Effects of Flood Protection Activities on Aquatic and Riparian Ecology in the Otaki River

Greater Wellington Regional Council (Flood Protection)

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MWH

BUILDING A BETTER WORLD

QUALITY STATEMENT

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Executive Summary

Greater Wellington Regional Council (GWRC) is seeking resource consents to allow for the continuation of its river management activities in the following parts of the Otaki River system ("the application area"):

- an 11 km length of the Otaki River, from the Otaki Gorge to the coastal marine area (CMA), and part of the river lying in the CMA,
- a 2.5km length of Rangiuru Stream,
- a 2km length of Ngatoko Stream,
- an 0.8km length of Waimanu Stream, and
- a 3.5km length of Pahiko/Katihiku drains.

The consent applications are described in detail in Tonkin and Taylor (2015). In parallel with preparation of these consent applications, GWRC has developed an Environmental Code of Practice (Code) and Monitoring Plan (EMP) which is intended to monitor and guide how all flood protection and erosion controls are undertaken (GWRC, working draft 2015).

The present report forms part of the consent application documentation. It describes the current state of watercourses within the application area, outlines the proposed flood protection activities, and provides an assessment of the potential effects of the proposed flood protection activities on river ecology. It also makes recommendations on measures that could potentially avoid or mitigate adverse effects, and environmental monitoring that should be undertaken to provide the ability to adaptively manage these activities and to provide for the maintenance or enhancement of aquatic ecosystem health. The recommendations of this report have been taken into consideration in the development of the Code and EMP.

The Otaki River drains the central Tararua Range and has a catchment area of 345 km^2. This is almost three times the size of the nearby Waikanae River catchment and the largest of all catchments on the western side of the Wellington Region. Almost 90% of the catchment is mountain or steep hill country in the Tararua Forest Park, with a base geology of hard sedimentary rock. The river emerges from the Forest Park through a series of gorges onto the Kapiti Coast plain. It flows for about 10km across this plain before discharging via an estuary to the Tasman Sea just south of Otaki Township. The Otaki River and tributaries support a moderately diverse fish fauna including the threatened (Nationally Vulnerable) shortjaw kokopu and seven fish species considered to be at risk (Declining). Brown trout are found throughout the river system and constitute a valued trout fishery. The river system supports breeding populations of three species of shorebird; the pied stilt, considered to be 'at risk' (Declining), the threatened banded dotterel (Nationally Vulnerable) and the black fronted dotterel. The river also supports a small colony of black shag. In addition the estuarine reach of the river provides important roosting and feeding habitat for a number of threatened shorebirds.

GWRC proposes that the full 'tool box' of flood protection activities as described in the Code should be available for use in the Otaki River application area. Many of the flood protection activities assessed here are identified as having potential adverse effects on the river ecology due to changes in water quality, riverine or riparian habitat, or due to direct impacts on river bird, benthic macroinvertebrate or fish communities. In many cases the adverse effects of individual works will be temporary, or can be avoided or mitigated by the application of good practice methods as specified in the Code, and by scheduling the works so as to avoid periods of peak sensitivity at specific locations, such as river-bird nesting, fish spawning and peak fish migrations.

Some practices such as the establishment of vegetative buffer zones, willow planting and layering, and construction of rock groynes, will have mostly positive effects on river ecology, while other activities involving a greater level of disruption to benthic habitats will tend to have more negative effects.

Bed recontouring, channel re-alignment and gravel extraction are identified as having the greatest potential for adverse effects on river ecology in the short term. These activities involve major mechanical disturbance of benthic habitats, and create a visible discharge plume as well as increased rates of fine sediment deposition downstream. Research conducted on rivers in the northern Wairarapa Valley shows that individual works on short reaches (100m to 150m lineal length) do not have a lasting

adverse effect on benthic ecology or fish communities, and that adverse effects are not likely to last much beyond the first fresh. More recently a study conducted in the Hutt River at Belmont shows that bed disturbance over a 220mm lineal length resulting in the loss of swift riffle habitat can have a more lasting effect, probably requiring a series of high river flow events to re-establish good riffle habitat. This could have been improved if the channel realignment had been based on creation of a meander pattern (which it was not) and reconstruction of some channel complexity had been incorporated into the works.

The potential effects of larger scale works, for instance where mechanical disturbance of the river bed extends over river lengths greater than 800m, are less well characterised, mainly because works on that scale occur infrequently and the opportunity to assess the effects of such activities has not arisen in recent years. It is assumed that the scale of effects might increase roughly in proportion with the scale of works, but that hypothesis is yet to be tested. For this reason the EMP proposes a tiered ‘event’ monitoring approach, with increasing monitoring effort required for larger scale work sites.

It is recognised that information on the cumulative effects of multiple small works undertaken at different locations and at different times is currently limited. Effects of this type are more difficult to identify and will not necessarily be detected by monitoring focused on individual works sites. For this reason, in addition to the proposed event monitoring, an ongoing baseline programme is proposed to detect changes in geomorphological characteristics at specified river reaches over time, utilising a natural character index (NCI) to combine these various monitoring results. Baseline monitoring will also include biological variables and it is anticipated that, in the longer term, the monitoring programme will provide an improved understanding of the relationship between natural character and ecological health.

The results of monitoring under the EMP will feed into a regular review of the activities and processes specified in the Code with the aim of improving environmental and other outcomes over time.

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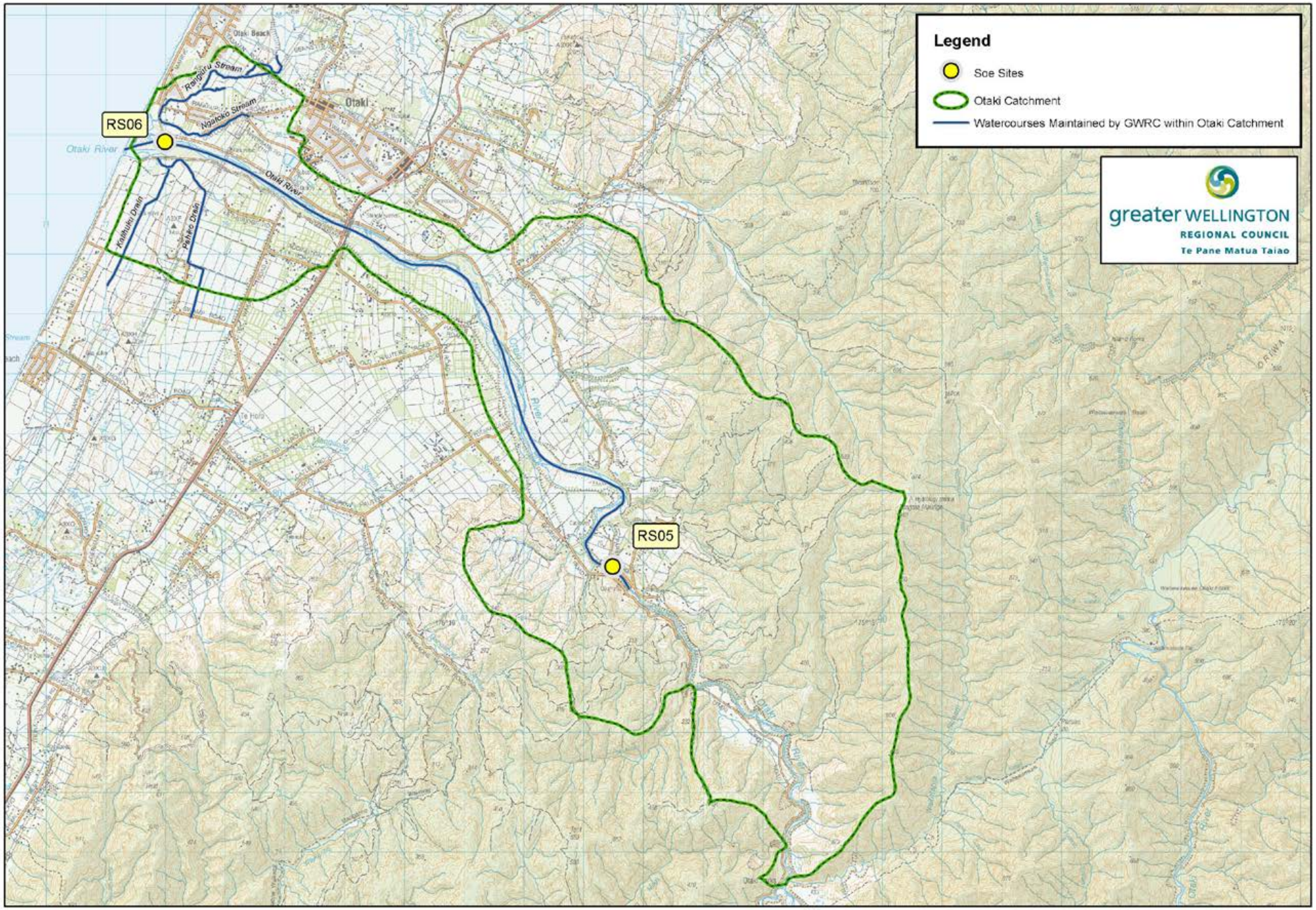
1 Introduction

Greater Wellington Regional Council (GWRC) has a responsibility to manage the region's waterways for the minimisation and prevention of flood and erosion damage, as well as the maintenance of aquatic ecosystem health. GWRC's Flood Protection Department (Flood Protection) has lodged resource consent applications to undertake flood protection activities in an 11 km length of the Otaki River, from the Otaki Gorge to the coastal marine area (CMA), and part of the river lying in the CMA. It will also cover parts of Rangiuru, Ngatoko and Waimanu Streams as well as the Katihiku and Pahiko Drains (refer Figure 1-1). Consent will be sought for 35 years.

The new consents are intended to replace existing consents that currently allow for flood protection activities on these watercourses. The consent applications are described in detail in Tonkin and Taylor (2015).

The aim of this report is to describe, as far as is practicable based on available information, the current state of watercourses within these areas and at nearby reference locations (Section 3), to outline the proposed flood protection activities (Section 4), and to assess the potential effects of the proposed flood protection activities on river ecology (Sections 5 & 6). It makes recommendations on measures that could potentially avoid or mitigate adverse effects (Section 7), and environmental monitoring that should be undertaken to provide the ability to adaptively manage these activities and to provide for the maintenance or enhancement of aquatic ecosystem health (Section 8).

In parallel with this report GWRC has developed an Environmental Code of Practice (Code) and Monitoring Plan (EMP) which is intended to monitor and guide how all flood protection and erosion controls are undertaken (GWRC, working draft 2015). The recommendations of this report have been taken into consideration in the development of the Code and EMP.



0 0.5 1 2 Kilometers

A4 Scale : 1:80,000

Figure 1 - 1 : OTAKI CATCHMENT

Indicating SoE Sites & Watercourses Maintained by GWRC

Drawn : P.cook
Date : 8 Aug 2013

File ref : Otaki Catchment.mxd

2 Information Sources

Information on the water quality and biology of the Otaki River application area and relevant information for other watercourses have been collected from a range of sources as summarised in Table 2-1.

Table 2-1: Information sources used in this report

Source	*Information*	*Sites sampled*	*Other details*
Boffa Miskell (2001)	Riparian vegetation, macroinvertebrates and fish	Five sites on the lower Otaki River	Surveys in January & February 2001
Boffa Miskell (1992)	Various Environmental investigation for Otaki River Floodplain Management Plan	Throughout Otaki River	
Cameron (2015)	Habitat quality, water quality and fish	Three sites on the Hutt River	Before-After-Upstream-Control assessment of FP channel re-alignment works
Cameron (2015a)	Habitat quality, aquatic vegetation, macroinvertebrates	Otaki River Estuary, Rangiuru Stream, Ngatoko Stream, Pahiko drain and Katihiku drain	Site walkover, July 2015
Death & Death (2013)	Habitat quality, deposited sediment, periphyton macroinvertebrates and fish	Three sites on each of the Waiohine, Waingawa and Upper Ruamahanga Rivers	Before-After-Upstream-Control assessment of various FP river works
Department of Conservation BioWeb *Herpetofauna* database.	*Herpetofauna* distributions	1km wide river corridor around the Otaki River application area	Database accessed August 2015 + Trent Bell, unpublished data
Leathwick *et al* 2010	Freshwater Ecosystems of New Zealand (FENZ) Geodatabase	River of New Zealand	Predicted invertebrate and fish distributions
Groundtruth (2013)	Restoration plan for Kathiku	Southern estuary, Pahiko/Katihiku drains	
GWRC data	GWRC water quality, periphyton, macroinvertebrates, landcover, land use	Two SOE sites on the Otaki River system	January 2004 to March 2015
GWRC maps	Application area, GWRC assets, RSoE sites, inanga spawning areas, riparian vegetation, NCI reaches	Entire application area	
New Zealand Freshwater Fish Database (NZFFD)	Fish	25 sites within and upstream of the application area	Data 1960 to 2015
McArthur, Small and Govella (2015)	Birds	Otaki, Waikanae and Hutt Rivers	Baseline monitoring 2012, 2013 and 2014
McArthur, Robertson, Adams and Small (2015)	Birds	Wellington Region	Habitats of significance for indigenous birds
Perrie *et al* (2012); Perrie and Conwell (2013); Morar and Perrie (2013); Heath *et al* (2014).	GWRC water quality, periphyton, macroinvertebrates, landcover, land use	Two SOE sites on the Otaki River	Monthly data from July 2008 to June 2014.
Perrie (2009, unpublished draft)	Habitat quality, periphyton macroinvertebrates and fish	Four sites on the Waingawa River	Before-After-Upstream-Control assessment of FP activities (instream)
Perrie (2013); Cameron (2013)	Habitat quality, macroinvertebrates and fish	Three sites on the Hutt River at the Harcourt-Werry beaches	Before-After assessment of FP gravel extraction works
Robertson & Stevens (2007)	Kapiti Coast risk assessment	Otaki Estuary	

3 Description of Existing Environment

GWRC undertakes flood protection operations and maintenance activities on the Otaki River below the Otaki Gorge to the boundary of the coastal marine area (CMA), a river length of approximately 11.1 km. Also included in the GWRC flood protection area are a number of minor watercourses associated with the River. These are the Rangiuru and Ngatoko Streams which flow into the northern side of the Estuary, the Pahiko and Katihiku Drains to the south of the Otaki Estuary, and the lower part of Waimanu Stream as well as Chrystalls Lagoon.

A detailed aerial view of the application area in the Otaki River, including the minor watercourses, is shown in GWRC Map Series O-243/1-11 included in Appendix A. The Otaki River design channel alignment in the vicinity of the Otaki River Estuary is shown on Figure 3-17.

3.1 Freshwater Habitats

3.1.1 Physical Characteristics

3.1.1.1 Otaki River

The Otaki River drains the central Tararua Range and has a catchment area of 345 km^2. This is almost three times the size of the nearby Waikanae River catchment and the largest of all catchments on the western side of the Wellington Region. Almost 90% of the catchment is mountain or steep hill country in the Tararua Forest Park, with a base geology of hard sedimentary rock. The river emerges from the Forest Park through a series of gorges onto the Kapiti Coast plain. It flows for about 10km across this plain before discharging via an estuary to the Tasman Sea just south of Otaki Township.

Within the Tararua Forest Park there are several significant tributaries including Waitewaiwai and Waitatapia streams to the north and Penn Creek and Waiotauru Stream to the south (note, these upper tributary catchments are not shown in Figure 1-1). On leaving the Tararua Range at the Otaki Gorge, the Otaki River bed gradient flattens for a short distance as it goes through an “S” bend and then steepens as it takes a relatively direct path to the sea across the coastal plain. The gradient across the plain is fairly uniform, dropping about 5m per km, until it flattens out in the last 500-800 m through the tidal estuarine zone near the river’s mouth.

Within the Tararua Range the Otaki River catchment retains its indigenous forest cover; a mix of alpine scrub, beech and broadleaf podocarp. On the coastal plain, natural forest has almost been entirely cleared and land-use is predominantly agricultural. The river takes the form of a semi-braided channel at moderate flows and a single thread channel with alternating gravel beaches during low flows. When the river first emerges from the gorge it is deeply entrenched in alluvial deposits with high gravel banks and terraces. By Chrystalls Bend, about half way across the plain, bank height has markedly reduced and in the reach below SH1 the channel is confined by rock-lined banks. The river has a direct opening to the sea through a gravel spit formation, which is enlarged by flood flows and then reduced by longshore movement of sediment. Large bed material (cobble to boulder) occurs throughout the lower river channel to the sea but there is some reduction in grain size moving downstream as well as an increasing proportion of fine sediment (Thompson, 2011).

GWRC maintains two state of the environment river monitoring sites (RSoE) on the Otaki River, one at Pukehinau just below the forested upper catchment and a second at the Otaki River mouth, approximately 700m upstream of coast. Both sites lie within the reach managed by GWRC Flood Protection; the “Pukehinau” site being located towards the upper end and the “Mouth” site towards the downstream end of the application area. Details of river characteristics at the RSOE sites within the application area are included in Table 3-1. GWRC habitat grades are presented in Table 3-2.

Table 3-1: GWRC RSoE %Land-cover types in contributing catchment (from Perrie, *et al,* 2012)

Site no.	*Site name*	*Site type*	*Habitat grade*	*% Landcover types in upstream catchment*						
				Indigenous forest and scrub	*Exotic forest*	*Horticulture*	*Pasture (high prod.)*	*Pasture (low prod.)*	*Urban (%)*	*Other (%)*
RS05	*Otaki River@ Pukehinau*	Reference	excellent	96	1.5	0.0	0.1	2.0	0.0	0.3

RS06	*Otaki River@ Mouth*	Impacted	fair	88	1.7	0.6	3.1	5.7	0.1	0.8

Table 3-2: Habitat scores for SOE sites assessed in summer/autumn 2014 (from Heath, *et al*,2014)

Site no.	*Site name*	*Fine sediment*	*Invert. habitat*	*Fish cover*	*Hydraulic hetergen-eity*	*Bank stability*	*Bank veg.*	*Riparian buffer*	*Riparian shade*	*Channel alteration*	*Total habitat score (of 220)*
RS05	*Otaki River@ Pukehinau*	20	36	36	18	18	18	19.5	2	20	187.5
RS06	*Otaki River@ Mouth*	15	20	16	10	18	8.5	12.5	1	12	113

3.1.1.2 Rangiuru and Ngatoki Streams

Rangiuru Stream is a small spring fed watercourse, flowing in a highly modified incised channel, through a low lying area which was formerly part of an extensive wetland system. Its longest branch is approximately 2.5km in length, and the stream flows in a south-westerly direction, passing under Rangiuru Road before reaching its confluence with the Ngatoko Stream (Figures 3-1 to 3-3). The stream then flows via a controlled outlet fitted with floodgates under Kapiti Lane and through coastal dunes to the northern side of the Otaki Estuary. The floodgates have been modified to slow the rate closing on the incoming tide to give more time for fish to move from the sea into into the Rangiuru catchment (Anna Burrows, GWRC, pers. com.). The bed substrate of Rangiuru Stream is predominantly sand and gravel. Water clarity is good under base-flow conditions, allowing high light levels on the bed. The results of a habitat assessment conducted on Rangiuru Stream at the Rangiuru Road Bridge during July 2015 show that there is some loss of ecological function due to relatively low hydraulic heterogeneity and low habitat diversity for invertebrates and fish (Tables 3-1 and 3-2). This is mostly due to the predominantly fine gravel/sand substrate with little cobble, boulder or wood. Riparian edge vegetation was often well developed on one bank but sparse on the other. These factors contribute to a low abundance and diversity of habitat for invertebrates and moderate habitat abundance for fish.

