MORPHUM ENVIRONMENTAL LTD

**Engineers & Consultants**

Receiving Environment and Rapid Erosion Assessment

# Rotokauri North Sub-Catchment

Draft

Prepared for Hamilton City Council by Morphum Environmental Ltd
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# Executive Summary

Morphum Environmental Ltd (Morphum) was engaged by Hamilton City Council (HCC) to undertake a watercourse assessment of the Rotokauri North sub-catchment and its receiving environments of the Te Otamanui Tributary and Ohote Stream, as outlined in Figure 1. The watercourses were assessed using two sets of HCC guidance 'modules'; the Receiving Environment Module (REM) and the Rapid Geomorphic Erosion Assessment (RGEA), developed by Morphum for HCC. All interpretation of data should be used in conjunction with these documents. Overall, 10 km of watercourse was assessed in July and August 2018, including 107 stormwater inlet and outlet structures.

The aim of this watercourse assessment was to collect baseline information on the channel morphology, riparian vegetation, ecological condition and erosion susceptibility within the sub-catchment and its receiving environments. This information is intended to be used to assist in determining the potential effects for increased volumes and flows from the Rotokauri North sub-catchment and the proposed diversion from part of the Mangaheka catchment to the Te Otamanui tributary.

This report summaries these findings and proposes erosion mitigation projects with associated approximate costs. The report also highlights enhancement opportunities within the sub-catchment and the receiving environments to improve the amenity, conveyance and ecological values of these watercourses, along with recommended options for managing the effects of existing and future issues and pressures.

The Rotokauri North sub-catchment is a relatively small catchment (~180 hectares), situated at the Northern extent of the larger Rotokauri catchment (~788 hectares). The Rotokauri North Development Area (RNDA) encompasses a total area of 163 hectares. The proposed development includes a new special housing area, with a public school and major roads. The development of this area will see a shift in land use from a predominately rural landscape to a suburban setting. An overview of the RNDA and scoped watercourses for this assessment report is provided in Figure 1.

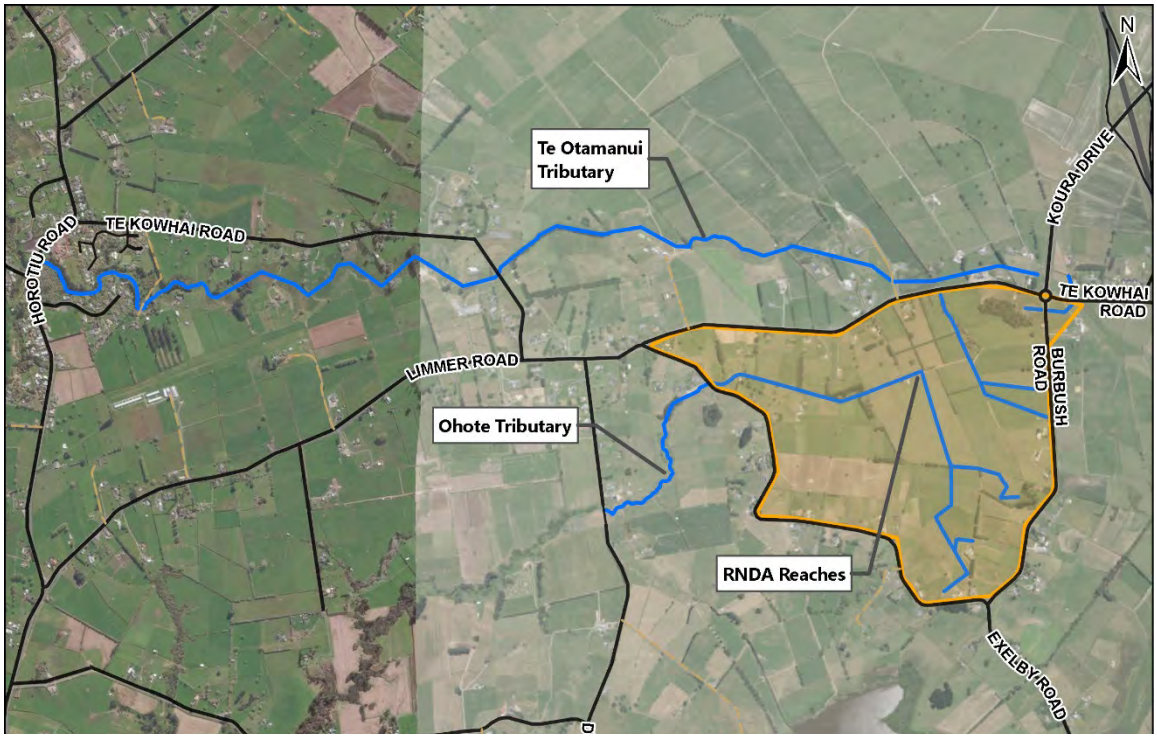


**Figure 1: Overview of the Rotokauri North Development Area**

The sub-catchment has four receiving environments; Mangaheka to the North, Ohote and Te Otamanui to the West, and Lake Rotokauri to the South. The watercourses within the Rotokauri North Development Area (RNDA) drain to each of these receiving environments.

The majority of the watercourses within the surveyed extent are located within agricultural pastoral land, with small areas of rural residential land use. These agricultural streams have little to no native woody riparian vegetation and direct stock access to the stream channel is common with damage from stock, such as pugging of banks, evident along many reaches. Modifications of the watercourses such as straightening, deepening and diversion of flows were recorded throughout the surveyed extent. In addition, an extensive farm drainage network exists in the Rotokauri North sub-catchment, assessment of which was not within the scope of this watercourse assessment. It is noted that HCC have engaged independent consultation on the classification of watercourses within the RNDA. Where this classification differs from that outlined in Appendix 2, we would advocate that HCC are best placed to define the interpretation to be carried forward. This will require communication with WRC so that they can provide their position on this issue.

Surveys for black mudfish were conducted at 4 sites, while sediment and water quality were conducted at five sites within the surveyed extent. No black mudfish were recorded at the sample sites. Water quality results indicate poor water quality, with five measured parameters – including nitrogen and phosphorus exceeding Australian and New Zealand Environment and Conservation Council (ANZECC) trigger values. Sediment quality was indicative of agricultural land use, with high concentrations of arsenic at one site, but relatively low concentrations of heavy metals such as zinc and lead across the sampled sites. Guidelines proposed in the National Policy Statement for Freshwater Management (NPS-FM), ANZECC and supporting Waikato Regional Council (WRC) documents suggest that the watercourses in the Rotokauri North Sub-Catchment and the receiving environments are degraded, and therefore should be enhanced through development where possible.

Existing erosion and bank instability issues in the Rotokauri North sub-catchment and its receiving environments are primarily driven by a lack of riparian vegetation, straightened channels with steep banks, and stock damage. The RGEA methodology identified nine 'unstable' reaches and two 'moderately unstable' reaches. A total of six erosion hotspots were observed in the sub-catchment, all located in the receiving environments of the RNDA.

The proposed management approach presented in this report aims to anticipate and plan for the increase in conveyance demands on stream systems. The management approach identifies key issues, objectives to address these issues, and options and actions to mitigate the actual and potential adverse effects associated with these issues. The broad management objectives outlined in this report align with the outcomes sought by the Stormwater Master Plan (HCC, 2016), the Rotokauri ICMP (2017), the Waikato vision and strategy document (2011), the NPS-FM (2016) and the Proposed Waikato Regional Plan Change (2018).

Fourteen erosion mitigation projects have been identified along the receiving watercourses of Rotokauri North sub-catchment and the receiving environments. Erosion remediation within the RNDA has not been included as part of this assessment, as it is anticipated that the developer will address any existing issues as part of the planned development. The erosion mitigation projects are comprised of four broad types; grade control, bank batter, erosion planting and toe protection. These engineered approaches aim to remediate existing erosion issues and mitigate further increases in erosion due to increased runoff within the catchment.

The mitigation projects identified in this assessment arise from existing issues that have the potential to be exacerbated by changes in the contributing catchment. It should not be inferred that the costs of these projects would be borne entirely by upstream greenfield growth areas. A further process of

assessing the contributing catchment, and existing and proposed on-site mitigation is necessary to consider a fair and reasonable allocation of costs between existing contributors and growth areas.

The total estimated cost, including contingency, of the physical works for the proposed erosion mitigation projects is approximately $2.5 Million. Unit costs rates are applied to represent high-level estimates of physical works only.

Five enhancement opportunity projects have been proposed within the Rotokauri North sub-catchment and the receiving watercourses. These projects highlight opportunities for the developer and Hamilton City Council to increase the amenity and ecological value of the watercourses, and improving resilience to land use changes in the future. The total estimated cost of the enhancement projects is approximately $1.2 Million.

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# 1.0 Introduction

## 1.1 Overview

The purpose of this watercourse assessment report is to collect baseline data on the ecological and physical attributes of the watercourses in the Rotokauri North sub-catchment and receiving environments, outlined in Figure 1. A specific objective of this watercourse assessment was to identify existing erosion issues and assess the potential effects of increased volumes and flows from the Rotokauri North sub-catchment and the proposed diversion from part of the Mangaheka catchment to the Te Otamanui tributary. In addition, the report recommends erosion mitigation projects and enhancement opportunities for managing existing and potential future erosion issues.

The watercourses that were assessed can be broken into three categories; reaches within the Rotokauri North Development Area (RNDA), reaches along the Ohote Stream tributary and reaches along the Te Otamanui Stream tributary, the latter two of which are downstream of the development area.

Assessing the watercourses within the greenfields development area (RNDA) has identified watercourses, indigenous vegetation and habitats that are recommended to be safeguarded and enhanced. Assessment of the Ohote Stream and Te Otamanui Stream tributaries has identified reaches that may be susceptible to the effects of urban development within the upstream greenfields catchment area.

## 1.2 Scope

Morphum Environmental Ltd (Morphum) was engaged by Hamilton City Council (HCC) to undertake a watercourse assessment of the Rotokauri North sub-catchment and its receiving environments.

The scope of works within the Rotokauri North sub-catchment and its receiving environments includes the following:

Field assessment of 10 km of open watercourse in accordance with ICMP Receiving Environment Module (HCC, 2011)

- Field assessment of 10 km of open watercourse using the updated HCC Rapid Geomorphic Erosion Assessment Methodology (HCC, 2018)
- Black Mudfish surveys at four sites[1]
- Sediment and water quality at five sites
- Macroinvertebrate sampling at five sites
- High-level identification of habitable and non-habitable buildings at risk of flooding from increased flows
- The development of a programme of works to manage existing issues and mitigate future erosion issues (concept level with high level costing)
- Selection and development of enhancement opportunities and potential management options and actions.

A literature review of available information and datasets in the catchment was outside the scope of this report. However, a comprehensive review has previously been conducted as part of the Rotokauri Integrated Catchment Management Plan (ICMP) (HCC, 2017). The outputs from the literature review

[1] Initial scope included black mudfish sampling at five sites. The variation in the number of sites reflects the absence of suitable habitats in the survey area.

include a number of technical investigations and assessments being undertaken to support the ICMP. These are outlined in Table 1.

**Table 1: ICMP technical investigations and assessment documents**

| Document Author and Title | TRIM Reference |
|---|---|
| AECOM, 2016. Rotokauri ICMP - Major Drainage: Options Report | D-2230265 |
| AECOM, 2016. Rotokauri ICMP - Major Drainage: Preferred Option & Stormwater Management Solution Report | D-2230077 |
| AECOM, 2016. Rotokauri ICMP – Three Waters Infrastructure: Integration Report | D-2238224 |
| CH2M Beca, 2016. Rotokauri: Hydrogeological Interpretive Report to Support ICMP | D-2230274 |
| CH2M Beca, 2015. Rotokauri - Additional Hydrogeological Investigations (Factual Report | D-2006869 |
| Kessels Ecology, 2016. Rotokauri ICMP – Ecological Assessment and Inputs | D-2230270 |
| Opus, 2015. Pukete Reservoir Bulk Water Main – Conceptual Design Report | D-1969497 |
| Morphum Environmental Ltd, 2016. Rotokauri Erosion Susceptibility Assessment | D-2230277 |
| Morphum Environmental Ltd, 2016. Rotokauri ICMP - Water Quality Treatment Concept Development Report | D-2200277 |
| Mott MacDonald, 2015. Rotokauri Water Supply Capacity Assessment | D-2172097 |
| Streamlined Environmental Ltd, 2015. Rotokauri ICMP - Broad Scale Water Quality Assessment | D-1998549 |

The extent of the watercourse assessment was defined by Morphum Environmental and agreed with the Hamilton City Council prior to the assessment survey being conducted. It should be noted that an extensive farm drainage network exists in the Rotokauri North sub-catchment, which was not part of this assessment scope. In some instances, these additional watercourses were recorded, but not assessed. The extent of the watercourse assessed is summarised in the catchment overview map in Figure 1.

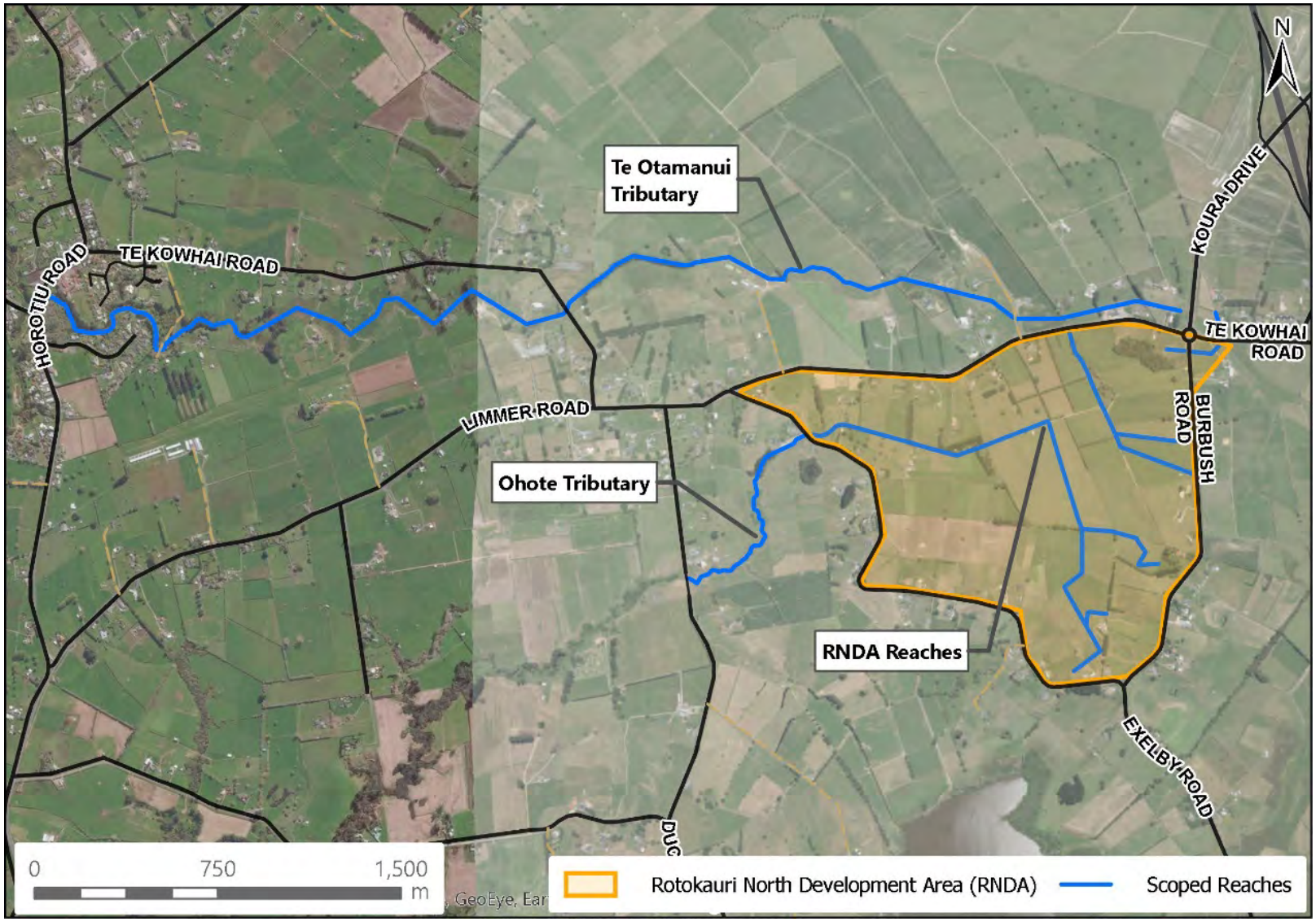



**Figure 2: Watercourses scoped for assessment**

## 1.3 Reach Naming Convention

The document provides references to each stream reach using a tributary code. The boundaries of each stream reach or 'ecoline' are defined by factors such as riparian cover, topography and channel morphology, as described in the Receiving Environment Module (REM). The numbering convention of the tributary codes is based on the number of tributaries entering the main stem of the network. For example:

- TEO_MAIN_1 is the 1st downstream reach of the main channel in the Te Otamanui Tributary
- OHO_TRIB1_5 is the 5th reach of the first tributary (heading upstream) of the Ohote Stream

The tributary codes are displayed against each reach as depicted in Figure 2 and on maps provided as Appendices.

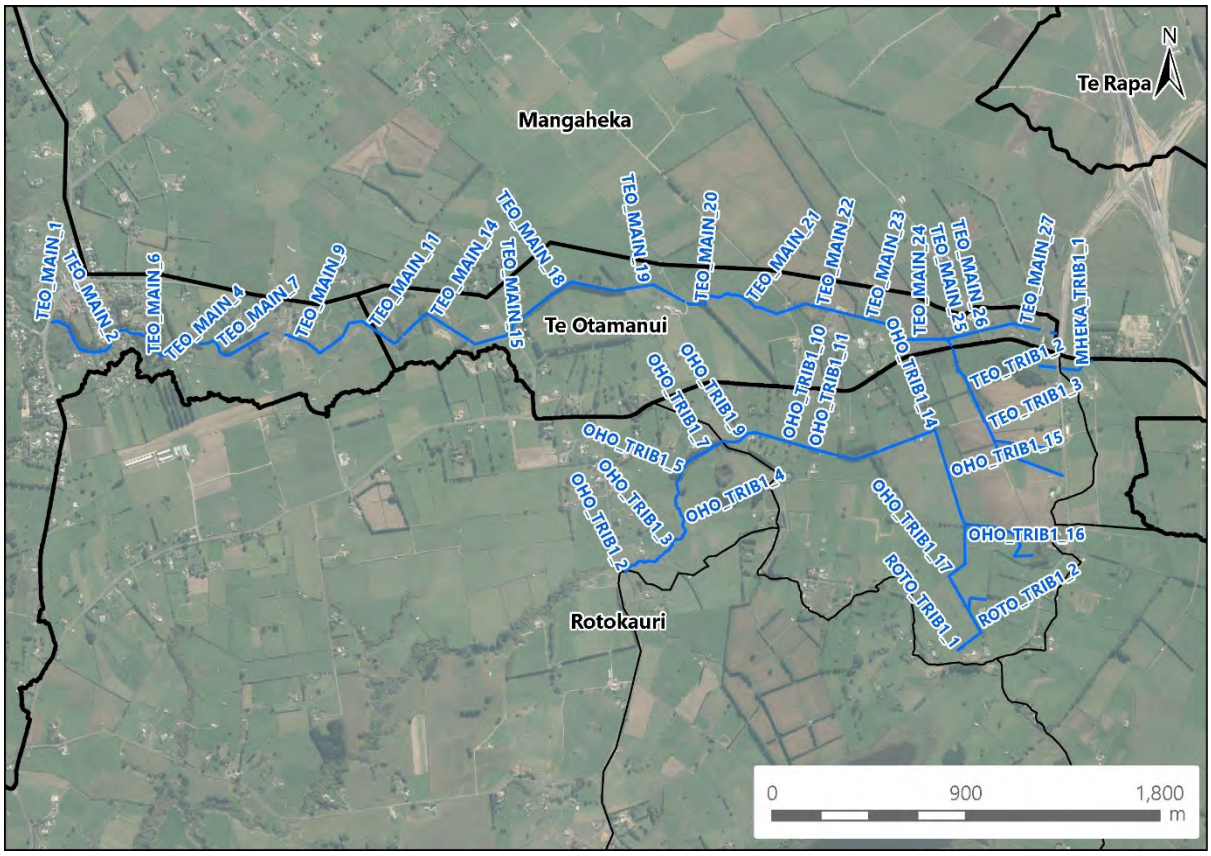



**Figure 3: Reach naming convention**

# 2.0 Catchment Overview

## 2.1 Catchment Location and Drainage

The Rotokauri North sub-catchment is a small, predominantly pasture and arable greenfields catchment, of approximately 180 hectares, at the northern extent of the wider 788 hectares Rotokauri catchment. The Rotokauri North sub-catchment incorporates the Rotokauri North Development Area (RNDA) and is located in the north-western area of Hamilton City. The Rotokauri South Development Area, also part of the Rotokauri ICMP, (RSDA) consists of three main sub-catchments; Waiwhakareke, Central Development Area and the Lake Rotokauri Development Area which were not assessed as part of this investigation.

The RNDA has four drainage points; the Exelby Road northern culvert, the Te Kowhai Road culvert, the Burbush Road Culvert and Exelby Road southern culvert.

- Exelby Road northern culvert primarily drains from east to west via a culvert under Exelby Road, where it continues to a confluence with the Ohote Stream at Duck Road. The Ohote Stream receives flows from the wider Rotokauri Catchment.
- Te Kowhai Road culvert flows north, under Te Kowhai Road, into a tributary of the Te Otamanui stream within the Te Otamanui Catchment.
- Burbush Road culvert drains north out of the north eastern extent of the RNDA and into the Mangaheka drain at the head of the of the Mangaheka catchment.
- Exelby Road southern culvert flows south under Exelby Road and into Lake Rotokauri however, this is a much smaller outlet and may primarily be active during high flows.

## 2.2 Land Use

### 2.2.1 Historic Land Use

The Te Reo name 'Rotokauri' translates to mean 'Lake of Kauri Trees', with the Lake gaining its name following the discovery of ancient buried kauri logs that were found in the bed of the lake. The historic landscape was typified by two predominant land types; rolling hills and ranges densely forested with kauri (*Agathis australis*), totara (*Podocarpus totara*), tawa (*Beilschmiedia tawa*), matai (*Prumnopitys taxifolia*) and miro (*Prumnopitys ferruginea*) whereas, the forests of the peat swamps and plains in areas such as the RNDA, were dominated by kahikatea (*Dacrycarpus dacrydioides*), titoki (*Alectryon excelsus*), raupo (*Typha* Spp.) and harakeke (*Phormium tenax*).

Within the RNDA area, a majority of the landscape was part of a large fen wetland; a type of wetland that is usually fed by mineral-rich surface water or groundwater. Fen wetlands are typically dominated by grasses, sedges and sphagnum mosses and appear on slopes, flats or depressions where surface water and ground water accumulate. Historical fen wetlands have typically been drained in the Waikato to accommodate agricultural land use, through the development of farm drains that disrupt and re-direct natural flow regimes.

