



**Kaimai Hydro-Electric Power
Scheme Sediment Monitoring
Plan**

Prepared for
Manawa Energy Ltd

Prepared by
Tonkin & Taylor Ltd

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1 Introduction

As part of the consenting of the Kaimai Hydro-Electric Power Scheme (Kaimai HEPS), Manawa Energy Limited (Manawa Energy) has assessed current sediment and erosion processes in the Wairoa River catchment¹.

Most reaches of the rivers below the Kaimai HEPS structures are bedrock dominated which do not require mobile sediment to maintain form and function, and are highly resistant to erosion. However, there are two exceptions, the Wairoa River below the Ruahihi Power Station (WAI-3), and the most downstream extent of the Omanawa River (OMW-4). Both of these reaches are alluvial rivers, which require mobile sediment to maintain their form and function, and are potentially susceptible to bed and bank erosion arising from changes in sediment loads and / discharge associated with the ongoing operation of the Kaimai HEPS.

However, there is very limited historical geomorphic data in these rivers. The Sediment and Erosion Effects Assessment¹ recommended 'sediment monitoring' to confirm that the on-going operation of the Kaimai HEPS is not causing or contributing to channel instability or geomorphic changes in the alluvial reaches of the Wairoa and Omanawa Rivers. As alluvial rivers typically respond slowly in response to natural variability and fluctuations in sediment and discharge regimes, as well as to human induced changes, geomorphic monitoring / data needs to span reasonably long time periods (decades) and be collected at intervals which are appropriate to each rivers specific character and behaviour.

This Sediment Monitoring Plan (SMP) summarises what is currently known of the potential and / or actual effects of the continued operation of the Kaimai HEPS on the lower Omanawa River (OMW-4) and Wairoa River (WAI-3) based on the Sediment and Erosion Effects Assessment¹. The objectives of the monitoring are to assess trends in channel form within WAI-3 and OMW-4, and to improve understanding of how reduced sediment supply, resulting from aspects of the Scheme, may influence future geomorphic responses.

As such, the SMP outlines the monitoring requirements to track potential geomorphic changes in the lower Omanawa River (OMW-4) and Wairoa River (WAI-3) compared to the non-scheme impacted adjacent Kopurererua River, to assist in identifying potential effects arising from the ongoing operation of the Kaimai HEPS.

1.1 Proposed consent conditions

Condition 12 in the draft Kaimai HEPS Consent Conditions from January 2026, specifically relates to the sediment and erosion process as follows.

12.1 Within six months of the grant of this resource consent, the consent holder must submit a Sediment Monitoring Plan prepared by a suitable qualified and experienced geomorphologist to the Bay of Plenty Regional Council for certification. The objective of the plan shall be to:

(a) Monitor any long-term changes in sediment continuity in the Wairoa River Catchment that may be a result of the continued operation of the Kaimai Hydro Electric Power Scheme.

12.2 In order to achieve the objective established in Condition 12.1 above, the Sediment Monitoring Plan must, as a minimum, address the following matters:

¹ Tonkin + Taylor. (2025). Kaimai HEPS Consent Renewal – Sediment and Erosion Effects Assessment. Report prepared for Manawa Energy Ltd.

- (a) *A summary of the baseline geomorphic conditions in the Wairoa River (WAI-3) and Omanawa River (OMW-4);*
- (b) *The monitoring methodology for:*
- i. *Baseline bathymetric and topographical surveys of the Wairoa River (WAI-3) and Omanawa River (OMW-4);*
 - ii. *Five-yearly bathymetric and topographical surveys of the Wairoa River (WAI-3) and Omanawa River (OMW-4);*
 - iii. *The detection of geomorphic change on the beds and the banks of the Wairoa River (WAI-3) and Omanawa River (OMW-4); and*
 - iv. *Targeted site assessments for any ‘hot spots’ of geomorphic change of the Wairoa River (WAI-3) and Omanawa River (OMW-4).*
- (c) *Reporting requirements to the Bay of Plenty Regional Council, which must:*
- i. *Presents, summarises and analyses the monitoring results from each survey;*
 - ii. *Assesses any geomorphic changes in the Wairoa River due to the ongoing operation of the Kaimai HEPS, major flood events, or longer-term trends as survey data becomes available over five-yearly intervals; and*
 - iii. *Provides recommendations regarding the methodology for the ongoing monitoring surveys (including the frequency of surveys over the life of this consent), and recommendation to manage sediment or erosion effects caused by the continued operation of the Kaimai Hydro-Electric Power Scheme.*

12.3 The Bay of Plenty Regional Council shall review the monitoring reports and determine whether any changes to the monitoring methodology and frequency of monitoring is required.

The Bay of Plenty Regional Council shall also determine whether there is a need to serve notice on the consent holder of its intention to review the conditions of this resource consent in accordance with Sections 128 to 131 of the Resource Management Act 1991 in order to implement changes to the management of sediment or erosion effects caused by the continued operation of the Kaimai Hydro-Electric Power Scheme.

1.2 Scheme description

The Kaimai HEPS was initially commissioned in 1915 with the Omanawa Falls Power Station (now separately owned), with subsequent power stations commissioned in 1925 (McLaren Falls, now decommissioned), 1972 (Lloyd Mandeno), 1979 (Lower Mangapapa), 1981 (Ruahihi) and 1994 (Kaimai 5).

The scheme operates as a cascading scheme of four power stations in sequence on 12 tributaries of the Wairoa River (see Figure 1.1). Thus, through a series of diversions (tunnels and canals) the scheme progressively combines water from across a large catchment, into a series of storage lakes that feed the successive power stations. The Kaimai HEPS is operated as an integrated power generation facility, where downstream stations rely on the discharges from those upstream, and directly supplies the electricity network that supports Tauranga and the Western Bay of Plenty.

All flow that is diverted throughout the scheme for the purposes of hydroelectric power generation is retained within the larger Wairoa catchment and is ultimately discharged back into the Wairoa River at the Ruahihi Power Station. Spill flows still occur with varying frequency across the Scheme and contribute flow to the various catchments within the wider Wairoa catchment.

This interconnectedness, and series of sediment sinks (storage lakes), has implications for sediment movement through the Kaimai Scheme.

There is no existing operational infrastructure associated with the three hydro-lakes, and associated dams, that could be used for sediment flushing through these sediment sinks. That said, there is also a lack of quantitative evidence of the ongoing effect of the Kaimai HEPS on sediment continuity to the alluvial sections of the Wairoa and Omanawa Rivers (WAI-3 and OMW-4). Therefore, monitoring of the potential effects of the Kaimai HEPS on the Wairoa and Omanawa Rivers is proposed and is outlined in this SMP.

A number of existing technical reports (relevant to this SMP) have been prepared as part of the Fast Track Approval Act (2024) (FTAA) application (Table 1.1). This SMP only provides a high-level summary of existing conditions.

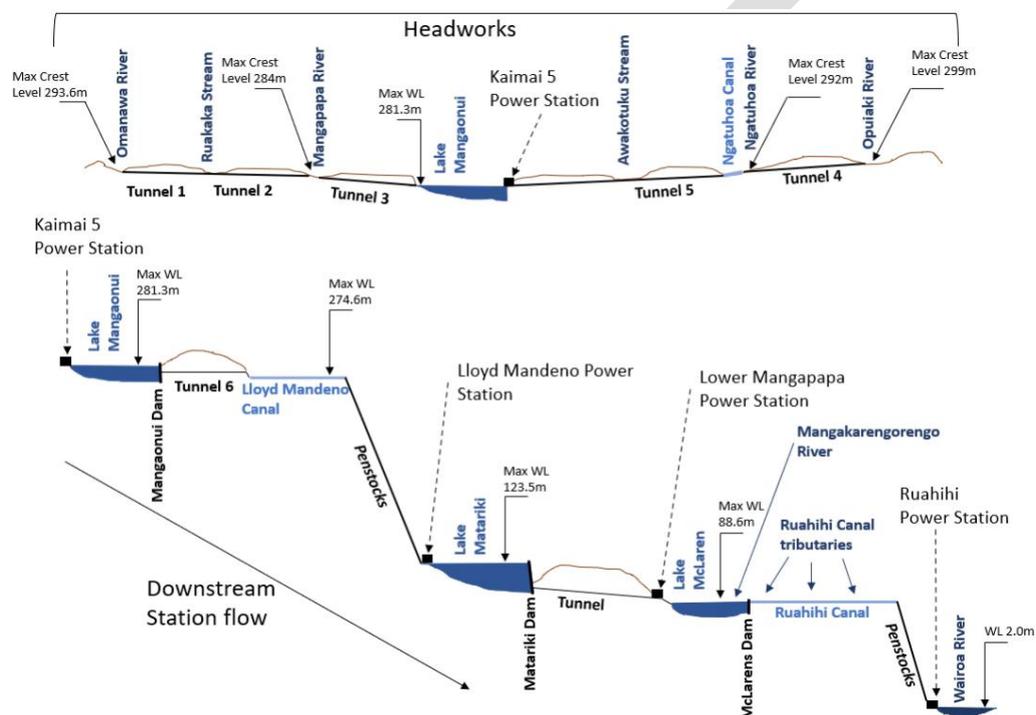


Figure 1.1: Schematic diagram showing the longitudinal configuration of the Kaimai HEPS

Table 1.1: Additional reports which provide detailed assessments and further information about various aspects of the Scheme and the environment

Author	Report Title	Description of relevance to SMP
Tonkin + Taylor Ltd (2025)	Kaimai HEPS Consent Renewal – Sediment and Erosion Effects Assessment. Prepared for Manawa Energy Ltd	<ul style="list-style-type: none"> • Provides a detailed assessment of actual and potential sediment effects (such as erosion and deposition) associated with the historic and contemporary operation of the Kaimai HEPS. • Outlines the reasoning for the SMP to be developed.
Tonkin + Taylor Ltd (2025)	Reconsenting of Kaimai Hydroelectric Power Scheme – Hydrology Report. Prepared for Manawa Energy Ltd.	<ul style="list-style-type: none"> • Provides a detailed assessment of the current hydrology of the Kaimai HEPS, including hydrological alterations caused by the Kaimai HEPS.
Greg Ryder Consulting Ltd (2025)	Kaimai Hydroelectric Power Scheme – Aquatic and Water Quality Assessment. Prepared for Manawa Energy Ltd.	<ul style="list-style-type: none"> • Provides a detailed assessment of the actual and potential aquatic ecology and water quality effects associated with the ongoing operation of the Kaimai HEPS.

