of County Road to a sump that drains via a pipe under the road to a drain between the road and the existing NIMT railway embankment to the Mangapouri Stream upstream of the existing railway culvert.

[7] The house floor level information has been provided by KCDC and GWRC.

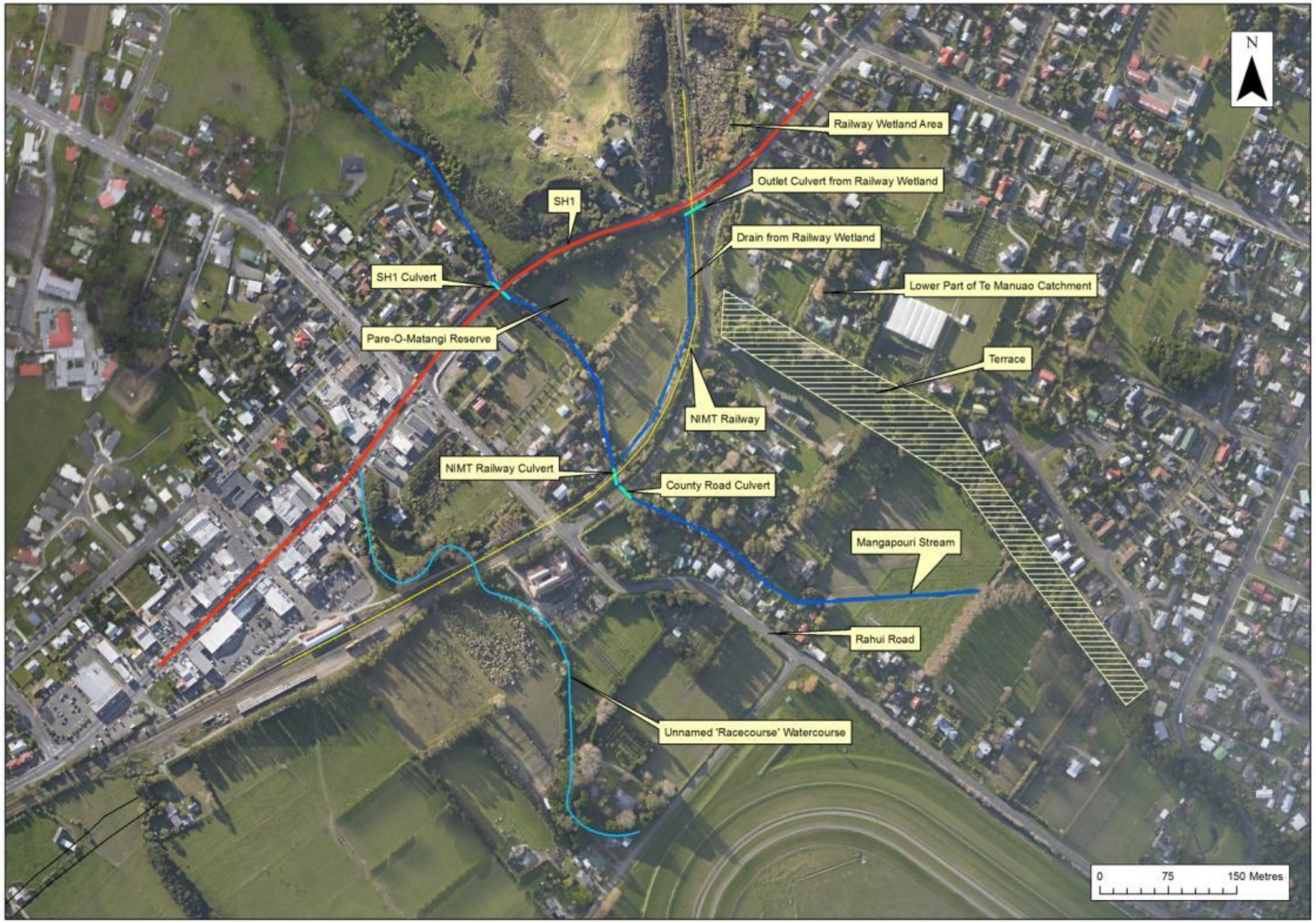

Figure 4-3 Aerial photograph of Mangapouri Stream in SH1 / Rahui Road / NIMT railway line triangle including lower end of Te Manuao Catchment and Railway Wetland area and unnamed watercourse conveying surface runoff from southern part of Ōtaki Racecourse

The Expressway will pass through the area of the secondary flood storage basin within the Pare-o Matangi Reserve and will require the relocation of the NIMT railway line to the west of the new road.

4.3 Ōtaki River

The Ōtaki River drains a 335km^2 catchment (at the existing SH1 Bridge) extending back to the main divide of the Tararua Ranges. It is therefore a major river which responds very rapidly to weather systems affecting the mountain range. After exiting from the foothills of the Tararua Ranges, the river flows westwards across a coastal plain to the sea over a distance of about 9km. The township of Ōtaki lies on the true right (north) on the coastal plain.

The Ōtaki River incorporates a stopbank system along the true right (north) bank (see Figure 4-4) providing a 1% annual exceedance probability standard of flood protection to the township of Ōtaki. The northern (right bank) approach embankment to the NIMT railway bridge across the river ties into the upstream section of stopbank and has been strengthened to form part of the primary flood defence system for Ōtaki Township. The stopbank continues along the right bank downstream of the existing State Highway (SH1) Bridge. Super-design floods (floods larger than the design standard) would overtop the stopbank system along the right bank upstream of the existing NIMT railway line and SH1 bridge crossings.

The stopbank upstream of the existing SH1 bridge protecting Ōtaki Township is relatively new. The design crest profile of this stopbank has been set based on current climate conditions but the stopbank cross-section profile has been defined to permit additional raising in the future to take account of the effects of possible future climate change.

Natural high ground (in the form of a river terrace) confines flood flows in the river along the true left (south) bank.

The Ōtaki River from Chrystall's Bend (the bend in the bottom right of Figure 4-4) downstream to the river mouth is an aggradational reach with continually rising bed levels. GWRC monitor these riverbed levels on a regular basis and allow gravel extraction to occur on a continuous basis with available extraction volumes strictly limited.

The existing SH1 road bridge has a shorter total span length than the existing NIMT rail bridge and causes an elevated backwater effect upstream. The minimum total span length for the proposed twin Expressway bridges will be approximately the same as that of the downstream rail bridge.

The proposed bridge crossing will be located sufficiently far upstream of the existing NIMT rail bridge to not cause any significant hydraulic interference (induced by wake vortices off the piers) or additional scour effects on the downstream piers of the rail bridge.

4.4 Ōtaki River Floodplain

The Expressway crosses the Ōtaki River floodplain to the north of the existing Ōtaki River Bridge Crossing (see Figure 4-4). The floodplain incorporates known secondary flow paths for residual flows from the river, either overtopping the stopbank system protecting Ōtaki Township or flowing through a stopbank breach. Figure 4-5 shows the extent of flood inundation across the floodplain in the existing situation resulting from stopbank overtopping by a 0.2% AEP flood adjusted for possible future climate change effects assuming that the stopbank can sustain the depth and duration of overtopping without breaching (the effects of stopbank breaching are considered in the detailed investigations report (Smith and Webby, 2013b)).

The Expressway will intersect the secondary flow paths across the floodplain shown in Figure 4-5 and will require it to be elevated above the floodplain and tied into the existing stopbank system. However the effect of elevating the Expressway will be to block off these secondary flow paths and to cause ponding to occur upstream. Some provision of passageways through the embankment will need to be made to provide for continuity of these secondary flow paths across the floodplain. Construction of the Expressway across the floodplain also provides an opportunity to potentially reduce the flood risk to Ōtaki Township.

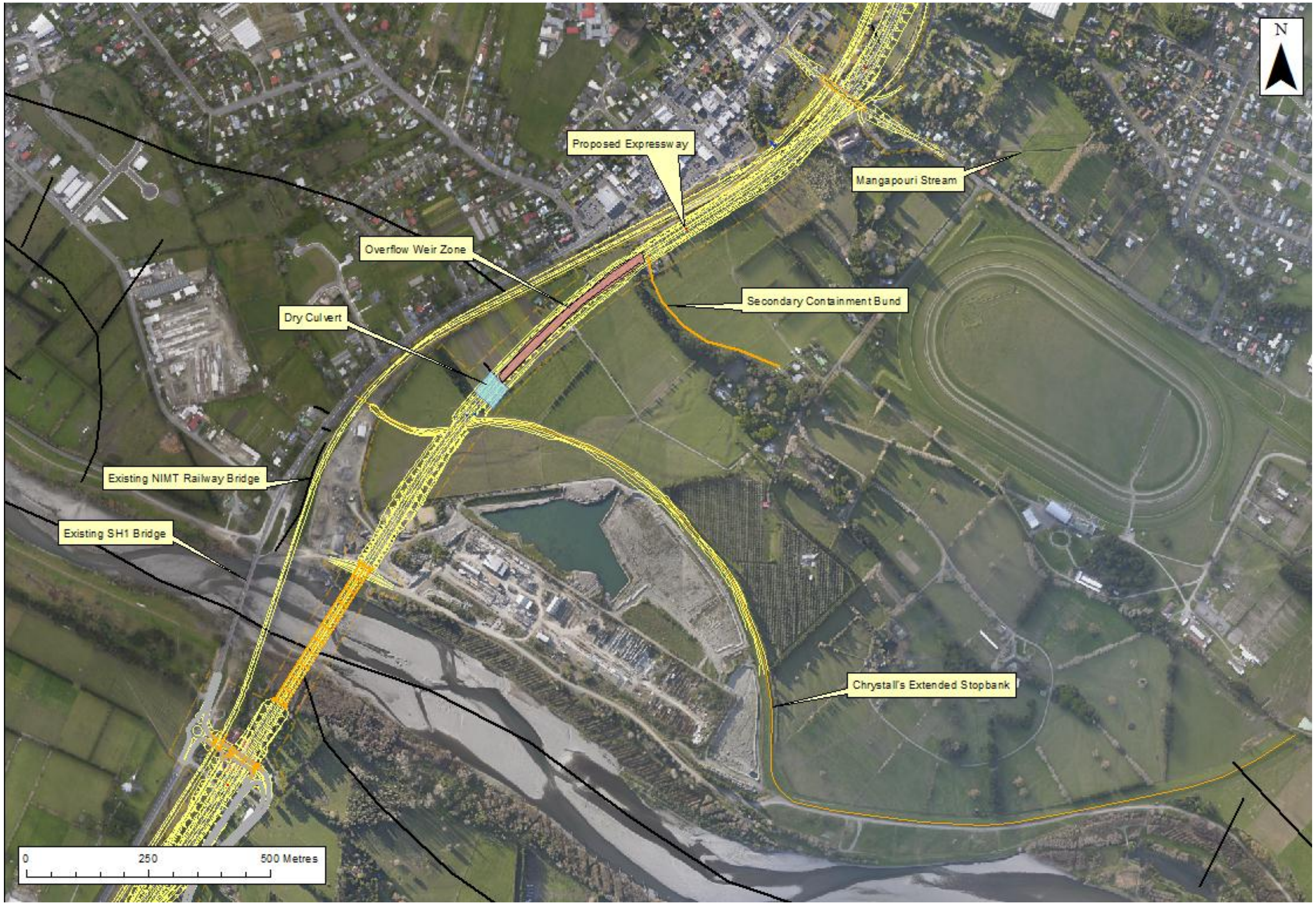

Figure 4-4 Aerial view of Ōtaki River and floodplain in vicinity of existing and proposed river crossings

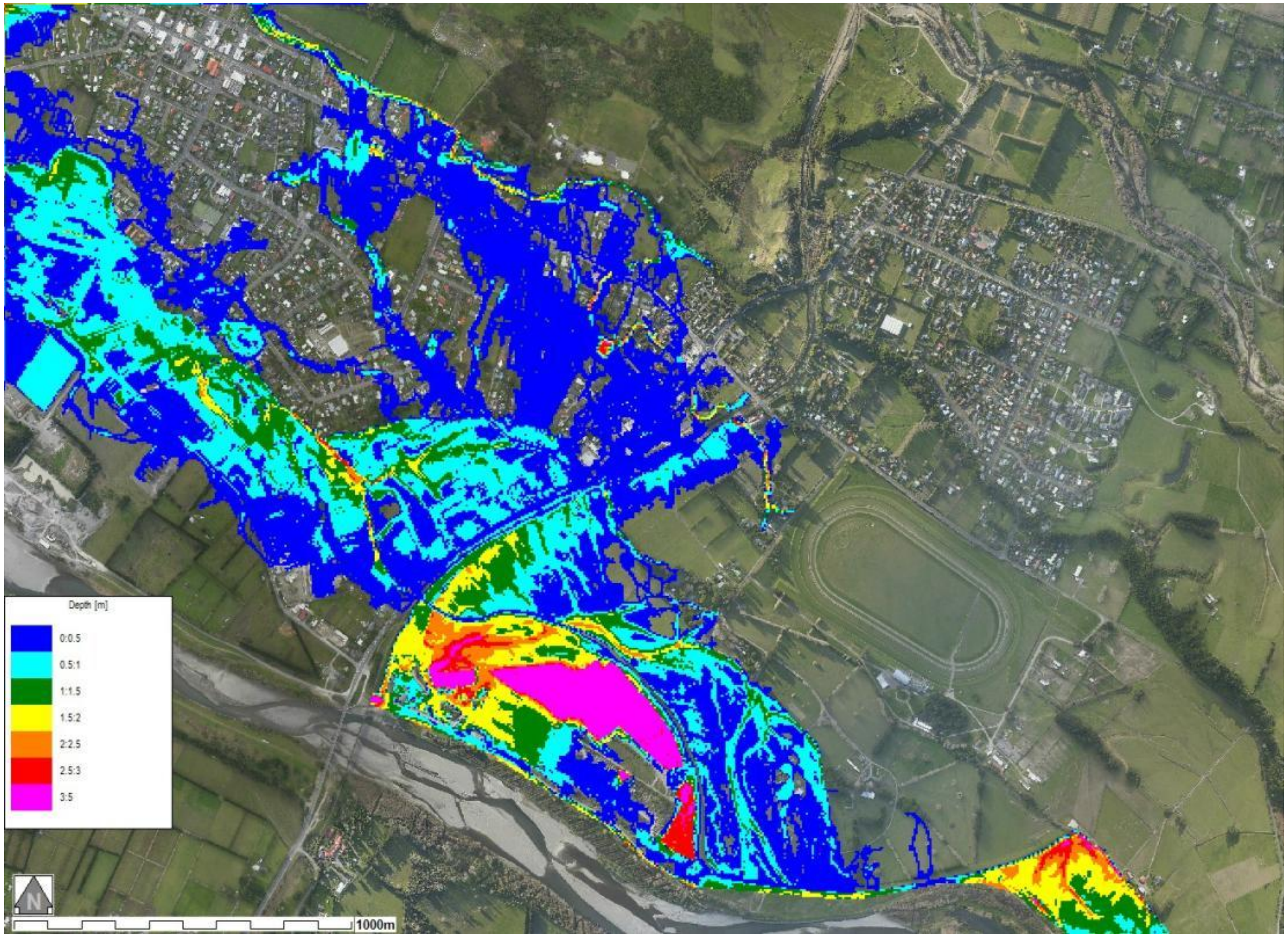

Figure 4-5 Extent of flood inundation for existing situation on Ōtaki River floodplain resulting from stopbank overtopping in 0.2% AEP flood adjusted for possible effects of future climate change to 2090

4.5 Mangaone Stream and Floodplain

The Mangaone Stream drains a 38.6km^2 catchment extending from the foothills of the Tararua Ranges to the sea at Te Horo Beach. After exiting from the foothills, the stream crosses the coastal plain over a distance of about 7km, cutting through lines of inland and coastal dune barriers to its beach exit (Figure 4-6). SH1 and the NIMT railway line cross the stream at Te Horo, about 3.5km to the south of the Ōtaki River.

In a geomorphologic sense the coastal plain area between the foothills and the sea is a steeply sloping (> 1%) alluvial fan. In an unconstrained and undeveloped situation, the drainage system across the fan surface would be in a continual dynamic state, changing course over time and potentially splitting into a number of smaller distributor channels. However, the alluvial fan in this context has historically been modified to facilitate development of the fan surface for agricultural, horticultural and residential purposes. This modification has interfered drastically with existing drainage paths such that many of the historical distributor channels across the fan surface have been rerouted or severed from the main stream. The presence of a couple of major transport links crossing transversely across the alluvial fan surface compound the historical interference in the natural drainage patterns.

Figure 4-7a shows an aerial photograph of the existing SH1 and NIMT railway crossings of the Mangaone Stream and alluvial fan with the drainage system marked (Figure 4-7b shows the location of the primary flow paths approaching the two transport links). Both transport links run essentially parallel with each other across the alluvial fan surface with the NIMT railway line on the “uphill” side. The railway line sits slightly elevated above the fan surface on a ballasted embankment which acts as a flood detention barrier for floodwaters flowing across the alluvial fan surface as seen in Figure 4-8. There are two culverts under the railway embankment to provide passage for flood flows – one on the main stream and another about 250m to the south acting as an overflow facility (Figure 4-7a). SH1 runs at grade across the alluvial fan surface and also incorporates two culverts in series with the upstream ones under the NIMT railway line to convey flood flows.

The SH1 crossings of the Mangaone Stream and Mangaone Overflow are known flooding hotspots with the road having been overtopped by floodwaters on a number of occasions in recent years. Figure 4-8 shows a photo-graph of the aftermath of one such event on 28 October 1998[8], although by the time the photograph was taken, any floodwaters inundating the SH1 had receded. In addition to ponding of floodwater upstream of the NIMT railway embankment, Figure 4-8 also shows evidence of breakout of floodwaters further upstream into a secondary distributor channel down the alluvial fan and breakout of floodwaters along the true right downstream of the main SH1 culvert through a dedicated secondary flow path known as the Lucinsky Overflow (Figure 4-7a).

Figure 4-9 shows another photograph of the same 28 October 1998 flood event looking in a south-easterly direction across Te Horo Village and the two existing primary transport links towards School Road. This provides evidence of the downstream drainage path following by flood flows conveyed by the overflow culvert system under the NIMT railway line and SH1. This follows a course across the alluvial fan surface between some of the houses in Te Horo Village on the western side of SH1 before crossing Te Horo Beach Road to re-join the main stream channel.

[8] This flood event is estimated to have had an annual exceedance probability of about 15%.

Figure 4-6 Aerial photograph of alluvial fan and floodplain system for Mangaone Stream alluvial fan and floodplain system from foothills to sea

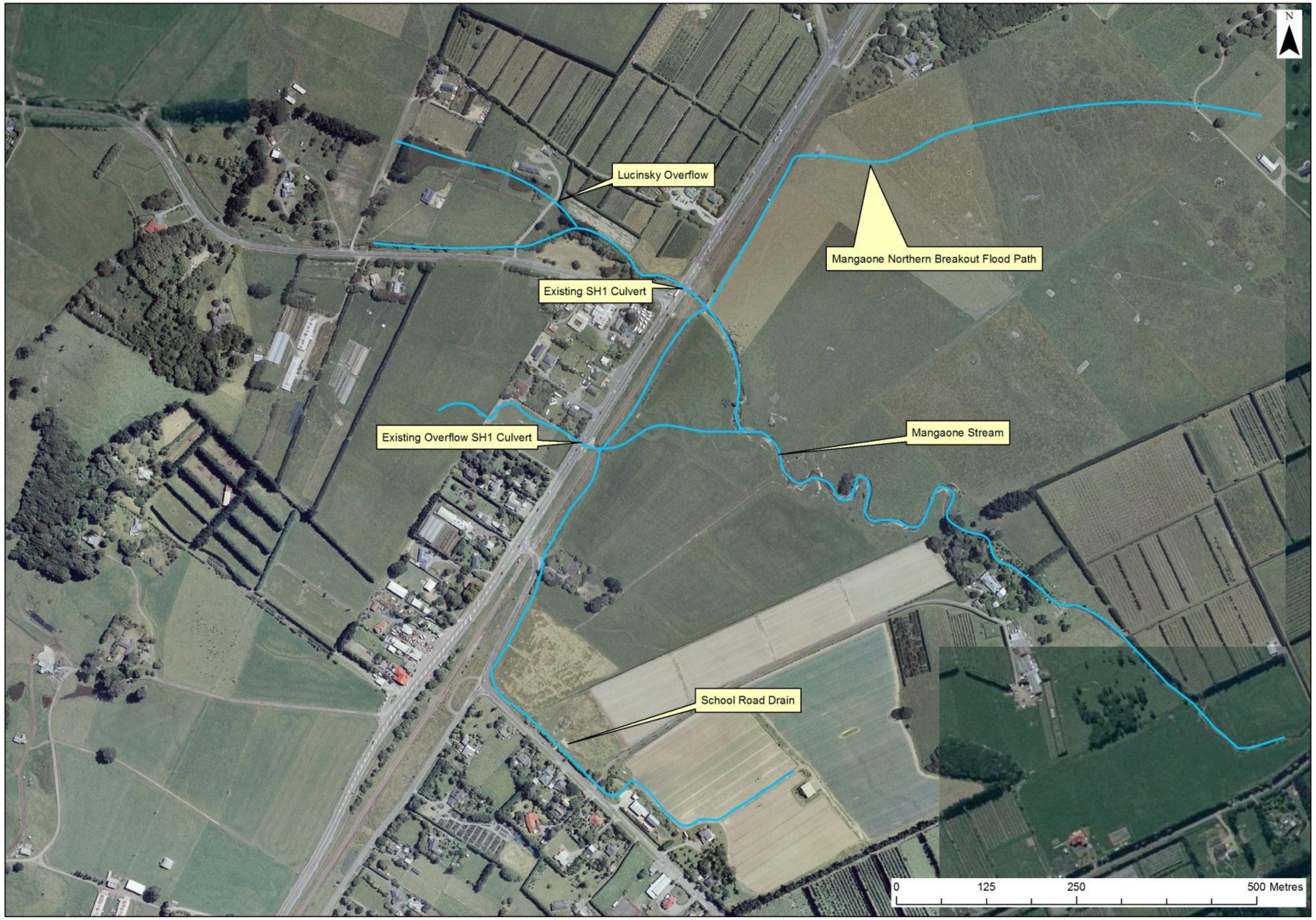

Figure 4-7a Aerial photograph showing existing SH1 and NIMT railway crossings of Mangaone Stream alluvial fan and floodplain system with main drainage paths marked

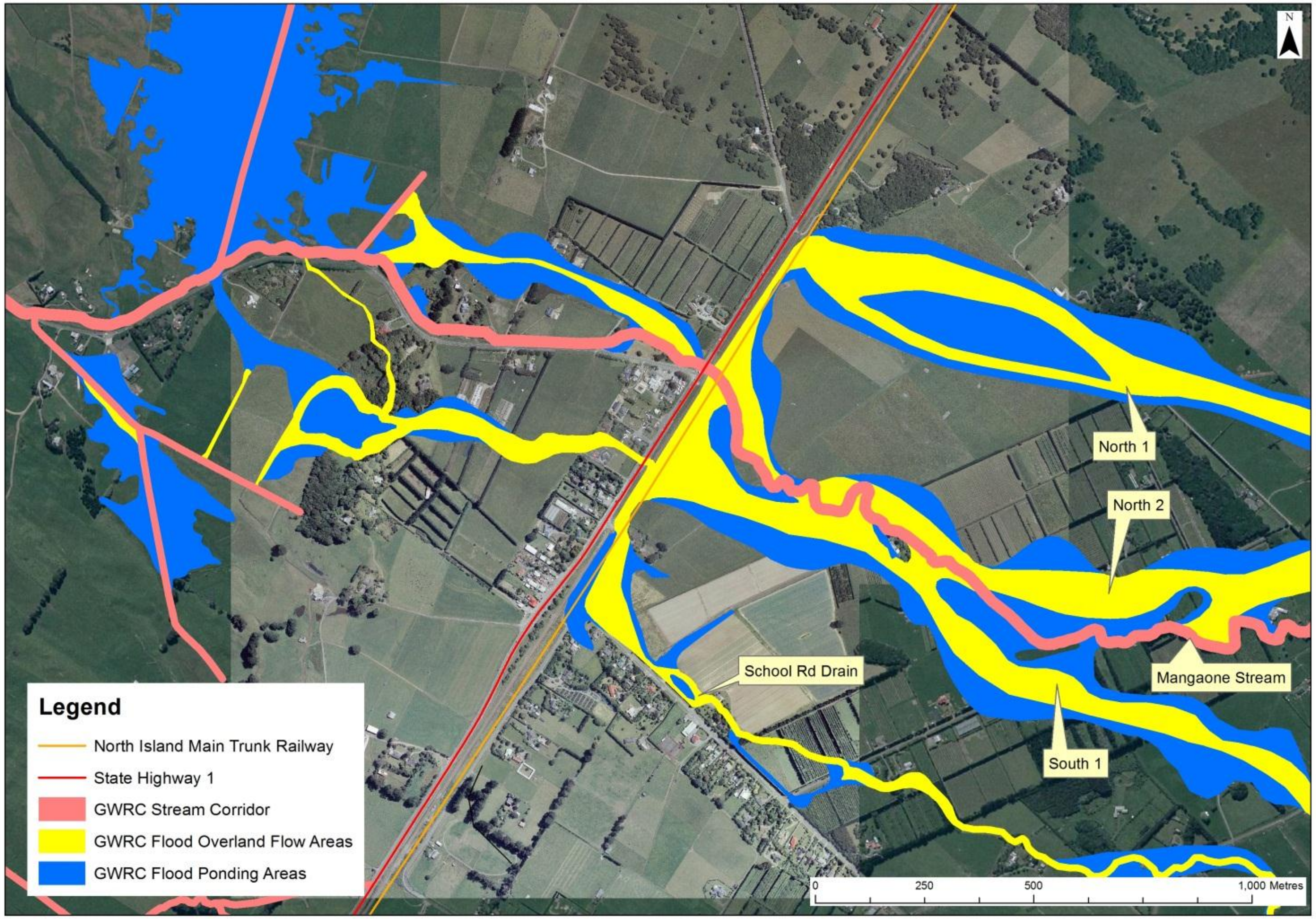

Figure 4-7b Flow paths for Mangaone Stream across surface of alluvial fan approaching NIMT railway and SH1road crossings

Figure 4-8 28 October 1998 flood in Mangaone Stream - view looking east across SH1 and NIMT railway line crossings of stream (photograph courtesy of GWRC)

Figure 4-9 28 October flood in Mangaone Stream - view looking south-east across Te Horo Village, SH1 and NIMT railway line with School Road in distance stream (photograph courtesy of GWRC)

The evidence of flood breakout from the main stream channel downstream of the primary SH1 culvert crossing of the Mangaone Stream highlights anecdotal evidence provided by local residents of existing flooding problems along Te Horo Beach Road.

Other anecdotal evidence provided by local residents has highlighted further flooding issues in the vicinity of School Road arising from historical interference with natural drainage paths across the alluvial fan surface associated with the Mangaone Stream. The School Road drain (Figure 4-7a) conveys floodwaters from a historically modified distributor channel to the overflow system under the NIMT railway line and SH1. However, from on-site observation, the size and flow capacity of the upstream channel, which skirts around the boundary of a horticultural property opposite the Te Horo Community Hall, is significantly greater than the size and capacity of the drain running alongside School Road. Whenever the upstream channel flows full, floodwaters will inevitably break out of the School Road drain and cause an inundation nuisance across the road and on neighbouring residential properties.

Figures 4-10a and b show the predicted extent of flood inundation across the alluvial fan surface in the existing situation for the 1% AEP flood adjusted for the effects of possible future climate changes to 2090. These highlight some of the existing flood inundation issues noted above. Inspection of the existing stream channel downstream of the SH1 and NIMT railway crossings underlines its limited flood capacity relative to estimates of flood magnitudes for the stream at the location of the two existing transport crossings. It is inevitable then that large floods will break out of the main stream channel and flow across the surface of the alluvial fan. Unfortunately historical development of the fan surface and modification of natural drainage paths has not fully recognised or appreciated this.

With respect to the predicted flood extent for the existing situation indicated in Figures 4-10a and b, a number of observations can be made:

- The predominant overland flow paths follow the course of natural dry channels across the alluvial fan and floodplain surface.
- Significant ponding to depths of 1.5-2m occurs upstream of the NIMT railway line along a width of nearly 900m. However the extent of ponding in the upstream direction is limited to less than 100m due to the steepness of the slope of the alluvial fan.
- Overland flow across the alluvial fan on the upstream (eastern) side of the NIMT railway line is generally very shallow, mostly less than 0.2m but up to a maximum of 0.4m in places away from the main stream channel.
- The northern overland flow path breaks out into several old dry channels across the alluvial fan surface upstream of the NIMT railway line. These channels intercept the railway embankment and result in floodwaters ponding upstream and then spreading southwards towards the main channel of the Mangaone Stream.
- Overtopping of the NIMT railway line and SH1 occurs:
  - opposite the intersection of School Road and Gear Road on the east side of the NIMT railway line (from the School Road drain);
  - intermittently between the School Road / Gear Road intersection and the Mangaone Overflow;

  - intermittently between the Mangaone Overflow and the main stream channel; and
  - opposite the SH1 / Te Waka Road intersection on the west side of SH1 (from the northern overland flow path).

- In addition overtopping of SH1 occurs at the Mangaone Overflow and the main stream channel.
- Extensive inundation occurs through Te Horo Village on the western side of the SH1 although the peak flow depths are very shallow (mostly less than 0.2m),
- The Lucinsky Overflow (Figure 4-1) forms a shallow 70-90m wide overland flow path breaking out along the north (right) bank of the main stream channel downstream of the SH1 culvert. Floodwaters overtopping SH1 and spreading northwards along SH1are the source of flow along the Overflow as a low bank along the right bank of the stream channel prevents floodwaters form breaking out of the channel.
- The NIMT railway / SH1 overflow originating from opposite the School Road / Gear Road intersection continues to follow old dry channels westwards across the alluvial fan surface on the south side of Te Horo Village with peak flow depths less than 0.2m.
- The NIMT railway / SH1 overflow at the SH1 / Te Waka Road intersection also continues to follow old dry channels westwards across the alluvial fan surface.
- All overflow paths west of SH1 are directed towards a floodplain storage area on the eastern side of a line of inland sand hills. The peak flow depths in this long linear storage area are much deeper (1.5-2m) to the north of Te Horo Beach Road.
- Floodwaters drain away from this ponding area via a narrow drain through the sand hills about 600m north of Te Horo Beach Road. Other floodwaters flowing along the main stream channel and overland across the alluvial fan surface to the south of Te Horo Beach Road drain through the narrow gap in the sand hills occupied by the road and the main stream channel.

The predicted flood extent shown in Figures 4-10a and b for the 1% AEP flood adjusted for the possible future climate change effects is much more widespread than that presently shown on the Kāpiti Coast District Plan flood hazard map, particularly to the west of SH1. The primary reason for this is the significant difference in peak flood estimates for the 1% AEP flood between that assumed for the flood hazard assessment on which the District Plan flood hazard map is based and that used for this investigation (43.6m^3/s and 85.2m^3/s respectively). However a secondary reason is that the one-dimensional computational hydraulic modelling used to predict the flood hazard extent for the District Plan map required overland flow paths to be predetermined (probably from previously observed flow paths) so that all flow paths for the simulated extreme flood were not necessarily correctly identified.