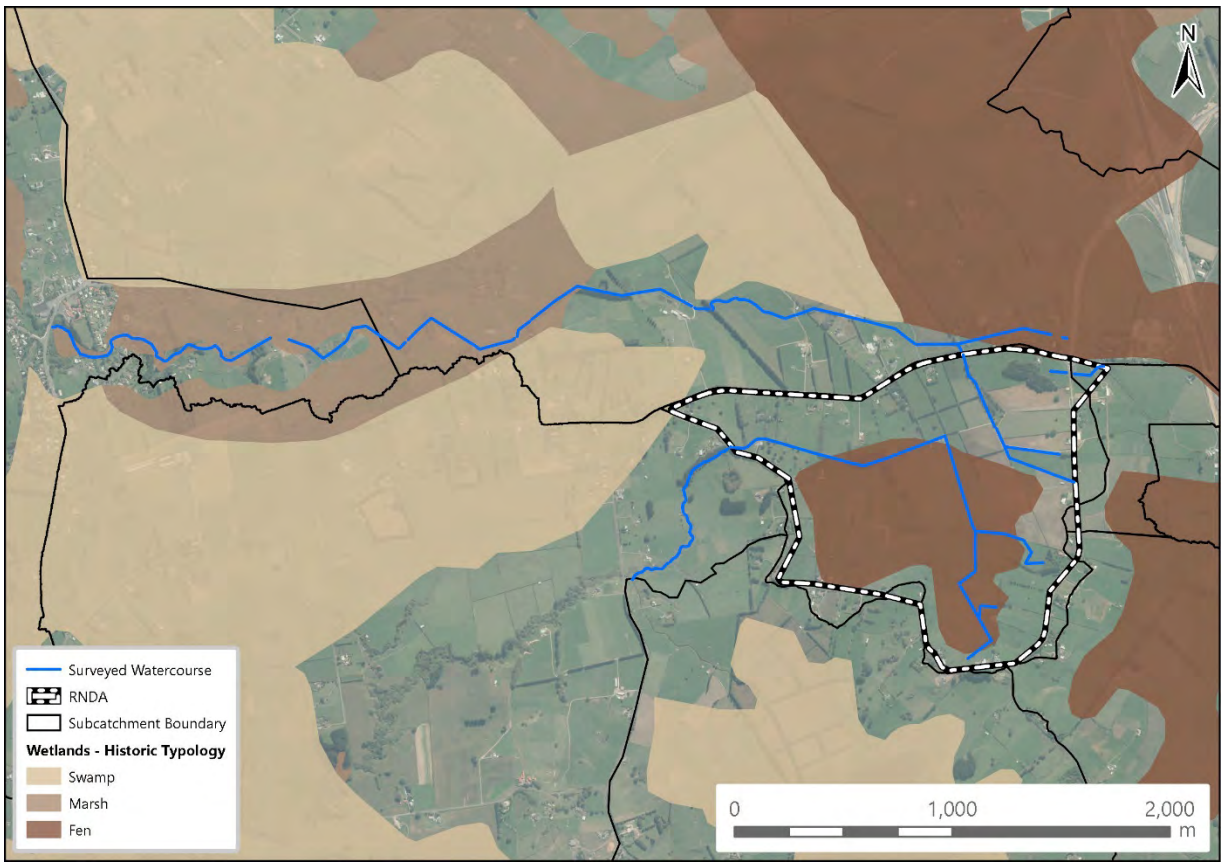



**Figure 4: Historic Fen wetland within RNDA and receiving environments of Ohote Stream and Te Otamanui Tributary**

### 2.2.2 Current Land Use

The Rotokauri North sub-catchment land use is currently entirely rural, 97.4% of land classified as high producing exotic grassland, 1.6% classified as exotic forest and the remaining 1.0% classified as indigenous forest as per the Land Cover Database (version 4.1) as depicted in Figure 4. The grasslands are used for a mixture of dairy grazing, recreation grazing and some arable cropping.

### 2.2.3 Future Land Use

The sub-catchment is zoned as 'future urban' under the HCC Operative Plan with land use currently being primarily 'high producing exotic grassland' (New Zealand Land Cover Database v4, 2017). The Rotokauri Structure Plan proposes a mixture of residential and open space zoning (Figure 4). Developing rural land to residential will increase the impervious areas within the sub-catchment and alter the run-off characteristics during storm events. As part of the Rotokauri ICMP, a network of multi-functional 'Green Corridors' have been planned throughout the Rotokauri structure plan area to manage stormwater flows, whilst also adding landscape and amenity values to the future urban areas.

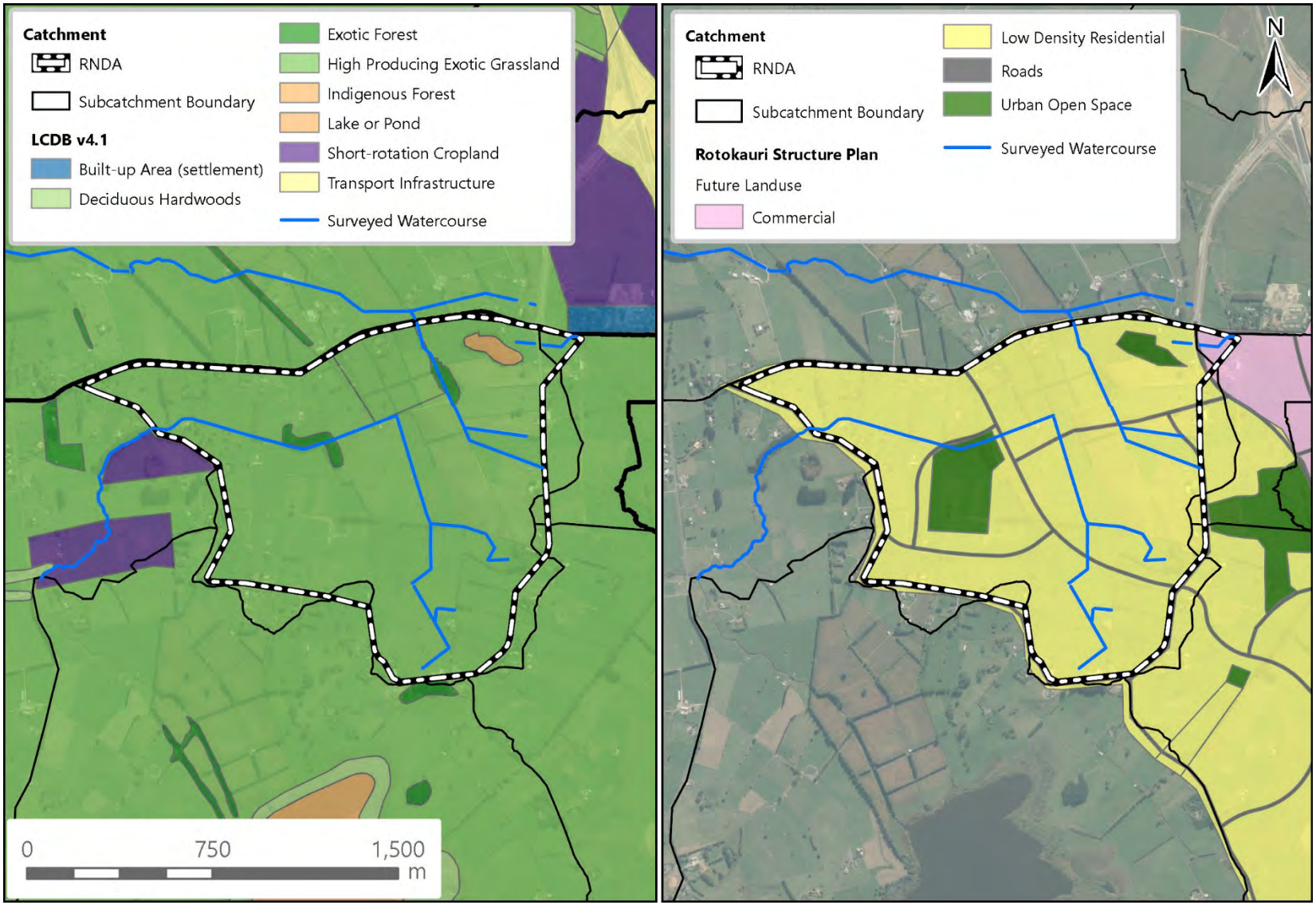



**Figure 5: Present and proposed future land use in the RNDA (New Zealand Land Cover Database, 2017; Proposed District Plan – Structure Plan, 2016)**

## 2.3 Catchment Topography

Topography varies from rolling hills along the south eastern boundary to exceptionally flat for a majority of the catchment (Figure 5). The extremely shallow gradient within the RNDA results in shallow watercourse grade and large bodies of standing water during the winter months.

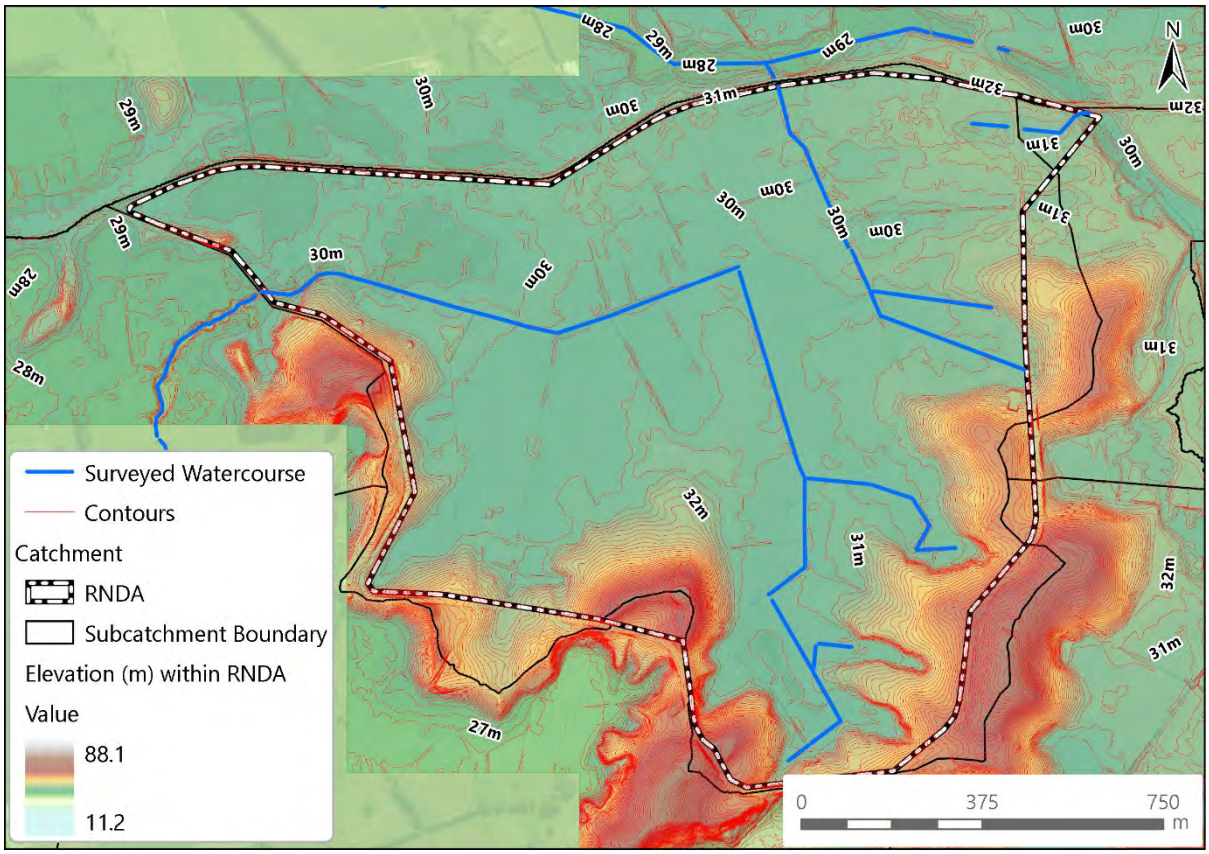



**Figure 6: Rotokauri North sub-catchment topography based on 2008 LiDAR**

## 2.4 Catchment Geology

Landcare Research's existing soil database (smap) classifies the dominant soil type within the RNDA as Allophanic and Organic (Figure 5). Allophanic soils are dominated by allophane minerals, sand and silt and are very porous with low density structure and weak cohesive strength. Erosion rates are generally low when soils are vegetated and not on steep slopes. Within the Te Otamanui catchment, the watercourse follows a vein of top soils depicted as recent soils. These recent soils are weakly developed soils that are common along alluvial floodplains as well as unstable steep slopes.

The allophanic soils here are part of the Te Rapa series, described as 'peaty sand', and the Horotui series which is predominately silty sand. The recent soils within the Te Otamanui catchment are also part of the Horotui series. The organic soils form in the partly decomposed remains of the historic fen wetland plants that has now formed as peat. Organic soils have little bearing strength and are prone to shrinkage when dried. The organic soils within the RNDA are part of the Kaipaki series and are usually described as 'loamy peat'. The Brown soil types present in the catchment are part of the Rotokauri series and are identified as 'clay loam' while the Gley soils are part of the Te Kowhai series and are a 'silt and clay loam'.

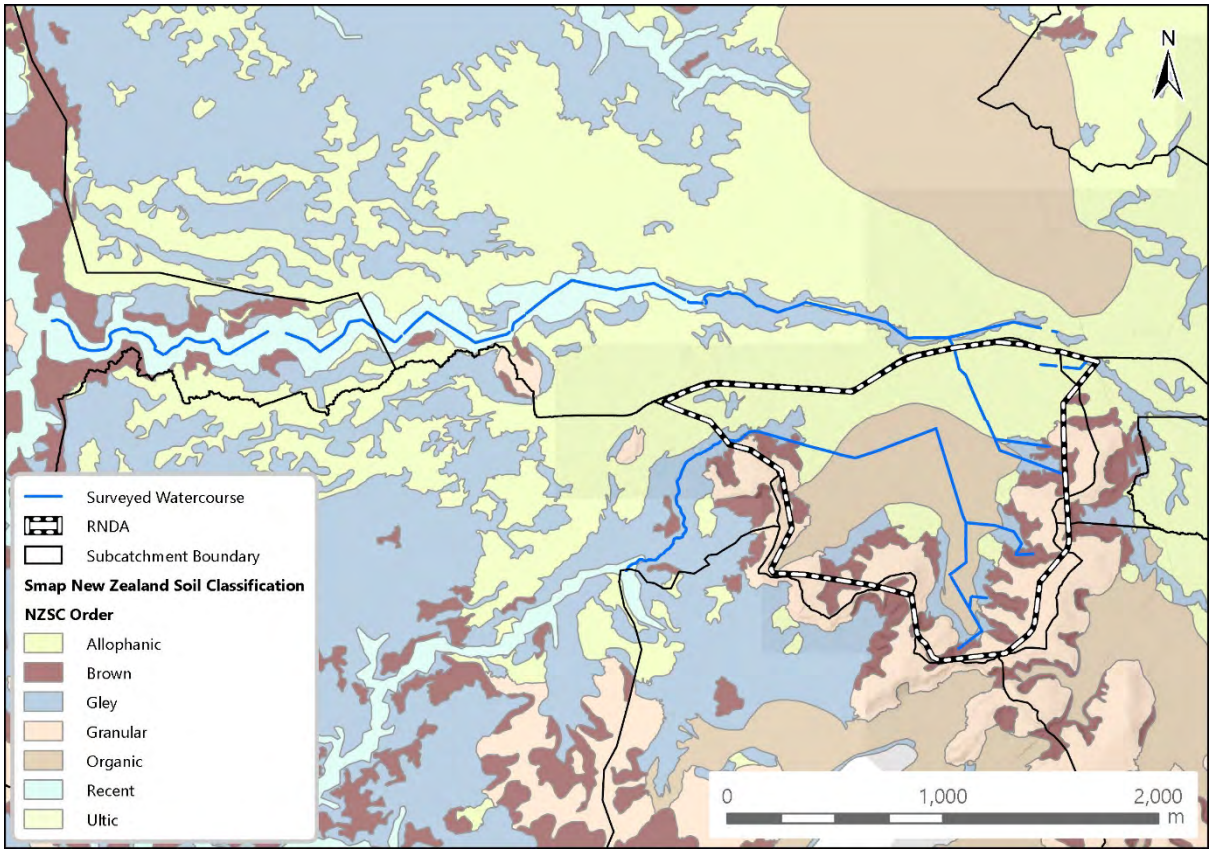



**Figure 7: Soil series of the RNDA sub-catchment and receiving environments (source, smap - Landcare Research)**

# 3.0 Methodology

The watercourses in the Rotokauri North sub-catchment and the receiving environments were assessed using two sets of method guidance 'modules'; the Receiving Environment Module (REM) and the Rapid Geomorphic Erosion Assessment (RGEA). The methodology used in this report aims to standardise data collection, modelling, data presentation, and reporting for all future HCC watercourse assessments.

## 3.1 Receiving Environment Assessment Methodology

The ICMP-REM was developed by Morphum Environmental for Hamilton City Council (HCC, 2015). All interpretation of the data from this report should be used in conjunction with the ICMP REM document. The Waikato Regional Council Plan (WRCP) classifications were used to define watercourse types (Table 2) and watercourse classification (Table 3).

**Table 2: WRCP watercourse types**

| Watercourse type | Definition |
|---|---|
| River | A stream or modified watercourse that does not include any artificial watercourse |
| Modified watercourse | An artificial or modified channel that may or may not be on the original watercourse and which has a natural channel at its headwaters. |
| Farm drainage canal | An artificial watercourse on a farm that contains no natural portions from its confluence with a river or stream to its headwaters and includes a farm drain or a farm canal. |

**Table 3: WRCP watercourse classification**

| Watercourse classification | Definition |
|---|---|
| Perennial | A stream that flows all year round assuming average annual rainfall |
| Ephemeral | A stream that flows continuously for at least three months between March and September but does not flow all year |

## 3.2 Limitations

The following limitations of the REM methodology should be considered in the interpretation of the data from this report.

**Watercourse Classification**

The watercourse assessment provides a field estimate of stream classification only and this classification is not specifically intended for Resource Consent purposes. Although specific and detailed assessment is required prior to consent approval for any works within a subject reach, the details contained in this document can be used to guide associated investigations for a resource consent application. Failure to identify a stream reach during this Watercourse Assessment process does not indicate that a stream is not present or that any such stream is ephemeral. The assessment has been based on the regional plan definitions and these definitions are open to considerable interpretation. We would note that this is evidenced by the T&T assessment dated 1 November 2018 which, defines the artificial vs modified

boundary of the subject watercourse, but states the arbitrary nature of their definition also. Furthermore, T&T also acknowledge the presence of the historical wetland and the lack of guidance within the WRP on how to interpret watercourse classification in modified wetlands.

**Temporal variations**

Watercourse assessments undertaken, as per this methodology, must be considered within the seasonal context. Variables such as water depth and velocity are dependent on the level of base flow, and antecedent conditions such as stormwater inflows prior to the assessment. Factors that are more variable over diurnal time scales, such as temperature, are not recorded as part of this assessment as time series data is required for meaningful and representative results.

**Assessment methodology**

It is acknowledged that the ICMP REM is largely a 'rapid' assessment of engineering assets, as well as, biological and geomorphologic stream state. Parameters are also typically averaged over the extent of each reach and there will be some variability along this length.

## 3.3 Rapid Geomorphic Erosion Assessment Methodology

The RGEA provides rapid baseline information on the bank and bed stability of a watercourse. It was developed by Morphum Environmental for Hamilton City Council (HCC, 2018) as a relatively simple assessment to rapidly identify reaches that may require stabilisation interventions. The RGEA records the dominant processes occurring along the subject reaches using twelve criteria that are directed at determining trends of recent channel adjustment, as processes migrate through a channel network with time. As this assessment is essentially a snapshot in time, assessment is usually carried out during summer months, when water levels are lower and more of the lower bank is exposed. The methodology utilises criteria of channel form to infer dominant channel processes and the magnitude of channel instabilities through the following twelve criteria:

1. Bed substrate material
2. Bank material and cohesion
3. Bank height
4. Bank angle
5. Presence of knickpoints/headwall cutting
6. Degree of constriction (relative decrease in top of lower bank width from upstream)
7. Erosion Scars (percentage of reach)
8. Erosion scars resulting from lateral flow sources
9. Established riparian woody vegetative cover
10. Stream bank erosion processes
11. Stage of incised channel evolution
12. Stream curvature

For each assessment reach, the dominant processes are recorded using a geospatial polyline feature class that evaluates the twelve criteria outlined above, to provide a channel stability ranking. Scoring in each criterion is such that a higher value indicates greater potential for erosion and instability. Each criterion has a maximum value of 4 to reduce subjective interpretation and to ensure the relative importance of each criterion is assessed equally. Scores from the twelve criteria are added to give a channel stability ranking (Table 4).

| Table 4: Channel stability scores | |
|---|---|
| **Ranking** | **Stability Scores** |
| Highly stable | 0 – 10 |
| Moderately stable | 11 – 16 |
| Stable | 17 – 22 |
| Unstable | 23 – 28 |
| Moderately Unstable | 29 – 34 |
| Highly Unstable | 35 – 44 |

## 3.4 New Zealand Black Mudfish Survey

The black mudfish (*Neochanna diversus*) is an endemic freshwater species. Previous surveys show black mudfish populations are present in the Waikato region (Hicks and Barrier, 1996; Ling, 2001). The preferential habitat of black mudfish includes wetlands and small swampy streams, much like the watercourses in the Rotokauri North sub-catchment.

The Department of Conservation methodology for monitoring New Zealand mudfish (Ling *et al.,* 2013) was used to develop a survey design for the Rotokauri North sub-catchment. Four sites in the sub-catchment were selected for sampling (Appendix 2). The selection of these sites was based on their potential to provide suitable habitat for resident mudfish populations. The four sites were also representative of the main habitat types present in the sub-catchment.

At each site, 30 non-baited gee minnow traps were set approximately 5 metres apart along a 150-metre transect. A combination of standard metal traps and collapsible net traps were used, all of which were set overnight and retrieved the following day. Traps were set at sites RNDA1 and OHOTE on 6 August and retrieved on 7 August, while the RNDA2 and TEOT1 sites had traps set on 7 August and retrieved on 8 August.

Upon retrieval of the traps, the number, size class and species of captured fish were recorded. Mudfish size classes were defined as per Ling *et al.,* (2013) (Table 5).

| Table 5: Black mudfish size classes | |
|---|---|
| **Age Group** | **Size Class (mm total length)** (Ling *et al.,* 2013) |
| Fry | 5 – 30 |
| Juveniles | 30 – 50 |
| Adults | > 50 |

## 3.5 Macroinvertebrate Community Index (MCI) sampling

Benthic macroinvertebrates are commonly used as bioindicators of ecosystem health in New Zealand. Macroinvertebrate taxa groups have been shown to respond differently to natural and anthropogenic stressors (Stark and Maxted, 2007). As such, the presence or absence of specific taxa can provide insights into the ecological condition of a local site.

Standardised protocols for sampling soft-bottom streams, as outlined in the Regional Guidelines for Ecological Assessments of Freshwater Environments (Environment Waikato, 2005) and described by Stark (2001) and, were used to collect macroinvertebrate samples at five sites within the Rotokauri North sub-catchment.

As per the REM methodology, the presence/absence of taxa, their relative abundance, and the percentage of EPT taxa were identified for each of the five sites. The overall ecological value was compared to MCI threshold scores as per Stark (2001) (Table 6).

The dominant habitat types sampled for macroinvertebrates were in-stream woody debris, macrophytes and undercut banks. The first four samples were collected at the same sample reaches as the black mudfish sites; RNDA1, RNDA2, OHOTE, and TEOT1. An additional site, TEOT2 situated at the downstream reach of the Te Otamanui Tributary was also included. At each of these five sites, water and sediment quality samples were also collected. These sample sites are briefly described in Table 7. Refer to Appendix 1 for the location of these sites.

**Table 6: Interpretation of Macroinvertebrate Community Index Scores**

| **Ecological health ranking** | **MCI Quality Thresholds (**Stark *et al.,* 2001, 2007) |
|---|---|
| Excellent | > 119 |
| Good | 100 – 119 |
| Fair | 80 – 99 |
| Poor | < 80 |

**Table 7: Site descriptions of ecological survey sites**

| Site Code | Descriptions | |
|---|---|---|
| **RNDA1** (TEO_TRIB1_3) | Incised, straightened channel surrounded by dairy farm land. No significant riparian shading or in-stream woody debris. Floating duckweed mats present in stream channel. |  |
| **RNDA2** (OHO_TRIB2_3) | Shallow, stagnant watercourse surrounded by harvested maize cropland. Riparian vegetation dominated by rank grasses. |  |
| **OHOTE** (OHO_TRIB1_1) | Wetland-like characteristics. Channel dominated by floating sweetgrass. |  |

| | | |
|---|---|---|
| **TEOT1**<br>(TEO_MAIN_26) | Incised, straightened channel. Macrophyte cover and overhanging rank grasses. |  |
| **TEOT2**<br>(TEO_MAIN_1) | Wide and relatively deep downstream reach of Te Otamanui. Overhanging vegetation and canopy cover. |  |

# 4.0 Summary of Findings

The Rotokauri North sub-catchment has four receiving environments; Mangaheka to the North, Ohote and Te Otamanui to the West, and Lake Rotokauri to the South. The watercourses within the Rotokauri North Development Area (RNDA) drain to each of these receiving environments.