2 Geomorphic Condition Summary

The Kaimai HEPS is located within the Wairoa River catchment (457 km²) in the Kaimai Ranges, drawing on a catchment area of approximately 340 km², and incorporates 12 tributaries (Figure 3.1). Sediment supply and transfer within the wider Wairoa catchment are strongly influenced by volcanic geology and associated soils. The southern extent of the catchment, where the Scheme lies, is dominated by strongly welded ignimbrite, forming flat bedrock sheets, often with narrow bedrock gorges / chutes and large waterfalls. The ignimbrite also contributes variable quantities of porous sands and lightweight gravels, particularly in areas where it is poorly welded and / or where the landcover is predominantly grassland, or recently harvested forest areas. Only two of the 12 tributaries show some form of active bed load (Opuiaki River and Tauwharawhara Stream).

Therefore, most river reaches downstream of HEPS structures are bedrock-dominated, are erosion resistant, and do not rely on mobile sediment to maintain form and function.

Two notable exceptions are the most downstream extents of the Wairoa River (WAI-3; below the Ruahihi Power Station to SH2) and the Omanawa River (OMW-4; most downstream 5 km of river to the Wairoa River confluence). Both are fine-grained alluvial rivers flowing through partly/unconfined floodplains.

Meandering rivers evolve continuously over long-time periods through bank erosion and bar deposition and are maintained in a quasi-equilibrium through a balance of driving forces (sediment supply and discharge) and resisting forces (bank / bed material strength and riparian vegetation) (Figure 2.1). When the balance between the driving and resisting forces is tipped, alluvial rivers will either erode or aggrade in response.

Threshold exceedance can be permanent, or temporary. For example, a single large landslide can produce a short-lived pulse of sediment to the river network, resulting in short-term / temporary channel aggradation which may only persist for several years before the river begins to re-incise and resume its original form. Alternatively, a permanent and geomorphically significant reduction in sediment supply would result in channel entrenchment (limited by base level) followed by channel widening (through bank erosion) which would occur slowly over multiple decades (Figure 2.1).

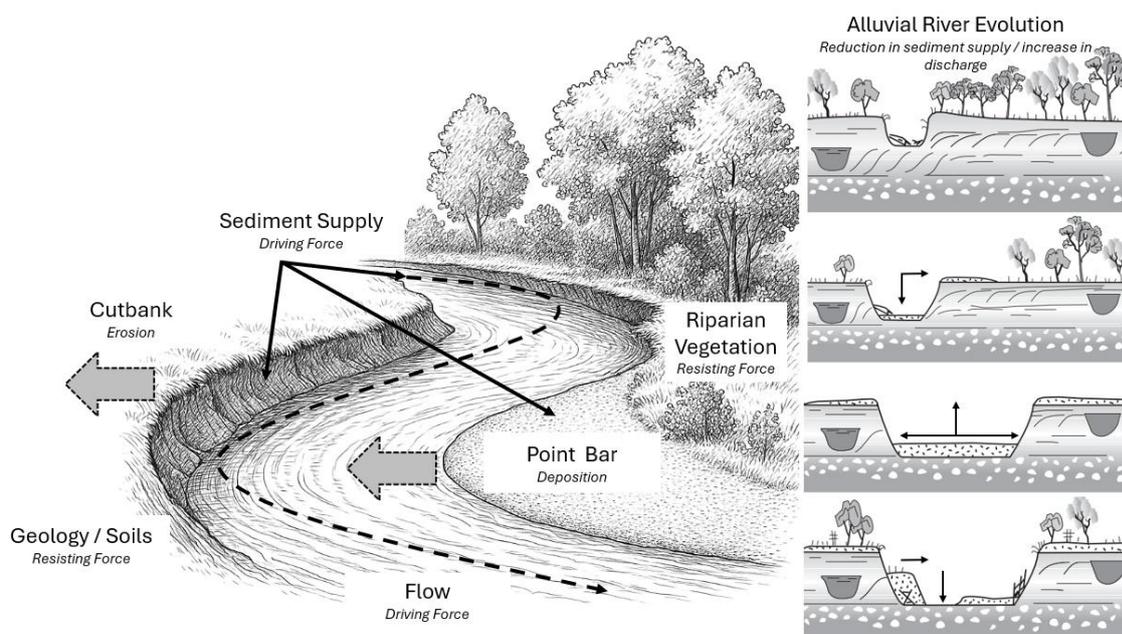


Figure 2.1: conceptual diagram showing the typical driving and resisting forces of an alluvial meandering river (left) and conceptual channel evolution with a geomorphically significant reduction in sediment supply or an increase in discharge.

2.1.1 Omanawa River – OMW-4

OMW-4 is the most downstream 5 km reach of the Omanawa River located near the Wairoa River confluence, approximately 13 km downstream of the Omanawa Weir. It has a low gradient (0.2%) and occupies a wide valley corridor with alluvial floodplains. There is minimal riparian vegetation, and stock appear to have access to the river banks, both likely to have an impact on bank stability (Figure 2.1; Figure 2.2). Active bank erosion is evident throughout the reach, particularly where there is no riparian vegetation. OMW-4 also exhibits evidence of historical vertical change, with a series of terraces along the true right bank, indicating long-term channel incision.

Sediment sources to OMW-4 include sediment contributed from the catchment upstream of the Kaimai HEPS (above the Omanawa Weir) during flood events when the Omanawa Weir spills, erosion (landslides/gullies²) of the valley margin downstream of the Omanawa Weir, and bed and bank erosion within OMW-4 itself (Figure 2.2). Aerial imagery suggests that the Omanawa River is, at times, a major contributor of fine-grained sediment to the Wairoa River (WAI-3).