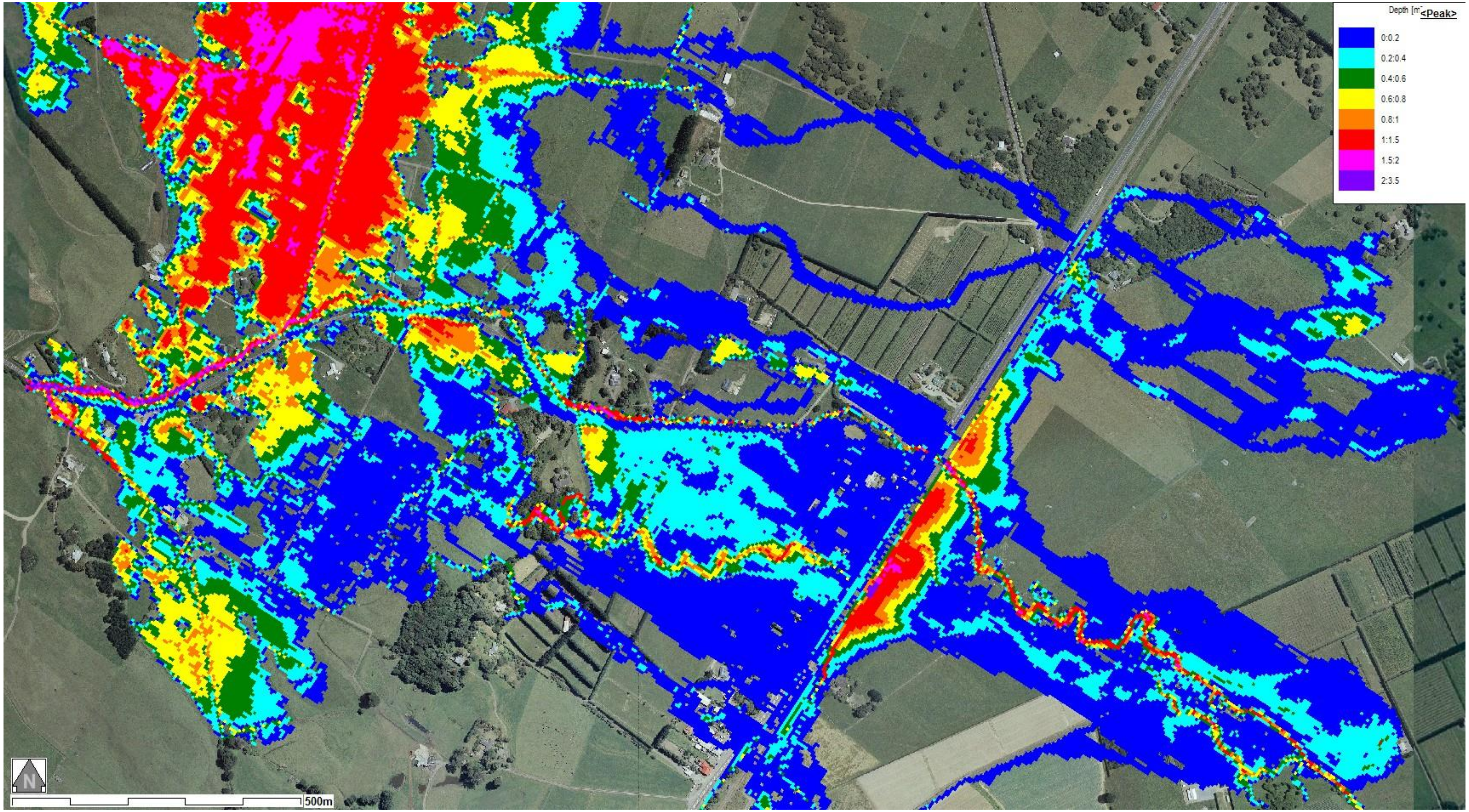

Figure 4-10a Small scale view of predicted flood extent across Mangaone Stream alluvial fan and floodplain system in existing situation for 1% AEP flood adjusted for possible future climate change effects to 2090

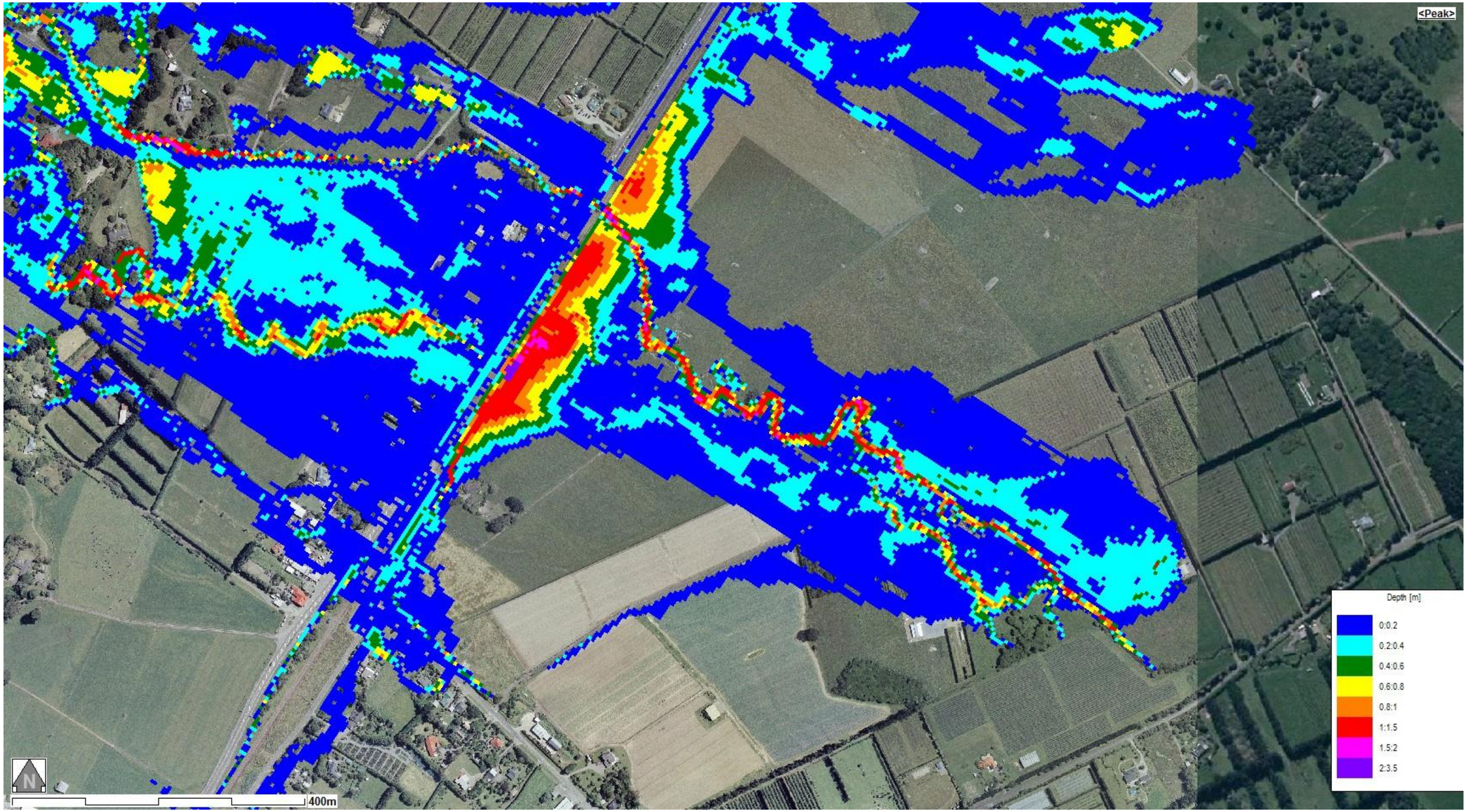

Figure 4-10b Effects of existing NIMT railway line and SH1 on predicted flood extent across Mangaone Stream alluvial fan and floodplain system in existing situation for 1% AEP flood adjusted for possible future climate change effects to 2090

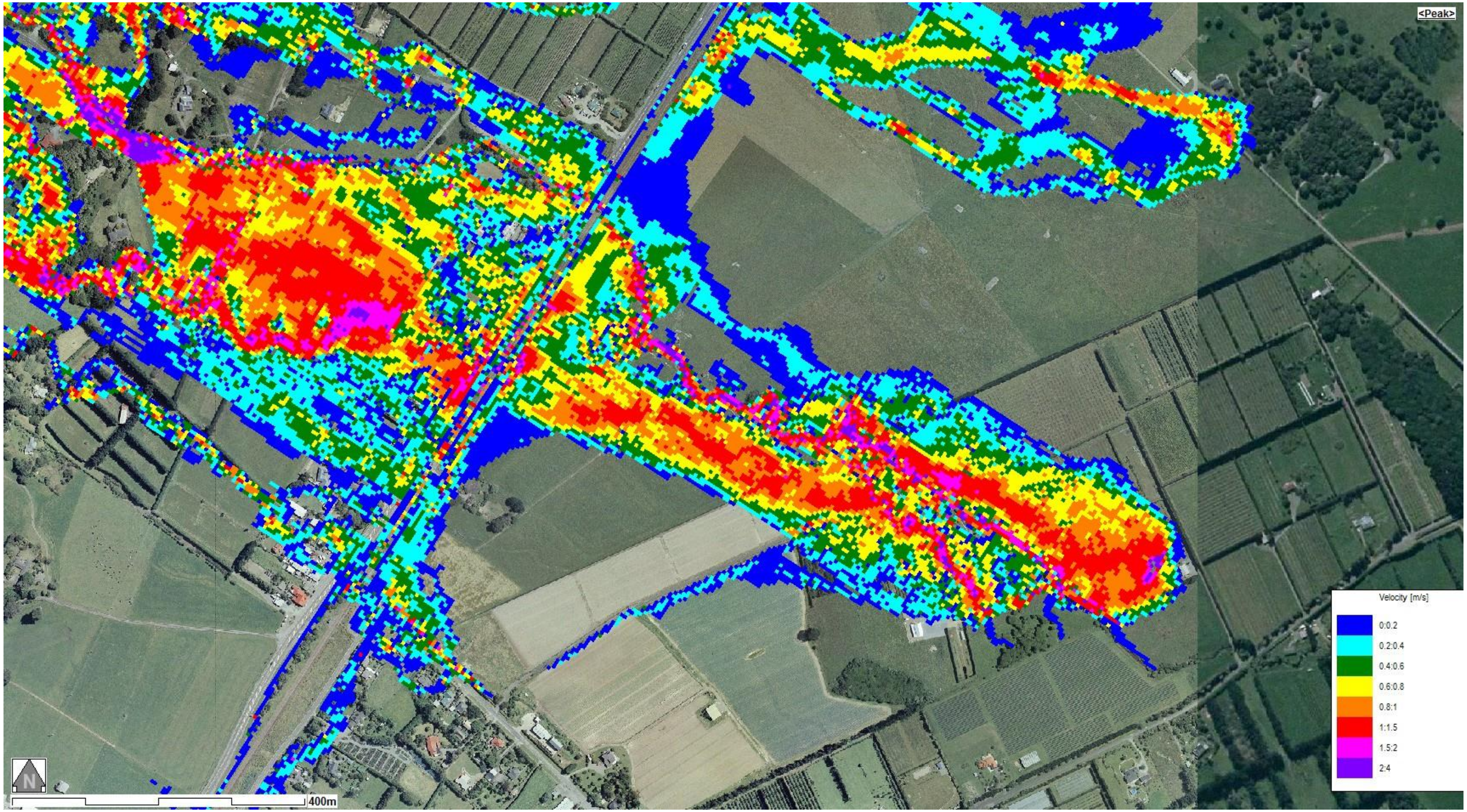

Figure 4-11a Predicted flow velocities across Mangaone Stream alluvial fan and floodplain system in existing situation for 1% AEP flood adjusted for possible future climate change effects to 2090

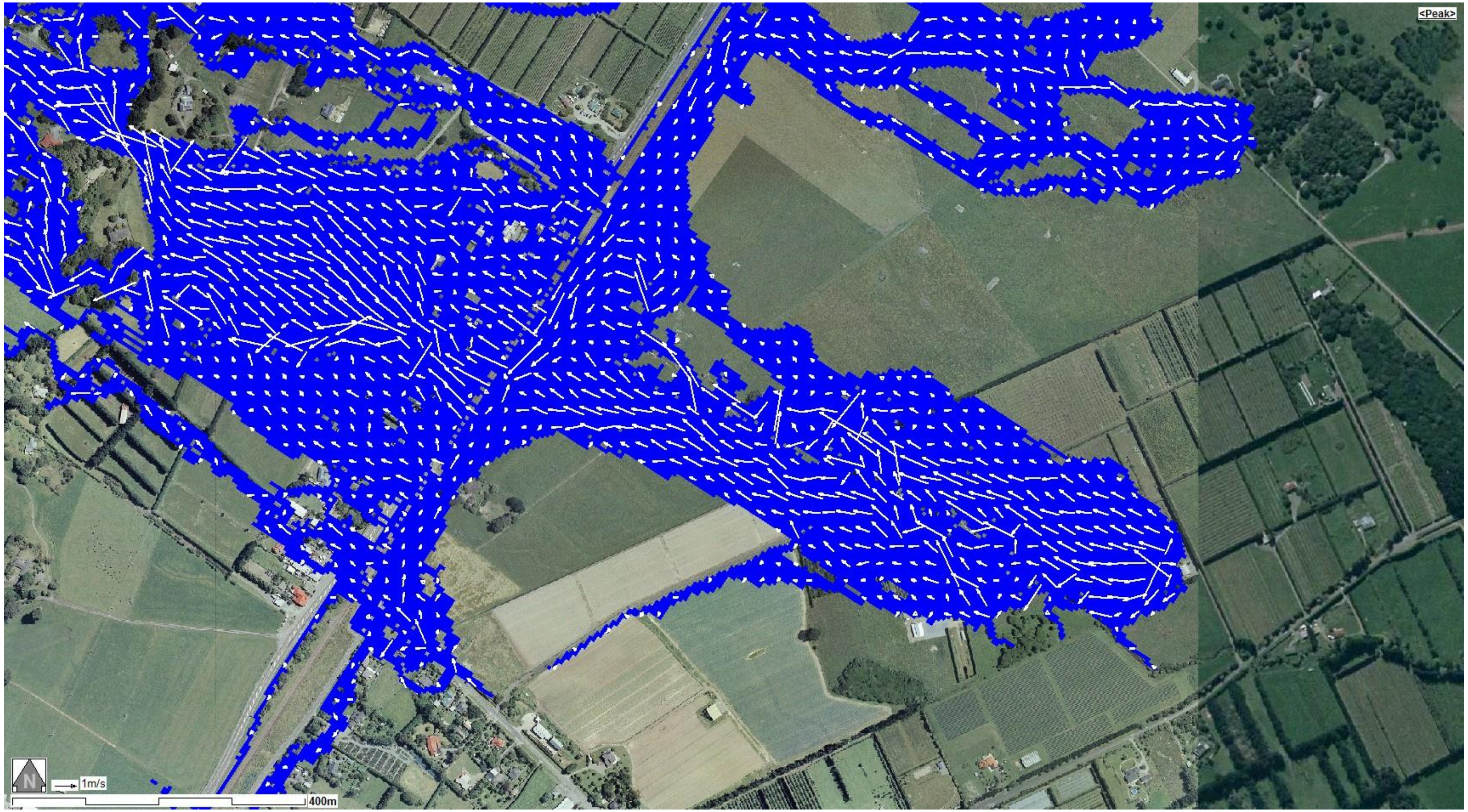

Figure 4-11b Alternative version of Figure 4-11a showing velocity vectors for overland flow past the existing SH1 and NIMT railway crossings of the Mangaone Stream and Overflow

Complementing Figures 4-10a and b, Figure 4-11a shows peak flow velocities across the floodplain predicted for the 1% AEP flood adjusted for the effects of possible future climate change to 2090. This figure highlights quite graphically the original course of the Mangaone Stream now followed by the Mangaone Overflow. Peak flow velocities along this overland flow path are predicted to be considerably higher than elsewhere across the alluvial fan surface (except in the main stream channel) with values typically in the range 1-1.5m/s and pockets as high as 1.5-2m/s. Elsewhere across the alluvial fan surface flow velocities are much lower (0.2-0.4m/s).

Figure 4-11b shows an alternative version of Figure 4-11a around the existing SH1 and NIMT railway crossings of the Mangaone Stream and Overflow with velocity vectors superimposed to indicate the directions of overland flow paths. This figure reinforces the understanding obtained from Figure 4-11a that the majority of the total flood flow follows the course of the Mangaone Overflow under and over the NIMT railway line and SH1 and through the middle of the part of Te Horo Village to the west of SH1. Figure 4-11b also indicates that the NIMT railway line acts as a partial barrier to flood flows by:

- directing School Road drain flows northwards towards the Mangaone overflow (excluding any flow which overtops the railway line and continues in a north-westerly direction); and also by
- directing flows in the northern overland path southwards towards the main channel of the Mangaone Stream (again excluding any flow which overtops the railway line and continues in a north-westerly direction).

In the proposed situation, the Expressway will be aligned parallel with but further to the east of SH1 and the NIMT railway line. It will therefore cross both the Mangaone Stream and the Mangaone Overflow on the upstream side of these transport links. The Expressway will need to be protected by an upstream bund elevated across the alluvial fan in order to achieve the required level of service and remain flood free up to that level. The ponding that currently occurs upstream of the NIMT railway line will therefore be transferred to upstream of the Expressway.

However the proposed situation is further complicated by the presence of an east/west local link road (connecting School Road on the east side of the Expressway with Te Horo Beach Road on the west side). The local link road will form an extension of a realigned Gear Road on the east side and loop around to cross over the Expressway via an overbridge and link up with Te Horo Beach Road on the west side. It will therefore have to cross the main stream channel twice as well as pass through existing overland flow paths approaching the Expressway across the alluvial fan. Again adequate flood capacity for these main stream channel and overland flow path crossings will need to be provided.

5. Treatment Philosophy for Expressway Crossing of Watercourses

5.1 Principle of Hydraulic Neutrality

An elevated transport link constructed across a floodplain or alluvial fan interferes with the natural drainage functions of these topographic features. Adequate provision must therefore be made for relief measures within an elevated link to allow the safe passage of floodwaters through it or over it.

A fundamental principle which has been applied consistently with respect to the treatment of individual watercourse crossings on the Expressway is that of hydraulic neutrality[9]. What this means is that the impact of flood hazards from the Expressway should in general be no worse than in the current situation. This objective can sometimes be extremely difficult to achieve while still maintaining the required level of service for the Expressway. Where it has not been possible to achieve this desired objective, a fall-back position has been adopted whereby flood hazards that have been made worse are kept away from residential properties and instead redirected towards uninhabited rural areas.[10]

5.2 Design Philosophy for Individual Watercourse Crossings

5.2.1 General

Each of the main waterway / floodplain crossings along the route of the Expressway has unique features requiring individual treatment with respect to defining and then implementing the desired level of service.

5.2.2 Waitohu Stream and Floodplain

The 1% AEP flood adjusted for possible future climate change effects to 2090 was adopted as the Serviceability Limit State flood for the proposed bridge crossing of the Waitohu Stream as per the guidelines of the NZ Transport Agency's *Bridge Manual* (Transit NZ, 2003).

In terms of a design freeboard standard for the bridge crossing, this is influenced by two factors: the potential for sediment aggradation along the stream bed past the bridge and the potential for snagging of flood transported woody debris by the either the bridge deck or the bridge piers.

The upper catchment is heavily forested and the stream channel across the alluvial fan and floodplain has willow trees for bank protection in places (including between the existing SH1 bridge and the proposed Expressway bridge) so there are two readily available sources for woody debris. However the stream is crossed by a number of existing bridges upstream (the waterworks access bridge, the Ringawhati Road bridge, the Waitohu Valley Road bridge and the State Highway 1 bridge). The first three bridges do not have particularly large waterway areas and are predicted to be overtopped and outflanked by the 1% AEP flood (Wallace, 2004) so that they will also act as a trap for flood transported woody debris. The same applies to the existing SH1 bridge.

[9] Hydraulic neutrality can relate to either compensating for loss of flood storage due to development or managing the difference between pre-development and post-development, particularly due to interruption of overland flow paths.
[10] In discussions with GWRC and KCDC, their preferred position is that complete hydraulic neutrality should be achieved if possible.

However the presence of these upstream bridges acting as debris traps for woody material and affording a degree of protection to the Expressway bridge needs to be balanced against the design life for the new structure. It is conceivable that over the design life of the Expressway bridge that all of the upstream bridges could eventually be replaced. In the case of the local road bridges and particularly the waterworks access bridge, these are very unlikely to be replaced by new structures with a significantly larger waterway area so that any replacement structure could still potentially act as a woody debris trap in extreme floods. If the existing SH1 bridge was replaced in the future, then there might be a case for designing it for a higher level of service than it currently has. Any replacement structure would still suffer adversely from being located immediately downstream of a sharp bend in the stream channel although, if it was designed for a higher level of service, then it would be less prone to snagging woody debris under flood conditions.

The NZ Transport Agency's *Bridge Manual* (Transit NZ, 2003) requires a minimum freeboard of 0.6m above the Serviceability Limit State design flood level in normal circumstances and 1.2m "*where the possibility that large trees may be carried down the waterway exists*". Therefore, from a woody debris perspective, a design freeboard allowance of between 0.6m and 1.2m from the design flood level to the underside of the Expressway bridge would be a minimum design standard in this context based on the guidelines of the *Bridge Manual*.

Williams (2004) has identified the reach between the existing SH1 bridge and the Wakapua Farm bridge downstream of the NIMT railway bridge as zone of sediment deposition due to a sharp reduction in the streambed slope. GWRC monitor stream bed levels by means of periodic cross-section surveys of the stream channel and have in the past actively managed the deposition of gravel bed material in the vicinity of the NIMT railway bridge which appears to be the primary sediment aggradation hotspot.

Gardner (2009) has analysed mean bed levels of the Waitohu Stream based on cross-section surveys in 1992, 2003 and 2009. He has confirmed increases in mean bed level in the reach between the existing SH1 bridge and the NIMT railway bridge of 0.1-0.3m and up to 1m at one cross-section 720 downstream of the railway bridge from 1992 to 2003 and much lesser increases in mean bed level including slight decreases at some cross-sections from 2003 to 2009. Gardner (2009) notes that gravel extraction since 2004 in this aggrading reach appears to have been effective in causing the reduced aggradational response over the 2003 to 2009 period.

It is clear then that the design freeboard allowance for the proposed Expressway bridge needs to reflect both the potential for increased head losses due to the snagging of woody debris material on the piers and the ongoing occurrence of sediment aggradation in the 1.7km long reach below the existing SH1 bridge. Based on the evidence available regarding sources of woody debris material and the magnitude of historic streambed aggradation, it would appear reasonable to adopt a design freeboard allowance for the Expressway bridge of 1.2m[11].The same Serviceability Limit State flood adopted for the proposed bridge crossing of the Waitohu Stream is also appropriate as the design standard for the large dry culverts through the left and right approach

[11] In view of the history of stream bed aggradation in the reach below the existing SH1 bridge where the proposed Expressway bridge will cross the Waitohu Stream, streambed levels will need to be actively monitored in consultation with GWRC. Any future aggradation within the immediate vicinity of the Expressway bridge may well require ongoing intervention by NZTA to maintain current streambed levels.

embankments and for the Greenwood sub-catchment culvert. Normally these culverts would require a minimum design freeboard allowance of 0.5m as per the guidelines of the NZ Transport Agency's *Bridge Manual* (Transit NZ, 2003). However, in the case of the left and right approach embankment culverts, there is potential for upstream flood levels to be partially influenced by bed aggradation in the mainstream channel. It would therefore be appropriate to adopt a higher design freeboard allowance of 0.8m for these culverts and for the approach embankments generally. The *Bridge Manual's* standard guideline for a design freeboard allowance of 0.5m would however be suitable for the Greenwood sub-catchment culvert and the road embankment either side of it.

In the case of the large dry culverts through the bridge approach embankments, it is very easy to satisfy these design standards as the approach embankments are elevated fairly high above the floodplain and provide ample freeboard. In the case of the Greenwood sub-catchment culvert, they will be more difficult to satisfy. This is because the existing culvert location is a known flooding hotspot with the culvert system being under capacity and the existing road being overtopped from time to time. The available depth in which to form any new culvert structure is very constrained as the proposed road level is no more than about 2m above the invert level of the dry channel leading to the culvert. Structural considerations will require a minimum depth of fill over any culvert.

The design philosophy originally adopted for the northern end of the Expressway was to accept the existing flood risk at the Greenwood sub-catchment culvert in the interim until the Ōtaki to Levin Expressway is constructed in the future. The existing flood risk would then be resolved. This philosophy has not changed even though the Ōtaki to Levin Expressway as part of the Wellington Northern Corridor RoNS Project is no longer the preferred option.

The vertical alignment for the Expressway at the northern end has been defined to transition into the existing vertical alignment of SH1 past Taylors Road. This is a fixed constraint therefore for this investigation. The limited discharge capacity of the existing culvert system has been addressed in order to future-proof the northern end of the Expressway. This means that an appropriate culvert size has to be determined so that only the vertical alignment of the Expressway needs to be raised in the future in order to achieve the required level of service with respect to freeboard.

5.2.3 Mangapouri Stream

It is proposed to retain the existing NIMT railway culvert so that the culvert continues to perform its flood throttling function to limit downstream flood flows and thereby provide flood relief to downstream properties through Ōtaki Township. The existing railway embankment which forms the flood detention barrier for the primary flood storage basin on the Mangapouri Stream[12] will also be retained except in the vicinity of the existing railway crossing of Rahui Road. Here County Road will be required to be realigned to pass under the new Rahui Road overbridge before looping back to intersect with Rahui Road before the start of the eastern approach embankment to the overbridge.

[12] Full details of the storage volume characteristics of the primary flood detention basin are given in the detailed investigations report on the Mangapouri Stream (Smith and Webby, 2013a). However there is only a marginal reduction in the storage volume of the basin due to the footprint of the eastern approach embankment to the Rahui Road overbridge.

In the proposed situation, the 1% AEP flood adjusted for possible future climate change effects to 2090 is an appropriate design flood standard for the primary flood storage basin upstream of the existing railway embankment (although it would also be desirable to consider the effects of other larger floods than this design standard). Normally the NZ Transport Agency's *Bridge Manual* (Transit NZ, 2003) would require a minimum design freeboard standard of 500mm to be applied to the railway culvert for the design flood. However the existing railway embankment which will form most of the impoundment barrier for the upstream flood storage pond is sufficiently elevated above peak flood levels in the basin to be fully compliant with this design freeboard requirement.

The critical location from a freeboard perspective would be the area directly underneath the new Rahui Road overbridge where the County Road is diverted to loop around and connect to Rahui Road to the east and the section of the Expressway embankment adjacent to the County Road diversion would take over the flood containment function of the removed section of railway embankment. Flood levels in the primary flood storage basin would be relatively undisturbed and calm because of the very slow moving nature of the floodwaters. For this reason it would be acceptable to adopt a lower design freeboard standard of 300mm at the critical location for the design flood. However it would be appropriate to also check the level of freeboard with other floods larger than the design standard.

The reduced area of the Pare-o-Matangi Reserve would still function as a secondary flood storage basin for floodwaters conveyed by the Mangapouri Stream after passing through the Expressway and NIMT railway culverts. The available spaces between the dual lanes of the Expressway in either direction and also between the Expressway and the relocated NIMT railway are required for road runoff treatment purposes and are not available for flood storage for the main stream channel. For these reasons, it is essential that the Expressway and railway culverts (downstream of the existing railway culvert) operate under a free surface regime in all flood conditions with minimal head losses. To achieve this requirement, the culverts would best be constructed from standard precast concrete box culvert units nearly as wide as the existing stream channel (~ 3.5m) through the Pare-o-Matangi Reserve and deep enough to allow free surface flow under the most extreme flood conditions considered (0.2% AEP flood adjusted for the effects of possible future climate change to 2090).

Constructing the Expressway and railway culverts from fairly deep standard precast concrete box culvert units would also allow as much light penetration from either end under normal flow conditions to promote fish passage. The other requirement from a fish passage perspective is to have a 0.5m deep gravel substrate layer along the base of the culvert structure[13] (ARC, 2009) which requires an over-deep culvert section to allow this layer to be formed. The two culverts could be constructed as one continuous culvert but it would be preferable to have two separate ones to allow as much light penetration as possible to encourage fish passage.

These practical design considerations to ensure a free surface flow regime and to promote fish passage negate the need for a design freeboard standard for the Expressway and railway culverts on the Mangapouri Stream. In short, both culverts are required to mimic as closely as possible the existing flow regime under flood conditions along the reach of the Mangapouri Stream between the existing railway and SH1 culverts.

[13] This gravel substrate layer will be comprised of large cobbles which will be either concreted in position to the invert of the over-deep box culvert sections or sized large enough to resist movement by flood flows passing over them. Either treatment is intended to ensure that the gravel substrate layer is immobile under flood conditions and that the hydraulic capacity of the culvert section is maintained.

Figure 5-1a Location of railway wetland in existing situation

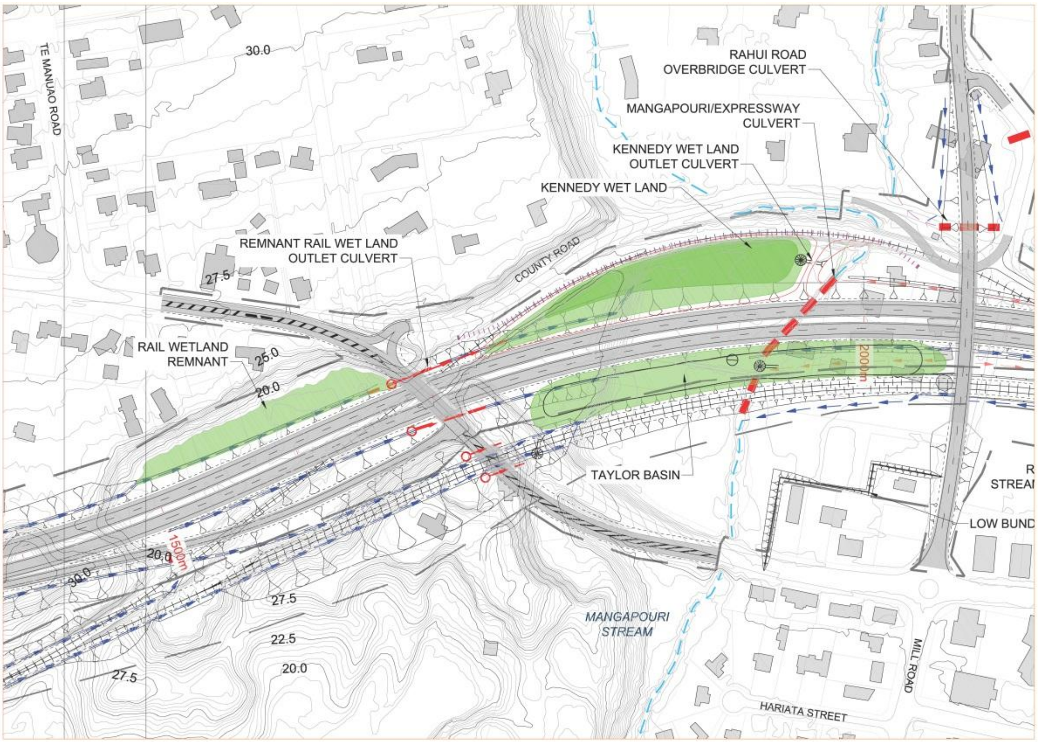

Figure 5-1b Location of remnant railway wetland and secondary wetland in series (Kennedy Wetland) in proposed Expressway situation

The existing Railway Wetland would be partially reduced in area (refer Figures 5-1a and b) with the construction of the Expressway. To compensate for this loss of wetland storage area for attenuating storm runoff from the Te Manuao Catchment, it is proposed to construct a second wetland area in series (refer Figure 5-1b) utilising the vacant space between the existing (and abandoned railway embankment) and the Expressway embankment to the north of the Mangapouri Stream[14]. This second wetland area would need to be impounded at the downstream end by a watertight bund. The existing railway embankment would also need to be made watertight to contain wetland flows. The two wetlands would be connected by a long pipe while the primary outlet from the second wetland to the Mangapouri Stream would also be a shorter pipe. The bund impounding the second wetland would need an emergency spillweir over the crest to discharge storm inflow in excess of the design flood standard. The impoundment bund crest level would need to be lower than the crest level of the existing railway embankment to prevent overtopping of the latter in the event of wetland storage pond capacity being exceeded.

It would be appropriate to apply a minimum design freeboard standard of 300mm to the wetland storage ponds on this system for the design 1% AEP flood adjusted for possible future climate change effects to 2090. This is based on the reasonable assumption that the water surface in the wetlands would remain fairly calm even under flood conditions due to the shallow flow depths, high flow resistance from aquatic vegetation and very slow flow velocities.

5.2.4 Ōtaki River

The existing SH1 bridge across the Ōtaki River partially constricts the river channel and causes a slight backwater effect[15] upstream. The NIMT railway bridge immediately upstream of the SH1 bridge has a longer overall length and does not appear to contribute to this backwater effect. The maximum 330m length of the Expressway crossing of the Ōtaki River, comprising two parallel bridges, has been selected to approximately match that of the existing NIMT railway bridge and thereby ensure adequate hydraulic performance. The pier to pier span length has been set at 30m giving a total of 11 spans.