The Rotokauri North sub-catchment and the receiving environments are comprised of meandering single thread rivers, modified watercourses and farm drainage canals as per the Waikato Regional Plan (WRP) (Appendix 2). The stream network within the RNDA is comprised of both perennial and ephemeral watercourses.

The physical attributes assessed for watercourses within the Rotokauri North sub-catchment are summarised in Table 8.

**Table 8: Summary of physical variables across the extent of watercourse surveyed**

| | | | | | | |
|---|---|---|---|---|---|---|
| Total Length of Surveyed Watercourse (km) | 10.03 | | | | | |
| Catchment Area (Ha) | 180.32 | | | | | |
| Catchment Imperviousness | 3.92% | | | | | |
| Receiving Environments | Ohote Stream, Te Otamanui Stream, Lake Rotokauri, Mangaheka Stream | | | | | |
| Dominant Substrate Type | Silt Sand | | | | | |
| **WRP Stream Classification** | **Perennial** | | | | **Ephemeral** | |
| Length of stream (km) | 9.054 | | | | 0.982 | |
| % of total stream length | 90.2 | | | | 9.8 | |
| **WRP Watercourse Type** | **River** | | **Modified watercourse** | | **Farm drainage canal** | |
| Total stream length (km) | 0.772 | | 7.809 | | 1.454 | |
| % of total stream length | 7.7 | | 77.8 | | 14.5 | |
| **Vegetation** | **0 – 10 %** | **10-30%** | **30-50%** | **50-70%** | **70-90%** | **>90%** |
| Average Overhead Cover (% of total stream length) | 37.7 | 27.8 | 21.3 | 9.8 | 3.3 | 0 |
| **Pfankuch Upper Bank stability assessment** | **Excellent** | | **Good** | **Fair** | | **Poor** |
| Overall Stability Index (% of total stream length) | 0 | | 69 | 31 | | 0 |
| **Erosion scarring** | **Percentage of reaches with >60% erosion scarring** | | | **Total No. Erosion hotspots** | | |
| | 36 | | | 6 | | |

## 4.1 WRC Watercourse Types

The three watercourse types present in the Rotokauri North sub-catchment and the receiving environments are meandering single thread rivers, modified watercourses and farm drainage canals. The findings are based on the assessment by the ecologists and geomorphologist involved in the field investigations and conclude that these points are defined as per Appendix 2. As there is no guidance in

the WRP on how to deal with modification to wetlands or how to classify channels that drain wetlands, a precautionary approach has been taken to classify these channels as modified. Additionally, the channels that drain the historic wetland within the RNDA do not clearly fall under the WRP definitions of an artificial or a modified watercourse.

It is noted that HCC have engaged independent consultation on the classification of watercourses within the RNDA. Where this classification differs from that outlined in Appendix 2, we would advocate that HCC are best placed to define the interpretation to be carried forward. This will require communication with WRC so that they can provide their position on this issue. Each of the three watercourse types is briefly described below.

### 4.1.1 Meandering single thread river

Meandering single thread rivers are natural streams which have retained natural geomorphic features and a meandering channel shape. These reaches have not been modified by anthropogenic activities such as straightening, deepening or widening of the stream channel and bed. This watercourse type was relatively rare within the receiving channels where intense historic and, present land use activities have extensively modified the physical and ecological attributes of these watercourses.

### 4.1.2 Modified watercourses

Modified watercourses are natural streams which have been modified by anthropogenic activities such as straightening, deepening or widening of the stream channel and bed, primarily through 'drain cleaning' activity which results in an overly steep bank and removal of bed material. Modified watercourses were the most common type of watercourse encountered as part of this assessment.

### 4.1.3 Farm drainage canals

Farm drainage canals are artificial watercourses on a farm that contain no natural portions from their confluence with a stream or river to their headwaters. An extensive network of farm drainage canals is present within the Rotokauri North sub-catchment. These reaches are straightened, and often deepened channels used to lower the water table and provide additional arable land.

## 4.2 Reach Summaries

The watercourses in the sub-catchment and the receiving environments are soft-bottom streams and silt/sand are the dominate benthic substrate types. The flat topography of the area is reflected by the slow-flowing streams in the catchment. The numerous farm drains and standing bodies of water (ponds) observed in this assessment indicate a high water-table throughout the sub-catchment and the receiving environments.

Generally, the watercourses show evidence of channel modification such as straightening, widening and deepening. Adjacent land use is dominated by agricultural, pastoral activities. Sparse vegetation consisting of gorse, barberry and poplar dominated these reaches. In the downstream reaches of the Te Otamanui (TEO_MAIN_1 to TEO_MAIN_6) mixed vegetation provides moderate shading to the stream channel.

Erosion scarring of stream banks is largely attributed to anthropogenic activities such as 'drain cleaning', stock access and damage and lack of riparian vegetation. Bank benching, bank instability and fine sediment deposition can be largely attributed to stock damage rather than erosion from high stormwater flows. In the downstream reaches of the Te Otamanui, there is some evidence of fluvial erosion caused by larger flows through constricted channels.

A total of seven debris jams were identified in the Rotokauri North sub-catchment and the receiving environments. The identified debris jams were large fallen trees causing localised changes in water velocity and depth in the stream channel. The identified debris jams did not pose any significant issues to stormwater flows.

The following Tables (Table 9 - Table 12) provide an overview of the channel morphology, riparian condition and erosion in each of the receiving watercourses in the Rotokauri North sub-catchment. For further detail regarding erosion in the Rotokauri North sub-catchment, refer to Section 4.3 of this report.

The reaches within each of the receiving environments have been grouped based on similar characteristics and geographic proximity. Representative photos of each group of reaches are presented in Table 13. Refer to Appendix 3 for stream overhead cover in the sub-catchment.

**Table 9: Reach Summaries - Te Otamanui Tributary**

| Reach | Watercourse type | Watercourse classification | Channel morphology | Riparian condition | Erosion |
|---|---|---|---|---|---|
| **Downstream reaches**<br>(TEO_MAIN_1 to TEO_MAIN_6) | River - Meandering single thread | Perennial | Meandering channel morphology and wide floodplains. Riparian corridors constrained by existing residential dwellings located at the top of the gully banks on TRB.<br>Average wetted width is 1.5 m. | Moderate cover (average 30 – 50% of reach) from riparian vegetation. Riparian corridors constrained by existing residential dwellings located at the top of the gully banks on TRB.<br>Riparian vegetation includes few mature native species such as tree fern, flax and karamu.<br>Dominant vegetation type is exotic weeds; kikuyu, elephant ear and reed sweet grass. | Predominately fluvial erosion on downstream reaches (TEO_MAIN_1 to TEO_MAIN_3).<br>RGEA stability ranking of 'unstable'.<br>Upper reaches (TEO_MAIN_4 to TEO_MAIN_6) are 'moderately stable'. |
| **Mid-reaches**<br>(TEO_MAIN_7 to TEO_MAIN_15) | Modified watercourses | Perennial | Agricultural streams with straightened and deepened channels. Floodplain connectivity is 'rare' as modifications contain most flows in the channel.<br>The average wetted width in the channel ranges from 1 - 2.5 m. | Sparse vegetation (< 10%) in this section of the sub-catchment. No canopy cover recorded for 78% of ecolines<br>Pastural land use with stock access noted along the reach. | RGEA stability ranking of 'stable' and 'moderately stable'<br>Two reaches (TEO_MAIN_7 and TEO_MAIN_14) are 'unstable.<br>The incised and steep banks (average 65- 75˚) had evidence of ongoing erosion, with 77% of ecolines showing evidence of recent erosion scarring along 40 - 60% of the lower bank. |
| **Upper reaches**<br>(TEO_MAIN_16 to TEO_MAIN_28 | Modified watercourses | Perennial | Relatively uniform channel morphology, with straightened channels ranging from 1.1 m – 1.8 m wide<br>Floodplain connectivity recorded as 'rare' to 'occasional' as channels have been modified to contain most flood flows. | Shelter belt of mature deciduous trees on TLB. Natural wetland dominated by Juncus on TRB along lower reaches (TEO_MAIN_16 to TEO_MAIN_18).<br>No riparian vegetation in the upper reaches. | RGEA stability ranking of 'stable' for 53% of ecolines.<br>Stability ranking of 'moderately stable' for 38% of ecolines.<br>TEO_MAIN_21 is 'unstable' due to mass failures on both banks. |
| **Te Otamanui Tributaries**<br>(TEO_TRIB1_1 to TEO_TRIB1_4)<br>*Watercourses in the RNDA* | Modified watercourses | Perennial | Watercourses are straightened and intersected by multiple farm track culverts.<br>Sections of stream have stagnant water and emergent macrophytes such as duckweed. | Surrounding land use is a cattle farm. Direct stock access to the watercourse is restricted by electric fences.<br>TEO_TRIB1_1 and TEO_TRIB1_2 have a narrow riparian margin of deciduous trees on the TRB. No other riparian vegetation is present. | RGEA stability ranking of 'stable' for 50% of reaches and 'moderately stable' for 25%.<br>TEO_TRIB1_2 has a ranking of 'unstable'. |
| **Te Otamanui Tributaries**<br>(TEO_TRIB2_1 and TEO_TRIB1_5)<br>*Watercourses in the RNDA* | Farm drainage canals | Ephemeral | Straightened and shallow channels with low bank height. | Channels are accessable by stock access and therefore lack definitive channel boundaries. No riparian cover | RGEA stability ranking of 'moderately stable'. |

**Table 10: Reach summaries - Ohote Stream**

| Reach | Watercourse type | Watercourse classification | Channel morphology | Riparian condition | Erosion |
|---|---|---|---|---|---|
| **Wetland reaches** (OHO_TRIB1_1 to OHO_TRIB1_7) | Riverine wetland | Perennial | Reaches lack definitive boundaries between stream channel and banks. | Reaches dominated by facultative wetland grasses such as kikuyu, native rushes such as Juncus and mature, individual willow trees. | 74% of reaches have a RGEA stability ranking of 'highly stable'<br><br>OHO_TRIB1_7 is low grade, fully shaded stream with some undercutting and a RGEA stability ranking of 'moderately stable' |
| **Lower-mid reaches** (OHO_TRIB1_8 to OHO_TRIB1_9) | Modified watercourses | Perennial | OHO_TRIB1_9 has recently been deepened to increase flow capacity within the channel. Lack of bank stabilisation from these works has resulted in ongoing soil deposition into watercourse. | Modification to riparian and channel morphology due to stock damage.<br>Riparian vegetation includes sparse individual Burberry and other exotic tree species on the TLB. | OHO_TRIB1_8 is 'stable' and OHO_TRIB1_9 is 'unstable' |
| **Mid reaches** (OHO_TRIB1_10 to OHO_TRIB1_14)<br><br>*Watercourses in the RNDA* | Modified watercourses | Perennial | Floodplain connectivity was 'rare' at 80% of the mid-reaches, due to modifications such as straightening and deepening of the channel. | The dominant surrounding land use is low-density residential dwellings and pastoral farms.<br>Downstream reaches (OHO_TRIB1_10 to OHO_TRIB1_12) have relatively high shading from Barberry, tree ferns and pine planting on TRB.<br>OHO_TRIB1_13 to OHO_TRIB1_14 are open, with low cover. | 50% of reaches have RGEA stability ranking of 'stable'<br>OHO_TRIB1_11 is 'unstable' |
| **Upper reaches** (OHO_TRIB1_15 to OHO_TRIB1_18 & OHO_TRIB2_2)<br><br>*Watercourses in the RNDA* | Modified watercourses | Perennial | Straightened channels and incised, steep banks.<br><br>OHO_TRIB2_1 is anoxic, with dense macrophyte cover. | Surrounding land use is cropland – predominately maize.<br>Low riparian vegetation is present along this section of the Ohote Stream, with gorse providing the only shade to the channel.<br>The dominant surrounding land use is maize cropland.<br>Low (<10%) riparian shading on the OHO_TRIB2_1. | Reaches range from 'stable' to 'moderately stable' with no significant issues identified in this section of the sub-catchment. |
| **Headwater Tributary** (OHO_TRIB2_2 & OHO_TRIB2_3)<br><br>*Watercourses in the RNDA* | Farm drainage canals | Ephemeral: | OHO_TRIB2_2 and TRIB2_3 are shallow (~ 0.1 m depth), with dense oxygen weed cover in stream. | No riparian cover was recorded for the ephemeral streams. | RGEA stability ranking of 'moderately stable' |

**Table 11: Reach summaries - Rotokauri Stream**

| Reach | Watercourse type | Watercourse classification | Channel morphology | Riparian condition | Erosion |
|---|---|---|---|---|---|
| **Rotokauri Stream** (ROTO_TRIB1_1 to ROTO_TRIB1_4) | Farm drainage canals | Perennial | Natural direction of flow has been altered.<br><br>Artificial agricultural streams with incised banks, unconsolidated soft sediment deposition in stream channel. | Low (<10%) riparian cover along bank margins. Cattle observed alongside stream banks. Direct stock access is restricted by fences approximately 1 m from top of stream bank. | RGEA stability ranking of 'stable'<br><br>Some fluvial and mass wasting recorded on both banks of channels. |

**Table 12: Reach summaries - Mangaheka Stream**

| Reach | Watercourse type | Watercourse classification | Channel morphology | Riparian condition | Erosion |
|---|---|---|---|---|---|
| **Mangaheka Stream** (MHEKA_TRIB1_1 to MHEKA_TRIB1_2) | Farm drainage canals | Perennial | The downstream reach (MHEKA_TRIB1_1) lacks definitive bank boundaries due to stock modification and have similar characteristics to wetlands. | Severely impacted by stock damage, with evidence of pugging along each reach.<br>No riparian vegetation on either bank. However, an ecologically significant remnant native kahikatea forest patch is present upstream of MHEKA_TRIB1_2. | RGEA stability ranking of 'moderately unstable' |

**Table 13: Examples of reaches in the Rotokauri North sub-catchment and receiving environments**

| Meandering single thread river in Te Otamanui | Agricultural reaches modified by stock access | Straightened channel, intersected with farm culverts |
|---|---|---|
|  |  |  |
| **Wetland reaches in the lower Ohote Stream** | **Ephemeral farm drain in the Rotokauri North Development Area** | **Modified watercourse surrounded by cropland** |
|  |  |  |

## 4.3 Erosion

### 4.3.1 RGEA Stability Ranking

Following the Rapid Geomorphic Erosion Assessment methodology, there were no 'highly unstable' reaches in the Rotokauri North sub-catchment. Most watercourses in the sub-catchment were ranked as 'stable' (Table 14). Refer to Appendix 4 and Appendix 5 in the Appendices for RGEA stability, and upper bank stability in the sub-catchment.

Some sections of the sub-catchment had RGEA stability rankings of 'moderately unstable' and 'unstable' (Table 15). These rankings highlight areas of concern within the sub-catchment which are prone to further erosion and degradation. Mass failure was recorded as the primary erosion process in these 'moderately unstable' and 'unstable' reaches. The high incidence of mass failures can be attributed to the relatively non-cohesive bank soil structure, composed primarily of silt clay loam and the lack of established woody riparian vegetation. Similarly, the dominate bed substrate material in the sub-catchment is clay/silty clay (86%), with a lower proportion of the reaches dominated by gravel (9%) and silt (5%).

The downstream reaches of the Te Otamanui (TEO_MAIN_1 to TEO_MAN_3) were ranked unstable and primarily impacted by fluvial erosion.

These erosion processes are likely exacerbated by surrounding land use activities, including riparian vegetation removal along bank margins, likely as part of pastoral and 'drain cleaning' activities. Riparian vegetation plays an important role in preventing lateral adjustment of watercourses and stabilising stream banks, whilst contributing to channel roughness and helping dissipate erosive forces.

**Table 14: RGEA Stability Rating**

| | Highly Stable | Stable | Moderately Stable | Moderately Unstable | Unstable | Highly Unstable |
|---|---|---|---|---|---|---|
| **Te Otamanui** | - | 17 | 10 | 1 | 7 | - |
| **Ohote** | 5 | 10 | 10 | - | 2 | - |
| **Mangaheka** | - | - | 3 | - | - | - |
| **Rotokauri** | - | 4 | - | - | - | - |
| **Total no. of reaches** | 5 | 31 | 13 | 1 | 9 | - |
| **Total length of watercourse (m)** | **683.7** | **4,312.4** | **2,806** | **110.8** | **2,067.9** | **0** |
| **% of watercourse length** | 6.8 | 43 | 28 | 1 | 20.6 | 0 |

The ten reaches in the Rotokauri North sub-catchment and the receiving environment with RGEA rankings of 'moderately unstable' and 'unstable' are described in Table 15. These low stability reaches are located primarily along the Te Otamanui Tributary (80%), with two unstable reaches identified on the Ohote Stream Tributary.

The Ohote Stream tributary is expected to be the primary receiving environment, downstream of the proposed Rotokauri North Development Area (RNDA). Te Otamanui Tributary is expected to be the secondary receiving environment, with potential additional increased flows from a possible diversion from the Mangaheka Stream.

The changes in land use from a greenfield, pastoral landscape to an urbanised residential land use within the RNDA presents the following pressures on the receiving environments:

- Increased imperviousness and associated changes in hydrograph and impacts on watercourses, including increased potential for channel erosion and reduced base flows
- Reclamation and diversion of watercourses
- Increased channel modification due to development of roads, privates accessways, and associated culvert structures.

**Table 15: Summary of low stability reaches**

| Reach | RGEA Stability Ranking | Description |
|---|---|---|
| TEO_MAIN_8 | Moderately Unstable | Narrow channel with incised banks, downstream of man-made pond (constructed between 2010 – 2012). Steepened reach with high channel constriction. |
| TEO_MAIN_1 to TEO_MAIN_3 | Unstable | Channel follows a meandering course. Widened channels through bank retreat, located on downstream reaches of the Te Otamanui Tributary. |
| TEO_MAIN_7 | Unstable | Incision and active channel widening of modified watercourse in operational cattle farm. |
| TEO_MAIN_14 | Unstable | Lateral flow erosion scars on both banks. Unstable, excessive undercut banks with leaning riparian sedges in stream channel. |
| TEO_MAIN_21 | Unstable | No riparian vegetation, mass failures on both banks. Lateral flow erosion scars present on TLB. Vertical face present. |
| TEO_TRIB1_2 | Unstable | Fluvial entrainment is the dominant erosion process. Some mass wasting on TRB. Incised channel banks. |
| OHO_TRIB1_9b | Unstable | Artificial reshaping of the existing banks through 'drain cleaning' activities. Banks steepened and straightened. Deposition of material on bed. |
| OHO_TRIB1_11 | Unstable | Excessive undercutting of banks. Leaning and fallen vegetation from shelter belt present in stream channel. |

To mitigate further degradation in the sub-catchment and minimise adverse impacts on the receiving environments, a programme of erosion mitigation projects is presented in Section 5.2.

### 4.3.2 Erosion Hotspots

Erosion hotspots are identified as discrete locations of severe erosion causing environmental, infrastructure, and health and safety risk. An erosion hotspot is defined as severe erosion located within the channel and or, lower or upper banks, resulting in slumping and exposed soil surfaces and must be:

- Actively eroding,
- Exceed two metres in length or have a total surface area of > 5 $m^2$

The instability score (3 or 4) classifies erosion hotspots as 'shallow' or 'deep'. The asset risk score (1 to 4) indicates the risk that erosion poses to surrounding infrastructure, with scores of 1 indicating open spaces with negligible impacts and 4 indicating risk to major structures such as roads and services. The

overall risk value is determined from the instability and asset risk scores. If the sum of the two scores is greater than 6, the hotspot is classed as 'high risk', while scores of 4 – 5 are classed as 'medium risk'.

A total of six erosion hotspots were identified in the Rotokauri North sub-catchment, summarised in Table 16. These identified erosion hotspots were all located outside the RNDA (Appendix 5). The erosion hotspots did not pose a significant risk to infrastructure and were classed as medium risk.

At two erosion hotspots located on the Te Otamanui Tributary; TEO_MAIN_19 and TEO_MAIN_1, it was identified that maintenance to assets are required. The asset at TEO_MAIN_19 is a private farm culvert, whilst TEO_MAIN_1 is a Council owned asset draining stormwater flows from Horotiu Road. The recommended maintenance types include redesign and replacement of culverts to facilitate future flows following development of the upstream catchment areas.

The most common contributing factors for erosion hotspots were minimal riparian vegetation, poorly maintained private stormwater assets, and channel modification (i.e. drain cleaning). Of the six erosion hotspots, 33% were assessed as caused by fluvial (flow) processes, 50% were attributed to steep banks and minimal riparian vegetation and the cause of one erosion hotspot on TEO_MAIN_21 (16%) was unknown.

**Table 16: Summary of erosion hotspots.**

| **Attribute** | | | |
|---|---|---|---|
| **Total Length of Surveyed Watercourse (km)** | | 10.03 | |
| **Total Length of Erosion Hotspots (m)** | | 207.6 | |
| **Total Number of Erosion Hotspots** | | 6 | |
| | **Mean** | **Min** | **Max** |
| **Height of erosion (m)** | 2.5 | 2 | 4 |
| **Depth of erosion (m)** | 0.8 | 0.5 | 2 |
| **Length of erosion (m)** | 14 | 3 | 30 |
| **Erosion Type** | **Shallow Instability** | **Deep Instability** | |
| % of erosion hotspots | 83.3 | 16.7 | |

## 4.4 Biodiversity

### 4.4.1 Black Mudfish Survey

The survey did not identify any black mudfish at the four samples sites in the Rotokauri North sub-catchment. The invasive mosquitofish (*Gambusia affinis*) was abundant (> 100 individuals) throughout and captured in traps at all sites except RNDA2. A single native shortfin eel (*Anguilla australis*) was recorded at TEOT1 (Figure 22).

**Figure 8: Small shortfin eel and a number of mosquitofish captured in a Gee minnow trap at TEO1**

The absence of black mudfish from the surveyed watercourses is most likely due to a lack of suitable habitat for this species throughout the sub-catchment. In addition, the presence of fish barriers (discussed further in Section 4.4.2) is likely to impede the migration of individuals in the watercourse network.

The Rotokauri North sub-catchment mudfish sample sites were highly modified watercourses, with mineralised substrates dominated by silt. Preferential habitat features for black mudfish such as emergent and overhanging vegetation, tree roots, and peat substrates were largely absent in the sub-catchment. Additionally, as Hicks and Barrier (1996) suggest, the invasive mosquitofish can exclude black mudfish from perennial habitats by outcompeting the native species for habitat and food resources.

The OHOTE site had wetland characteristics and good riparian vegetation with dense sedges and small thickets of willows present along the survey transect. However, the mineralised river silt and the dominance of *Glyceria* indicated a high level of disturbance in the system.

It is acknowledged that the detection of black mudfish was limited to a single night at each site. However, the extensive sample area (150 metre), concentrated trapping effort (30 traps at 5 metres spacing), and the inclusion of a range of habitat types in the sub-catchment indicates a comprehensive survey was undertaken. The results suggest that the presence of black mudfish populations in the Rotokauri North sub-catchment is unlikely.

### 4.4.2 Fish Passage

Barriers to fish passage can severely limit native fish populations by restricting the amount of stream habitat that they can access. Many native species complete their larval life-stage in the marine environment before migrating into freshwater catchments as juveniles, where they continue to develop into adults once they are established in suitable upstream habitats. Artificial and natural barriers in freshwater systems can limit this migration.

All barriers to fish passage were classified into one of three categories (Swimmer, Climber or Anguilliform) according to the locomotory function of the fish that were likely to impede. Barriers to swimmers will affect species that are only capable of swimming (e.g. inanga, common bully), while barriers to climbers will also prevent species such as banded kokopu and redfin bully from migrating

upstream. The most difficult instream barriers will also affect anguilliformes (adult eels), which are capable of traversing short distances across land between waterbodies.