Ngatoko Stream is a minor watercourse, approximately 2 km long, which flows across the plain immediately to the north of the Otaki River. It skirts around the southern side of the settlement of Rangiuru before joining with Rangiuru Stream on the eastern site of Kapiti Lane. The stream has been heavily modified by agricultural development, in places removing all of the edge vegetation (see Figure 3-4). This has resulted in significantly degraded habitat quality in the reach beside Old Coach Road South, due to absence of shade or cover over the streambed, lack woody inputs to the stream, and increased inputs of fine sediments from an agricultural catchment.

Figure 3-1: Rangiuru Stream with culvert entrance in foreground

Figure 3-2: View of Rangiuru Stream bed and aquatic macrophytes (beside Kapiti Lane)

Figure 3-3: View of Rangiuru Stream from Rangiuru Road bridge

Figure 3-4: View of Ngatoko Stream at Old Coach Road (South)

Table 3-3: Stream Channel characteristics of minor watercourses in the Otaki application area

Habitat Parameter	*Sampling Site*		
	Rangiuru Stream	*Ngatoko Stream*	*Pahiko/Katihiku drains*
Location	Rangiuru Road Bridge	Old Coach Road	Above stop-bank
NZTM Ref	N5486573; E1778323		
Time sampled	10:30am	10:10am	2:30pm
Mean wetted width (m)	10	3	4
Mean thalweg depth (cm)	0.4	0.2	?
%fine sediment cover	40	40	100
Dominant substrate	Sand/gravel	Sand/gravel	Silt/sand
Periphyton %cover			
Filamentous >2cm long	none visible	30%	none visible
Cyanobacteria >1mm thick	none visible	none visible	none visible
All mats >3mm thick	none visible	20%	none visible
Macrophytes	Submerged *Myriophyllum triphyllum* *Potamogeton crispus* *Nitella hookeri* *Callitriche stagnalis* Emergent *Persicaria decipiens* *Persicaria hydropiper* *Myriophyllum aquaticum*	not assessed	Emergent *Apium nodiflorum* *Carex germinata* *Festuca arundinacea*

Table 3-4: Rapid habitat assessment results summary (using a protocol from Clapcott, 2015)

Habitat parameter	*Sampling Site*		
	Rangiuru Stream	*Ngatoko Stream*	*Pahiko drain*
	Rangiuru Road Bridge	Old Coach Road	Above stop-bank
Deposited sediment	4	3	1
Invertebrate habitat diversity	4	3	2
Invertebrate habitat abundance	2	2	2
Fish cover diversity	3	2	3
Fish cover abundance	6	2	4
Hydraulic heterogeneity	3	3	2
Bank erosion	10	7	7
Bank vegetation	7	1	3
Riparian width	5	1	1
Riparian shade	5	1	1
Habitat quality score (of 100)	49	25	26

3.1.1.3 Katihiku and Pahiko Drains

South of the Otaki River mouth, the Pahiko drain to the east and Katihiku drain to the west were both constructed through the Whakapawaewae wetland as part of the drainage system, some time prior to the 1930s. Whakapawaewae wetland is an ecologically important remnant of a once more extensive wetland which stretched across the coastal plain between the Otaki and Waikanae Rivers.

The drains converge approximately 200m upstream of the stop-bank, passing via a culvert through the stop-bank into the estuary (Figure 3-5). The outflow through the stop-bank is controlled by a flood gate that blocks incoming tidal flows. The drains are cleared annually to maintain capacity and, being constructed and maintained by excavation, are deep, steep-sided waterways. The drains have a soft sediment bed with invertebrate habitat largely limited to macrophytes. Fish habitat is limited in both quality and abundance in the straight sided channels, although prolific macrophytes provide abundant cover.

Figure 3-5: View of Pahiko Drain (left) and culvert through stopbank at Otaki Estuary (right)

3.1.1.4 Waimanu Stream

Waimanu Stream is a minor watercourse which flows into Chrystalls lagoon on the true right bank of the Otaki River, within the floodplain. The lagoon is a man-made structure formed during construction of the flood protection works at Chystalls bend, in order to mitigate loss of habitat resulting from the works. (The lagoon has a tendency to accumulate silt and therefor needs to be cleared by excavator from time to time.) Waimanu Stream flows through the lagoon before entering the Otaki River at the downstream end of the bend. The Stream runs through grazing pasture in its middle and lower reaches, but has retained at least some riparian vegetation for much of its length. The upper reaches run under a cover of mature and/or regenerating indigenous forest and have retained relatively high in-stream values. GWRC manage the lower 800m reach of the Waimanu Stream within the floodplain (Fig 3-6).

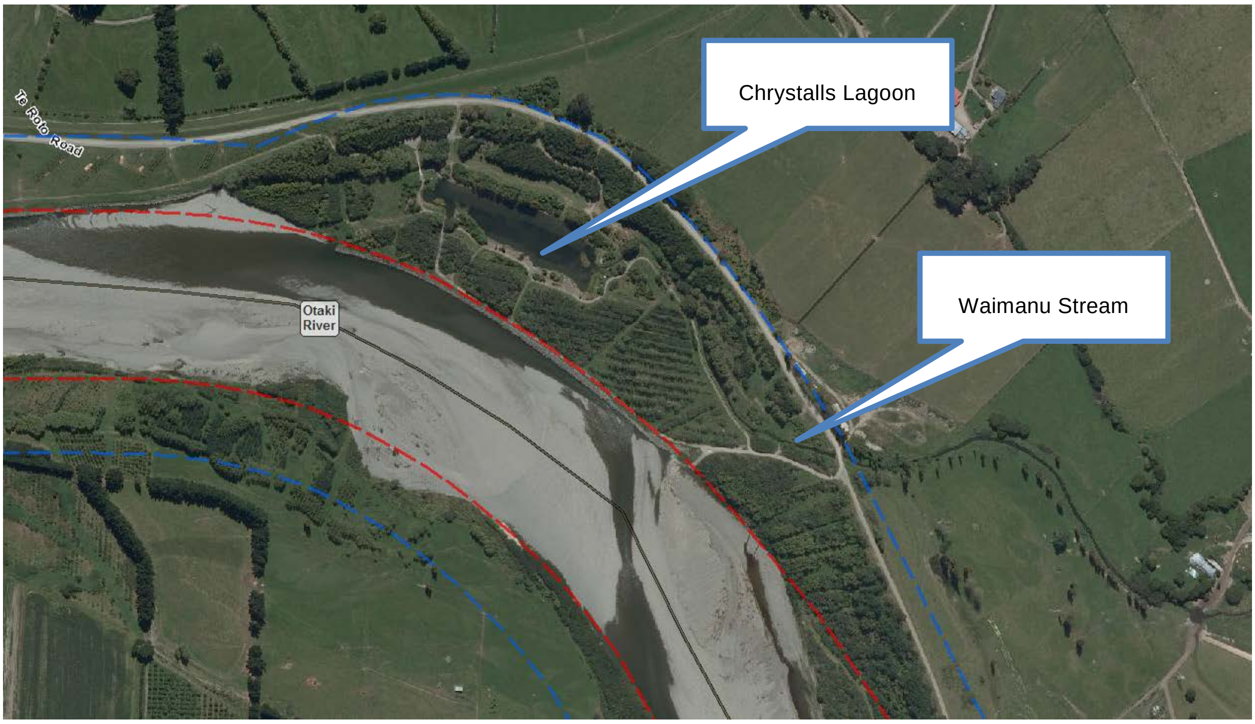


Figure 3-6: Waimanu Stream and Chrystalls Lagoon adjacent to Otaki River. Only the lower reach of the Waimanu Stream (within the blue dashed lines) is within the application area.

3.1.2 Water quality

Surface water quality is routinely monitored by GWRC at two RSoE sites on the Otaki River, one at Pukehinau just below the forested upper catchment and a second at the Otaki River mouth, approximately 700m upstream of coast. Both sites lie within the reach managed by GWRC Flood Protection; the “Pukehinau” site being located towards the upper end and the “Mouth” site towards the downstream end of the application area (refer Figure 1-1).

GWRC uses a water quality index (WQI) to facilitate inter-site comparisons of the state of water quality in the Region’s rivers and streams (Morar & Perrie, 2013). The WQI is derived from the median values of the following six variables: visual clarity (black disc), dissolved oxygen (%sat), dissolved reactive phosphorus, ammoniacal nitrogen, nitrate-nitrite nitrogen and *Escherichia coli (E. coli).* The WQI enables water quality at each site to be classified into one of four categories:

- Excellent: median value of all six variables comply with guideline values.
- Good: median values for five of six variables comply with the guideline values, of which dissolved oxygen is one variable that must comply.
- Fair: median values for three or four of the six variables comply with guideline values, of which dissolved oxygen is one variable that must comply.

- Poor: median values of less than three of the six variables comply with the guideline values.

Guidelines and trigger values used by GWRC in the WQI assessment and more generally to assess the current state of water quality in rivers and streams in the Wellington Region are listed in Table 3-5. WQI grades for the year to June 2014 for RSoE sites located within and upstream of the application area are shown in Table 3-6 and water quality results for the five year period from January 2010 to March 2015 are summarised in Table 3-7.

The annual monitoring report for the year to June 2014 (Heath, *et al*, 2014) graded both sites as having "excellent" water quality (and indeed both sites have achieved an excellent classification for each of the last five years). Although sites RS05 and RS06 are both located within the application area and are potentially affected by flood protection activities, these sites were ranked 3rd and 7th, respectively, out of the 55 RSoE sites monitored in the Wellington Region for the year to June 2014.

Water quality at the RSoE sites at times when the river flow is less than median are summarised in Table 3-8. These results are relevant to the extent that in-river flood protection works are most likely to be undertaken during moderate to low flows. Table 3-8 indicates that total suspended solids and turbidity values are lower and visual water clarity correspondingly higher when river flows are low.

Results of selected variables at sites RS05 and RS6 are summarised by annual boxplot for the years 2004 to 2015 to show trends over time (Appendix B). A Mann-Kendall Trend Test identified increasing trends ($p<0.05$ and rate of change >1% per year) for water clarity at sites RS05 and RS06 over that period. Decreasing trends were detected for turbidity and TP at both sites, and for DRP at Pukehinau only (site RS05).

Table 3-5: Guidelines and trigger values used by GWRC to assess current state of water quality in rivers and stream (after Perrie, et al, 2012)

Variable	Guideline value	Reference	GW WQI
Water temperature (°C)	≤19	Quinn and Hickey (1990) & Hay et al (2007	-
	≤25	Regional Freshwater Plan (RFP) (WRC 1999)	-
Dissolved oxygen (%sat)	≥80	RMA 1991 Third Schedule and WRC 1999 RFP 'bottom line'	✓
pH	6.5-9.0	ANZECC (1992)	-
Visual clarity (m)	≥1.6	MfE (1994) – guideline for recreation	✓
Turbidity (NTU)	≤5.6	ANZECC (2000) lowland TV	-
Nitrate-nitrogen (mg/L)	≤0.444	ANZECC (2000) lowland TV	✓
Ammoniacal nitrogen (mg/L)	≤0.021	ANZECC (2000) lowland TV	-
	Varies	ANZECC (2000) freshwater toxicity TV (95% protection level)	✓
Dissolved inorganic nitrogen (mg/L)	≤0.465	ANZECC (2000) by addition of the nitrate, nitrite and ammonia TVs	-
Total nitrogen (mg/L)	≤0.614	ANZECC (2000) lowland TV	-
Dissolved reactive phosphorus (mg/L)	≤0.10	ANZECC (2000) lowland TV	✓
Total phosphorus (mg/L)	≤0.033	ANZECC (2000) lowland TV	-
E. coli (cfu/100ml)	≤100	ANZECC (2000) stock water TV	✓
	≤550	MfE/MoH (2003) action level for recreation	

Table 3-6: Water Quality Index grades for RSoE sites in the application area (grey) and at upstream sites (unshaded) from monthly samples collected from July 2013 to June 2014 (Heath, et al, 2014)

Site	Site name	Water quality grade	Rank (of 55)	Guideline compliance (median values)					
				DO	Clarity	E. coli	NNN	Amm. N	DRP
RS05	*Otaki River@ Pukehinau*	Excellent	3	✓	✓	✓	✓	✓	✓
RS06	*Otaki River@ Mouth*	Excellent	6	✓	✓	✓	✓	✓	✓

Table 3-7: Summary of GWRC monthly water quality data at Otaki River RSoE sites sampled monthly between Jan 2010 and March 2015 (n=69). Median values that did not meet a guideline are shown in bold font.

Determinand	*Otaki River@ Pukehinau (RS05) (within the application area)*			*Otaki River@ Mouth (RS06) (within application area)*			*Guideline value*
	median	*min*	*max*	*median*	*min*	*max*	
Water temp. (°C)	10.3	3.9	17.1	12.4	5.26	20.3	≤19
DO (%saturation)	99.9	74.8	119	101	67.5	118.8	≥80
pH	7.46	6.19	8.07	7.45	6.3	8.54	6.5-9.0
Visual clarity (m)	4.03	0.120	11.54	2.97	0.08	9.07	≥1.6
Turbidity (NTU)	0.72	0.230	48	0.940	0.260	69	≤5.6
Suspended solids (mg/L)	<1	<1	60	<0.1	<1.0	72	--
Conductivity (µS/cm)	65.2	37	85	67.5	37	86	--
TOC (mg/L)	1.4	0.250	5.5	1.3	0.250	6.7	--
NNN (mg/L)	0.032	0.001	0.073	0.042	0.001	0.116	≤0.444
Ammoniacal N (mg/L)	<0.005	<0.003	0.024	<0.005	<0.003	0.029	≤0.021
Total N (mg/L)	0.055	0.055	0.180	0.055	0.055	0.270	≤0.614
DRP (mg/L)	0.004	0.002	0.011	0.004	0.002	0.009	≤0.010
Total P (mg/L)	0.005	0.002	0.054	0.005	0.002	0.072	≤0.033
E. coli (cfu/100ml)	5	<1	130	30	2	600	≤550

Table 3-8: Median water quality values at Otaki River sites at times when river flow is less than median, from monthly samples collected between 2004 and 2009 (n=31) provided by GWRC.

Determinand	*Otaki River@ Pukehinau (RS05)*	*Otaki River@ Mouth (RS06)*	*Guideline value*
Water temp. (°C)	13.4	15.2	≤19
DO (%saturation)	99	104	≥80
pH	7.42	7.60	6.5-9.0
Visual clarity (m)	4.25	3.21	≥1.6
Turbidity (NTU)	0.71	0.69	≤5.6
Suspended solids (mg/L)	<1	<1	--
Conductivity (µS/cm)	69	70.4	--
TOC (mg/L)	0.86	0.89	--
NNN (mg/L)	0.031	0.035	≤0.444
Ammoniacal N (mg/L)	<0.005	<0.005	≤0.021
Total N (mg/L)	0.055	0.055	≤0.614
DRP (mg/L)	0.0041	0.0025	≤0.010
Total P (mg/L)	0.0068	0.0062	≤0.033
E. coli (cfu/100ml)	5.5	42	≤550

3.1.3 Minor streams

None of the minor watercourses included in the Otaki River application area (Rangiuru Stream, Ngatoko Stream, Waimanu Stream, Pahiko Drain, Katihuku Drain) are part of the GWRC RSoE monitoring programme, and routine water data are not available for these watercourses.

3.1.4 Periphyton

GWRC monitors periphyton cover and biomass at the Pukehinau and river mouth SoE sites. Two data sets are used: monthly observations of percent periphyton streambed cover and periphyton biomass (as indicated by chlorophyll *a* concentration) from annual surveys.

GWRC compares these data sets against the New Zealand periphyton guideline values which are summarised in Table 3-9. The results of periphyton biomass monitoring for the years to June 2010, 2011, 2012, 2013 and 2014 are summarised in Table 3-10. Monthly observations of filamentous and mat forming periphyton covering for the same period are summarised in Table 3-11.

Table 3-9: MfE guidelines used to assess periphyton stream bed cover and biomass (Biggs, 2000)

Instream value	Periphyton cover (%cover)		Periphyton biomass Chlorophyll a (mg/m^2)
	Mat >0.3 cm thick	Filamentous >2cm long	
Aesthetics/recreation	60%	30%	-
Benthic biodiversity	-	-	50
Trout habitat and angling	-	30%	120

Over the five year period from 2010 to 2014 inclusive, the Pukehinau and river mouth sites complied with the MfE guidelines for periphyton biomass on all sampling occasions. Over the same five year period the periphyton cover guideline for filamentous was achieved in 48 of 50 monthly surveys at Pukehinau and in 45 of 50 monthly surveys at the river mouth. The algae 'mat' guideline was achieved in all surveys at both sites. Percent cover of cyanobacteria mats was recorded only for the 2014 year during which both sites complied with the guideline on all monthly sampling occasions. These results show that excessive periphyton growth occurs rarely on the Otaki River, which is consistent with the low proportion of agricultural or urban land-use in the catchment and the consistently low nutrient levels recorded in river water.

Table 3-10: Summary of streambed peripyton biomass at RSoE sites in the Otaki River application area from 2009 to 2014 (after Perrie *et al,* 2011; Perrie and Conwell, 2013; Morar and Perrie, 2013; and Heath, Perrie, & Morar, 2014). Non-compliance with MfE (2000) guidelines is highlighted in bold type

Site no.	*Site name*	*Chlorophyll a (mg/m^2)*				
		2010	*2011*	*2012*	*2013*	*2014*
RS05	*Otaki River@ Pukehinau*	2.2	1.0	0.47	1.56	0.37
RS06	*Otaki River@ Mouth*	2.1	1.8	12.61	2.04	15.35

Table 3-11: Summary of monthly observations of visible streambed filamentous and mat-forming periphyton cover in relation to exceedances of the MfE (2000) guidelines at RSoE sites within the application area for the years to June 2010, 2011, 2012, 2013 and 2014 (after Perrie and Conwell, 2013; Morar & Perrie, 2013; Heath, Perrie, & Morar, 2014).