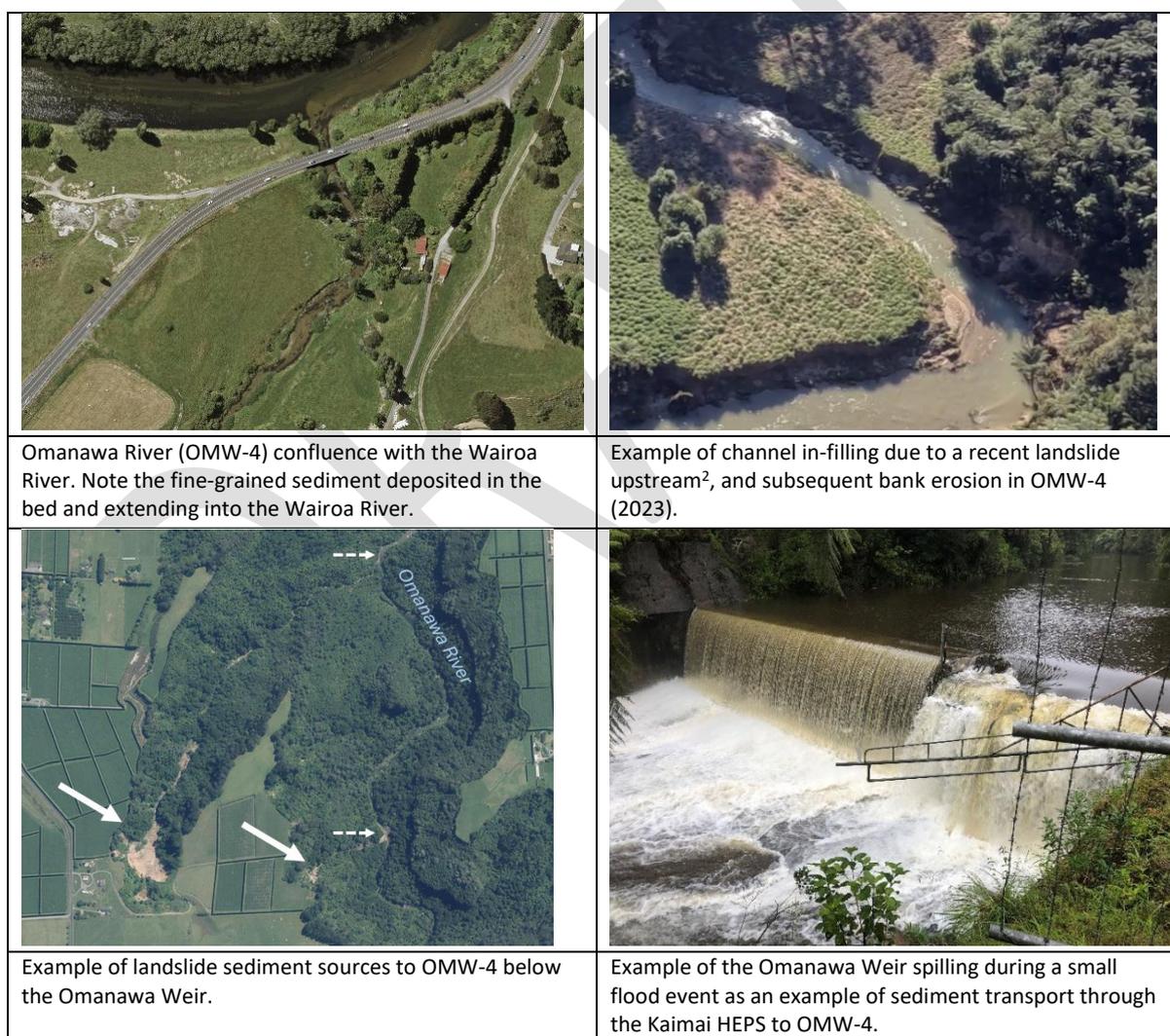


Figure 2.2: Existing condition of the alluvial section of the Omanawa River (OMW-4)

² There is a large landslide / gully on the Omanawa River between the Omanawa Falls and OMW-4 which reactivated after Cyclone Gabrielle in 2023, and is still contributing large volumes of sediment to river: <https://www.boprc.govt.nz/your-council/news/news-and-media-releases/media-releases-2023/may-2023/record-rain-across-the-rohe-causing-erosion-and-river-discolouration/>

2.1.2 Wairoa River – WAI-3

The Wairoa River is the principal river of the catchment and the receiving environment for all Kaimai HEPS diverted flows. WAI-3 extends downstream from the Ruahihi Power Station to SH2 near Tauranga Harbour. WAI-3 is a fine-grained meandering river and relies on a balance of sediment supply and discharge to maintain its form and function (Figure 2.1). Unlike OMW-4, WAI-3 is very low gradient (0.001%) and is tidally influenced, meaning the geomorphic effect of any change in discharge may be somewhat buffered by the tidal cycle, and future sea level rise.

WAI-3 is characterised by occasional depositional benches (potentially acting as inset floodplains), undercut banks, and a predominantly fine-grained bed (Figure 2.3). No obvious active bank erosion was observed above the water level, but large clay blocks were present on the channel bed downstream of the Ruahihi Power Station which may be from localised bank erosion occurring at some point (Figure 2.3). For most of its length, WAI-3 has variable riparian vegetation, with areas of continuous woody vegetation increasing bank stability.

Sediment sources to WAI-3 include sediment contributed from the flood events when the McLaren Dam spills (Figure 2.3), Mangakarengorengo River and Omanawa River, natural erosion of the bed and banks of the river downstream of McLaren's Dam, and bed and bank erosion within WAI-3 itself. It is unlikely that marine sediment sources from tidal action is a geomorphically significant sediment source for most of WAI-3, but will be present in the most downstream extent of the reach (near SH2).

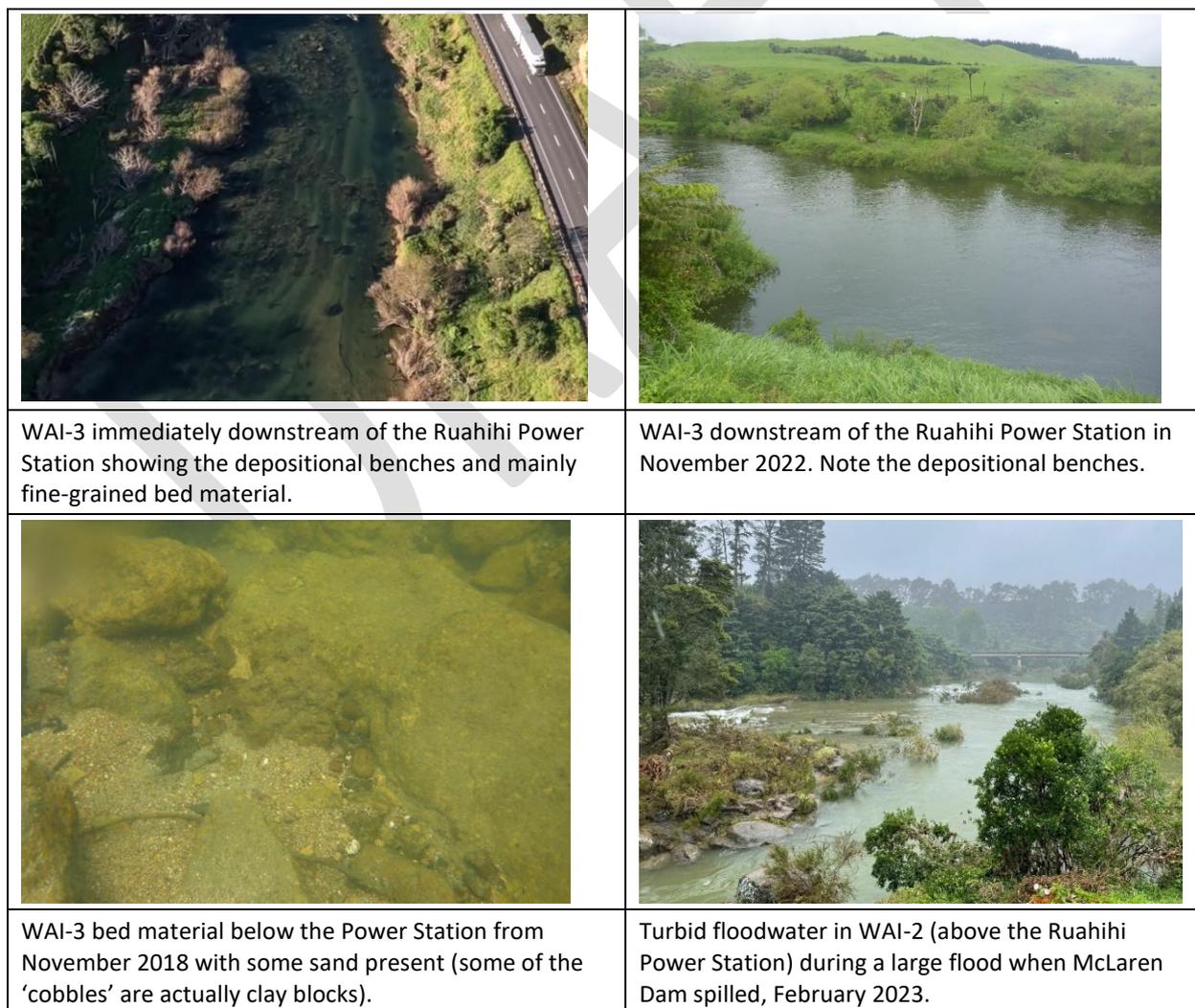


Figure 2.3: Existing condition of the alluvial section of the Wairoa River (WAI-3)

2.2 Potential Kaimai HEPS Impacts

The current Scheme operates as a cascading system of four power stations on 12 tributaries of the Wairoa River. Through a network of tunnels and canals, water from a large catchment is progressively diverted into storage lakes that supply successive stations. This interconnected system, combined with multiple sediment sinks (storage lakes), requires careful consideration of sediment continuity.

Sediment generation in the wider Wairoa River Catchment is naturally highly variable and is linked to the nature of the catchment geology / soils, land use and large storm events. Sediment yields would have increased since the 1960's due to changes in landuse within the catchment coinciding with the establishment of the Kaimai HEPS.

Sediment budgets for the Wairoa and Omanawa Rivers are constrained by data gaps, which make it difficult to quantify how much sediment is 'geomorphically significant' for sustaining downstream channel form and function. The indicative sediment budget (Figure 2.4), suggests that the low-level weirs (and drop pipes) within the Kaimai HEPS act as partial barriers to sediment transport within their respective catchments (Omanawa, Mangapapa, Opuiaki, and Mangakarengorengo Rivers). In contrast, the three hydro-lakes; Mangaonui, Matariki, and McLaren—function as effective sediment sinks, preventing sediment from reaching downstream reaches of the Mangapapa and Opuiaki Rivers and ultimately the Wairoa River (Figure 2.4). Across the Scheme, an estimated 10,000 – 20,000 t/year of sediment is estimated to be permanently trapped in impoundments such as head ponds, canals, and hydro-lakes. This may represent a 25 – 50% reduction in the 'contemporary' lower Wairoa River sediment yield, and potentially up to a 65% reduction in the 'contemporary' lower Omanawa River sediment yield. However, sediment generating processes downstream of Kaimai HEPS infrastructure (particularly in the Omanawa River; Refer to Section 2.1.1) are still active and contributing fluctuating volumes of fine-grained sediment to alluvial reaches of the Omanawa and Wairoa Rivers.

