

REPORT

**HAWKES BAY REGIONAL
COUNCIL**

**Wairoa River Bank Stability
Assessment**

Report prepared for:
HAWKES BAY REGIONAL COUNCIL

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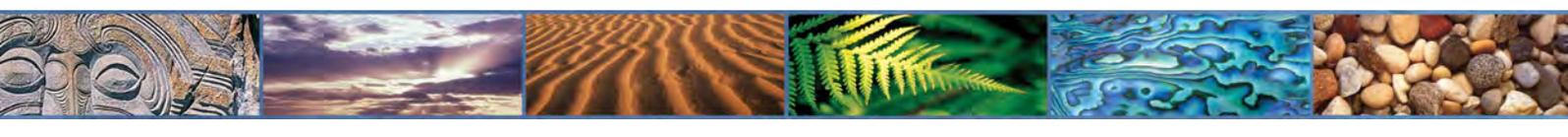


Table of Contents

1	Introduction	1
1.1	Background	1
1.2	Scope of Study	1
1.3	Sources of Information	1
1.4	Site Inspections	2
2	Geology	2
2.1	Published Information	2
2.2	Exposures	2
2.3	Engineering Geology and Form of Instability	3
3	River Bank Assessment	3
3.1	Section 1	6
3.2	Section 2	6
3.3	Section 3	7
3.4	Section 4	8
3.5	Section 5	8
3.6	Section 6	9
3.7	Section 7	10
3.8	Section 8	11
3.9	Section 9	11
3.10	Section 10	12
3.11	Section 10.1	12
3.12	Section 10.2	12
3.13	Section 10.3	13
3.14	Section 10.4	13
3.15	Section 10.5	13
3.16	Section 10.6	14
4	Hazard Lines and Further Geotechnical Assessment for Development	15
4.1	Introduction	15
4.2	Form of Instability	15
4.3	Hazard Assessment	15
4.4	Required Level of Geotechnical Assessment	16
4.5	Areas Requiring Further Assessment	17
5	Applicability	19

Appendix A: Figures

Appendix B: Annotated Site Inspection Photographs

1 Introduction

1.1 Background

Tonkin & Taylor Ltd ('T&T') were engaged by Hawke's Bay Regional Council ('HBRC') to undertake an assessment of the bank stability over a 12km reach of the lower Wairoa River, extending from approximately 3km downstream to 9km upstream of the SH2 bridge in Wairoa town (see Figure 1 included in Appendix A).

The purpose of the study is to provide a preliminary assessment of the existing condition and medium- to long-term stability of the banks to assist HBRC in setting hazard lines along the river for future planning purposes and identify any areas requiring remedial works or further investigation in the short-term.

1.2 Scope of Study

The proposed scope of the present study was set out in a proposal prepared by T&T dated 13 February 2009, with authorisation to proceed on those terms received from HBRC on 18 February 2009.

It was proposed to undertake the study in three stages, as detailed below:

Desk Study - Including the collation and review of aerial photographs (provided by HBRC), topographical and geological maps and any other readily available data and preparation of worksheets for use in the subsequent field inspections.

Site Inspection and Mapping - Physical inspection of the river banks was to take place primarily from the river, mapping and logging features on both sides of the river, located by handheld GPS and sections taken using a hand held laser. Where possible, the tops of the river banks were also to be inspected from the land. Features to be recorded included river bank geology where visible, slope condition (height, angle and vegetation cover), groundwater seepages, surface flows over the banks, existing slope failures and evidence of scour and bank erosion. T&T also proposed to discuss the historic condition/performance of the river banks with HBRC staff / local residents.

Assessment and Reporting - Integration of the results of the two previous stages in order to prepare summary topographic, geological and geomorphic information, which can be used to produce susceptibility and hazard maps of the banks, to delineate zones of set back from the bank crest which have a low, moderate and high probability of being affected by bank instability within the next 50 years. This information can then be used to help identify an appropriate level of investigation and/or remedial works that may be considered for land use planning and development.

1.3 Sources of Information

In undertaking this review, we have made use of the following principal sources of information:

- 'Geology of the Raukumara Area', 1:250,000 Geological Map 6, published by Institute of Geological & Nuclear Sciences Limited (2000).
- Twenty-one small scale aerial photographs of the lower Wairoa River taken on 14 March 1988 (provided by HBRC).
- 0.25m and 0.5m contour plans of the lower Wairoa River developed from the Council's LIDAR dataset (provided by HBRC).

- Aerial photography presented on Terraview Platinum and Google Earth.

1.4 Site Inspections

The site inspections were carried out by a senior engineering geologist from T&T on 03 and 04 March 2009. This comprised a visual inspection of both sides of the river by boat (provided by HBRC) on the first day, followed by a land based inspection of the most critical and accessible sections on the second day.

The sections inspected from land included:

1. The whole of the right bank from approximately 0.5km upstream (Churchill Street) to 3km downstream of the SH2 bridge (downstream end of the study area, opposite Lion Street);
2. The left bank from 200m or so upstream of the SH2 bridge (just beyond Carroll Street) to approximately 1km downstream (refrigeration plant);
3. The section of river alongside which the SH2 follows the right bank, covering a total distance of around 3.5km; and
4. A short section of the left bank adjacent to the Marae on Ruataniwha Road was also completed due to the special circumstances at this location, as detailed further below (see Section 3.16).

A selection of annotated photographs taken during the boat and land based inspections are included in Appendix B and referenced further with regards to the specific features identified in Section 3.

2 Geology

2.1 Published Information

The geological map covering the study area indicates that the Wairoa River has incised into the undifferentiated fossiliferous mudstones and tuffaceous sandstones of the Mangaheia Group, which was deposited during the early Pliocene (approximately five million years ago). These are indicated as being overlain by recent alluvial deposits comprising poorly to moderately sorted gravel with minor sands and muds, overlain in places by Tephra. These recent deposits occupy the extensive low-lying areas bordering the river, including the whole of Wairoa town, and extending approximately 20km upstream.

2.2 Exposures

Opportunities to inspect the geology exposed on the river banks were confined largely to those areas accessible by foot and where relatively recent landslips had occurred. It was possible however to determine the likely geology at further exposures viewed from the boat where recent landslips had exposed the underlying materials. Road cuttings along the SH2 upstream of Wairoa were also inspected.

The mudstones and tuffaceous sandstones of the Mangaheia Group are exposed at two main locations within the study area. The left bank of the river approximately 2km downstream of the SH2 bridge is actively eroding the high, steep slopes over a distance of around 1 to 1.5km, extending to the downstream end of the study area and also from around 2km upstream of Wairoa, where the SH2 runs alongside the right bank for

approximately 3.5km. The river is actively eroding the bedrock materials along these sections and the materials are further exposed in the road cuttings.

The majority of the river banks are however formed within the more recent alluvial materials, predominantly estuarine muds within and downstream of Wairoa, becoming sandier upstream with some exposed overlying Tephra. These finer grained deposits are likely to be underlain by higher energy fluvial materials, particularly sands and gravels, but we did not observe these in any of the exposures.

2.3 Engineering Geology and Form of Instability

The finer grained alluvial materials present at the downstream end of the study area is predominantly affected by erosion leading to relatively small-scale 'undrained' failures, particularly when the ground is fully saturated and the tidal range is large (i.e. rapid drawdown failures). Further upstream, where the alluvial deposits become coarser grained, a 'drained' form of instability predominates, comprising principally of shallow surface slips following erosion of the lower river bank.

3 River Bank Assessment

The following sub-sections provide a summary of the principal observations covering different lengths of the river. The individual sections represent areas with reasonably similar conditions, although there is some variability within those reaches. An overview of the extents of the sections is shown on Figure 1. Each section also includes a summary of the likely future condition of the river banks, which forms the basis of the hazard identification detailed in Section 4.

Reference to the right and left banks assumes facing downstream.

Table 3.1 below provides a summary of the main features of the river banks within each section.

Section	Approximate Location (see Figure 2)	Length (km)	Vegetation	Dominant Geology	Typical Bank Height (m)	Typical Bank Slope (°)	Bank Form ¹	Land Designation ² ()	Erosion (%)	Landslip (%)	Existing Bank Protection Works (Y/N)
1	Right Bank, Lion Street to Queen Street	1.35	Light	Alluvium	1 - 2	>45	A	CR	75 - 100	25 - 50	N
2	Right Bank, Queen Street to just downstream of SH2 Bridge	1.25	Varies	Alluvium	4 - 5	20 - 35	B	CR	50 - 75	0 - 25	N
3	Right Bank, just downstream of SH2 Bridge to Churchill Street	0.90	Light	Alluvium	0.5 - 2	>45	A	CR/RES	50-75	0 - 25	Part
4	Right Bank, Churchill Street to Archilles Street (SH2)	1.30	Medium	Alluvium	3 - 8	20 - 25	B/C	CR/RUR	50 - 75	25 - 50	N
5	Right Bank, adjacent to SH2	3.50	Heavy	Alluvium/ Mudstone	5 - 8	20 - 30	C	RUR	50 - 75	25 - 50	N
6	Right Bank, SH2 to upstream end of study area	3.20	Light to Medium	Alluvium	4 - 10	20 - 30	B	RUR	0 - 25	0 - 25	N
7	Left Bank, Tirohia Road to Flaxmill Road	1.60	Medium to Heavy	Alluvium	4 - 5	15 - 25	B/D	IND/TC/CR	75 - 100	25 - 50	Part
8	Left Bank, Flaxmill Road and outside of river bend	1.0	Medium to Heavy	Alluvium	2 - 3	20 - 30	B	RUR	75 - 100	25 - 50	N

9	Left Bank, High, steep slopes at downstream end of study area	1.20	Light	Mudstone/Sandstone	>10	>45	D	RUR	75 - 100	50 - 75	N
10.1	Left Bank, Tirohia Road to change in river direction	2.35	Light to Medium	Alluvium	3 - 5	20 - 30	B	RUR	0 - 25	25 - 50	N
10.2	Left Bank, from Section 10.1 upstream to start of meander	1.50	Light to Medium	Alluvium	6 - 8	20 - 30	B	RUR	0 - 25	25 - 50	N
10.3	Left Bank, inside of meander upstream of Section 10.2	0.50	Light to Medium	Alluvium	4 - 5	<20	B	RUR	0 - 25	0 - 25	N
10.4	Left Bank, straight section of River between meanders	1.40	Light to Medium	Alluvium	8 - 9	25 - 35	B	RUR	0 - 25	0 - 25	N
10.5	Left Bank, inside of meander upstream of Section 10.4	1.30	Light to Medium	Alluvium	5 - 6	20 - 25	B	RUR/CR	0 - 25	0 - 25	N
10.6	Left Bank, outside of meander from upstream end of study area	1.10	Heavy	Alluvium	9 - 10	20 - 30	B	RUR	0 - 25	0 - 25	N

Table 3.1: Summary of River Bank Conditions.

