Mangatainoka River at Mowbrays Rd

WATER QUALITY AND ECOLOGICAL REPORT FOR GRAVEL EXTRACTION APPLICATION BY PRENTERS AGGREGATES

FOR KAHUNGUNU KI TĀMAKI NUI-A-RUA

17 FEBRUARY 2022

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Looking downstream over the Mangatainoka River at Mowbrays Rd. Image: Thomas Kay (Kāhu Environmental).

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Summary and recommendations

Summary

Prenters Aggregates proposes to extract 40,000 m^3 gravel from a section of the Mangatainoka Awa (Figure 1), near Mowbrays Rd, Eketāhuna. This report is intended to help inform the potential impacts of gravel extraction on the health of the Awa and form a baseline against which the state of the river in future (during and after gravel extraction) can be assessed to determine the scale of any environmental effects that might result from the activity and any potential remedial actions which might be undertaken.

Ecological health in the Mangatainoka Awa in the vicinity of the proposed gravel extraction site is good to excellent. A healthy range of macroinvertebrates, indigenous fish, and large invertebrates (including taonga species) are known to inhabit the catchment, including threatened and at risk taxa. Water quality is relatively high and there is a range of important habitat available for indigenous fish, including a mosaic of flow types, instream wood, and undercut banks. Cultural values at the extraction site are high and the cultural health assessment results reflect the health and well-being of the site.

Recommendations

As kaimahi/kaitiaki from the Mangatainoka Awa, tangata whenua representatives may express different or more stringent views and recommendations for how the consent should proceed (or not) and what consent conditions may be imposed.
Whilst we have recommended below potential steps which may reduce the impacts of the gravel extraction on tangata whenua and ecological values, we acknowledge that we do not speak for tangata whenua and we are not cultural experts of this awa.

Recommendations:

1. All recommendations raised, adopted, or supported by tangata whenua are worded as specific consent conditions in a manner that allows for compliance monitoring to be assessed.
2. Accidental discovery protocols must be agreed with mana whenua.
3. People undertaking gravel extraction shall make themselves aware of the current good to excellent health of the awa, and of the requirement to avoid, remedy, or mitigate the impact of their activities on the awa and the aquatic life it supports.
4. People undertaking gravel extraction shall make themselves aware of the cultural values of the site for mana whenua and requirements to avoid,

remedy, or mitigate effects on tangata whenua values in the vicinity of the extraction site. This may require cultural and ecological induction for all staff accessing the site for extraction purposes and the employment of kaimahi (or cultural monitors) to be present whenever extraction activities are taking place.

5. Gravel extraction shall only occur from exposed, dry gravel bars.
6. Heavy machinery shall not operate in or within 2 metres of the wetted channel.
7. Extraction shall ensure gravel bars are not reduced to a level < 0.5 m above the surface of the water.
8. The number of river crossings by heavy machinery shall be minimised. Where crossings are required, these shall use the same tracks.
9. Additional surveys (repeating this one) shall be undertaken during and following the proposed gravel extraction. Ideally this would include:
    a. A survey in the period during gravel extraction to determine effects during the activity
    b. A survey immediately after the end of all gravel extraction at the site to determine the full extent of effects of the activity on the river
    c. A survey approximately 12 months after gravel extraction has finished to determine any ‘legacy’ effects of the activity (this survey should only occur once the river has experienced some higher flows capable of moving riverbed gravels)
10. Remediation of significant habitat features lost through the gravel extraction activities (as measured by the surveys) shall be undertaken.

Contents

1 Background

Prenters Aggregates proposes to extract 40,000 m^3 gravel from a section of the Mangatainoka Awa (Figure 1), near Mowbrays Rd, Eketāhuna. Extraction will involve the use of an excavator to take gravel from dry river bars, with aggregate then loaded into dump trucks and transported to stockpiles on adjoining land at the end of Mowbrays Road.

We (the authors) were engaged to undertake an assessment of the water quality, ecology, physical habitat, and some aspects of cultural health of the proposed gravel extraction reach in advance of the extraction. This is intended to help inform the potential impacts of gravel extraction on the health of the Awa and can form a baseline against which the state of the river in future (during and after gravel extraction) can be assessed to determine the scale of any environmental effects that might result from the activity and any remedial actions that can be taken as appropriate.