Discharge regimes have also been altered in the Omanawa and Wairoa Rivers as a result of the Kaimai HEPS. As a result of the Scheme, the magnitude and frequency of medium sized flow events below 4 m³/s in the Omanawa River have been reduced (refer to T+T 2025³). However, the Omanawa Weir spills reasonably regularly (averages 38 spill events annually), which is likely to maintain the magnitude and frequency of channel forming flows required for sediment transport and alluvial channel form and function in OMW-4 (refer T+T, 2025⁴).

WAI-3 receives the combined flow from all diversions via the Ruahihi Power Station discharge (maximum consented discharge of 28 m³/s), and sporadically from McLaren Dam. While the hydro-lakes in the Scheme may provide some minor flood attenuation, they may only result in a very slight (10-20%) reduction in the size and frequency of channel forming flows (MAF is 435 m³/s) required for alluvial channel form and function in WAI-3, as per T+T (2025)³. As the discharge from the Ruahihi Station is considerably less than the channel-forming flows in this reach of the Wairoa River the hydrological change arising from generation flows themselves is also unlikely to initiate substantive bed incision or bank erosion. This may be further buffered by the tidal influence in WAI-3, where high-tides may reduce the available erosive energy from generation flows.

Therefore, it is the reduction in sediment supply (as opposed to hydrological change) that is more likely have some form of impact on alluvial river form and function in WAI-3 and OMW-4. The

³ Tonkin + Taylor Ltd (2025). Reconsenting of Kaimai Hydroelectric Power Scheme – Hydrology Report. Prepared for Manawa Energy Ltd.

⁴ Tonkin + Taylor Ltd (2025). Kaimai HEPS Consent Renewal – Sediment and Erosion Effects Assessment. Prepared for Manawa Energy Ltd.

expected channel response to a geomorphically significant reduction in sediment supply to WAI-3 and OMW-4 would be incision and subsequent channel widening through bank erosion (Figure 2.1).

Active bank erosion is evident in OMW-4, but due to a lack of repeat topographic or bed level data, it is unclear if the erosion is attributable to incision (therefore potentially associated with the Kaimai HEPS), or from the lack of riparian vegetation and continued stock access.

Based on assessments⁵ to date¹, there was an episodic channel-narrowing in WAI-3 downstream of the Ruahihi Power Station to the Omanawa River confluence between 1970 and 1988, and channel recovery (e.g. restoration of channel width) observable from 1992 onwards in most of the assessment extent of WAI-3. The channel narrowing trend persists until 2022 over a 600 m stretch of WAI-3 immediately downstream of the Ruahihi Power Station, which is where the material from the canal collapse would have entered the Wairoa River.

As the canal collapse was a singular short pulse of sediment, it doesn't wholly account for the ongoing narrowing (10 m over a 34 year period; an average rate of 20 cm per year). But geomorphic process-response relationships in tidally influenced alluvial rivers can be complex, with slow or even delayed responses to threshold exceedances. The reductions in fine-grained sediment from upstream Kaimai HEPS rivers may be contributing to this. However, as WAI-3 is at sea level, the expected response would be limited incision (entrenchment) followed by a 'wave' of downstream progressing channel widening (bank erosion), as the channel forming flow regime has not been notably altered.

Based on this, the Wairoa River is still recovering from the Ruahihi Canal collapse, due to the volume of sediment delivered to the channel and the subsequent stabilisation of some of that material on banks by vegetation. Because of the effect of the canal collapse on channel form and function, effects of fine-grained sediment reduction arising from the Kaimai HEPS are difficult to determine. However, should the channel narrowing trend continue downstream in the future, this may suggest the driver for channel narrowing could be the reduction in sediment load in the Wairoa River as a result of the Kaimai HEPS.

The impacts of the Kaimai HEPS on OMW-4 and WAI-3 therefore remain difficult to isolate due to the complex interplay of processes, including residual effects from historic sediment inputs, tidal influence, and stock access / riparian vegetation condition. Sediment monitoring in WAI-3 and OMW-4, focusing on trends in channel form as a result of diminished sediment supply, is required to better understand the potential long-term geomorphic responses to the Kaimai HEPS.

⁵ Aerial imagery analysis was undertaken on seven epochs (1943, 1953, 1962, 1970, 1988, 1992 and 2022). Aerial imagery analysis of channel change is inherently challenging, as it is strongly biased towards wetted width in the absence of topographical data which would enable the active bank to be more accurately identified. As this section of the Wairoa River is subject to both tidal influences and daily changes in generation flows, it is more challenging than most river reaches to assess channel width changes in the absence of long-term topographic data.

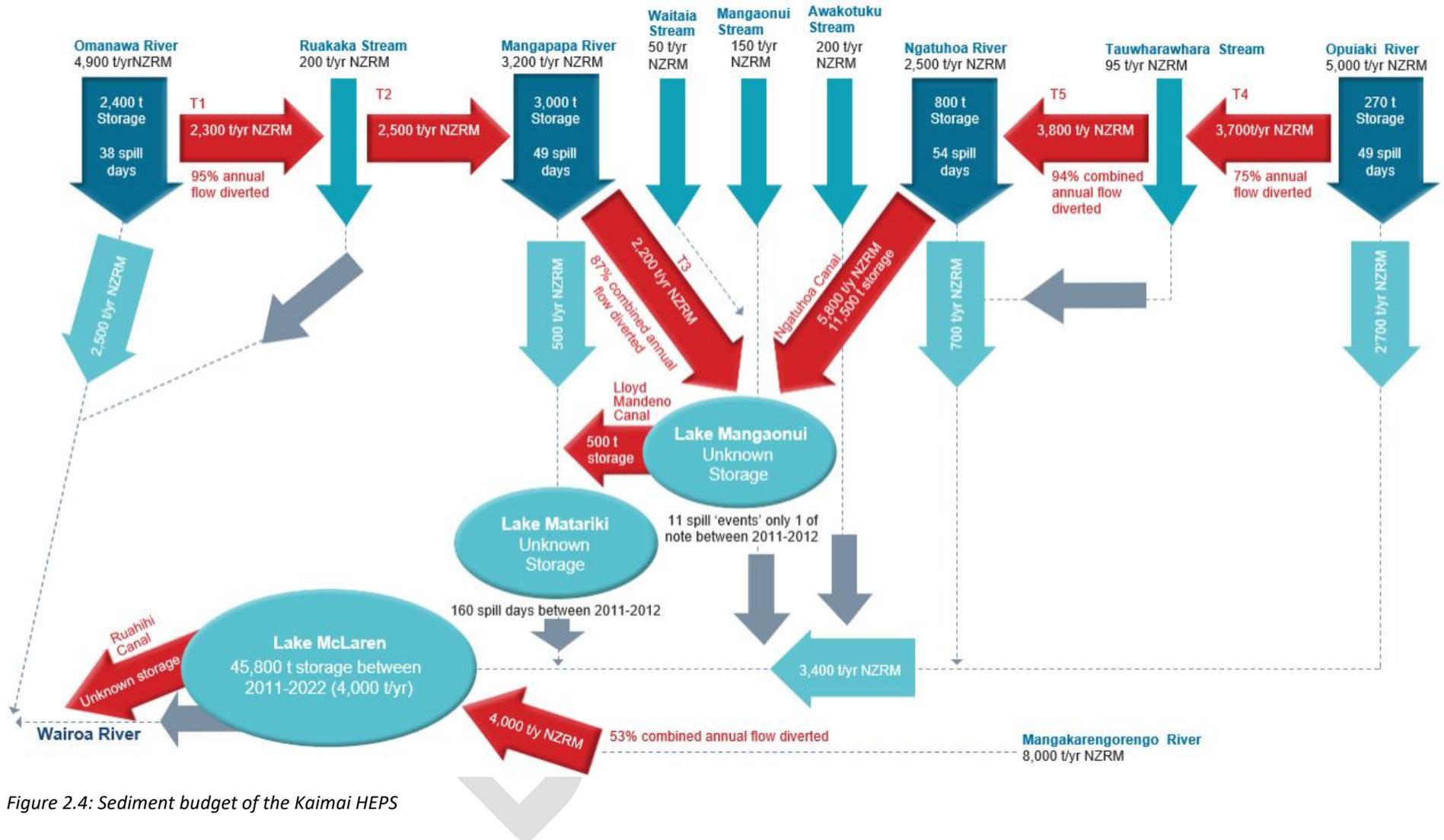


Figure 2.4: Sediment budget of the Kaimai HEPS

3 Sediment Monitoring Plan Objective

The objective of the SMP is primarily as follows:

Monitor any long-term changes in sediment continuity in the Wairoa and Omanawa Rivers that may be a result of the continued operation of the Kaimai HEPS.

Most of the river reaches within the footprint of the Kaimai HEPS itself are dominated by bedrock, and will not manifest geomorphic change as a result of any Scheme induced change in the sediment regime. Therefore, the monitoring approach will focus on observable channel changes within the alluvial sections of the Wairoa River (WAI-3) and Omanawa River (OMW-4), and compare this to geomorphically appropriate reaches from the adjacent non-scheme impacted Kopurererua River (KOP-1 and KOP-2)(Figure 3.1).