Notes:

¹ A - Steep to near vertical bank formed by erosion related to tidal variation in water level, predominantly towards mouth of river on right bank.

B - Base of bank is steep to near vertical formed by scour from river with linear to gently convex/concave slope above.

C - Base of bank is steep to near vertical formed by scour from river with concave slope above.

D - Base of bank is steep to near vertical formed by scour from river with convex slope above.

² - TC = Town Centre, IND = Industrial, RES = Residential, RUR = Rural, STL = Settlement, CST = Coastal, CR = Conservation and Reserve. See Wairoa District Plan (June 2005).

3.1 Section 1

This includes the section of right bank extending from Lion Street (downstream end of study area) to the sharp bend in river adjacent to Queen Street.

3.1.1 Observations

This section covers a total distance of around 1.35km and typically comprises low (1.0 to 2.0m high), near vertical banks backed either by relatively flat or gently sloping ground extending back to Kopu Road and/or the surfaced footpath (see Photograph 1). In places, particularly towards the upstream end, the banks increase to 2 to 3m high, typically at around 20 to 30°.

The near vertical sections of the slope probably correspond with the typical tidal variation of the river and generally comprise firm clayey organic silts with little or no vegetation on the bank face and are generally grassed behind the crest with occasional tree cover. The near vertical sections show evidence of scour which exerts a significant control on the form of minor instability observed. These typically comprise narrow failures with near vertical back scars (see Photographs 2 and 3), although some more extensive rotational slips do occur. Where steep slopes are present extending up from the vertical face, these are affected by shallow slipping associated with loss of toe support.

Broken concrete slabs and other man-made materials have been pushed over the edge of the bank in areas between Grey Street and Sturdee Street (see Photographs 4 and 5) and act as an ad hoc bank defence, but are unlikely to provide any medium- to long-term protection. No existing engineered protection measures were observed along this section.

3.1.2 Potential Future Condition

The river banks are designated as Conservation and Reserves (CR), but only over a narrow strip, beyond which the land is zoned as Residential. Within 50 years the Conservation and Reserves area could be significantly reduced and some of the Residential (RES) area lost unless engineered bank protection measures are established. The river bank around Sturdee Street comes to within 5 to 10m of Kopu Road and up to the edge of the footpath (see Photograph 6). Damage of the footpath and/or road is anticipated within 10 to 20 years unless formal protection measures are put in place.

3.2 Section 2

This section extends from the northern end of Section 1 to just east of the SH2 bridge in the centre of Wairoa, covering a distance of approximately 1.25km.

3.2.1 Observations

Marine Parade runs parallel to the river bank along much of this reach with residential areas to the rear of this along the eastern half and predominantly commercial buildings along the western half (either side of Murrae Street).

From the bend in the river to just beyond Murrae Street, the banks are typically 4 to 5m high with 20 to 30° slopes. Occasionally there is a lower, steep section (45 to 90°) with a narrow bench and flatter, upper slope. The slopes are generally grassed with occasional trees near the toe of the slopes and large broadleaved trees to the rear of the crest (see Photographs 7 and 8). There is ongoing scour of the lower banks and some surface instability of the upper slopes (see Photograph 9).

Beyond Murrae Street the slopes continue to be around 4 to 5m high but become heavily vegetated with well-established mature trees and thick bushes (see Photograph 10). The slopes are typically a little steeper (25 to 35°) and lack the defined bench observed to the east, although there is a rough footpath along much of the slope which has been terraced into the bank. There are further signs of scour of the river banks (see Photograph 11) but less instability of the high slopes, or these may be masked by the relatively thick vegetation.

There are a number of 'engineered' retaining walls along parts of the upper slopes (see Photographs 12 to 14), but these generally appear to have been installed to retain sections of the bank that have been terraced for amenity or landscaping purposes, rather than in response to natural slope failures induced by fluvial processes. No engineered bank protection measures were observed at the toe of the slopes over this section of the river.

3.2.2 Potential Future Condition

The river banks are designated as Conservation and Reserves up to Marine Parade. Beyond Marine Parade the area downstream of Murrae Street is zoned Residential and that upstream is Town Centre (TC). Ongoing scour of the river bank will result in continued minor instability of the lower slopes which could, over time, undermine the higher sections of the banks. Such failures are unlikely to extend as far as Marine Parade on a large scale over the next 50 years and may be dealt with in a piecemeal fashion. Engineered protection measures are however likely to be required to ensure the Conservation and Reserves area is not significantly depleted over this period.

3.3 Section 3

Section 3 extends from approximately 150m east of the SH2 bridge to Churchill Avenue, covering a total distance of around 0.9km.

3.3.1 Observations

The distance of the river bank from Marine Parade increases from the eastern end of this section to around 150m upstream of the bridge. The intervening ground comprises open grassed amenity space zoned as Conservation and Reserves, containing a children's playground to the east of the bridge and community centre to the north (see Photograph 15). The banks are generally less than 2m high and reduce to less than 1m upstream of the SH2. They are often near vertical or very steep (>45°), but in places, particularly towards the western end, slope gently from the river (see Photographs 16 to 18). The slopes are generally grassed but with occasional isolated trees and bushes. The banks are quite heavily vegetated west of the Water Ski Club building to the end of this section.

A small section of filled ground is located in front of the community building to the west of the SH2 bridge and some form of matting protection has been put in place to reduce erosion of the increased bank height/gradient here (see Photograph 20).

3.3.2 Potential Future Condition

The area downstream of the SH2 and upstream as far as Lockwood Point is zoned as Conservation and Reserves, with the remaining section adjacent to Churchill Avenue being Residential. As with Sections 1 and 2, there is ongoing minor instability associated with scour of the banks (see Photograph 19). This is likely to continue at a slow rate with limited loss of Conservation and Reserves areas but could impact on Churchill Avenue

within the next 10 to 20 years. Formal bank protection in this area may therefore be required within this period to prevent damage to the road.

3.4 Section 4

Section 4 extends from Churchill Street to where the SH2 (Archilles Street) converges back to the right bank of the river, a distance of about 1.3km.

3.4.1 Observations

It was not possible to inspect this section by foot as a result of private residences on Mitchell Road / Rimu Drive running up to the river bank and therefore the following description is based entirely on observations made from the river.

The banks along this section vary from around 3 to 4m at the eastern end increasing gradually to around 6 to 8m at the western end. The slopes are typically 20 to 25°, but locally up to 40°. The slopes and crest is generally quite well vegetated (see Photograph 21). Signs of bank instability were present along much of this section and it is possible that further slips / erosion may have been hidden by the thick vegetation cover. The largest observed slips were located just beyond Mitchell Road (see Photographs 22 and 23). These typically occur, or were more apparent, where the vegetation cover was less.

No significant engineered protection structures were observed along this section.

3.4.2 Potential Future Condition

The river banks adjacent to Mitchell Street / Rimu Drive are zoned Residential and the remaining section upstream is allocated as Rural. The residential properties along Mitchell Street / Rimu Drive extend up to the river bank. Any future building development on these lots close to the river bank should take into account the presence of existing instability and future regression of the slope. Suitable set-back lines and/or bank protection measures will need to be included and any development in these areas should be subject to a specific geotechnical assessment. Any proposed development within the Rural section should be subject to a similar level of assessment.

3.5 Section 5

This covers the section of river bank along which the SH2 follows before diverging away from the river in a northerly direction. It covers a distance of approximately 3.5km.

3.5.1 Observations

This section of the river was viewed from both the river and from along the crest of the slopes. The slopes vary in height from around 2m to in excess of 11 or 12m, but typically between 5 and 8m high. The slope gradients vary but are generally around 20 to 30°, but often increase to 45° over short sections. The slopes are generally heavily vegetated, mostly with large mature trees and thick bush, which makes assessment of the lower slopes difficult either from the river or on foot (see Photographs 24 to 26).

There is evidence all the way along of ongoing instability resulting from erosion of the toe and from shallow instability of the upper sections of the slope. Some of these affect relatively long sections of the bank and on the highest parts of the slope (see Photographs 24 to 27).

The road hugs the edge of the river and is often within a few metres of the top of the slopes, in places less than 1m, and barriers have recently been installed (see Photographs 25 and 27) with further barriers being installed at the time of the inspection.

Some instability of the upper to middle sections of the slopes was observed resulting from surface water runoff, either directly from the road or via highway drainage. Some of the highway drains were observed to include sheeting placed over the surface of the slopes (see Photograph 28A). The majority however simply discharge out of a pipe located a short distance down the slope, which is resulting in erosion and subsequent localised instability of the slopes (see Photograph 28).

No engineered bank protection measures were observed along this section of the river.

3.5.2 Potential Future Condition

It is anticipated that ongoing erosion of the lower river banks is likely to result in minor instability of the toe and that this loss of support could result in slips occurring higher on the slopes. These could impact on the highway itself, although would be of limited lateral extent and be relatively shallow seated. Further erosion resulting from surface water runoff from the road and via highway drains is likely to continue and could result in larger instability of the upper sections of the slopes.