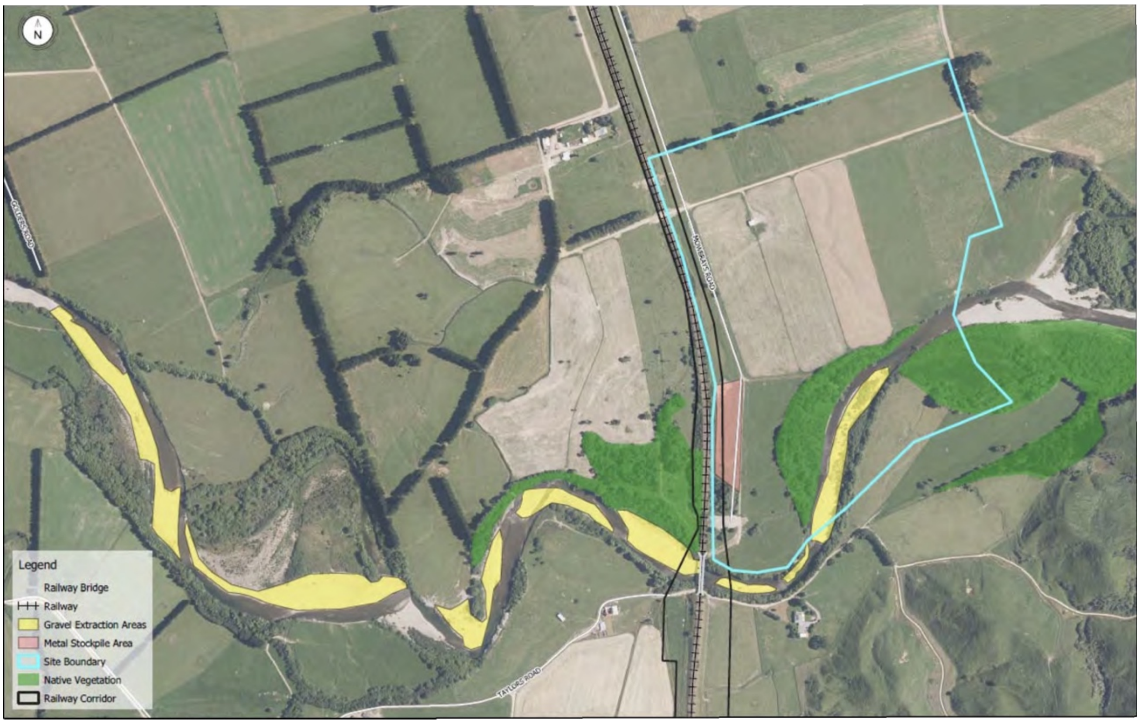

Figure 1: *Site plan / gravel extraction reach. (Good Earth Matters Consulting, 2020).*

2 Summary of middle Mangatainoka Awa water quality and aquatic ecology

The Mangatainoka Awa (One Plan water management zone Mana_8b Middle Mangatainoka) is a tributary of the Manawatū Awa. There are nine state of the environment (SOE) sites monitored by Horizons Regional Council (HRC) on the Mangatainoka Awa (from upstream to downstream):

a. Mangatainoka at Putara
b. Mangatainoka at Larsons Road
c. Mangatainoka at Hukanui Road
d. Mangatainoka at Scarborough Konini Road
e. Mangatainoka at Pahiatua Town Bridge
f. Mangatainoka at u/s Pahiatua STP (Sewage Treatement Plant)
g. Mangatainoka at d/s Pahiatua STP
h. Mangatainoka at SH2 Bridge
i. Mangatainoka at u/s Tiraumea confluence

Mangatainoka at Larsons Road is approximately 8 to 10km upstream of the proposed Mowbrays Road gravel extraction site and Mangatainoka at Hukanui Road is approximately 3km downstream of the site.

Land Air Water Aotearoa (LAWA) shows a summary of the data collected from these sites and any trends in water quality (along with other sites across the motu).

The Mangatainoka at Mobrays Road (upple/middle of proposed extraction site) and the Mangatainoka at Golders Road (upstream of site) (Figure 1) were assessed on 2 February 2022 for ecological and some aspects of cultural health as part of this report. The sites were also assessed for sediment and morphological characteristics and drone surveys were undertaken for the purposes of establishing a baseline for future habitat quality index (HQI) assessment.

2.1 Upstream water quality and ecology

Microbial contaminants and feacal indicator bacteria (*E. coli*)

Long-term water quality in the Mangatainoka at Larsons Road, classed as an upland forest site, shows that *E. coli* is in the worst 25% of like sites across the country. It is in the National Objectives Framework (NOF) D band for faecal contaminants (median 505 *E. coli*/100ml), with a very likely degrading ten-year trend. However, the five-year median *E. coli* concentration of 120 /100ml indicates that under low to median flow conditions the river is likely to be safe for contact recreation much of the time with respect to microbial contaminants from faecal sources. Although the site is classed as upland forest there is a proportion of the contributing catchment in intensive dairying land use, which likely contributes to the poorer water quality when compared with other upland forest sites nationally and will result in elevated *E. coli* through overland run-off when there is rainfall in the catchment and river flows are elevated.

Water clarity and turbidity

Water clarity and turbidity at the Larsons Road site were in the worst 50% of like sites (clarity five-year median 1.8 metres) and best 25% (turbidity five-year median 0.62 NTU) of like sites respectively. Clarity and turbidity showed very likely degrading ten-year trends. Clarity measures indicate the site is suitable for contact recreation (a median clarity of 1.6 metres or greater is recommended for recreational sites).

Nitrogen

Total nitrogen, total oxidised nitrogen and dissolved inorganic nitrogen were in the worse 50% of like sites nationally, although concentrations were low with medians of 0.15 mg/L, 0.06 mg/L and 0.065 mg/L respectively. Total nitrogen and total oxidised nitrogen show very likely degrading ten-year trends and dissolved inorganic nitrogen (DIN) is likely degrading over that time also. Nitrate is in the NOF A band for toxicity and is also very likely degrading. Ammoniacal nitrogen is within the worst 50% of like sites nationally (five-year median 0.005 mg/L), although in the NOF A band for toxicity so concentrations are low, with a very likely improving trend. Dissolved inorganic nitrogen contains total oxidised nitrogen and ammoniacal nitrogen and is the bioavailable fraction of nitrogen in water that can stimulate algal growth. The five-year median DIN concentrations are well within the One Plan target for this management sub-zone of 0.444 mg/L.

Phosphorus

Dissolved reactive phosphorous (DRP) (five-year median 0.003 mg/L) and total phosphorous (five-year median 0.008 mg/L) were in the best 50% of like sites. A very likely improving ten-year trend was apparent for the bioavailable form of phosphorous (DRP) and total phosphorous showed an indeterminate trend (no apparent trend). Dissolved reactive phosphorous was within the One Plan target for the middle Mangatainoka management sub-zone of 0.01 mg/L.