Two artificial barriers to fish passage were identified in the receiving environments of the RNDA. These barriers were;

- Perched private farm culvert (Asset ID: UNK026)
- Series of perched farm culverts and artificial pond (Asset ID: UNK094 – UNK097)

No natural in-stream fish barriers such as cascades, waterfalls or dams were found in the sub-catchment.

One of the most notable fish barriers present within the Rotokauri North sub-catchment is located on a downstream reach of the Ohote Stream (OHO_TRIB_1). The outlet of a private 1000 mm concrete culvert (ID: UNK026) is perched 0.35 m, forming a complete barrier to swimming and climbing species (depending on water levels). The structure impedes fish passage to more than 2 km of upstream reaches of the Ohote Stream.

**Figure 9: Fish barrier for swimming fish species located on the culvert outlet (Asset ID: UNK026)**

The second fish passage barrier is a series of perched farm culverts upstream of a constructed online pond. The culverts were noted to be poor – average condition due to a lack of maintenance. The culverts form a complete barrier for swimming fish species, and a partial barrier to climbing species.

It should be acknowledged that assessment of potential fish barriers was conducted during winter between July and August. The water depth in the watercourses was elevated, and flooded culverts were noted throughout the sub-catchment. It is possible that additional farm and road culverts are partial or complete barriers for various fish locomotory groups during drier months of the year, these were not identified as part of this study.

### 4.4.3 Macroinvertebrate Community Index

Macroinvertebrate Community Index (MCI) samples were taken at five sites in the Rotokauri North sub-catchment along 100 metre reaches. The summary of the biodiversity index scores for the five sites are listed in Table 15. Overall, MCI scores in the catchment were indicative of 'poor' to 'fair' ecological health.

The highest MCI score (97.2) was recorded in the agricultural site RNDA1. The pollution-sensitive EPT taxa group was only found at the RNDA1 site, with a single stick caddisfly (Triplectides) recorded in the sample.

The site TEOT1, situated in the mid-reaches of the Te Otamanui Tributary, had a MCI score of 90. Similarly, TEOT2 situated further downstream of the Te Otamanui had a MCI score of 87. These scores indicate 'fair' ecological value. The most common taxa at these sites were midges (Orthoclad), seed shrimps (Ostracoda) and worms (Oligochaetes). These taxa are often abundant in unshaded, nutrient-enriched streams with prolific algal growth.

The remaining two sample sites (OHOTE and RNDA2) had MCI scores ranging from 77 to 79, indicating poor ecological condition. Similar to Te Otamanui Tributary sites, these sites were dominated by taxa groups such as worms and midges which are indicative of moderate to high organic pollution.

MCI guidelines proposed in the NPS-FM suggests that discharges, subdivision use and development in this area should be managed to enhance freshwater values. It should also be noted that base flows were slightly elevated at time of sampling in winter (July - August 2018).

**Table 17: Summary of biodiversity index values across sites**

| Site Code | MCI | No. Taxa | EPT Taxa | MCI Ecological Quality Threshold |
|---|---|---|---|---|
| **RNDA1** | 97.2 | 16 | 1 | Fair |
| **RNDA2** | 77.0 | 10 | 0 | Poor |
| **OHOTE** | 79.5 | 19 | 0 | Poor |
| **TEOT1** | 90 | 14 | 0 | Fair |
| **TEOT2** | 87 | 19 | 0 | Fair |

## 4.5 Water Quality

As per the project scope, one water quality grab sample was obtained at each of the five sample sites. A summary of the water quality parameters is provided in Table 18 below.

The results indicate that the water quality of the watercourses in the Rotokauri North sub-catchment is poor. Five parameters exceeded the ANZECC trigger values set for lowland rivers and streams (protection of 95% of species) and the 'satisfactory' levels set by Waikato Regional Council for river water quality in the region (WRC, 2012). These exceedances are shown in red, and orange shows exceedances of one set of guidelines in Table 18.

Turbidity exceeded the guideline values at all five sites, and by a magnitude of five at TEOT2 (25 NTU). Turbidity indicates water clarity and studies have shown turbidity levels above 5 NTU have adverse effects on underwater light – and thus on plant and invertebrate production (Davies-Colley, 1991). Loss in water clarity also adversely impacts migration of common native freshwater fish species (Boubee et al., 1997). High sediment loads from the surrounding land use is contributing to high turbidity in the sub-catchment.

Total nitrogen concentrations also exceeded the guideline values at all five sites. The highest concentrations were recorded in RNDA1 (4 $g/m^3$) and TEOT1 (4.3 $g/m^3$). Similarly, Total Kieldahl Nitrogen, which indicates the concentrations of biologically available nitrogen, exceeded guideline values at these two sites. The nitrogen concentrations results fall within the 'C' attribute state of the

NPS-FM indicating an adverse effect on some sensitive species. These sites are downstream of cattle farms and stock access to the stream was recorded upstream of both these sites.

Total phosphorus concentrations were also high in RNDA (0.18 g/m$^3$), TEOT1(0.03 g/m$^3$) and TEOT2 (0.07 g/m$^3$). Additionally, the site OHOTE, situated in the downstream reaches of the Ohote Stream (OHO_TRIB_1) also exceeded WRC guideline concentrations. Overall, the high concentrations of nutrients (N and P) are reflective of intensive agricultural land use in the sub-catchment.

It is acknowledged that these results provide only a single 'snapshot' in time of water quality in the sub-catchment.

**Table 18: Surface water quality results**

| Contaminant | Unit | RNDA1 | RNDA2 | OHOTE | TEOT1 | TEOT2 | ANZECC Lowland[1] | WRC[3] |
|---|---|---|---|---|---|---|---|---|
| pH | | 6.4 | 6.2 | 6.8 | 6.2 | 6.6 | 7.2 – 7.8 | 6.5 – 9 |
| Suspended Sediment (TSS) | g/m$^3$ | 19 | 6 | 9 | 10 | 15 | - | - |
| Turbidity | NTU | 18.3 | 9.2 | 8.7 | 22 | 25 | 5.6 | 5 |
| Total Nitrogen | g/m$^3$ | 4 | 0.9 | 1.53 | 4.3 | 2.9 | 0.614 | 0.5 |
| Total Kieldahl Nitrogen (TKN) | g/m$^3$ | 1.45 | 0.43 | 0.75 | 1.07 | 0.84 | - | 0.88 |
| Total Phosphorus | g/m$^3$ | 0.178 | 0.03 | 0.063 | 0.036 | 0.076 | 0.033 | 0.04 |
| Total Iron | g/m$^3$ | 5.2 | 1.33 | 1.74 | 4.7 | 3.9 | - | - |
| Total Nickel | mg/m$^3$ | 2.9 | 3.7 | 1.6 | 1.6 | 0.9 | 11[2] | - |
| Total Lead | mg/m$^3$ | 0.14 | 0.11 | 0.15 | <0.11 | 0.15 | - | - |
| Total Copper | mg/m$^3$ | 1.22 | 5 | 0.92 | 0.53 | 0.68 | - | - |
| Total Zinc | mg/m$^3$ | 40 | 23 | 15.1 | 80 | 13.1 | 8000 | - |
| PAH's | ug/L | <0.008 | <0.008 | <0.008 | <0.008 | <0.008 | - | - |
| E. coli | E. coli/100 mL | 99 | 96 | 85 | 70 | 260 | - | 550 |
| cBOD | g O$^2$/m$^3$ | 3 | <2 | <2 | <2 | <2 | - | - |

[1]95% protection level for freshwater
[2] Values for protection of species are more appropriately applied to dissolved values than total values
[3] Satisfactory levels from the WRC River water quality levels
- No value or Insufficient Data

Anaerobic conditions were noted throughout the low and mid-reaches of the Te Otamanui Tributary. These reaches were characterised by stagnant water, macrophytes and a thick layer (~0.2 m) of unconsolidated soft sediment in the stream channel. Anaerobic conditions were identified as strong sulphuric odours and bubbling from the dark benthic sediment. Other indicators of poor water quality such as white foam and sheens were also present in the Rotokauri North sub-catchment.

## 4.6 Sediment Quality

Composite sediment samples were taken along each of the five MCI (100 metre) sample reaches. These samples were analysed for heavy metals including copper, lead, zinc, chromium, arsenic and nickel.

The ANZECC Interim Sediment Quality Guidelines (ISQG) low trigger values are the single-contaminant thresholds where adverse biological effects could occur as an early warning for management intervention. The ISQG high trigger values are indicative of contaminant concentrations where significant biological effects are expected.

Arsenic concentrations exceeded ISQG high trigger values at the Te Otamanui Tributary site TEO1. The site TEOT1 is situated in the mid-reaches of the Te Otamanui Tributary, with surrounding land dominated by pastoral land use. The other tested heavy metals did not exceed ISQG trigger values at the five sites.

Overall, sediment contaminant results are reflective of the predominately intensive agricultural land use in the Rotokauri North catchment. The sediment concentrations of heavy metals such as nickel and zinc are low, reflecting the low urban land use.

As Rotokauri undergoes a land use change from agricultural to urban areas, there is likely to be a shift in the contaminants most of concern. For instance, nutrients such as nitrogen and phosphorus will likely decrease in concentrations overtime, whilst heavy metals such as zinc and copper are likely to increase. Management strategies which aim to improve water quality in the region should consider these land use changes and their associated pressures over time.

**Table 19: Summary of sediment contaminants (mg/kg/dry wt)**

| | **Zn** | **Cu** | **Pb** | **As** | **Cr** | **Ni** |
|---|---|---|---|---|---|---|
| | *(>200 (Low) >410 (high))* | *(>65 (Low) >270 (high))* | *(>50 (Low) >220 (high))* | *(>20 (Low) >70 (high))* | *(>80 (Low) > (370 high))* | *(>21 (Low) > (52 high))* |
| **RNDA1** | 28 | 5.2 | 7.1 | 6 | 5.1 | 2.4 |
| **RNDA2** | 24 | 2.8 | 3.7 | 4.8 | 3.8 | 3.1 |
| **OHOTE** | 38 | 1.9 | 2.9 | 2.9 | 2.5 | 2.3 |
| **TEOT1** | 74 | 5.9 | 4.3 | 71 | 7.8 | 3.6 |
| **TEOT2** | 80 | 5.6 | 4.5 | 32 | 4.2 | 4.2 |

*Cells highlighted in red exceed ISQG – High limits.*

## 4.7 Infrastructure

Stormwater inlet and outlet structures were assessed in the Rotokauri North sub-catchment, following the methodology outlined in the REM (HCC, 2015). At each inlet and outlet, a number of variables were recorded, including asset ownership, material of structure, erosion issues and structural safety Table 20.

Of the 106 surveyed assets:

- 92% were inlets or outlets with no headwall, wingwall or dissipating structure
- 8 % were inlets or outlets, with headwalls and/or wingwalls
- 43% were inlets or outlets in the Rotokauri North Development Area

Most of the stormwater infrastructure in the Rotokauri North sub-catchment are private farm track culverts. A large proportion (72%) of these assets do not present significant risks of flooding or erosion.

However, 51% of assets had a condition rating of 'average' or lower and require some form of remedial action.

Common issues noted for stormwater infrastructure in the sub-catchment include:

- Aging culvert material (spalling, cracking, displacement, rust of reinforcing)
- Scour at inlets and outlets
- Undercutting below culvert outlets due to erosion
- Erosion to banks around structures caused by stock access
- Excessive macrophytes and debris blocking inlets and outlets

**Table 20: Summary of stormwater assets (inlets/outlets) and significant issues and remedial actions**

| | | | | | |
|---|---|---|---|---|---|
| | **Assets Surveyed** | | | | |
| **Number of assets (inlets/outlets)** | 107 | | | | |
| **Condition Assessment** | **Very Good** | **Good** | **Average** | **Poor** | **Very Poor** |
| Condition of structure | 2 | 46 | 48 | 9 | 2 |
| **Erosion Assessment** | **None** | **Slight** | **Moderate** | **Severe** | |
| Extent of erosion | 32 | 45 | 15 | 15 | |

**Table 21: Engineering structure safety risk matrix for structures (inlets/outlets)**

| | | | | | |
|---|---|---|---|---|---|
| | | **Access** | | | |
| **Safety** | | **Appears Safe** | **Not Safe** | **Not Safe (Drop 1.5m)** | **Uncertain** |
| **Pedestrian Access** | Easy | 4 | | | |
| | Moderate | 45 | 1 | 4 | 1 |
| | Difficult | 47 | 2 | 1 | 2 |
| **Erosion severity** | | **None** | **Slight** | **Moderate** | **Severe** |
| **Asset Ownership** | Unknown | - | - | - | - |
| | Council | 6 | 7 | 1 | 2 |
| | Private | 26 | 38 | 14 | 13 |

Two structures in the sub-catchment present risks to infrastructure and stream channel. These are described below:

- The inlet at Te Kowhai Road (UNK031) is in relatively good condition, with some iron bacteria recorded upstream of the culvert and inside of the pipe. However, the 1200 mm Ø pipe appears to be undersized and is causing backwater, scour and erosion on both banks upstream of the culvert (Figure 9).

- The outlet at Horotiu Road (UNK107) is a near-vertical outflow draining from the main road. The discharge of flows from a height of approximately 2 metres into the stream channel below has caused severe erosion at the downstream end of the Te Otamanui stream. It is recommended that this infrastructure is upgraded or replaced with a design which mitigates channel erosion.

**Figure 10: Left: Erosion and coir lining on banks upstream of the Te Kowhai Road culvert (UNK031); Right: Erosion downstream of outlet UNK107**

## 4.8 Flood Floor Levels

As part of the watercourse assessment, Morphum conducted initial flagging of both habitable and non-habitable buildings that may potentially be at risk of flooding from increased flows. The assessment was a visual inspection only, using an inclinometer to identify building floor levels that were within 1.75 m elevation of the top of the bank. It is anticipated that this initial assessment will be used in conjunction with the flood assessment to identify areas for further investigation. All houses within the Rotokauri North development area were excluded from this assessment. As a result of the investigation, two houses were identified as being within 1.75 m of the top of the bank and are illustrated in Figure 10. The houses within this area require further investigation into the risk of flooding from development within the upstream catchment, however these are new dwellings, so a resource consent process is considered likely to have assessed flood levels.


**Figure 11: Results of Habitable Floor Level Surveying**

# 5.0 Options and Actions

## 5.1 Management Zones

Four management zones have been identified in the Rotokauri North sub-catchment and the receiving environments based on reaches with similar pressures, issues and opportunities. A brief description of each of the management zones is outlined in Table 22, while a detailed description of each management zone is described in Sections 5.1.1 to 5.1.4.

The common pressures on watercourses identified within the surveyed extent result from historic and existing rural land uses. The most common pressures and their effects within each management zone are outlined in Table 23, while further issues and pressures specific to each management zone are described in Table 24 - Table 27.

In addition to existing land uses, proposed future growth and development also poses potential issues and pressures on watercourses within the catchment. There is, however, an opportunity to remedy and mitigate existing and future pressures through the greenfields development process and manage rural land use issues in areas outside of the RNDA.

The proposed management approach presented in this report aims to anticipate and plan for the increase pressures on watercourses. The management approach identifies key issues, objectives to address these issues, and recommends options and actions to mitigate their actual and potential adverse effects.

A summary of possible objectives to manage these pressures within each management zone in the Rotokauri North sub-catchment and the receiving environments is presented in Table 28. The broad management objectives outlined in this report align with the outcomes sought by (but not limited to) the Stormwater Master Plan (HCC, 2016), Rotokauri ICMP (2017), the Waikato vision and strategy document (2011), the NPS-FM (2016) and the Proposed Waikato Regional Plan Change (2018).

**Table 22: Summary of Management Zones**

| | Management Zone | Description |
|---|---|---|
| MZ1 | Rotokauri North Development Area | Encompasses 163 hectares of greenfields land marked for the Rotokauri North Special Housing Area |
| MZ2 | Ohote Tributary downstream of Exelby Road and TEO_MAIN_18 | Watercourse with wetland-like characteristics, wide floodplains and high ecological potential |
| MZ3 | Lower Te Otamanui Tributary (TEO_MAIN_1 to TEO_MAIN_7) | Meandering watercourses with moderate riparian cover and wide floodplains with erosion issues caused by fluvial processes and stock access |
| MZ4 | Upper Te Otamanui Tributary | Incised and straightened channels, modified for efficient conveyance but degraded ecological value. Surrounding landscape is primarily agricultural with stock access issues |

**Table 23: Common pressures across management zones in the Rotokauri North sub-catchment and the receiving environments**

| Common Issues across the management zones | Description of impacts | Suggested Objectives | Impacted management zone |
|---|---|---|---|
| **Stock access to waterways** | Reduced water quality through faecal contamination.<br>Reduced bank stability.<br>Increased suspended sediments and deposition.<br>Change in morphology and hydrodynamics of the watercourse. | Exclude stock from watercourses. Establish set-backs from the stream and plant riparian vegetation buffers. | Management Zones 1, 2,3 and 4. |
| **Channel erosion** | Ecological impacts include;<br>• increased sediment deposition on the channel bed from erosion of upper and lower banks, which can adversely affect macroinvertebrates through change in habitat and loss of interstitial space.<br>• Fish populations are also affected by availability of habitat for spawning and food supply.<br>Channel erosion can impact private/public land and is particularly an issue where it poses a risk to assets such as walkways, roads, fences, buildings and/or channel lining. | Soft engineering approaches which aim to improve conveyance capacity and mitigate future erosion, whilst enhancing the ecological value of these watercourses.<br>This can include the regrading and naturalisation of stream channels to restore natural channel morphology and planting on banks. | Management Zones 1, 2, 3 and 4. The severity and the processes driving erosion in these reaches varies across the management zones. Specific issues are discussed for each management zone in the sections below. |
| **Lack of riparian margin vegetation** | The lack of riparian vegetation impacts the biochemical and geomorphic processes in streams including;<br>• Decreased channel shading, resulting in increased macrophyte abundance and increased temperatures<br>• Loss of dissolved oxygen levels<br>• Reduction in non-point source filtration, both in surface flow and groundwater<br>• Reduced stable organic matter input<br>• Loss of fish spawning habitat and habitat for adult stages of macroinvertebrates<br>• Loss of habitat connectivity (both freshwater and terrestrial fauna)<br>• Loss of root reinforcement provided by riparian plants, reducing bank stability | Establishing set-backs and riparian planting as per the guidelines in the Proposed Waikato Regional Plan Change 1 (2018) to support ecological outcomes. | Management Zones 1, 2, 3 and 4. |
| **Degraded water quality** | Degraded water quality due agricultural land use and agricultural sourced contaminants such as sediment, nutrients and heavy metals. Impacts include;<br>• High suspended or deposited sediment levels<br>• Low dissolved oxygen<br>• High temperatures<br>• High nutrient levels<br>These water quality conditions adversely impact the aquatic life in these watercourses and have cumulative impacts on the low energy downstream receiving environments | Implementing treatment devices to address stormwater discharges.<br>Ensuring best practice measures are in place during the development phase to reduce sediment inputs into these systems | Management Zones 1,2,3 and 4. |

### 5.1.1 Management Zone 1 – Rotokauri North Development Area

*Description*

Management Zone 1 is comprised primarily of perennial watercourses however there are small ephemeral watercourses present in the headwaters of these tributaries.

The perennial watercourses are dominated by pastoral land use, with sparse riparian cover and low channel shading. The channels show evidence of straightening, deepening and widening, and have incised, steep gradient banks. At the time of sampling, slow flows were observed in the channels, and emergent macrophytes such as duckweed on the water surface were recorded along some reaches.

The watercourses are drained to the Te Otamanui Tributary through a culvert under Te Kowhai Road and to Ohote Stream through a culvert under Exelby Road. Field assessment of these inlets and outlets indicated that these assets are likely to be undersized for managing existing flows. For example, the Te Kowhai Road culvert (Inlet Asset ID: UNK032) shows evidence of severe erosion caused by flows and backwater pooling upstream of the culvert. This issue is likely to be exacerbated with increased flows and discharge from the proposed development.

These watercourses are all within the development footprint for the proposed Rotokauri North Special Housing Area. As a result, these watercourses will undergo a shift from agricultural streams to urban streams. The specific issues and suggested objectives and actions associated with the RNDA are outlined in Table 24.

The susceptibility of the catchment to erosion and the impacts of associated sediment in the immediate receiving environments (Te Otamanui and Ohote Stream) and further downstream (Waipa River) are long term issues that are likely to increase in severity through the development of the Rotokauri area. The proposed development also has the potential to increase the source of other contaminants such as heavy metals associated with urban runoff. It is therefore critical that increased peak flows and contaminant loads associated with urban development in the RNDA are controlled and managed before reaching the receiving environment in order to minimise impacts. In the short-term, sediment control measures will be required during the land development phase to ensure that contaminants are not being flushed into the receiving environment. Water quality treatment for sediment and contaminants can be met through the implementation of the HCC Regional Infrastructure Technical Specification (RITS) Standard at the development stage. The treatment of greenfield areas to a minimum of RITS standards is required by the WRC Stormwater Discharge Consents. The following management objectives are based on baseline data collected in this report.

**Table 24: MZ1 Issues and Objectives**

| Specific Issues | Suggested Objectives and Actions | Guiding/ Statutory documents |
|---|---|---|
| Potential piping, diversions and/or reclamations of watercourses. | Preserve remaining open watercourses within the sub-catchment. Streams and wetlands should only to be piped and culverted in exceptional circumstances where no other practical alternative exists.<br><br>Any diversion of watercourses should consider the groundwater recharge implications and maintain or improve pre-diversion hydrology and habitat. Existing groundwater seepages should also be considered.<br><br>In some instances, the surrounding low-gradient topography and location of existing ponds or pugged wetland-like reaches within the catchment may be suitable for the creation of wetlands for the primary purpose of stormwater treatment.<br><br>Naturalisation or enhancement of stream corridors to improve ecological values and provide amenity value through green spaces. | WRC Plan Section 3.6. Damming and Diverting<br><br>WRC Plan Section 4.3. River and Lake Bed Disturbances, 4.3.1 Issues<br><br>Supported by RMA, 1991 |
| Modified hydrographs due to increased impervious surfaces in the RNDA | Advocate for best practice stormwater management controls above the receiving environment<br><br>Implementation of a water sensitive design including re-use or infiltration practices | Regional Infrastructure Technical Specifications (RITS)<br><br>WRC Stormwater Discharge Consents |
| Contaminants such as sediment, heavy metals, pollutants associated with development and urban land use | Stormwater quality treatment upstream of the receiving environment to reduce impacts | The NPS-FM sets two compulsory values (ecosystem health and human health for recreation)<br><br>Water quality parameters set in;<br>- the Proposed Healthy Waters Wai Ora Plan Change,<br>- ANZECC guideline levels<br>- WRC trigger values<br><br>Reference in Rotokauri ICMP |
| Potential undersized road culverts (Inlet Asset ID: UNK032) | Redesign and upgrade of culverts to manage increased discharges at greater velocities, whilst also including erosion mitigation at both the inlet & outlet, including energy dissipating structures where required.<br><br>Redesign of culverts should also consider best practice guidelines for fish passage. Options for reducing barriers to fish. | New Zealand Fish Passage Guidelines, NIWA<br><br>Regional Infrastructure Technical Specifications (RITS) |

### 5.1.2 Management Zone 2 – Ohote Tributary downstream of Exelby Road

*Description*

Management Zone 2 is comprised of peat-like wetland reaches. These reaches have high (~3 metre) upper gully banks and wide floodplains. There is low (10 – 30%) riparian cover along these reaches, and pastoral grasses are the dominant vegetation type. One erosion hotspot was recorded in this management zone.

Some parts of this management zone are fenced off from stock and OHO_TRIB1_7 has newly planted riparian vegetation on the TRB. However, the lower sections show evidence of stock damage along bank margins and in the stream channel.

The channel and floodplains are dominated by extensive floating mats of *Glyceria*. The reaches appear to be heavily modified due to vegetation clearance on the banks and surrounding land use. As a relatively rare habitat type in the area, peat/ boggy wetlands have ecological values that should be protected.

The reach (OHO_TRIB1_7) directly downstream of the Exelby Road culvert is narrow, incised and near (~ 20 m) an existing residential property. The reach is susceptible to further erosion and bank instability issues as a result of increased flows from the development upstream. There is also potential that contaminant aggregation can occur within the wetland reaches if not treated to adequate standards in the upstream development area.