It is possible that the risks of instability associated with the section adjacent to the SH2 may have been assessed by Transit New Zealand. However, if this is not the case we would advise that some sections of the road could be affected by shallow instability in the near future and a more detailed assessment would be beneficial.

3.6 Section 6

The remaining length of the right bank upstream from Section 5, extends for approximately 3.2km and borders rural, predominantly agricultural land.

3.6.1 Observations

The banks vary from around 4.5 to 10m high, generally at between 20 to 30°, but up to 40° in places, particularly in the central part of this section where the slopes are the highest. The slopes are generally grassed with some well established trees and large bushes (see Photographs 29 to 32).

There are a number of relatively small landslips affecting the lower parts of the slopes below and just above the normal river level (see Photographs 29 and 31) and a few larger slips affecting a large part or all of the slope and extending some distance laterally (see Photograph 30). The larger failures appear to occur predominantly on the higher, steeper slopes within the central area of this section.

The relatively small slips located at the base of the slopes are likely to result predominantly from scour of the river bank and of are little significance in this area of the rivers reach. However, these failures may be precipitating larger failures affecting the upper slopes. The failures observed on the upper slopes, whilst only viewed from the boat, appear shallow and do not therefore take much of the above land.

No evidence of instability was observed from out of bank flood flows or surface water drainage into the river, other than that associated with minor instability around tributaries.

3.6.2 Potential Future Condition

The land along the banks of the river over this section are zoned Rural with a short section of Conservation and Reserves in the central portion. Ongoing erosion of the river banks may lead to instability of the higher slopes and some loss of ground. This is likely to proceed at a slow pace and is not considered to represent a significant hazard or loss of land.

3.7 Section 7

This section was inspected by boat and subsequently on foot and extends from Tirohia Road to Flaxmill Road, covering a distance of approximately 1.55km. It includes the only parts of the left bank in which Industrial, Town Centre and Residential zones occur, the remainder being all Rural.

3.7.1 Observations

The slopes along this section are generally between 4 and 5m high, reducing to between 2 and 3m at the downstream end. They are generally around 20° but there are some steeper sections and the lower parts of the slopes into the river are often near vertical up to between 1 and 1.5m high. The slopes are generally well-vegetated with dense bushes and some larger trees towards the base of the slopes and often well-established mature trees at or just beyond the crest (see Photographs 33 and 34).

The lower parts of the slopes close to river level are affected by scour and resulting shallow slips. There are few signs however of larger failures affecting the upper parts of the slopes downstream of the SH2 bridge.

Immediately upstream of the SH2 bridge to the end of this section (a distance of approximately 0.5km), there are several quite large rotational failures affecting the entire slope (see Photographs 33, 35, 37 and 40). Some timber retaining walls have been constructed along the river bank in this area (see Photograph 36) and a concrete retaining wall (which has failed) on the upper part of the slope (see Photographs 38 and 39). It is noticeable that the river bank immediately upstream of the bridge forms a narrowing of the channel on the outside of the meander and therefore greater scour of the banks at this location might be expected.

3.7.2 Potential Future Condition

The section of river bank upstream of the SH2 is zoned as Town Centre (along River Parade) and Industrial to Tirohia Road. Parts of this section include bank protection in the form of low timber walls extending just above river level. However, there is ongoing erosion of the banks and subsequent instability of the slopes. We anticipate that this will continue at a reasonable pace without specific engineered bank protection. This is likely to impact both on the industrial and town centre zoned areas and potentially undermine parts of River Parade within the next 10 to 20 years.

It was not possible to gain safe access to the existing bank protection to inspect its present condition. Further inspections of this section of the bank are recommended and it is likely that some form of further bank protection will be required to prevent further significant loss of ground.

Downstream of the bridge is zoned as Conservation and Reserves and Industrial (IND) adjacent to the refrigeration plant. Ongoing erosion will lead to further instability of the slopes along this section unless engineered protection works are included. This could lead

to a loss of ground from the CR and IND areas but this is unlikely to exceed 5 to 10m over the next 50 years.

3.8 Section 8

This section stretches from Flaxmill Road to the high, steep mudstone slopes at the downstream end of the study area, covering a distance of around 1km.

3.8.1 Observations

Immediately downstream of Section 7 the banks are generally between 2 and 3m high and typically between 20 to 30°, but with some steeper sections locally. The slopes are generally quite heavily vegetated, but in places more grassed with isolated bushes/trees (see Photograph 41 to 43). The banks continue like this for approximately 1km before starting to increase in height and steepness. This change marks the boundary between the predominantly alluvial deposits making up the river banks upstream and the mudstones and sandstones that constitute the high slopes further downstream (Section 9).

Several minor slips were observed affecting the river banks along the lower slopes (see Photograph 43). Although not apparent from the boat inspection, possibly due to the presence of dense tree cover, a large portion of the river bank downstream of the tributary that discharges into the river just downstream of Flaxmill Road, appears to constitute a large subsided area adjacent to the river. An arc extending approximately 550m along the river bank, increasing to approximately 60m back from the bank, is backed by a further 1.5 to 2.5m high slope. This is revealed by the LIDAR data and can be seen on the aerial photographs. Further detailed inspections will be required to confirm whether this is the case.

3.8.2 Potential Future Condition

This section is zoned as Rural. We anticipate that ongoing erosion of the bank, particularly on the outside of the bend in the river, will continue at a reasonable pace. Development within this area and particularly that within or adjacent to the apparent subsided area should be subject to specific geotechnical investigation.

3.9 Section 9

Section 9 comprises the section on the left bank extending from the end of Section 8 to the downstream end of the study area, covering a distance of around 1.2km.

3.9.1 Observations

The relatively low-lying ground upstream of this point with river banks formed primarily in the alluvial deposits, passes into the steep slopes incised into the mudstones and sandstones of the Mangaheia Group. These rise to in excess of 80m and generally include a very steep (>45°) lower section rising typically to between 5 and 10m, followed by a slacker (30 to 45°) slope above. These are generally grassed but bare areas occur close to river level, indicating recent shallow instability (see Photograph 44).

3.9.2 Potential Future Condition

Whilst there are signs of ongoing erosion and instability of the mudstone and sandstone slopes, these are likely to continue at a slow rate and given the severity of the slopes, development in this area is not considered realistic. Any proposed development in this area would be subject to detailed geotechnical assessment.

3.10 Section 10

Section 10 covers the remaining length of the left bank extending from Tirohia Road to the upstream end of the study area, covering a total distance of around 8.2km. There is very little development along this section of the river except for isolated individual properties and these are generally set back some distance from the banks, with a few exceptions as highlighted below. Details of the banks along this section have been sub-divided to make it easier to follow.

3.11 Section 10.1

This section extends from Tirohia Road for approximately 2.35km upstream to the change in direction of the river.

3.11.1 Observations

The river bank is typically 4 to 5m high with reasonably steep slopes (20 to 30°) (see Photograph 46), but increasing to around 7m in the central portion. It is backed by a further relatively consistent slope of around 2 to 3m high which has a gentle gradient. This rear slope is separated by a relatively flat area which increases to around 100m from the river bank. This may represent a former large-scale subsidence over this reach, which extends between two bends in the river. This feature was not apparent during the boat inspection but can be seen from the LIDAR data and also on the aerial photographs.

3.11.2 Potential Future Condition

There are no apparent existing residential or commercial developments within this area, which is zoned Rural. The river banks along this section are subject to ongoing minor instability but regression of the slope is considered to be slow. Future development within the area identified as possible former subsidence should be subject to detailed geotechnical assessment, although it is unlikely that this is at significant risk of future large scale movements.

3.12 Section 10.2

This section extends from the bend in the river at the upstream end of Section 10.1 to the start of the sharp meander approximately 1.5km further upstream.

3.12.1 Observations

The banks are generally between 6 and 8m high with reasonably steep slopes (20 to 30°). They are generally grassed but some sections contain relatively mature trees within and at the top of the slopes. There is extensive instability of these slopes, with many of the slips extending over quite large distances and affecting quite a large proportion of the slope. They do not however generally extend to the full height of the banks (see Photographs 47 and 48). There is little or no development of the land to the rear of the slopes except for one residential property with associated farm buildings towards the upstream end.

3.12.2 Potential Future Condition

These banks are likely to continue to erode and regress at a steady pace but this is unlikely to extend by more than 5 to 10m on average over the next 50 years.

3.13 Section 10.3

This section covers the inside of the meander upstream of section 10.2, covering a distance of approximately 0.5km.

3.13.1 Observations

The bank occupying the inside of the meander appears to have been affected by past large scale instability with a 4 to 5m high, 20 to 30° slope extending up from the river followed by a relatively level bench up to 50m wide, backed by a further 3 to 4m high slope. This feature covers the entire meander over a distance of about 0.5km. The lower slopes are generally grassed but with some bushes and small trees within the slope and larger mature trees beyond the crest (see Photographs 49 and 50). There is evidence of small scale instability and scour of the river banks but no examples of larger slips were observed, although these may have been masked by the vegetation.

3.13.2 Potential Future Condition

The river banks along this section are subject to ongoing minor instability but regression of the slope is considered to be slow. Future development within the area identified as possible former subsidence should be subject to detailed geotechnical assessment. However, it is considered unlikely to be at significant risk of future large scale movements.

3.14 Section 10.4

This section occupies the length of river between the two meanders detailed for Sections 10.3 and 10.5, covering a distance of around 1.3km.

3.14.1 Observations

The slopes over this section are at a relatively constant height of around 8 to 9m leading to level ground to the north of Ruataniwha Road. The slopes are generally at between 25 and 35° and grassed but with occasional trees within and at the base of the slopes. Some relatively large scale slips affect the full height of these slopes with many smaller slips affecting the lower banks (see Photographs 51 to 53).

There are a few properties with buildings located close to the crest of the slopes which could be at risk of future slope instability.