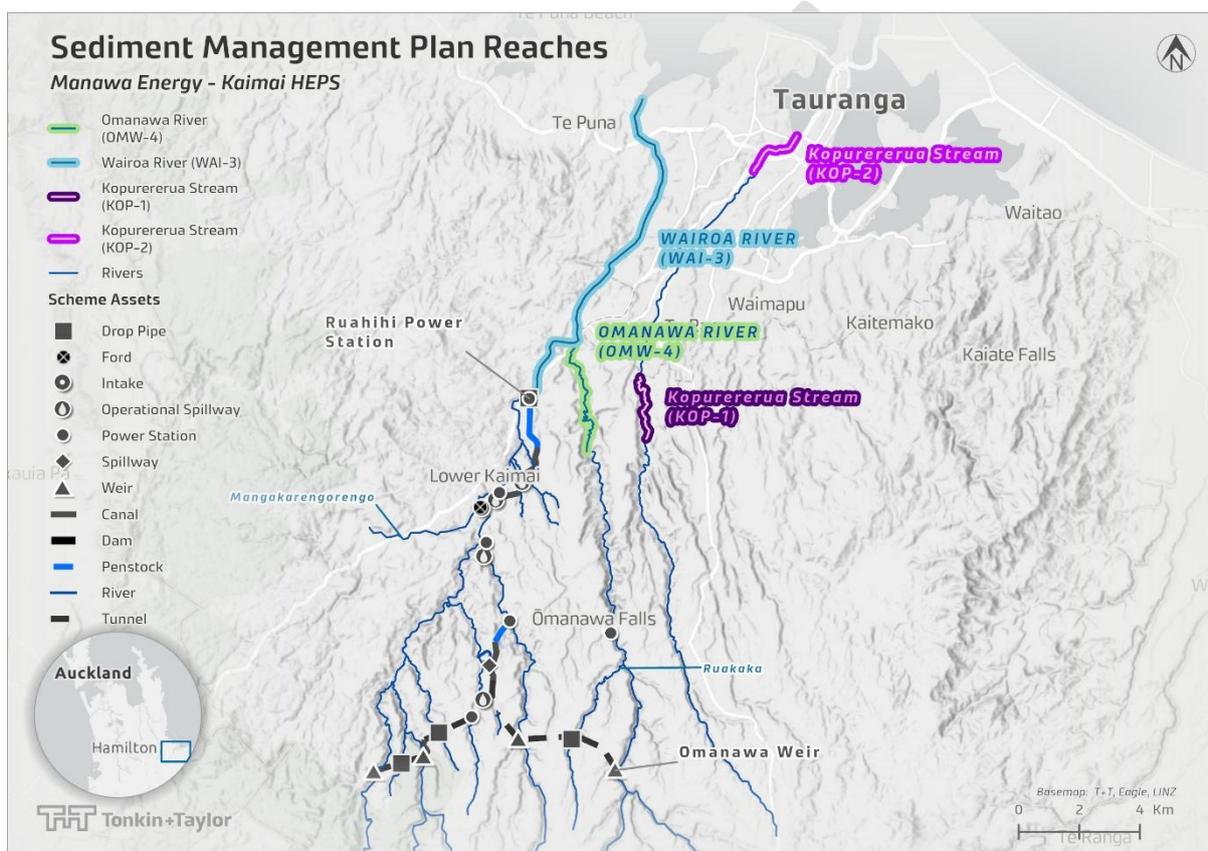


Figure 3.1: Kaimai HEPS layout with the location of the monitoring reaches as part of this SMP

3.1 Omanawa River

There is a lack of historic geomorphic data in the Omanawa River which makes it challenging to quantify the Omanawa River sediment budget and the potential sediment load reduction as a result of the on-going operation of the Kaimai HEPS. In addition, there are historic and on-going land management impacts in OMW-4 which may be contributing to channel instability (stock access and lack of riparian vegetation). Accordingly, monitoring of the Omanawa River will focus on potential changes in channel form in the context of the geomorphic drivers of change in operation in the Omanawa River catchment, including, but not limited to the Kaimai HEPS.

Specifically, the monitoring will cover the 5 km reach of OMW-4 starting approximately 13 km downstream of the Omanawa Weir to the confluence with the Wairoa River (Figure 3.2), and will include the following components:

- Identify and track active geomorphic 'hot spots'.
- Identify and track potential changes in channel width, depth and sinuosity.
- At a high-level, identify and track possible drivers of erosion and channel change (such as land use practices, riparian management, flood / flow history, sediment budget).
- Compare the geomorphic changes and drivers of change with the geomorphic changes and drivers of change in the adjacent non-scheme impacted Kopurererua River (KOP-1), to help distinguish between scheme and non-scheme related geomorphic impacts.
- Assess any observed geomorphic change against the operation of the Kaimai HEPS compared to other geomorphic drivers.

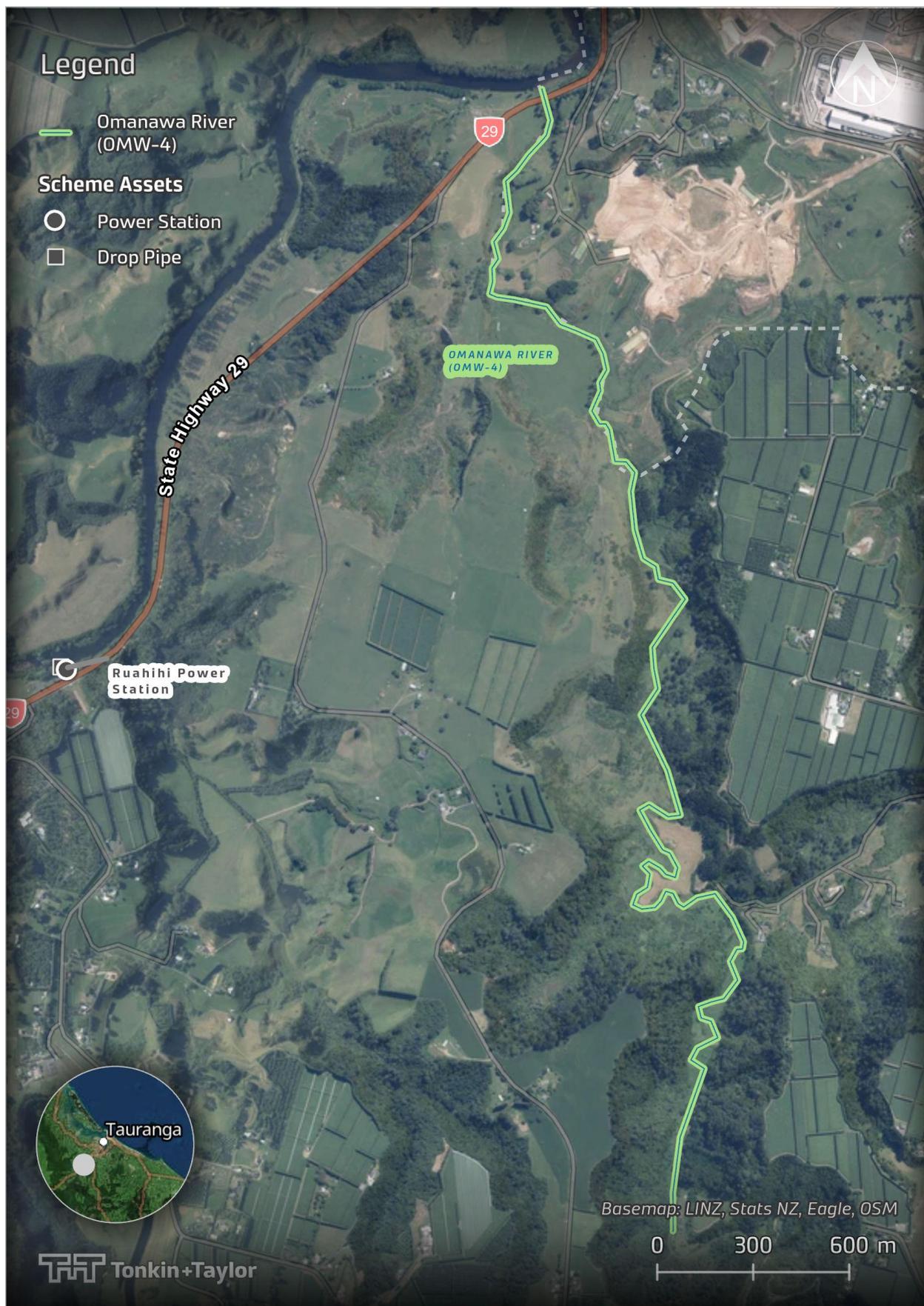


Figure 3.2: OMW-4 monitoring reach

3.2 Wairoa River

There is a lack of historic geomorphic data in the Wairoa River which makes it challenging to quantify the Wairoa River sediment budget and the potential sediment load reduction as a result of the on-going operation of the Kaimai HEPS.

In addition, the oversupply of sediment to WAI-3 from the Ruahihi Canal collapse is masking possible channel response to the operation of the Kaimai HEPS.