Year	Site no.	Site name	*n*	Streambed cover (%)						
				Filamentous (>2 cm long)		Mats (>0.3 cm thick)		Cyanobacteria mats (>0.1cm thick)		
				Max	n>30% cover	Max	n>60% cover	Max	n 20-50 %	n>50 %
2010	RS05	*Otaki River@ Pukehinau*	11	39	1	4	0	nt	nt	nt
	RS06	*Otaki River@ Mouth*	12	50	1	12	0	nt	nt	nt
2011	RS05	*Otaki River@ Pukehinau*	9	2.5	0	26.5	0	nt	nt	nt
	RS06	*Otaki River@ Mouth*	9	31	1	16	0	nt	nt	nt
2012	RS05	*Otaki River@ Pukehinau*	10	2	0	1	0	nt	nt	nt
	RS06	*Otaki River@ Mouth*	10	32	1	18	0	nt	nt	nt
2013	RS05	*Otaki River@ Pukehinau*	11	25	0	2	0	nt	nt	nt
	RS06	*Otaki River@ Mouth*	11	70	2	22	0	nt	nt	nt
2014	RS05	*Otaki River@ Pukehinau*	9	0	1	23	0	3	0	0
	RS06	*Otaki River@ Mouth*	9	33	0	0	0	11	0	0

Nt = not tested

3.1.5 Macrophytes

3.1.5.1 Otaki River

No records of aquatic macrophytic vegetation for the Otaki River have been located (other than the salt marsh species listed in Section 3.2). Observations from bankside inspections of the river channel between the SH1 bridge and the river mouth indicate that the River is virtually free of bottom-rooted aquatic macrophytes and that they are not an important feature of the river ecology (D. Cameron pers. obs.).

3.1.5.2 Rangiuru & Ngatoko Streams

Aquatic macrophytes are an important feature of the Rangiuru/Ngatoko stream system. The bed substrate of Rangiuru Stream is predominantly sand and gravel. Water clarity is good under base-flow conditions allowing high light levels on the bed, producing a lush macrophyte growth covering 30 to 40 percent of the stream bed surface at the time of the site inspection (see Figures 3-2 and 3-3). Submerged macrophytes include the native species *Myriophyllum triphyllum* and exotic species such as *Potamogeton crispus* and *Callitriche stagnalis*. Emergent and bankside macrophytes include *Persicaria decipiens*, *Persicaria hydropiper* and *Myriophyllum aquaticum* which form a dense cover in places.

3.1.5.3 Katihiku & Pahiko Drains

The aquatic and bankside vegetation of Pahiko Drain is dominated by water celery (*Apium nodiflorum)*, and tall fescue grass (*Festuca arundinacea*), with patches of native sedges (*Carex germinate* and *Isolepis prolifera*). The grasses and sedge potentially provide inanga spawning habitat (groundtruth, 2013, Taylor & Kelly, 2001), however it is not clear to what extent the area upstream of the flap would be utilised when the flapgates are shut on the spring tides. Inanga spawning habitat is also present downstream of the flapgate, of a slightly lower standard (Taylor & Kelly, 2001).

3.1.6 Riparian vegetation

3.1.6.1 Otaki River

While most native vegetation has disappeared from the river banks below SH1, there are still some good forest remnants in the Otaki Gorge area (mostly upstream of the Otaki River application area). These remnants usually include kohekohe together with species such as mahoe, kaikomaiko (*Pennantia crymbosa*), rewarewa, titoki, tawa, and occasional totara and karaka trees. In an evaluation of rare terrestrial plants in the floodplain, Boffa Miskell (1992) describe a large hebe species with local distribution (*H. angutissima*) growing on steep riverside cliffs and is only known from the Otaki Gorge area, as well as the shrub daisy, *Olearia cheesemanii*, both of which has restricted distribution. However, the known distribution of these species is upstream of the application area and consequently will not be affected by flood protection activities.

Riparian vegetation within the application area is highly modified and has few indigenous elements. The great majority of riparian edge vegetation within the application area is planted willows. Of the 22.2km of total river bank length within the application area, it is estimated that 18.8km (85%) has been planted with willows as vegetative bank protection. Scattered bushes of shrubby weeds such as gorse, lupin and wattle are common. On the edges of the open gravel river bed and gravel bars lupin is common. There are many introduced weeds, grasses and scramblers of which the most ubiquitous are fennel, montbretia, yarrow, purple top, clover, cocksfoot, tall fescue, Yorkshire fog, blue morning glory and greater bindweed (Boffa Miskell, 2001).

Vegetation within the riparian margins is shown in GWRC Map Series O-243 (Maps 1a to 11a), which are included in Appendix A. A GIS layer identifies area of planted willows and native vegetation, but does not provide further detail. GWRC has recognised that more detailed mapping of vegetation types within the riparian margins is desirable and has included this as a baseline monitoring item in the EMP, to be completed within three years of the consents being granted and repeated at 9-year intervals thereafter.

3.1.6.2 Rangiuru & Ngatoko Streams

These watercourses lie within rural and urban landscapes. The stream margins are vegetated with flax, toetoe, grasses and a variety of exotic species to provide a moderately intact vegetation on at least one bank (refer to maps 1 and 9 in Appendix A).

3.1.6.3 Katihiku & Pahiko Drains

The bankside vegetation of Pahiko Drain is dominated by water celery (*Apium nodiflorum*), and tall fescue grass (Festuca arundinacea), with patches of native sedges (*Carex germinata* and *Isolepis prolifera*). The Katihiku drain is dominated by water celery and *Carex germinata.*

3.1.7 Macroinvertebrate communities

GWRC undertakes annual monitoring of macroinvertebrate communities at the Pukehinau and river mouth RSoE monitoring sites. Both sites are located within the Otaki River application area. Macroinvertebrate abundance results from the February 2014 sampling round and from an additional site on Rangiuru Stream (collected by MWH) are included in Appendix C. These results together with predictions from the FENZ database[1] were used to describe core macroinvertebrate communities of the Otaki River, Rangiuru Stream, Ngatoko Stream and Piako/Katihihu Drains (Table 3-12). Macroinvertebrate composition by relative abundance is illustrated in Figure 3-7 and macroinvertebrate metric scores for the period 2010 to 2014 are summarised in Table 3-13.

The Otaki River at the upstream end of the application area (Site RS05) supports a macroinvertebrate fauna dominated by sensitive EPT[2] taxa, which make up 87% of individuals and 62% of taxa recorded at this site. The mayfly *Deleatidium* is the dominant taxa and is often 10-fold more abundant than the next most abundant species, which typically include the caddisfly *Aoteapsyche*, Orthocladiinae midges and the riffle beetle Elmidae*.* Macroinvertebrate Community Index (MCI) and Quantitative Macroinvertebrate Community Index (QMCI) scores indicate “excellent” quality class in the upper river reflecting the high proportion of indigenous forest land cover, the small proportion of agricultural land-use and an absence of urban development.

Deleatidium remains the dominant taxa in the lower Otaki River at RS06 but the abundance of two winged flies (Diptera) is higher than at RS05, probably in response to slightly higher nitrogen levels and increased algae production in the lower river. These changes are reflected in small reductions in MCI and QMCI scores at RS06 compared with RS05. Nevertheless, the biotic index scores indicate good to excellent invertebrate quality classes in the Otaki River near the mouth.

Table 3-12: Otaki River monitoring locations and dominant macroinvertebrate taxa (data from GWRC RSoE, Feb 2014, Cameron, 2015; and FENZ predictions)

Site name	*Catchment land-use*	*Dominant invertebrate taxa (FENZ predictions in brackets)*
Rangiuru Stream R1 (MWH, 2015)	Within application area	*Potamopyrgus>Paracalliope>Phreatogammarus>Ostracoda* *(Potamopyrgus>Austrosimulium>Orthocladiinae>Ostrocoda>Oxythira)*
Piako/Katihihu Drains	Within application area	*(Potamopyrgus>Austrosimulium>Orthocladiinae>Ostrocoda>Oxythira)*
Otaki River@ Pukehinau (RS05)	Indigenous forest 96% Pasture 2.1% Urban 0.0% Within application area	*Deleatidium>Aoteapsyche>Archichauliodes>Olinga>Orthocladiinae* *(Deleatidium>Elmidae>Aoteapsyche>Aphrophila>Olinga>Beraeoptera)*
Otaki River@ Mouth (RS06)	Indigenous forest 88% Pasture 8.8% Urban 0.1% Within application area	*Deleatidium>Orthocladiinae>Tanytarsini>Aoteapsyche* *(Deleatidium>Elmidae>Aoteapsyche>Aphrophila>Olinga>Beraeoptera)*

[1] Leathwick, et al , 2010: Freshwater ecosystems of New Zealand (FENZ) Geodatabase

[2] EPT includes sensitive taxa from the Ephemeroptera (mayfly) Plecoptera (stonefly) and Trichoptera (caddisfly) insect groups.

Table 3-13: Mean macroinvertebrate metric scores (and standard deviation) at the Otaki River and Rangiuru Stream RSoE sites based on GWRC data collected annually in 2010, 2011, 2012, 2013 and 2014. MCI and QMCI quality classes (from Stark & Maxted 2007) are also included.

Site no.	*Site name*	*N*	*MCI*	*QMCI*	*N. Taxa*	*N. EPT taxa*	*%EPT taxa*	*%EPT indiv.*
R1	Rangiuru Stream (MWH, 2015)	1	63.9 (Poor)	3.2 (Poor)	16	1	6	
RS05	*Otaki River@ Pukehinau*	5	132.3 (4.95) (Excellent)	7.37 (0.31) (Excellent)	18.2 (3.70)	11.2 (2.17)	62.4 (8.99)	88.6 (2.34)
RS06	*Otaki River@ Mouth*	5	112.5 (13.7) (Good)	6.87 (0.87) (Excellent)	16.2 (2.49)	6.8 (1.64)	42.4 (11.43)	80.1 (11.8)

Note: [1]R1 Rangiuru Stream data from MWH, July 2015.

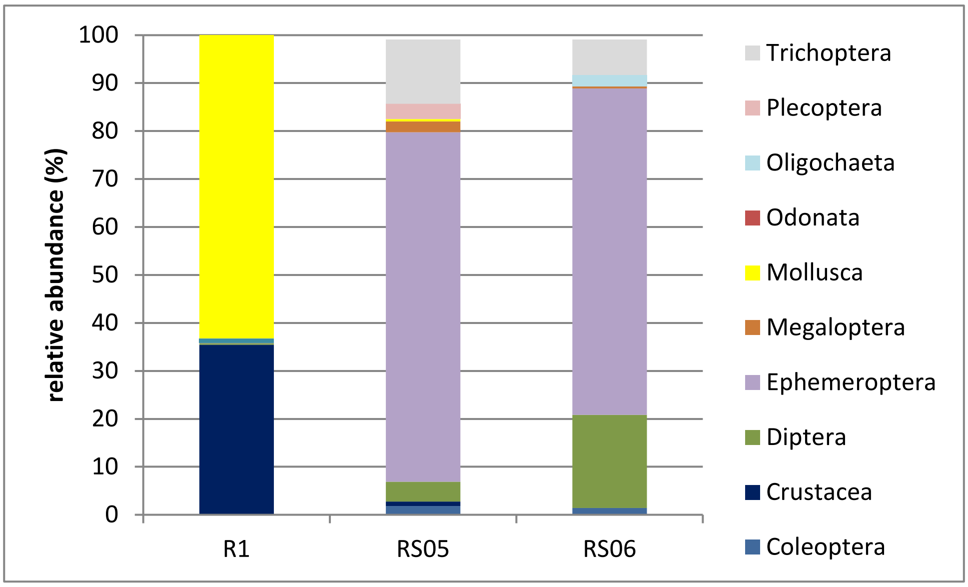


Figure 3-7: Macroinvertebrate community composition by relative abundance at sites on the Otaki River and Rangiuru Stream.

3.1.7.1 Limitations of the data

All of the macroinvertebrate monitoring data assessed as part of this investigation have been collected from wadeable areas in riffle or fast-run habitat, in accordance with standard protocols for sampling macroinvertebrate in New Zealand (i.e. Stark, et al, 2001; Stark & Maxted, 2007). It is recognised that macroinvertebrate communities in pools and slow runs have not been described.

Similarly, we have not sighted any specific information on the macroinvertebrate fauna that live within the gravel substrate of the Otaki River; that is the hyporheic invertebrates. Inhabitants of the hyporheic zone, defined as the water saturated sediment beneath the streambed, includes the “permanent hyporheos”, mainly small crustaceans, mites and worms that spend their entire life cycles there, as well as the “occasional hyporheos” which comprises insects, snails and other taxa more typically associated with surface sediments (Winterbourn & Wright-Stow, 2003). In the absence of specific information it has been assumed for the purpose of this assessment that flood protection activities which include mechanical disturbance of bed material, such as bed re-contouring and gravel extraction, will affect both habitat types, and that the effects on the hyporheos may be of a similar order to those documented for benthic fauna at the surface.

3.1.7.2 Comparison between the application area and upstream reaches

Both of the GWRC RSoE monitoring sites on the Otaki River are located within of the application area and are potentially affected by flood protection activities. Consequently a direct comparison between ‘affected’ and ‘unaffected’ reaches has not been made. Nevertheless, we note that site RS05 is near the upstream extent of the application are and is characterised as a “reference” site with “excellent” habitat quality, 96% of the catchment in indigenous forest and 0.1% in production pasture. The lower site (RS06) near the downstream extent of the application area is characterised as “impacted” with “fair” habitat quality, 88% indigenous forest and 8.8% production pasture. The land-use differences between the two sites result in a modest increase in nitrogen concentrations in the river, as well as a modest increase in algae productivity, and a small reduction in macroivertebrate index scores. Perrie *et al* (2012) found a strong positive relationship between MCI scores and the proportion of indigenous forest cover in the upstream catchment, and that nitrogen enrichment is strongly linked with macroinvertebrate community composition.

The observed differences in macroinvertebrate community composition between sites RS05 and RS06 are largely explained by the reduction in indigenous forest cover and increase in production pasture in the contributing catchment. It is not possible to draw conclusions about the effects of flood protection activities on macroinvertebrate communities at the RSoE sites because both sites are potentially affected by these activities, and because of the underlying differences in macroinvertebrate habitat caused by land-use. For that reason GWRC has instead undertaken a series of targeted investigations which are specifically focused on the effects of flood protection activities on macroinvertebrate communities (Perrie, 2013b; Death & Death, 2013), as discussed in Section 5 of this report.

3.1.8 Fish communities

The New Zealand Freshwater Fish Database (NZFFD) was queried for records of sites sampled within the Otaki River and associated minor stream catchments over the period 1960 to 2015 (25 records). Only two of NZFFD sites are located within the Otaki River application area and 23 sites are located on watercourses outside (upstream) of the application area. There are no NZFFD records for the Rangiuru or Ngatoko Streams or the Paiko/Katihiku drains. The number of survey sites within and upstream of the application area is listed in Table 3-14.

Table 3-14: Number of NZFFD fish survey sites in each watercourse (1960-2015)

Watercourse	Number of sites/records within application area	Number of sites/records upstream of application area	Sampling period
Otaki River	2	2	1985 - 2007
Upper tributary streams	0	20	1965 - 2002
Rangiuru/Ngatoko Stream	0	0	none
Waimanu Stream	0	1	1980
Pahiko/Katihiku Drain	0	0	none

3.1.8.1 Otaki River

Twelve species of fish have been recorded within the Otaki River and tributaries, including eleven native fish and the introduced brown trout (Table 3-15). In addition, freshwater shrimp and freshwater crayfish (koura) are common in the lower catchment. The distributions of key fish species are shown in Figures 3-8 to 3-12. One species recorded in the Otaki River system, the shortjaw kokopu, is considered to be threatened (Nationally Vulnerable) while eight fish species are considered to be ‘at risk’ due to declining numbers nationally, as indicated in Table 3-15 (Goodman, *et al*., 2014).

Seven fish species have been recorded within the Otaki River application area, the most common of which are torrentfish (at 100% of survey sites), longfin eel (75%), and inanga, koaro, and common bully (50%). Predictions of fish species occurrence from the FENZ database (Leathwick, et al., 2010) based on geographical locations and physical attributes are generally consistent with recorded occurrence. (It is noted however that only 4 fish records are available for the Otaki River application area, including 2 NZFFD records, and two reported by Boffa Miskell (2001), and that a more comprehensive characterisation of the lower river fish population would be desirable, as discussed in Section 8).

The limited information that is available for the main-stem suggests that the abundance of fish in the lower river may be limited by a scarcity of good quality habitat. Boffa Miskell (2001) reported “a relatively low abundance of freshwater fish compared with the neighbouring Waikanae River and Waitohu Stream”. The authors suggested that this may be due to the uniformly coarse substrate and extensive flood control works in the lower river. This conclusion is consistent with the natural character index scores (NCI) as discussed in Section 3.1.9, which showed that the lower river, from just above the SH1 bridge to the river mouth had a relatively high degree of departure from the natural (reference) condition.

The core fish community of the Otaki River application area consists of longfin eel, torrentfish, inanga, koaro, and common bully. Other species such as banded kokopu are likely to be seasonally abundant but not necessarily resident within the application area.

Most of the indigenous fish species recorded in the catchment, except dwarf galaxias, are diadromous, that is, they migrate to and from the sea at well-defined life stages, and in most cases the migrations are obligatory. Periods of peak sensitivity for upstream migrations from the sea into the lower river are shown in Appendix D and include the following:

- Peak periods of upstream migration of juvenile galaxiid species (whitebait), torrentfish and redfin bully occur between August and December;
- Peak periods of upstream migration for juvenile longfin eel, shortfin eel and common bully are later during the summer, from December through to February.

Sea run brown trout migrate from the sea into the river during the autumn, moving up through the river and into headwater tributaries to spawn in the winter, however trout are not obliged to spend time in the sea and most trout in the Otaki River system may simply move upstream from adult riverine habitat to spawning areas during May, June and July.

Downstream migration from the river into the sea occurs for most indigenous species during summer to late-winter and is undertaken by eels as adults and by galaxiids, and bullies as larvae. Downstream migratory activity is influenced by a number of environmental factors including rainfall, water temperature and phase of the moon but is generally assisted by increased river flows, which may make it less susceptible to disruption by in-channel river works.

Given the relatively dispersed character of upstream fish migrations, it is expected that some disturbance due to active-channel works can be tolerated during the migration period without serious disruption to fish recruitment, provided the active channel disturbance does not continue for more than a few days at any particular location or for more than a few weeks within the 12km length of the application area. Recommendations for the protection of indigenous fish are provided in Sections 7.4, 7.5 and 7.6 and have been incorporated into the Code.