3.14.2 Potential Future Condition

The banks along this section will continue to erode resulting in further instability of the slopes but this is unlikely to exceed 5 to 10m over the next 50 years.

3.15 Section 10.5

This section includes the inside of the large meander stretching over a distance of approximately 1.3km near the upstream end of the study area.

3.15.1 Observations

The slopes are typically around 5 to 6m high with gently sloping ground rising a further 2 to 3m beyond, such that the overall height of the slope is similar to that immediately downstream and upstream (Sections 10.4 and 10.6). The slopes are generally less than 25°, grassed with occasional trees and bushes. There is minor instability of the lower banks

along much of this section and a few larger slips extending up to halfway up the slope (see Photographs 54 and 55), but generally less than observed further downstream.

There are a few properties with buildings located close to the crest of the slopes which could be at risk of future slope instability.

3.15.2 Potential Future Condition

The banks along this section will continue to erode resulting in further instability of the slopes but this is unlikely to exceed 5 to 10m over the next 50 years.

3.16 Section 10.6

The final 1.3km length of river bank to the upstream end of the study area comprises the outside of a large meander.

3.16.1 Observations

The banks are typically 9 to 10m high, relatively steep slopes (20 to 30°), which are generally heavily vegetated (see Photographs 56 and 57). There is evidence of several small slips close to river level but few signs of larger scale instability. This may be masked by the vegetation to some extent, but there is certainly less larger-scale instability along this section than further downstream.

HBRC staff indicated some concerns over the proximity of the Marae and associated burial grounds at the downstream end of this section. This area was inspected from the land but due to the dense vegetation and steepness of the slopes, only a limited inspection was possible. The Marae buildings are set back some distance from the crest of the slopes, which are around 9 to 10m high and up to 30 to 35° and covered with heavy vegetation (see Photograph 58). The burial grounds with headstones however are located within 5m of the crest slope (see Photograph 59) and it is understood that further burial grounds associated with the 1920s flu outbreak may be located even closer to the slope.

3.16.2 Potential Future Condition

Whilst the speed of regression of these slopes may be relatively low, the proximity of a number of buildings (including the Marae) and Ruataniwha Road, dictate that the potential impact of any future instability may be more severe than further downstream. It is considered that further instability of the slope adjacent to the Marae may occur within the next 10 to 20 years and that more detailed geotechnical assessment is warranted.

4 Hazard Lines and Further Geotechnical Assessment for Development

4.1 Introduction

This section presents recommendations with regards to hazard lines to be adopted along the river banks for future development and identifying those areas where further assessment may be beneficial to determine whether bank protection measures are required to prevent further significant instability in the short- to medium-term.

4.2 Form of Instability

Our inspections of the river banks suggest that the slopes have largely reached a stable morphology under normal conditions (i.e. excluding extreme storm/flood and/or seismic events) with slope gradients generally in the 20 to 30° range. However, ongoing erosion of the river banks, both under normal flow conditions and during high flow events, is likely to result in a loss of toe support, resulting in further instability of the slopes.

At the lower end of the river, particularly around Wairoa town and further downstream, the near surface subsoils contain a significant proportion of fine-grained material and tend to behave as cohesive deposits. Ongoing erosion in these areas leads to relatively small scale 'undrained' rotational failures. These are most likely to occur when the ground is fully saturated and the river water level drops quickly in response to tidal variations (rapid drawdown mechanism). Further upstream, the proportion of fine grained material reduces and the slopes behave more in a 'drained' manner. Erosion of the lower banks in these areas therefore precipitates relatively shallow, but more extensive, surface failures.

4.3 Hazard Assessment

It is difficult to estimate the likely speed of retreat of river banks where the primary control is loss of toe support resulting from erosion of the river banks. This is best achieved by assessing the historic speed of retreat of the river banks over an extended period of time, usually from inspection of historic aerial photographs and/or maps. This information is not available for the present study area at sufficient detail or over an adequate period of time. In estimating the level of hazard at different distances back from the crest of the river banks, we have therefore considered the existing morphology of the slope as the primary determining factor.

We have categorised the assumed level of hazard into low, medium and high. These relate to the likelihood of the ground being affected by bank instability within the next 50 years. The hazard assessment does not take into account the likely impact of the instability in terms of the existing or proposed land use. The significance of instability will be greater in some areas, particularly the town centre, residential and industrial areas when compared to rural and conservation/reserves, but the impact on any individual development within those zones will be similar.

The categories are provided principally to assist the Council in determining the appropriate level of geotechnical assessment required for any proposed development within those zones, as detailed in Table 4.1 below:

Zone	Colour	Level of Geotechnical Assessment Appropriate (see Section 4.4)	Hazard
Low	Yellow	Low	The risk of instability is considered to be low or negligible
Medium	Orange	Moderate	There is a moderate chance of instability affecting this zone within 50 years requiring careful development
High	Red	Detailed	Existing instability of ground within this zone and/or high level of risk of further instability within 50 years. This zone may be considered unsuitable for development unless works are undertaken to avoid, remedy or mitigate the hazard.

Table 4.1: Summary of hazard zones and level of geotechnical assessment appropriate.

The extents of these zones are shown on Figures 2 to 8 included in Appendix A. These have been determined on the following basis:

- Any ground located within the area defined by a 1 in 2.5 slope projected up from the toe of the existing river bank or within 5m of the crest of the slope, whichever is the greater, shall be determined to fall within the High Hazard (Red Zone);
- Any ground located beyond the red zone as above and within the area defined by a 1 in 3.5 slope projected up from the toe of the existing river bank or within 10m of the crest of the slope, whichever is greater, shall be deemed to fall within the Moderate Hazard (Orange Zone); and
- Any ground located beyond the red and/or orange zones shall be deemed to fall within the Low Hazard (Yellow Zone).

There are some areas where future development beyond this criteria have been defined, as shown on the figures, where it is apparent that historic subsidence may have occurred (as detailed in Section 3).

It is important to note that these criteria apply strictly to the risks of erosion and instability of the river banks resulting from fluvial processes. Land stability in terms of erosion and landslip from sources other than the river banks are not included in this assessment nor are issues relating to bearing capacity and settlement. These aspects would need to be considered separate to the recommendations contained in this report.

4.4 Required Level of Geotechnical Assessment

4.4.1 Low Hazard

Development within the low hazard areas should not require any additional geotechnical assessment above that required for standard development where the proposed dwellings are to be constructed in accordance with NZS 3604:1999 – Timber Framed Buildings.

Larger or more complicated structures may however require further investigation and assessment.

4.4.2 Moderate Hazard

Areas within the moderate hazard areas should include a specific site assessment by a geotechnical specialist and would likely include some intrusive investigations and site specific stability assessment. Slope stabilisation and/or bank erosion protection may be required to ensure the long-term performance of the structure.

4.4.3 High Hazard

Any development within the high hazard areas would require detailed assessment by a geotechnical specialist. Any development within this area would need to be supported by a comprehensive ground investigation, stability analyses and is likely to require measures taken to avoid, remedy or mitigate the hazard, such as slope stabilisation and bank erosion protection. Council may require any such assessment be subject to a peer review process.

4.5 Areas Requiring Further Assessment

Observations made during the site inspections for this study were of a preliminary nature. Where particular sections were observed to have been affected by existing instability and/or at risk of instability in the near future that could have a significant impact on the river bank and/or ground beyond, these sections were to be highlighted for further assessment.

These have been identified in Section 3 in the general observations regarding existing and potential future instability. Those sections identified as requiring further assessment in the near future are summarised in Table 4.2 below. The table identifies specific locations where further assessment is required to determine the nature and extent of bank protection measures, such as the right bank immediately upstream of the SH2. These areas require intrusive investigations and progress directly to detailed design.

Also highlighted in the table are those sections where a more detailed assessment would be beneficial to determine the extent and likely form of bank protection measures at specific locations within the individual sections. This will be required prior to intrusive works and the subsequent detailed design. The extent of these further assessments should be determined in consultation with HBRC and Wairoa District Council with respect to any ongoing maintenance plans and policy requirements.

Affected Section	Condition	Type of Assessment Required
Section 1	The banks have, in places, regressed to within a few meters of Kopu Road / surfaced footpath. These are considered at risk within the next 10 to 20 years.	Further visual inspection is required to determine which parts within this section are at greatest risk and identify the possible types of bank protection measures that may be suitable.
Section 2	Ongoing erosion and instability is likely to impact on the amenity space adjacent to the commercial areas of Marine Parade (upstream of Murrae Street)	Further visual inspection is required to determine which parts within this section are at greatest risk and identify the possible types of bank protection measures that may be suitable.
Section 3	Ongoing erosion/instability of the banks adjacent to Churchill Avenue could impact on the road	Further visual inspection required to identify the possible types of bank protection measures suitable.
Section 5	Damage to SH2 is expected within the next 10 years from ongoing erosion/.instability.	Further visual inspection is required to determine which parts within this section are at greatest risk and identify the possible types of bank protection measures that may be suitable.
Section 7	The area immediately upstream of SH2 to beyond Carroll Street is experiencing significant ongoing erosion/instability which is likely to result in significant loss of land over the next 10 to 20 years, including River Parade without further bank protection.	Further visual assessment of river banks and existing protection structures required. Intrusive investigations required to determine possible protection measures.
Section 10.6	Ongoing erosion of river banks adjacent to Marae is not considered to be more rapid than elsewhere along this section of the river but the potential impact of further instability is greater.	Further visual inspection required to define risk and identify possible protection measures.

Table 4.2: Summary of areas requiring further assessment.

Note that all areas will require intrusive investigations prior to detailed design of protection measures.