The Ōtaki River drains a fairly large catchment which extends back to the main east / west divide of the Tararua Ranges. The catchment includes extensive forest cover so that there is a high likelihood of large volumes of woody debris being flushed out of the catchment under extreme flood conditions with some of the debris snagging on the piers of the proposed upstream Expressway bridge, thereby inducing the formation of a debris raft and causing increased pier head losses (the wide spacing of the piers would limit the size of any debris raft on a pier). For this reason it is appropriate to adopt at least a minimum design freeboard value of 1.2m for the bridges based on the guidelines of the NZ Transport Agency's *Bridge Manual* (Transit NZ, 2003). The piers of the two bridges will be aligned so that those on the upstream bridge will have a sheltering effect on those of the downstream bridge.

However the reach of the Ōtaki River from Chrystall's Bend to the river mouth, which the existing road and rail bridges cross and which the Expressway bridges will also cross, is a known aggradational reach. Gravel

[14] Full details of the storage volume characteristics of the proposed twin wetland system relative to the storage volume of the existing railway wetland are given in the detailed investigations report for the Mangapouri Stream (Smith and Webby, 2013a). However the combined storage volume of the two wetlands in the proposed situation at a depth of 2m in each approximately matches the storage volume of the existing railway wetland at the same depth.

[15] A backwater effect in this context means that upstream flood levels along the river are slightly elevated due to the bridge constriction compared to the situation without the bridge present. The effect diminishes with increasing distance upstream.

extraction is actively exercised as management tool to try and maintain riverbed levels to a desired profile, thereby ensuring that the design flood standard for the Chrystall's Bend stopbank is not eroded and the flood risk to Ōtaki Township is not exacerbated by bed aggradation[16]. To monitor the effects of gravel extraction, regular cross-section surveys are undertaken to ensure that the mining of gravel bed material is sustainable.

Gardner (2011) analysed changes in mean bed level and the volume of gravel bed material in the Ōtaki River based on river cross-section surveys in 1991, 2006 and 2011. He calculated that mean bed levels in the reach from Chrystall's Bend to the river mouth had mostly increased in the range 0-0.3m over the period 1991 to 2011 with increases of 0.3-0.5m at some cross-sections and decreases at a few cross-sections.

Gardner (2011) also found that, between 2006 and 2011, mean bed level changes in part of the Ōtaki River reach from Chrystall's Bend down to about where the Expressway bridges will cross the river (cross-section 380) were roughly in balance - some increases up to 0.12m and some decreases up to -0.23m. However in the remainder of the reach downstream of the Expressway crossing point, he found that mean bed levels had mostly increased in the range 0-0.15m with increases at some cross-sections of 0.15-0.37m and decreases at other cross-sections of up to -0.3m and at one section up to -0.6m. On balance though, the mean bed level increases dominated over the decreases over the whole of the reach resulting in a net increase in the gravel bed volume (implying a net aggradation trend of the riverbed).

The design freeboard allowance for the two Expressway bridges therefore needs to allow for the effects of gradually occurring bed aggradation in addition to the effects of potential debris raft formation on the bridge piers. Based on the minimum freeboard requirements of the NZ Transport Agency's *Bridge Manual* (Transit NZ, 2003) for the latter factor and the recent aggradational history of the Ōtaki River with an increasing bed level trend, it would be appropriate to adopt a slightly higher freeboard standard for the two Expressway bridges than the *Bridge Manual* value. We would recommend a minimum freeboard standard of 1.7m derived from the 1.2m allowance from the *Bridge Manual* and the maximum mean bed level increase between 1991 and 2011 of 0.5m.

In view of the longevity of the projected design life for the Expressway bridges and the importance of these structures, it is appropriate for the Serviceability Limit State Flood to be at least the 0.2% AEP flood based on current climate conditions. This flood is approximately the same as the 1% AEP flood adjusted for possible future climate change effects to 2090. This design standard is in accordance with the requirements for the serviceability limit state flood of the NZ Transport Agency's *Bridge Manual* (Transit NZ, 2003).

5.2.5 Ōtaki River Floodplain

Ōtaki Township is sited on the floodplain of the Ōtaki River but is protected by a stopbank along the north bank of the river (this is referred to as the Chrystall's Bend extended stopbank). The design standard for the stopbank is the 1% AEP flood with freeboard based on current climate conditions. The stopbank would therefore be overtopped by any super-design flood with an annual exceedance probability of less than 1% based on current climate conditions. Overtopping floodwaters could also induce a breach in the stopbank.

[16] GWRC hold the resource consents for gravel extraction and license others to undertake this with constraints on the volume of gravel bed material that is allowed to be extracted.

Consideration of residual risk resulting from super-design floods is an important aspect of flood hazard management. Therefore it is reasonable to consider the impact of stopbank super-design floods in this floodplain context. It is desirable that the existing residual flood risk to Ōtaki Township is not exacerbated by the Expressway.

In a stopbank overtopping scenario, floodwaters from the Ōtaki River spill across the floodplain predominantly following a secondary flow path along the landward side of the Chrystall's bend stopbank and parallel with the river. There would be some lateral spread of floodwaters into residential parts of Ōtaki Township.

Construction of the Expressway on a raised embankment across the floodplain will interfere with the main secondary flow path as the embankment would act as a flood detention barrier. The most important treatment objective for the Expressway crossing of the floodplain is to incorporate some means of providing continuity for this main secondary flow path. Other additional treatment objectives are:

- if practicable, reduce the impact of stopbank overtopping flows on Ōtaki Township, particularly residential areas; and
- contain the spread of stopbank overtopping flows into the Mangapouri Stream.

Given the context of the Expressway, it is not possible to pre-define a suitable design flood standard or design freeboard value for the Expressway embankment. These parameters can only be determined by carrying out a range of flow simulation trials exploring the effects of different embankment geometries and complementary mitigation measures for a stopbank overtopping event. The approach taken therefore was to undertake a series of computational hydraulic model simulations to gauge the effects of stopbank overtopping by the 0.2% AEP flood adjusted for the effects of possible future climate change to 2090 with various mitigation measures in place to safely pass ponded floodwaters through the Expressway embankment.

5.2.6 Mangaone Stream and Floodplain

SH1 has a history of being overtopped by floodwaters every few years in the immediate vicinity of the culvert system for the Mangaone Stream because the vertical alignment of the road is essentially at-grade through Te Horo. The stream channel downstream of the existing SH1 culvert also has limited channel capacity which results in extensive overland flow and floodplain inundation.

Construction of the Expressway past this location therefore represents an opportunity to improve the level of flood security to downstream properties. The Expressway will be constructed slightly above the ground surface but, in order to achieve the required level service at the Mangaone Stream and Overflow crossings, a bund will need to be constructed on the upstream side of the road. This bund will function as a flood detention barrier. Under significant flood conditions, floodwaters will pond upstream of the Expressway embankment as they currently do upstream of the NIMT railway embankment.

The 1% AEP flood adjusted for possible future climate change effects to 2090 was adopted as the Serviceability Limit State flood for the Expressway crossing of the Mangaone Stream alluvial fan and floodplain system in accordance with the guidelines of the NZ Transport Agency's *Bridge Manual* (Transit NZ, 2003). The same document indicates that culverts under the Expressway on the main stream channel and providing continuity for existing overland flow paths across the alluvial fan would require a minimum design freeboard allowance of 500mm. Structural considerations would also require a minimum depth of fill over any culvert.

The local link road providing east / west connectivity across the Expressway between School Road and Te Horo Beach Road will also cross the main channel of the Mangaone Stream twice, the overland flow path leading to the Mangaone Overflow culvert system (within the flood ponding area upstream of the bund protecting the Expressway) and the Lucinsky Overflow. Based on the importance level of the local link road, the Serviceability Limit State flood according to the guidelines of the NZ Transport Agency's *Bridge Manual* (Transit NZ, 2003) for these stream and overland flow path crossings would be either the 4% or 2% AEP flood adjusted for possible future climate change effects to 2090. The minimum design freeboard allowance of 500mm would also apply to the culvert structures forming these crossings.

The existing Mangaone and Lucinsky Overflows form an integral part of the alluvial fan drainage system to ease floods past the residential areas of Te Horo. It is a critical design requirement that this drainage system continues to function as intended after the Expressway is constructed with these overland flow paths not impeded adversely.

6. Overall Potential Effects of Individual Watercourse Crossings

6.1 Potential Effects of Waitohu Stream and Floodplain Crossing

6.1.1 Outline of Proposed Situation

The proposed Expressway bridge will cross the Waitohu Stream approximately 260m downstream and to the west of the existing State Highway 1 bridge crossing. As noted in Section 5, the proposed Expressway crossing of the stream is located within a geomorphologic zone of instability characterised by sediment deposition and potential lateral channel instability (Williams, 2004). The bridge crossing has therefore been designed to have an approximately 75m total span length so as not to encroach on the 75m wide fairway width defined by GWRC to allow for potential future channel migration. The effect of the resulting large set back of the bridge abutments from the current active channel location minimises the risk of future abutment attack by high velocity flood flows.

The alignment of the proposed Expressway passes directly through the extensive overland flow paths across the alluvial fan and floodplain system on both sides of the Waitohu Stream seen in Figures 4-2a and b. In order to achieve the required level of service outlined in Section 5 for this watercourse crossing, the Expressway will need to be elevated on an embankment. However, on the northern side of the stream crossing the vertical alignment of the proposed Expressway will now slope down to grade and transition into the existing horizontal alignment of SH1 before the twin Greenwood sub-catchment culverts. This culvert system location is a known flooding hotspot and achieving the desired level of service while maintaining a near at grade vertical alignment for the new road is problematic.

To provide continuity for existing overland flow paths across the alluvial fan and floodplain system and to allow overland flows to pass under the Expressway, culverts to convey these flood flows will be provided in addition to a replacement culvert on the Greenwood sub-catchment overland flow path. Table 6-1 summarises the recommended culvert types, dimensions and levels. The location of these culverts is illustrated in Figure 6-1. Note that modification of the existing State Highway 1 bridge to increase its waterway capacity and reduce the volume of flood breakout flows upstream of the bridge does not form part of the proposed PP2O Scheme.

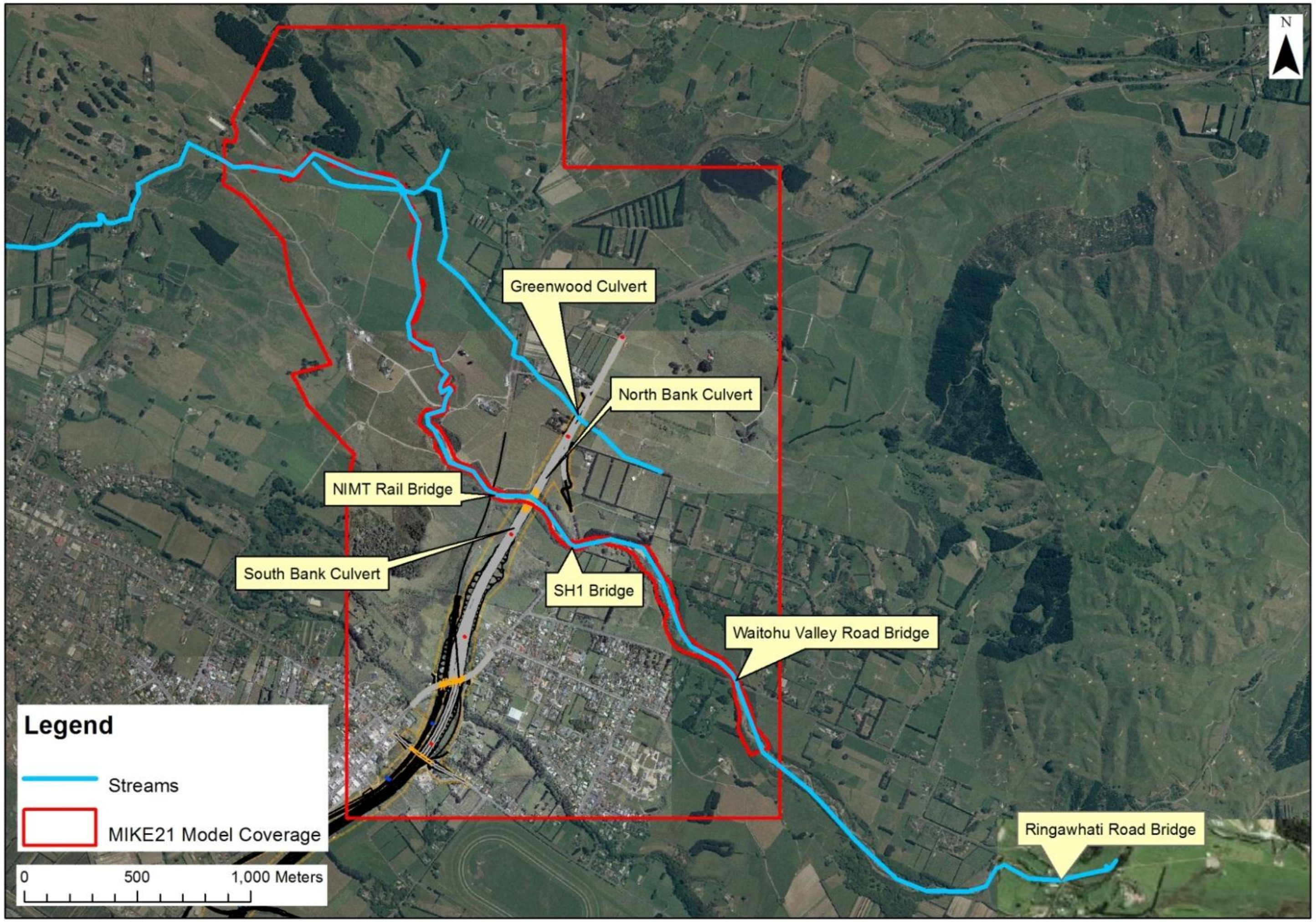

Figure 6-1 Proposed treatment measures to mitigate effects of PP2O Expressway on overland flows across Waitohu Stream alluvial fan and floodplain system resulting from an extreme flood

Table 6-1 Culvert types, dimensions and levels for proposed Expressway crossing of Waitohu Stream and floodplain

Location	Type	Size (m)	Invert Level (m MSL Wellington)		Length (m)	Slope (%)	Road Level (m MSL Wellington)
			u/s	d/s			
Southern approach embankment	box	8m x 2.5m [1]	24.5	24	50	1.0	27.7
Northern approach embankment – Cooper's overland flow path	box	10m x 1.5m [1]	25.5	25	45	1.1	28.3
Greenwood sub-catchment overland flow path	box	4m x 1.5m	23.05	22.65	40	1.0	25.1

[1] Dimensions given as width x depth.

The design flood magnitude for the Greenwood sub-catchment culvert under the Expressway (1% AEP flood adjusted for possible future climate change effects to 2090) is such that it requires a much larger capacity culvert system than exists currently. The low height of the road relative to natural dry channel levels at the Greenwood sub-catchment overland flow path crossing constrains the maximum culvert size able to be used. The recommended 4m wide by 1.5m culvert in Table 6-1 has very similar invert levels to the existing culverts yet would still have sufficient depth of fill over the top to satisfy structural requirements. The culvert will be inlet controlled and will require an energy dissipation facility at the downstream end.

6.1.2 Effects of Expressway Crossing

Figure 6-2a shows a flood inundation map indicating the predicted flood extent across the Waitohu Stream alluvial fan and floodplain system in the proposed situation for the 1% AEP flood adjusted for possible future climate change effects to 2090. The ranges of peak flood depths are shaded in different colours across the flood inundation map. The predicted flood inundation pattern is very similar to that shown in Figure 4-2a for the existing situation.

Figure 6-2b shows the changes in peak flood depth between the proposed and existing situations for the 1% AEP flood adjusted for possible climate change effects. Peak flood depths are generally increased upstream of the Expressway crossing of the stream and floodplain due to the partial damming effect of the bridge approach embankments across the floodplain.

Table 6-2 summarises peak flood levels at common locations upstream of the Expressway for both the existing and proposed situations. Across the floodplain, the Expressway causes flood levels upstream of the 8m wide by 2.5m wide dry culvert on the left bank floodplain overflow path to increase by 0.84m and flood levels upstream of the 10m wide by 1.5m high dry culvert on the right bank floodplain overflow path (referred to as Cooper's Culvert by Coles and Bird (2012)) to increase by 0.48m. Figures 6-2a and b indicate that the extent of these increased flood levels is limited to a distance of only about 100m upstream of the Expressway stream crossing approach embankments. The affected areas are both used for pastoral purposes and are uninhabited.

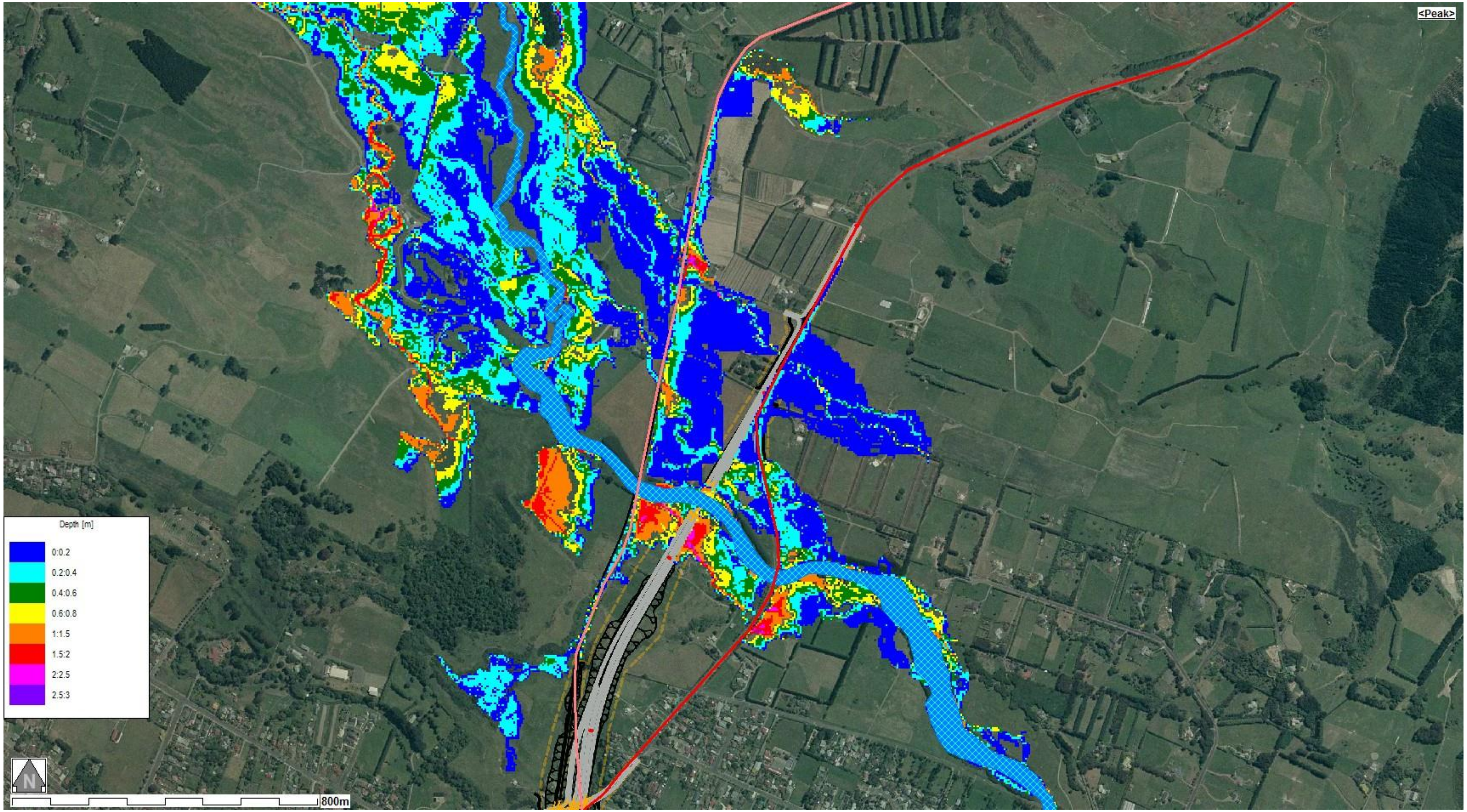

Figure 6-2a Predicted peak flood depths across the Waitohu Stream alluvial fan and floodplain system in proposed situation for 1% AEP flood adjusted for possible future climate change effects to 2090

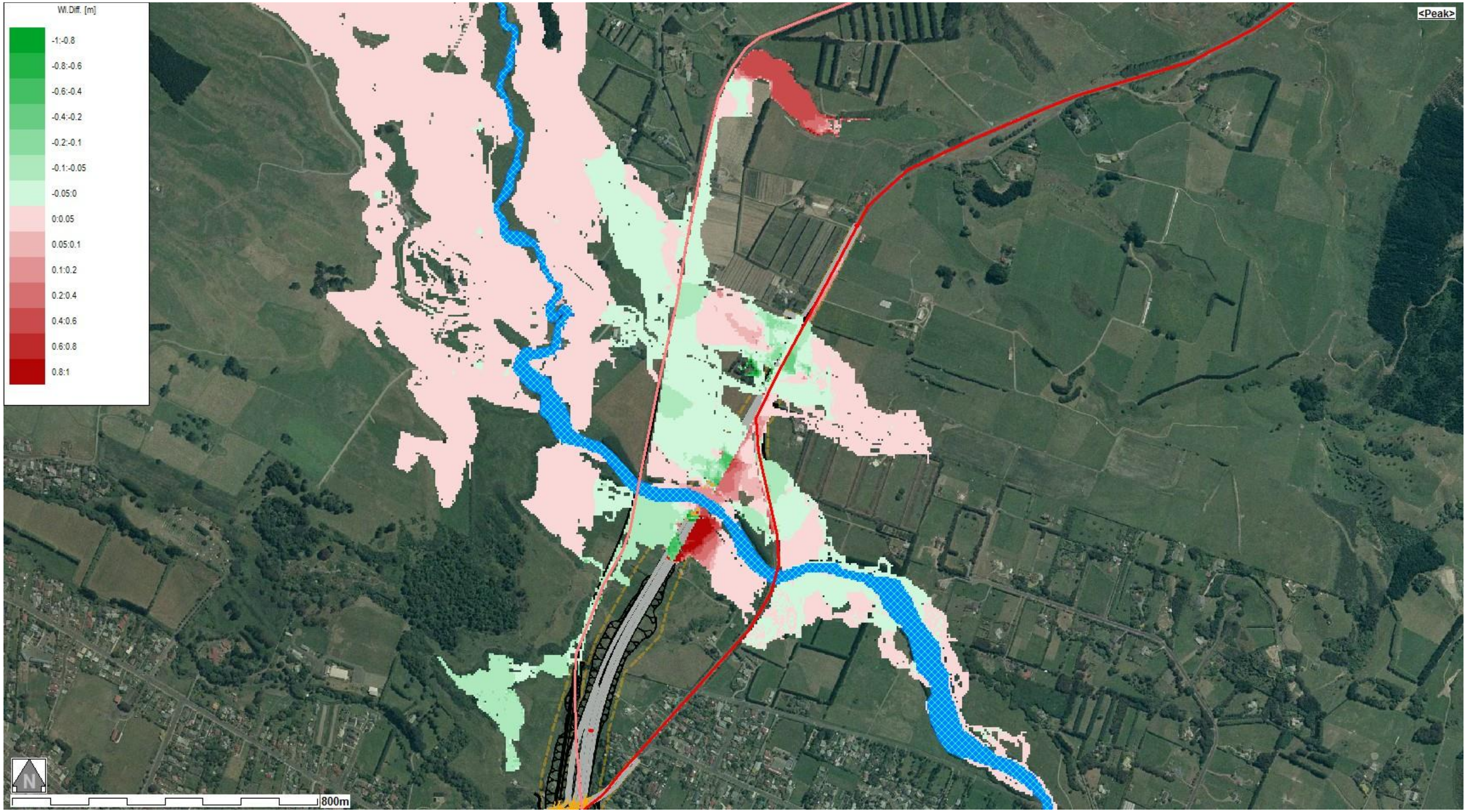

Figure 6-2b Changes in predicted peak flood depths across the Waitohu Stream alluvial fan and floodplain system between proposed and existing situations for 1% AEP flood adjusted for possible future climate change effects to 2090 (pink and red shading indicates areas of increased flow depths, green shading indicates areas of decreased flow depths)

Table 6-2 Predicted peak flood levels for existing and proposed situations for flood induced by 2 hour duration design 1% AEP rainfall adjusted for effects of possible future climate change to 2090

Location	**Peak Flood Level (m MSL Wellington (1953) datum)**		**Difference (m)**
	Existing Situation	Proposed Situation	
u/s of existing SH1 Bridge	30.62	30.62	0
u/s of dry culvert on southern approach embankment to proposed Expressway bridge	25.64	26.48	0.84
u/s of proposed Expressway bridge	25.54	25.70	0.16
u/s of dry culvert on northern approach embankment to proposed Expressway bridge	25.86	26.34	0.48
u/s of Greenwood sub-catchment culvert	25.15	24.29	-0.86
House 1 – Lot 1 DP 59942	no flood inundation	no flood inundation	-
House 2 – Pt Lot 2 DP59942	no flood inundation	no flood inundation	-
House 3 – Pt Pukehou SL7	23.28	23.19	-0.05

The increased inundation would also only be of limited duration (about 2.5 hours for the left bank overflow path and about 1 hour for the right bank overflow path for the 1% AEP flood adjusted for possible future climate change effects) as well as fairly rare.

In the main stream channel, the Expressway will cause flood levels to increase by 0.16m (Table 6-2) excluding the effect of the bridge piers. The two piers will be rectangular-shaped with a tapered nose and tail (measuring up to 3.1m long and 1.75m wide) and will induce additional head losses. The pier head losses for the 1% AEP flood adjusted for possible future climate change effects are estimated be about 0.09m for this flood (this assumes that the existing SH1 bridge remains unmodified[17] and limits the flow past it in a significant flood). Overall then the Expressway will cause flood levels to increase by up to 0.25m upstream of the bridge crossing in the main stream channel.

Except for the localised areas of increased peak flood depths immediately upstream of the Expressway seen in Figure 6-2b for the 1% AEP flood adjusted for possible future climate change effects, the rest of the floodplain upstream of these localised areas shows an apparent mix of increased (light pink shading) and decreased (light green shading) peak flood depths. However these correspond to peak flood depth differences of ±0.05m which is within the predictive accuracy of the MIKEFLOOD model across the floodplain. The effect of the Expressway would not be expected this far upstream in any case due to the steepness of the slope of the alluvial fan and floodplain. Therefore it can be reasonably concluded that the Expressway will have no influence on peak flood levels (and hence depths) upstream beyond the localised areas in front of the Expressway embankment. This conclusion also applies to the flood inundation area for the Greenwood sub-catchment upstream of the Expressway culvert (which also has light pink shading in Figure 6-2b).

Between the Expressway and the NIMT railway line, Figure 6-2b shows a mix of green and pink shading. In those areas where the shading is either light green of light pink (indicating peak flood depth differences of within ±0.05m) it is again reasonable to say that there is no real difference between the proposed and existing

[17] This assumption is based on the brief for the PP2O Project which excludes any remedial treatment of the existing SH1 bridge.

situations as the differences are within the predictive accuracy of the MIKEFLOOD model. However there is one area on the south bank of the Waitohu Stream along the NIMT railway line where the reduction in peak flood depths is slightly greater (up to 0.1m) which may be more credible. This could be caused by the containment of left bank floodplain flows by the Expressway embankment and the channelling of these flows through the large dry culvert in the embankment on that bank.

Downstream of the NIMT railway line, Figure 6-2b also shows a mix of light green and light pink shading indicating peak flood depth differences are within ±0.05m. Again it is reasonable to say that there is no real difference between the proposed and existing situations in this area as the differences are within the predictive accuracy of the MIKEFLOOD model.

Upstream of the new Greenwood sub-catchment culvert, Table 6-2 indicates that the peak flood level will be reduced by 0.86m for the 5% AEP flood (adjusted for possible climate change effects). However this reflects a localised drawdown effect of the significantly increased culvert capacity as the overland flow across the floodplain either side of the shallow vee-shaped meandering channel draining the sub-catchment is very shallow and unchanged from the existing situation (< 0.2m).

Peak flood levels for the 1% AEP flood (adjusted for possible future climate change effects) resulting from floodwaters breaking out along the right bank of the Waitohu Stream and flowing overland across the existing SH1 towards the Greenwood sub-catchment culvert are predicted to be within about 0.1m of the crest level of the Expressway. Allowing for the cross-fall on the road, this means that these peak flood levels would be approximately coincident with the shoulder of the road within about 100m south of the Greenwood sub-catchment culvert. Meanwhile peak flood levels on the north side of the Greenwood sub-catchment culvert resulting from the 5% AEP flood (adjusted for possible future climate change effects) in the Greenwood sub-catchment would be on the point of starting to spill over the road.

Two houses are located close to the flood inundation area upstream of the Greenwood sub-catchment culvert. However Table 6-2 indicates that these houses would not be inundated in either the existing or proposed situations.

There is one additional house on the downstream side of the Expressway along the Greenwood sub-catchment overland flow path. Table 6-2 indicates that there would be a reduction in peak flood depth at this location for the 5% AEP flood adjusted for possible future climate change effects in the Greenwood sub-catchment. However as has been argued previously, this is within the predictive accuracy of the MIKEFLOOD model so that it can only be concluded that the Expressway will not make the flood hazard affecting this house any worse than in the existing situation.

Figure 6-3a shows predicted peak flow velocities across the Waitohu Stream alluvial fan and floodplain system in the proposed situation for the 1% AEP flood adjusted for possible future climate change effects to 2090 in a similar fashion to the peak flood depths in Figure 6-2a. Figure 6-2b shows a zoomed-in part of Figure 6-1a around the existing SH1 and NIMT railway crossings of the Waitohu Stream and floodplain with velocity vectors superimposed to indicate the directions of overland flow paths (similar to Figure 4-6b for the existing situation). Similarly Figure 6-3c shows changes in peak flow velocity between the proposed and existing situations.