Macroinvertebrates

Long term ecological data showed a five-year median macroinvertebrate community index (MCI) of 122 and quantitative macroinvertebrate community index (QMCI) of 6.33, classed as indicators of 'excellent' water quality and within the NOF B band. Average score per metric (ASPM) had a five-year median of 0.586 and was within the NOF A band. The median taxonomic richess was 23 taxa and 57% of all taxa were sensitive ephemeroptera (mayflies), plecoptera (stoneflies) and trichoptera (caddisflies), also known as EPT taxa. No trends in macroinvertebrate data were available.

2.2 Downstream water quality and ecology

Water quality and aquatic ecology in the Mangatainoka at Hukanui Road, classed as an upland rural site, has been measured by HRC since 2014. Because of the shorter period of record, long-term trend data and trend information (i.e., 10 years or greater) is not available for the site. No *E. coli*, clarity or turbidity data was available for the site on the LAWA data platform.

Nitrogen

Total nitrogen, total oxidised nitrogen and dissolved inorganic nitrogen were in the worst 50% of like sites nationally with five-year medians of 0.62 mg/L, 0.44 mg/L and 0.45 mg/L respectively. Nitrate nitrogen is in the worst 50% of upland rural sites nationally but is in the NOF A band for toxicity. Ammoniacal nitrogen is within the best 25% of sites nationally (five-year median 0.05 mg/L) and is in the NOF B band. Dissolved inorganic nitrogen, comprised of total oxidised nitrogen and ammoniacal nitrogen are the bioavailable forms of this nutrient, which can stimulate algal growth. Dissolved inorganic nitrogen just exceeds the One Plan target of 0.444 mg/L for this management sub-zone and all forms of nitrogen are found in significantly greater concentrations than the Larsons Road site upstream.

The significant increases in nitrogen concentration from the upstream site are attributable to the greater proportion of intensive dairy farming land in the catchment contributing to the Hukanui Road monitoring site.

Phosphorus

Dissolved reactive phosphorous (five-year median 0.003 mg/L) and total phosphorous (five-year median 0.01 mg/L) were in the best 50% of like sites. Dissolved reactive phosphorous is well below the One Plan target of 0.01 mg/L for the middle Mangatainoka management sub-zone.

Macroinvertebrates

Ecological data showed a five-year median MCI of 108 (NOF C band) and QMCI of 6.10 (NOF B band), classed as indicators of 'good' and 'excellent' water quality respectively. Five-year median ASPM was 0.509 and was within the NOF B band. The median taxonomic richess was 23 taxa and 45% of those taxa were sensitive EPT species. No trends in macroinvertebrate data were available.

A reduction in macroinvertebrate health has been recorded in the last five years between the upstream Larsons Road and downstream Hukanui Road sites and this is likely related to the increase in contaminants (such as nitrogen or fine sediment) from the increasing proportion of intensive dairy farming in the catchment contributing to the monitoring site.

3 Site surveys for ecological and habitat quality assessment

The Mowbrays Road gravel extraction reach (Figure 2) and an upstream control reach were assessed for ecological, cultural, and habitat quality features on 2 February 2022 by Kate McArthur (consultant ecologist – KM Water), James Kendrick (cultural expert – Kahungunu ki Tāmaki-nui-a-Rua) and Thomas Kay (Kahū Environmental). Two types of assessment were undertaken:

1. 'On-the-ground' / instream assessments at a single site in each of the control and gravel extraction reaches (this was used to measure fine sediment cover, substrate particle size, macroinvertebrates, clarity, cultural measures, etc.).
2. Desktop-based assessments of aerial orthomosaic imagery produced with a drone (this was used to estimate the area of different flow types, sinuosity, area of shading, etc.).

Figure 3 shows the gravel extraction and control reaches (indicated by red dashed lines) and the locations of on-the-ground/instream surveys (white dots). It also provides an indication of surrounding land uses.

Figure 2: *Looking downstream over the Mangatainoka River at Mowbrays Road. Mowbrays Rd can be seen behind the rail bridge on the left of the river.*

Figure 3: *Mowbrays Road gravel extraction reach (bottom) and upstream control reach (top).*

3.1 Summary of methods

On-the-ground assessments at each site included:

1. 'Walk over' and bankside assessments of deposited fine sediment, river morphology, and riverbed/bar partical size
2. Instream visual assessments of deposited fine sediment (using transects and a bathyscope).[1]
3. Visual clarity (using a clarity tube)*
4. Benthic macroinvertebrates[2] (using a kick net)*
5. Shuffle index[3]
6. Particle size distribution using a Wolman walk[4]
7. Cultural health index assessment using the Atua domain[5]*

   *Gravel extraction site only

Desktop assessment using aerial drone imagery included:

1. Flow types (riffles, runs, pools, backwaters)
2. Instream cover
3. Sinuosity
4. Overhanging vegetation/shading

The full method for HQI assessment is provided in Appendix 1.

3.2 Flow

River flow at the nearest recording location (Mangatainoka at Larsons Rd) was approximately 253 l/s during the survey.[6] This flow is significantly less than the 7-day mean annual low flow (MALF) recorded for the site (using flow records collected between 1983 and 2006) by Henderson and Diettrich (2007) of 395 l/s and is close to the minimum recorded flow for that time period of 211 l/s. The long-term median flow for the Mangatainoka at Larsons Road Bridge is 2,130 l/s. Flows were very low when the baseline surveys were undertaken, this needs to be accounted for when comparing with future survey data.