5 Applicability

This report has been prepared for the benefit of Hawke's Bay Regional Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

TONKIN & TAYLOR LTD

Environmental and Engineering Consultants

Report prepared by:

Authorised for Tonkin & Taylor by:



Richard Phillips

Senior Engineering Geologist

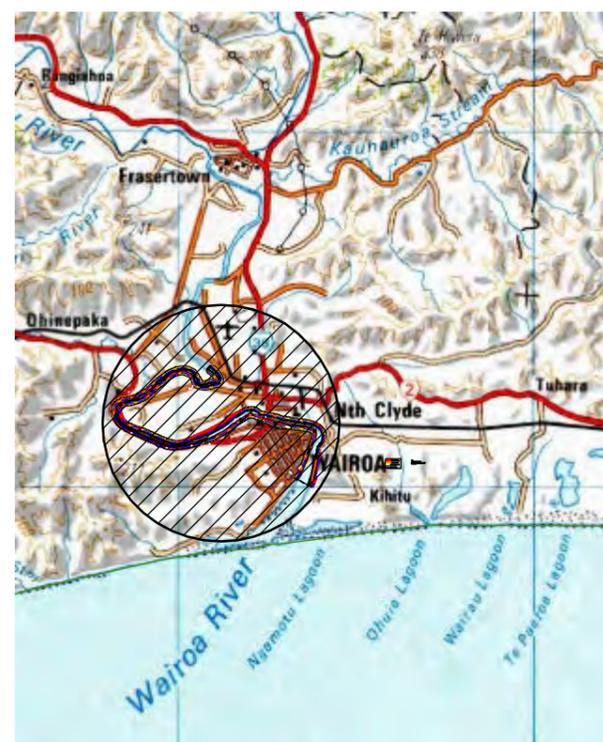
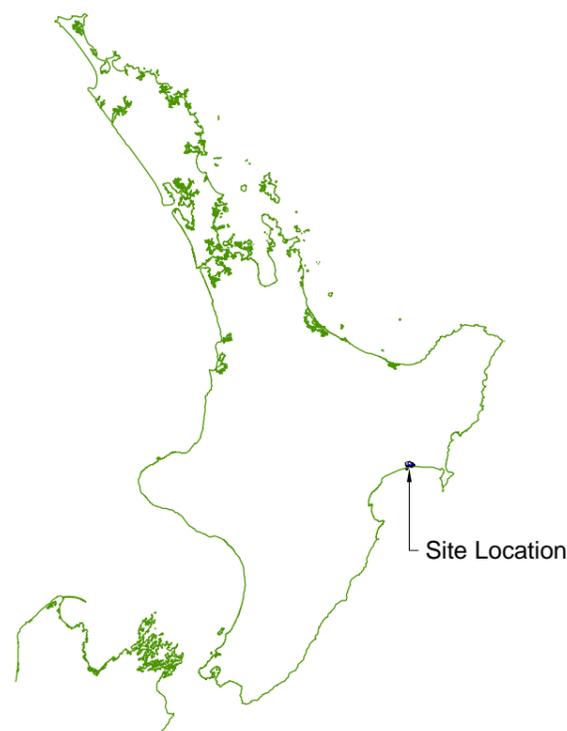
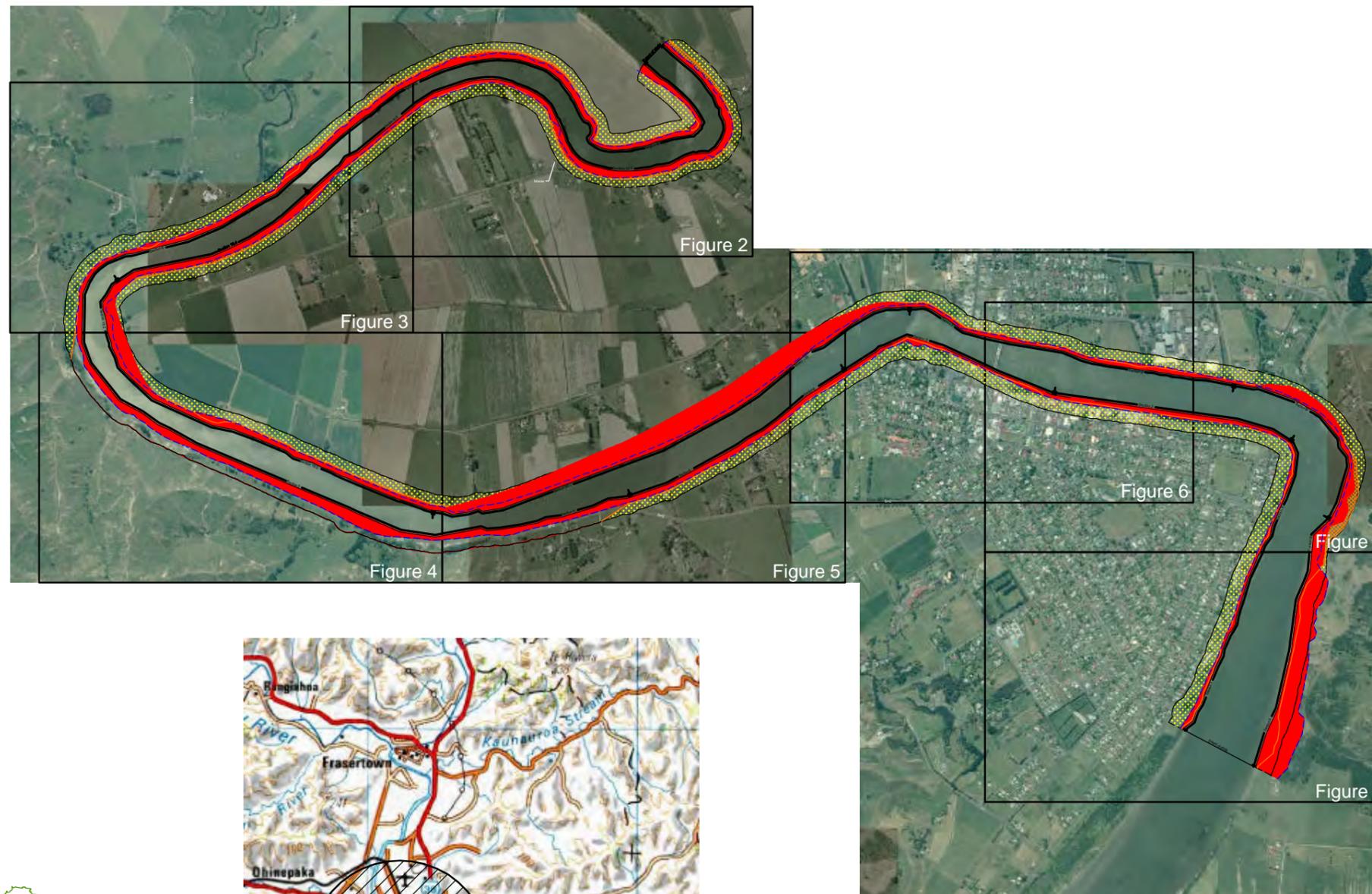


for Doug Johnson

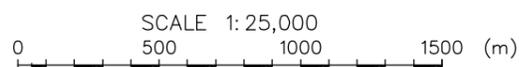
Geotechnical Group Manager

Appendix A: Figures

- **Figure 1 Location Plan**
- **Figures 2 to 8 Hazard Line Details**



SITE LOCATION PLAN
SCALE 1:200,000



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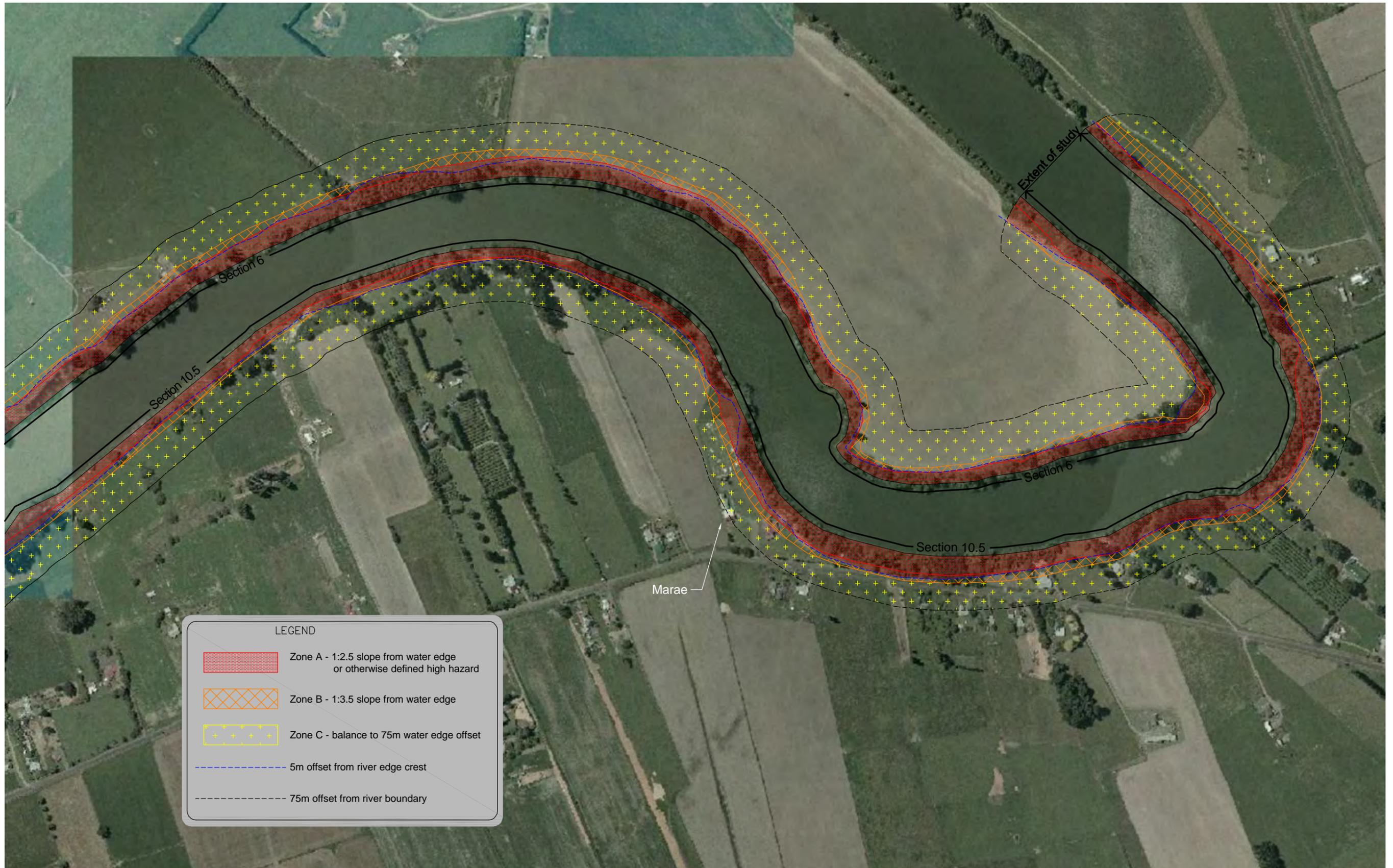
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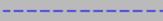
FIG. No. Figure 1