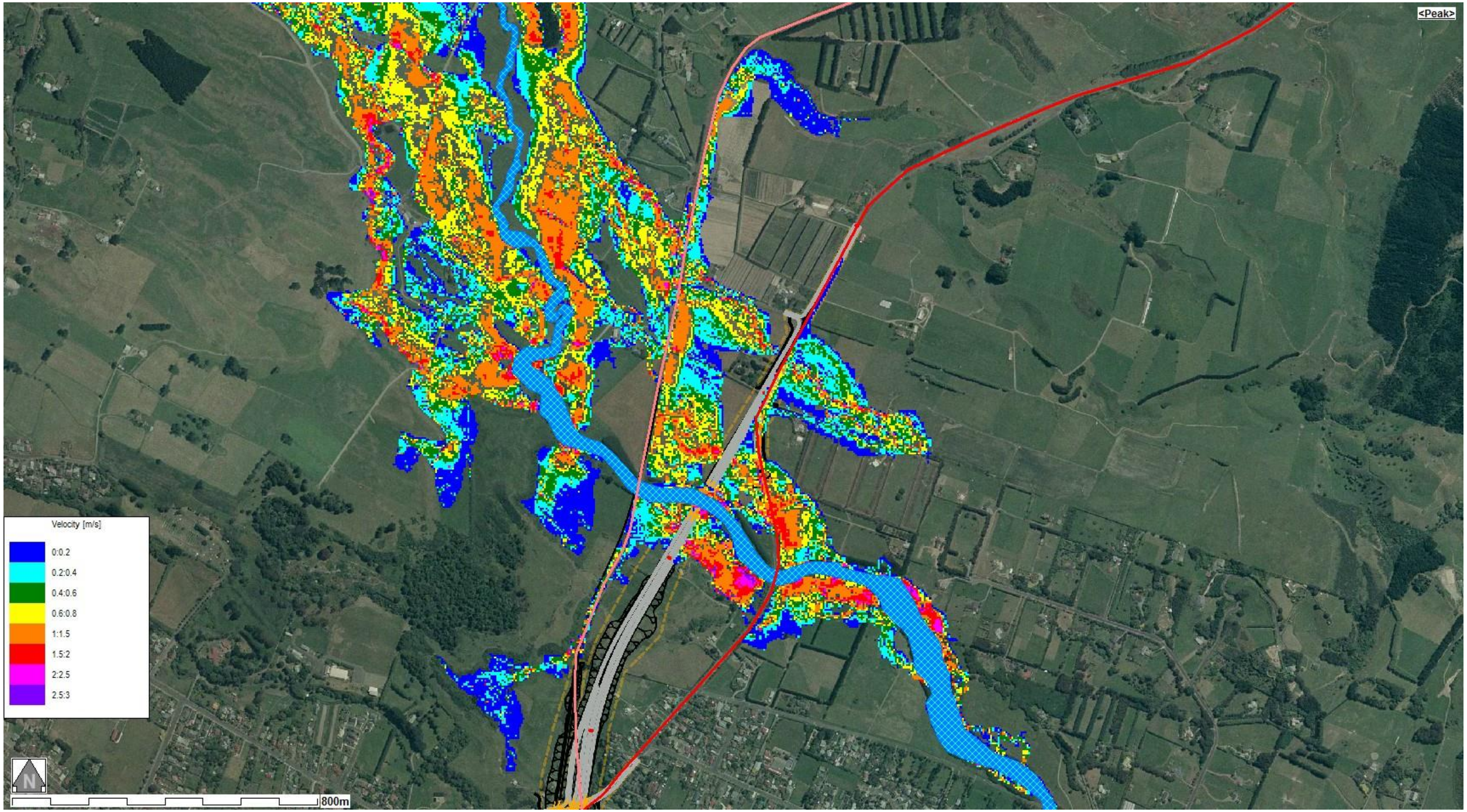

Figure 6-3a Predicted peak flow velocities across the Waitohu Stream alluvial fan and floodplain system in proposed situation for 1% AEP flood adjusted for possible future climate change effects to 2090

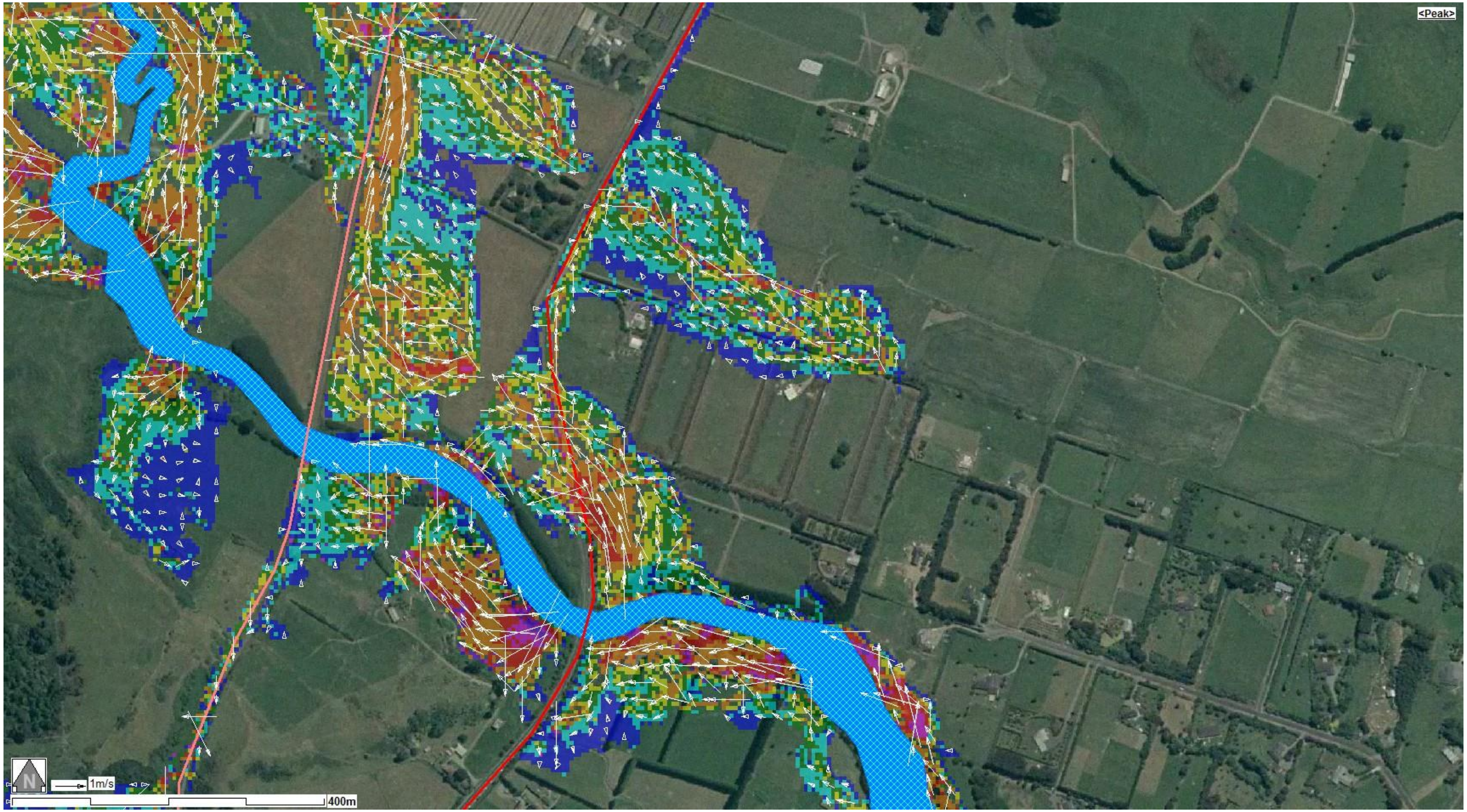

Figure 6-3b Blown-up section of Figure 5-6a showing directions of overland flow paths past the old SH1, new Expressway and NIMT railway crossings of the Waitohu Stream and floodplain

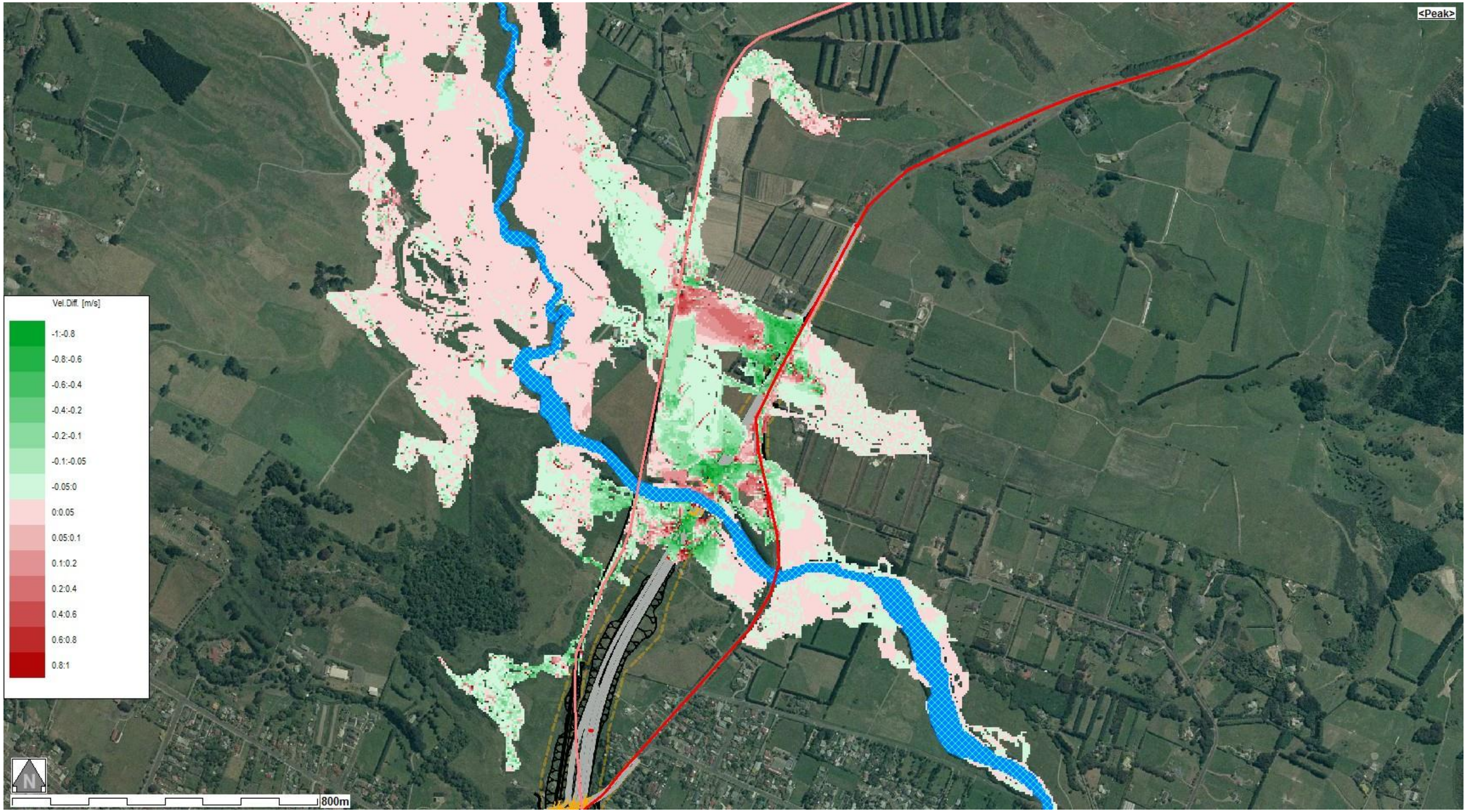

Figure 6-3c Changes in predicted peak flow velocities across the Waitohu Stream alluvial fan and floodplain system between proposed and existing situations for 1% AEP flood adjusted for possible future climate change effects to 2090 (pink and red shading indicates areas of increased flow depths, green shading indicates areas of decreased flow depths)

Figures 6-3c indicates that the Expressway causes a reduction in flood flow velocities along the floodplain overflow paths on both banks relative to the existing situation. This reflects the upstream ponding and downstream sheltering effects of the bridge approach embankments. Locally increased flow velocities through the dry culverts in both approach embankments will occur although the scale of the Figures 6-2a and c is too small to show these. Figure 6-2b shows the flow velocity vectors converging towards the entrance of these dry culverts and then diverging away from the exit.

Elsewhere across the floodplain, changes in peak flow velocities between the existing and proposed situations are minimal. The isolated spots of red indicating much larger increases in peak flow velocity, principally downstream of the NIMT railway line are almost certainly an artefact of model inaccuracy and do not reflect real differences. This area downstream of the railway line is well beyond the influence of the Expressway.

The partial blocking effect of the bridge approach embankments forces a redistribution of flood flows across the left and right bank floodplain.in the proposed situation. The flow volumes conveyed by these overland flow paths is quite significant in the existing situation (78m3/s and 25m3/s for the left and right bank floodplains respectively). These flow volumes could be reduced by up to about 30 per cent in both cases although the 75m wide bridge waterway has ample capacity to absorb the redistributed flow volume.

Peak flood levels upstream of the Expressway are only mildly sensitive to increases in the flood magnitude. For the 0.5% AEP adjusted for possible future climate change effects to 2090 which represents an increase in peak flood discharge of 25m^3/s (i.e. from 217m^3/s to 242m^3/s), peak flood level increases are expected to about:

- 0.16m upstream of the dry culvert on the south (left) bank;
- 0.09m on the mains stream channel (including the effect of bridge pier head losses); and
- 0.19m upstream of the dry culvert on the north (right) bank.

Again the effect of these increased ponding flood levels relative to the existing situation occur principally over a distance of less than 100m upstream of the Expressway approach embankments.

The potential for the culverts through the Expressway and Waitohu Stream bridge approach embankments to become partially blocked by flood-transported woody debris is considered to be very low because these culverts are normally dry and remote from the main stream channel. Any flood-transported woody debris would be confined predominantly to the main stream channel. If any large items of woody debris did get conveyed away from the main stream channel by breakout flows spreading across the floodplains, the shallow flow depths would be highly likely to ground these large items. The amount of wind-blown woody debris available from hedges and shelterbelts across the floodplains is not likely to be sufficiently large to induce a partial blockage of any of the culverts.

Any flood-transported woody debris conveyed by the main stream channel would tend to follow the higher velocities in the centre of the channel. Therefore, while the potential for such debris to be snagged by the piers on the proposed single bridge across the Waitohu Stream cannot be discounted, the potential is significantly reduced by the location of these piers outside the active bed of the stream. More significantly, any flood-transported woody debris would first need to get past the existing SH1 bridge. This latter bridge with its shorter span, lower height above stream bed level and much lower discharge capacity is much more likely to capture large woody debris conveyed by the Waitohu Stream.

Since the overall extent of flood inundation and the magnitude of the flow velocities across the alluvial fan and floodplain system predicted for the proposed situation are broadly similar to those for the existing situation, the proposed situation will not exacerbate the existing sediment deposition risk resulting from suspended sediment-laden floodwaters in front of the bridge approach embankments.

Floodplain drainage times from upstream of the Expressway in the proposed situation will be similarly unaffected.

It is conceivable that the existing SH1 bridge could be replaced sometime within the lifetime of the Expressway bridge over the Waitohu Stream and a new bridge built to a higher design standard. This scenario is considered in the detailed investigation report (Smith and Webby, 2013a). It was found that the resulting flood inundation pattern would differ very little from that shown in Figure 6-2a for the proposed Expressway situation with the existing SH1 bridge in place.

6.2 Potential Effects of Mangapouri Stream Crossing

6.2.1 Outline of Proposed Situation

Figure 6-4 shows an aerial photograph of the Mangapouri Stream in the SH1 / Rahui Road / NIMT railway line triangle with the layout of the Expressway and realigned NIMT railway line superimposed. The old NIMT railway alignment would be abandoned allowing the Expressway to make use of that corridor to the south of Rahui Road and through the Railway Wetland north of the existing SH1 overbridge over the railway line.

The existing NIMT railway culvert / County Road culvert system for throttling storm runoff from the Mangapouri Catchment will be retained. This means that the geometry of the primary flood storage basin on the Mangapouri Stream upstream of County Road and the existing railway embankment would remain fairly similar.

However there would be one significant change with the primary storage pond geometry. The location of the eastern approach embankment to the Rahui Road overbridge as shown in Figure 6-4 is such that it almost completely blocks the Rahui Road overflow path between the old Dairy Factory site to the west and the corner of Rahui Road and Te Roto Road in the east (refer to the Rahui Road overflow pattern for the existing situation in Figure 6-5). To allow for this blockage of the overflow relief path in the proposed situation, it will be necessary to incorporate a gap (or gaps) in the overbridge approach embankment. The gap in the Rahui Road approach embankment would best take the form of a large box culvert that is deep enough to ensure the occurrence of free surface flow conditions through it, wide enough section to minimise the head loss through it and set low enough to achieve an adequate discharge capacity.

One other effect of the Rahui Road overbridge construction will be the slight loss of storage volume in the primary flood storage basin on the Mangapouri Stream upstream of County Road and the existing NIMT railway embankment. However this could be partially compensated for by excavation of the area between the stream and the overbridge approach embankment.

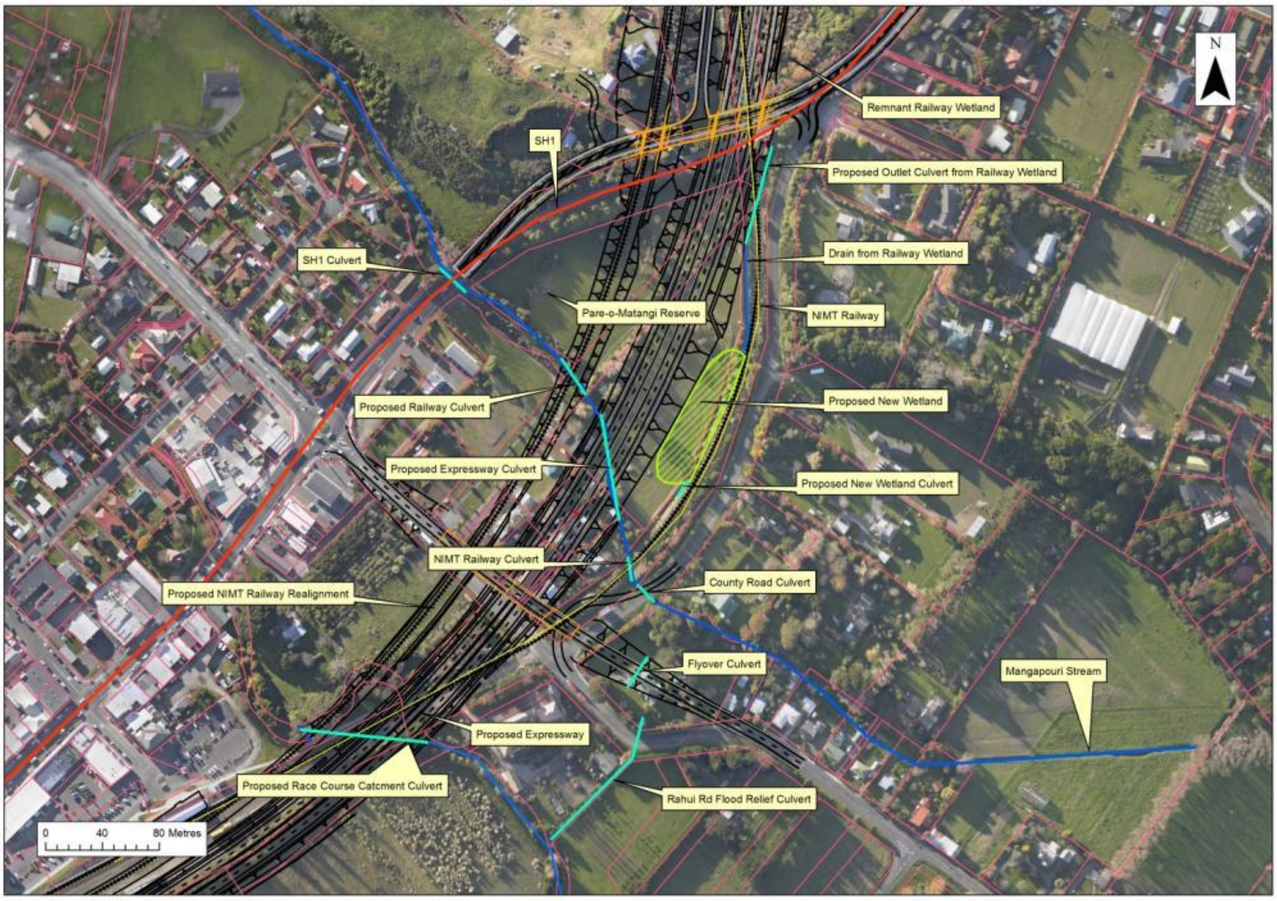

Figure 6-4 Aerial photograph of Mangapouri Stream in SH1 / Rahui Road / NIMT railway line triangle with layout of proposed Expressway and realigned railway line superimposed

Similarly the flood storage basin in the Pare-o-Matangi Reserve upstream SH1 will also be affected by loss of storage due to the Expressway embankment and the realigned NIMT railway passing through it.

There will be negligible flood storage volume available between the Expressway embankment and the realigned NIMT railway embankment.

The pattern of Rahui Road overflow seen in Figure 6-5 for the existing situation is very wide and shallow. The wide approach from the primary flood storage area to the overflow zone ensures that head losses are minimal with this overflow relief path. By contrast in the proposed situation, the contraction of flood relief flows into a narrow gap through the Rahui Road overbridge approach embankment and subsequent expansion out of the narrow gap to the wide overflow crest formed by Rahui Road means that overflow head losses will be much greater and it will be impossible to match the overflow discharge characteristics of Rahui Road in the current situation without some means of mitigation. Figure 6-6 shows a topographic relief map for the Rahui Road overflow zone with the layout of the proposed Rahui Road over-bridge superimposed.

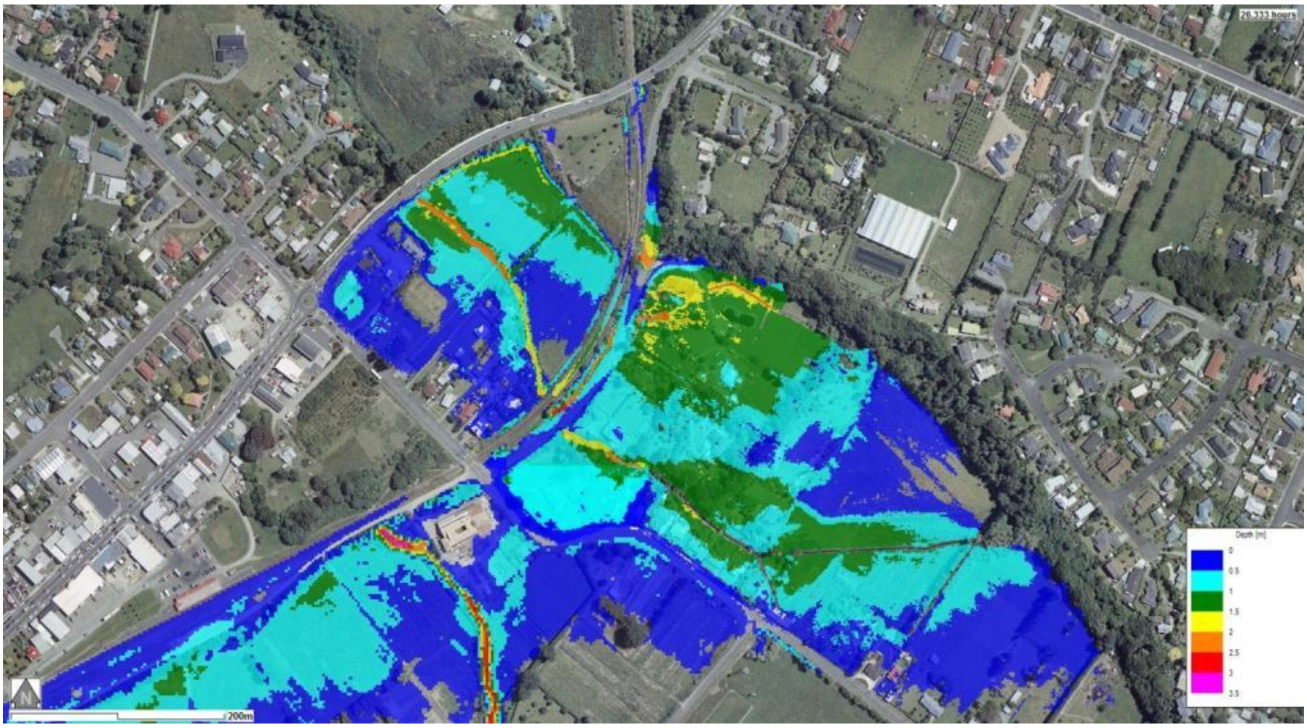

Figure 6-5 Predicted flood inundation extent for the 1% AEP flood adjusted for effects of possible future climate change to 2090 within the general area of the SH1 / Rahui Road / NIMT railway triangle for existing situation

Figure 6-6 Topographic relief map for Rahui Road overflow zone with layout of proposed Rahui Road over-bridge superimposed

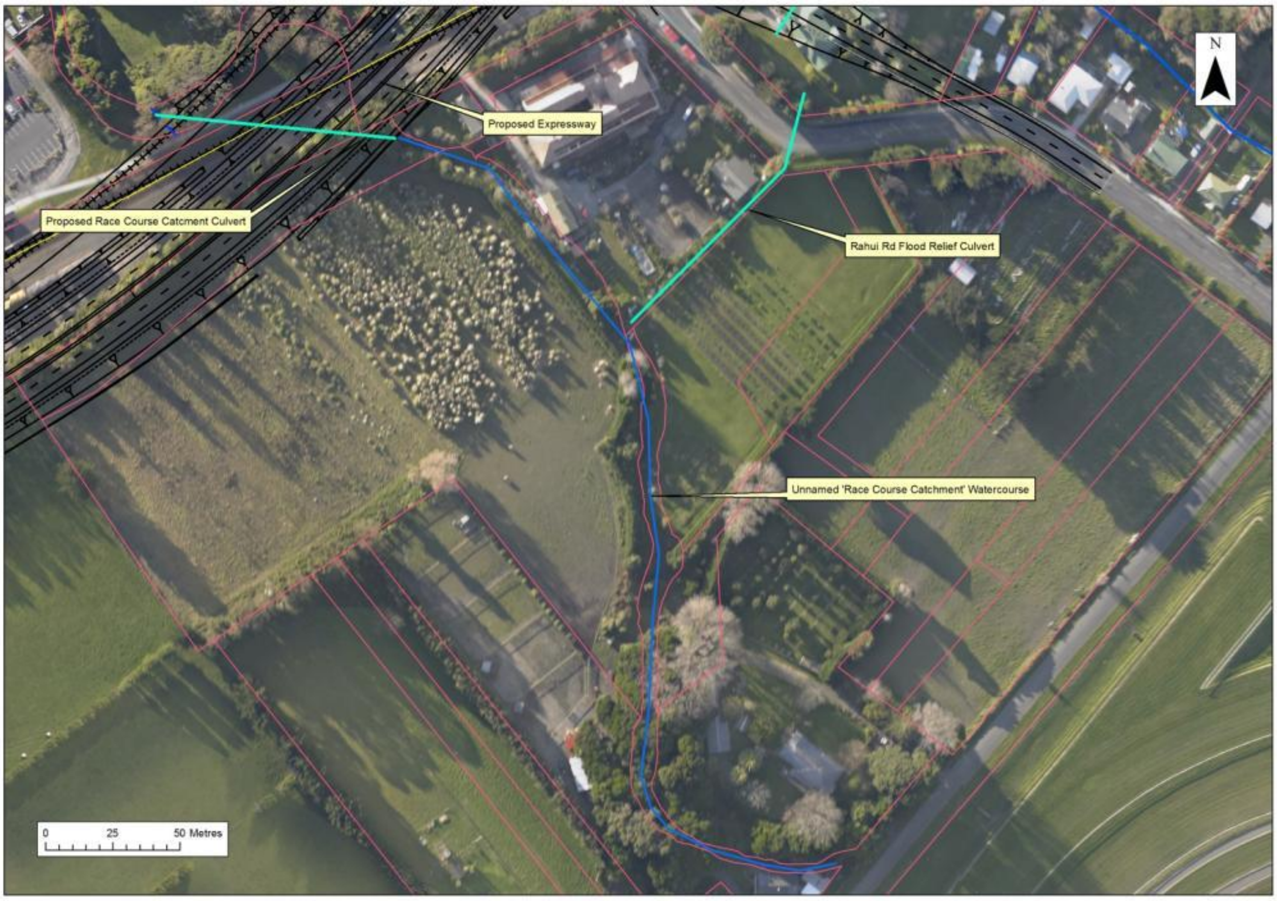

Figure 6-7 Aerial photograph showing drainage system for unnamed watercourse conveying storm runoff from part of Ōtaki Racecourse

The only way of emulating the current overflow discharge characteristics of Rahui Road is to incorporate a long relief culvert under Rahui Road to the unnamed watercourse that historically would have drained surface runoff from the racecourse area to the east. Figure 6-7 shows the route of this proposed relief culvert which has been selected to follow existing property boundaries to minimise disruption to their owners.

The unnamed watercourse into which this relief culvert is proposed to discharge currently conveys surface runoff via a 1.25m wide by 1.25m deep box culvert under the NIMT railway line and a 0.9m diameter culvert under SH1 to a dedicated soakage area on the grounds of Ōtaki College. As the existing railway line is being relocated to make way for the Expressway, the existing railway culvert will need to be replaced with a 95m long, 1.5m diameter culvert under both the Expressway and the realigned railway line.

It can be seen from the relief shading on the topographic plan in Figure 6-6 that road levels on Rahui Road are up to 0.4m higher around the bend where the proposed overflow relief culvert would be sited (Figure 6-7). One additional way of slightly improving the overflow discharge characteristics of the Rahui Road would be to locally reshape the vertical profile of the road to lower the level from about 15.0-15.2m MSL Wellington datum to approximately the same level as that further west (14.6-14.8m MSL Wellington datum).

A third means of slightly enhancing the overflow discharge characteristics of the Rahui Road in the proposed situation is to locally lower the level of the link road connection that loops around under the Rahui Road overbridge adjacent to the eastern abutment. This link road connection overlies the existing NIMT railway line and current ground levels would need to be lowered by about 0.4m to achieve this effect. Floodwaters breaking out of the primary flood storage basin and following this overflow path would flow around the inside of the overbridge abutment and then eastwards along Rahui Road to the overflow zone.

The new Mangapouri Stream culverts under the Expressway and the relocated NIMT railway line would be box culvert structures with the following characteristics:

- a width that approximately matches that of the existing stream;
- a depth that is large enough to ensure free surface flow conditions through the structure; and
- an invert that is deep enough to allow a surface layer of cobbles and large gravel material to be placed over it to form a natural stream bed through it.

The purpose of having a very deep box culvert section is to prevent the structure from heading up under extreme flood conditions and to ensure as much natural light can enter it to encourage fish passage up the structure.

The route of the Expressway passes through the Railway Wetland area as seen in Figure 6-4. The available storage volume for attenuating storm runoff from the Te Manuao Catchment will be significantly reduced. The face of the Expressway embankment will be used to form the western boundary of the remnant wetland.

Figure 6-8 Aerial photograph of Railway Wetland area and drainage system with layout of proposed Expressway superimposed

To compensate for the loss of storage volume in the remnant Railway Wetland, it is proposed to make use of the "dead space" between the old NIMT railway embankment and the Expressway embankment to the south of the new local link road overbridges to form a second wetland area in series with the remnant Railway Wetland (see Figure 6-8). The two wetland areas would be connected by a 75m long, 1m diameter pipe. Construction of the second wetland area would involve minimal excavation but would require:

- an approximately 3.5m high (above the basin invert) bund at the downstream end to impound the wetland; and
- lining of the inside face of the existing railway embankment with an impervious material to form a watertight barrier.

The impoundment bund for the proposed new wetland would incorporate a short 15m long, 1m diameter outlet pipe to the Mangapouri Stream and an emergency overflow spillway.

Table 6-3 summarises details of all the culverts along the Mangapouri Stream and the remnant Railway Wetland drainage system while Table 6-4 summarises details of the culverts along the unnamed watercourse draining the Racecourse Catchment.

Table 6-3 Culvert types, dimensions and levels for proposed situation in Mangapouri Stream in SH1 / Rahui Road / NIMT railway line triangle (existing culvert data in black, new culvert data in red)

Location	Type	Size (m)	Invert Level (m MSL Wellington)		Length (m)	Slope (%)	Road / Track Level (m MSL Wellington)
			u/s	d/s			
County Rd [1]	circular	1.2 (dia)	11.97	12.01	19.3	negative	14.39 [2]
NIMT railway [1]	custom-built arch	0.95 x 1.2	12.08	11.98	12.2	0.82	16.28 [3] 15.39 [4]
Rahui Rd overbridge	box	10 x 2	13.5	13.5	≈ 20	0.00	≈ 18.5
Rahui Rd overflow relief	box	1.5 x 0.5	13.6	12.6	115	0.87	14.6
Expressway	box	3 x 3 [7]	11.40 [8]	11.10 [8]	60	0.50	16.37
Realigned railway	box	3 x 3 [7]	10.90 [8]	10.88 [8]	20	0.10	not known
Existing SH1 [1]	twin circular	0.9 (dia)	11.06	10.96	20	0.50	13.74
Remnant railway wetland outlet	circular	1.0	17.5	16.2	75	1.73	20 [5]
Second wetland outlet	circular	1.0	13.45	11.8	15	11.0	15.50 [6]

[1] Details for these culverts obtained from Wellington Regional Council February 1998 report "*Ōtaki Floodplain Management Plan, Mangapouri Stream Upgrade, Hydraulic Modelling Report*", Report No. WRC/RI-T-97/48.
[2] Road levels further north from this culvert along County Road are lower than this level.
[3] Track level on existing railway embankment at culvert location.
[4] Road level on upstream shoulder of Expressway embankment beneath Rahui Road overbridge.
[5] Ground level at entrance to remnant railway wetland outlet culvert.
[6] Crest level of bund impounding wetland through which outlet culvert passes.
[7] Depth dimension given for these culverts is the height between the surface of the assumed cobble bed layer and the culvert soffit. The depth of the box culvert sections needs to be at least 3.5m to accommodate a 0.5m thick cobble layer.
[8] These invert levels are for the top level of the cobble invert layer in the culverts.