Sensitive periods and locations for fish spawning are summarised in Appendix D and include:

- Inanga spawning habit is located in tidal estuary edge vegetation and occurs during March, April and May. Taylor and Kelly (2001) note that while the Otaki River main-stem, lacking riparian vegetation, is not suitable for inanga spawning, two spring fed tributaries in the lower reaches (the Rangiuru Stream and Pahiko/Katihiku Drain) offer good habitat for inanga spawning (see Figure 3-17). Both of these systems drain low lying pastoral land, and probably as a consequence of this incorporate floodgates. Recommendations for the protection of inanga spawning habitat are provided in Section 7.6 and have been incorporated into the Code.
- Other galaxiid species including koaro, banded kokopu, shortjaw kokopu and giant kokopu, spawn in vegetation or cobbles at the riparian margin between April and August. Spawning habitat is generally thought to occur near typical adult habitats (McDowell, 1990; Smith, 2015).
- Bullies spawn in riverbed substrate, often under large rocks, between August and February. Spawning habitat is thought to occur near or upstream of adult habitats (McDowell, 1990; Smith, 2015).
- Torrentfish spawn in riverbed substrate, probably in the lower river near the coast, mostly between January and April.
- Trout move into headwater tributaries to spawn during May and June. Development of brown trout eggs takes about four to six weeks, and after hatching the young alevins remain in the redd gravels for several weeks (McDowell, 1990). Trout spawning habitat in the Otaki appears to be limited to upper tributaries (Strickland & Quarterman, 2001) and it is thought that the main-stem of the Otaki below the gorge does not provide important trout spawning habitat due to the generally coarse nature of the bed substrate (refer Appendix I, important trout spawning habitat and recruitment water in the Wellington Region). Recommendations for the protection of trout spawning habitat are given in Section 7.6. and have been incorporated into the Code.

Table 3-15: Summary of the NZFFD records for the Otaki River as of June 2015 (n=31) and FENZ predictions of occurrence inside and outside of the application area (Leathwick, et al., 2010).

Scientific name	Common name	%Occurrence			Migratory species	Threat status (Goodman *et al* 2014)
		Recorded within application area (n=4)*	Recorded outside application area (n=23)	Predicted within/ upstream (FENZ)		
Anguilla australis	Shortfin eel	25	21	40/40	yes	Not threatened
Anguilla dieffenbachii	Longfin eel	75	70	100/100	yes	At risk (declining)
Cheimarrichthys fosteri	Torrentfish	100	39	40/50	yes	At risk (declining)
Galaxias argenteus	Giant kokopu	0	9	0/0	yes	At risk (declining)
Galaxias postvectis	Shortjaw kokopu	0	13	20/90	yes	Threatened (Nationally Vulnerable)
Galaxias brevipinnis	Koaro	50	39	10/100	yes	At risk (declining)
Galaxias fasciatus	Banded kokopu	0	13	10/50	yes	Not threatened
Galaxias divergens	Dwarf galaxias	0	9	10/10	no	At risk (declining)
Galaxias maculatus	Inanga*	50	0	100/0	yes	At risk (declining)
Gobiomorphus cotidianus	Common bully	50	9	100/50	yes	Not threatened
Gobiomorphus huttoni	Redfin bully	25	52	100/100	yes	At risk (declining)
Salmo trutta	Brown trout	25	26	20/60	yes	Introduced/naturalised

Note: *Includes two surveys conducted by Boffa Miskell (2001) not recorded in the NZFFD.

3.1.8.2 Tributary Streams

Fish species recorded in the Waimanu Stream are listed in Table 3-16. As no fish records are available for Rangiuru/Ngatoko Stream or the Paiko/Katihiku drains we have used predictions from the FENZ database to identify the core fish community (Leathwick, et al., 2010). Based on this information and observations of habitat quality, the predicted core fish communities are as follows:

- Waimanu Stream: longfin eel, shortfin eel, torrentfish, giant kokopu, common bully, redfin bully and brown trout.
- Rangiuru/Ngatoko Stream and Paiko/Katihiku drains: longfin eel, shortfin eel, inanga and common bully

Table 3-16: Recorded (NZFFD) and predicted %occurrence of fish species in Waimanu Stream, Rnagiuru/Ngatoko Stream and Pahiko/Katihiku drains

Common name	Waimanu Stream %occurence			Rangiuru/Ngatoko Stream %occurance	Pahiko/Katihiku drains %occurance
	Within application area (n=0)	Outside application area (n=3)	Predicted in/out (FENZ)	Predicted in/out (FENZ)	Predicted in/out (FENZ)
Shortfin eel	0	100	100/100	100/100	100/100
Longfin eel	0	100	100/100	60/60	60/60
Torrentfish	0	33	10/10	0/0	0/0
Giant kokopu	0	33	10/10	10/10	10/10
Shortjaw kokopu	0	0	10/10	10/10	10/10
Koaro	0	0	10/10	10/10	10/10
Banded kokopu	0	0	10/90	10/50	10/50
Dwarf galaxias	0	0	10/10	10/10	0/0
Inanga*	0	0	10/10	100/100	100/100
Common bully	0	33	60/60	90/20	50/20
Redfin bully	0	33	50/50	10/10	10/10

Common name	Waimanu Stream %occurence			Rangiuru/Ngatoko Stream %occurance	Pahiko/Katihiku drains %occurance
	Within application area (n=0)	Outside application area (n=3)	Predicted in/out (FENZ)	Predicted in/out (FENZ)	Predicted in/out (FENZ)
Brown trout	0	66	50/50	10/10	0/0

3.1.8.3 Comparison between the application area and upstream reaches

The application area in the Otaki River begins at the sea and extends 11km upstream through urban Otaki, and the agricultural area between Rahui Road and Otaki Gorge Road, terminating at the Waihoanga Suspension Bridge near the Otaki Gorge. The application area contains the urban reach of the river, and is affected by urban and agricultural development within that reach.

Based on the geographical and geomorphological differences between these areas, some difference in the fish community is to be expected. In particular, low elevation fish taxa such as inanga and common bully are predicted to be rare or absent upstream of the application area while other taxa such as dwarf galaxias, koaro and banded kokopu are predicted to be more common at upstream locations. The records summarised in Tables 3-15 and 3-16 are generally consistent with those predictions.

In addition to geographical changes, the transition from an indigenous forest catchment of upper catchment to the rural and urban areas of Otaki has caused a range of habitat changes associated with the reduced integrity of riparian vegetation, increased inputs of nutrients (especially nitrogen), and increased occurrence of pest species.

While it would be possible to compare the fish data from application area with an upstream area unaffected by flood protection activities, such a comparison would be meaningless in the context of this assessment because of the geographical, geomorphological, and land-use differences. It would is not possible to draw any conclusions about the influence of flood protection activities on the distribution of fish on the basis of the NZFFD records. For that reason GWRC has undertaken a series of targeted investigations which are focused on the effects of flood protection activities (i.e., Cameron 2015; Death & Death, 2013; and Perrie, 2013a) as discussed in Section 5.

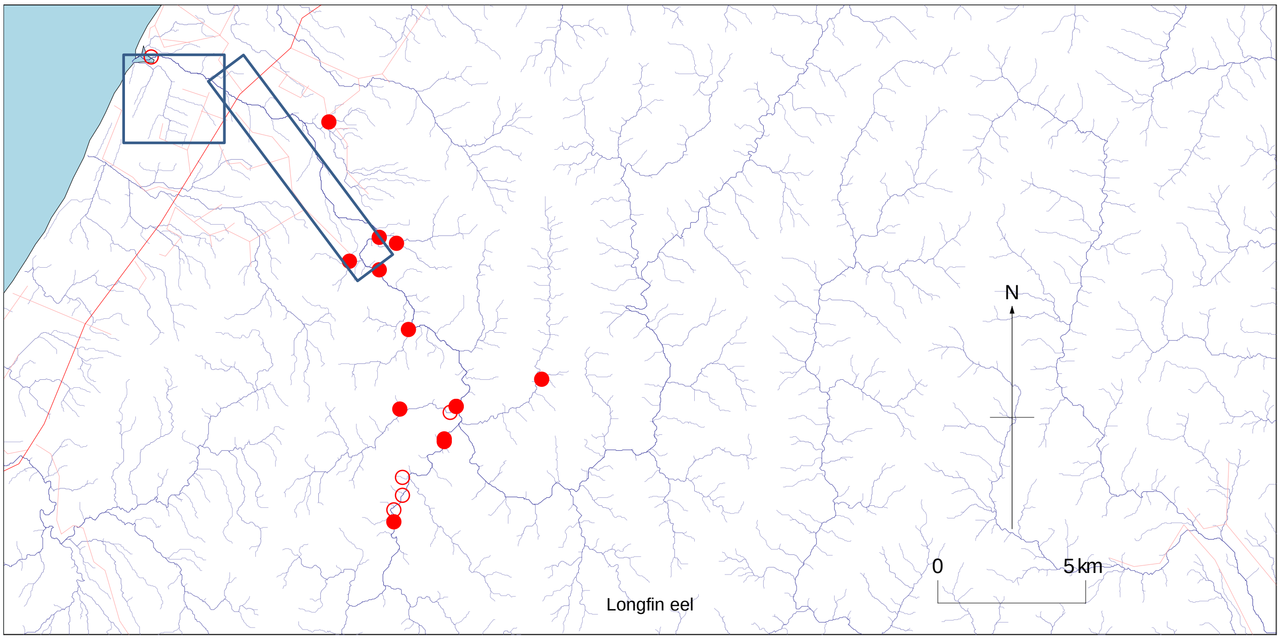


Figure 3-8: Longfin eel records for the Otaki River (presence indicated as red dots, absence by a circle). Data from NZFFD 1990-2013.

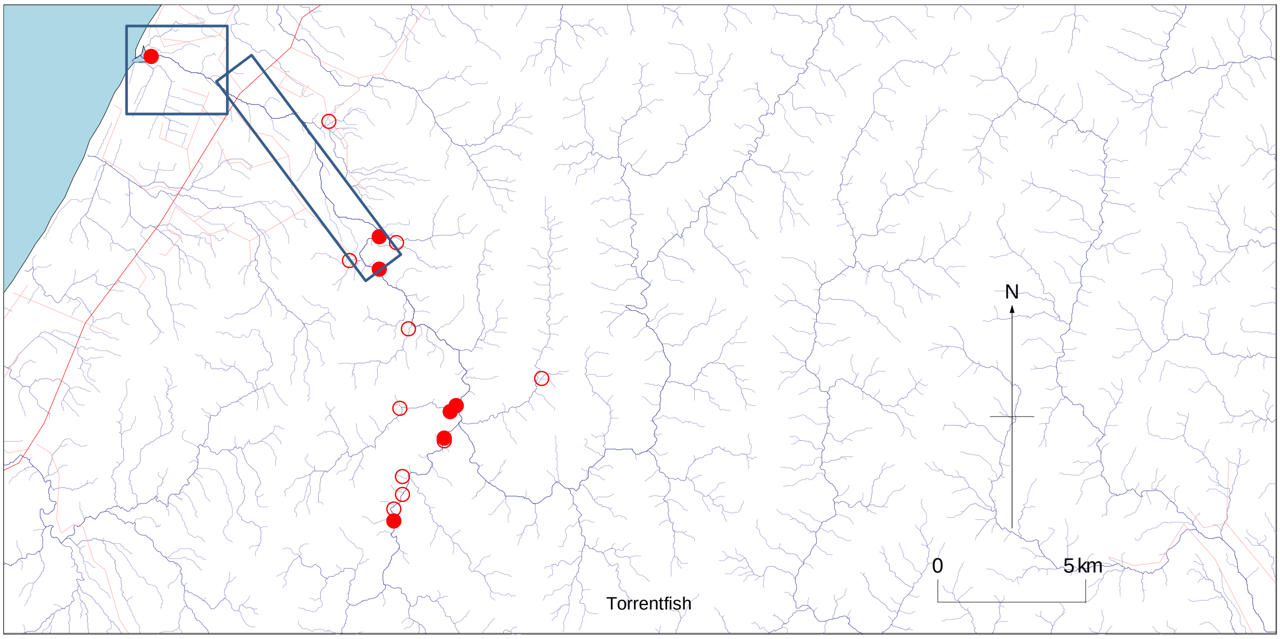


Figure 3-9: Torrentfish records for the Otaki River (presence indicated as red dots, absence by a circle). Data from NZFFD 1990-2013.

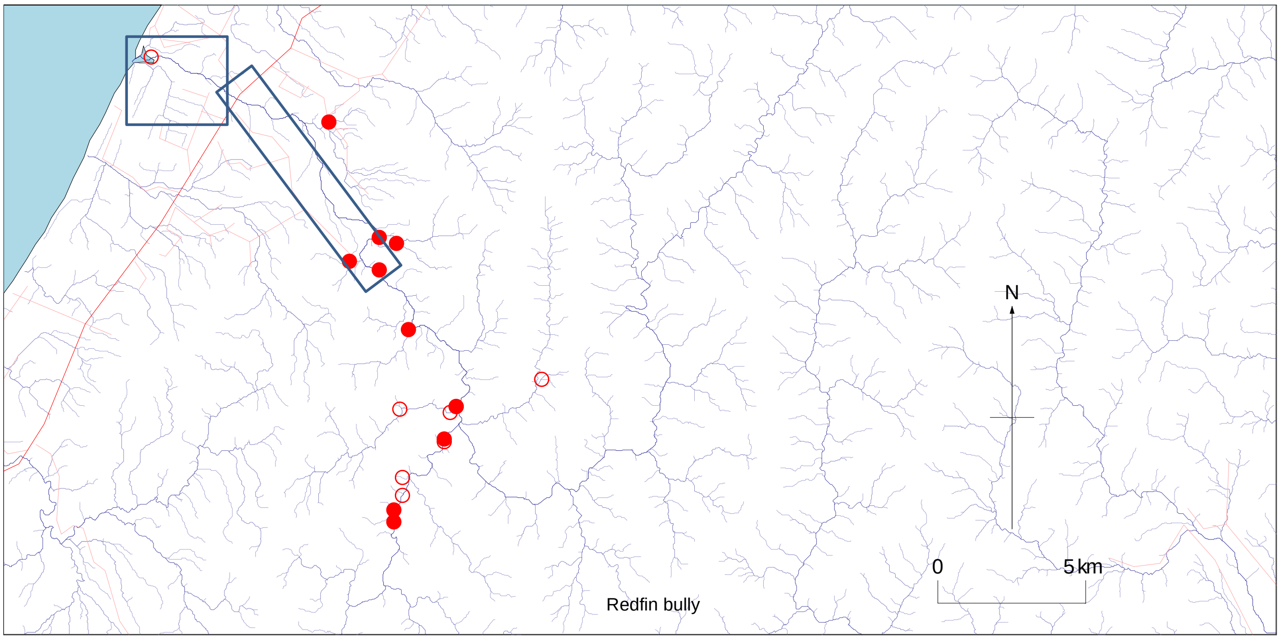


Figure 3-10: Redfin bully records for the Otaki River (presence indicated as red dots, absence by a circle). Data from NZFFD 1990-2013.

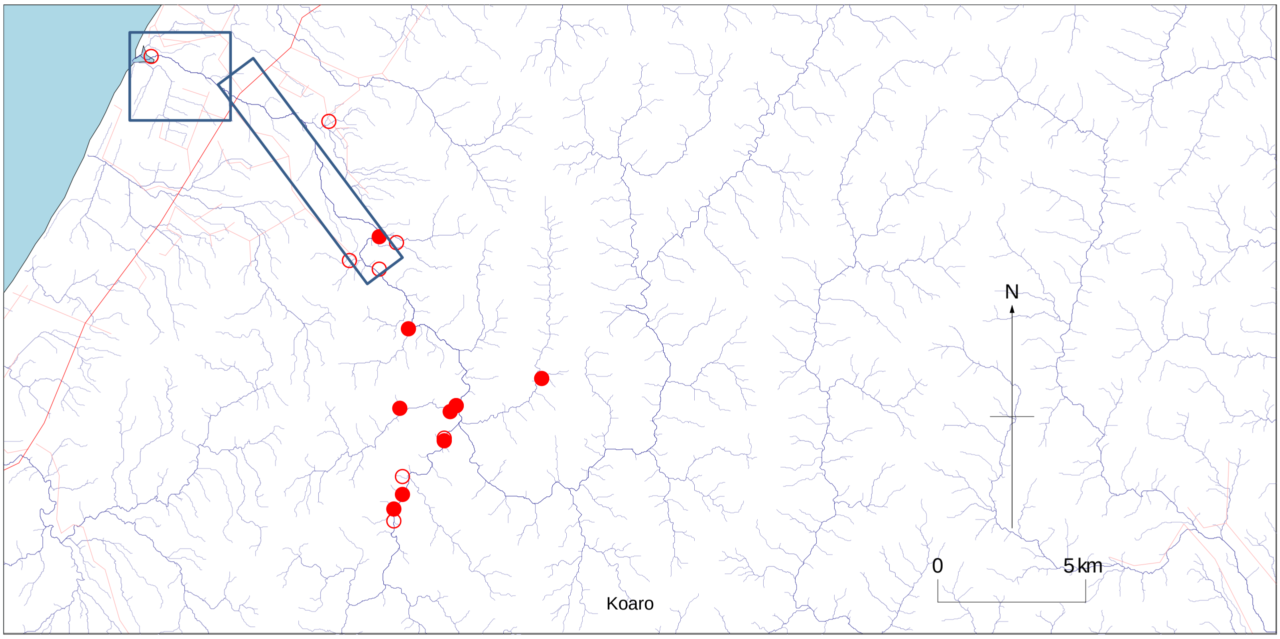


Figure 3-11: Koaro records for the Otaki River (presence indicated as red dots, absence by a circle). Data from NZFFD 1990-2013.

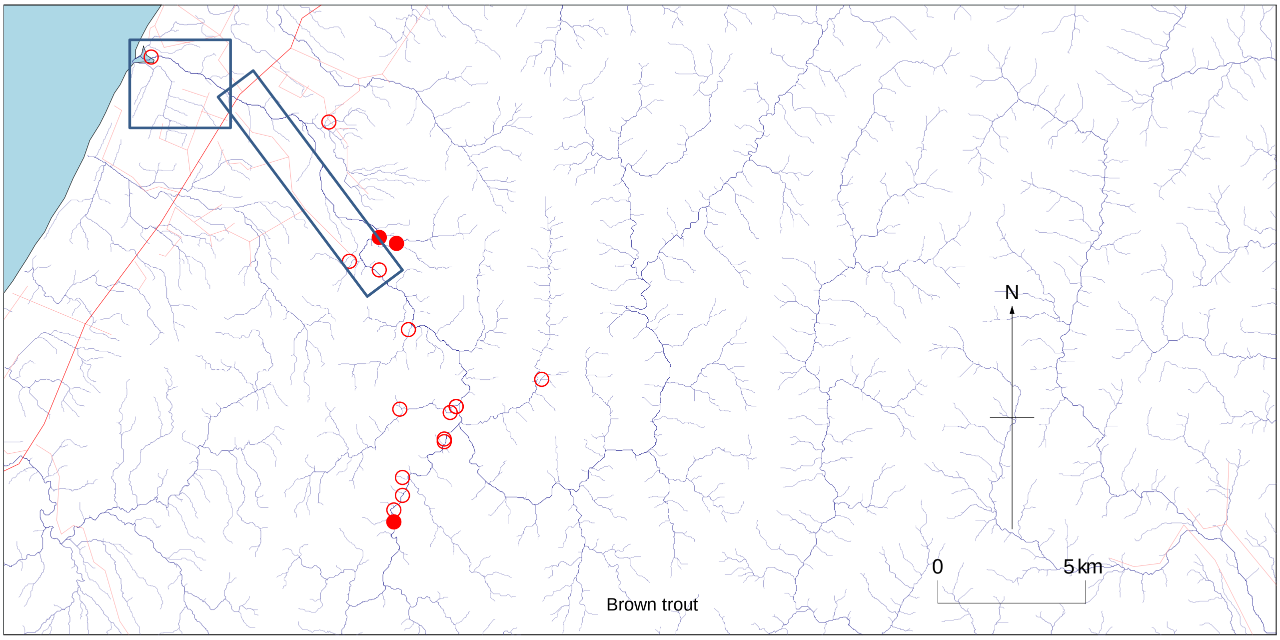


Figure 3-12: Brown trout records for the Otaki River (presence indicated as red dots, absence by a circle). Data from NZFFD 1990-2013.