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[1] Using the SAM2 protocols of Clapcott et al (2011).
[2] Macroinvertebrates were collected from riffles using a kick net, visually identified onsite, and returned live to the stream. The MCI was estimated from the observations and later coroborated by nearby SOE ecological monitoring data.
[3] Clapcott et al. (2011).
[4] Wolman (1954).
[5] Young et al. (2008).
[6] https://envirodata.horizons.govt.nz/?siteName=Mangatainoka%20at%20Larsons%20Road&collectionName=Flow

4 Results

4.1 Fine sediment

Baseline deposited fine sediment was significantly greater at the downstream site (27%) within the proposed extraction reach than at the upstream control site (2%) according to the results of the instream visual assessment (SAM2 protocols of Clapcott et al., 2011). The fine sediment observed at the site was predominantly fine sand (<2mm) as opposed to silt. However, Clapcott et al. (2011) propose the maximum percent cover of the bed by fine deposited sediment should not exceed 20% to protect instream biodiversity and fish spawning habitat. Deposited sediment greater than 25% is considered to have adverse effects on recreational and aesthetic values.

There was some evidence of recent extraction or river control works at the upstream control site in the vicinity of a grade control structure (Figure 4) and wire groynes. It is possible the increase in fine deposited sediment on the bed of the downstream proposed extraction site has resulted from upstream works. Enquiries have been made with the Regional Council Area Engineer to ascertain the nature and timing of works upstream. No consented works have been confirmed for the area. It is possible the potential negative effects of this sediment cover on the habitat of instream aquatic life have been 'softened' to some degree by the relative intactness of other important components of stream habitat through this reach — for example, the diversity of flow types.

Figure 4: *Grade control structure in the upstream control reach with flattened gravel beaches suggesting engineering works or gravel extraction has recently occurred.*

4.2 Water quality

Clarity at the proposed extraction site was assessed using a clarity tube. Observations of clarity exceeded the length of the tube (i.e., >1 metre), indicating high water clarity and low turbidity. The clear state of the water is beneficial to sight feeding fish and improves recreational, aesthetic and cultural values at the site.

Water quality degrades markedly in this stretch of the middle Mangatainoka River (in particular through increased nitrogenous nutrient concentrations). Small patches of filamentous green algae were observed, including some growth of potentially toxic benthic cyanobacteria beginning to establish within riffle habitats.

4.3 Macroinvertebrates

Macroinvertebrate samples collected at the proposed extraction sites contained a wide range of sensitive mayfly and caddisfly taxa as well as clean water diptera taxa and a low density of snails. Samples were congruent with the 'good' to 'excellent' classification for water quality from the long-term ecological data from the upstream and downstream SOE monitoring sites described above.

An unidentified bully (*Gobiomorphus spp.)* was collected in the kick net during macroinvertebrate sampling and more bullies and several large rainbow and brown trout were sighted in pools and deeper runs.

4.4 Fish and large invertebrates in the Mangatainoka Awa

Ten indigenous fish species have been recorded in the Mangatainoka catchment in 293 freshwater fish database records (Table 1), along with kōura (freshwater crayfish), kākahi (freshwater mussel) and introduced brown and rainbow trout. Of the ten indigenous fish, eight are migratory fish, requiring access to and from the sea to complete their life-cycles. Three species (shortjaw kōkopu, lamprey and freshwater mussel), are listed as threatened and nationally vulnerable and a further three species (longfin eel, kōaro and torrentfish) are at risk of becoming threatened and declining in population nationally (Dunn et al. 2018; Grainger et al. 2014).

The recent record[7] of *E. aucklandica* in the Mākakahi tributary of the Mangatainoka outside of their traditional Northern range may be an indicator

[7] 1 July 2021 by Wildland Consultants Ltd.

of Māori translocation of this species into the catchment, which is more likely to be naturally populated by *E. menziesii.* *E. aucklandica* are found in Wairarapa Moana and thought to have been translocated there by Māori.

Table 1. Fish and large invertebrate freshwater taonga species in the Mangatainoka catchment (New Zealand Freshwater Fish database records 1918 - 2021).[8]

Common name	Scientific name	Threat status
Shortfin eel	*Anguilla australis*	Not threatened
Longfin eel	*Anguilla dieffenbachii*	At risk – declining
Shortjaw kōkopu	*Galaxias postvectis*	Threatened – nationally vulnerable
Kōaro	*Galaxias brevipinnis*	At risk – declining
Upland bully	*Gobiomorphus breviceps*	Not threatened
Cran's bully	*Gobiomorphus basalis*	Not threatened
Common bully	*Gobiomorphus cotidianus*	Not threatened
Common smelt	*Retropinna retropinna*	Not threatened
Kanakana/pīharau (lamprey)*	*Geotria australis*	Threatened – nationally vulnerable
Torrentfish	*Cheimarrichthys fosteri*	At risk – declining
Kōura (freshwater crayfish)	*Paranephrops planifrons*	Not threatened
Kākahi (freshwater mussel)	*Echyridella aucklandica*	Threatened – nationally vulnerable
Brown trout	*Salmo trutta*	Introduced
Rainbow trout	*Oncorhynchus mykiss*	Introduced

*Only one observation of lamprey for the Mangatainoka catchment exists for 1918.

4.5 Atua domain assessment results

A cultural health index assessment was undertaken during the site visit relying on the expertise of James Kendrick in assessing the cultural values of the site. The assessment used the Atua domain assessment developed by Young et al.

[8] The Manawatū catchment is no. 325 in the New Zealand Freshwater Fish Database. Mangatainoka is catchment 325.201.

(2008) and used for previous cultural values assessments by Kahungunu ki Tāmaki-nui-a-Rua in the Tararua District with respect to wastewater treatment plant discharges and river control works at Ngāawapūrua (the confluence of the Manawatū and Tiraumea Rivers).