As such, channel change in WAI-3 as a result of the Kaimai HEPS may not be evident within the next 40 years, but will likely manifest as a downstream 'wave' of channel widening if it does occur. Over this timeframe, sea level rise may begin to buffer any possible channel entrenchment as a result of the Kaimai HEPS. Accordingly, monitoring of the Wairoa River will focus on potential changes in channel form in the context of the geomorphic drivers of change in operation in the Wairoa River catchment, including, but not limited to the Kaimai HEPS.

Specifically, the monitoring will cover the 12.5 km WAI-3 reach, from the Ruahihi Power Station to the River Mouth at the SH2 Bridge (Figure 3.3), and will include the following components:

- Identify and track active bank erosion 'hot spots'.
- Identify and track potential changes in channel width and depth.
- At a high-level, identify and track possible drivers of erosion and channel change (such as land use practices, riparian management, flood / flow history, sediment budget, tidal regime, sea level rise).
- Compare the geomorphic changes and drivers of change with the geomorphic changes and drivers of change in the adjacent non-scheme impacted Kopurererua River (KOP-2), to help distinguish between scheme and non-scheme related geomorphic impacts.
- Assess any observed geomorphic change against the operation of the Kaimai HEPS compared to other geomorphic drivers.



Figure 3.3: WAI-3 monitoring reach

3.3 Kopurererua River

The Kopurererua River will be used as a 'control' river to help differentiate between scheme and non-scheme related geomorphic changes. For example, if a specific type of geomorphic change is identified in the Omanawa River (such as increased bank erosion rates) but not identified in the Kopurererua River, but all the geomorphic drivers remain the same across both catchments (except the scheme operation), then the change in the Omanawa River would be more consistent with the on-going operation of the Kaimai HEPS.

Two separate reaches within the Kopurererua River have been identified that more closely match the geomorphic drivers and controls in the Omanawa and Wairoa Rivers. These are discussed below.

3.3.1 KOP-1

KOP-1 is a 4 km reach of the Kopurererua River where it exits the confined gorge and enters a wide valley corridor with alluvial floodplains either side (Figure 3.4). This section of the Kopurererua River has a low gradient (0.2%), variable riparian vegetation and areas of stock access to the river banks. The river is actively meandering and experiencing some bank erosion. KOP-1 is similar enough to OMW-4 to be considered an appropriate control reach.

Monitoring in KOP-1 will include the following components:

- Identify and track potential changes in channel width, depth and sinuosity.
- At a high-level, identify and track possible drivers of erosion and channel change (such as land use practices, riparian management, flood / flow history, sediment budget).
- Compare the geomorphic changes and drivers of change with the geomorphic changes and drivers of change in OMW-4, to help distinguish between scheme and non-scheme related geomorphic impacts.

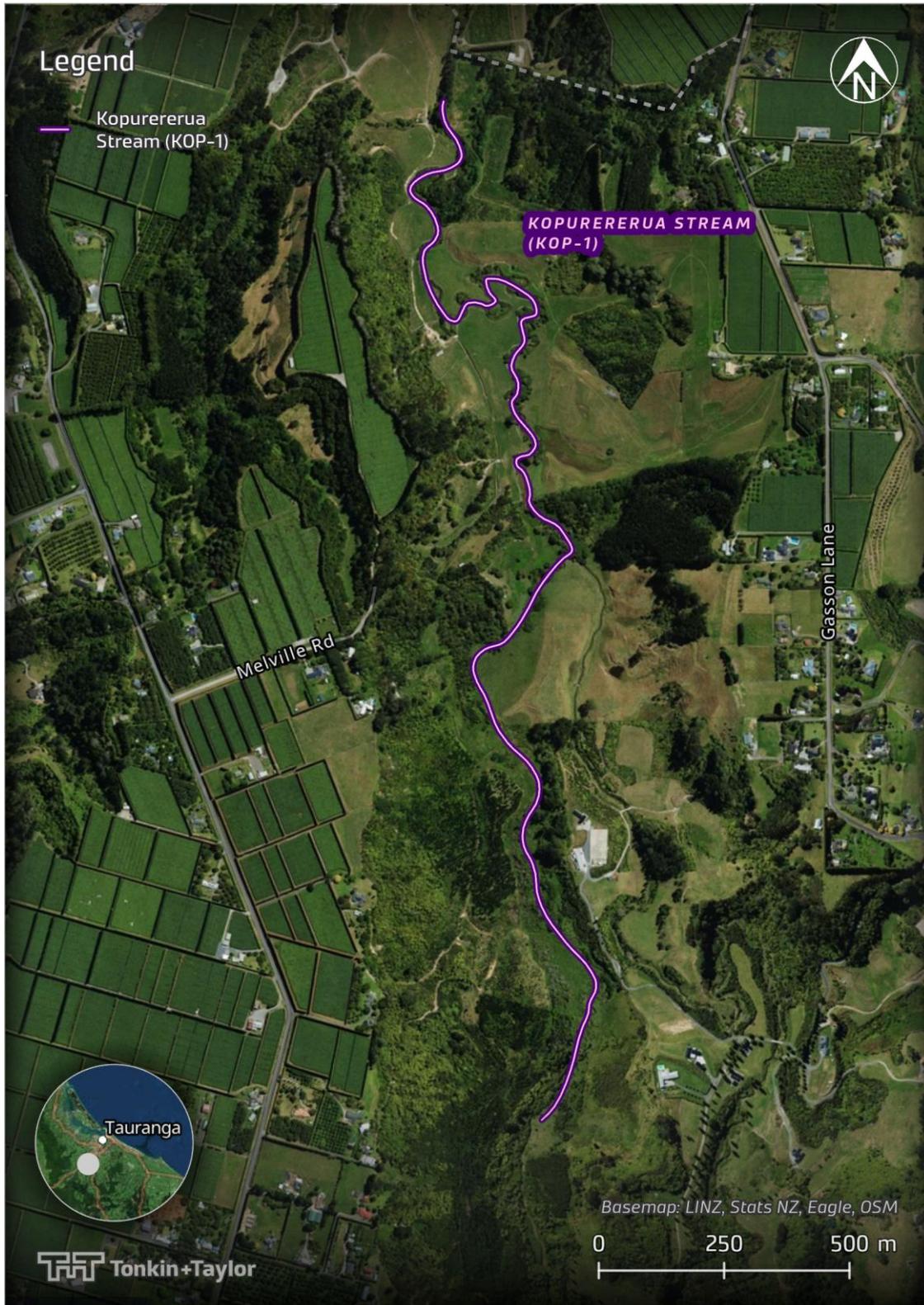


Figure 3.4: KOP-1 monitoring reach

3.3.2 KOP-2

KOP-2 is the most downstream 2 km stretch of the Kopurererua River, and is strongly influenced by tidal processes (Figure 3.5). The lowland section of the Kopurererua River has had a long history of modification, having been straightened in the early 1920's to facilitate agricultural use of the floodplains, and then the mouth was realigned in the 1950's to facilitate the development of the Judea Industrial Estate. Regardless, this reach has a very low gradient (0.01%), and is a fine-grained system similar enough to the WAI-3 that geomorphic adjustments should be reasonably similar between the two reaches.

Monitoring in KOP-2 will include the following components:

- Identify and track potential changes in channel width and depth.
- At a high-level, identify and track possible drivers of erosion and channel change (such as land use practices, riparian management, flood / flow history, sediment budget, tidal regime, sea level rise).
- Compare the geomorphic changes and drivers of change with the geomorphic changes and drivers of change in WAI-3, to help distinguish between scheme and non-scheme related geomorphic impacts.