Table 6-4 Culvert types, dimensions and levels for proposed situation on unnamed watercourse draining part of Ōtaki Racecourse (existing culvert data in black, new culvert data in red)

Location	Type	Size (m)	Invert Level (m MSL Wellington)		Length (m)	Slope (%)	Road / Track Level (m MSL Wellington)
			u/s	d/s			
Combined Expressway / realigned railway	Box [1]	1.25 x 1.25 [1]	11.75	11.7	95	0.05%	15.19
Existing SH1	circular	0.9 (dia)	11.3	10.7	175	0.34%	13.59

[1] See note below on this culvert.

The new box culvert under the Expressway on the unnamed watercourse draining part of the Ōtaki Racecourse has been assumed to be the same size as the existing culvert (1.25m x 1.25m). However this size is a non-standard size for precast box culvert units and could be replaced with a standard 1.5m diameter pipe section which approximately matches the discharge characteristics of the existing box culvert, taking account of the increased overall culvert length for the alignment shown in Figure 6-7. Alternatively a 1.35m diameter pipe could be used on an alignment perpendicular to the Expressway which would be shorter but would require a diversion of the downstream drainage channel.

6.2.2 Effects of Expressway Crossing

The primary flood storage basin for the Mangapouri Stream is a special case. It is not strictly a "floodplain" but a dedicated flood storage area "designed" to relieve flood risks further downstream through Ōtaki Township. Whereas the standard flood test that has generally been applied to other floodplain areas (except the Ōtaki River floodplain which is another special case) is the 1% AEP flood adjusted for possible future climate change effects to 2090, we have considered it important to cover a much wider range of floods in the case of the Mangapouri Stream because of the special function of the primary flood storage basin upstream of the existing County Rd and NIMT railway culverts. In addition to the standard 1% AEP flood adjusted for possible future climate change effects, we have also considered the larger magnitude but lower probability 0.5% and 0.2% AEP floods adjusted for possible future climate change effects as well as a range of smaller magnitude floods.

Table 6-5 summarises peak flood levels through the detention pond system predicted by the MIKE11 model for the different floods. These are sourced from the companion detailed investigation report for the Expressway crossing of the Mangapouri Stream (Smith and Webby, 2013a).

Table 6-5 Predicted peak flood levels for proposed situation in Mangapouri Stream (data for current situation in brackets)

Flood Case (AEP %)	Peak Flood Level (m MSL Wellington datum)					
	Upstream of County Road culvert	Upstream of old railway culvert	Upstream of Expressway culvert	Upstream of old SH1 culvert	Remnant Railway Wetland area	Second wetland area
42.9	14.07 (14.18)	13.50 (13.57)	12.77	12.72 (12.64)	18.33 (19.15)	14.22
20	14.25 (14.36)	13.60 (13.93)	12.97	12.92 (12.92)	18.48 (19.50)	14.37
10	14.38 (14.45)	14.08 (14.44)	13.25	13.20 (13.31)	18.60 (19.55)	14.48
5	14.47 (14.60)	14.46 (14.60)	13.49	13.45 (13.43)	18.73 (19.59)	14.57
2	14.67 (14.81)	14.67 (14.81)	13.65	13.60 (13.57)	18.92 (19.63)	14.70
1	14.79 (14.86)	14.79 (14.86)	13.75	13.70 (13.63)	19.07 (19.66)	14.78
1 + CC to 2090	14.88 (14.92)	14.88 (14.92)	13.81	13.76 (13.72)	19.31 (19.70)	14.93
0.5 + CC to 2090	14.97 (14.95)	14.97 (14.95)	13.82	13.77 (13.76)	19.51 (19.72)	15.04
0.2 + CC to 2090	15.11 (14.99)	15.11 (14.99)	13.85	13.78 (13.77)	19.80 (19.75)	15.15

The Mangapouri Stream in the SH1 / Rahui Road/ County Road triangle continues to behave approximately as a twin detention pond system in series as in the existing situation. In particular the County Road and old railway culverts behave in the same manner as they are unchanged from the existing situation.

The invert level of the proposed Rahui Road flood relief culvert has been set fairly low so that it comes into operation in much lower floods (the 10m wide culvert through the Rahui Road approach embankment has also been set fairly low and a connection with the Mangapouri Stream excavated in front of it to facilitate operation of the flood relief culvert). However the flood relief culvert has been purposely limited in size so that the volume of outflow released through it is constrained. Incorporation of the Rahui Road flood relief culvert means that the existing overflow discharge characteristics are able to be approximately reproduced except at very high primary flood storage pond levels.

The net effect of the modified Rahui Road overflow discharge relationship is that lower flood levels are predicted in the primary flood storage basin on the Mangapouri Stream upstream of the old railway embankment in the proposed situation (Table 6-5) for all except the two largest floods. In particular:

- for the 1% AEP flood adjusted for possible future climate change effects, the peak flood level would be 0.04m lower than in the existing situation;
- for the 0.5% AEP flood adjusted for possible future climate change effects, the peak flood level would be 0.02m higher than in the existing situation; and
- for the 0.2% AEP flood adjusted for possible future climate change effects, the peak flood level would be 0.12m higher than in the existing situation.

Note that in these floods, there would also be widespread inundation through Ōtaki Township due to the limited capacities of the urban stormwater system and the Mangapouri Stream below the SH1 culvert, as indicated by the KCDC flood hazard map for the Ōtaki area.

The results given in Table 6-5 are based on the assumptions that all Te Manuao Catchment flows are directed to the remnant Railway Wetland rather than the primary flood storage basin, and that all surface runoff from the Racecourse part of the Mangapouri Catchment enters the primary storage basin. As noted previously, these assumptions are not necessarily correct but they are conservative (they are examined further with the aid of sensitivity tests reported in the companion detailed investigation report (Smith and Webby, 2013a)).

Figure 6-9 shows predicted flood depths and extent of inundation for the 1% AEP flood (adjusted for possible future climate change effects to 2090) within the general area of the SH1 / Rahui Road / old railway embankment triangle and the Rahui Road overflow zone. In contrast to the existing situation flood inundation map in Figure 6-5, Figure 6-9 takes account of the inflow contribution from the upstream Racecourse Catchment and the outflow via the 1.35m diameter culvert under the Expressway on the unnamed watercourse to the south (Figure 6-7).

The flood storage inundation pattern shown in Figure 6-9 is much the same as that shown in Figure 6-5 for the existing situation for the same size flood. This is not surprising given that the peak flood levels in the primary and secondary flood storage basins are predicted to be 0.04m lower and 0.04m higher respectively for the 1% AEP flood adjusted for possible future climate change effects to 2090 (see data in Table 6-5 for upstream of County Road culvert and upstream of old SH1 culvert).

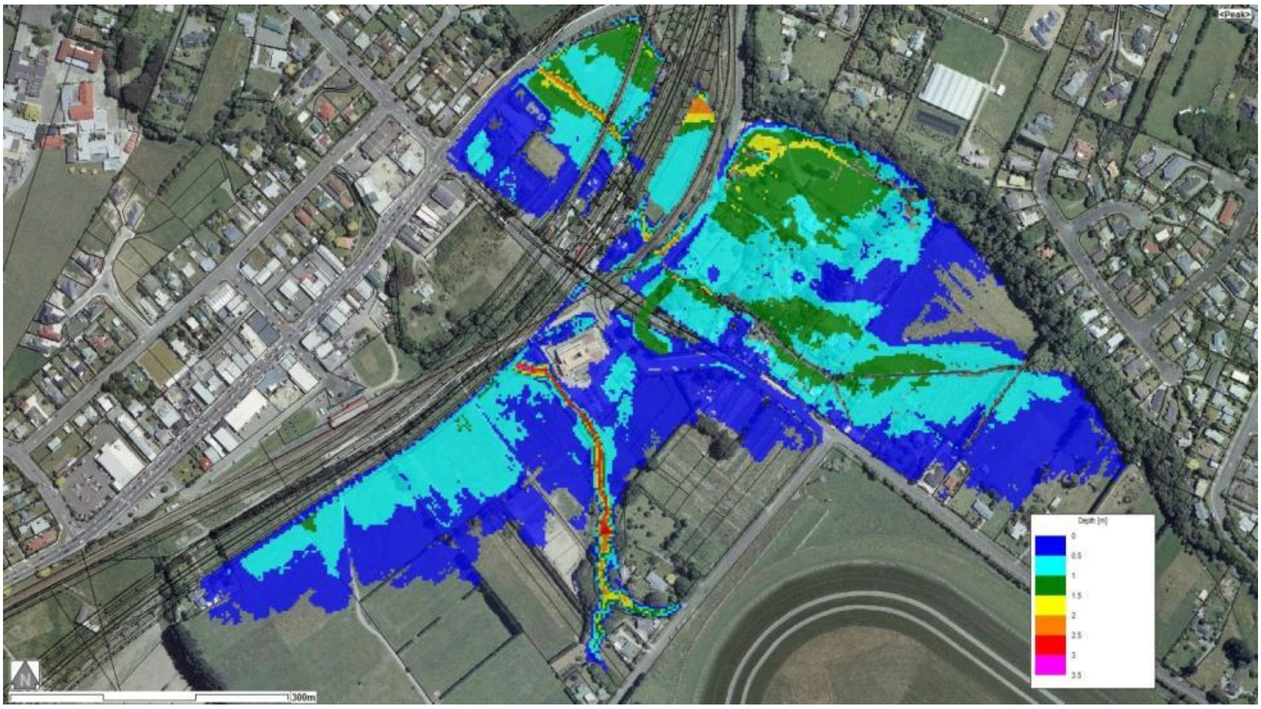

Figure 6-9 Predicted flood inundation extent for the 1% AEP flood adjusted for effects of possible future climate change to 2090 within the general area of the SH1 / Rahui Road / NIMT railway triangle for the proposed situation

Figure 6-9 also confirms the uncertainty identified with respect to the path of surface runoff from the northern part of the Ōtaki Racecourse (assumed to be within the Mangapouri Catchment area) with overland flow shown across the intersection of Te Roto Road with Rahui Road and spreading into the unnamed watercourse. The extent of inundation in the Pare-o-Matangi Reserve is constrained by the physical boundaries of the Reserve (including the new railway embankment) and flood inundation depths are not significantly different between the two flood cases. The floodplain area on the downstream side of the Expressway was not included within the MIKE21 floodplain model although the model predictions of flood levels upstream of the SH1 culvert on the unnamed watercourse imply that widespread inundation of this area would start to occur between a 5% AEP and 2% AEP flood even in the existing situation.

The culvert under the Expressway on this unnamed watercourse has been deliberately sized to match as closely as possible the discharge characteristics of the existing 1.25m wide by 1.25m deep culvert under the NIMT railway line.

Peak flood levels in the secondary flood storage basin in the Pare-o-Matangi Reserve upstream of SH1 (which is much reduced in size due the Expressway construction and NIMT railway realignment) are lower for floods smaller than the 5% AEP flood and slightly higher for floods larger than this. For the two largest floods considered, the differences are within 0.01m as by then overtopping of the road has occurred. For the intermediate sized floods (2% AEP flood, 1% AEP flood and 1% AEP flood adjusted for possible climate change effects), the flood level increases are slightly larger (up to 0,07m for the 1% AEP flood and 0.03-0.04m for the other two floods). The reason for this slightly adverse change relative to the existing situation for the intermediate sized floods is primarily the loss of flood storage within the basin. This is despite the increased attenuation efficiency of the twin wetland system on the remnant Railway Wetland branch which markedly attenuates inflows from the Te Manuao Catchment relative to those for the existing situation for all floods larger than the 2% AEP flood.

The remnant Railway Wetland has peak flood levels substantially lower than those for the existing situation (Table 6-5) for all except the largest flood considered, the 0.2% AEP flood adjusted for possible future climate change effects to 2090 (flood levels would start to overtop the Expressway at about a level of 20.0m MSL Wellington datum).

The peak flood level predictions in Table 6-5 are based on the assumption of all Te Manuao Catchment flows entering the remnant Railway Wetland without any being diverted to the primary flood storage basin on the Mangapouri Stream which is conservative but not necessarily correct. If a significant proportion of the runoff from the Te Manuao Catchment was diverted directly to the primary flood storage basin on the Mangapouri Stream, then this would give rise to slightly higher peak flood levels in the primary flood storage basin and lower peak flood levels in the secondary flood storage basin in the Pare-o-Matangi Reserve. Peak flood levels in the remnant Railway Wetland and the second downstream wetland (see Figure 6-8) would, not surprisingly, be significantly lower.

Figure 6-10 shows the number of houses affected by flood levels in the primary flood storage basin on the Mangapouri Stream in the proposed situation for a range of flood magnitudes[18]. Because peak flood levels in the primary storage basin are predicted to be slightly lower in the proposed situation (with the Expressway)

[18] This house count excludes those properties which need to be acquired for the Project as they fall within the footprint of the proposed works.

compared to the existing situation, the number of houses with inundated floor levels would be generally slightly lower for floods up to and including the 1% AEP flood adjusted for possible future climate change effects to 2090 and either the same or increased by one for the two floods larger than this[19].

It is important to emphasise that these effects, even though they are reduced in the proposed situation compared to the existing situation, are entirely a consequence of the deliberate decision in the past by the responsible local authorities to restrict the size of the existing railway culvert in order to throttle down-stream flood flows.

In the case of the 0.5% AEP flood adjusted for possible climate change effects, the proposed situation will result in a peak flood level within the primary flood storage basin (and hence floor level inundation depths) 0.02m higher than in the existing situation. For six of the affected houses, the relative increases in floor level inundation would be very small as the predicted inundation depths in the existing situation are already large (0.27-0.94m). For the other two affected houses, the relative increases in floor level inundation with the Expressway would be much larger as the predicted inundation depths in the existing situation are very low (less than 0.05m) although the actual increases would remain low in the proposed situation (less than 0.07m).

In the case of the 0.2% AEP flood adjusted for possible climate change effects, the proposed situation will result in a peak flood level within the primary flood storage basin (and hence floor level inundation depths) 0.12m higher than in the existing situation. As with the 0.5% AEP flood adjusted for possible future climate change effects, for six of the affected houses, the relative increase would be modest as the predicted inundation depths in the existing situation are already large (0.31-0.98m). For the four other affected houses, the relative increase in floor level inundation with the Expressway would be more significant as the predicted inundation depths in the existing situation are low. The inundation depths would increase from less than 0.00-0.09m in the existing situation to 0.06-0.21m in the proposed situation.

Figure 6-11 shows the number of houses affected by flood levels in the secondary flood storage basin (within the Pare-o-Matangi Reserve) on the Mangapouri Stream for the proposed situation[3]. The small number of properties affected remains the same in both the proposed (with the Expressway) and existing situations. However the impact of elevated flood levels on these properties could be easily mitigated in the following manner.

[19] The effects on individual properties have been assessed, based on property information and floor levels provided by KCDC and GWRC, which have formed the basis of this effects assessment. While it is possible to list individual buildings and the increased effects on them, this has not been done for various reasons, including because:

- we would be reluctant to release this information without the NZ Transport Agency first having the opportunity to discuss potential effects with the relevant landowners (we understand this is to occur shortly); and
- this information would add little to our assessment, because of the small increases in effect that have been assessed to occur (0.02m or 0.12m) and the rarity of the flood events considered (0.2% AEP and 0.5% AEP).

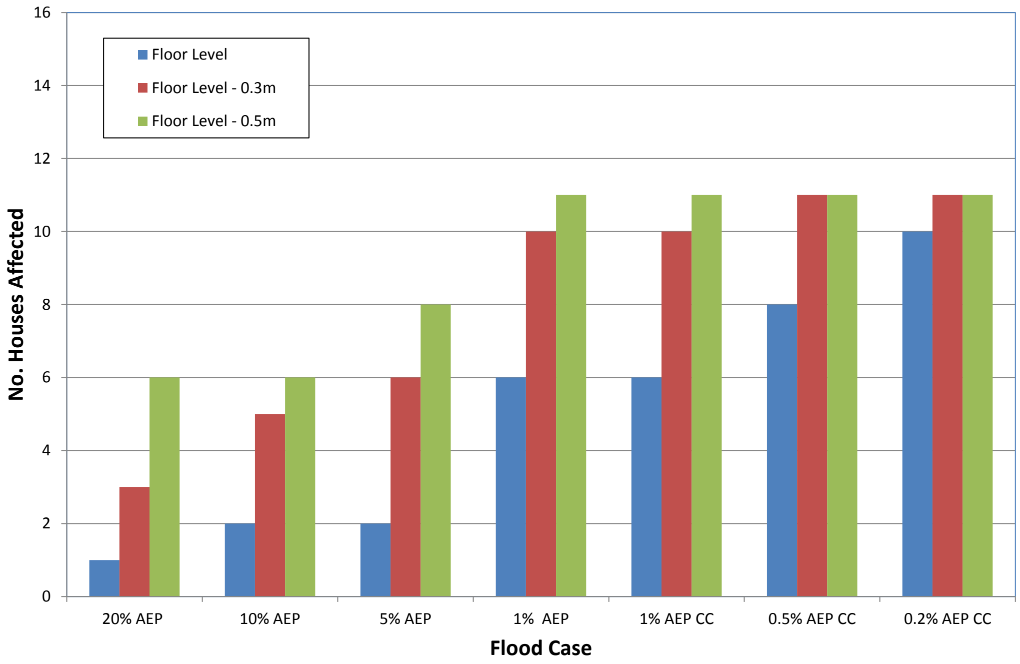

Figure 6-10 Number of flood affected houses in proposed situation along County Road and Rahui Road upstream of old railway culvert on Mangapouri Stream (excluding properties required for Expressway)

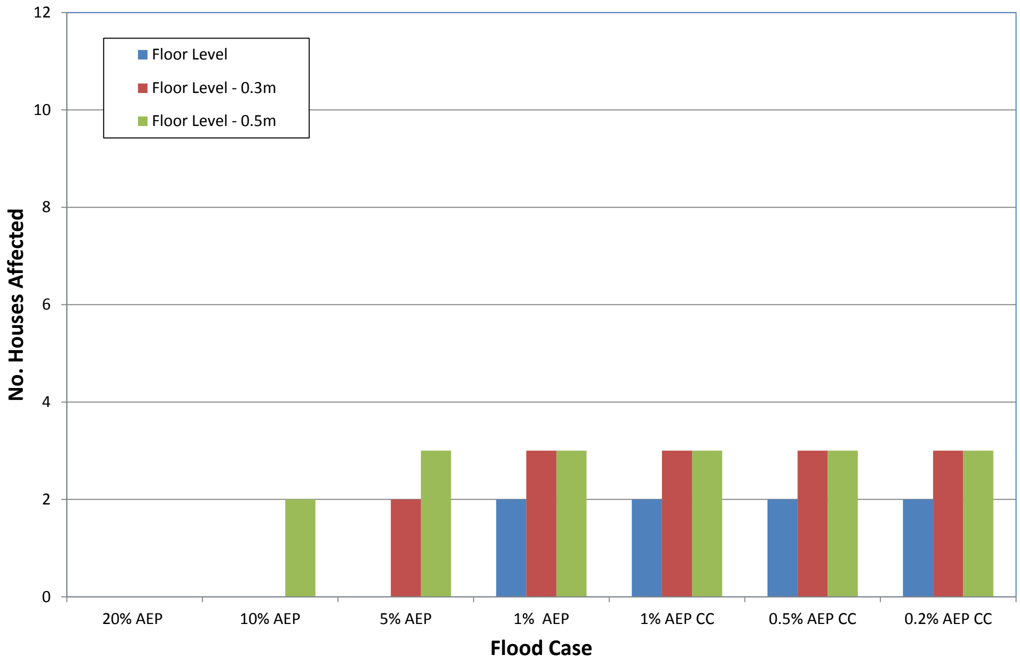

Figure 6-11 Number of flood affected houses in proposed situation along SH1 and Rahui Road between old railway culvert and SH1 culvert on Mangapouri Stream (excluding properties required for Expressway)

As part of the landscaping of the Pare-o-Matangi Reserve associated with construction of the Expressway, a low bund will be formed along the boundaries of the five remaining properties on the corner of SH1 and Rahui Road (this low bund would be entirely within the area of the Reserve)[20]. The purpose of this bund would be to prevent the ingress of floodwaters from the secondary storage pond within the Reserve onto these properties. Floodwaters from the flood storage pond would start to overtop SH1 to the north of these properties in about a 2% AEP flood and Rahui Road to the east in about a 1% AEP flood. Floodwaters overtopping these roads would spread along them and could potentially backflow into the corner properties protected by the low bund along their boundaries with the Reserve.

The low bund protecting these corner properties would not have the effect of further reducing the flood storage capacity of the Pare-o-Matangi Reserve.

6.3 Potential Effects of Ōtaki River Crossing

The proposed twin parallel Expressway bridges crossing the Ōtaki River have no real effect on the backwater profiles along the main river channel. The bridge abutments have been set back from the edge of the active river channel so that the total span length closely matches that of the existing NIMT railway bridge and therefore does not induce any backwater effect upstream. The piers supporting the superstructure of each bridge however are widely spaced to minimise the total number of piers. The pier head losses with such a wide spacing are minimal (~ 0.01-0.02m). However these head losses would increase if the bridge piers snagged flood-transported woody debris, thereby reducing the actual freeboard (the downstream NIMT rail and SH1 road bridges with their lower soffit levels pose more of a risk with respect to this particular hazard).

The northern approach embankment to the twin bridge crossings of the Ōtaki River bisects the off-channel storage basin on the right bank occupied by the Stresscrete concrete factory. The effect of this is to partially dam the floodwaters in the basin such that a water level differential is created across the Expressway embankment as seen in Figure 6-12. Water levels in the off-channel storage basin remain approximately horizontal on either side of the Expressway embankment. However the magnitude of the water level differential across the embankment increases with the magnitude of the flood.

Floodwaters enter the off-channel storage basin occupied by the concrete factory over lower bank levels at the downstream end although, for more extreme floods, they also spill over higher ground into the basin at the upstream end. This backfilling of the storage basin primarily from the downstream gives rise to the following stopbank overtopping behaviours with different sized floods for the Chrystall's Bend stopbank around the perimeter of the storage basin:

- the stopbank would still contain the 1% AEP flood as in the existing situation with a freeboard of about 0.6m;
- the stopbank would just start to be overtopped by a 0.2% AEP flood (for existing climate conditions) over a distance of about 100m upstream of the Expressway embankment and between the Expressway embankment and the NIMT railway embankment;

[20] The location of this low bund is shown on the Sheet 2 of the Drainage Plan (Drawing 5/2664/1/6504/DR02).

- due to the way the concrete factory flood storage basin fills from the main river channel, the Expressway embankment acting as a partial dam causes flood levels upstream of the embankment in a 0.2% AEP flood to be about 0.4m lower than those downstream between the Expressway embankment and the NIMT railway embankment;
- the stopbank would be overtopped by up to 0.45m in a 0.2% AEP flood adjusted for possible climate change effects to 2090 over a distance of about 200m upstream of the Expressway embankment; and
- the stopbank would be overtopped by up to 0.2m in a 0.2% AEP flood adjusted for possible climate change effects to 2090 between the Expressway embankment and the NIMT railway embankment.

Compared to the existing situation then, the effects of the Expressway crossing of the Ōtaki River are only minor. The depth of overtopping of the existing Chrystall's Bend stopbank upstream of the approach embankment to the bridge crossing is slightly increased only for the 0.2% AEP flood adjusted for possible climate change effects to 2090 (~ 0.3m, see Figure 6-12).

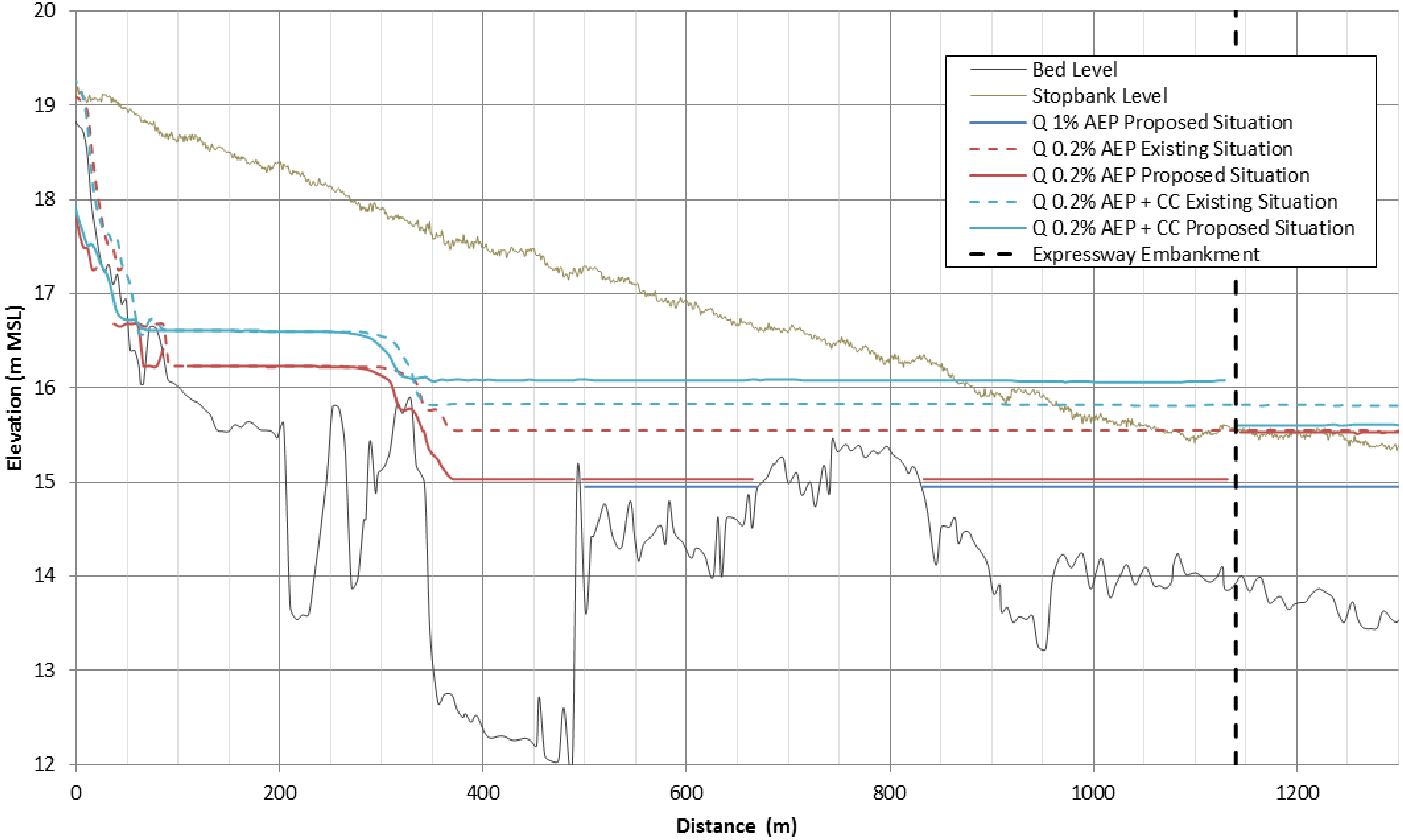

Figure 6-12 Peak flood levels along Chrystall's Bend stopbank past concrete factory for range of floods in existing and proposed situations (left hand axis coincides with where stopbank veers away from river, right hand axis corresponds to location of NIMT railway embankment)

Gravel extraction currently takes place in the main river under a regime managed by GWRC. The twin bridges forming the Expressway crossing of the Ōtaki River will not hinder this process. As long as the extraction regime is based on sustainable management principles with the extraction rate no greater than the long term delivery rate by floods (recognising that this rate from year to year varies depending on the amount of flood activity experienced) and the extraction sites are spread along the river, then bed levels should not significantly degrade or aggrade over time and affect flood level profiles past the bridge. There may be some temporal variation over time in bed levels but regular ongoing monitoring of cross-sections along the main river can highlight adverse bed level changes and allow appropriate corrective action to be taken with respect to the gravel extraction regime.

6.4 Potential Effects of Ōtaki River Floodplain Crossing

6.4.1 Outline of Proposed Situation

The following mitigation measures are required to reduce the blocking effects of the Expressway embankment on stopbank overtopping flows flowing across the Ōtaki River floodplain:

- a secondary flood containment bund projecting upstream of the Expressway embankment roughly parallel with the main river channel (secondary containment bund in Figure 6-13);
- a dry culvert through the Expressway embankment immediately to the north of the Chrystall's Bend stopbank (dry culvert in Figure 6-13); and
- re-shaping the vertical alignment of the Expressway embankment between the Chrystall's Bend stopbank and the secondary flood containment bund to form a preferential weir overflow path across the roadway for stopbank overtopping flows (overflow weir zone in Figure 6-13).

The location of these mitigation measures is illustrated in Figure 6-13.

6.4.2 Effects of Expressway Crossing

Figure 6-14 shows peak flood level profiles for the proposed situation along a curved section across the floodplain immediately upstream of the horizontal alignment of the Expressway embankment. These profiles are for a 0.2% AEP flood and a 0.2% AEP flood adjusted for possible climate change effects to 2090.

Based on the results of the hydraulic model simulations shown in Figure 6-14, the following flood mitigation measures are required to provide satisfactory downstream flood inundation behaviour:

- a 350m long, approximately 1.75m high secondary flood containment bund in the approximate location shown in Figure 6-13;
- a 40m wide dry culvert through the Expressway embankment located approximately as shown in Figures 6-13 and 6-14; and
- a road overflow weir section along the Expressway embankment measuring approximately 300m long with a minimum crest level of 15.3m (MSL Wellington datum) and rising up to about 15.8m (MSL Wellington datum) to the north of the line of the secondary flood containment bund and then falling again beyond this high point.

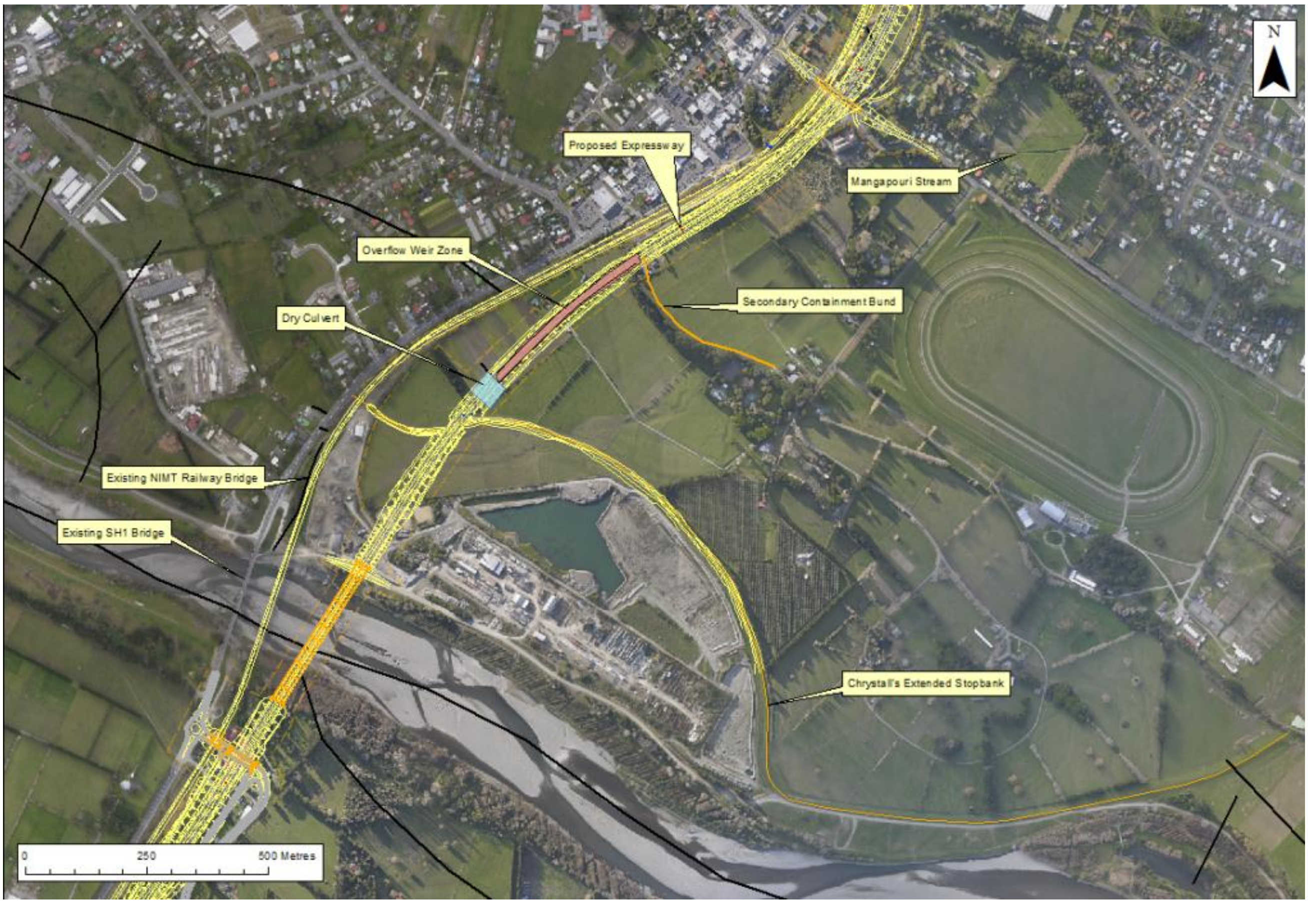

Figure 6-13 Proposed mitigation measures to reduce blocking effects of PP2O Expressway embankment on stopbank overtopping flows flowing across Ōtaki River floodplain

Figure 6-14 shows that with the optimised overflow weir geometry, stopbank overtopping flows arising from a 0.2% AEP flood (approximately equal to a 1% AEP flood adjusted for possible climate change effects to 2090) would be able to be passed through the Expressway embankment without the embankment being overtopped.