The overall score was 49.5 out of a possible 75 with the highest scoring attributes in the domain of Tangaroa, reflecting the high water quality, ecological health, water clarity and the overall health/well-being and positive feelings felt at this site. This is the highest cultural health index score for a measured site in the Mangatainoka catchment by Kahungunu ki Tāmaki-nui-a-Rua whānau and was marginally higher than the Mangatainoka Awa measured near the Pahiātua Township.

Cultural values for the proposed extraction site are high and there are significant historical associations with nearby pā, urupa and he ara haere (navigational routes) elevating the mana of this site for Kahungunu whānau.

4.6 Habitat Quality Index (HQI) baseline

Drone and desktop surveys showed both the upstream (control) and downstream (gravel extraction) reaches have a range of habitat available for indigenous fish, including a mosaic of flow types, instream wood, and undercut banks.

Baseline measurements for HQI assessment are provided in Table 2 below. Spaces for measurements 'after' the gravel extraction and the associated HQI scores have been left to indicate these will be completed following a future survey. It is at that point that HQI scores will be able to be calculated to quantify potential impacts of gravel extraction.

Riparian vegetation and floodplain width are not proposed to be affected by the gravel extraction so were not measured. They would be assigned an HQI score of 1.00 by default if unchanged. If they are found to be affected, they can be measured from the survey imagery later.[9]

Maps illustrating the measurement of habitat variables are provided in Figures 5 to 8. A full description of methods used to assess each habitat variable is provided in the Appendix.

[9] Imagery and GIS files can be sourced from the authors.

Table 2: *Habitat measurements for the control (upstream) and gravel extraction (downstream) reaches before the planned gravel extraction. Spaces for measurements 'after' the gravel extraction and the associated HQI scores have been left blank to indicate these will be completed following a future survey. Measurements are approximate.*

	Control (Upstream)			Extraction (Downstream)		
	Before	After	HQI	Before	After	HQI
Substrate						
Deposited Sediment (% without) (representative run habitat)	97.7			72.85		
Particle Compaction[1]	2			1		
Inorganic Substrate Diversity (Simpson's Diversity Index)[2]	0.89			0.88		
D_{50} (mm)	43			30		
Instream Cover						
Undercut Banks (m)	280			336		
Instream Wood (m^2)	273			1114		
Macrophytes (m^2)	0			0		
Flow Types						
Riffles (m^2)	2879			3125		
Runs (m^2)	12,592			28,283		
Pools (m^2)	6715			8293		
Backwaters (m^2)	1064			2500		
Riverbank						
Overhanging Vegetation (%)	15			17		
Sinuosity	1.53			1.66		
Riparian Vegetation (non-grass)[3]	n/a			n/a		
Floodplain Width[3]	n/a			n/a		
Results						
HQI (median)						
HQI (mean)						
Maximum individual component reduction						

[1] 1 = Loose, 2 = Mostly loose, 3 = Moderately packed, 4 = Tightly packed

[2] A number closer to 1 represents higher diversity. See appendix for formula.

[3] Riparian vegetation and floodplain width are not proposed to be affected by the gravel extraction so were not measured. They would be assigned an HQI score of 1.00 by default if unchanged. If they are found to be affected, they can be measured survey imagery later.

Figure 5: *Upstream control reach aerial orthophoto (left) and mapped flow types (right). The start of the downstream (gravel extractrion) reach can be seen at the bottom of the images.*