**Table 25: MZ2 Issues and Objectives**

| Specific Issues | Suggested Objectives and Actions | Guiding/ Statutory documents |
|---|---|---|
| Increased erosion susceptibility in reach OHO_TRIB1_7 directly downstream of Exelby Road culvert | Redesign of culvert in accordance with RITS Standards. Engineering approaches to provide armouring – e.g. rock rip rap, gabion.<br>Bank regrading to introduce a transition with gradual bank slope, widening stream channel to dissipate flows and riparian planting.<br>Advocating for stormwater retention/detention above the receiving environment | Regional Infrastructure Technical Specifications (RITS) |
| Potential loss or further deterioration of peat-wetland | Exclusion of stock. Fencing on both banks. Removal of weed and exotics such as willow, parrots feather and *Glyceria*.<br>Planting gully banks and upper stream banks to promote connectivity with wetlands directly downstream of Duck Road.<br>Planting to also promote in-stream conditions such as temperature and provide potential fish spawning habitat on banks | Healthy Rivers Proposed Waikato Regional Plan Change. Rule 1 and Rule 2 farming activities.<br>Rotokauri ICMP (2017) and as highlighted in an objective generic for ICMPS: Maintaining natural hydrology "groundwater level in peat soils are sustained" |

### 5.1.3 Management Zone 3 – Lower Te Otamanui Tributary

*Description*

Management Zone 3 includes the downstream reaches of the Te Otamanui Tributary, which are dominated by low-density residential land use. The surrounding land use also a public school. The lower reaches have wide floodplains and the top of the high gully banks (~4 metres) are planted with mature pine on the TRB. The floodplains are dominated by exotic weed species such as *Glyceria*. Similarly, further upstream (TEO_MAIN_3 to TEO_MAIN_5), the TRB has moderate riparian cover from mixed native and exotic vegetation.

There are multiple small, informal crossings along the stream channel, as well as a public access way and walking bridge from Horotiu Road to the stream.

**Table 26: MZ3 Issues and Objectives**

| Specific Issues | Suggested Objectives and Actions | Guiding/ Statutory documents |
|---|---|---|
| Fluvial erosion caused by constricted channel flows | Engineering approaches to naturalise the stream channel and improve engagement with floodplain. | Stormwater Master Plan, 2016 |
| Pest plant species within the riparian corridor | Weed control and enhancement of existing riparian corridor. Encourage greater diversity of native vegetation which reflect the ecological district and historic vegetation.<br>Planting should also consider the functional requirements of species to provide the required stability and filtration.<br>Improving amenity and aesthetics values, as well as maintaining and enhancing public access | Waikato Pest Management Plan 2014 - 2024<br>Maintenance of riparian areas and public green spaces can assist towards goals outlined in the Hamilton Plan (2015) |
| Outfall erosion at Horotiu Road | Redesign in accordance with RITS standards. Consideration for altered hydrology from upstream development. | Regional Infrastructure Technical Specifications (RITS)<br>New Zealand Fish Passage Guidelines, NIWA |

### 5.1.4 Management Zone 4 – Upper Te Otamanui Tributary

*Description*

Watercourses transect multiple private properties which are dominated by agricultural and cropland activities. The channels are heavily modified, with little to no riparian cover. Stock exclusion is limited to single electric wires along bank margins of some reaches, whilst other reaches have open stock access. Bank slumping and erosion in these channels can be largely attributed to stock damage rather than erosion caused by stormwater flows.

It is understood that a potential diversion from part of the Mangaheka catchment to the Te Otamanui tributary is being investigated by BECA and WSP Opus. It is further understood that only flows generated

from events greater than a 1 in 10-year event are proposed to be diverted. Therefore, dependant on flows, the increased risk on channel and bank erosion is not considered to be significant as these flows are greater than the anticipated channel forming flow for these reaches and are likely to be assimilated within overbank floodplains which exist for a majority of the upper reaches. Further investigation is recommended to determine the actual anticipated changes in flow regime and risks this poses on flooding and erosion based on rainfall scenario modelling.

The Stormwater Master Plan for HCC (2016), outlines management priorities for open watercourses and drains, much like the reaches found in this management zone. These management actions include channel erosion remediation, outfall erosion remediation, improvement of riparian corridors and vegetation, mitigation of fish barriers and improved water quality.

Management objectives such as naturalisation of channels are considered low priority as there are often land constrictions on private land. Nevertheless, there are opportunities for Council, supported by guiding documents such as the Proposed Healthy Waters Waikato Regional Plan Change, to engage with landowners to improve the ecological outcomes in these reaches. The properties surrounding the Te Otamanui Tributary can be categorised as small and low intensity rural properties under 4.1 ha.

**Table 27: MZ4 Issues and Objectives**

| Specific Issues | Suggested Objectives and Actions | Guiding/ Statutory/ Reference documents |
|---|---|---|
| Direct stock access, causing erosion and damage to bank margins | Set-backs, fencing to exclude stock, and riparian planting. | Proposed Healthy Waters Waikato Regional Plan Change 1. Schedule C – stock exclusion. Rule 1 and Rule 2 apply to properties surrounding Te Otamanui Tributary |
| Multiple undersized private culverts | Redesign and upgrade to improve conveyance, particularly with potential increased flows from the upstream development and diversion of the Mangaheka Stream.<br>Redesign of culverts should also consider removing redundant culverts and fish passage friendly infrastructure | Regional Infrastructure Technical Specifications (RITS)<br>New Zealand Fish Passage Guidelines, NIWA |
| Incised, steep channels with localised areas of severe erosion | Engineering approaches to address existing erosion issues and mitigate further erosion in the channel | Stormwater Master Plan (2016) |
| Online pond upstream of TEO_MAIN_7 | Restoration to natural hydrology and removal of a series of culverts which are barriers to mitigation | Regional Infrastructure Technical Specifications (RITS)<br>New Zealand Fish Passage Guidelines, NIWA<br>Waikato Regional Plan; Section 3.6 |
| Proposed diversion from part of the Mangaheka catchment to the Te Otamanui tributary | Further investigation is required to determine the actual anticipated changes in flow regime and risks on flooding | Potential catchment inflows from Mangaheka stream identified in Rotokauri ICMP (2017) |

**Table 28**: **Summary of Management Zones and Objectives**

| Management Zones | | Stream Naturalisation | Erosion Remediation and Sediment Control | Stock Exclusion and Fencing | Riparian Vegetation Enhancement | Wetland Enhancement | Pest Plant Control | Water Sensitive Communities | Infrastructure Remediation | Fish Passage Remediation | Artificial Pond Remediation | Conveyance Improvement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MZ1 | Rotokauri North Development Area | ✓ | ✓ | | ✓ | | | ✓ | ✓ | | | |
| MZ2 | Ohote Tributary downstream of Exelby Road and TEO_MAIN_18 | | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | | ✓ |
| MZ3 | Lower Te Otamanui TEO_MAIN_1 to TEO_MAIN_ 8 | | ✓ | ✓ | | | ✓ | | ✓ | | | |
| MZ4 | Upper Te Otamanui Tributary | | ✓ | ✓ | ✓ | | | | | | ✓ | ✓ |

## 5.2 Erosion Mitigation Projects

The conversion of greenfield areas to developed urban areas will result in an increase in impervious surfaces, and associated changes in the hydrograph of receiving watercourses. These changes in the hydrograph often include 'flashy' hydrology with elevated flow depths and velocity, as well as lower base flows.

Mitigation of frequent flow changes is likely to be incorporated in development proposals, however there will be a residual potential that upstream development in the RNDA will increase the erosion and channel instability downstream. Remediation of current instabilities is important to mitigate this further erosion risk in the sub-catchment resulting from the proposed development. Engineering approaches to remediate channel instabilities include reducing channel bank grade, placement of boulders for bank protection, and planting riparian vegetation buffers.

The mitigation projects identified in this assessment arise from existing issues that have the potential to be exacerbated by changes in the contributing catchment. It should not be inferred that the costs of these projects would be borne entirely by upstream greenfield growth areas. A further process of assessing the contributing catchment, and existing and proposed on-site mitigation is necessary to consider a fair and reasonable allocation of costs between existing contributors and growth areas.

Where erosion hotspots, 'moderately unstable' or 'unstable' reaches were identified, engineering approaches to mitigate further erosion are recommended. A summary of these erosion mitigation projects is presented in Table 30. Refer to Appendix 6.

It should be noted that the primary objective of these erosion mitigation projects is to manage existing erosion issues and mitigate residual future erosion effects only. The scope of these erosion mitigation projects does not provide mitigation solutions for agricultural best practices such as stock exclusion to waterways and have therefore not been costed for but have been noted where applicable. The projects do not directly seek but may have co-benefits to improve water quality, ecological enhancement, or amenity values. For enhancement opportunities within the Rotokauri North sub-catchment where erosion mitigation is not the primary driver, refer to Section 5.3.

High-level costs for the proposed erosion mitigation measures within each reach are provided in Table 29. It is recommended that a detailed options analysis and planning assessment is conducted to inform capital works. Table 30 describes the erosion mitigation projects and expected outcomes.

The unit rates and costs applied to erosion mitigation works are derived from quotes and invoices from physical works in the last five years in the Auckland market. The rates are therefore considered conservative. The final costings presented in this report should be considered as indicative only with further refinement required during concept design.

**Table 29: Proposed erosion mitigation works costs ($)**

| Reach/Tributary | Bank Batter Excavation | Coir Matting | Newbury Rock Riffle | Keystone Boulders | Cost Planting | Total Cost | Design and Feasibility (10%) | Resource Consent (3%) | Defects Liability (10%) | Sub-total | Total including 20% Contingency |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TEO_MAIN_1 | 141,457 | 7,777 | | | 63,751 | 212,985 | 21,298 | 6,390 | 21,298 | 261,971 | 314,365 |
| TEO_MAIN_2 | 34,904 | 2,728 | | | 19,574 | 57,205 | 5,721 | 1,716 | 5,721 | 70,363 | 84,435 |
| TEO_MAIN_3 | 28,889 | 2,252 | | | 20,089 | 51,230 | 5,123 | 1,537 | 5,123 | 63,013 | 75,615 |
| TEO_MAIN_4 | - | | | | 13,360 | 13,360 | 1,336 | 401 | 1,336 | 16,433 | 19,720 |
| TEO_MAIN_7 | 7,348 | 1,643 | | 67,044 | 27,170 | 103,205 | 10,321 | 3,096 | 10,321 | 126,942 | 152,331 |
| TEO_MAIN_8 | 28,957 | 3,871 | 44,270 | - | 23,720 | 100,818 | 10,082 | 3,025 | 10,082 | 124,006 | 148,807 |
| TEO_MAIN_9 | - | | | 25,404 | - | 25,404 | 2,540 | 762 | 2,540 | 31,247 | 37,497 |
| TEO_MAIN_11 | 200,161 | 5,575 | | - | 15,794 | 221,531 | 22,153 | 6,646 | 22,153 | 272,483 | 326,979 |
| TEO_MAIN_14 | 52,222 | 9,014 | | - | 45,618 | 106,854 | 10,685 | 3,206 | 10,685 | 131,430 | 157,716 |
| TEO_MAIN_15 | 28,026 | 2,758 | | 13,852 | 9,815 | 54,451 | 5,445 | 1,634 | 5,445 | 66,975 | 80,370 |
| TEO_MAIN_21 | 401,441 | 15,131 | | - | 53,924 | 470,496 | 47,050 | 14,115 | 47,050 | 578,710 | 694,452 |
| TEO_MAIN_24 | - | | | - | 25,838 | 25,838 | 2,584 | 775 | 2,584 | 31,781 | 38,137 |
| TEO_MAIN_26 | 28,503 | 6,088 | | 89,068 | 32,146 | 155,806 | 15,581 | 4,674 | 15,581 | 191,641 | 229,969 |
| TEO_TRIB1_1 | 1,207 | 2,630 | 50,418 | | 2,812 | 57,067 | 5,707 | 1,712 | 5,707 | 70,192 | 84,230 |
| OHO_TRIB1_3 | 1,813 | 159 | | | 17,116 | 19,089 | 1,909 | 573 | 1,909 | 23,479 | 28,175 |
| OHO_TRIB1_7 | - | - | | | 10,223 | 10,223 | 1,022 | 307 | 1,022 | 12,574 | 15,088 |
| Total costs ($) | 954,929 | 59,626 | 94,688 | 195,368 | 380,950 | 1,685,561 | 168,556 | 50,567 | 168,556 | 2,073,240 | |
| **Total overall costs for erosion mitigation works with 20% contingency** | | | | | | | | | | | **2,487,888** |

** Unit rates used to calculate costs are in Appendix 9*

**Table 30: Proposed Erosion Mitigation Works in the Rotokauri North Sub-Catchment**

| Location in the sub-catchment | Issue | Proposed Erosion Mitigation Works | Approximate area or length of proposed works | Expected Outcomes |
|---|---|---|---|---|
| TEO_MAIN_1 to TEO_MAIN_3 | Fluvial erosion resulting in highly incised, steep stream banks.<br>Constricted, narrow channel with wide floodplains. | Bank battering to a 1:3 grade.<br>Weed plant removal and riparian planting with coir matting. | Earthworks removal = 10518 $m^3$<br>Floodplain planting = 2892 $m^2$<br>Grade control = 53 $m^3$ | Reduce channel incision and bank angle. Increase floodplain connectivity.<br>Riparian planting to reduce upper bank and floodplain erosion and improve cohesive strength of soils. |
| TEO_MAIN_4 | Highly incised, steep stream banks. Mass wasting from banks and undercutting on TLB<br>Bare or minimum groundcover on TLB. | Riparian planting on TLB. | Floodplain planting = 760 $m^2$ | Riparian planting to reduce upper bank and floodplain erosion on TLB. |
| TEO_MAIN_7 | Incised banks with active bank widening. Toe erosion and degradation.<br>Direct stock access, and damage to banks. | Bank battering to a 1:3 grade.<br>Placement of keystone boulders.<br>Riparian planting with coir matting | Earthworks removal area = 164 $m^3$<br>Keystone boulders = 45 $m^2$<br>Floodplain planting = 760 $m^2$ | The keystone boulders will provide toe protection and bank stabilisation without requiring additional grading of banks.<br>Planting of banks to improve riparian vegetation condition, stock exclusion is recommended. |
| TEO_MAIN_8 | Constructed pond at head of reach has caused steepening of the reach. Active incision, with channel and bed scour, and Knick points. | Bank battering to a 1:3 grade.<br>Newbury Rock Riffle<br>Riparian planting with coir matting | Floodplain planting = 664 $m^2$<br>Earthworks removal = 598 $m^3$ | Reduce channel grade, dissipate flows and protect the stream bed from further degradation.<br>Increase habitat complexity |
| TEO_MAIN_9 | Straightened channel with steep banks | Placement of keystone boulders | Keystone boulders = 35 $m^2$ | Toe protection and stream bank stabilisation to reduce further erosion |
| TEO_MAIN_11 | Straightened channel with steep banks Bank erosion exacerbated by stock access | Riparian planting with coir matting | Floodplain planting = 442 $m^2$ | Reduce sediment release and discharge from the channel. Protect the morphology and hydrodynamics of the watercourse and planting of banks to improve riparian vegetation condition. Stock fencing exclusion is recommended. |
| TEO_MAIN_14 | Steep, incised banks. Toe scour. | Bank battering to a 1:3 grade.<br>Riparian planting with coir matting | Earthworks removal = 423 $m^3$<br>Floodplain planting = 1276 $m^2$ | Reduce channel incision and bank angle and stabilise bank with riparian buffer planting. Increase floodplain connectivity. |
| TEO_MAIN_15 | Unstable undercutting on both banks, bank and bed scour leading to deepening of stream and incision | Placement of keystone boulders<br>Riparian planting with coir matting | Erosion mitigation planting = 275 $m^2$<br>Keystone boulders = 19 $m^2$ | Toe protection to mitigate further toe erosion and widening of the stream bed. Riparian planting to reduce bank slumping. |
| TEO_MAIN_21 | Erosion on low lying TRB primarily exacerbated by stock access. Toe undercutting caused by fluvial processes and bank slumping | Bank battering to a 1:3 grade<br>Riparian planting with coir matting | Earthworks removal = 6918 $m^3$<br>Floodplain planting = 1508 $m^2$ | Stability from riparian planting and gradual slope to prevent further bank slumping. Fencing for stock exclusion is recommended. |
| TEO_MAIN_24 | Drain cleaning resulting in loose, exposed soils slumping into stream channel | Riparian planting with coir matting | Floodplain planting = 723 $m^2$ | Planting to provide bank stability for resilience against increased flows and retention of valuable top soils |
| TEO_MAIN_26 | Erosion hotspot on TLB. Bank slumping recorded along the length of reach. Ongoing toe erosion leading to widening of stream channel.<br>No significant risk to existing infrastructure. | Bank batter to a 1:3 grade<br>Riparian planting<br>Placement of keystone boulders | Floodplain planting = 899 $m^2$<br>Earthworks removal = 503.7 $m^3$<br>Keystone boulders = 123 $m^2$ | Protection against loss of further land from adjacent property.<br>Reduce channel incision and bank angle. Increase floodplain connectivity.<br>Riparian planting to reduce upper bank and floodplain erosion and improve cohesive strength of soils. |
| TEO_TRIB1_1 | Steepened and deepened channel. Increased flow velocity causing scouring along banks and at the confluence | Bank batter to a 1:3 grade<br>Riparian planting with coir matting | Earthworks removal = 40.8 $m^3$<br>Floodplain planting = 78 $m^2$ | Dissipate energy from flows to prevent further scouring of banks. Riparian vegetation providing bank stability and soil retention |

| Location in the sub-catchment | Issue | Proposed Erosion Mitigation Works | Approximate area or length of proposed works | Expected Outcomes |
|---|---|---|---|---|
| OHO_TRIB1_3 | Erosion hotspot on the upper banks and gully banks due to lack of riparian vegetation and stock access | Bank batter to a 1:3 grade<br>Riparian planting with coir matting | Earthworks removal = 91.2 $m^3$<br>Floodplain planting = 479 $m^2$ | Riparian planting to reduce upper bank and floodplain erosion and improve cohesive strength of soils. |
| OHO_TRIB1_7 | Erosion on TLB, primarily due to a lack of riparian vegetation and stock access | Riparian planting | Floodplain planting = 286 $m^2$ | Reduce sediment release and discharge from the channel. Protect the morphology and hydrodynamics of the watercourse and increase bank stabilisation with riparian planting. |

## 5.3 Enhancement Opportunities

Five enhancement opportunities were identified in the Rotokauri North sub-catchment and receiving environments. In some instances, these enhancement opportunities are intended to work in tandem with the proposed erosion mitigation works to improve management outcomes. Other enhancement projects highlight opportunities to utilise water sensitive design and best practice green infrastructure design to minimise adverse impacts on watercourses within the RNDA and the receiving environments as discussed in Sections 5.1 and 5.2 above. Enhancement opportunities are intended to increase the amenity and ecological value of the watercourses, whilst improving flow conveyance and improving resistance to further changes to surrounding land use.

The enhancement projects identified in this assessment represent opportunities only. It should not be inferred that these projects are allocated to any particular party to implement. The enhancement information has value in that it can inform a range of parties (e.g. HCC, WDC, WRC, land owners) who may be considering or undertaking other works in the vicinity. Parties will be able use this information to, if they choose, influence project scoping to deliver or maximise environmental benefits, perhaps with no significant additional investment required. Identifying these opportunities also provides an information base for not-for-profit or environmentally focused delivery agencies looking for opportunities to invest in environmental improvement works (e.g. Streamcare groups, WRC, WRA).

All the enhancement opportunities are located within the Waikato District and are not on public land. In order for these enhancement opportunities to be realised, co-operation with landowners will be required and, in some cases, easements developed for maintenance of these areas.

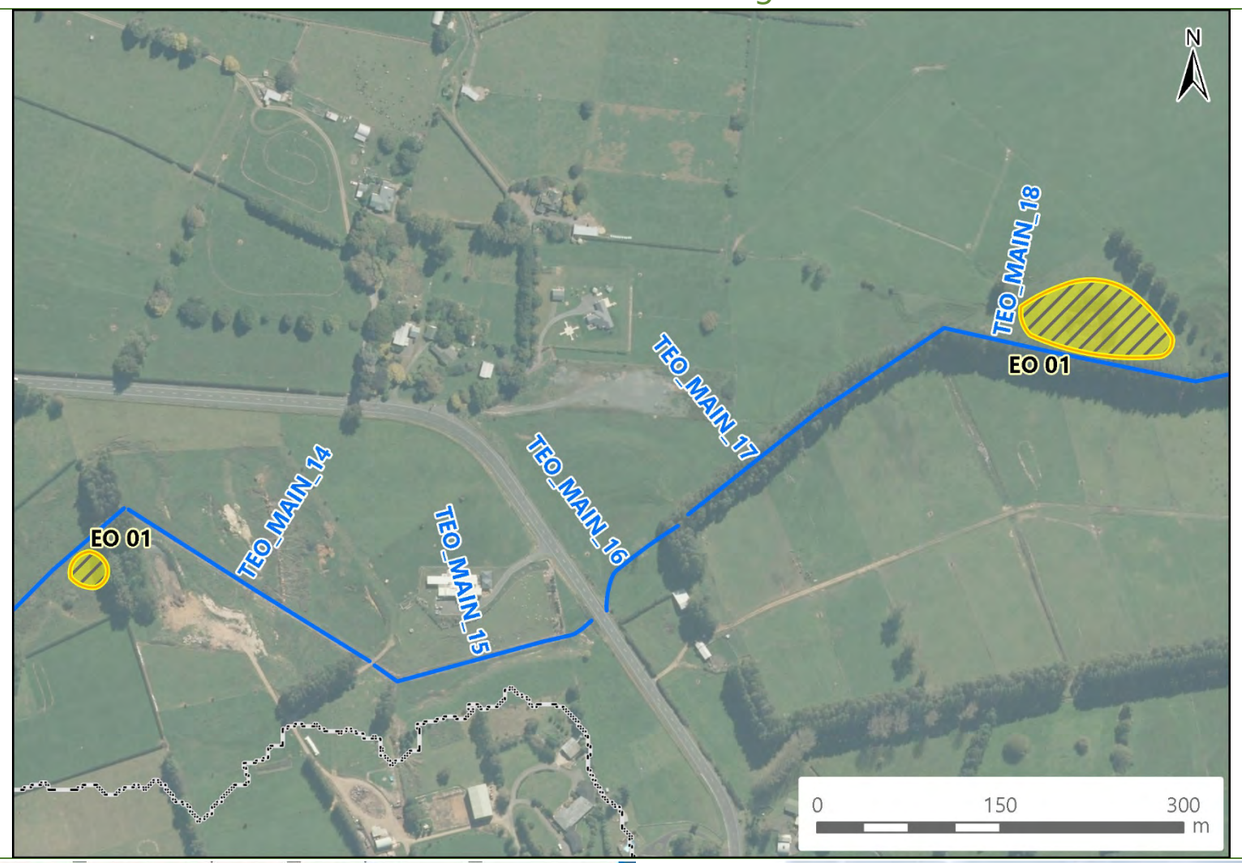
As per the REM methodology, each enhancement opportunity is assigned a high-level prioritisation score based on the potential benefits to the public and local amenity values, ecological values such as biodiversity and habitat improvements, and conveyance. An overview of the projects and their prioritisation is presented in Table 31. Refer to Appendix 7 for the location of these areas.