3.1.9 Recreational fisheries

3.1.9.1 Trout

Trout were first liberated in the Otaki River in 1872 (Adams, *et al*, 1987). Trout numbers have historically been relatively low compared to other New Zealand rivers, which may reflect the moderately high flow variability of the river, with floods regularly turning over a relatively unstable bed (Jowett & Duncan, 1990). The Otaki is listed in GWRC Regional Freshwater Plan as a body with important trout habitat, particularly in the reaches from the headwaters to the SH1 Bridge. It is considered by New Zealand Fish & Game to be a regionally important trout fishing destination and in terms of “angler days” is in the top 25 % of recognised angling water bodies in the Wellington Region.

The lower reaches of the Waimanu Stream is known to provide habitat for trout when the Otaki River is in flood.

3.1.9.1 Whitebait and other recreational fisheries

The Otaki River mouth and estuary support locally important whitebait and flounder fisheries, and yellow eyed mullet and kahawai are also fished in the lower river. The estuary provides spawning and rearing habitat for freshwater and marine species including kahawai, snapper, dogfish, red cod, gurnard and yellow eyed mullet (Department of Conservation, Index Database, referenced in Boffa Miskell, 2001). Whitebaiting occurs both within the river and on the seaward side of the Rangiuru and Pahiku floodgates where fish congregate to access the Rangiuru Stream and Pahiku/Katihiku drains.

3.1.10 Birds of Otaki River

3.1.10.1 Introduction

GWRC has recognised that there is potential for flood protection activities to have both positive and negative impacts in bird populations present in the river corridors. In response to this, GWRC's Code and EMP (GWRC, Working Draft, March 2015) has committed to a bird monitoring programme that involves carrying out annual surveys on a three year on, five year off cycle on most of the major rivers affected by flood protection activities. The first three-year series of annual bird surveys on the western sector rivers, including the Otaki River, commenced in late 2012, with three consecutive annual surveys having being completed in the summers of 2012/13, 2013/14 and 2014/15. The results these surveys are reported by McArthur, Small, & Govella (2015).

The river bird surveys are specifically designed to provide estimates of the local population sizes of four shorebird species that are known to breed on the open gravels of rivers subject to flood protection activities (McArthur et al, 2015). Because these four species are largely restricted to these riverine gravel habitats in the Wellington Region, they are considered to be at relatively high risk of being adversely impacted by these activities. Furthermore, three of these four species are of relatively high conservation concern nationally. The banded dotterel (*Charadrius bicinctus*) is ranked as Nationally Vulnerable under the New Zealand Threat Classification System, with a predicted national rate of decline of 30-70% over the next decade. The black-billed gull (*Larus bulleri*) is ranked as Nationally Endangered, with a predicted national rate of decline of >70% over the same period. Pied stilt (*Himantopus hinantopus*) is ranked as 'At Risk', Declining, with a predicted rate of decline of 10-50% over 10 years. The final species is black-fronted dotterel (*Elseyornis melonops*), a recent addition to the New Zealand avifauna, having self-colonised from Australia in the early 1950s. The southern North Island is currently a stronghold for this species in New Zealand, however the black-fronted dotterel is not ranked as either Threatened or 'At Risk'.

In contrast to the locally-breeding shorebird species that provide the focus for this monitoring, the majority of the remaining bird species recorded in the river corridor are terrestrial species that are common and widespread in the surrounding landscape, and are considered unlikely to be adversely impacted by the localised effects of flood protection activities occurring in the bed of the river itself (McArthur, Playle, & Govella, 2013; McArthur *et al*, 2015). A number of additional shorebird and waterfowl species do make use of the lower reaches of the river and estuary during certain stages of their life cycle however, so in addition to monitoring trends in population sizes of the four most vulnerable locally breeding shorebird species, numbers of non-breeding shorebirds, waterfowl and terrestrial bird species are also undertaken during these surveys. This will enable broad trends in both the diversity and distribution of these species to be monitored over time.

3.1.10.2 Riverbed nesting shorebirds

McArthur, et al, (2015) reported that three species of shorebirds were observed using the exposed gravel beaches and islands of the Ōtaki River during the 2012-2015 surveys. The pied stilt, a species ranked as 'At Risk, Declining' under the New Zealand Threat Classification System was the most common shorebird species, followed by the banded dotterel (ranked as Nationally Vulnerable) and the black-fronted dotterel, a recent coloniser from Australia.

An average of 41 pied stilts was recorded along the 11.6 km of river surveyed each year, or 3.5 birds per km of river (Table 3-17). Territorial pairs of adult pied stilts were found to be fairly evenly distributed along the length of the Ōtaki River, but became uncommon upstream of XS890, and between XS350 and XS260 (from the SH 1 bridge to approximately one km further downstream) (Figure 3.1). Pied stilts were recorded breeding on the riverbed between XS120 and XS700, with both nests and chicks observed during these surveys. During the 2012/2013 survey, a small nesting colony of six breeding pairs, (each pair of birds incubating a clutch of three eggs), was found on the gravel island near XS130 (approximately 1.5 km upstream of the Ōtaki River mouth).

Table 3-17: Numbers of pied stilts, banded dotterels and black fronted dotterels counted along the Otaki River, 2012-215 (from McArthur, et al, 2015).

Year	Pied stilt		Banded dotterel		Black fronted dotterel	
	Total number counted	Number of birds per km	Total number counted	Number of birds per km	Total number counted	Number of birds per km
2012/13	41	3.5	38	3.3	11	0.9
2013/14	22	1.9	18	1.6	11	0.9
2014/15	59	5.1	45	3.9	23	2.0
Mean ±SD	41 ±15	3.5 ± 1.3	34 ±11	2.9 ± 1.0	15 ± 6	1.3 ± 0.5

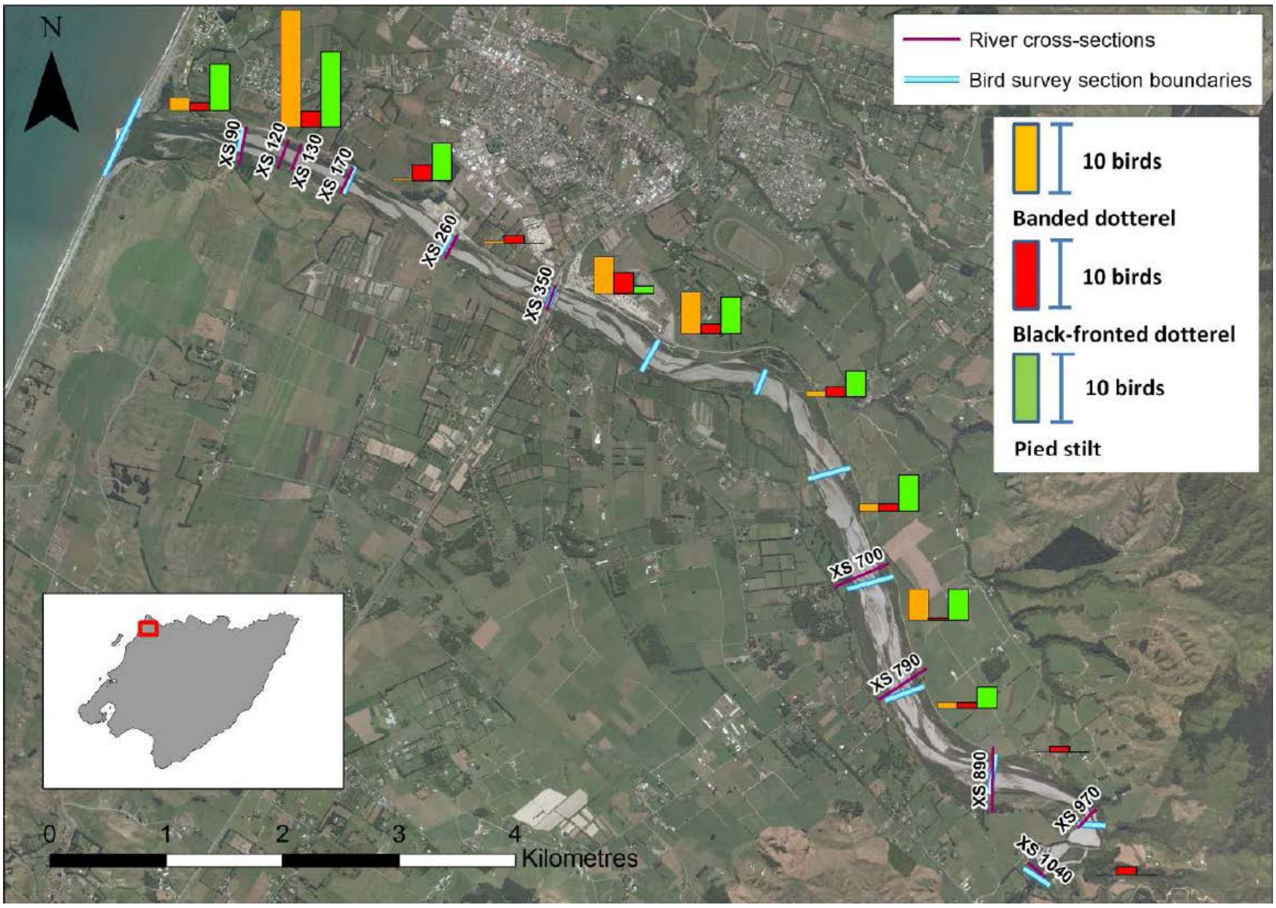


Figure 3-13: Map of the Otaki River showing spatial patterns in the relative abundance of riverbed nesting shorebirds. Coloured bars represent the mean number of birds counted along each 1 km of survey section during the three annual surveys between 2012 and 2015 (from McArthur, et al, 2015)

An average of 34 banded dotterels was recorded along the Ōtaki River each year, or 2.9 birds per km of river (Table 3-17). Territorial pairs of adult banded dotterels were found to be fairly evenly distributed along the length of the Ōtaki River, but became uncommon upstream of XS890, and between XS350 and XS170 (from the SH 1 bridge to approximately two km downstream) (Figure 3-13). A relatively high number of non-territorial banded dotterels were counted between XS90 and XS170 during the second and third year of surveys. Many of these birds appeared to be part of a small post-breeding flock of both adult and juvenile birds that were using this stretch of river as a roost site during late summer. Banded dotterels were recorded breeding on the riverbed between XS350 (the SH 1 bridge) and XS790, with both nests and chicks observed during these surveys. No black-fronted dotterel nests or chicks were found during the 2012-2015 surveys, however the presence of territorial adult pairs along the river during the breeding season suggests that breeding is almost certainly occurring. Several pairs were also seen exhibiting various defensive behaviours as fieldworkers traversed their territories, which also indicated that either a nest or chicks were present. An average of 15 black-fronted dotterels was recorded along the Ōtaki River each year, or 1.3 birds per km of river (Table 3-17). Unlike both banded dotterels and pied stilts, black-fronted dotterels continued to be recorded both upstream of XS890 and in the reach immediately downstream of the SH 1 bridge (Figure 3-14).

3.1.10.3 Spatial patterns in bird species diversity

McArthur et al (2105) recorded a total of 48 bird species were recorded on the Ōtaki River during the 2012-2015 bird surveys, including 30 native species and 18 introduced species. Of the native species, nine species are ranked as Nationally Threatened or 'At Risk' under the New Zealand Threat Classification System (Robertson et al, 2013). In addition to the 48 species recorded during the 2012-2015 surveys, a further 15 species (13 native and two introduced) have been recorded on the Ōtaki River since 1982 (McArthur, et al, 2015), bringing the total number of birds species so far recorded on the Ōtaki River to 63.

Both the total number of species and the ratio of native to introduced species encountered within each 1 km survey section varied little along the 11.6 km of the Ōtaki River that was covered during these surveys (Figure 3-14). A lower total number of species tended to be recorded upstream of XS890 and between XS350 and XS260 (from the SH 1 bridge to approximately one kilometre further downstream). In contrast, the Ōtaki Estuary supported a much higher total number of species, a higher ratio of native to introduced species and a higher number of Nationally Threatened and 'At Risk' species than any other reach of the Ōtaki River.

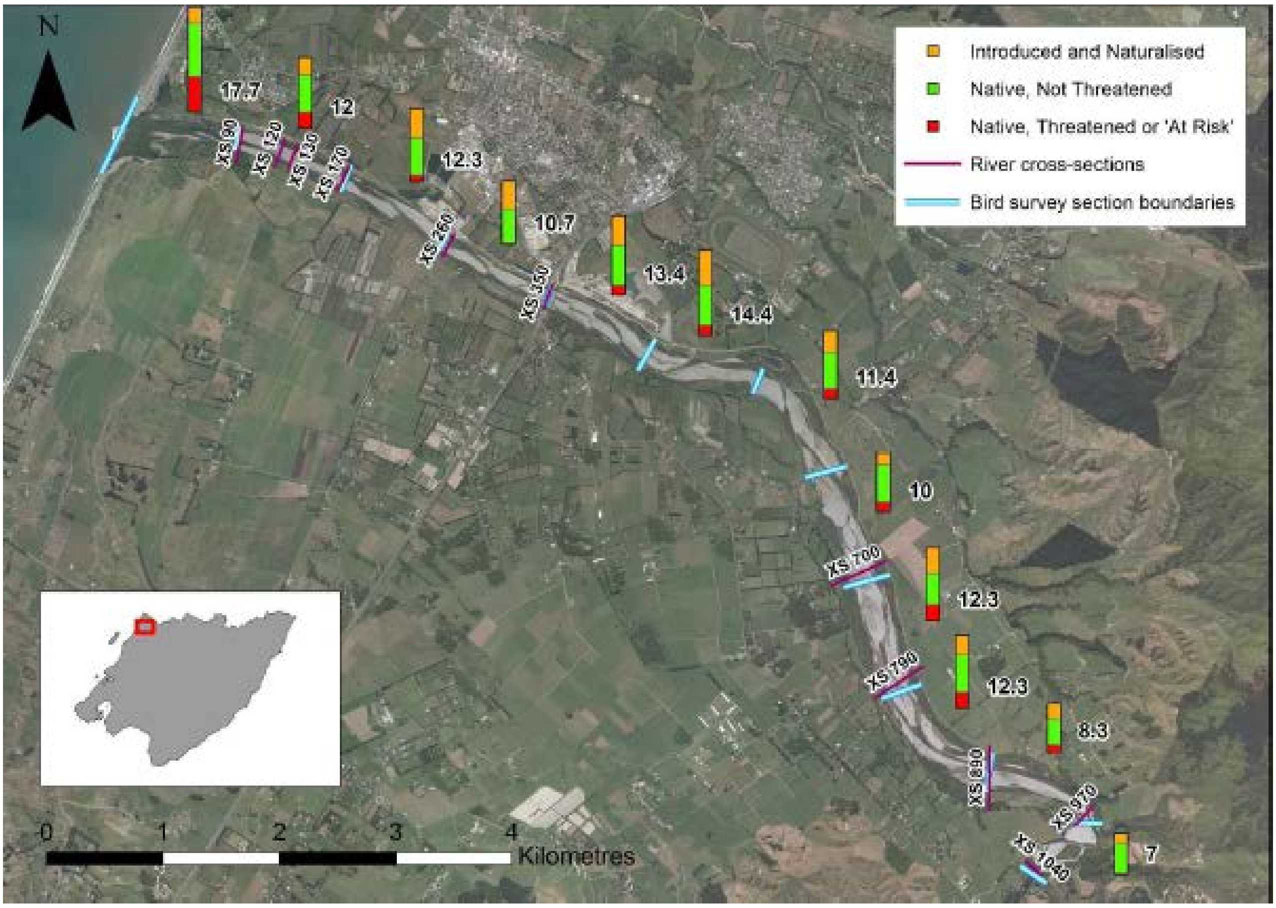


Figure 3-14: Map of the Otaki River showing spatial patterns in bird species diversity. Coloured bars and adjacent values represent the mean number of species detected along each 1km survey section during three annual surveys between 2012 and 2015 (from McArthur, et al, 2015)

3.1.10.4 Sites of value for indigenous birds on the Otaki River

Four sites of value for native birds have been identified on the Ōtaki River based on the data collected during these surveys (Figure 3-15).

Virtually the entire length of the 11.6 km of the Ōtaki River surveyed, between the Ōtaki Estuary and XS1040 provides breeding habitat for regionally- significant populations of both banded and black-fronted dotterels, and for a relatively large local breeding population of pied stilts. Approximately 8% of the Wellington Region populations of both banded and black-fronted dotterels breed on the Ōtaki River (McArthur et al, 2015).

A previously un-documented nesting colony of black shags (*Phalacrocorax carbo;* a species ranked as 'At Risk, Naturally Uncommon') was discovered on the escarpment on the true right of the Ōtaki River at XS970 during the first year of these surveys, with nesting activity also observed during the second and third years' surveys. Only two to three occupied nests were observed at the colony each year during these surveys, however peak egg-laying at inland black shag colonies in the Wellington Region occurs between April and October so the colony is likely to support a greater number of pairs than the results of these surveys suggest (Powlesland et al, 2007). Although the colony itself is situated on the escarpment well above the bed of the Ōtaki River, both adult black shags and recently-fledged juveniles from the colony were observed using the adjacent river channel and riverbed for foraging and roosting. This colony is one of only eight black shag nesting colonies known to be active in the Wellington Region at the present time (Birds New Zealand, unpublished data).

The lower reach of the Ōtaki River between XS90 and XS170 appears to be utilized by banded dotterels as a post-breeding staging area prior to migration. In late summer (January), a relatively high number of non-territorial adult and juvenile dotterels roost in this downstream reach of the river before departing on migration.