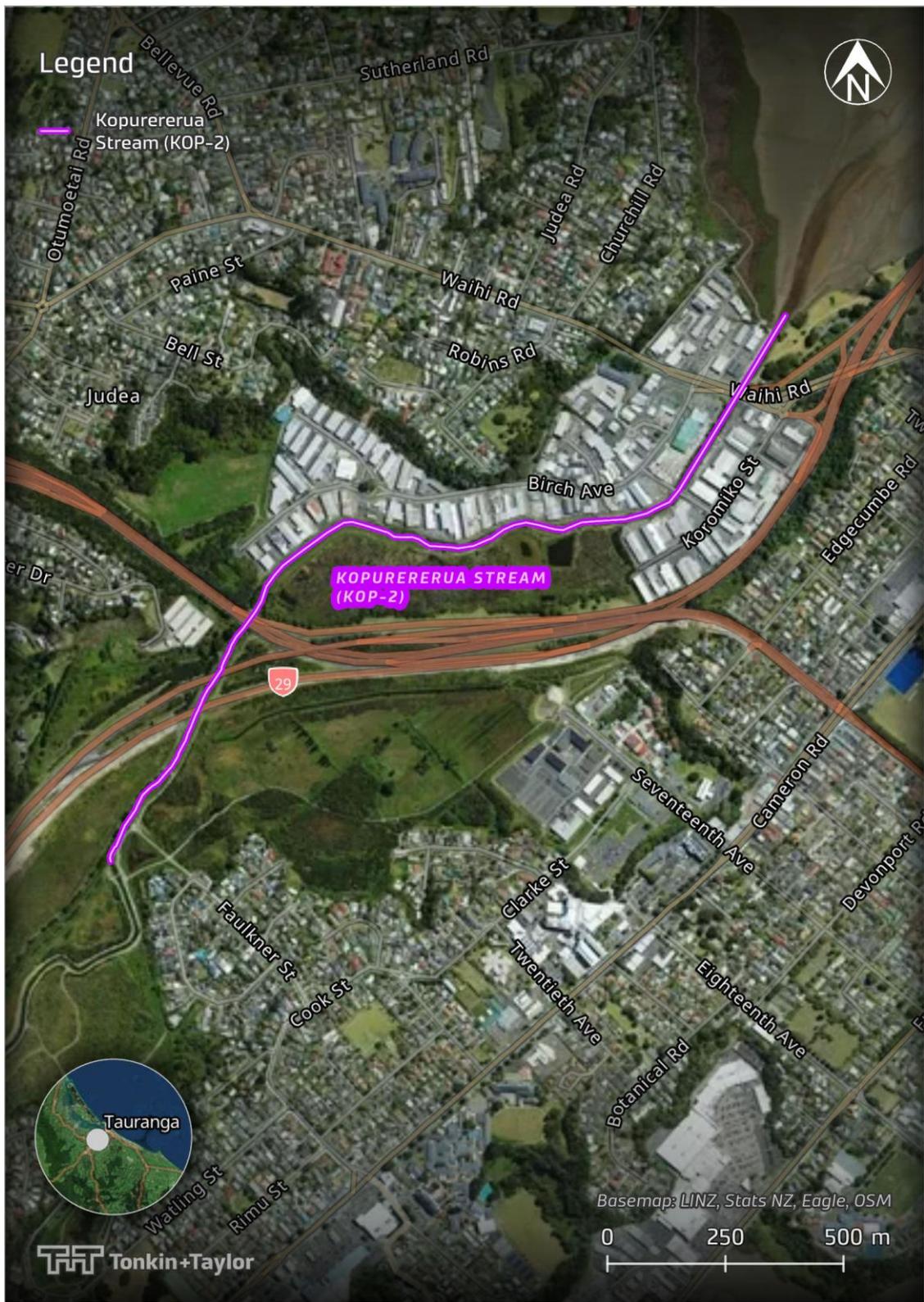


Figure 3.5: KOP-2 monitoring reach

4 Sediment Monitoring Plan Methodology

The sediment monitoring methodology is tied to the proposed consent conditions (Section 1), and aligns with the reach specific sediment monitoring objectives (Section 3) which are based on the reach-specific geomorphic drivers and channel responses. This section outlines the recommended methodology for assessing potential channel response to a reduction in sediment supply to the alluvial sections of the Omanawa and Wairoa Rivers (WAI-3 and OMW-4).

Rivers respond dynamically in space and time in response to episodic and / or permanent changes in driving and resisting forces. The sediment monitoring methodology recommends monitoring intervals and timeframes that will separate short-term fluctuations from longer-term geomorphic trends, allowing event-driven changes (e.g. floods or landslides) to be distinguished from sustained geomorphic trends which may be manifesting from changes in sediment regime as a result of the on-going operation of the Kaimai HEPS.

To further support the differentiation between scheme and non-scheme related geomorphic change, the Sediment Monitoring Methodology relies on a ‘paired catchment’ approach with selected similar reaches of the adjacent Kopurererua River (KOP-1 and KOP-2).

Unless otherwise stated, the same methods can be applied to all assessment reaches. However, as the monitoring progresses it may be identified that the monitoring methodologies, extents, or intervals specified in this SMP may need to be adjusted, modified, or discontinued (e.g. if a reach shows no observable geomorphic adjustment between five yearly intervals, but ten yearly comparative data is able to detect geomorphic change). This is covered in further detail in Section 5.

4.1 Topographic Survey

Topographic survey of the bed and banks of the monitoring reaches is fundamental to all aspects of the SMP methodology. While terrestrial LiDAR is a suitable survey method for river ‘banks’, it cannot penetrate water, and so topographic survey of the bed of the monitoring reaches will be required to support the SMP. Table 4.1 (and Appendix A) outlines the existing project or freely available topographical and imagery data sets, up to November 2025.

Table 4.1: Available ‘baseline’ topographic data for the monitoring reaches as of November 2025

Data type	Date captured	Resolution	Owner	Extent
Orthophotography	2024	0.1 m	BOPRC	WAI-3 + OMW-4 + KOP-1
	2025	0.1 m	BOPRC	KOP-2 + KOP-1 (partial)
	January 2025	0.05 m	Manawa Energy	WAI-3 only
Terrestrial LiDAR DEM	January 2025	1 m	Manawa Energy	WAI-3 only
	2019-2022	1 m	BOPRC	WAI-3 + OMW-4 (partial) + KOP-1+ KOP-2
Bathymetric LiDAR DEM	January 2025	1 m	Manawa Energy	WAI-3 only
<i>River Cross-section survey*</i>	<i>January/March 2016</i>	<i>Unknown</i>	<i>Aurecon / TCC</i>	<i>WAI-3 and two XS in OMW-4</i>
<i>Bathymetric survey*</i>	<i>2017</i>	<i>Unknown</i>	<i>BBO / NZTA</i>	<i>WAI-3 (SH2 to 3km upstream)</i>

Note: **This data was not collected as part of this project and is held by third parties. T+T has not reviewed or requested this data in the preparation of this SMP. Data was reported in DHI (2018)⁶.*

⁶ DHI (2018) Wairoa Catchment Numerical Modelling – MIKE FLOOD Model Build, Validation and Flood Hazard Mapping. Report prepared for Tauranga City Council.

Bed and bank topographic and aerial imagery surveys of the extent of OMW-4, WAI-3, KOP-1 and KOP-2 should be undertaken every five years. The survey should be captured to the same specification as the baseline 2025 survey as outlined below (Table 4.2) and extent shown in Figure 3.2, Figure 3.3, Figure 3.4, and Figure 3.5.

Bathymetric LiDAR data can be unreliable when rivers are turbid, and capture should be timed to for suitable water / flow conditions. However, should unsuitable conditions persist, an alternative (and comparable) method of bathymetric survey can be used.

There is currently no baseline bathymetric survey covering the entirety of OMW-4 to the confluence of the Wairoa River, or the Kopurererua River (KOP-1 and KOP-2). This will be captured within the first year of the granting of the consent.

Table 4.2: Metadata for the Bathymetric LiDAR and Orthophotography capture in January 2025

Metadata	Information
Bathymetric and Terrestrial LiDAR Capture	
Date Captured	Similar time of year (mid-January)
Sensors	Riegl VUX-240, and Riegl VQ-840-G
Capture Height	150 m AGL
Vertical QC against control points	Av Dz = 0.013, Av Mag. = 0.02, RMSE = 0.029
Horizontal QC	Visually assessed: < 0.1 m
DEM/DSM	
Grid size	1 metre
CRS	NZTM2000 : NZVD2016

4.2 Geomorphic Change Detection

Geomorphic Change Detection (GCD) is used to calculate and visualise topographic change between two Digital Elevation Models (DEM's), visualised as surface raising (aggradation/deposition) and surface lowering (bed scour or bank erosion). GCD is the primary geomorphic assessment method that will identify and quantify areas of any potential geomorphic change within OMW-4, WAI-3, KOP-1 and KOP-2 as well as used to identify and track geomorphic 'hotspots' as described in Section 4.3.

The GCD analysis utilises the DEM generated from the bathymetric and terrestrial topographic survey data outlined in Section 4.1, needs to assess the bed⁷, banks⁸ and 'geomorphic hotspots', and will be undertaken five yearly using the following assessment epochs:

- Most recent survey - Baseline survey.
- Most recent survey – Five yearly survey immediately prior.

For each of the assessment epochs for both OMW-4, WAI-3, KOP-1 and KOP-2 the GCD analysis will produce the following:

⁷ The RMA defines the bed of a river as "... the space of land which the waters of the river cover at its fullest flow without overtopping its banks". CON-1022-Whatisawaterway-V06.pdf

⁸ The RMA defines the bed of a river as "... the space of land which the waters of the river cover at its fullest flow without overtopping its banks". CON-1022-Whatisawaterway-V06.pdf

- 1 Quantification of Bed erosion vs deposition and net change (m³);
- 2 Bank erosion vs deposition volumes and net change (m³), and calculation of average bank retreat rates (m);
- 3 Total net sediment volume change for whole of OMW-4 and WAI-3 only (m³);
- 4 A series of maps to highlight the following;
 - a) Areas of erosion/deposition which have occurred between surveys;
 - b) Any areas of erosion which have been identified during the baseline assessment compared to recent surveys to determine if the erosion is active or has stabilised;
 - c) Any channel migration or bank retreat which has occurred between surveys; and
 - d) Identify any localised areas of substantial change (erosion or deposition) in OMW4 and WAI-3 only that may require further investigation or monitoring (geomorphic hotspot assessment detailed in Section 3.3).

In addition, every five years, the sinuosity of OMW-4 and KOP-1 will be determined, based on the river centerline⁹.

4.3 Geomorphic hotspots

Geomorphic hotspots are localised areas of substantial geomorphic change (such as a large area of bank erosion, or a large build-up of sediment deposits). Geomorphic hotspots are typically the manifestation of natural river evolution and are often transient (i.e. may be active one year after a large flood, and then never again). However, persistent change in one location, or a proliferation of localised areas of change in any given year may indicate that that balance between driving and resisting forces may have been tipped (Figure 2.1).