However stopbank overtopping flows arising from a 0.2% AEP flood adjusted for possible climate change effects would overtop the Expressway embankment within the overflow weir section by up to 0.5m for a duration of at about 2.5 hours.

The design flood standard for the Expressway embankment would therefore be at least the 0.2% AEP flood with a design freeboard value in the order of 0.6m from the predicted water surface profile to the low point on the modified vertical profile for the Expressway embankment which forms the weir flow section.

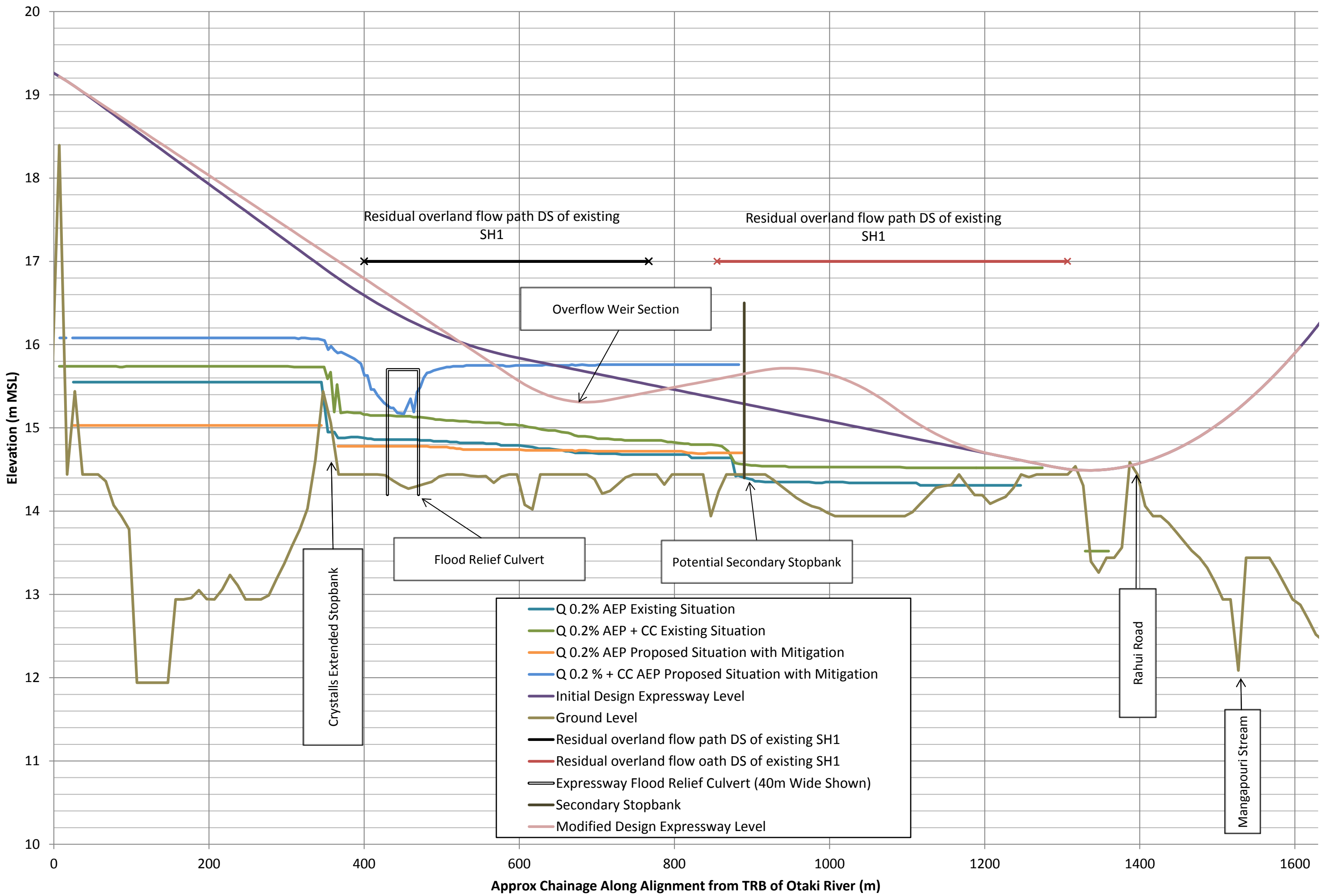

Figure 6-14 Predicted flood levels across the Ōtaki River floodplain along a curved line immediately upstream of proposed Expressway for floods overtopping Chrystall's Bend stopbank in proposed situation

The modified vertical profile for the Expressway shown in Figure 6-14 is an interim modification and has yet to be formally incorporated in the final design concept. It has been modelled geometrically on the basis of the results of the computational hydraulic model simulations to confirm that it is in fact feasible to modify the vertical alignment in this manner. It may be possible to refine the alignment further by shifting the whole of the overflow weir section southwards towards the Ōtaki River crossing so that high point at the north end coincides with the line of the secondary containment bund.

Figure 6-15 shows a map of peak flood inundation depths across the floodplain for the Expressway situation incorporating the above mitigation measures for stopbank overtopping resulting from a 0.2% AEP flood adjusted for possible climate change effects assuming that the stopbank can sustain the depth and duration of overtopping (the effects of stopbank breaching in the proposed situation are considered in the detailed investigations report (Smith and Webby, 2013c)) as the ability of the stopbank to sustain the predicted level of overtopping is uncertain

Figure 6-16 shows a peak flood depth difference map between the proposed (Figure 6-15) and existing situations (Figure 4-5) across Ōtaki River floodplain resulting from stopbank overtopping by a 0.2% AEP flood adjusted for possible future climate change effects. Although this map indicates that peak flood depths through Ōtaki Township are marginally lower compared to those for the existing situation, the flood depth differences over this part of the floodplain are within the order of accuracy of the model predictions. Flood depths through Ōtaki Township induced by the Expressway embankment incorporating the optimised mitigation measures outlined above are therefore no worse than those in the current situation. Peak flood depths are increased by up to 0.9m within the area of the secondary containment bund upstream of the Expressway embankment but this area is uninhabited. Peak flood depths are locally increased around the exit from the large dry culvert through the Expressway embankment but this area is also uninhabited. Peak flood depths through the basin in which the Stresscrete concrete factory is located are also increased although this basin is outside the stopbank protecting Ōtaki Township and is directly exposed to floods in the Ōtaki River.

Figure 6-17 shows a map of peak flow velocities across the floodplain for stopbank overtopping flows in a 0.2% AEP flood adjusted for possible climate change effects. Figure 6-18 shows a peak flow velocity difference map comparing the peak flow velocity patterns and magnitudes for the proposed and existing situations respectively.

As with Figure 6-16, Figure 6-18 shows that peak flow velocities from stopbank overtopping flows spreading laterally through Ōtaki Township are slightly lower than in the existing situation for this flood case although the differences are small and again are probably within the order of accuracy of the model predictions. Flow velocities through Ōtaki Township induced by the Expressway embankment are therefore no worse than in the current situation. Flow velocities are marginally higher across the uninhabited part of the floodplain upstream of the Expressway embankment and up to 0.8m/s higher locally around the exit from the wide culvert through the embankment.

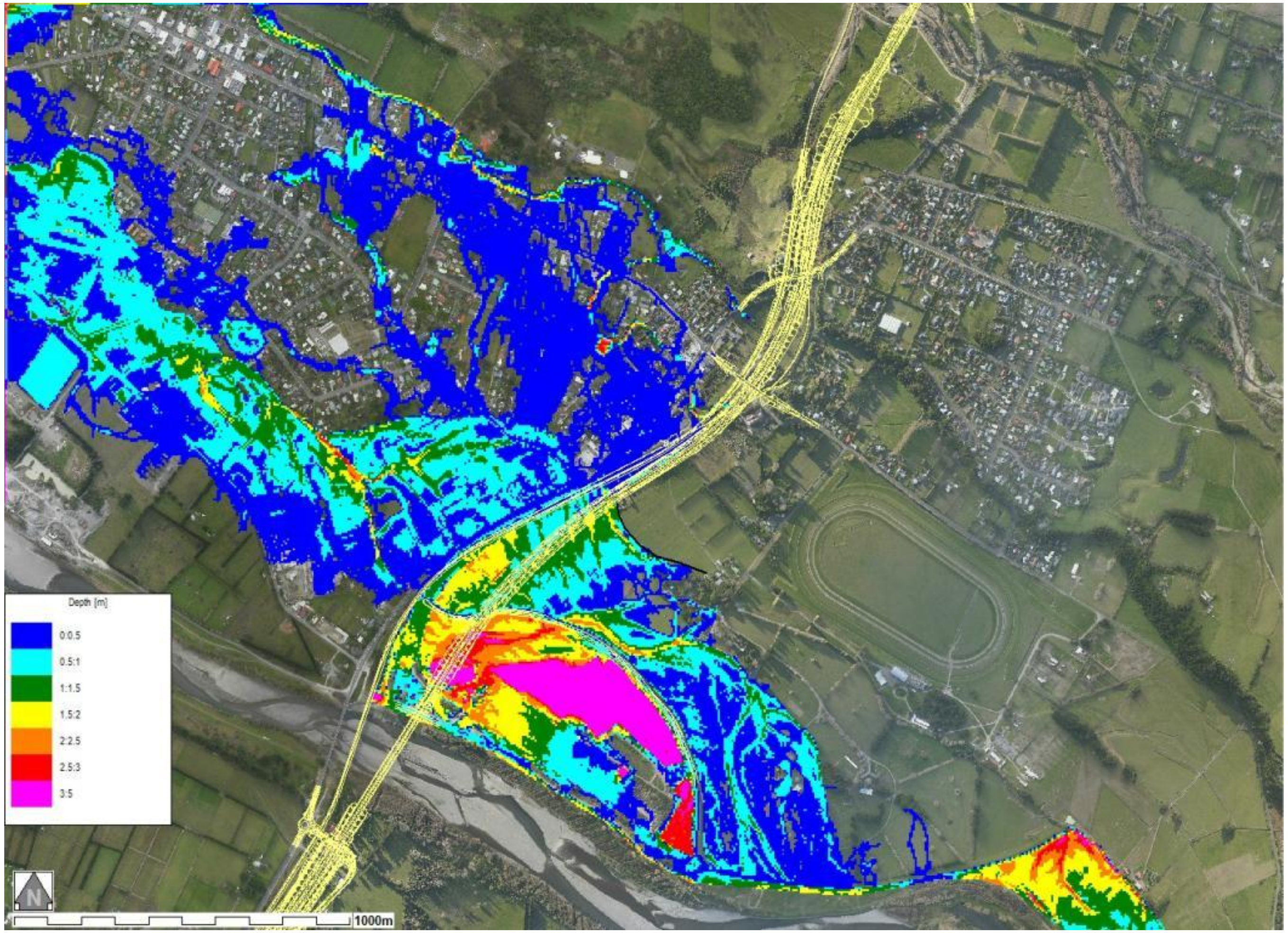

Figure 6-15 Peak flood inundation depths for proposed situation on Ōtaki River floodplain resulting from stopbank overtopping in 0.2% AEP flood adjusted for possible effects of future climate change

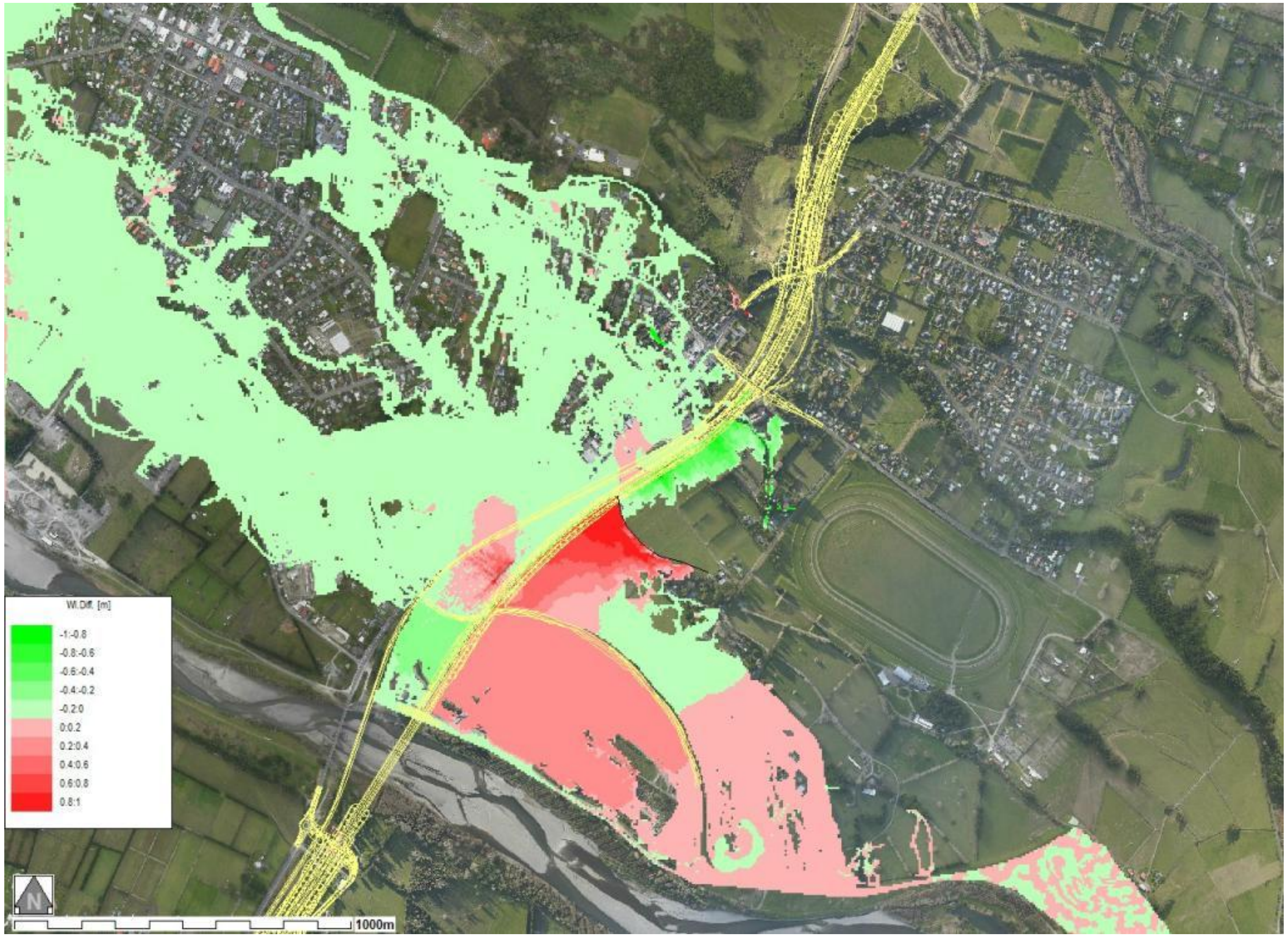

Figure 6-16 Peak flood depth differences between proposed and existing situations on Ōtaki River floodplain resulting from stopbank overtopping in 0.2% AEP flood adjusted for possible effects of future climate change (pink and red shading indicates increased peak flood depths, green shading indicates decreased peak flood depths)

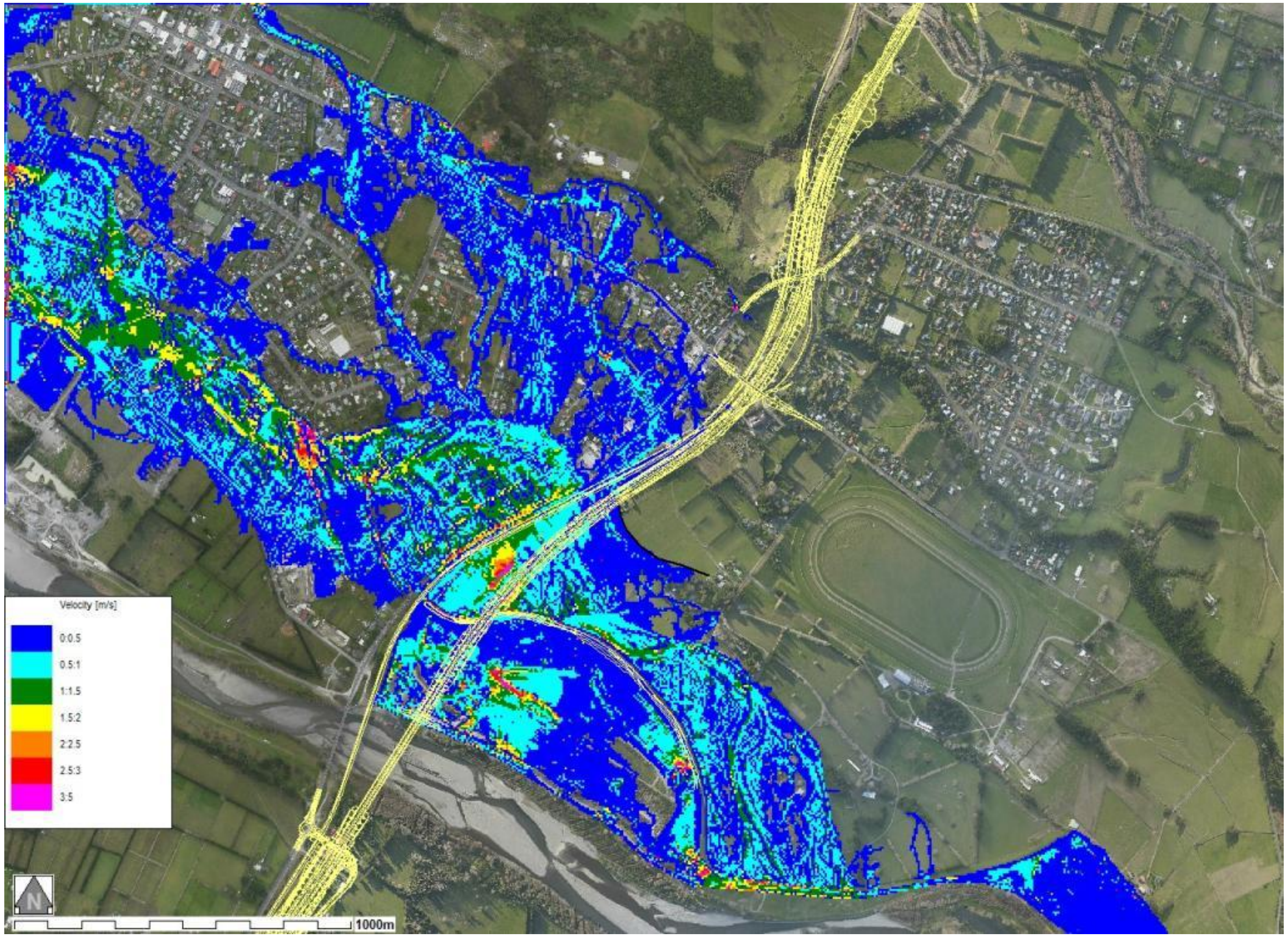

Figure 6-17 Peak flow velocities for proposed situation on Ōtaki River floodplain resulting from stopbank overtopping in 0.2% AEP flood adjusted for possible effects of future climate change

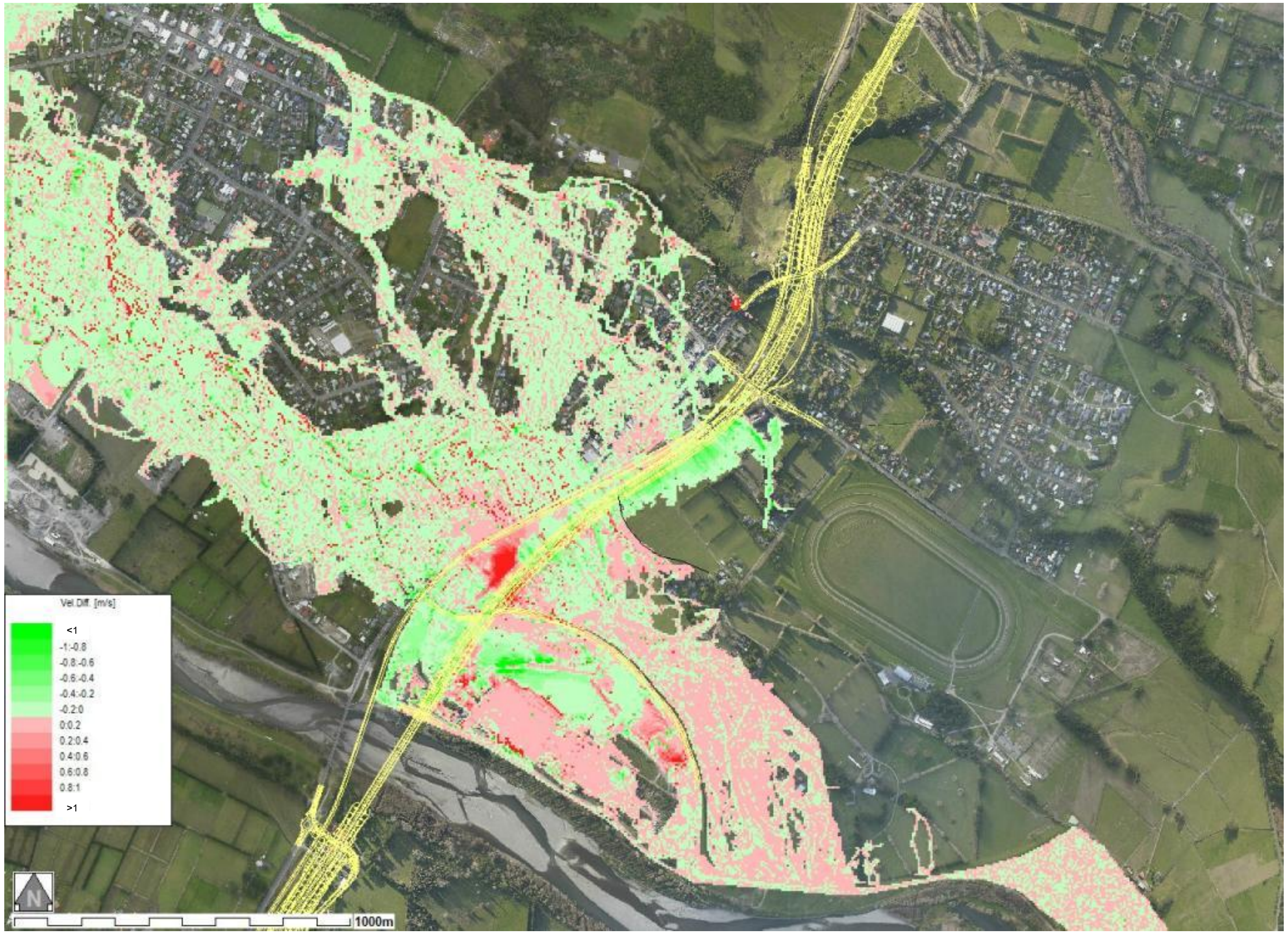

Figure 6-18 Peak flow velocity differences between proposed and existing situations on Ōtaki River floodplain resulting from stopbank overtopping in 0.2% AEP flood adjusted for possible effects of future climate change (pink and red shading indicates increased peak flow velocities, green shading indicates decreased peak flow velocities)

6.5 Potential Effects of Mangaone Stream and Floodplain Crossing

6.5.1 Outline of Proposed Situation

The Expressway will run parallel with the NIMT railway line and SH1 but on the upstream (eastern) side of the railway line. This will require new culverts under the Expressway to provide continuity with existing drainage paths (see Figure 6-19).

The situation is further complicated by the need to provide an east / west local road link connecting Gear Road / School Road with Te Horo Beach Road. This will take the form of a northerly extension to a relocated Gear Road on the east side which loops round to cross over the Expressway via an overbridge and then loops southwards to connect up with Te Horo Beach Road at a tee intersection (see Figure 6-19).

The east / west local road link configuration involves two additional crossings of the Mangaone Stream, with both the eastern and western approach embankments to the overbridge located through known overland flow path areas. In the case of the eastern approach embankment, the overland flow path runs parallel to the general direction of the stream upstream of the NIMT railway and SH1 road crossings (see Figure 4-8). With the western approach embankment, the overflow path runs through the old Lucinsky property having broken out of the main channel along the right bank downstream of the existing SH1 culvert (see Figures 4-8 and 4-9).

Road geometric design considerations indicate that the eastern approach embankment to the overbridge does not need to rise above natural ground level in order to achieve the required clearance over the Expressway till north of the additional Mangaone Stream crossing upstream of the Expressway. However the governing criterion for setting road levels in this area will be achieving an adequate level of service with sufficient freeboard for the Serviceability Limit Flood level (Transit NZ, 2003). This will require the roadway to be elevated as it crosses the alluvial fan on the eastern side of the Expressway between the School Road/ Gear Road intersection and the Mangaone Stream crossing.

The Expressway will require very long culverts on both the main stream channel and the overflow aligned and providing hydraulic connectivity with the existing NIMT railway and SH1 culverts immediately downstream on each watercourse. The local link road will similarly require culverts on both these main watercourses. In addition the local link road will require:

- a culvert on the School Road drain where this has been relocated to run parallel with the realigned Gear Road;
- either a wide (~ 10m) gap between the flood detention barrier upstream of the Expressway and the eastern abutment to the local link road overbridge or a dry culvert through the eastern approach embankment) in order to provide continuity for the overland flow path between the northern overland flow system and the main stream channel (the wide gap option would require the overbridge to have an additional span);
- a dry culvert through the western approach embankment to the overbridge to provide continuity for the existing Lucinsky Overflow: and
- a single span bridge crossing on the main stream channel on the western side of SH1where the local link road approaches the tee interception with Te Horo Beach Road.

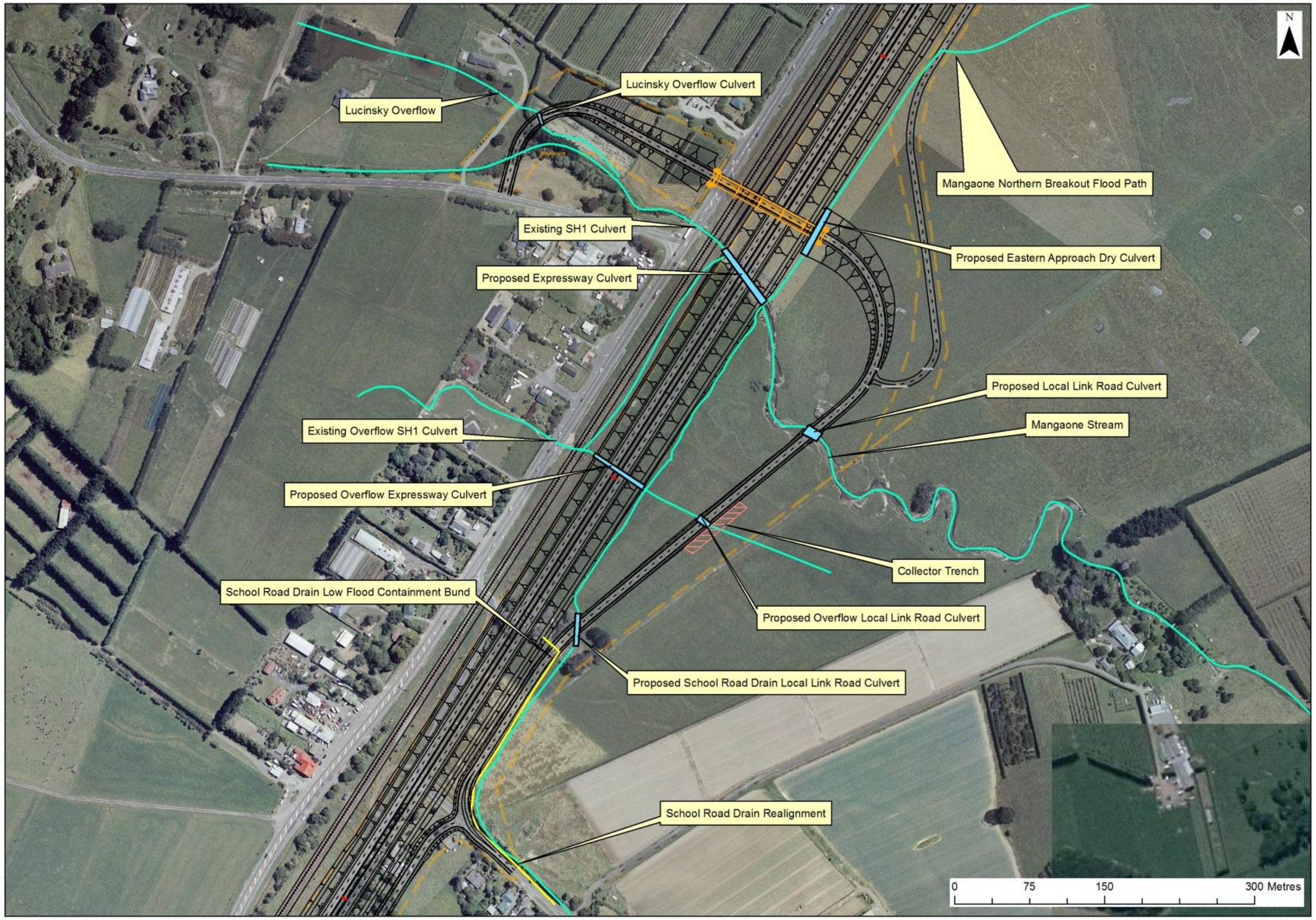

Figure 6-19 Proposed Expressway and local east / west local link road crossings of Mangaone Stream alluvial fan and floodplain system with main drainage paths marked

Table 6-6a gives the dimensions and levels of these culverts (in addition to those of the existing SH1 and NIMT railway culverts) and Table 6-6b gives the dimensions of the single span bridge on the local link road on the Mangaone Stream downstream of the SH1 crossing.

Table 6-6a Culvert types, dimensions and levels for Expressway, local link road and other existing transport link crossings of Mangaone Stream alluvial fan and floodplain system

Location	Type	Size (m)	Invert Level (m MSL Wellington (1953))		Length (m)	Slope (%)	Road Level (m MSL Wellington)
			u/s	d/s			
Mangaone Stream							
Local link road (eastern side) proposed	box	5.0 x 2.5 [2]	19.27	19.10	16	1.06	22.30 (minimum)
Expressway – proposed	box	5.0 x 2.0 [2]	17.17	16.70	50	0.94	19.77 (at road chge 7250m)
NIMT railway - existing	box	3.00 x 2.38	16.34	16.34	4.4	0.0	19.34
SH1 - existing	box	4.00 x 1.76	16.64	16.30	15	2.3	18.65
Mangaone Overflow							
Local link road – proposed	box	5.0 x 1.5	18.95	18.65	20	1.50	20.95
Expressway - proposed	box	8.0 x 1.5	17.51	16.97	50	1.08	19.52 (at road chge 7500m)
NIMT railway - existing	box (2 cells)	3.00 x 2.05 (1 cell)	15.53	15.48	5.0	1.0	19.24
SH1 - existing	box	3.70 x 1.95	15.08	15.08	13.6	0.0	17.74
School Rd Drain							
Local link road – proposed	box [1]	2.5 x 1.0	17.90	17.78	16	0.75	19.40 (minimum)
Lucinsky Overflow							
Local link road (western side)– proposed	box	5.0 x 1.0	15.5	15.4	16	0.63	17.20
Northern Overland Flow Path							
Local link road (eastern approach to over-bridge)– proposed	box	10.0 x 1.5	18.9	18.9	50	0.0	>28m

Note

1. School Road Drain assumed to be diverted to run parallel with new local link road from Gear Road / School Road intersection to a low point in the ground topography opposite existing Gear Road / SH1 intersection. A box culvert under local link road conveys drain flows to an extension of drain to connect with Mangaone Overflow. Drain extension to run alongside flood detention bund upstream of Expressway.
2. Culverts on main stream channel to be constructed from oversize box culvert sections to allow normal sediment transport processes to continue and to facilitate fish passage with a gravel invert (depth dimension given from soffit to bed).