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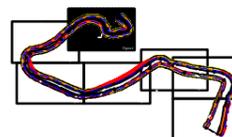
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-  Zone B - 1:3.5 slope from water edge
-  Zone C - balance to 75m water edge offset
-  5m offset from river edge crest
-  75m offset from river boundary

NOTES:

1. See report for definition of Zone A, B and C
2. Zone A is defined by a 1 in 2.5 slope projected up from the toe of the existing river bank or within 5m of the crest of the slope, whichever is the greater.



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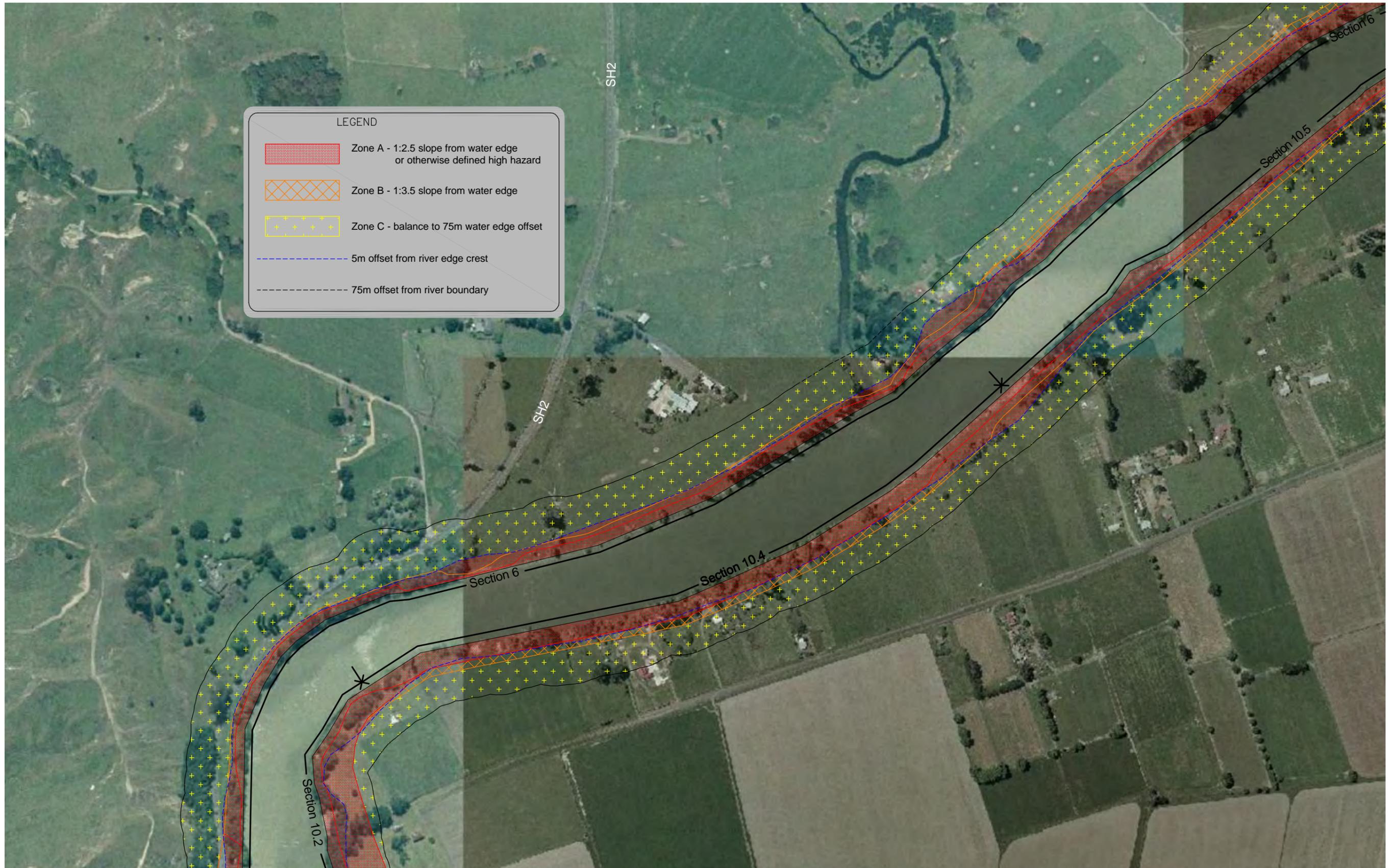
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 Hazard Line Plan – Sheet 1 of 7

FIG. No. Figure 2

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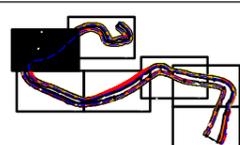
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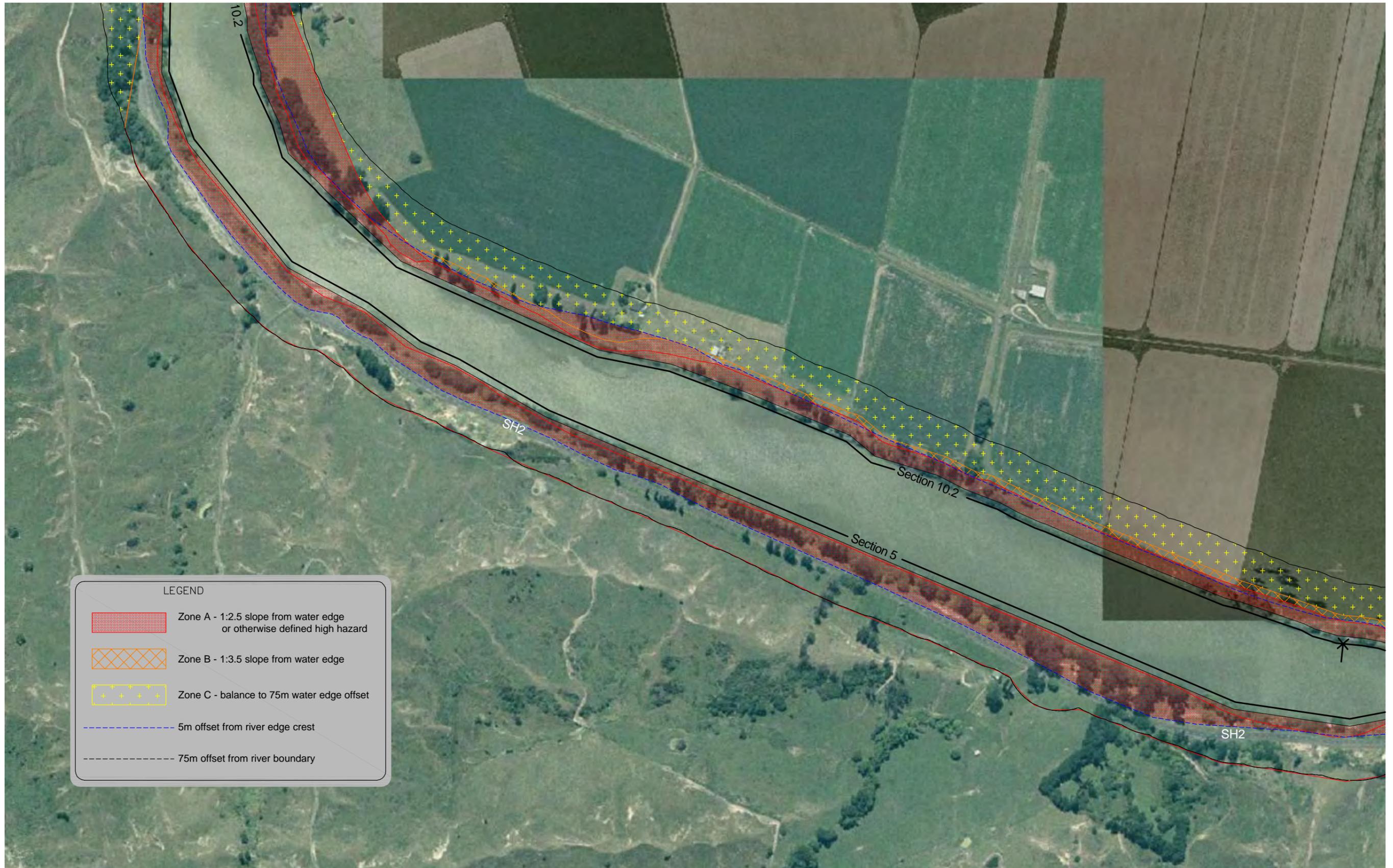
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 Hazard Line Plan – Sheet 2 of 7