The Ōtaki Estuary supports a relatively high total number of bird species, a relatively high number of Nationally Threatened and 'At Risk' species, and a higher ratio of native to introduced bird species than any other reach of the Ōtaki River

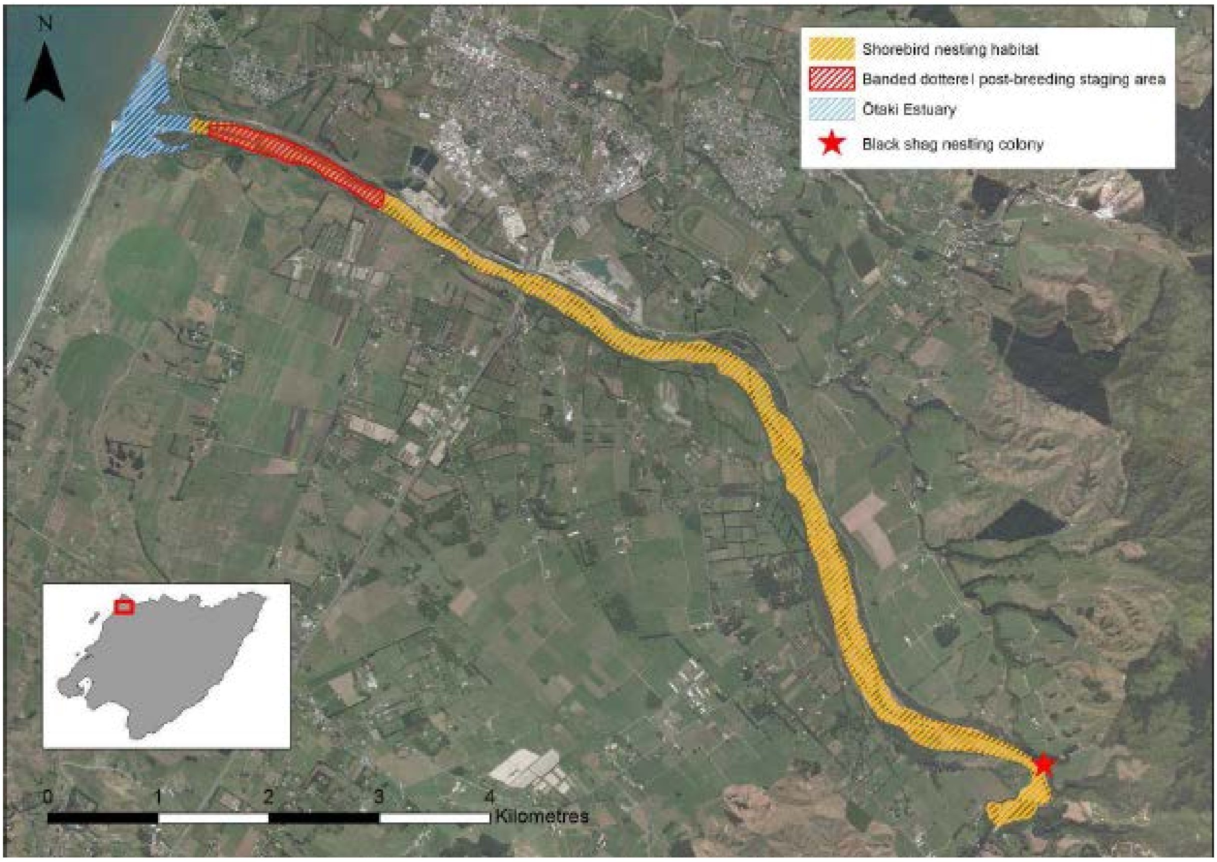


Figure 3-15: Map of the Otaki River showing bird sites of value identified as a result of the 2012-15 bird surveys (from McArthur, et al, 2015).

3.1.11 Herpetofauna

A search of lizard and frog records in the Department of Conservation BioWeb Herpetofauna database was undertaken within a corridor extending 1km either side of the Otaki River channel centreline. (The search area extends well beyond the application area which has a typical width of 300 to 400m.)

Only one lizard species is positively identified within the search area, the northern grass skink, which is recorded near the estuarine reach of the river (Table 3-18 and Figure 3-16). The BioWeb database also holds one record of an unidentified skink and one record of unidentified frog, both located near the upstream end of the application area. The northern grass skink is assessed as having a moderate likelihood of presence within the Otaki River corridor where there is rank grassland and scrubland, however the likelihood of presence is low in those areas frequently flooded by the river. The record of a northern grass skink near the Otaki Estuary indicates the presence of a population in that area, and indicates some potential for other lizard species to be found in that vicinity. Elsewhere, however, the Otaki River corridor is highly developed and contains little habitat of value for lizards (Trent Bell, pers com.).

Table 3-18: Herpetofauna records within the Otaki 1km radius flood corridor. Reptile threat classification obtained from Hitchmough *et al.* (2012). Herpetofauna records obtained from Department of Conservation BioWeb *Herpetofauna* database, accessed 08-08-2015

Species	Common name	Threat Classification	Number of records	Species habitat preference	Likelihood of presence
Oligosoma polychroma	Northern grass skink	Not Threatened	1	Macro: Grassland and scrubland. Micro: Dense rank grass, wood piles, rock piles.	Moderate at one location; Low elsewhere
Skink sp.	N/A	Unknown	1	N/A.	N/A
Litoria sp.	N/A	Introduced and Naturalised	1	Macro: Forest, scrubland, grassland, wetland, stream banks. Micro: Rock & wood piles, rank grass.	Moderate

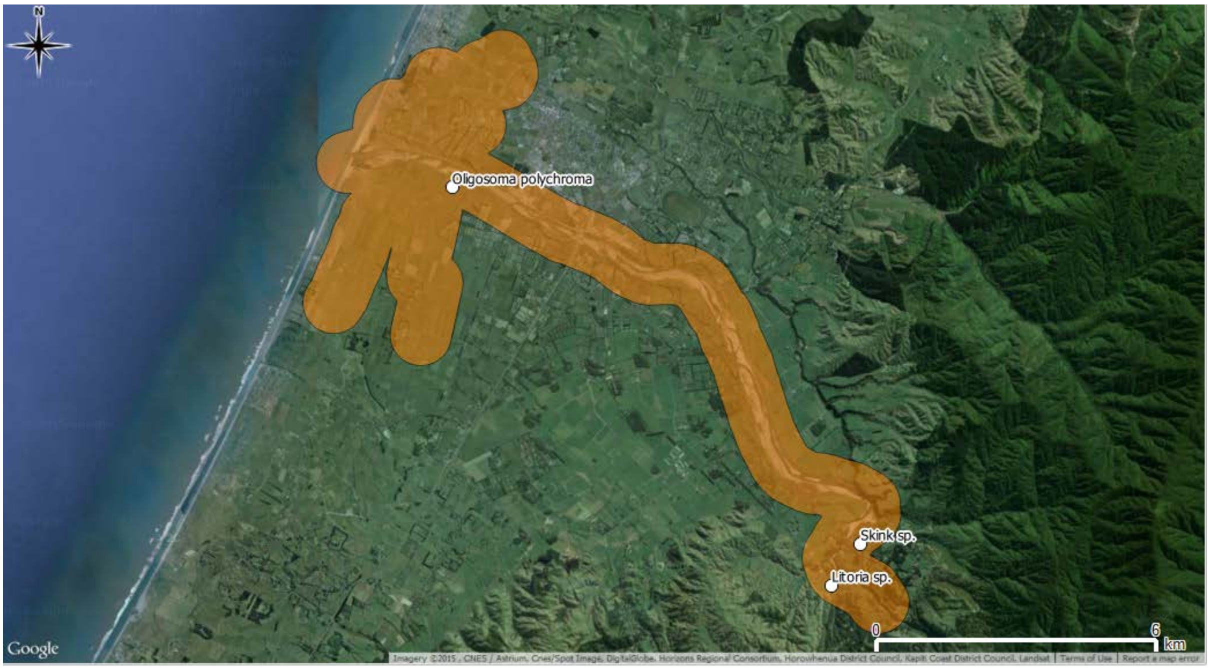


Figure 3-16: Location of herpetofauna records within the Otaki River corridor

3.1.12 Natural character

A natural character index (NCI) developed by Massey University (Death R. , Death, Fuller, & Jordan, 2015) has been used to assess the degree of departure from the reference condition of geomorphological characteristics for the Hutt, Otaki and Waikanae rivers. The NCI is determined from physical features including bed width ratios (i.e., active, bank-full and permitted channel widths compared with natural channel width), channel sinuosity and pool-riffle sequence. These characteristics are measured from aerial photography and Lidar imagery surveying. The NCI provides a proxy for the environmental condition and health of these waterways. In particular it provides a repeatable method for assessing changes in condition over time for defined reaches of each river. An NCI assessment on the Hutt, Otaki and Waikanae rivers was completed in 2013 and referenced against the earliest available aerial photographs for these rivers (1939 for the Otaki River) and is reported in Williams (2013). A summary of results for the Otaki River is provided in Table 3-19. The locations of the seven NCI reaches on the Otaki River are shown in Appendix A.

The NCI values are the ratios of the present to historic (reference) measurements, where a value of 1 means no change over the assessment period. Results for three reaches from the just above SH1 down to the River mouth (XS 480-370, XS360 – 220 and XS 210 – 80) show a high degree of departure from the reference condition and would therefore be expected to reflect reduced habitat quality and environmental health.

Table 3-19: NCI assessment for the Otaki River (from Williams 2012)

Reach Cross section	Sinuosity	Pools	Natural Floodplain width to:			Overall NCI
			Active	Bank-full	Permitted	
XS 990 – XS 870	0.97	0.67	0.62	0.71	0.82	**0.76**
XS 860 – XS 780	1.21	0.00	0.94	0.57	0.36	**0.62**
XS 770 – XS 610	0.86	0.00	0.68	0.25	0.84	**0.53**
XS 600 – XS 490	0.83	1.00	0.75	0.62	0.34	**0.71**
XS 480 – XS 370	0.99	0.00	1.01	0.34	0.24	**0.52**
XS 360 – XS 220	0.91	0.33	1.13	0.26	0.11	**0.55**
XS 210 – XS 80	0.92	0.25	0.48	0.25	0.10	**0.40**
Average	*0.96*	*0.32*	*0.80*	*0.43*	*0.40*	***0.58***

3.2 Otaki River Estuary

3.2.1 Physical characteristics

The Otaki Estuary is a shallow, medium sized “tidal river mouth” estuary that is nearly always open to the sea, although river mouth alignment is undertaken mechanically from time to time in response to defined trigger points. It includes a relatively exposed area to the south, associated with the Pahiko/Katihiku drains, and a sheltered lagoon to the north associated with Rangiuru and Ngatoko Streams (Figure 3-17). The estuary has a mean depth of 1-2m and a total area of approximately 10 ha. Sediments are relatively coarse, predominantly gravels and cobbles. The estuary is dominated by river flows, and is well-flushed with a residence time of less than one day. The length of salinity intrusion is less than 500m. It is assessed as having low susceptibility to eutrophication or sedimentation issues (Robertson & Stevens, 2007).

The northern tidal lagoon receives inflow from Rangiuru and Ngatoko Streams, via floodgates under the stopbank, and discharges into the Otaki River. The lagoon has an area of approximately 3 ha. A small area of sand flats is exposed at low tide (approximately 1 ha).

Semi sheltered estuarine habitat occurs on the south side of the river in an arc from the seaward end of the large gravel bar (also known as Mangahenene Island) to the coastal dune gravels, including the mouth of Pahiko drain.

Historical aerial photographs included in the Katihiku restoration plan (Groundtruth 2013) show that the large gravel bar was an island as recently as 1966, but that channel alignment has varied considerably in this dynamic environment. Currently the large gravel bar extends from the true left bank at normal river flows. It is evident from aerial photographs taken in 2005 that this area is occasionally stripped of vegetation during large flood events, leaving an extensive area of open gravels. The gravel bar currently encroaches well into the design channel alignment (see Figure 3-17) and has been identified by GWRC flood protection as an area where channel widening would be required to re-establish the design channel alignment.

3.2.2 Human and ecological values

The Otaki Estuary has been designated a “Key Native Ecosystem” by GWRC. A number of organisations including the Friends of Otaki River, Kapiti Coast District Council and Greater Wellington Regional Council have been working to enhance the Otaki River Estuary on the north bank to provide for the ecological, cultural and community values of the area. An enhancement strategy developed for the area aims to restore the estuarine area by protecting and helping restore the native biodiversity of the area. This is to be achieved by planting projects as well and weed and pest management. These groups also aim to improve public access to the area.

Greater Wellington Regional Council has also developed a restoration strategy for the Whakapawaewae wetland at Katihiku to the south of the estuary (Groundtruth, 2013) including the Katihiku and Pahiko drains as well as the south bank of the estuary.

Human use of the estuary is low-moderate but is seasonally popular for fishing and white-baiting. Ecologically, habitat diversity was assessed as low by Robertson & Stevens (2007) due to the small areas of tidal flats and salt marsh.

3.2.3 Marginal vegetation

The northern tidal lagoon margins have a mixed vegetation of flax, taupata, cabbage trees, raupo, grasses, rushes including jointed rush (*Apodasmia similis*) and the native sedge *Isolepis prolifera*. Native salt meadow species reported by Boffa Miskell (1992) include glasswart (*Salicornia australis*), shore primrose (*Samolus repens*), *Selliera redicans* and Batchelor’s button (*Cotula coronopifolia*). The total area of salt marsh habitat associated with the northern tidal lagoon is estimated at approximately 2 ha. This area is well outside of the design channel alignment and is unlikely to be disturbed by flood protection activities.

Semi sheltered estuarine habitat located on the south side of the river also contains some saltmarsh habitat. The strip along the stop bank contains the most significant vegetation community including *Selliera radicans*, *Samolus repens*, toetoe, quillwort, oioi, sharp spike sedge, *Isolepis cernua*, *Shoenoplectus tabernaemontani* and the regionally rare *Carex litorosa* (Groundtruth, 2013). Groundtruth (2013) notes that some of these species are very sparse and vulnerable to the encroachment of weeds such as tall fescue, sharp rush and pampas from around the margins. The majority of this habitat is outside of the design channel alignment and is unlikely to be disturbed by flood protection activities.

The flats at the western tip of the gravel bar are less diverse containing quillwort, *Isolepis cernua*, and scattered rushes. Much of the margin is covered with exotic species, particularly tall fescue, *Senecio graveolens*, and lupin, however on an area of loose fine gravels the native *Carex pumila* is widespread (Groundtruth, 2013).

The part of the gravel bar located within the design channel alignment, which is likely to be affected by channel widening, is heavily covered in weeds. As recently as 2008 this area was relatively bare open gravel which would have provided valuable habitat for shorebirds, but has subsequently been colonised by exotic scrubs including pampas, gorse, lupin, Montpellier broom, and tree lucerne. Groundtruth (2013) has identified this area as “Area 7”, and have recommended that it be managed as ‘open shingle shorebird habitat’, which would be achieved by removal of the existing vegetation and ongoing maintenance by re-spraying and predator trapping.

3.2.4 Macroalgae, phytoplankton and sedimentation

Macroalgae distribution in the Otaki Estuary has not been comprehensively mapped. Nevertheless Robertson & Stevens (2007) describe the estuary as having low risk of macroalgal blooms, low risk of phytoplankton blooms, low risk of dissolved oxygen depletion and low risk of anoxic sediments. No information is available for sediment quality or sedimentation rates. Nevertheless, the authors describe the Otaki Estuary as being dominated by rivers flows and well flushed and having low susceptibility to eutrophication and sedimentation issues

3.2.5 Fish

The fish community of the Otaki River and minor tributaries within the application area has been described in Section 3.1.8. Of the 25 NZFFD records available for the catchment none are located within the estuarine reach. However, Boffa Miskell (2001) carried out a limited fish survey by trapping (box net and fyke net) in the lower Otaki River including sites located in ‘upper estuary’ and ‘middle estuary’. That survey identified four freshwater species: inanga, longfin eel, torrentfish and common bully. Species such as shortfin eel, koaro, banded kokopu, giant kokopu, shortjaw kokopu, black flounder and redfin bully, although not recorded in the survey, would be expected to be either resident or transient in the estuarine reach.

The estuary is also known to provided spawning and/or rearing habitat for a number marine species including kahawai, snapper, dogfish, red cod, gurnard and yellow eyed mullet (DoC Database, referenced in Boffa Miskell, 2001).

Taylor and Kelly (2001) note that while the main-stem of the Otaki River, lacking riparian vegetation, is not suitable for inanga spawning, two spring fed tributaries in the lower reaches (the Rangiuru Stream and Pahiko/Katihiku Drain) offer good habitat for inanga spawning (see Appendix A, map 1a). Both of these systems drain low lying pastoral land and incorporate floodgates. The floodgates at the entrance to Rangiuru Stream have been modified to slow the closing on the incoming tide to give fish more time to move from the sea to the stream. Recommendations for the protection of inanga spawning habitat are provided in Section 7.6 and have been incorporated into the Code.

3.2.6 Birds

Bird species reported by Boffa Miskell (2001) and Groundtruth (2013) in and around the river mouth are listed in Table 3-20. McArthur, et al, 2015 noted that the Otaki Estuary supports a relatively high number of bird species, a relatively high number of Nationally Threatened and ‘At Risk’ species, and a higher ration of native to introduced bird species that any other reach of the Otaki River. The Otaki Estuary is identified as a “habitat of significance for indigenous birds”. As noted previously the Otaki Estuary has also been designated a “Key Native Ecosystem” by GWRC.