Table 6-6b Dimensions and levels for local link road bridge across Mangaone Stream downstream of SH1 culvert

Location	Type	Span (m)	Soffit Level (m MSL Wellington (1953))	Deck Level (m MSL Wellington (1953))
Local link road (western side) – proposed	single span bridge	8m	16.05	16.75 (minimum)

To keep the elevation of the local link road as low as possible, the Mangaone Overflow channel upstream of the Expressway culvert will need to be partially excavated into the ground. A trapezoidal-shaped and grassed channel with an 8m base width and 2: 1 (h: v) side slopes is envisaged between the local link road and Expressway culverts with the invert levels matching the downstream invert level of the local link road culvert at the upstream end and the upstream invert level of the Expressway culvert at the downstream end. To ease the entry of overland flows into the upstream end of the depressed local link road culvert on the Mangaone Overflow, a shallow vee-shaped collector trench will need to be excavated into the ground. This trench will be 10m wide and 160m long parallel with the local link road (80m in either direction away from the culvert and sloping up to natural ground level over this distance).

The School Road drain presently runs alongside School Road, the existing Gear Road and the NIMT railway line to connect with the Mangaone Overflow (Figure 4-7a). With the existing Gear Road being realigned to make room for the Expressway, the School Road drain will also need to be relocated (Figure 6-19). Relocation of the drain will need to allow space for the construction of a low flood containment bund on the upslope side of the realigned Gear Road. This flood containment bund will need to turn through ninety degrees, cross the local link road and link in to the flood detention barrier along the upstream (eastern) side of the Expressway. It will therefore form part of the primary flood defence protecting the Expressway and the Te Horo Village to the west of SH1.

The local link road will need to be elevated where the flood containment bund crosses it. However further south it can run at grade across the alluvial fan surface.

This flood containment bund will also need to be extended upstream along School Road to assist in solving an existing local flooding nuisance. This will require the School Road drain along School Road to be relocated and enlarged to approximately match the discharge capacity of the drain around the perimeter of a horticultural unit opposite the Te Horo Village Hall. These measures will prevent floodwaters from spilling out of the School Road drain and flowing down the road and causing inundation of the School Road / Gear Road intersection and neighbouring residential properties as occurs at present. This local drainage improvement to solve the existing flooding nuisance is strictly outside the scope of the Expressway Project and would need to be carried out in cooperation with KCDC.

The School Road drain would need to pass under the local link road by means of a culvert and then be extended to connect with the Mangaone Overflow upstream of the Expressway. Table 6-6a gives the culvert dimensions. The drain extension would be formed by a trapezoidal-shaped and grass-lined channel with a base width of 2.5m and side slopes of 2: 1 (h: v).

Alongside School Road, the trapezoidal-shaped drain would need to be enlarged to a base width of about 1.5m with side slopes of 1.5: 1 (h: v) while, alongside the realigned Gear Road, the base width of the drain would need to gradually expand from 1.5m to 2.5m.

Floodwaters along the Lucinsky Overflow in the existing situation appear to originate from the floodwaters overtopping SH1 to the north of the SH1 culvert on the main stream channel and flowing along the right bank parallel with the mains stream channel downstream of the SH1 culvert. Floodwaters in the main stream channel are prevented from breaking out along the right bank by a low stopbank which also prevents Lucinsky Overflow flows spilling back into the main stream channel.

In the proposed situation, the footprint of the western approach embankment to the local link road overbridge blocks out a substantial proportion of the 70-90m wide overland flow path along the Lucinsky Overflow which significantly reduces the conveyance capacity of the Overflow. In order to provide continuity for the Overflow through the overbridge approach embankment, it will be necessary to provide a dry culvert through the embankment. Table 6-6a gives the dimensions and levels of this culvert.

6.5.2 Effects of Expressway Crossing

Figures 6-20a and b show the predicted extent of flood inundation across the Mangaone Stream alluvial fan and floodplain system in the proposed situation for the 1% AEP flood adjusted for possible future climate change effects to 2090. These figures are comparable to Figures 4-10a and b for the existing situation with Figure 6-20a providing a wider perspective of the flood extent across the Mangaone Stream alluvial fan and floodplain and Figure 6-20b focusing on the flood extent around the three key transport links crossing the Mangaone Stream and Overflow and Figure 5-2b providing a wider perspective of the flood extent across the alluvial fan and floodplain. As with Figures 4-10a and b, Figures 6-20a and b show ranges of peak flood depths shaded in different colours.

Figure 6-21 shows a difference map of peak flood depths between Figures 6-20b and 4-10b. The areas in this figure with the lightest pink and green shading indicate areas where the predicted change in peak flood depth is within ±0.05m which is within the predictive accuracy of the MIKEFLOOD model. Therefore there is effectively no change in peak flood depth in these areas with the lightest shading of pink and green between the existing and proposed situations.

Downstream of SH1, the flood inundation pattern in the proposed situation is broadly similar to that in the existing situation. However there are several notable differences. The local link road and western approach embankment to the overbridge in the proposed situation confine the initial width of the Lucinsky Overflow over the approximately 170m distance downstream of SH1. The overbridge approach embankment also dams the Lucinsky Overflow although the dry culvert through the embankment provides hydraulic connectivity for the overland flow path. The overland flow path observed at the south end of Te Horo Village in the existing situation has been eliminated in the proposed situation. Similarly the overtopping of SH1 by the northern overland flow path in the existing situation has also been eliminated in the proposed situation.

Within the primary area of alluvial fan inundation downstream of SH1 in the proposed situation, peak flood depths are much the same as in the existing situation (see Figure 6-21).

The major differences in the flood inundation pattern in the proposed situation occur upstream of the Expressway. The following observations can be made from Figures 6-20a and 6-20b and 6-21:

- The Expressway and the local link road are not inundated, although much of SH1 continues to be inundated as in the existing situation.
- There is more extensive inundation between the Expressway and the local link road in the proposed situation compared to upstream of the NIMT railway line in the existing situation. However the extent of inundation in the proposed situation is again limited by the steepness of the slope of the alluvial fan. The maximum depths of inundation upstream of the local link road and in the enclosed area between the Expressway and the local link road are in the range of 1.0-1.5m.

- The combination of the elevated local link road and the flood containment bund for the School Road drain cause ponding to occur upstream but the extent of ponding extends no more than about 100m upstream due to the steepness of the alluvial fan slope. As with the enclosed area between the Expressway and the local link road, the maximum depths of inundation across the alluvial fan upstream of the local link road and the School Road flood containment bund are in the range of 1.0-1.5m.
- The flood nuisance around the School Road / Gear Road intersection in the existing situation has been eliminated in the proposed situation with flood flows conveyed by the School Road drain contained by the flood containment bund along School Road and the local link road. Floodwaters sourced from the School Road drain contribute the flood ponding that occurs upstream of the local link road culvert on the School Road drain.

Figure 6-22a shows predicted peak flow velocities across the Mangaone Stream alluvial fan and floodplain system in the proposed situation for the 1% AEP flood adjusted for possible future climate change effects to 2090 in a similar fashion to Figure 4-11a for the existing situation. Figure 6-22b shows the flow vectors superimposed on the pattern of peak flow velocities.

Figure 6-23 shows changes in peak flow velocity between the proposed and existing situations. The areas in this figure with the lightest pink and green shading indicate areas where the predicted change in peak flow velocity is within ±0.05m/s which is within the predictive accuracy of the MIKEFLOOD model. Therefore, as with Figure 6-21 showing the changes in peak flow depth, there is effectively no change in peak flow velocity in these areas with the lightest shading of pink and green between the existing and proposed situations.

Figures 6-22a again highlights that the peak overland flow velocities for the 1% AEP flood adjusted for possible future climate change effects to 2090 are confined primarily to the Mangaone Overflow overland flow path. However the occurrence of flood ponding upstream of the Expressway culvert is to cause flow velocities along the Overflow between the local link road culvert and Expressway culvert to be significantly reduced. This is indicated by the darker green shading in the area between the local link road and the Expressway in Figure 6-23.

Conversely, peak flow velocities are increased upstream of the local link road (indicated by the darker red areas in Figure 6-23) although the magnitude of the increased flow velocities seen in Figure 6-22a in this area is generally very low (< 0.4m/s) except in the immediate vicinity of the Mangaone Overflow and School Road drain culverts under the local link road. The primary reason for the apparent increase in peak flow velocities upstream of the local link road is that this area is not inundated in the existing situation (see Figure 4-10a) for the 1% AEP flood adjusted for possible climate change effects to 2090.

Downstream (to the west) of SH1, peak flow velocities are reduced in the proposed situation over a 170m wide strip through the residential and retail area of Te Horo Village to the south of Te Horo Beach Road, and also along the Lucinsky Overflow.

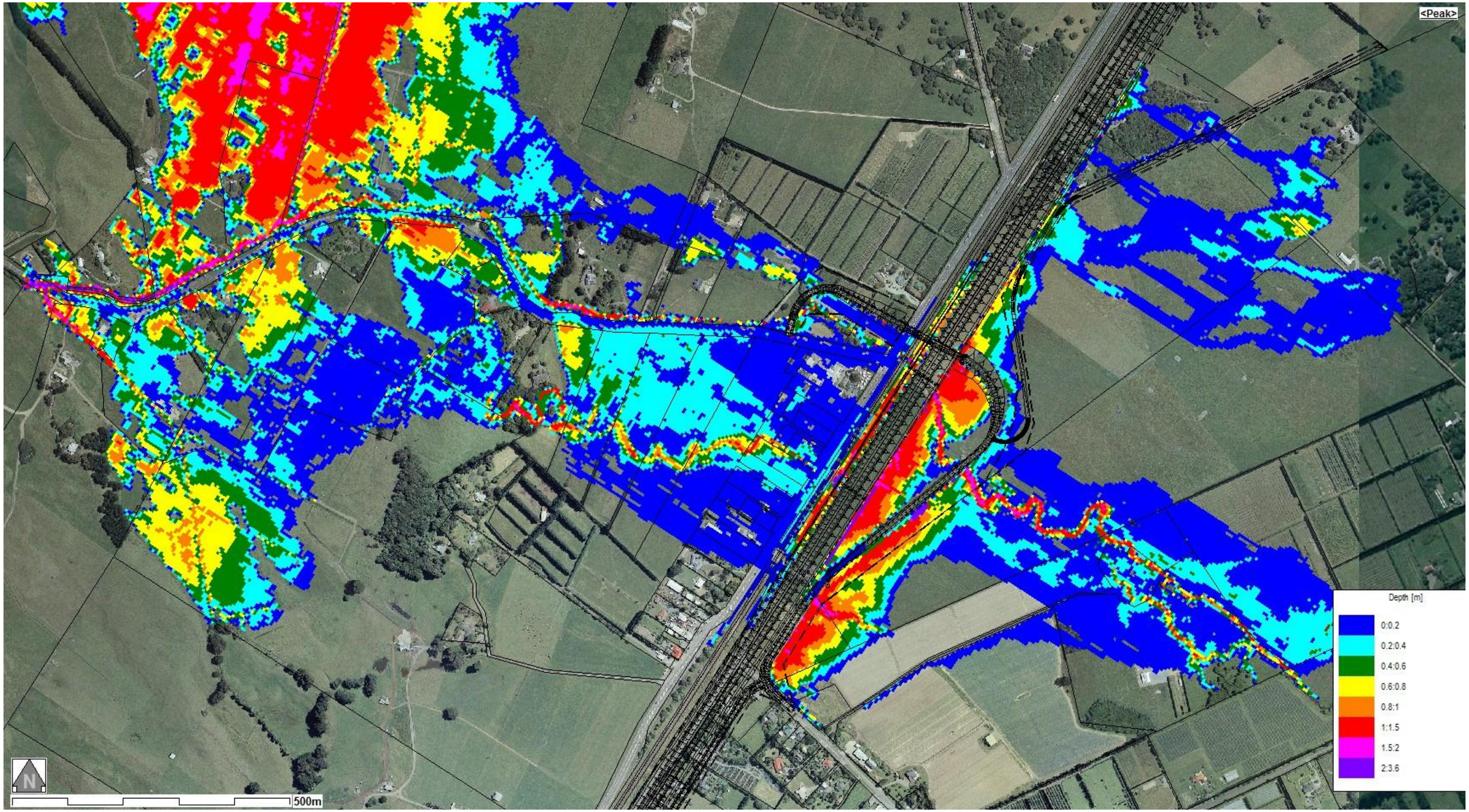

Figure 6-20a Small scale view of predicted flood extent across Mangaone Stream alluvial fan and floodplain system in proposed situation for 1% AEP flood adjusted for possible future climate change effects to 2090

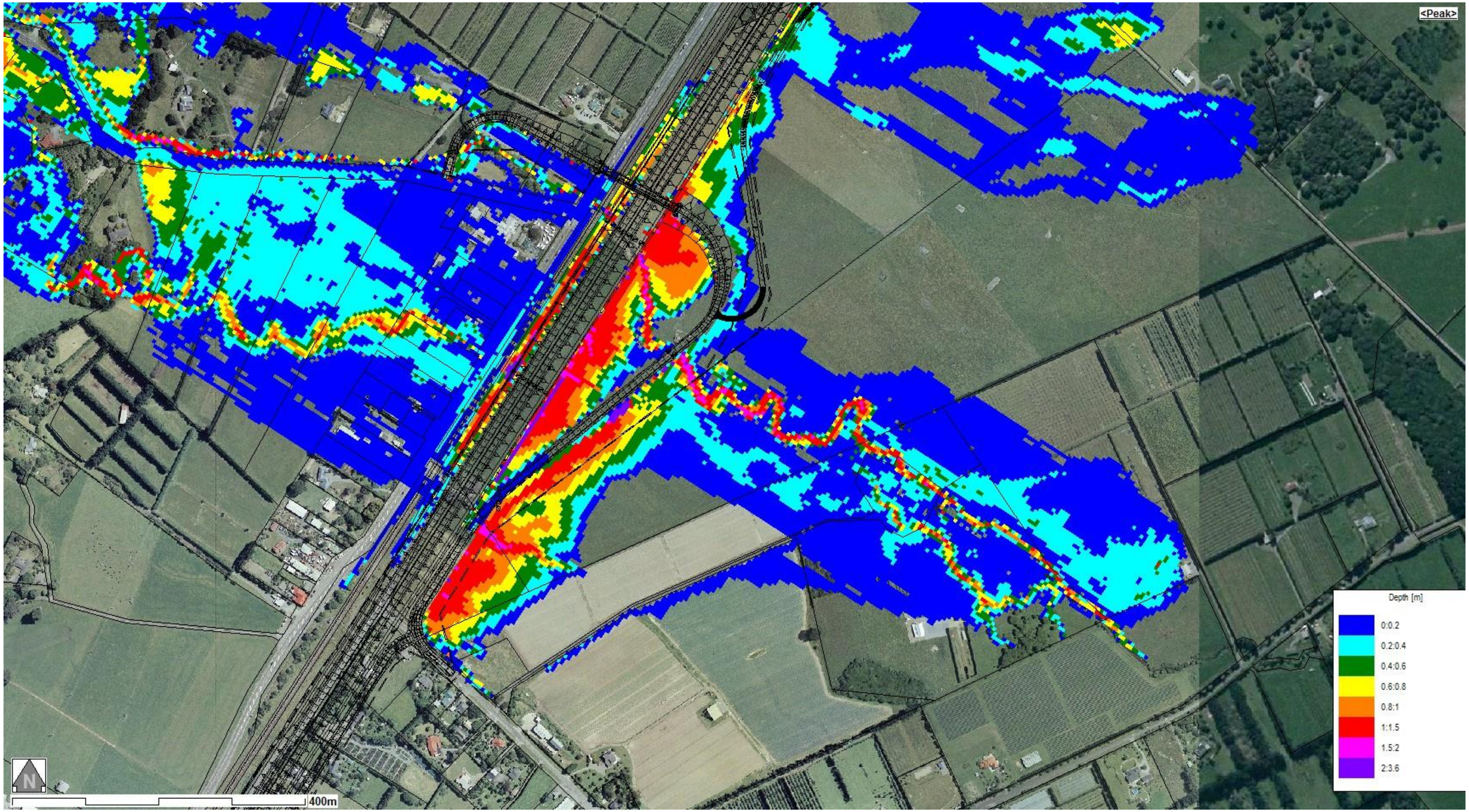

Figure 6-20b Effects of Expressway, local link road, NIMT railway line and SH1 on predicted flood extent across Mangaone Stream alluvial fan and floodplain system in proposed situation for 1% AEP flood adjusted for possible future climate change effects to 2090

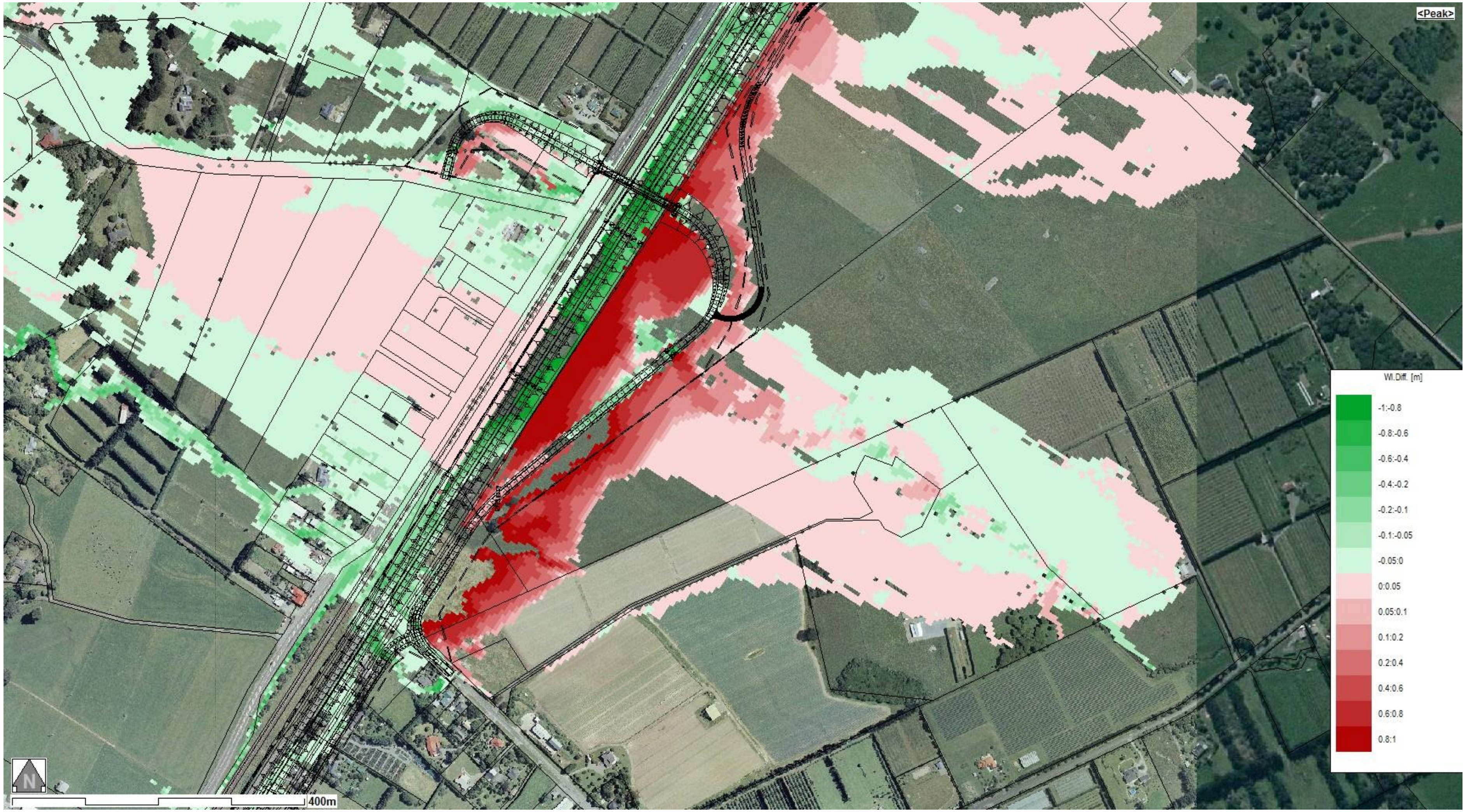

Figure 6-21 Changes in predicted peak flood depths across the Mangaone Stream alluvial fan and floodplain system between existing and proposed situations for 1% AEP flood adjusted for possible future climate change effects to 2090 (pink shading indicates areas of increased flow depths, green shading indicates areas of decreased flow depths)

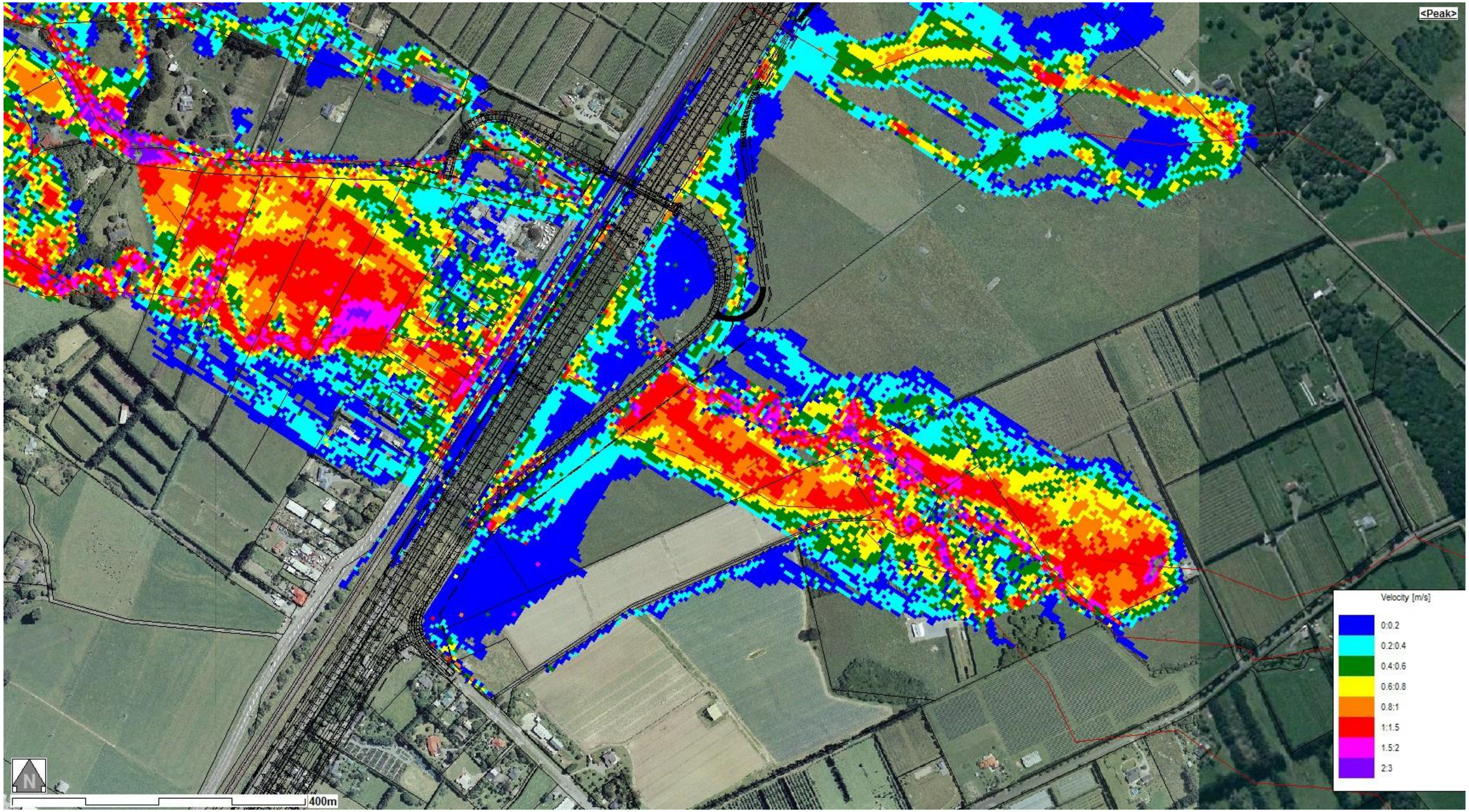

Figure 6-22a Predicted flow velocities across Mangaone Stream alluvial fan and floodplain system in proposed situation for 1% AEP flood adjusted for possible future climate change effects to 2090

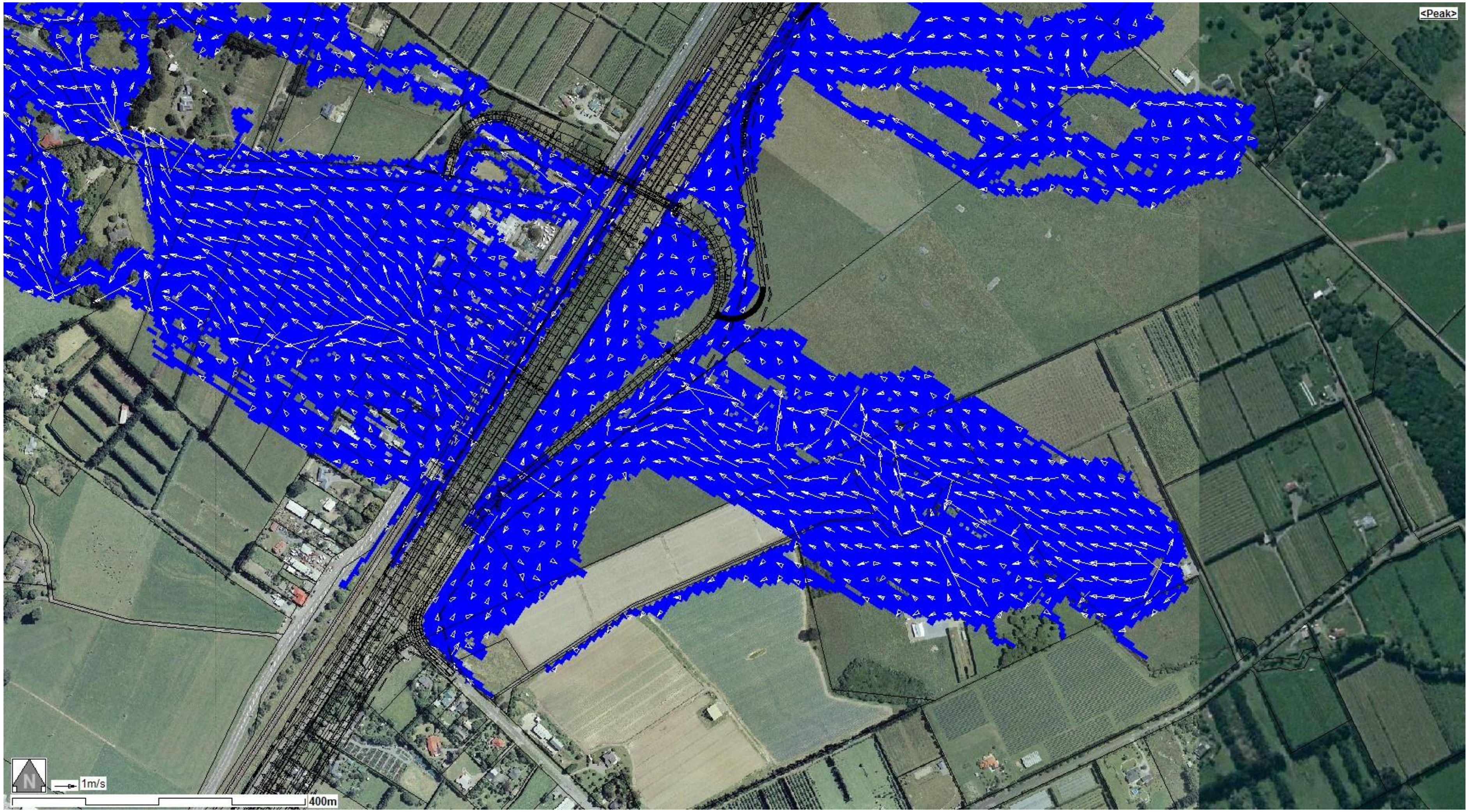

Figure 6-22b Alternative version of Figure 6-22a showing velocity vectors for overland flow past the local link road, Expressway ,NIMT railway and SH1 crossings of the Mangaone Stream and Overflow

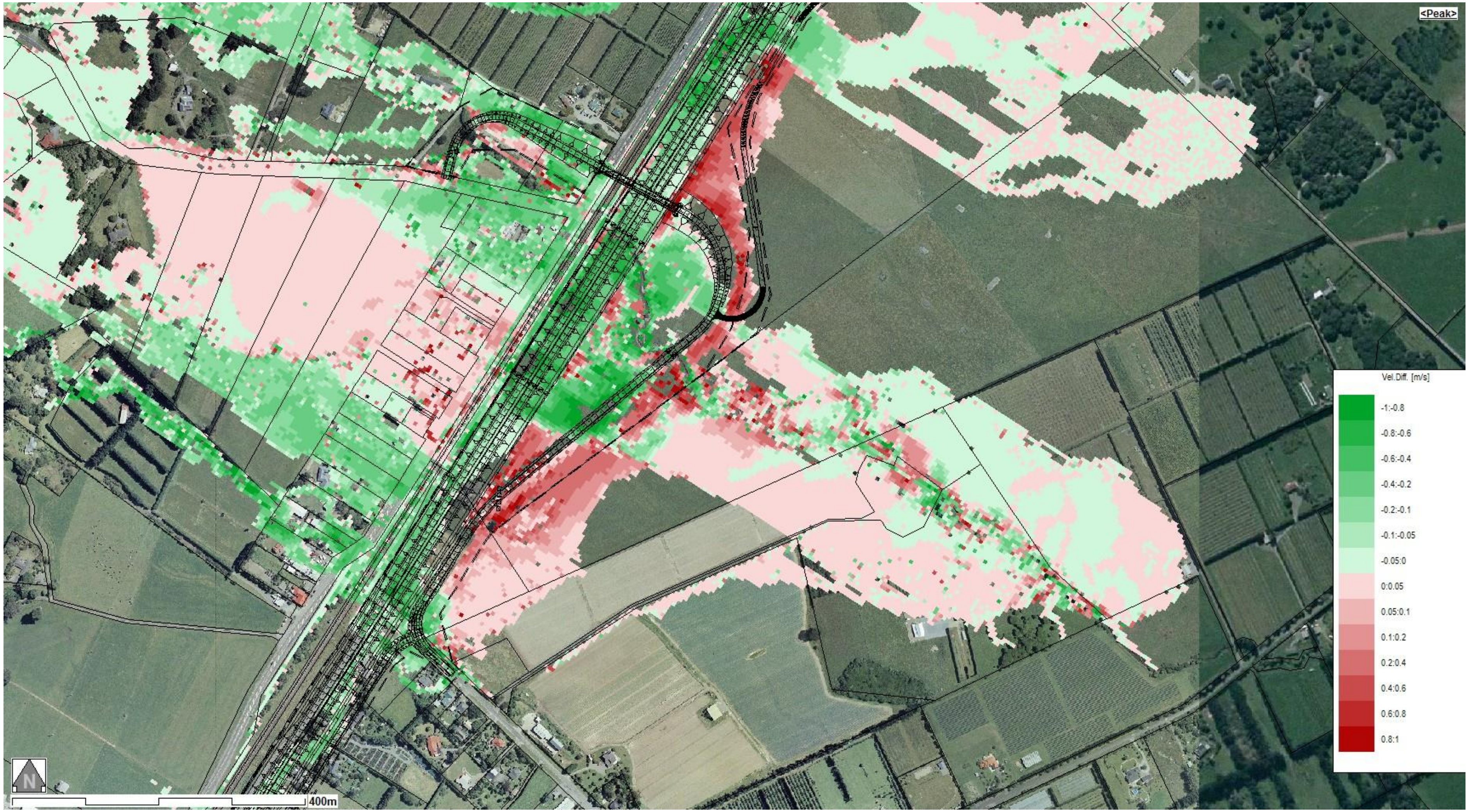

Figure 6-23 Changes in predicted peak flow velocities across the Mangaone Stream alluvial fan and floodplain system between proposed and existing situations for 1% AEP flood adjusted for possible future climate change effects to 2090 (pink shading indicates areas of increased flow depths, green shading indicates areas of decreased flow depths)

Figure 6-22b showing the predicted directions of flow across the alluvial fan and floodplain is very illuminating. The length of the velocity vectors is proportional to the magnitude of the flow velocities so that the course of the Mangaone Overflow where the higher flow velocities are concentrated is readily apparent. The magnitude of the 1% AEP flood adjusted for possible climate change effects to 2090 is such that the floodwaters approaching the local link road are spread across the alluvial fan either side of the main stream channel. The effect of the elevated local link road is to deflect the overland flow sideways to follow the line of the road embankment away from the main stream channel culvert. The elevated flood detention bund upstream of the Expressway has a similar deflection effect except in this case the eastern approach embankment to the local link road overbridge contains the spread of floodwaters northwards and floodwaters are primarily directed southwards along the line of the Expressway to the Mangaone Overflow culvert under the Expressway. The Expressway also acts to deflect overland flows in the northern overland flow path in a southerly direction along the upstream side to the gap between the Expressway and the eastern abutment of the local link road overbridge to re-enter the main stream channel.