**Table 31: Summary of prioritisation of enhancement opportunities**.

| Enhancement Opportunity | Management Zone | Description | Amenity | Ecology | Conveyance | Overall Score | Prioritisation Score |
|---|---|---|---|---|---|---|---|
| **EO 1** | MZ4 | Wetland naturalisation and planting at two existing wetland sites along the mid- Te Otamanui Stream | L | M | M | 8 | 3 |
| **EO 2** | MZ2 | Wetland naturalisation and planting along the lower reaches of the Ohote Tributary | M | H | H | 11 | 1 |
| **EO 3** | MZ4 | Pond naturalisation at head of TEO_MAIN_8 | L | M | H | 9 | 2 |

| Enhancement Opportunity | Management Zone | Description | Amenity | Ecology | Conveyance | Overall Score | Prioritisation Score |
|---|---|---|---|---|---|---|---|
| **EO 4** | MZ3 | Stock exclusion and riparian enhancement along erosion prone reaches | L | H | M | 9 | 2 |
| **EO 5** | MZ4 | Stock exclusion and riparian restoration along Te Otamanui Tributary | L | M | M | 8 | 3 |

# EO1- Wetland naturalisation and enhancement along mid-Te Otamanui Stream




**Location:** Upper Te Otamanui Tributary

**Tributary ID:** TEO_MAIN_18 and TEO_MAIN_13 **Ownership:** Private

**Priority score:** 3

**Description:** Opportunity for the restoration of wetlands to help regulate stream flows and enhance ecological functions.

Currently modified straightened and incised channels drain pastoral land use along the Te Otamanui. The floodplains maintain some wetlands with species such as Juncus, but the land has been planted with pastoral grasses and heavily modified by stock access.

The source of flow is likely comprised of groundwater seepage and rain fall. These areas can be defined as natural palustrine wetlands.

At TEO_MAIN_18, existing artificial farm pond can be naturalised and connected to the wider wetland area.

| Upstream Catchment Area: | Wetland Area: | Wetland Area as Percentage of Upstream Catchment: |
|---|---|---|
| 284 Hectares | 0.64 Hectares | 0.2% |

**Considerations**

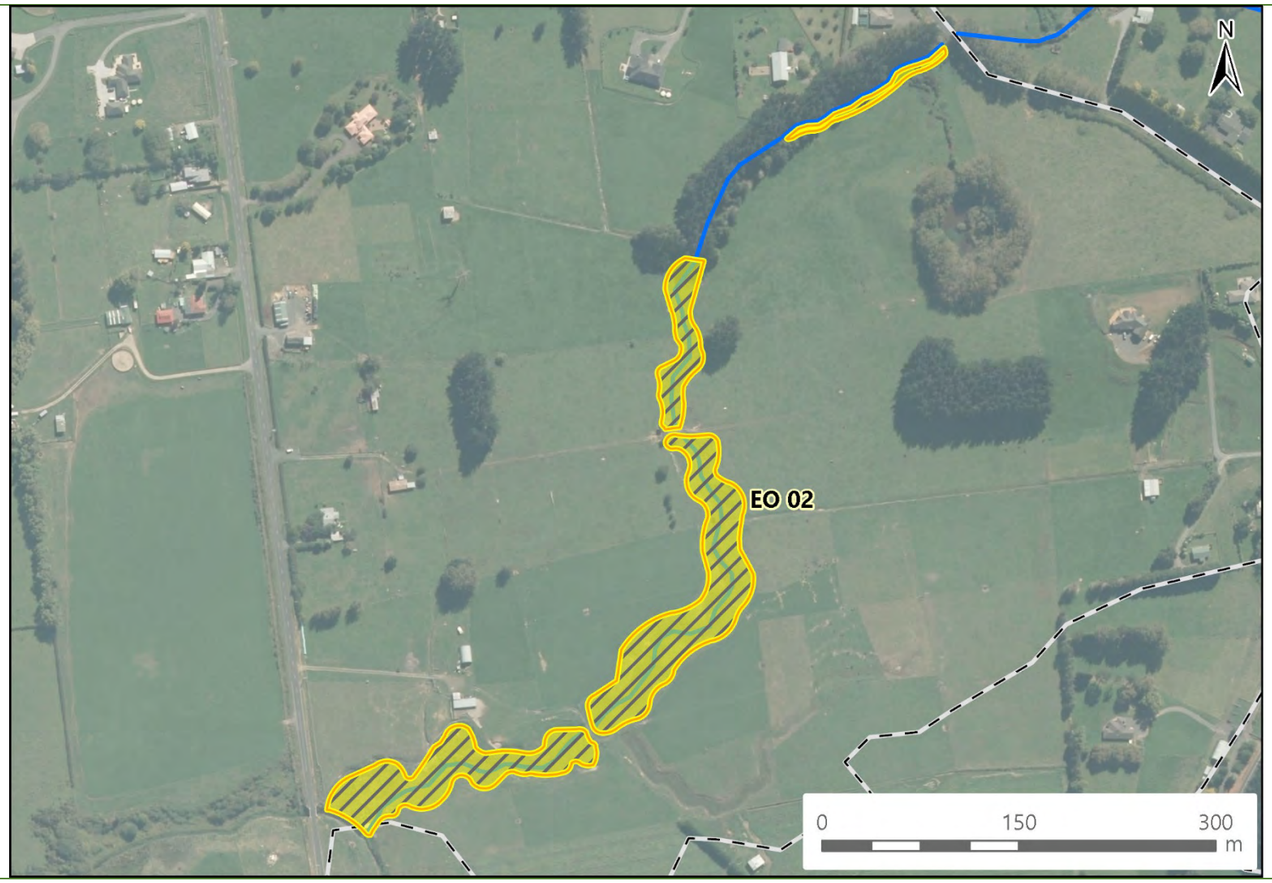
These areas outside the RNDA will likely remain private. Enhancement and stream management in these receiving environments requires land-owner cooperation. Opportunity for Council and community engagement

| Enhancement Types | Stakeholders |
|---|---|
| Naturalisation | Residents |
| Fencing/Stock Exclusion | HCC |
| Conveyance Improvements | Community groups |
| Aquatic Weed Control | |


**Artificial farm pond on TRB of TEO_MAIN_18 embedded in a natural palustrine wetland**

**Palustrine wetlands heavily modified by stock damage and planted by pastoral grasses**

# EO2- Wetland naturalisation and enhancement in lower Ohote Stream reaches




**Location:** Ohote Stream downstream of Exelby Road

**Tributary ID:** OHO_TRIB1_1 to OHO_TRIB1_7

**Ownership:** Private

**Priority score:** 1

**Area:** 1.79 Ha

**Description:**

The downstream reaches of the Ohote Stream are identified as low grade, meandering channels which vary from single thread channel to anastomosing channels during periods above normal flow. In these riverine wetland-like reaches, the floodplains have secondary and tertiary channels that are highly connected. These riverine wetland-like reaches provide valuable water filtering and sediment retention services.

Opportunity to exclude stock, create set-backs of 10 metre riparian buffers and plant the gully banks with native vegetation will improve the ecological value of this watercourse type in the sub-catchment. In addition, removal and re-design of the farm culvert which is a fish barrier to upstream habitat.

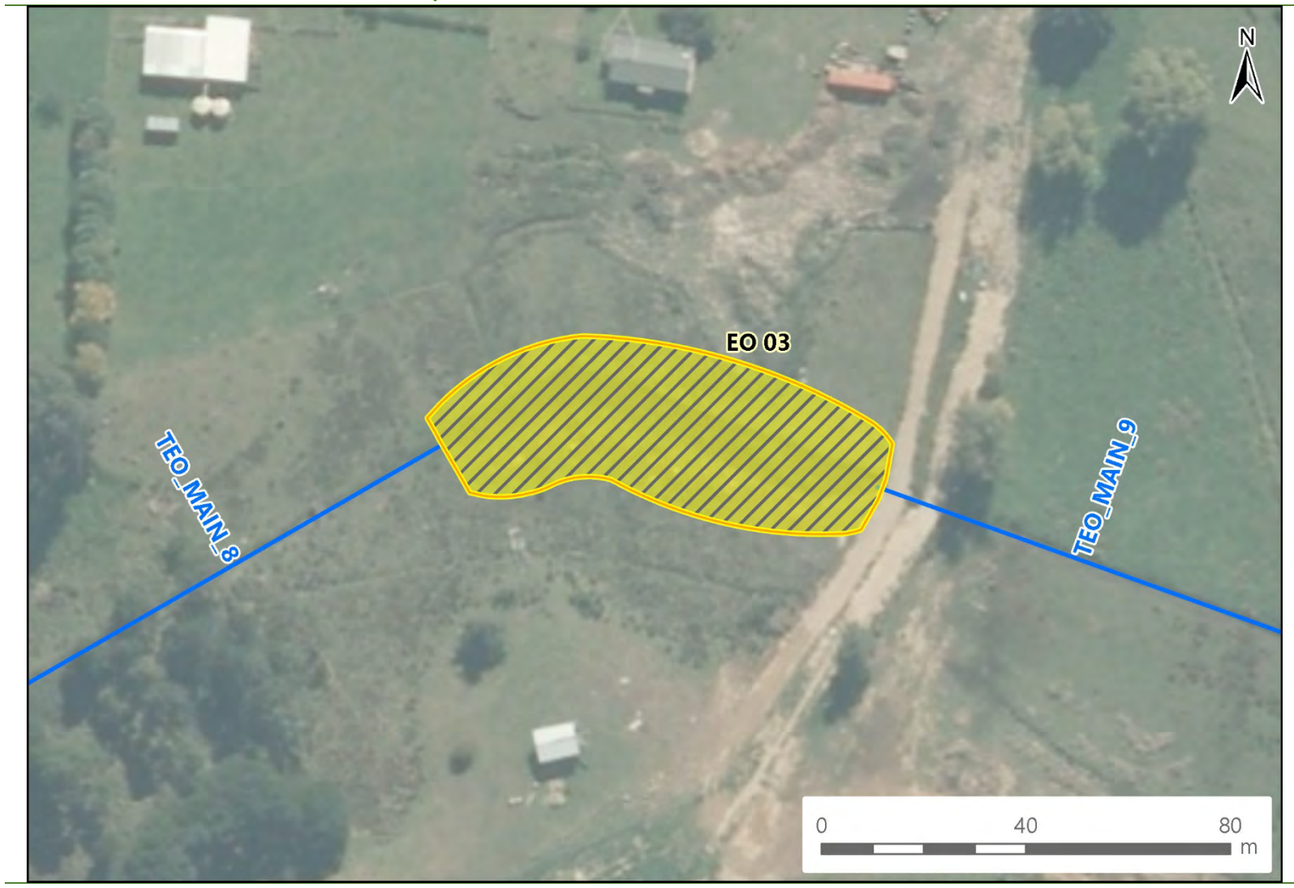
**Considerations**

- Erosion and scour protection
- Weed removal and planting appropriate, eco-sourced vegetation
- Fish passage
- Maintaining conveyance capacity
- Flooding risk to reach directly downstream of the culvert

| Enhancement Types | Stakeholders |
|---|---|
| Naturalisation | Residents |
| Fencing/Stock Exclusion | HCC |
| Conveyance Improvements | Community groups |
| Aquatic Weed Control | |

**Riverine wetland-like reaches in the downstream reaches of the Ohote Stream**

## EO3– Pond naturalisation upstream of TEO_MAIN_8




**Location:** Lower Te Otamanui Tributary

**Tributary ID**: TEO_MAIN_8

**Ownership:** Private

**Priority Score**: 2

**Area:** 0.24 Ha

**Description**

Artificial farm pond created through damming on private property. WRC Plan recognises farm damming as a permitted activity where it does not adversely impact neighbouring properties or increase erosion and flooding risk. The aesthetic farm pond has altered local hydrology and ecological processes. The reaches directly downstream of the pond are unstable, and highly prone to erosion.

Opportunity to naturalise the pond, stabilise stream banks, remove fish barriers and enhance the riparian margins with native riparian vegetation.

The pond is on private property and therefore requires co-operation with landowners for stream management and remediation works.

**Considerations**

- Maintenance required for conveyance efficiency
- Downstream effects of naturalising pond to a stream channel
- Erosion and scour protection
- Remediation of fish barrier
- Earthworks required for re-shaping of channel
- Weed and pest control

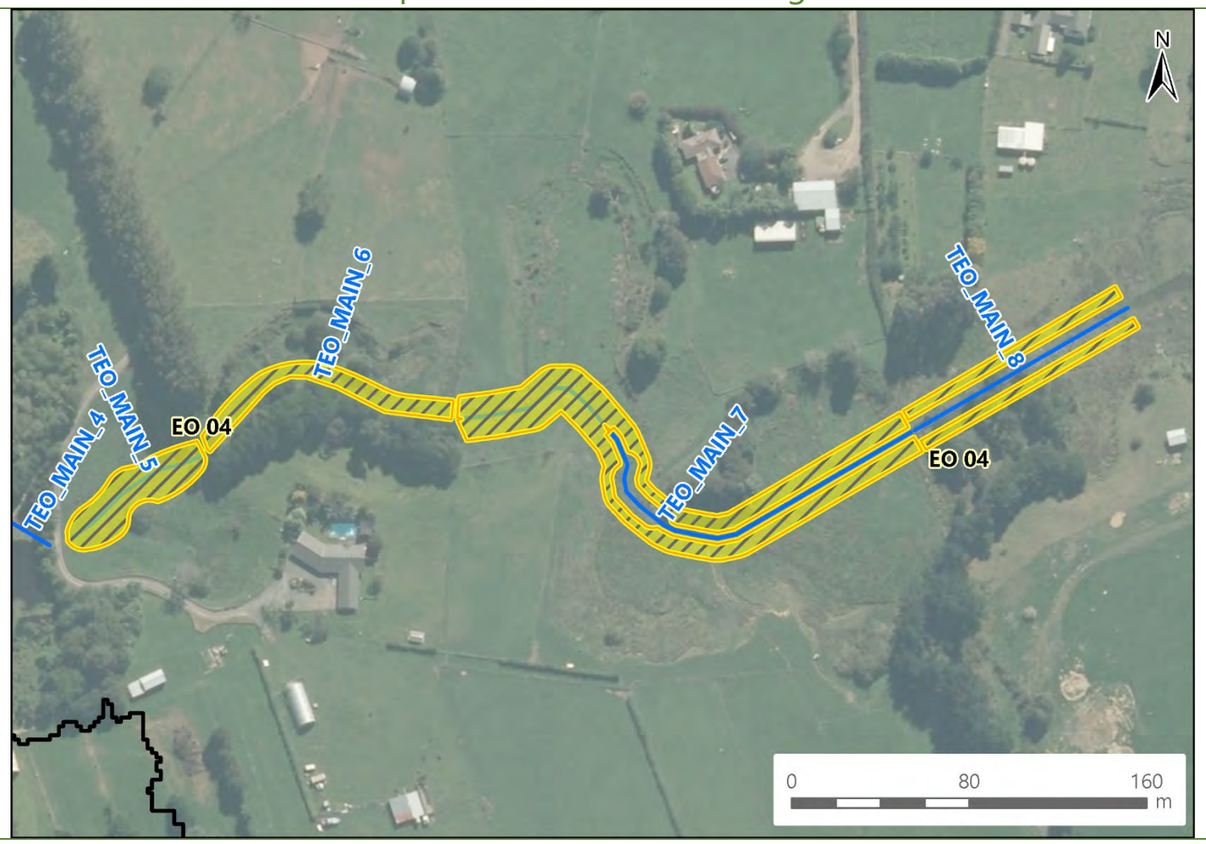
| Enhancement Types | Stakeholders |
|---|---|
| Conveyance Improvements | HCC |
| Fish Barrier | Residents |
| Erosion Protection | |
| Weed Control and Planting | |

**Artificial pond**

**Downstream reach erosion**

**Culvert requiring remediation upstream of pond**

## EO4 – Stock exclusion and riparian enhancement along the lower Te Otamanui Tributary




**Location:** Lower Te Otamanui Tributary

**Tributary ID**: TEO_MAIN_1 to TEO_MAIN_8

**Ownership:** Private

**Priority Score**: 2

**Area:** 0.74 Ha

**Description**

This enhancement opportunity augments erosion mitigation works previously outlined in this report. In addition to the minimal works required to address current erosion mitigation issues, there is an opportunity to improve the ecological outcomes by maximising riparian buffer to the recommended 20 metre width.

Opportunity to create wider set-backs with exclusion fencing and native vegetation riparian buffers. The larger-scale management approach mitigates further risk whilst enhancing the stream habitats. Privately owned land. Enhancement and stream management in these receiving environments will therefore require landowner co-operation. There are also opportunities to create community projects which encourage community engagement.

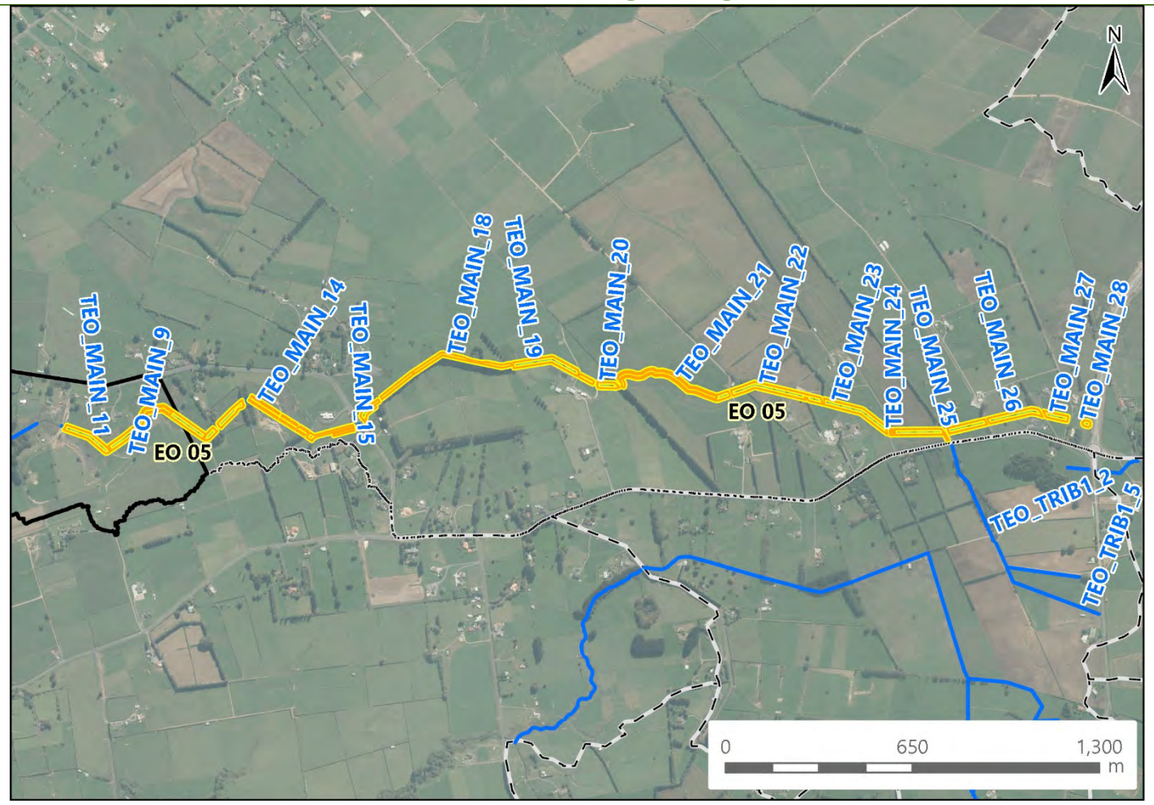
**Considerations**

- Maximising riparian buffer width to reduce extent of edge habitat
- Maintaining required conveyance capacity through floodplain appropriate species
- Linking any remnant vegetation patches to minimise impacts of fragmentation

| Enhancement Types | Stakeholders |
|---|---|
| Weed Control and Planting | HCC |
| Erosion Protection | Residents |
| Fencing/ Stock Exclusion | |

**Downstream reaches of the Te Otamanui Stream, creating dominated by low growing exotic plant species**

# EO5 – Stock exclusion and riparian planting along upper Te Otamanui Tributary




**Location:** Upper Te Otamanui Tributary

**Tributary ID**: TEO_MAIN_9 to TEO_MAIN_28

**Ownership:** Private

**Priority Score**: 3

**Area:** 5.94 Ha

**Description**

This enhancement opportunity augments erosion mitigation works previously outlined in this report. The Te Otamanui Tributary consists of heavily modified reaches with stock damage on stream banks, poor water quality and little to no riparian cover. As an alternative to *ad-hoc* localised erosion mitigation works exclusively in highly prone reaches, there is an opportunity to create set-backs with exclusion fencing and 20 metre riparian buffers along the Te Otamanui Tributary. The larger-scale management approach mitigates further risk whilst enhancing the stream habitats.

Privately owned land. Enhancement and stream management in these receiving environments will therefore require landowner co-operation. There are also opportunities to create community projects which encourage community engagement.

**Considerations**

- Maximising riparian buffer width to reduce extent of edge habitat
- Maintaining required conveyance capacity through floodplain appropriate species
- Maintenance of channel to mitigate flood risks
- Linking any remnant vegetation patches to minimise impacts of fragmentation
- Long term maintenance requirements

| Enhancement Types | Stakeholders |
|---|---|
| Weed Control and Planting | HCC |
| Erosion Protection | Residents |
| Fencing/ Stock Exclusion | |

**Upper Te Otamanui Tributary reaches with no riparian cover, stock access and high erosion susceptibility**

**Table 32: Summary of Enhancement Opportunity Costs**

| Enhancement Opportunity | Enhancement Planting Cost | Exclusion Fencing | Pond Naturalisation | Land Purchase | Total |
|---|---|---|---|---|---|
| **EO1** | $46,191 | $5,190.48 | - | $7,922 | $59,304.04 |
| **EO 2** | $129,618 | $4,803.73 | - | $22,229 | $156,651.98 |
| **EO 3** | - | $3,591.12 | $126,940 | $2,971 | $133,502.50 |
| **EO 4** | $53,654 | $8,460.40 | - | $9,201 | $71,316.26 |
| **EO 5** | $430,603 | $72,762.70 | - | $73,850 | $577,216.52 |
| **Total overall costs for enhancement opportunity works with 20% contingency** | | | | | **$1,210,372** |

** Unit rates used to calculate costs are in Appendix 9*

# 6.0 Conclusions

In summary, the observations made during the field assessment indicate that the receiving watercourses downstream of the Rotokauri North Development Area are dominated by agricultural pastoral land uses, with small areas of rural residential land use. As a result, these predominately agricultural streams display a varying level of channel stability with stock access and stock damage of both the upper and lower banks evident across the survey extent.

The lack of established native woody riparian vegetation and high incidence of channel modifications have resulted in a system that often displayed unnatural channel geometry, a lack of geomorphic features and vegetation to support a healthy freshwater ecosystem. Of the 61 reaches identified, one was classified as moderately unstable and nine as unstable.

The proposed management approach presented in this report aims to anticipate and plan for the increase in conveyance demands on stream systems. The management approach identifies key issues, objectives to address these issues, and recommends options and actions to mitigate their actual and potential adverse effects.

The broad management objectives outlined in this report align with the outcomes sought by the Stormwater Master Plan (HCC, 2016), Rotokauri ICMP (2017), the NPS-FM (2016) and the Proposed Waikato Regional Plan Change (2018). The erosion mitigation projects highlight areas of concern and provide remediation options to address localised issues. The enhancement opportunities aim to address broader issues within the survey extent to enhance the ecological, conveyance and amenity values.

The fourteen erosion mitigation projects have been developed at a high level consists of four types; grade control, bank batter, erosion planting and toe protection. These engineered approaches aim to remediate existing erosion issues and mitigate further risk within the receiving watercourses.

The total estimated cost including contingency of the physical works for the proposed erosion mitigation projects is approximately $2.5 Million. Unit costs rates are applied to represent high-level estimates of physical works only.

Six enhancement opportunity projects have been proposed within the Rotokauri North sub-catchment and the receiving watercourses. These projects highlight enhancement opportunities for the developer, private land owners and Hamilton City Council to increase the amenity and ecological value of the watercourses, whilst improving flow conveyance and improving resistance to further changes to surrounding land use. The total estimated cost of the enhancement projects is approximately $1.2 Million.

Erosion remediation within the RNDA has not been included as part of this assessment, as it is anticipated that the developer will address any existing issues as part of the planned development. Enhancement opportunities have been identified within the development area and it is recommend that, where possible, the developer reduces diversion or piping of existing watercourses and instead, incorporates enhancement of existing features into any urban landscape design plans.

It is anticipated that the baseline data, summary of findings and recommendations proposed in this report will go towards supporting decision making in the development process.