Geomorphic hotspots in OMW-4 and WAI-3 will be identified through the GCD analysis (Section 4.2) every five years, and each new hotspot will have a unique identifying code assigned to it¹⁰. New geomorphic hotspots, and active hotspots identified from the five years immediately prior will be visually inspected in the field by a suitable qualified and experienced fluvial geomorphologist to determine channel stability. This inspection will include¹¹:

- 1 Photo survey – the photo survey should include photos looking upstream, downstream, across stream and at the bed of the river, the latter being particularly important for the pool habitat.
- 2 Geomorphic hotspots should be mapped in the field using a geospatial mapping software to record the points for the following information:
 - a) Type (erosion / deposition);
 - b) Relevant bank / channel geometry (m) (e.g. bank height or channel width / depth);
 - c) Location (i.e. toe, bank face, bank top, mid-channel, bank attached);
 - d) Status (active / not active);
 - e) Severity (high / moderate / low);
 - f) Extent (m);
 - g) Erosional or depositional mode (e.g. scour, mass wasting, debris jam, backwatering);
 - h) Indicative bed and bank material description;
 - i) Indication of the primary driver; and

⁹ The river centerline should be derived from the delineated 'banks' used in the GCD analysis to ensure consistency when comparing sinuosity between years.

¹⁰ If a hotspot 'reactivates' in future monitoring, the same unique identifier should be used from when it was originally active.

¹¹ Given the variability in water level in the Wairoa River, it is recommended to undertake the visual inspection during low tide with no generation flow.

- j) Observations of the riparian vegetation, and the effect this may be having on erosional / depositional processes.
- 3 Bank material samples (only at any new bank erosion hotspots) to determine the particle size distribution, in particular the relative percentage of sand¹² and clay¹³.
- 4 Recommendations for additional monitoring if required.

Every five years, the geomorphic hotspot analysis will produce the following:

- 1 A photo compilation of the assessed erosion hotspots clearly showing the evolution of the erosion hotspot over successive surveys.
- 2 Tabulated results from Task 2, 3 and 4 above for each hotspot (including the unique identifier).
- 3 Accompanying maps to show type and severity of active geomorphic hotspots, and recently inactive hotspots.

4.4 Analysis of geomorphic drivers

Alluvial rivers have reasonably predictable responses to changes in the driving and resisting forces (Figure 2.1). The Kaimai HEPS is potentially only impacting one of these driving forces (sediment load), while the remaining driving / resisting forces are outside of the Schemes footprint and influence and are likely to vary through time.

As such, every five years, a high-level review of the potential driving and resisting forces potentially influencing geomorphic response in OMW-4, WAI-3, KOP-1 and KOP-2 should be undertaken and include the following:

- 1 Download flow data for the proceeding five years from the following gauging sites¹⁴:
 - a) WAI-3: Site No. 14132, Wairoa at Power Station: Virtual river flow computed as the sum of the flow at Site No. 14130 and the Ruahihi PS discharge giving flow in the lower Wairoa River below the station.
 - b) OMW-4: Synthetic flows derived from the Manawa Energy Omanawa Intake Weir Gauge and spill flows over the Omanawa Weir.
 - c) KOP-1 and KOP-2: Site No.14302 Kopurererua at SH29 Bridge.
- 2 From the hydrological data, identify potential channel forming flow events which may be responsible for observed geomorphic change over the assessment epoch. This may include:
 - d) Recorded spill events at the Omanawa Weir and McLarens Dam;
 - e) Flood events (at or greater than Mean Annual flood);
 - f) Climatic trends which may influence rainfall / flood frequency (such as the El Niño Southern Oscillation (ENSO));
 - g) Tidal regime and / or sea level rise trends.
- 3 To determine (non-channel) sediment inputs, use aerial imagery to identify any changes in land use (high level) which may influence a change in river form and function between McLarens Dam and SH2 (WAI-3), downstream of the Omanawa Weir to the Wairoa River

¹² Sand includes particles between 63µm and 2mm. More than 10%. Banks with a higher sand content are more susceptible to fluvial erosion.

¹³ Clay includes particles less than 0.39µm. Banks with clay content in excess of 10% are considered cohesive (and less prone to fluvial erosion and mass wasting), as per Cardno (2020) Resistance and Critical Height of Streambanks in Selected Catchments of the Auckland Region. Report prepared for Auckland Council; and Raudkivi, A. J., (1990) Loose Boundary Hydraulics. Pergamon Press, Oxford. 538 p.

¹⁴ Refer to Table 2.1 on Page 6: Tonkin + Taylor (2025) Reconsenting of Kaimai Hydroelectric Power Scheme – Hydrology Report. Prepared for Manawa Energy Ltd.

(OMW-4), and Taumata Scenic Reserve to Waikareo Estuary (Waihi Road) (KOP-1 and KOP-2). This may include but is not limited to

- h) Forest removal/forest harvest (including riparian vegetation);
- i) Landsliding/gullyng;
- j) Afforestation;
- k) Urban or Industrial development;

Every five years, the geomorphic driver analysis will produce the following:

- 4 Hydrographs for the five year assessment period, with potential channel forming flow events highlighted (Task 2).
- 5 Accompanying maps to show location and type of changes in sediment inputs (Task 3).

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5 Reporting against the Sediment Monitoring Plan

The following reporting is recommended:

- 1 A five yearly report detailing the results of the Sediment monitoring in the Omanawa (OMW-4) and Wairoa (WAI-3) Rivers as follows:
 - a) The findings of the geomorphic change analysis, focussing on changes in channel width and depth (and sinuosity in OMW-3) between the most recent survey and the five yearly survey immediately prior, any changes from the Baseline survey (to identify long term trends), and compared to the relevant Kopurererua River reach (to determine possible scheme impacts).
 - b) Results of the geomorphic hotspot assessment, with commentary on any unusual (compared to the relevant Kopurererua River reach), severe, or extensive geomorphic hotspots.
 - c) Summary of the net volumetric sediment changes in WAI-3 and OMW-4 determined through the GCD and the geomorphic driver assessment to help determine if more or less sediment is moving through the system from previous years.
 - d) Commentary on any links between volumetric sediment changes, geomorphic change (including hotspots) and possible geomorphic drivers, including the potential impact of the Kaimai HEPS).
 - e) Identification or discussion of any emerging medium to long term geomorphic trends, particularly in WAI-3 as it recovers from the Ruahihi Canal collapse.
 - f) Recommendations for any future sediment monitoring surveys, including the methodology, frequency of future surveys, and if the paired catchment assessments need to continue.
 - g) Any geomorphically appropriate recommendations to manage sediment or erosion effects caused by the continued operation of the Kaimai Hydro-Electric Power Scheme. Recommendations must be tied to the geomorphic driver of change (e.g. reduction in sediment load), or the specific manifestation of a geomorphic process (e.g. bank erosion) (refer to Section 6 below).

6 Effect management or mitigation

Geomorphically appropriate mitigation or management is proposed if the sediment monitoring identifies adverse geomorphic change in OMW-4 and WAI-3 as a direct result of the on-going operation of the Kaimai HEPS. Mitigation and management actions have been differentiated and examples of geomorphically appropriate actions for each are listed below.

Mitigation actions are linked to the specific scheme related drivers that may be resulting in observed geomorphic change in OMW-4 and WAI-3. For example, a reduction in sediment loads resulting in erosion in WAI-3 and OMW-4, or flow ramping from the Ruahihi Power Station resulting in erosion in the upstream extent of WAI-3. Therefore, mitigation actions include the following:

- Increasing sediment transport through the Kaimai HEPS, with a focus on the Omanawa Weir and McLarens Dam.
 - Sediment throughput actions could include sluicing or flood flushing from the Omanawa Weir or McLarens Dam.
 - This option is limited by current infrastructure constraints.
- Changing the rate at which flows ramp up at the Ruahihi Power Station.

Management actions are linked to the site-based manifestation of scheme related geomorphic effects. For example, if a scheme-related reduction in sediment loads results in areas of localised bank erosion which can be managed at site. Therefore, management actions include the following:

- Increasing the resilience of the channel to erosive forces¹⁵, such as:
 - Riparian planting in areas with active banks that are less than 2 m high (on average), to increase the effectiveness of root cohesion.
 - Localised armouring of the bed where vertical channel adjustments have been identified.
 - Localised armouring of discrete areas of bank where erosion is specifically linked to lateral channel adjustments (not vertical channel adjustments).

¹⁵ Some channel resilience measures (such as riparian fencing and planting) in the Wairoa Catchment forms part of the BOPRC Wairoa River Sub-Catchment Plan (2012) and the WBOPDC Wairoa River Strategy (2013). If channel resilience measures are recommended to manage sediment and erosion effects arising from the Kaimai HEPS, the approach should be confirmed in collaboration with BOPRC and WBOPDC.

7 Applicability

This report has been prepared for the exclusive use of our client Manawa Energy Ltd, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our client will submit this report as part of an application for resource consent and that Bay of Plenty Regional Council as the consenting authority will use this report for the purpose of assessing that application.

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Appendix A High-resolution data extents for WAI-3