Table 3-20: Bird species observed in and around the Otaki River mouth (Boffa Miskell, 2001; Groundtruth, 2013)

Native birds	*Exotic birds*
Australasian shoveler	Black swan
Banded dotterel	Blackbird
Black backed gull	Canada goose
Black fronted dotterel	Goldfinch
Black shag	Hedge sparrow
Caspian tern	Mallard duck
Fantail	Magpie
Little shag	Pheasant
Little black shag	Skylark
Grey teal	Spur-winged plover
Grey warbler	Starling
King fisher	Thrush
Paradise shelduck	Yellowhammer
Pied shag	
Pied stilt	
Pukeko	
Royal spoonbill	
Silvereye	
Tui	
White-faced heron	

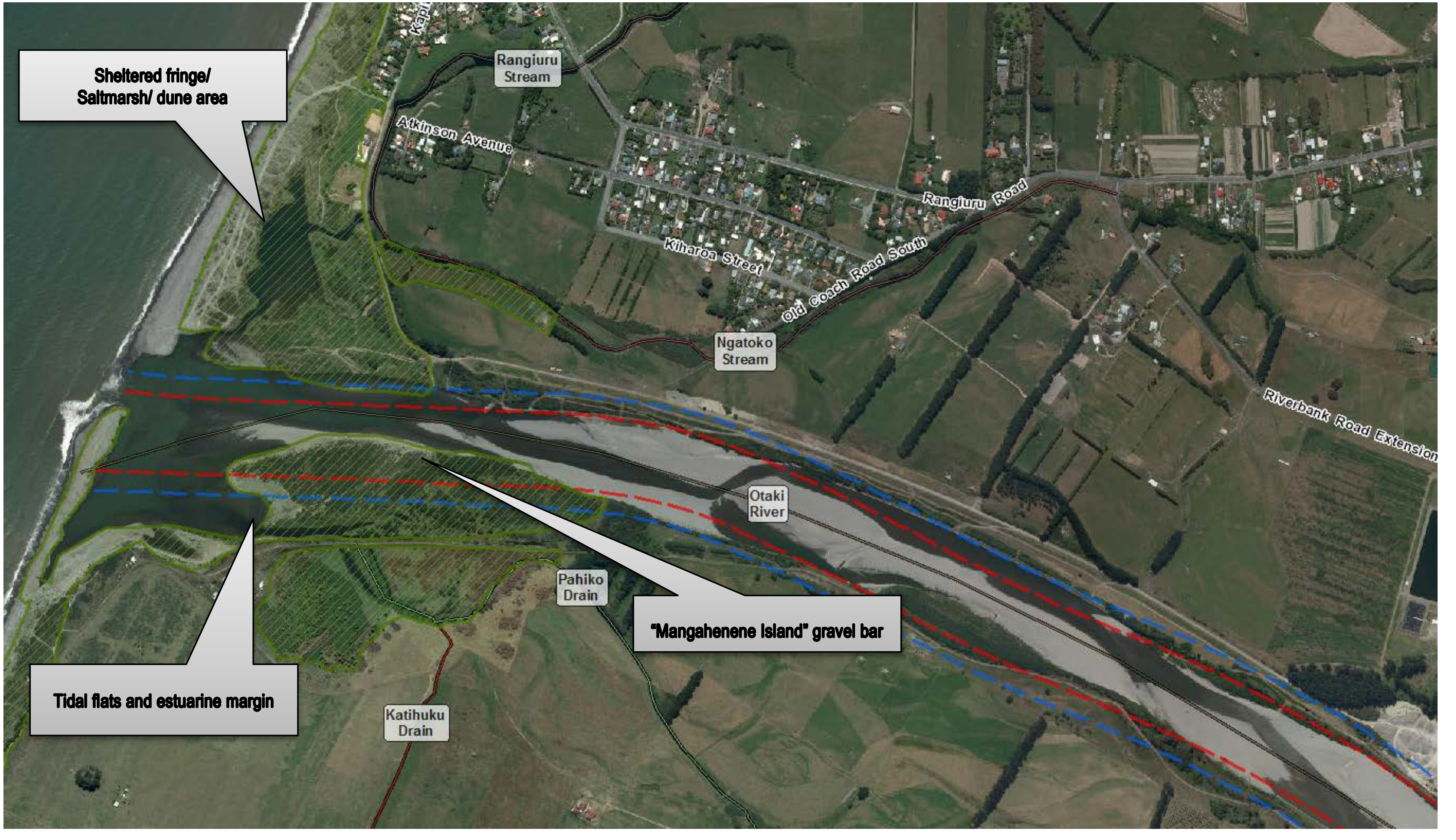


Figure 3-17: View of Otaki River Estuary showing the flood protection river buffer zone (dashed blue lines), design channel alignment (dashed red lines) and areas defined by GWRC as 'key native ecosystems' (hatched). Note, the full extent of the Otaki River application area (including Rangiuru Stream, Ngatoko Stream, Pahiko Drain and Katihuku Drain) is shown in Appendix A

4 Flood Protection Activities

4.1 Purpose

As described in the Resource Consent Applications for Operations and Maintenance Activities in the Otaki River (Tonkin and Taylor, 2015), the main aims of the river operation and maintenance work programme are to:

- maintain a design channel alignment (as defined in the defined in the Otaki River Floodplain Management Plan);
- maintain the flood capacity of the existing channel by removal of obstructions and gravel build-ups as necessary;
- maintain the integrity and security of existing flood defences, (including stop banks and bank protection works).

In addition, the works programme aims to maintain, or where possible improve, the in-river and adjacent riparian environment.

These aims are applicable to flood protection operations and maintenance activities throughout the Wellington Region.

4.2 Description of Activities

To achieve the purposes listed above, GWRC currently undertakes a range of flood protection activities in the Otaki River, Rangiuru Stream, Ngatoko Stream, Waimanu Stream, Pahiko Drain and Katihiku Drain, as listed below in Table 4-1. The consent application seeks to have the continued ability to use these tools as appropriate; it should be noted that many of these activities are not used frequently (or at all in some areas) and the pattern and frequency of use is not expected to change significantly in future.

4.2.1 Maintenance of channel alignment

Channel alignment is maintained using a combination of:

- Hard edge protection works such as rock rip-rap linings or groynes
- Soft edge protection works such as planted, or layered and tethered, willows
- Mechanical shaping of the beaches and channel (beach and bed re-contouring)
- River mouth realignment

4.2.2 Maintenance of channel capacity

Tools currently used to maintain channel capacity are:

- Gravel Extraction
- Clearance of vegetation from gravel beaches (scalping)
- Removal of unwanted vegetation
- Clearance of flood debris
- Excavation of berms

4.2.3 Maintenance of existing flood defences

This includes all of the works necessary to maintain the existing in-river structures, and repairs to flood defences outside the river bed, principally the stop banks.

Table 4-1: Summary of operations and maintenance activities for Otaki River

Type of Activity	Individual Activities
Construction of "Impermeable" Erosion Protection Structures on & in the river bed	Groynes constructed of rock and/or concrete block Rock linings (rip-rap and toe rock) Gabion baskets Driven rail and mesh gabion walls Reno mattresses Rock or concrete grade control structures
Construction of "Permeable" Erosion Protection Structures on & in the river bed	Debris fences Debris arrestor Permeable groynes
Construction of other works outside the river bed (on berms and stopbanks within the river corridor)	Cycleway/walkway construction and associated new stormwater drainage, culverts, footbridges and accessways Fences Floodwalls
Demolition and removal of existing structures on & in the river bed	Demolition by mechanical and/or hand methods. Removal of material from river bed.
Maintenance of existing structures on & in the river bed	Structural repairs and maintenance to: • Existing erosion protection structures in the river bed • Existing culverts and outlet structures that discharge directly to the Otaki River (including clearance of debris)
Structural maintenance work outside the river bed	Structural repairs and maintenance to: • Stopbanks & training banks • Flood and/or retainin walls • Stormwater culverts (including clearance of debris) • Stormwater drainage channels • Footbridges located on the river berms • Fences located on the river berms • Bank and berms
Development of vegetative bank protection	Tree Planting Willow layering, cabling & tethering
Maintenance of vegetative works	Trimming of trees and mulching of trees (from the riverbed) Removal of old trees Removal of damaged structures Additional planting New layering of trees Re-cabling of tethered willows
Channel shaping or realignment	Mechanical: • beach re-contouring (including 'ripping') • bed re-contouring • Channel diversion cuts • Re-contouring (shaping and/or infilling) of bank edges • Ripping in the wetted channel
Channel maintenance	Removal of vegetation (both aquatic and terrestrial) Beach scalping Clearance of flood debris Gravel extraction from Otaki Riverbed Removal of silt and debris from drains and Chystalls Lagoon
Non-structural maintenance works outside the river bed	Mowing stopbanks & berms (not involving machinery in river bed) Drain maintenance Water blasting Trimming and mulching of vegetation

Type of Activity	Individual Activities
	Planting & landscaping
Excavation, disturbance of, and deposition on, beach areas above MHWS level.	Mechanical excavation, disturbance of sand, and deposition of sand and sediment
Contingency works	Any of the above undertaken in response to a flood or emergency situation
Works in the Coastal Marine Area	This includes: • Clearance of flood debris • Minor disturbance associated with gravel extraction • River mouth alignment including periodic cutting of a new opening in response to defined trigger points (excavation of foreshore; movement and re-deposition of excavated material onto the foreshore). • Contingency structures

5 Effects of Flood Protection Activities on River Ecology

5.1 Overview

The physical character of a river determines the quality and quantity of habitat available to biological organisms and the river's aesthetic and amenity values. Physical habitat is the living space for all in-stream flora and fauna, it is spatially and temporally dynamic and its condition and characteristics set the background for any assessment of the health of a waterway. The quantity and quality of physical habitat has a major bearing on the successful colonisation and maintenance of populations (Harding *et al* 2009) and it is well recognised that morphological change in river channels can impact the ecology of riverine environments.

River management schemes in New Zealand have in many instances influenced channel morphology, particularly in terms of reducing channel width and area, reduced morphological complexity, and reduced connectivity to the floodplain. Such changes can have significant implications for the composition and distribution of riparian and aquatic communities (i.e. Richardson and Fuller 2010; GJ Williams, 2013).

In the Otaki catchment the lower river, especially below SH1, has been progressively straightened and confined to allow for development while the upper river remains relatively unconstrained. The challenge facing GWRC is to continue to meet its statutory responsibility for the minimisation and prevention of flood and erosion damage, while ensuring that there is no further loss of biodiversity and, where possible, the quality of the environment is enhanced.

The following sections provide an assessment of the potential effects of individual operations and/or maintenance activities listed in Table 4-1 on the water quality and ecology of the Otaki River and specified tributaries. While all of the listed activities are potentially available for use in the smaller tributaries covered by the consent application, in practice, and based on past experience, they are most likely to be limited to those listed below in Table 5-1.

Table 5-1: GWRC Flood Protection activities likely to be required in Otaki River tributaries

Watercourse	Activities likely to be undertaken in the future
Rangiuru Stream	• Removal of vegetation and silts (by mechanical excavation) • Clearance of flood debris • Maintenance of existing culverts, floodgates and other structures • Planting and landscaping
Ngatoko Stream	• Removal of vegetation and silts (by mechanical excavation) • Clearance of flood debris • Planting and landscaping
Pahiko Drain	• Removal of vegetation and silts (by mechanical excavation) • Clearance of flood debris
Katihiku Drain	• Removal of vegetation and silts (by mechanical excavation) • Clearance of flood debris • Maintenance of existing culverts, floodgates and other structures
Waimanu Stream	• Removal of vegetation and silts (by mechanical excavation) • Clearance of flood debris • Clearance and maintenance of debris arrester
Chrystalls Lagoon	• Removal of vegetation and silts (by mechanical excavation)

5.2 Water Quality

The primary effects on water quality associated with mechanical disturbance of the river bed are those relating to the release of fine sediment into the water column, resulting in increased levels of suspended sediment and turbidity, reduced water clarity, and increased sediment deposition downstream. Other potential water quality effects include the release of nutrients or bacteria into the water column.

The results of turbidity and suspended solids measurements undertaken in the Hutt River during a gravel extraction operation are summarised in Table 5-2. The gravel extraction activity entailed extensive mechanical disturbance of the river bed, including pushing river bed material from the flowing river up onto a beach. This type of activity is at the high end of the scale for flood protection routine activities discussed in this report. Maximum turbidity and suspended solids values of 306 NTU and 207 mg/L, respectively, were recorded in the River during bulldozer operation. Turbidity levels ranging from 70 to 163 NTU were recorded in the River 1400m downstream of the works over the same period (Perrie, 2013a).

Table 5-3 summarises the results of turbidity and suspended solids monitoring undertaken during repeated truck crossings of the Hutt River at the same location. Truck crossing activity had a relatively minor effect on river water quality, causing turbidity and suspended solids increases of up to 16 NTU and 2 mg/L, respectively; which is at the low end of the scale for activities discussed in this report. River crossings by larger tracked vehicles can generate suspended solids levels of around 130 mg/L (refer Table 5-4). Bulldozer channel shaping in the Waikanae River has generated suspended solids concentrations as high as 690 mg/L.

These results confirm earlier observations that while very high suspended solids concentrations may occur during a large disturbance, water clarity returns to near ambient levels rapidly, often within one hour of the activity ceasing.

In the Hutt River, and probably also in the Otaki River, suspended solids concentrations as high as 780 mg/L occur during larger flood events (a one-year flood). For smaller more frequent events, i.e., those occurring three to four times each year, suspended solids concentrations typically fall in the range 100 to 400 mg/L (data from HCC and GWRC). Hicks & Griffiths (1992) note that, in rivers around New Zealand, peak suspended solid concentrations during floods range from a few hundred to a few thousand mg/L for relatively small undisturbed catchments in low hill country. The channel shaping results listed above are therefore not outside of the normal range for a mobile gravel bedded river.

Recent monitoring of water quality variables during channel realignment in the Hutt River at Belmont showed that, in addition to elevated levels of suspended solids, the discharge plume contained elevated levels of total nitrogen and total phosphorus. There was, however, no corresponding increase in dissolved nutrients in the water column indicating that the nutrients were bound to particulate matter (Table 5-5). The river bed disturbance is therefore unlikely to have stimulated periphyton growth because the nutrients were not present in a form that could be readily taken up by aquatic plants[3]. The particulate material in the discharge plume may also harbour microbiological contaminants, but the results of the Hutt River study indicate that any increase in indicator bacteria in the water column is likely to be intermittent and localised (Cameron, 2015).

Mechanical disturbance during low flows is likely to result in some settlement of fine sediment on the riverbed downstream of the works area, however this effect is relatively short lived in run and riffle habitat as water velocities during subsequent minor flood flows are generally sufficient to remove most of the fine sediment from the affected reach (Death & Death, 2013; Cameron, 2015).

In summary, the available data indicate that:

- River crossings by off-road truck generate relatively low suspended solids concentrations, from 2 to 10 mg/L above background;
- River crossings by bulldozer can increase river suspended solids concentrations by 130 mg/L;

[3] It is noted that biochemical conditions inside *Phormidium* dominated mats can, in some instances, be conducive to the release of loosely bound phorphorus, in which case phosphorus may become available for uptake by periphyton (Mark Heath, pers. com.)

- Channel shaping by bulldozer can increase suspended solids concentrations by nearly 700 mg/L;
- Suspended solids and turbidity levels return close to ambient levels rapidly, typically within 1 hour of the river works activity ceasing.
- Typically a major gravel extraction operation has been undertaken for a number of weeks, for up to eight hours a day, five days a week. The presence of elevated suspended solids concentrations have therefore occurred over the same timeframes;
- The discharge plume may also contain elevated levels of total nitrogen and total phosphorus, but monitoring undertaken in the Hutt River indicates that these nutrients are bound to particulate material and that there is no associated increase in water column concentrations of dissolved nutrients (and therefore little risk of stimulating excessive algae growth).
- Channel shaping may result in a temporary increase in fine sediment deposition on the riverbed downstream of the works.
- A larger flood event (annual and above) in the river can increase river suspended solids by over 700 mg/L, but more common smaller events typically increase river concentrations in the range 100 to 400 mg/L.

Table 5-2: Turbidity and suspended solids (SS) monitoring results for the Hutt River during gravel excavation by bulldozer in flowing water 500m Upstream of Kennedy Good Bridge on 28 November 2012 (data from Geotechnics Ltd)

Time*	Bulldozer activity	Upstream		100m Downstream		500m Downstream	
		Turbidity (NTU)	SS (mg/L)	Turbidity (NTU)	SS (mg/L)	Turbidity (NTU)	SS (mg/L)
16:10	Excavating gravel from river	6	1	175	90	47	29
16:35	Excavating gravel from river	5	2	306	207	102	51
17:00	No activity (work ceased at 17:00)	6	1	52	180	84	100
17:35	No activity	4	1	13	72	64	17
18:00	No activity	5	1	7	1	8	1

*Sampling commenced at the upstream site followed by 100m and 500m downstream over a 15 minute period.

Table 5-3: Turbidity and suspended solids monitoring results for the Hutt River during truck crossings of the river 500m Upstream of Kennedy Good Bridge on 28 November 2012 (data from Geotechnics Ltd)

Time	Truck activity	Upstream		100m Downstream	
		Turbidity (NTU)	Suspended solids (mg/L)	Turbidity (NTU)	Suspended solids (mg/L)
15:40	Prior to crossing river	1	1	6	2
15:48	Truck crossing river (1)	-	-	17	4
15:52	Truck crossing river (2)	-	-	5	2
15:54	Truck crossing river (3)	-	-	8	3
15:56	Truck crossing river (4)	-	-	12	2
15:58	Truck crossing river (5)	-	-	4	2
16:00	Truck crossing river (6)	-	-	7	2
16:02	Post crossing river	1	1	7	3

Table 5-4: Suspended solids concentrations in Waikanae River at river works (GWRC data 1998).

River	Activity	Suspended solids concentration in river (mg/L)		
		Background	Downstream (100m)	Downstream (300m)
Hutt	Channel shaping	2	480	-
	Bulldozer crossing river	2	130	-
	High river flow event (410m³/s @ Birchville on 19/11/96)	780	-	-
	High river flow event (160m³/s @ Birchville on 8/10/2007)	397	-	-
	High river flow event (80m³/s @ Birchville on 5/2/2013)	65	-	
Waikanae	Placement of rip-rap	<2	98	68
	Truck crossing	<2	<2	11

River	Activity	Suspended solids concentration in river (mg/L)		
		Background	Downstream (100m)	Downstream (300m)
Hutt	Channel shaping	2	480	-
	Bulldozer crossing river	2	130	-
	High river flow event (410m³/s @ Birchville on 19/11/96)	780	-	-
	High river flow event (160m³/s @ Birchville on 8/10/2007)	397	-	-
	High river flow event (80m³/s @ Birchville on 5/2/2013)	65	-	
	Thalweg cutting by bulldozer	<2	690	160

Table 5-5: Water quality results at three sites on the Hutt River on two occasions prior to realignment works and two occasions during the works (from Cameron, 2015)

	Upstream				Works Area				Downstream			
	Pre-works#1	Pre-works#2	Works#1	Works#2	Pre-works#1	Pre-works#2	Works#1	Works#2	Pre-works#1	Pre-works#2	Works#1	Works#2
Date sampled	4/05/2015	11/05/2015	26/05/2015	29/05/2015	4/05/2015	11/05/2015	26/05/2015	29/05/2015	4/05/2015	11/05/2015	26/05/2015	29/05/2015
Time sampled	15:00	10:40	10:39	11:37	14:20	10:30	10:55	12:00	13:30	10:15	11:24	12:20
Easting	2672993	2672993	2672993	2672993	2672293	2672293	2672993	2672993	2671686	2671686	2672993	2672993
Northing	6000694	6000694	6000694	6000694	6000046	6000046	6000694	6000694	5999634	5999634	6000694	6000694
Water Quality												
turbidity (NTU)	0.64	1.54	1.04	0.96	0.79	2.2	1010	59	0.96	1.8	29	20
TSS (g/m^3)	<0.5	1.6	1	<0.6	<0.5	3.3	770	82	<0.5	1.7	30	14.8
TN (g/m^3)	0.35	0.33	0.45	0.42	0.33	0.34	1.05	0.5	0.47	0.48	0.49	0.48
Total ammoniacal-N (g/m^3)	<0.010	0.01	<0.01	<0.01	<0.010	<0.01	<0.01	<0.01	<0.010	<0.010	<0.01	<0.01
Nitrate+nitrite-N (g/m^3)	0.28	0.26	0.34	0.36	0.28	0.26	0.35	0.36	0.38	0.36	0.38	0.4
TKN (g/m^3)	<0.1	<0.1	0.11	<0.10	<0.1	<0.1	0.7	0.14	<0.1	0.12	0.11	<0.1
DRP (g/m^3)	0.006	0.007	0.008	0.006	0.006	0.007	0.006	0.006	0.01	0.009	0.006	0.006
TP (g/m^3)	0.006	0.008	0.014	0.008	0.006	0.01	0.62	0.077	0.012	0.018	0.032	0.018
E. coli (cfu/100ml)	65	250	140	110	130	200	2100	150	150	300	230	220

5.3 Effects of channel and bank maintenance on minor tributaries

5.3.1 Rangiuru and Ngatoko Streams

GWRC maintains the Rangiuru Stream from the floodgates upstream to just beyond Tasman Road, a lineal length of nearly 3km, and Ngatoko Stream as far as Riverbank Road Extension, a length of nearly 2km. In both cases the maintenance activities may include the removal of vegetation and silts by mechanical excavation, clearance of flood debris, maintenance of existing culverts and floodgates, as well as planting and landscaping.