# 7.0 References

Gardiner, D. 2017. Applying an ecosystem services approach to policy development. Waikato Regional Council. Hamilton

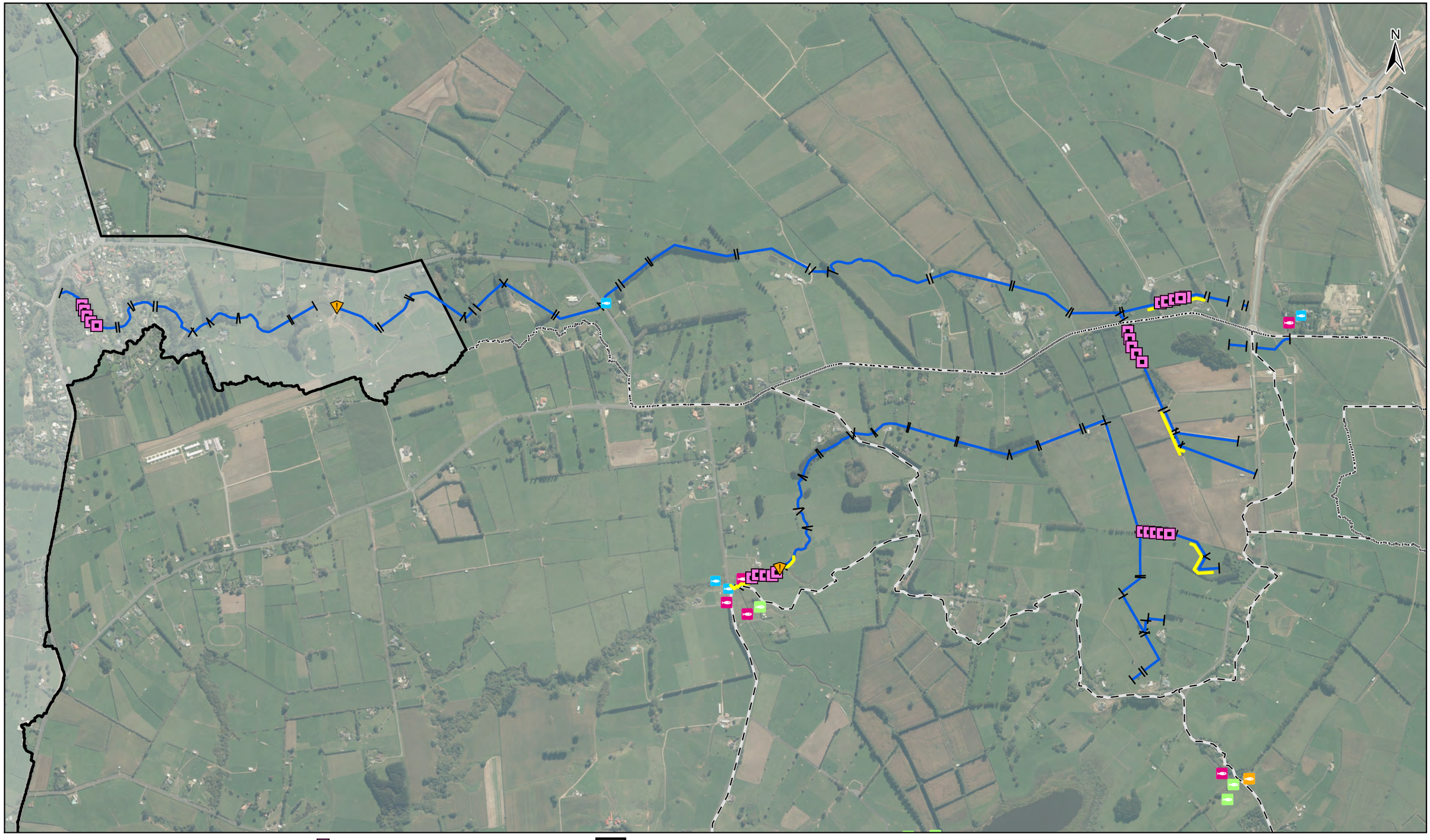
Ling, N. 2001. New Zealand mudfishes: a guide. Department of Conservation, Wellington

Stark, J. D., & Maxted, J. R. 2007. A user guide for the Macroinvertebrate Community Index. *Prepared for the Ministry for the Environment*, 58.

Stark, JD, Boothroyd, IKG, Harding, JS, Maxted, JR, Scarsbrook, MR. 2001. Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Macroinvertebrate Working Group Report No. 1. Prepared for the Ministry for the Environment. Sustainable Management Fund Project No. 5103. 57p.

# Appendix 1 Fish Survey and Fish Barriers

# ROTOKAURI NORTH - FISH SURVEY & FISH BARRIER




**NZFFDB**

- Anguilliform
- Climber
- Swimmer
- Exotic

**Eng. Barrier to:**

- Climbers

- Water and Sediment Sample Points
- Black Mudfish Survey Locations
- Ecoline

- ICMP Catchment Boundary
- ICMP Subcatchments

Client HAMILTON CITY COUNCIL

Project **ROTOKAURI NORTH REA**

0 500 1,000 m

Project no. P01733

Date 14 Nov 2018

Drawn SM

Approved CC



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# Appendix 2 Stream Watercourse Classification

# ROTOKAURI NORTH - STREAM WATERCOURSE CLASSIFICATION

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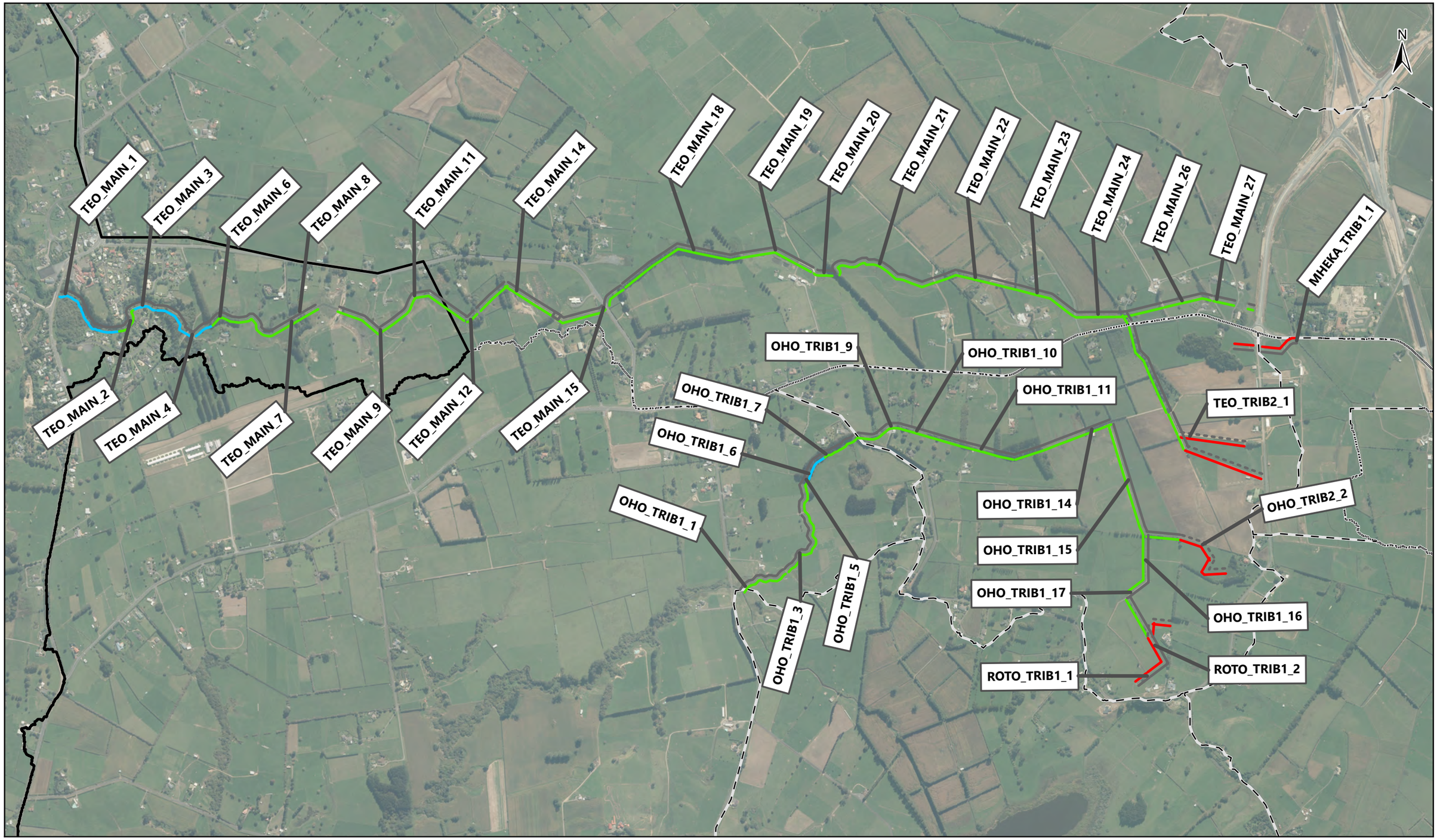


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**WRC Classification**

- Farm drainage canal
- Modified watercourse
- River

**WRC Type**

- Ephemeral
- Perennial

- ICMP Catchment Boundary
- ICMP Subcatchments

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Project **ROTOKAURI NORTH REA**

0 500 1,000 m

Project no. P01733

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# Appendix 3 Stream Overhead Cover

# ROTOKAURI NORTH - STREAM OVERHEAD COVER

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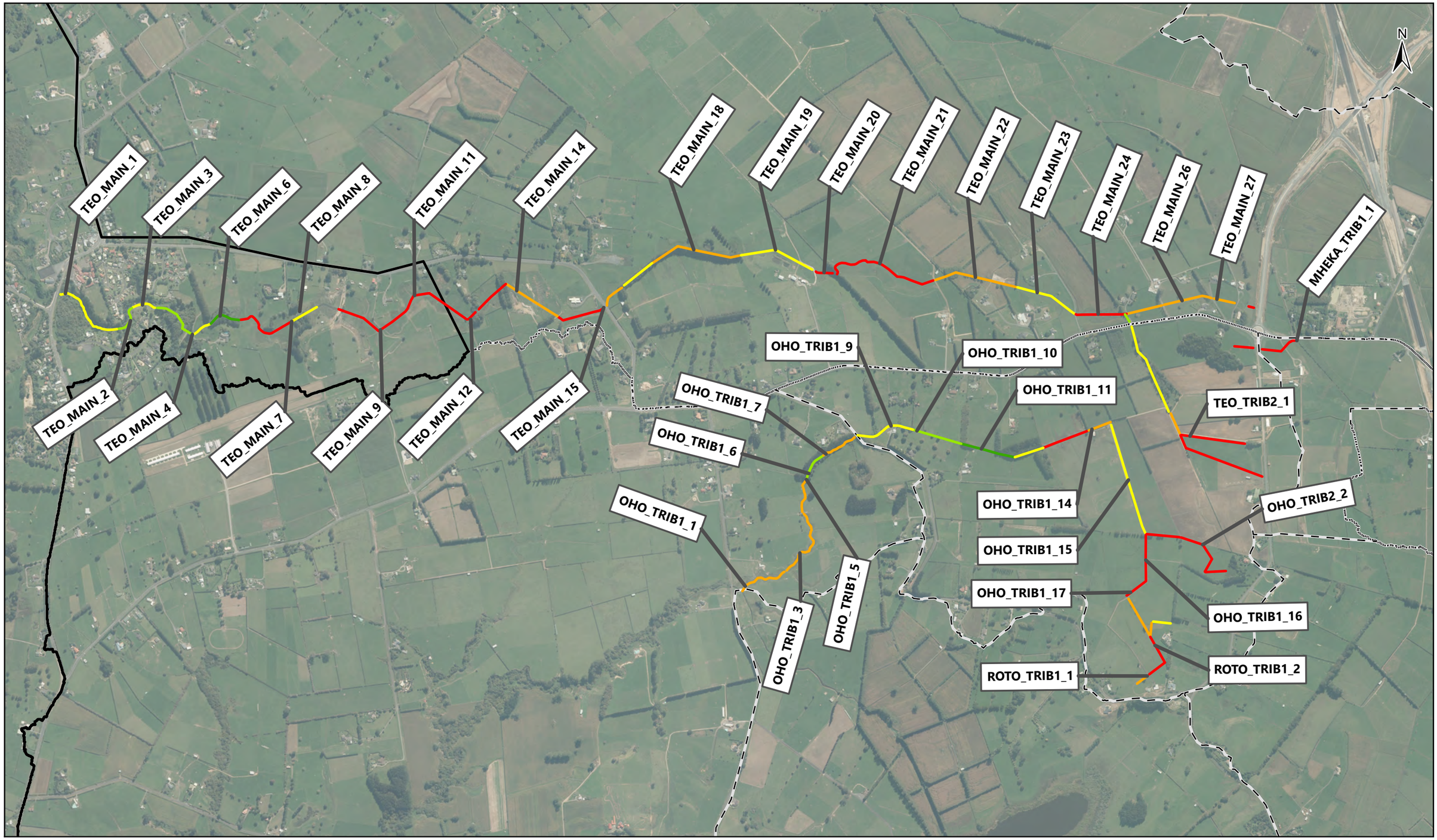


**Overhead Cover %**

- <10%
- 10-30%
- 30-50%
- 50-70%
- 70-90%
- >90%

- ICMP Catchment Boundary
- ICMP Subcatchments

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Project **ROTOKAURI NORTH REA**

0 500 1,000 m

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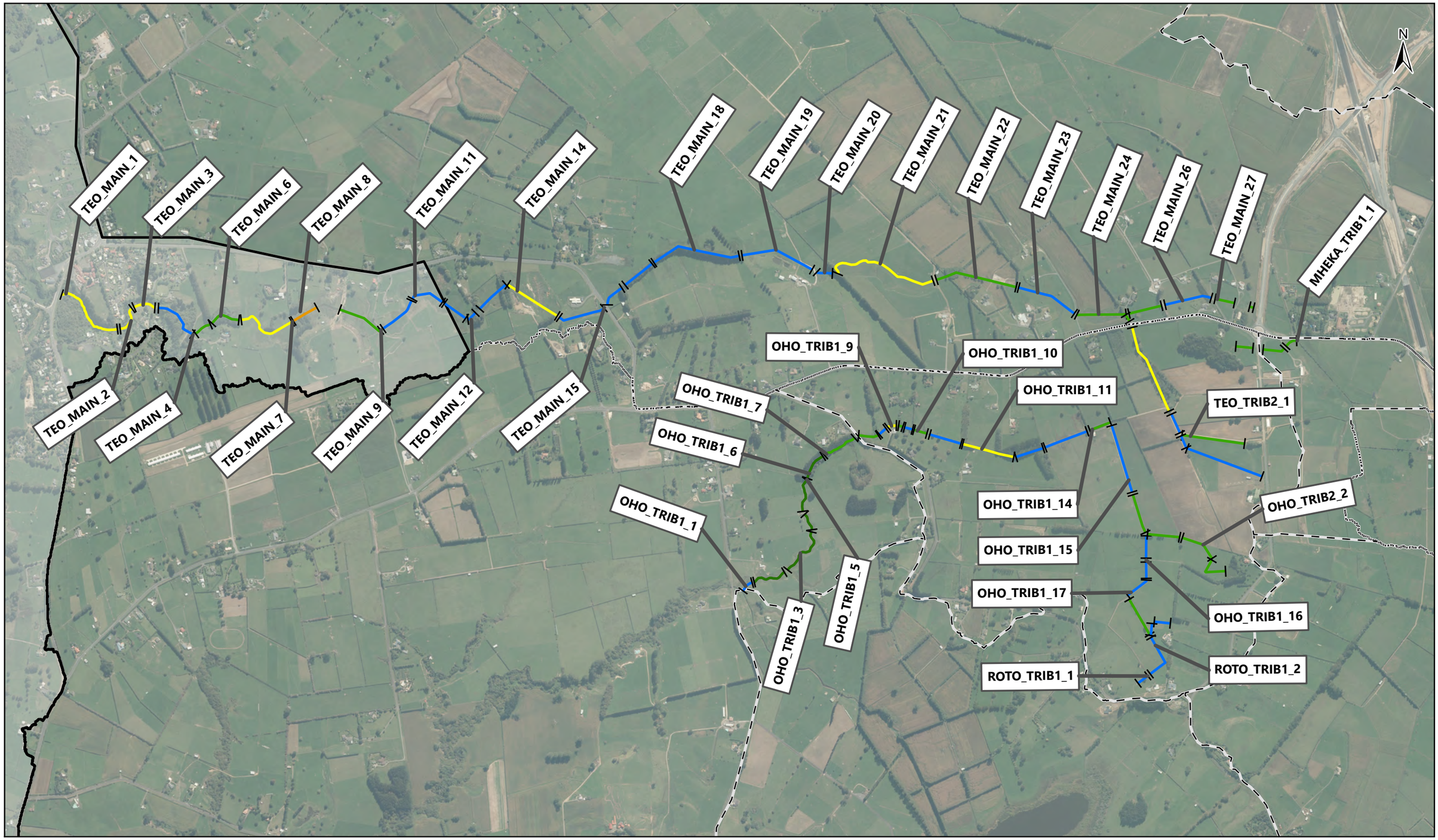
# Appendix 4 Stream Erosion Susceptibility

# ROTOKAURI NORTH - STREAM EROSION SUSCEPTIBILITY

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**Erosion Susceptibility**

- Highly Stable
- Moderately Stable
- Stable
- Unstable
- Moderately Unstable

- ICMP Catchment Boundary
- ICMP Subcatchments

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Project **ROTOKAURI NORTH REA**

0 500 1,000 m

Project no. P01733

Date 14 Nov 2018

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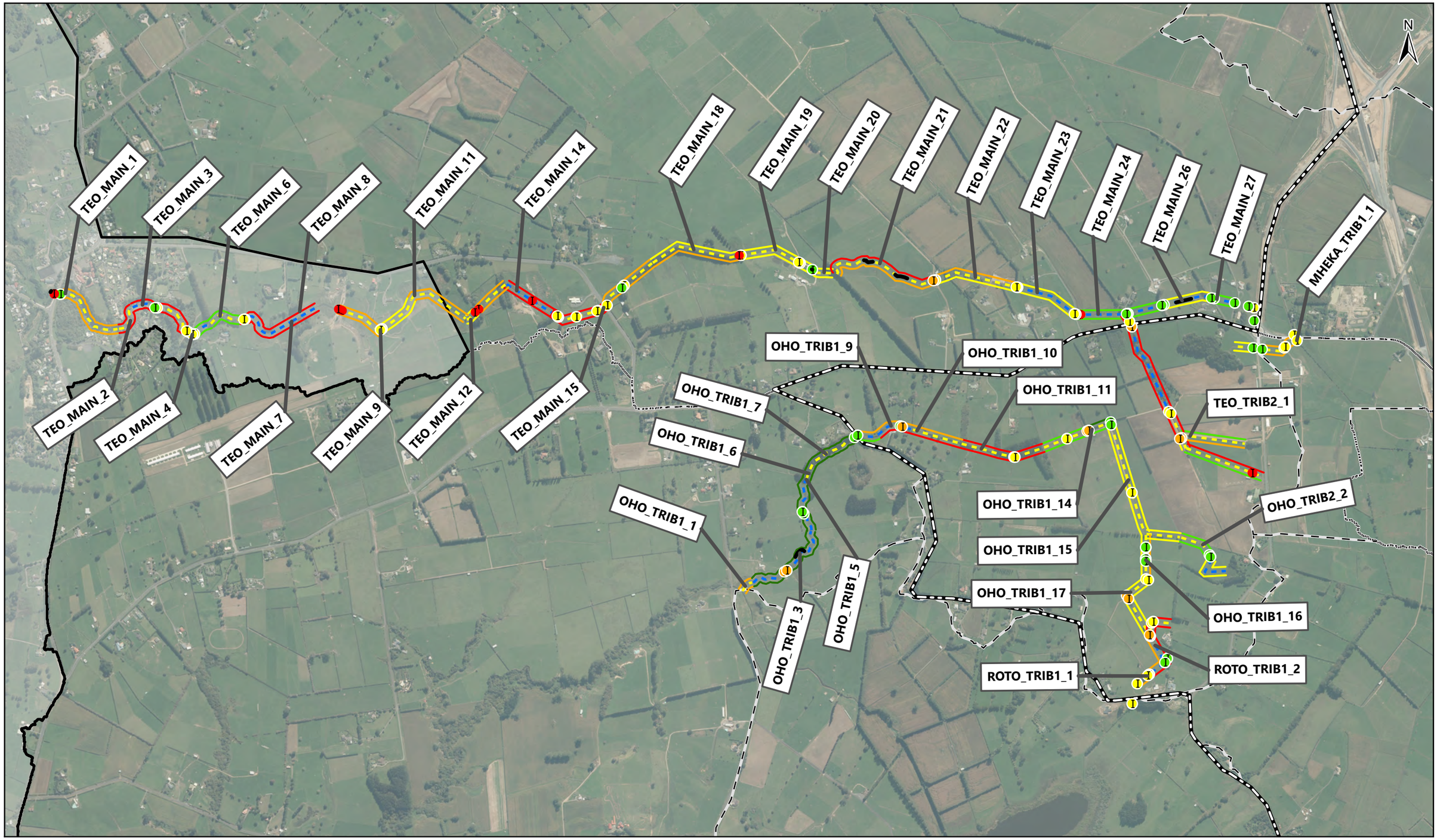
# Appendix 5 Stream Erosion & Upper Bank Stability

# ROTOKAURI NORTH - STREAM EROSION & UPPER BANK STABILITY

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**Current Erosion Bank %**

- None
- <20%
- 20-40%
- 40-60%
- >60%

**Upper Bank Stability Score**

- Excellent
- Good
- Fair
- Poor

**Erosion Hotspot**

Overall Risk Value

- Medium

**Infrastructure Erosion**

- None
- Slight
- Moderate
- Severe

- ICMP Catchment Boundary
- ICMP Subcatchments

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Project **ROTOKAURI NORTH REA**

0 500 1,000 m

Project no. P01733

Date 14 Nov 2018

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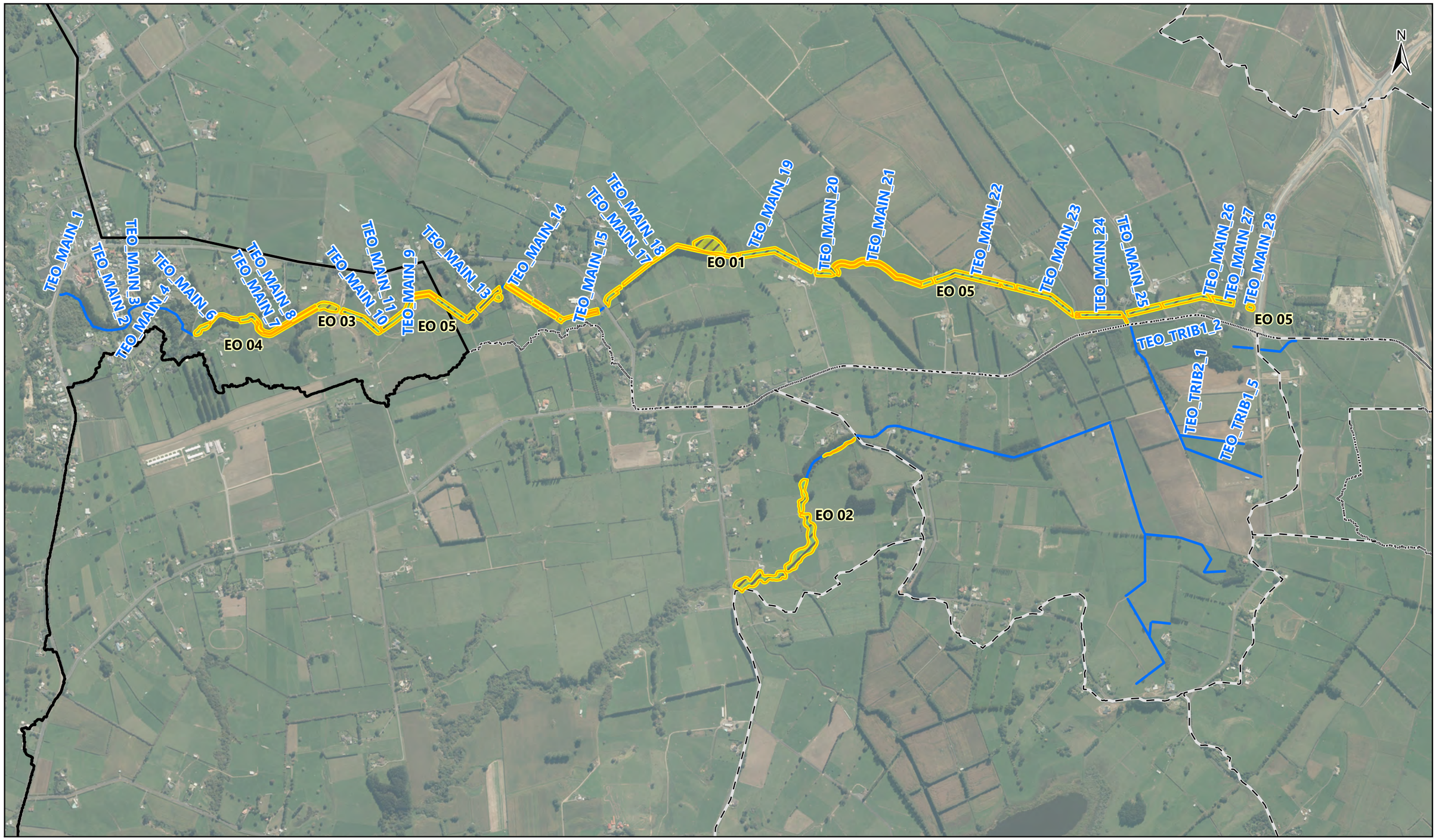
# Appendix 6 Stream Enhancement