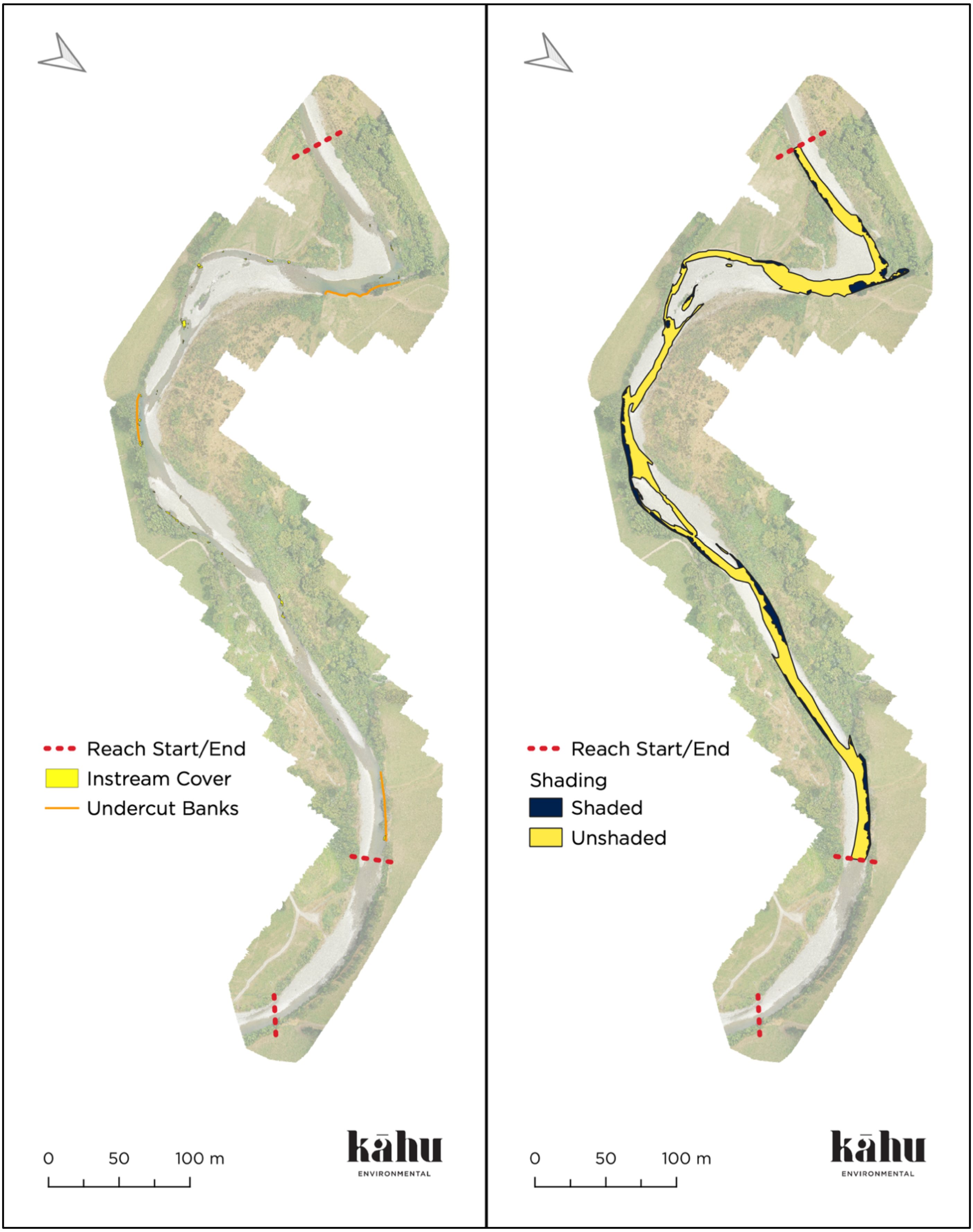

Figure 6: *Upstream control reach instream cover and undercut banks (left) and shading/overhanging vegetation (right). The start of the downstream (gravel extractrion) reach can be seen at the bottom of the images.*

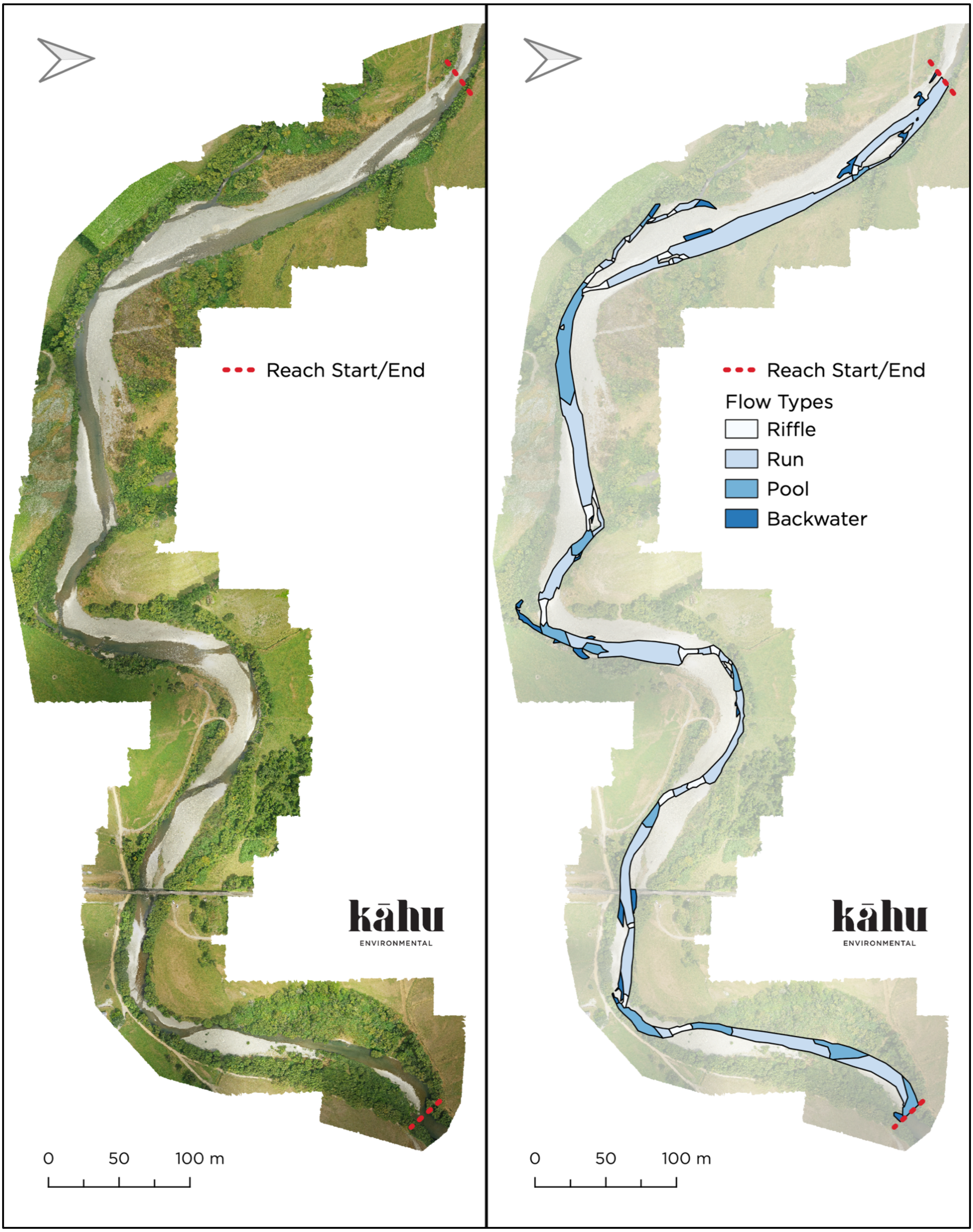

Figure 7: *Downstream (gravel extraction) reach aerial orthophoto (left) and mapped flow types (right).*