FIG. No. Figure 3

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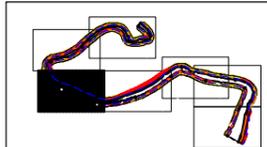
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- Zone A - 1:2.5 slope from water edge or otherwise defined high hazard
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- NOTES:**
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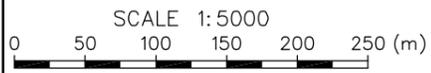
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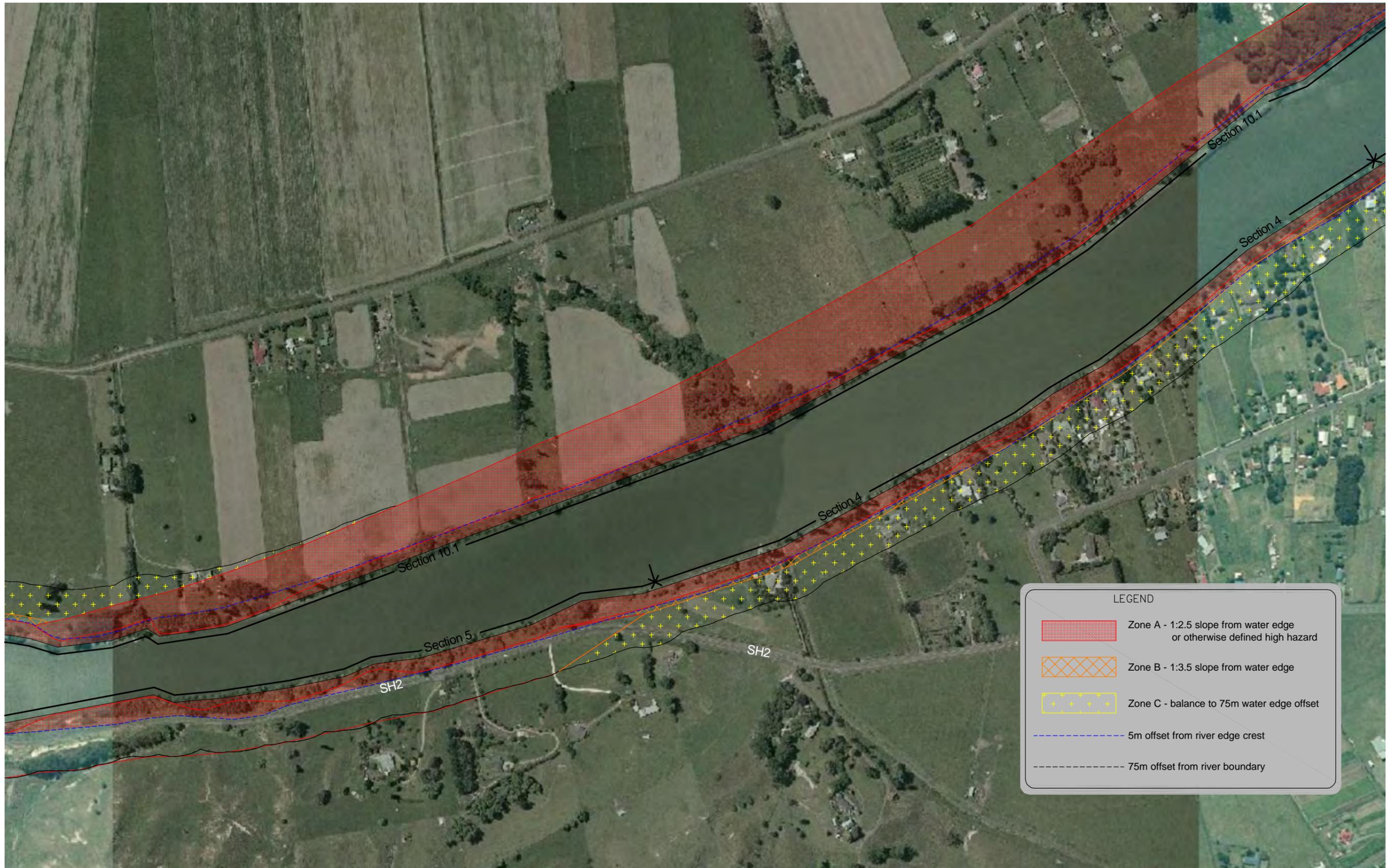
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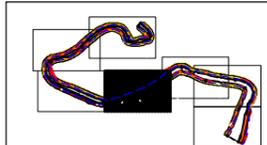


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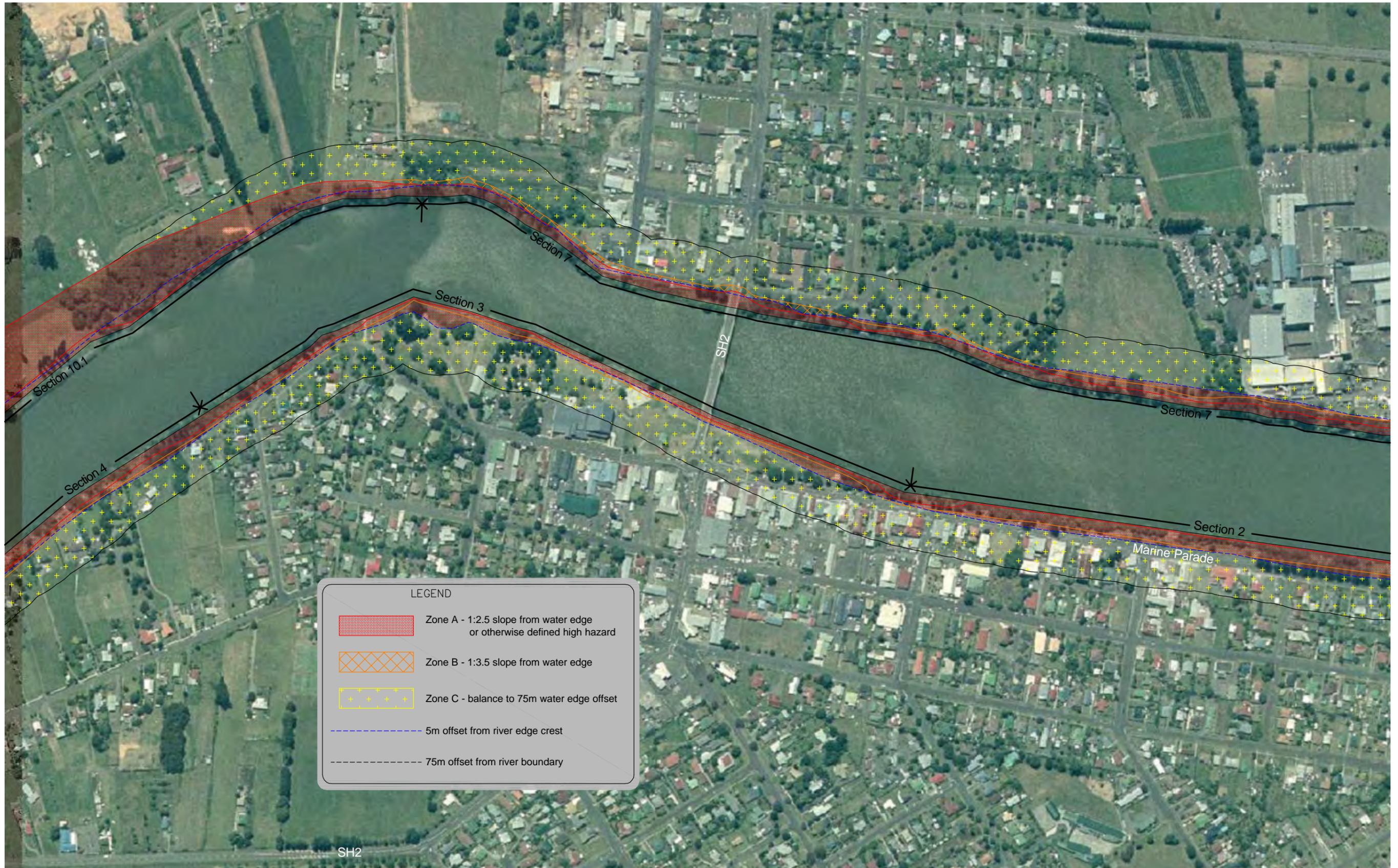
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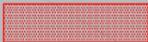
HAWKES BAY REGIONAL COUNCIL
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 Hazard Line Plan – Sheet 4 of 7

FIG. No. Figure 5

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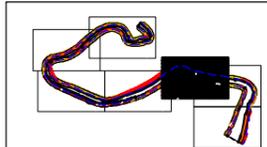