# ROTOKAURI NORTH - STREAM ENCHANCEMENT

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Enhancement Opportunities

Ecoline

ICMP Catchment Boundary

ICMP Subcatchments

Client HAMILTON CITY COUNCIL

Project **ROTOKAURI NORTH REA**

0 500 1,000 m

Project no. P01733

Date 12 Sep 2018

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# Appendix 7 Erosion Remediation Projects

# ROTOKAURI NORTH - EROSION REMEDIATION PROJECTS: OVERVIEW

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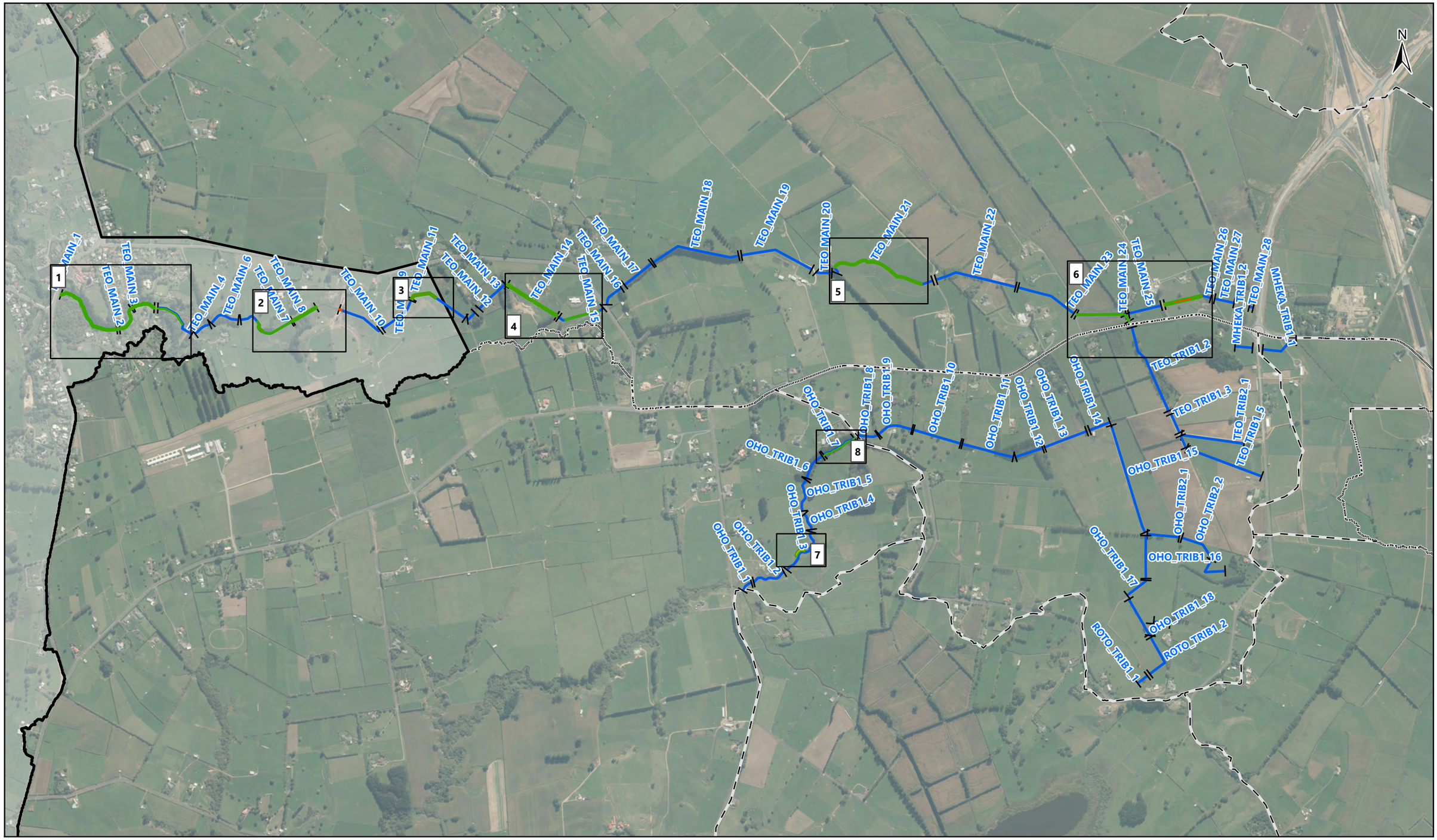


**Erosion Mitigation Works**

- Toe Protection
- Bank Batter
- Erosion Planting
- Grade Control

- Ecoline
- ICMP Catchment Boundary
- ICMP Subcatchments

Client HAMILTON CITY COUNCIL

Project **ROTOKAURI NORTH REA**

0 500 1,000 m

Project no. P01733

Date 12 Sep 2018

Drawn SM

Approved CC



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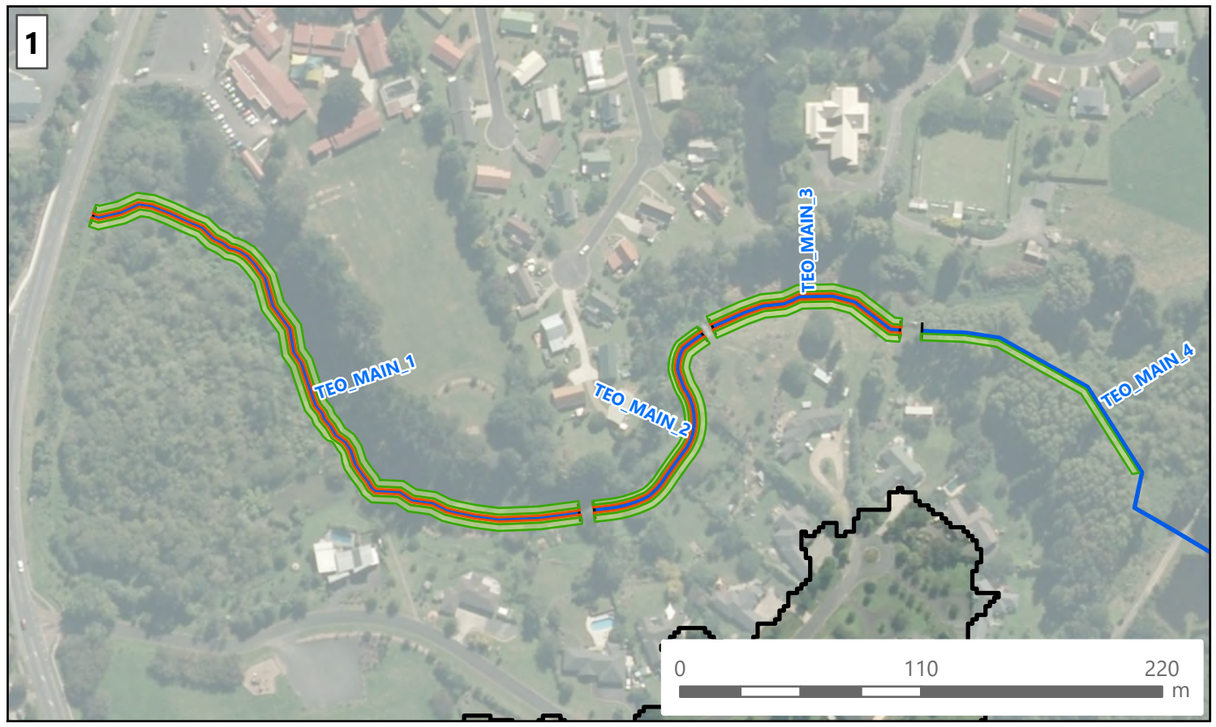



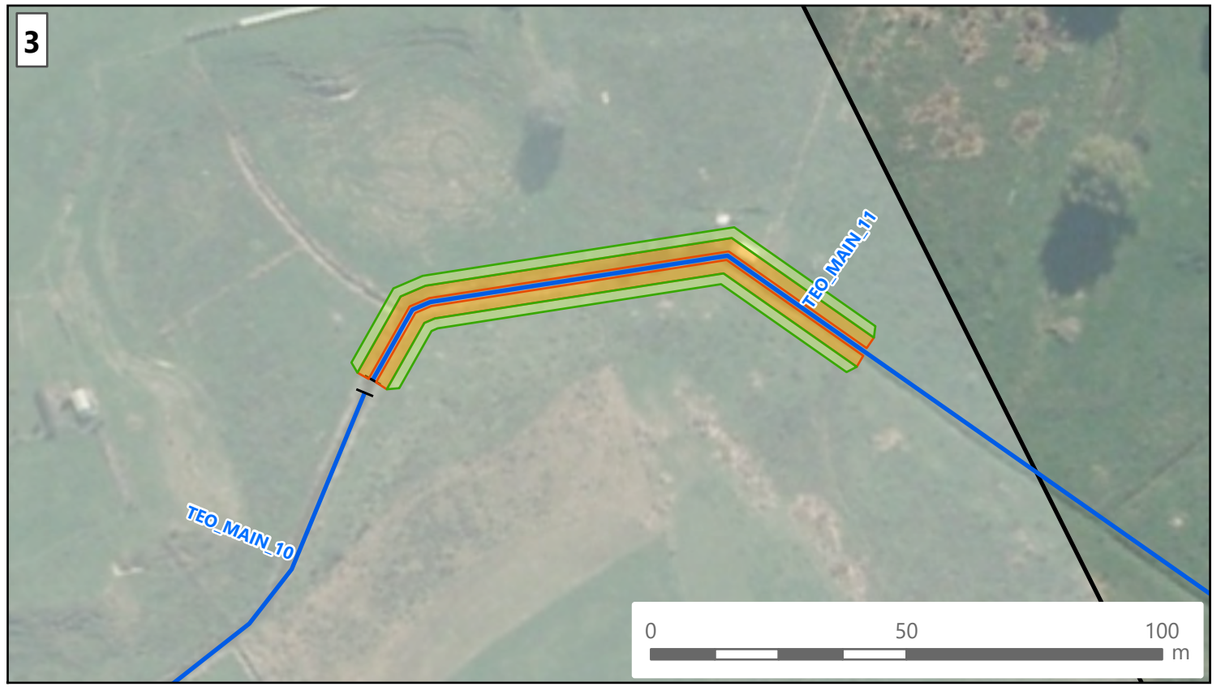


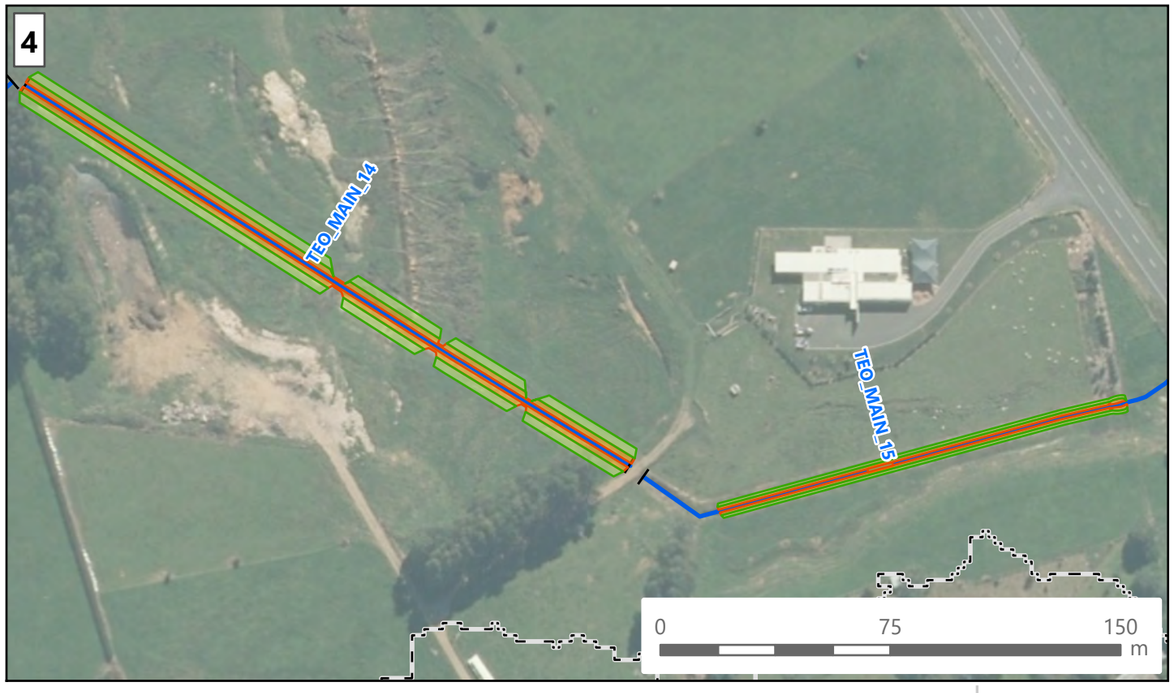


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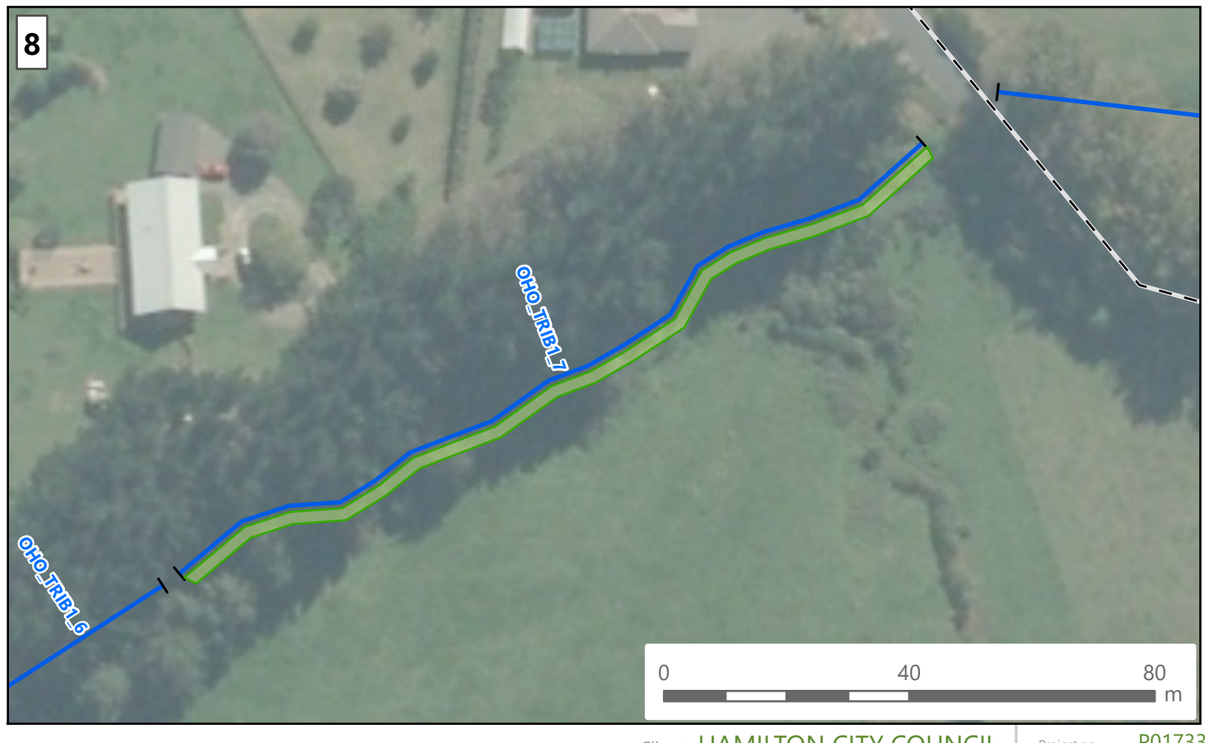


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# Appendix 8 Management Zones

# ROTOKAURI NORTH - MANAGAMENT ZONES

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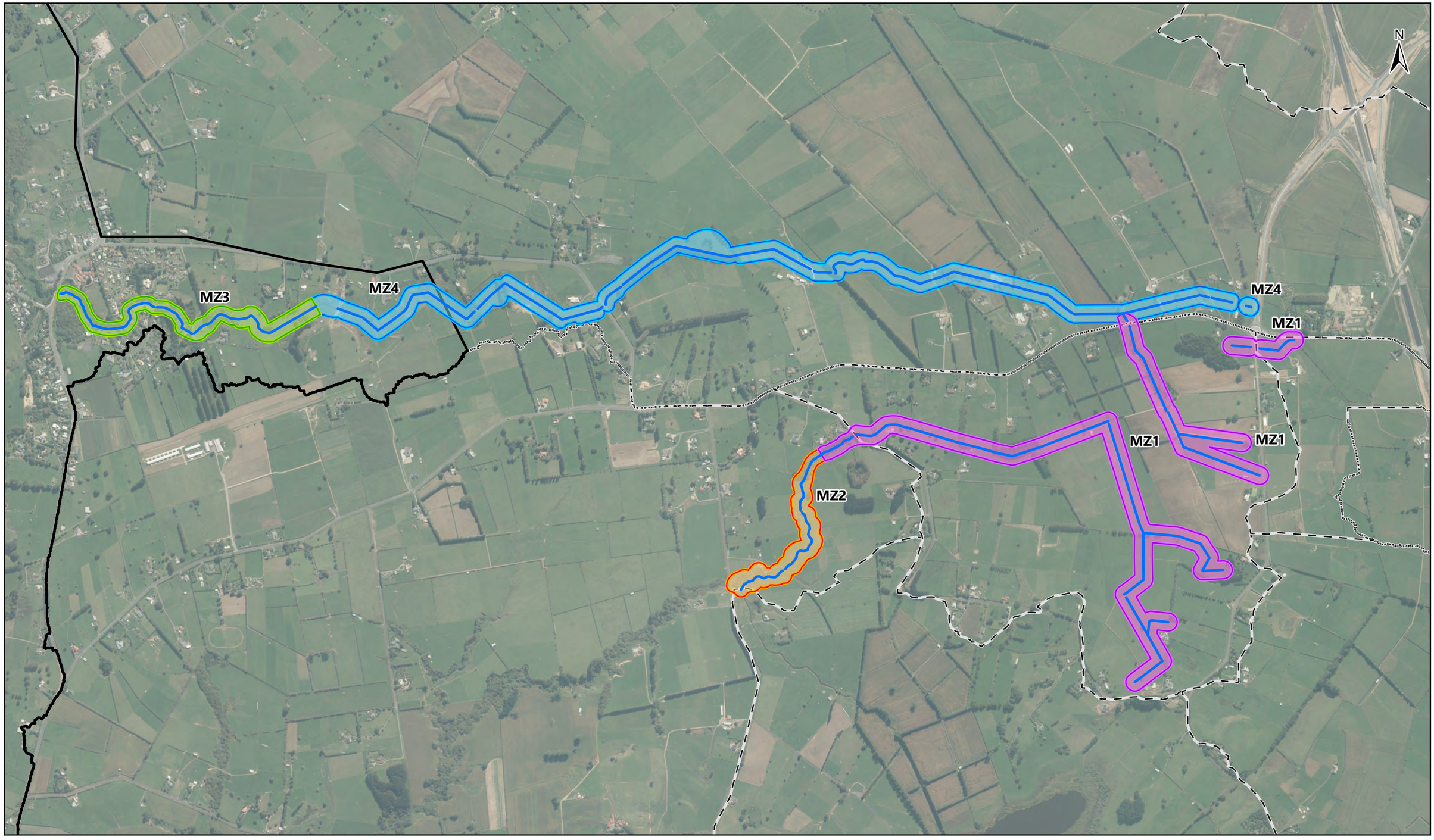


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Management Zones
- MZ1
- MZ2
- MZ3
- MZ4

- Ecoline
- ICMP Catchment Boundary
- ICMP Subcatchments

Client HAMILTON CITY COUNCIL

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# Appendix 9 Cost & Unit Rates for Mitigation Options

| Mitigation | Unit | Cost | Assumptions and exclusions |
|---|---|---|---|
| **Planting of Banks and Floodplains** | $m^2$ | $35 | Includes boom spray of glyphosate single application;<br>Planting at up to 4 plants per m2. *Carex, Juncus*, toetoe, flax and cabbage tree;<br>Plant grade PB3s;<br>Assumes team of 6 planting 350 plants each per day;<br>Cost includes vegetation removal, planting, weeding and maintenance for 5 years. |
| **Newbury Rock Riffles as Grade Control** | $m^2$ | $950 | Import and place rock riffles. Weirs to be 400-500 mm boulders, riffles to be $D_{50}$=300 mm well graded angular rip rap in combination with 5-50mm railway ballast, approximately 20$m^3$ of rip rap per riffle. 50mm bedding layer of GAP30 installed over existing ground surface.<br>Crushed aggregate $D_{50}$=50 mm to be installed to fill gaps around rip rap. |
| **Bank batter** | $m^3$ | $70 | $50/m^3$ for excavation;<br>$20/m^3$ for haulage away from site and disposal to clean fill;<br>Does not include setting up diversions/erosion and sediment control;<br>Assumes 45° banks from toe of existing bank, does not include the excavation required to install the rip rap. The rip rap volume may need to be excavated also for installation of the rip rap. This could be avoided by placing the rip rap directly on the cut bank.<br><br>Rip rap may not be required at all sites of bank batter but has been used here to allow for the cost of stabilisation. Determination of the best stabilisation material will be decided during concept design or detailed design. |
| **Keystone Boulders** | $m^3$ | $1,500 | 600 mm boulders placed within a 400 mm deep trench |
| **Fencing** | m | $7.50 | 7 wire fencing with 5 m posting. |
| **Grazing Land Purchase** | $m^2$ | $1.24 | Based on 10% of average land sale cost in Waikato Region as reported by REINZ 2018; 10% assumes land lease rather than sale; http://www.interest.co.nz/rural/resources/farm-sales. |
| **Pond Restoration** | - | $126,940 | Planting cost: $ 50, 000.00<br>Outlet Installation includes outfall wingwall and rip rap $ 2,500.00<br>Scruffy Dome with man hole. Scruffy dome is ~ 10m of pipe<br>$ 20,000.00<br>Embankment stabilising, assumes 0.5m3/1m2 at $40/ $m^3$.<br>Total: $ 14,620.00<br>Scour protection includes rip rap at inlet: $ 2,500.00<br>Sediment removal includes $ 5,000 to drain and prepare for removal.<br>Removal of 0.5m depth at $40/$m^3$. Total: $ 37,320.00 |