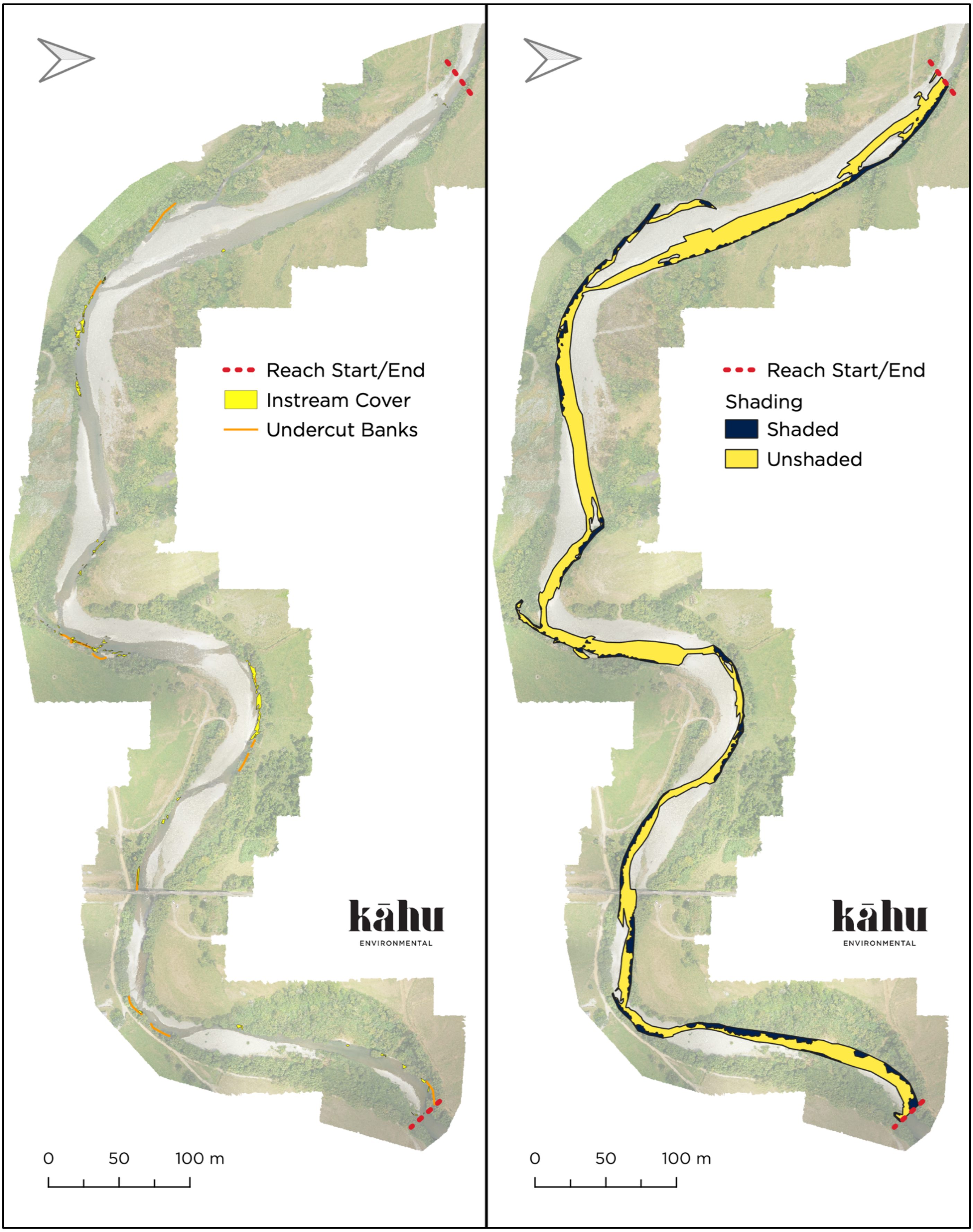

Figure 8: *Downstream (gravel extraction) reach instream cover and undercut banks (left) and shading/overhanging vegetation (right).*

5 Conclusion

Ecological health in the Mangatainoka Awa in the vicinity of the proposed gravel extraction site is good to excellent, as indicated by macroinvertebrates and some attributes of water quality. A healthy range of indigenous fish and large invertebrates (including taonga species) are known to inhabit the catchment, including threatened and at risk taxa. Water clarity was very good at low flows (approx. 253 l/s, as noted above) at the proposed extraction site. At the upstream (control) site deposited fine sediment was low. However, deposited fine sands are found in the vicinity of the proposed extraction reach at proportions with the potential to have adverse effects on benthic biodiversity and aquatic life. It is possible the intactness of other physical habitat (the mosaic of flow types, instream cover, etc.) compensate somewhat for this higher level of fine deposited sediment cover.

Cultural values at the extraction site are high and the cultural health assessment results reflect the health and well-being of the site.

Both the upstream (control) and downstream (gravel extraction) reaches have a range of important habitat available for indigenous fish, including a mosaic of flow types, instream wood, and undercut banks. With a baseline for these variables now established, future surveys can be used to determine whether the planned gravel extraction is having an effect on the habitat and to inform potential remedial actions to be undertaken.

5.1 Recommendations

As kaimahi/kaitiaki from the Mangatainoka Awa, tangata whenua representatives may express different or more stringent views and recommendations for how the consent should proceed (or not) and what consent conditions may be imposed.
Whilst we have recommended below potential steps which may reduce the impacts of the gravel extraction on tangata whenua and ecological values, we acknowledge that we do not speak for tangata whenua and we are not cultural experts of this awa.

Recommendations:

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avoid, remedy, or mitigate the impact of their activities on the awa and the aquatic life it supports.