Downstream of SH1, Te Horo Beach Road appears to act as a natural flow path for overland flows. However this is not an effect of the Expressway as the flow path is the same in both the existing and proposed situations (see Figure 4-11b and Figure 6-22b).

In combination, the flood ponding that occurs upstream of the elevated local link road and the Expressway and the systems of existing and new culverts on the main stream channel on the Mangaone Overflow have a number of effects on extreme floods:

- flood discharge peaks are smoothed out and throttled;
- maximum flood discharges are progressively reduced through successive culverts on each culvert system; and
- maximum flood levels become relatively constant over a period of time before gradually falling.

For the 1% AEP flood adjusted for possible climate change effects, although there is a slight reduction in the main stream channel flow and a slight increase in the Mangaone Overflow flow in the proposed situation, overall there is a slight reduction in the total flow downstream of SH1 along the two primary watercourses compared to the total flow in the existing situation. The main stream channel passes 42-44 per cent of the total flow past SH1 while the Mangaone Overflow passes 56-58 per cent of the total flow with the main stream channel fraction reducing and the Overflow fraction increasing with the increasing magnitude of the flood. For the 5%, 1% and 0.5% AEP floods adjusted for possible climate change effects (with estimated peak discharges of $64.1m^3/s$, $80.2m^3/s$ and $88.7m^3/s$ respectively), the culvert systems on the main stream channel and the Mangaone Overflow in the proposed situation are estimated to attenuate the flood discharge peaks by progressively increasing amounts from about 28 per cent to over 40 per cent.

The extent of flood inundation upstream of both the local link road and the Expressway in the proposed situation for the 5% AEP flood floods adjusted for possible climate change effects is reduced compared to that shown in Figure 6-20b for the 1% AEP flood adjusted for possible climate change effects while the extent of flood inundation is only slightly increased for the 0.5% AEP flood adjusted for possible climate change effects. However, despite these variations in the extent of flood inundation, peak flood levels are predicted to increase over the range of floods:

- by only 0.26m upstream of the local link road culvert on the main stream channel (0.03m between the 1% and 0.5% AEP floods);
- by only 0.11m upstream of the Expressway culvert on the main stream channel (0.01m between the 1% and 0.5% AEP floods);
- by 0.52m upstream of the local link road culvert on the Mangaone Overflow (0.09m between the 1% and 0.5% AEP floods); and
- by 1.35m upstream of the Expressway culvert on the Mangaone Overflow (0.36m between the 1% and 0.5% AEP floods).

The link road culvert on the main stream channel is the culvert most at risk of a partial blockage by flood transported woody debris while the local link road culverts on the Mangaone Overflow and on the School Road drain are also at risk but to a lesser extent. Other downstream culverts (Expressway, NIMT railway and SH1 culverts) are shielded by the local link road culverts so that the risk of a partial blockage of any of these culverts is negligible. The effect a partial blockage of one or other of the local link road culverts is simply to cause a redistribution of flood flows laterally to the other two culverts. The increase in peak flood level at each of the other two culverts is relatively small.

Sediment deposition can be expected to occur in the flood ponding areas upstream of the local link road, the School Road drain flood containment bund and the Expressway in the proposed situation due to the still nature of the ponded floodwaters and the suspended sediment material contained in them (see the sediment- laden floodwaters in Figures 4-8 and 4-9). However this is the same as occurs in the existing situation upstream of the NIMT railway line. It would only be an infrequent occurrence and would only affect land used for pastoral purposes.

As noted previously, the maximum peak flow velocities across the alluvial fan and floodplain surface of the Mangaone Stream occur along the course of the Mangaone Overflow in both the existing (Figure 4-11a) and proposed (Figure 6-22a) situations. On the whole then, the Expressway in the proposed situation has no effect on the maximum peak flow velocities along the Mangaone Overflow. The Expressway does not increase the erosion potential of high flood flow velocities across the alluvial fan and floodplain surface. Notwithstanding this, the magnitude and duration of peak flow velocities along the Mangaone Overflow in a 1% AEP flood adjusted for possible future climate change effects in both situations are such that some minor damage to pasture might be expected to occur.

No real change in the drainage times of flood ponding areas is expected between the existing and proposed situations. Maximum durations of flood ponding of up to 8-10 hours are expected for the 1% AEP flood adjusted for possible future climate change effects.

In the proposed situation, hydraulic connectivity for the Lucinsky Overflow will be provided for by means of 5m wide by 1m high dry culvert through the western approach embankment to the local link road overbridge. However, as in the existing situation, the computational hydraulic modelling of flood flow patterns suggests that the origin of the flood flows passed by the Lucinsky Overflow is floodwaters overtopping SH1 to the north of the SH1 culvert of the main stream channel (flood flows in the mainstream channel downstream of the SH1 culvert are prevented from breaking out along the right and joining the overland flow along the Lucinsky Overflow). As the footprint of the western approach embankment blocks off a substantial part of the 70-90m width of the Lucinsky Overflow in the proposed situation, the peak discharge passed by the Lucinsky Overflow culvert is predicted to be only 0.7m^3/s compared to 3.5m^3/s in the existing situation.

However the computational hydraulic modelling results from which the inference about the about the origin of the flood flows along the Lucinsky Overflow may be affected by possible localised errors in the LiDAR sourced topographic data (used to define the MIKEFLOOD model DTM) which are induced by the tall vegetation along the banks of the main stream channel downstream of the SH1 culvert seen in Figure 4-8. The apparently high right bank levels incorporated into the MIKEFLOOD model around the main stream channel bend where it veers back towards Te Horo Beach Road prevent floodwaters from breaking out of the main stream channel and entering the Lucinsky Overflow as appears to have occurred in the 28 October 1998 flood (see the overland flow path through the line of trees and across the private property access road in the centre of the photograph in Figure 4-8).

In order to preserve hydraulic neutrality along the Lucinsky Overflow between the existing and proposed situations, the right bank of the main stream channel at this bend downstream of the SH1 culvert could be locally lowered in the proposed situation to achieve the predicted peak discharge of 3.5m^3/s that occurs in the existing situation.

7. Summary of Proposed Mitigation Measures and Effects of Mitigation for Individual Crossings

7.1 Proposed Configuration and Mitigation Measures for Waitohu Stream and Floodplain Crossing

Floodwaters naturally break out of the Waitohu Stream upstream of the existing SH1 bridge due to a number of factors including the limited waterway capacity of the bridge, the bridge location immediately downstream of a very sharp bend and the low height of the stream banks. Flood breakout gives rise to extensive floodplain inundation along both banks including inundation of the highway.

The approach embankments to the 75m long bridge crossing of the Waitohu Stream and floodplain will act as a barrier to these overland flow paths. An 8m wide by 2.5m high box culvert on the south (left) bank and a 10m wide by 1.5m high box culvert on the right (north) bank are recommended to provide continuity for the overland flow paths. The large size of the culverts is necessary because of the large flow volumes that are conveyed by the left and right bank floodplains.

The proposed bridge crossing of the Waitohu Stream is located near the beginning of a zone of geomorphic instability (Williams, 2004) caused by a change in streambed slope. The 75m bridge span provides ample fairway width for future potential lateral migration of the active stream channel and sediment deposition induced by this geomorphologic instability. The active stream channel is monitored by GWRC in response to natural river processes including channel migration and sediment aggradation with gravel mining within strict volume limits licensed on an on-demand basis.

The effects of the Expressway with the 75m long bridge crossing of the Waitohu Stream and floodplain and the large culverts incorporated in the bridge approach embankments are minimal and acceptable:

- the extent of flood inundation upstream and downstream is very similar to that for the existing situation;
- flood levels across the flood plain and in the main stream channel immediately upstream of the Expressway are increased relative to those in the existing situation but the increased levels extend no more than 100m upstream due to the steepness of the floodplain slope;
- the duration of flood inundation across the floodplain is not exacerbated; and
- flow velocities across the floodplain are not made any worse with the large culverts in the bridge approach embankments providing continuity for existing overland flow paths.

Table 7-1 summarises the predicted maximum flood depth at each culvert location, the flood duration and the approximate flood volume within the upstream ponding areas on the floodplain for the 1% AEP flood adjusted for possible future climate change effects to 2090.

Table 7-1 Predicted maximum flood depth, flood duration and flood storage volume at each culvert location on Expressway crossing of Waitohu Stream floodplain for 1% AEP flood adjusted for possible future climate change effects to 2090

Location	**Maximum Flood Depth (m)**	**Flood Duration * (hrs)**	**Approximate Ponding Area Volume (m^3)**
Dry culvert – south bank Waitohu Stream	2.0	~ 2.5	~ 10,000
Dry culvert – north bank Waitohu Stream	0.8	~ 1.5	~ 0 (maintains continuity of existing overland flow path)
Greenwood sub-catchment culvert	1.7 (above culvert invert level)	~ 4	~ 0 (maintains continuity of existing overland flow path)

* depends on characteristics of flood

The Greenwood sub-catchment is a known flooding hotspot for SH1 with the present culvert system considerably undersized for the sub-catchment runoff. Floodwaters breaking out of the Waitohu Stream along the right bank upstream of the SH1 bridge and flowing overland also spread into the Greenwood sub-catchment although this flow contribution lags and is secondary to the direct surface runoff contribution.

Right bank breakout flows from the Waitohu Stream upstream of the Expressway in the proposed situation also spread into the Greenwood sub-catchment along the upstream side of the Expressway embankment. However because the embankment is only slightly elevated above the floodplain, peak flood levels for the 1% AEP flood adjusted for possible future climate change effects will be approximately coincident with the shoulder of the road.

SH1 is presently overtopped at the location of the Greenwood sub-catchment culvert by floods smaller than a 5% AEP flood adjusted for the effects of possible future climate change. There is minimal flood storage volume upstream of the culvert system so that there is negligible attenuation of peak flows past the culverts.

Because the vertical alignment of the Expressway is required to transition into the existing vertical alignment of SH1 immediately to the north of the Greenwood sub-catchment culvert, the recommended 4m wide by 1.5m high box culvert under the Expressway only just eliminates the occurrence of road overtopping for the 5% AEP flood adjusted for the effects of possible future climate change and satisfies the design freeboard standard. It does not make downstream flood inundation any worse than it would be in the existing situation. The 1% AEP flood adjusted for the effects of possible future climate change in the Greenwood sub-catchment would overtop the Expressway over about a 70m width at a very shallow depth to the north of the Greenwood sub-catchment culvert.

The recommended size for the Greenwood sub-catchment culvert would enable the flood risk at this location to be reduced in the future by requiring only the road level to be raised.

7.2 Proposed Mitigation Measures for Mangapouri Stream Crossing

The following mitigation measures are required in the vicinity of the Expressway crossing of the Mangapouri Stream to preserve as closely as possible the delicate balance of the current hydraulic response of the modified storage basin system along the stream under flood conditions:

- The existing railway embankment and its associated culvert on the Mangapouri Stream will be retained in order to preserve the flood detention function of the primary flood storage basin upstream of the railway embankment / County Road.
- A dry culvert is required through the eastern approach embankment to the Rahui Road overbridge to maintain hydraulic connectivity between the primary flood storage basin and the (old) Rahui Road overflow zone. The area in front of the culvert will need to be excavated to ensure the downstream Rahui Road flood relief facilities come into operation at the desired flood magnitude.
- A limited size, low level flood relief culvert needs to be provided under Rahui Road to allow a small volume of floodwaters to be discharged to the unnamed watercourse which drains the Racecourse Catchment.
- Localised reshaping of the vertical profile of the old Rahui Road to remove a local high point needs to be undertaken to provide a uniform crest level through the Rahui Road overflow zone.
- The new culvert under the Expressway and realigned NIMT railway line which replaces the existing railway culvert for the Racecourse Catchment needs to be sized to limit flows through it to no more than the present discharge capacity. The slightly elevated Expressway road formation will allow floodwaters to head up in front of the new culvert and utilise the rough land area upstream for flood storage purposes.
- The Expressway and realigned NIMT railway culverts on the Mangapouri Stream need to be nearly as wide as the existing stream channel and deep enough so that both continue to operate under a free surface flow regime in extreme flood conditions.
- The loss of flood storage in the Railway Wetland needs to be rectified by making use of the dead space between the old railway embankment and the new Expressway embankment just to the north of the Mangapouri Stream Crossing to form a second wetland area in series with the remnant Railway Wetland. Figure 7-1 compares the volume of the Railway Wetland in the existing and proposed situations while Figure 7-2 shows the volume of the new additional wetland providing compensatory storage. At the depth of 2m the total volume of the modified Railway Wetland and the new wetland approximately matches the volume of the original Railway Wetland.
- The outlet culverts on the remnant Railway Wetland system need to be sized to maximise the attenuation efficiency of the system in order to reduce outflows to the Mangapouri Stream.
- As part of the landscaping of the Pare-o-Matangi Reserve associated with construction of the Expressway, a low bund[21] will be formed along the boundaries of the remaining properties of the corner of SH1 and Rahui Road. The purpose of this bund would be to prevent the ingress of floodwaters from the secondary storage pond within the Reserve onto these properties which would already occur in the existing situation.

[21] This bund would have a maximum height of about 0.9m but for most of its length it would no more than 0.5m high.

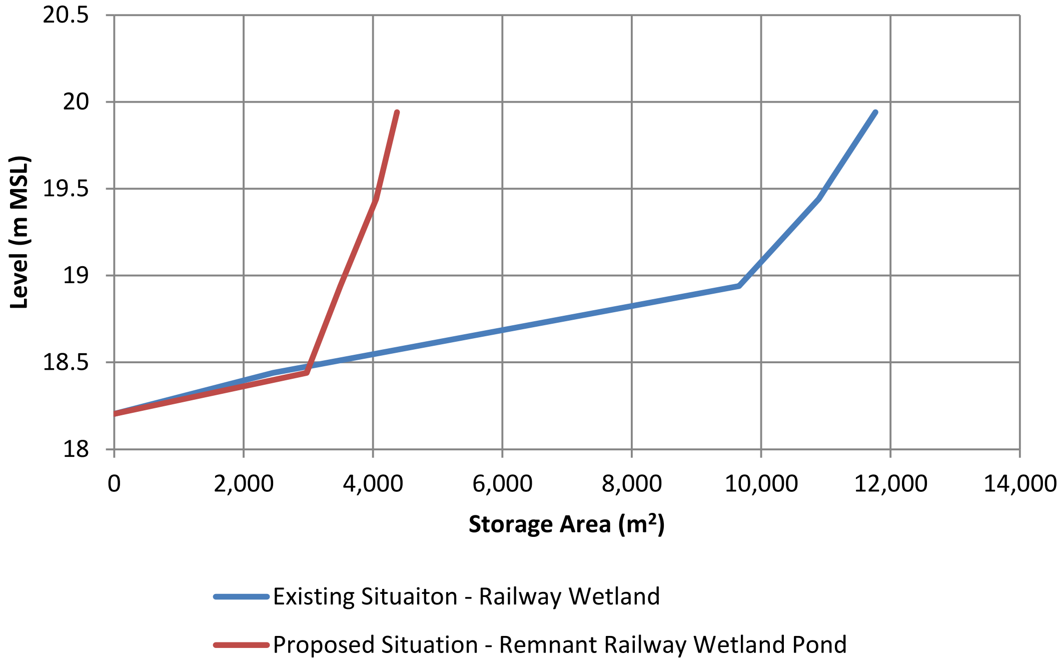

Figure 7-1 Storage area / elevation relationship for remnant Railway Wetland draining Te Manuao sub-catchment on Mangapouri Strean compared to equivalent relationship for existing Railway Wetland (based on LiDAR data)

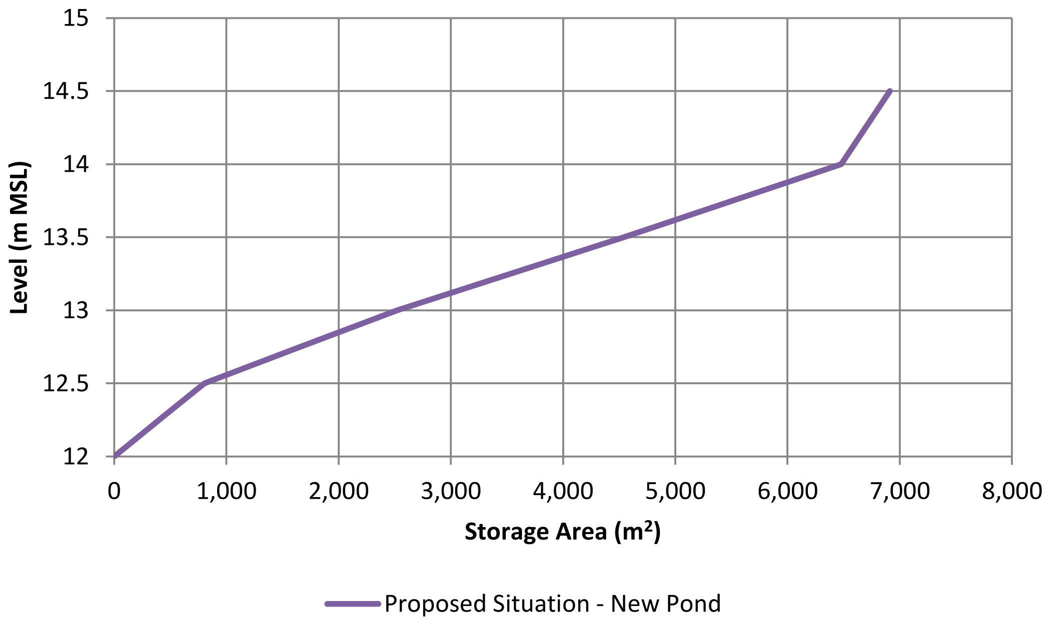

Figure 7-2 Storage area / elevation relationship for new wetland area between old railway embankment and proposed Expressway embankment draining Te Manuao sub-catchment on Mangapouri Strean (based on LiDAR data)

Table 7-2 summarises the predicted maximum flood depth at each culvert location, the flood duration and the approximate flood volume within the upstream ponding area for the 1% AEP flood adjusted for possible future climate change effects to 2090.

Table 7-2 Predicted maximum flood depth, flood duration and flood storage volume at each culvert location on Expressway crossing of Mangapouri Stream System for 1% AEP flood adjusted for possible future climate change effects to 2090

Location	**Maximum Flood Depth (m)**	**Flood Duration * (hrs)**	**Approximate Ponding Area Volume (m^3)**
Old County Rd / NIMT railway line culverts	2.8 (above invert) 1.2 (above bank level)	~ 24	~ 64,000
Old SH1 culvert	2.7 (above invert) 1.8 (above bank level)	~ 24	~ 14,500
Remnant railway wetland	1.8 (above invert)	~ 24	~ 3,400
Secondary wetland (Kennedy's)	1.5 (above invert)	~ 24	8,800 (at peak level) 2,000 (wetland level)

* depends on characteristics of flood

The effects of the Expressway crossing of the Mangapouri Stream and its ancillary features are minimal and acceptable. In very rare floods such as the 0.5% AEP and 0.2% AEP floods adjusted for possible change effects to 2090 where the effects would be slightly greater than in the existing situation (but with the same number of properties affected), there would be widespread flood inundation elsewhere through Ōtaki Township.

7.3 Proposed Configuration for Ōtaki River Crossing

The Ōtaki River crossing on the Expressway will be comprised of two parallel bridges with a total span similar to that of the downstream railway bridge, although the pier spacing will be much larger. This geometry means that, unlike the existing SH1 bridge, the Expressway bridges will not act as a constriction to flood flows in the main river. Pier head losses will also be minimal.

The effects of the proposed Expressway crossing of the Ōtaki River on flood levels in the Ōtaki River and within the off-channel storage basin occupied by the concrete factory will be minimal and acceptable.

7.4 Proposed Mitigation Measures for Ōtaki River Floodplain Crossing

In order to minimise the effects of the Expressway on stopbank overtopping flows spreading across the Ōtaki River right (north) bank floodplain, it will be necessary to provide a means of flow through the embankment for floodwaters ponded behind the embankment barrier. In particular the following mitigation measures are recommended to be implemented:

- a 350m long, approximately 1.75m high secondary containment bund projecting upstream from the Expressway embankment and following naturally higher ground (located about 550m along the Expressway embankment from the Chrystall's Bend stopbank);
- a 40m wide, 1.5m high dry culvert through the Expressway embankment (located about 50m along the Expressway embankment from the Chrystall's Bend stopbank); and
- an approximately 300m long overflow weir section formed by the vertical profile of the road between the dry culvert and the line of the secondary stopbank with a crest level of about 15.3m (MSL Wellington datum) – the road profile would need to rise up to a high point of about 15.8m (MSL Wellington datum) to the north of the line of the secondary containment bund to provide a lateral constraint for the weir section.

The secondary containment bund will prevent the lateral spread of ponded floodwaters into the Mangapouri Stream Catchment along the northern boundary of the Ōtaki River floodplain. The dry culvert will provide the primary means of evacuation for ponded floodwaters behind the Expressway embankment while the overflow weir will provide a secondary means of evacuation for ponded floodwaters.

In terms of peak flow depths and velocities, these mitigation measures would be able to reduce the effects of the Expressway from stopbank over-topping sourced floodplain flows on populated areas to less than those that would occur in the current floodplain situation. However, upstream of the Expressway embankment, peak flood inundation depths would be increased (by up to 0.9m in a 0.2% AEP flood adjusted for possible future climate change effects to 2090) due to the partial damming effect of the embankment while peak flow velocities would be reduced except in the localised area approaching and through the dry culvert. These latter effects would only impact on land currently used for pastoral purposes.

It should also be emphasised that the occurrence of these effects would be extremely rare given the very low annual exceedance probability of Ōtaki River floods (0.2% AEP and larger) which would overtop the stopbank system protecting Ōtaki Township. However the potential for occurrence cannot be dismissed.

Table 7-3 summarises the predicted maximum flood depth at the flood relief culvert location on the floodplain, the flood duration and the approximate flood volume within the ponding area confined by the Expressway embankment to the west, the secondary flood containment bund to the north and the Chrystall's Bend stopbank to the south and for the 0.2% AEP flood adjusted for possible future climate change effects to 2090 overtopping the stopbank.

Table 7-3 Predicted maximum flood depth, flood duration and flood storage volume at flood relief culvert location on Expressway crossing of Ōtaki River floodplain for 0.2% AEP flood adjusted for possible future climate change effects to 2090 overtopping Chrystall's bend stopbank

Location	Maximum Flood Depth (m)	Flood Duration * (hrs)	Approximate Ponding Area Volume (m^3)
Flood relief culvert	1.5	~ 4	~ 40,000

* depends on characteristics of flood overtopping stopbank

On balance the effects of the Expressway crossing of the Ōtaki River floodplain will be minimal and acceptable with the proposed mitigation measures implemented.

7.5 Proposed Configuration and Mitigation Measures for Mangaone Stream and Floodplain Crossing

The Expressway will run parallel with the existing NIMT railway and SH1 transport links and will be located upstream of the former. It will therefore also cut transversely across the Mangaone Stream alluvial fan. To be able to satisfy the required serviceability design flood standard (the 1% AEP flood adjusted for possible climate change effects to 2090), the Expressway will need to emulate the present flood detention function of the elevated NIMT railway line. This will be achieved by means of an elevated bund upstream of the Expressway functioning as a flood detention barrier. To provide continuity for the existing main watercourses, the Expressway will also need to incorporate the following culverts aligned with the downstream NIMT railway and SH1 culverts on each primary watercourse:

- a 5.0m wide by 2.0m high box culvert structure on the main stream channel; and
- an 8.0m wide by 1.5m high box culvert structure on the Mangaone Overflow.

The proposed situation is further complicated by the presence of an east / west link road connecting School Road and Gear Road on the east side with Te Horo Beach Road on the west side via an overbridge across the Expressway. The route of this local link road also intercepts existing overland flow paths across the Mangaone Stream alluvial fan. The serviceability design flood standard for this local link road is lower than that for the Expressway (between the 4% and 2% AEP flood adjusted for possible climate change effects to 2090) so that the road will need to be slightly elevated above the alluvial fan surface to meet the design flood standard. The route of the local link road crosses the main channel of the Mangaone Stream and the Mangaone Overflow upstream of the Expressway on the east side and the Lucinsky Overflow and main stream channel on the west side. The local link road will therefore also require the following culverts and bridge:

- a 5.0m wide by 2.5m high culvert on the main stream channel upstream of the Expressway (east side);

- a 5.0m wide by 1.5m high culvert on the Mangaone Overflow upstream of the Expressway (east side);
- a 5.0m wide by 1.0m high dry culvert on the Lucinsky Overflow (west side); and
- an 8m span single span bridge across the main stream channel downstream of SH1 (west side).

The invert levels of the local link road and Expressway culverts on the Mangaone Overflow have been set fairly low in order to keep road levels as low as possible. A shallow 8m wide excavated channel will need to be formed to provide hydraulic connectivity between the two culverts. A shallow 10m wide, 160m wide trench running parallel with the local link road will also need to be formed upstream of the local link road culvert on the Mangaone Overflow to act as collector basin for overland flows approaching the Overflow.

In order to provide hydraulic connectivity with the main stream channel upstream of the Expressway culvert for overland flows in the northern breakout flow path deflected southwards by the Expressway, either a 10m wide gap between the Expressway and the eastern abutment of the local link road overbridge or a 10m wide by 1.5m high dry culvert incorporated within the overbridge approach embankment needs to be provided.

The School Road drain will need to be relocated and enlarged as part of the relocation of Gear Road to form the new local link road. However, to provide containment of floodwaters along the drain and the flood ponding induced by the elevated local link road across the Mangaone Overflow and main channel of the Mangaone Stream, a flood containment bund will need to be constructed between the local link road and the relocated School Road drain. The bund will need to extend upstream along School Road to cover the extent of flood ponding on the alluvial fan surface. It will also need to incorporate a ninety degree dogleg extension to connect with the flood detention barrier upstream of the Expressway, located to the south of a 2.5m wide by 1.0m high culvert on the School Road drain under the local link road. The School Road drain flood containment bund therefore forms part of the primary flood defence for the Expressway rather than the local link road.

A 5m wide by 1.0m high dry culvert will need to be provided through the western approach embankment to the local link road overbridge to provide hydraulic continuity for the Lucinsky Overflow.

Table 7-4 summarises the predicted maximum flood depth at each culvert location, the flood duration and the approximate flood volume within the upstream ponding areas on the floodplain for the 1% AEP flood adjusted for possible future climate change effects to 2090.

Table 7-4 Predicted maximum flood depth, flood duration and flood storage volume at each culvert location on Expressway crossing of Mangaone Stream Floodplain for 1% AEP flood adjusted for possible future climate change effects to 2090

Location	**Maximum Flood Depth * (m)**	**Flood Duration ** (hrs)**	**Approximate Ponding Area Volume (m^3)**
Expressway culvert (main stream channel)	< 1.5	~ 12	~ 12,000
Local link road culvert (Mangaone Overflow)	~ 1.3	~ 12	~ 18,000
Expressway culvert (Mangaone Overflow)	~ 1.6	~ 12	~ 18,000
Local link road culvert (School Road drain)	< 2.0	~ 12	~ 25,000

* above floodplain level

** depends on characteristics of storm

The effects of the Expressway crossing of the Mangaone Stream alluvial fan and floodplain system will be minimal and acceptable with the proposed mitigation measures implemented.

.

8. References

ARC (2009). "Fish Passage in the Auckland Region – a synthesis of current research". Auckland Regional Council, Technical Report No. 084, prepared by NIWA for ARC, June 2009.

Coles, R and Bird, W (2013). "Peka Peka to North Ōtaki Expressway: Assessment of Stormwater Effects". Report prepared by Opus International Consultants Limited for NZ Transport Agency, Issue 4, February 2013.

Gardner, M (2009). "Waitohu Stream Gravel Analysis – 1992 to 2009". Greater Wellington Regional Council Report No. N/06/30/05, December 2009.

Gardner, M (2011). "Ōtaki River Gravel Analysis – 1991-2011". Greater Wellington Regional Council Report, September 2011.

GWRC (2007). "Hydraulic Assessment of Chrystall's Bend Extended Stopbank". Greater Wellington Regional Council File Report prepared by P Wallace, March 2007.

Harkness, M (2003). "Waitohu Stream Study, Flood Report". Report prepared by Resource Investigations Department, Greater Wellington Regional Council, July 2003.

MfE (2010). *Tools for Estimating the Effects of Climate Change on Flood Flow: A Guidance Manual for Local Government in New Zealand*. Ministry for the Environment, Publication No. ME 1013, New Zealand Government, May 2010.

MWH (2002a). "Mangaone Stream Flood Hazard Assessment, Summary Report". Report prepared by Montgomery Watson New Zealand for Wellington Regional Council, WRC Publication No. WRC/FPSA-T-02/25, June 2002.

MWH (2002b). "Mangaone Stream Flood Hazard Assessment, Hydraulic Modelling Report". Report prepared by Montgomery Watson New Zealand for Wellington Regional Council, 2 Volumes, WRC Publication No. WRC/FPSA-T-02/27, June 2002.

Smith, H W and Webby, M G (2013a). "Peka Peka to North Ōtaki Expressway, Detailed Investigations for Expressway Crossing of Mangapouri Stream". Report prepared by Opus International Consultants Limited for NZ Transport Agency, Revision 1, January 2013.

Smith, H W and Webby, M G (2013b). "Peka Peka to North Ōtaki Expressway, Hydraulic Investigations for Expressway Crossing of Ōtaki River Floodplain". Report prepared by Opus International Consultants Limited for NZ Transport Agency, Revision 1, January 2013.

Smith, H W and Webby, M G (2013c). "Peka Peka to North Ōtaki Expressway, Hydraulic Investigations for Expressway Crossing of Waitohu Stream and Floodplain". Report in preparation by Opus International Consultants Limited for NZ Transport Agency, Revision 1, January 2013.

Smith, H W and Webby, M G (2013d). "Peka Peka to North Ōtaki Expressway, Hydraulic Investigations for Expressway Crossing of Mangaone Stream and Floodplain". Report in preparation by Opus International Consultants Limited for NZ Transport Agency, Revision 1, January 2013.

Transit NZ (2003). *Bridge Manual*. Second edition, Transit New Zealand (now part of New Zealand Transport Agency), June 2003.

Williams, G (2004). "Waitohu Stream Study: River Characteristics and Sedimentation", Channel Management. Report prepared by G & E Williams Consultants Ltd for GWRC, Greater Wellington Regional Council, April 2004.