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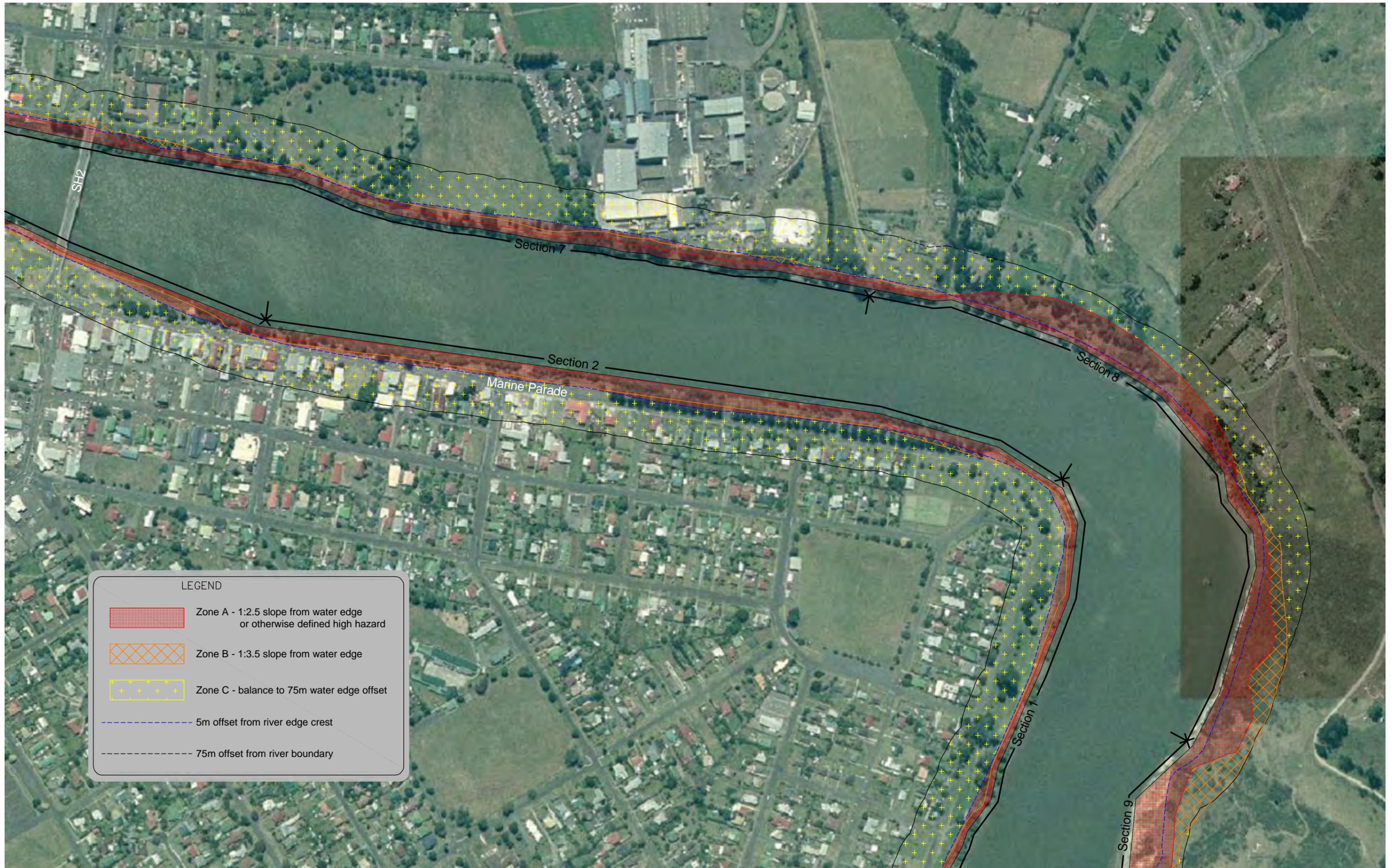
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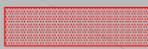
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Hazard Line Plan – Sheet 5 of 7

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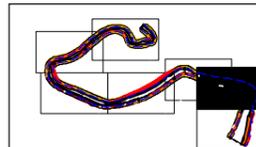


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-  Zone A - 1:2.5 slope from water edge or otherwise defined high hazard
-  Zone B - 1:3.5 slope from water edge
-  Zone C - balance to 75m water edge offset
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FIG. No. Figure 7

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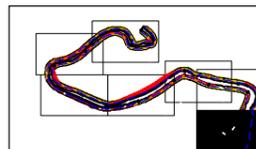
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- Zone A - 1:2.5 slope from water edge or otherwise defined high hazard
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FIG. No. Figure 8

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**Appendix B: Annotated Site Inspection
Photographs**



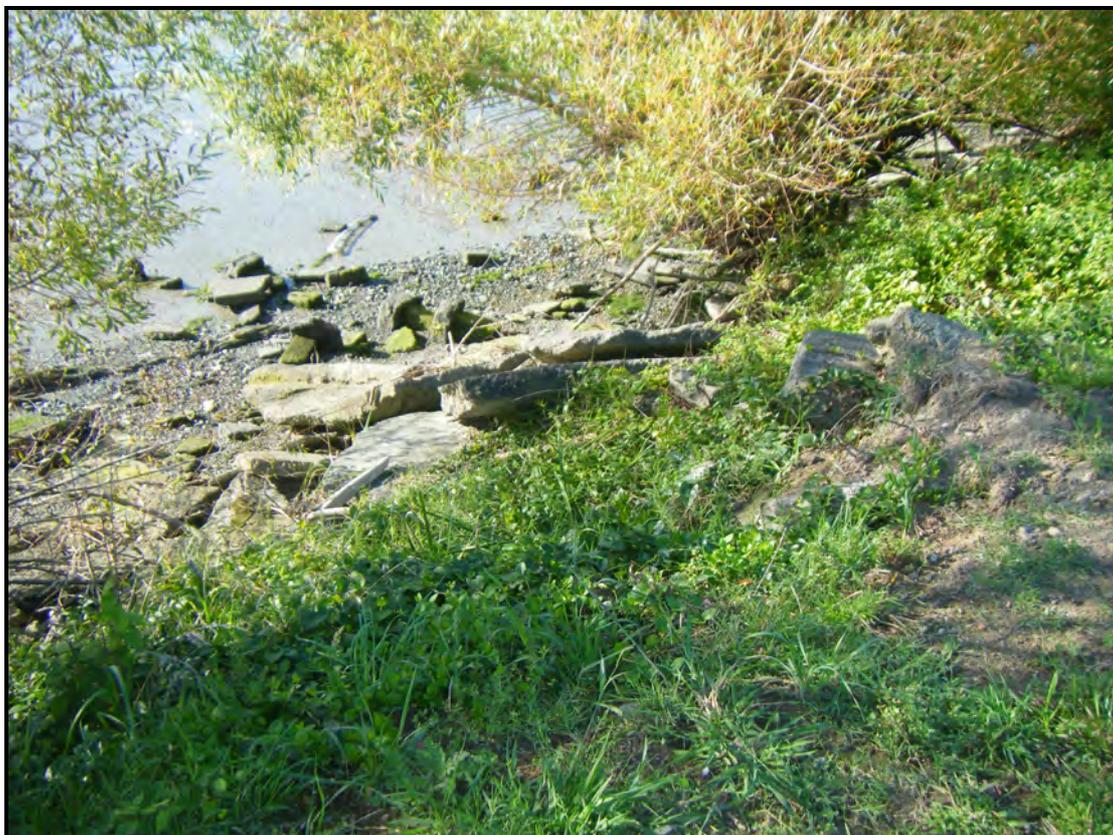
Photograph 1: Low, near vertical slopes adjacent to Kopu Street.



Photograph 2: Narrow failures of near vertical river banks at southern end of Kopu Street.



Photograph 3: Rotational failures of near vertical river banks along southern end of Kopu Street.



Photograph 4: Broken concrete pushed over river bank in area of Grey Street / Sturdee Street.



Photograph 5: As Photograph 3, taken from river.



Photograph 6: River bank adjacent to Kopu Road and surfaced footpath in the area of Sturdee Street.



Photograph 7: Facing west along river bank adjacent to Marine Parade between Mansfield Street and Murrae Street.



Photograph 8: Section of bank between Mansfield Street and Murrae Street (eastern half of Section 2).



Photograph 9: Shallow instability of slopes at eastern end of Section 2.



Photograph 10: Facing west along river bank adjacent to Marine Parade close to Delhi Street.



Photograph 11: Scour of river bank adjacent to Marine Parade close to Locke Street.



Photograph 12: 'Engineered' retaining wall on upper part of slope adjacent to Marine Parade close to Locke Street.



Photograph 13: ‘Engineered’ retaining wall on upper part of slope adjacent to Marine Parade.



Photograph 14: ‘Engineered’ retaining wall on upper part of slope adjacent to Marine Parade.



Photograph 15: Looking west towards SH2 bridge at eastern end of section 3.



Photograph 16: Gently sloping ground adjacent to river banks close to Water Ski Club building, west of SH2.



Photograph 17: River bank west of SH2 bridge roughly in line with King Street.



Photograph 18: Right bank at SH2 bridge.



Photograph 19: Minor instability of river bank west of SH2 bridge, likely to have been initiated by ongoing scour and loss of toe support.



Photograph 20: Filled area supporting basketball ring and associated hardstanding adjacent to community building. Note surface matting.



Photograph 21: Heavily vegetated slopes with signs of localised instability along right bank west of Churchill Street, at back of properties along Mitchell Road.



Photograph 22: Instability of slope beyond Mitchell Road.



Photograph 23: Instability of slope beyond Mitchell Road.



Photograph 24: Slope adjacent to SH2 at eastern end (adjacent to Section 4). This instability extends to the west but slope too heavily vegetated to show on photograph and determine extent.



Photograph 25: Slope adjacent to SH2 with signs of recent instability and new crash barrier.



Photograph 26: Slope adjacent to SH2 with signs of recent instability of upper slopes and erosion with instability of lower river bank.



Photograph 27: Instability of upper part of 7 to 8m high slope adjacent to SH2 with new barrier recently completed.



Photograph 28: Erosion and subsequent instability of slope adjacent to highway drainage outfall. Concrete pipe has collapsed and broken due to instability.



Photograph 28A: Protection of slope from highway outfall.



Photograph 29: Instability of lower sections of lightly vegetated slope in Section 6.



Photograph 30: Large scale instability of entire slope located within middle part of Section 6.



Photograph 31: Scour induced instability of bank located at upstream end of Section 6.



Photograph 32: Scour induced instability on inside bend of meander at upstream end of Section 6.



Photograph 33: Instability of heavily vegetated slope upstream of SH2 bridge adjacent to former motel.



Photograph 34: Vegetated slopes downstream of SH2 showing some minor instability of river banks.



Photograph 35: Large rotational failures adjacent to River Parade immediately upstream of SH2 bridge (see also Photograph 37 below).



Photograph 36: Timber retaining wall on river bank along River Parade immediately upstream of SH2 bridge.



Photograph 37: Rotational failure of slope as shown from river in Photograph 35 above.



Photograph 38: Failure of concrete retaining wall adjacent to parking spaces on River Parade immediately upstream of SH2 bridge.



Photograph 39: Top of failed concrete retaining wall (as shown in Photograph 38 above) located along River Parade.



Photograph 40: Slope failure in front of former motel at western end of River Parade.



Photograph 41: Densely vegetated slopes on left bank of river within Section 8.



Photograph 42: Grassed slopes with small trees within Section 8.



Photograph 43: Minor instability of low slopes within Section 8.