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Appendix

Habitat Quality Index — Assessment Methods
Thomas Kay. 17/02/2022.

HQI assessment involves measuring components of physical habitat (relevant to fish likely to be present at a site) before and after an activity, such as flood protection engineering, in a section of river and quantifying the changes caused by the activity.

In this case, gravel extraction is proposed on the unwetted bars of a reach of the Mangatainoka River. A survey of the reach, as well as an upstream 'control' reach (which can be used to help determine if changes in the gravel extraction reach should be attributed to floods or other natural changes), was undertaken using the Habitat Quality Index (HQI) protocol used in Kay (2020) on 2 February 2022. Drone imagery was collected covering the entirety of the gravel extraction reach (2426m) and for a representative length of control reach upstream (1550m) (this reach was shorter as it was limited by the remaining capacity of the drone batteries).

Indigenous fish species likely to be present in the survey reaches were identified using data in the Freshwater Fish Database (NZFFD) (see Table 1 in the report above). Ten indigenous fish species were identified in total. Habitat variables important for five of these species were then identified using the information collated by in Petrove et al. (as summarised in Death et al., n.d.).[10] Habitat variables were then measured using a combination of aerial orthophotos and on-the-ground assessments.

Aerial surveys were undertaken using a DJI Mavic 2 Pro drone. Flights were pre-programmed and flown automatically using the DJI Groundstation Pro app. They followed a grid pattern capturing nadir images with 75% front and 65% side overlap using the 'hover & capture at point' setting. A flight elevation of 122 m (400 ft) above ground level (AGL) was used to achieve a Ground Sampling Distance (GSD) of approximately 2.7-2.9 cm (i.e. each pixel in the photos taken measures 2.7-2.9 cm in reality). A mixture of automatic and manual image settings was used, a polarised filter was used, and images were saved in JPEG format.

Orthophotos of the survey reaches before and after engineering were then produced in the open-source Structure from Motion (SfM) software Web

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[10] This was limited to five species as the other fish species were not covered in Death et al. (n.d.). One variable important to one species, 'stream bank height', was not included as it was impractical to measure across such long reaches, and there were not sufficient drone batteries or computing power available to capture sufficient imagery to create 3D models of the stream banks for desktop measurement later. Despite this, it is considered the variables measured provide a good representation of relevant habitat variables for all indigenous fish species present.

OpenDroneMap (WebODM).[11] Orthophoto processing was undertaken using WebODM's 'Lightning Network' cloud processing service (https://webodm.net/) with mostly default settings.[12] WebODM processing reports can be accessed by contacting the authors.

The methods used to assess each of the habitat variables are described below:

Substrate

Deposited fine sediment was assessed using in-stream visual estimate method SAM2 (Clapcott et al., 2011). It was estimated by an observer in the river (with a bathyscope along transects) as the percent cover of fine sediment within a representative run habitat upstream of and then within the gravel extraction reach. 'Percent cover' values were converted to 'percent without cover' to ensure any change in this metric will be consistent with other HQI scores (Death et al., n.d.).

Particle compaction was assessed on a scale of 1-4, where 1 = Loose, easily moved substrate, 2 = Mostly loose, little compaction, 3 = Moderately packed, and 4 = Tightly packed substrate (Harding et al., 2009).

Substrate diversity (Simpson's Diversity Index) and the D_{50} were calculated based on phi class using data from a Wolman pebble count of 50 pebbles (Wolman, 1954) undertaken with a gravelometer, in the same representative run reaches used for sediment assessments.

Simpson's Diversity Index (D) was calculated as:

$$D = 1 - \frac{\sum n(n-1)}{N(N-1)}$$

n = number of clasts in each category
N = total number of clasts of all categorys

High scores (closer to 1) indicate high diversity. Low scores (closer to 0) indicate low diversity.

[11] WebODM is comparable in its approach and performance to commercial SfM software such as Pix4D, DroneDeploy, and AgiSoft Photoscan. See Toffanin (2020) for performance comparisons.

[12] Except for auto boundary, build-overviews, fast-orthophoto, optimize-disk-space, and skip-3dmodel, which were all turned on (set to 'true').

Instream cover

The length of undercut banks and the area of instream cover (wood and macrophytes) were visually estimated from aerial orthophotos and traced in QGIS. Delineation was based on the assessor's judgement, and can be refined if necessary against future survey imagery.[13]

Flow types

The area of riffles, runs, pools, and backwaters was assessed by tracing their extent in aerial orthophotos using QGIS. The combined area of each flow type was then calculated. Delineation was based on the assessor's judgement, and can be refined if necessary against future survey imagery.[14]

Riverbank

Overhanging vegetation was visually estimated from aerial orthophotos and traced in QGIS as the area of vegetation covering the wetted channel. The area of cover was calculated and then converted to percent cover.

Sinuosity was calculated in QGIS by measuring the distance between the start and end points of each reach following the midpoint of the wetted channel, then dividing this by the straight-line distance between the two points.

Riparian vegetation and floodplain width are not proposed to be affected by the gravel extraction so were not measured. If they are found to be affected, they can be measured from the survey imagery later.[15]

[13] Imagery used to produce this report can be accessed from the authors.

[14] As per above footnote.

[15] As per above footnotes.

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Disclaimer

We have used various sources of information to write this report. Where possible, we tried to make sure that all third-party information was accurate. However, it's not possible to audit all external reports, websites, people, or organisations. If the information we used turns out to be wrong, we can't accept any responsibility or liability for that. If we find there was information available when we wrote our report that would have altered its conclusions, we may update our report. However, we are not required to do so.

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VERSION	DATE	AUTHOR	REVIEWER	COMMENTS
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