As described in Section 3.1 these are spring fed watercourses with a sandy gravel substrate, relatively high water clarity, macrophyte cover over a significant proportion of the bed, and variable riparian edge vegetation. While no fish records are available, the core fish community is likely to include longfin eel, shortfin eel, common bully and inanga (see Section 3.1.8.2). Other galaxiid species such as giant kokopu, shortjaw kokopu, banded kokopu and koaro may also be present where suitable habitat is available.

As this watercourse is likely to contain habitat of relatively high value for 'At Risk' fish species the periodic (annual) mechanical removal of aquatic vegetation and silt does present some risks which will need to be effectively managed. The potential adverse effects associated with silt and vegetation removal are outlined in Section 5.11.2 and a possible mitigation strategy is provided in Section 7.5.

5.3.2 Pahiko and Katihiku Drains

GWRC maintains the Pahiko Drain from the floodgates upstream to near the northern end of Harakeke Road Road, a lineal length of 2.7km, and Katihiku Drain as far as Swamp Road, a stream length of nearly 3.5km. In both cases the maintenance activities may include the removal of vegetation and silts by mechanical excavation and clearance of flood debris.

These watercourses were both constructed through the Whakapawaewae wetland as part of the drainage system. The drains are cleared annually to maintain capacity. They are deep, steep sided waterways with soft sediment substrate, with macroinvertebrate habitat is largely limited to macrophytes. Fish habitat is limited in both quality and abundance in the straight sided channels, although prolific macrophytes provide cover. Although no fish records are available it is expected that the core fish community will consist of longfin eel, shortfin eel, inanga and common bully.

As these watercourses may contain limited habitat for longfin eel, inanga, and possibly other species, the periodic (annual) mechanical removal of aquatic vegetation and silt presents some risks which will need to be managed. The potential adverse effects associated with silt and vegetation removal are outlined in Section 5.11.2 and a possible mitigation strategy is provided in Section 7.5.

5.4 Construction of impermeable erosion protection structures

5.4.1 Rock groynes

Description of activity

Rock groynes are structures that extend from the bank into the river bed and which deflect the direction of flow. They are designed to slow flow velocities and gravel bed movement in the immediate vicinity of the river bank and hence prevent bank erosion. Groynes are constructed by using an hydraulic excavator to excavate a trench typically 1.0 – 3.0m deep. Rock is placed in the trench and keyed into the adjacent bank to form the base of the groyne. Additional rock is then placed to shape the groyne. In most cases groynes are constructed from solid rock but for larger groynes a river gravel core may be used. Size is dependent on the situation, but typically 10 to 15m long by 6 to 8m wide at the bank, tapered to 4m wide at the toe. The structure would not normally project more than 10m beyond the bank edge into the channel. A series of four or five groynes may be constructed on a long sweeping bend.

Records for the Otaki River show that 14 rock groynes have been constructed between 2007 and 2013, at an average rate of 1 per year, and that regular maintenance of these structures is undertaken. This amounts to a low level of bed and bank disturbance.

Potential effects

Construction of a trench and placement of rock would include some disturbance of bed materials and would also include a localised increase in suspended solids concentrations, possibly by as much as 100 mg/L immediately downstream of the works area. A suspended solids concentration of this order would cause a noticeable reduction in water clarity and would be clearly visible from the bank. It would, however, be less than that generated by a moderate fresh in the river.

Monitoring in gravel bedded rivers has confirmed that suspended solids concentrations return rapidly to ambient levels once the in-stream activity ceases. Therefore, the maximum continuous duration of a discharge plume generated by in-stream channel works would be little more that the length of a working day; the aquatic biota would have the benefit of normal water quality for at least half of each 24 hour period.

An investigation conducted before and after installation of rock groynes and bed recontouring on the Waiohine River in the Wairarapa (Death & Death, 2013) identified some changes in macroinvertebrate and fish communities at the works site and at a downstream site (due to deposited sediment) however these communities recovered within a few weeks, returning to their pre-works state after the first fresh. A similar response could be expected in the Otaki River provided key habitat types such as swift riffles are retained.

Rock groynes are typically placed on the outside of bends where there are relatively high current velocities and deeper water. The introduction of rock groynes at such locations may increase the morphological complexity of the river particularly if they are constructed against what was previously an eroding bank. This often results in deep pools associated with the toe of the structure, and sheltered water sheltered in its lee (Cameron, 2015a). This combination of fast water, sheltered water, deep pools and large crevices amongst the boulders can potentially provide a variety of habitat for both native fish and trout. In the Hutt River, Perrie (2013) recorded shortfin eel, longfin eel, koaro, inanga, crans bully, common bully, giant bully, brown trout and shrimp in deep water habitat associated with groynes near Kennedy Good Bridge. The longfin eels were up to 800mm and trout up to 500mm in length. Mitchell (1997) considered that rock groynes could provide feeding lies for trout in areas where this type of habitat is naturally uncommon. A Fish & Game survey in the Hutt River near Kennedy Good Bridge showed that trout numbers are relatively high, and that many were located in deep holes associated with the rock groynes (Cameron, 2015a).

It can be concluded that rock groynes have the potential to enhance some forms of fish habitat and that the overall effect of this structure on native fish and trout populations in the Waikanae River is likely to range from neutral to positive.

Four sites of value for native birds have been identified on the Otaki River based on the 2012 to 2015 surveys (see Figure 3-15). None of these sites are likely to be at risk from groyne construction, although consideration should be given to the locations of these sites as part of the pre-works planning prior to any construction in the Otaki River.

Figure 5-1: Rock groynes, Hutt River (left) and a large rock groyne near Otaki River mouth (right)

5.4.2 Rock rip-rap lining

Description of activity

Rock rip-rap consists of rock boulders placed against a section of river bank to form a longitudinal rock wall (Figure 5-2). Hydraulic excavators are used to batter a section of river bank to a specified slope and to excavate a trench in the river bed to the design scour depth. Rock is then placed in the trench and against the battered bank. A full rock wall extends up to a height equivalent to a 2 year return period flood.

In areas requiring lesser amounts of protection, rock lining may be placed at the toe of a bank; this is constructed in a similar way except that the structure generally does not extend higher than approximately 1m above the low flow water level and is not deeply founded into the riverbed.

Rock linings have been used been extensively in the Otaki River where 19% of the total bank length within the scheme has a rock rip-rap lining. That proportion is less than on the Hutt but more than on the Waikanae River as indicated in Table 5-6. It includes significant lengths of rock lining above SH1 at Chrystalls Bend below SH1 at Lethbridge and at the 'transmission lines'.

Table 5-6: Summary of rock rip-rap lineal lengths

River	Total bank length (left + right bank)	Total rock rip-rap lineal length	Percentage of bank length lined with rock rip rap
Otaki	22.2km	4.3km	19%
Hutt	56km	13.8km	25%
Waikanae	14km	1.6km	11%
Wainuiomata	9.6km	0.015km	0.2%

Potential effects

Construction of a trench and placement of rock would include disturbance of bed materials and a localised increase in suspended solids concentrations. Short term effects on water quality and habitat quality are likely to be similar to those described for the construction of rock groynes in the previous section.

Mechanical disturbance of the bed will disrupt invertebrate habitat and may cause some mortality of smaller fish which seek shelter within the substrate. The extent of this disturbance would depend on the quantum of rip-rap to be constructed and the type of habitat which is being replaced.

Longer term effects of rock rip-rap lining are likely to be site specific. Bank contouring could destroy valuable fish habitat beneath undercut banks or overhanging vegetation, and placement of boulders against the bank may reduce the availability of deep water habitat for larger fish. Within the tidal reach, especially in vicinity of the Rangiuru Stream and Pahiko Drain, construction of rip-rap rock lining could potentially destroy inanga spawning habitat, however rock lining is not likely to be used in these areas.

A suggested monitoring plan outlined in Section 8 and in the EMP includes the re-survey and mapping of potential inanga spawning habitat so that adverse effects on areas of remaining habitat can be avoided.

In other instances, where deep water is maintained against the toe of the rock rip-rap lining, protruding boulders and those which have worked free might potentially provide feeding lies for trout and shelter for other fish species. Crevices between boulders may provide shelter for small and in some cases larger fish. The establishment of vegetation amongst the rock lining has the potential to provide overhanging cover, which may improve fish habitat.

Overall this activity would appear to have a neutral to negative ecological impact, depending on the extent of undercut banks and/or the net loss of overhanging vegetation. There is, however, opportunity to include specific design elements which may potentially result in a net positive effect in some instances. These might include:

- Planting at the rear of the rip-rap where this is likely to provide bankside shade, cover and woody inputs;

- Provision of fish refuges, for instance by placement of boulders to form crevices within the structure; and
- Inclusion of additional boulders protruding out from the wall to break up the uniform flow.

Four sites of value for native birds have been identified on the Otaki River based on the 2012 to 2015 surveys (see Figure 3-16). None of these sites are likely to be at risk from rock rip-rap construction, although consideration should be given to the locations of these sites as part of the pre-works planning prior to any construction in the Otaki River.

Figure 5-2: Rock rip-rap linings, Hutt River

5.4.3 Other impermeable erosion protection structures

Construction of other impermeable erosion protection structures including driven rail and mesh gabion walls, gabion baskets, reno mattresses include the same basic components as outlined above for rock rip-rap linings. Some excavation or disturbance of riverbed material is required in preparation for construction, and the finished structure will generally result in some loss of channel complexity. This may include some loss of fish habitat, particularly if the structure is replacing an undercut bank or dense overhanging vegetation. However, in other instances erosion protection structures may enhance channel complexity and create new habitat for fish, particularly where they incorporate large gaps, crevices and occasional blocks to break up the uniform flow of water.

Rock or concrete grade control structures would also include minor, localised riverbed disturbance during construction, and care would need to be taken that such structures did not impede fish passage subsequently.

5.5 Construction of permeable erosion protection structures

5.5.1 Debris fence, debris arrestor, timber groyne

Description of activity

Debris fences are iron and cable fences that extend from the bank into the river channel. They are used to create or re-establish a willow buffer zone along the edge of the river channel, and so maintain channel alignment. They are inter planted with willows and afford protection to these by trapping flood debris and slowing flows and gravel movement.

Fences are constructed by driving railway iron posts 3 - 5 metres apart into the river bed in a series of discrete lines generally at an angle of 45 degrees from the channel alignment. The posts stand approximately 1.2m above the bed. Three or four steel cables are strung through the posts to form the fence. It is usually necessary to shape the site with a bulldozer to create a smooth construction platform and also to divert the flowing channel away from the site. Irons are driven with a hydraulic hammer

Debris arresters are generally constructed from railway irons driven into the bed and tied together with horizontal irons and in general would entail some mechanical disturbance of river bed material as described for debris fences. A debris arrestor located on Waimanu Stream upstream of Chystalls Lagoon consists of four driven railway irons across the width of the stream at 1m spacing.

Timber groynes are constructed in a similar way to debris fences, but typically consist of round hardwood timber piles with two horizontal hardwood cross members.

Figure 5-3: Completed debris fence, Otaki River.

Potential effects

Diversion of the river and shaping of the site by bulldozer involves some disturbance of river bed materials. The initial diversion of the river flow away from the works area will likely result in the discharge of suspended sediment into the flowing river, causing elevated turbidity and suspended solids levels, probably in the upper end of the range outlined in Tables 5-2 to 5-4. However the diversion (and subsequent removal of the bund) would typically be completed quickly, usually within a matter of hours, after which the works are undertaken mostly in the dry, with minimal effects on river water quality.

Mechanical disturbance of riverbed materials will disrupt invertebrate habitat and may cause some mortality of smaller fish which seek shelter within the substrate. The extent of this disturbance would depend on the quantum of debris fence to be constructed and the type of habitat which is being replaced.

The maintenance of debris arrestors, including one located in Waimanu Stream, causes a temporary release of sediment and other material into the stream, but such a discharge is of short duration and is unlikely to have any lasting adverse effect on aquatic biota.

These structures work as sediment and debris traps so that flood borne debris snags on the rails or cables and rapidly accumulates. At high flows turbulence causes scour on the lee of the structure, often creating a gutter which leads downstream to intersect with the main channel. When this gutter remains full of water at normal flows it can provide sheltered rearing habitat for juvenile fish. Larger eels, trout and a range of native fish may also find cover beneath the debris trapped on the cables, provided the hole is both stable and large enough (Mitchell, 1997).

Mitchell (1997) also noted that as a debris fence or groyne ages, willows and other plants can begin to grow from the trapped debris, until the structure eventually becomes largely obscured and supplanted by the establishment of vegetation. This may result in the accumulation of gravels and silts around the structure causing the river channel to shift away from the structure, with the area around the groyne gradually becoming dewatered. The structure will then have become largely irrelevant for instream values except as shelter for fishes during flood conditions. These structures can create sheltered habitat in areas where it previously may not have been available and, on balance, would appear to have a positive to neutral effect on fish habitat.

5.6 Construction of other works outside of the river bed

Activities such as the construction of cycle ways, walkways, fences and drainage channels outside of the river bed (on berms and stop banks within the river corridor) are unlikely to have any direct effect on the aquatic ecology of these rivers, except possibly by way of sediment runoff from areas of disturbed soils. Sedimentation effects can be adequately managed by the preparation of and adherence to an erosion and sediment control plan, in accordance with the Erosion and Sediment Control Guidelines for the Wellington Region (GWRC, 2002).

5.7 Demolition and removal of existing structures

The effects of demolition and removal of an existing structure will be site specific, depending on the type of structure and its location. The magnitude of these effects could be expected to fall within a range up to and including those described above for the construction of those structures. It is noted that in the past structures have been removed where they presented a health and safety risk to river users. This is not a major activity and is undertaken on an as required basis, typically for no more than one or two days per year in the Otaki River. It is unlikely to have a significant impact on invertebrate or fish habitat.

5.8 Maintenance of existing structures on and in the river bed

The repair, replacement, extension or alteration of existing structures on or in the river bed may have a wide range of effects depending on the type of structure and its location. The magnitude of these effects could be expected to fall within a range up to and including those described above for the construction of those structures.

5.9 Maintenance of works outside of the river bed

This activity includes regular maintenance work on berms or stopbanks such as mowing and riparian planting as well as intermittent repairs to damaged structural works (stopbanks, flood walls, culverts, drainage channels, and berms) caused by flood events, stormwater runoff or vandalism. It may also include repairs, enhancements or extensions to walking tracks and cycle ways, and upgrade or repair to any drainage channels that cross the berm, including mechanical or hand removal of weeds from stormwater drains. Some of these drains may potentially provide habitat for eels or other fish. Strategies for mitigating the adverse effects of drain clearance on the aquatic ecology are outlined in Section 7.5. Subject to the provisions in Section 7.5, and provided appropriate measures are taken to control sediment runoff and erosion, these activities are not expected to have significant adverse effects on river ecology or water quality.

5.10 Development of vegetative bank protection

5.10.1 Willow planting

Description of activity

Willows were introduced to New Zealand and Australia in the 1880's for the purpose of stream-bank stabilisation in degraded pastoral systems and as shelter and supplementary fodder for livestock. Extensive willow plantings for erosion control, however, took place in New Zealand in the 1970s to early 1980s (Wagenhoff & Young, 2013). Willow planting forms an essential part of current river protection work nationwide. Willows are easy to establish, grow rapidly and form an intricate root system that is ideal for binding and strengthening river banks and structural measures such as permeable groynes and debris fences. Generally, the same results cannot be achieved using native species. GWRC established a trial at three sites on the Hutt River in 2001 to investigate the use of native planting for river edge protection. The results of this work are reported in Phillips *et al (*2009). In summary, the report concluded that while native plants could be used to stabilise smaller order streams, there were limitations to the use of native planting for edge protection in larger rivers. In particular, natives are:

- slower to establish
- have shallower root systems
- have higher maintenance costs

The native species with the most potential for river edge protection are toetoe (*Cortaderia fulvida*), flax (*Phormium tenax*) and some grasses (*Carex sp*.). However it was also noted that in flood events there is potential for erosion of these clump-type plants to cause channel blockages. In light of the trial outcomes, native planting cannot be regarded as a comprehensive or comparable alternative to willows; the most realistic alternative at this stage is likely to be structural work (e.g. rock lining), which involves higher costs and arguably increased environmental impact.

As indicated in Table 5-7 approximately 85% of the total river bank length within the Otaki River flood protection area has vegetative bank protection. GWRC has advised that it does not plan to significantly extend the total area of willow plantings in the Otaki River corridor in the future, and that it undertakes significant planting of native trees in the river corridor behind the 'frontline' willow defence plantings. Native planting in these areas is consistent with the Otaki River Environmental Strategy (WRC 1999).

Table 5-7: Summary of vegetative bank protection lineal lengths within managed flood protection areas

River	Total bank length (left + right bank)	Total vegetative planting lineal length	Percentage of bank length with vegetative protection
Otaki	22.2km	18.8km	85%
Hutt	56km	32km	57%
Wainuiomata	9.6km	5.6km	59%
Waikanae	14km	7.4km	53%

The development of vegetative bank protection involves planting vegetation along the edges of river banks generally within the design buffer zone, in order to bind and support the bank edge and so maintain a stable river alignment. Branch growth also reduces water velocities at the bank edge which assists in erosion protection. Trees may be used to further reinforce structural works. Planting is generally carried out between June and August. Four planting methods are used:

- By hand, using a crow bar. Willow stakes are cuttings approximately 1.5 m long and 2.5 cm in diameter.
- Planting using an excavator or planting tine. The tine is dragged through the soil at up to 1 m depth and the stakes or rooted stock planted behind the moving tine. The movable arm of the excavator allows planting to be undertaken on quite steep banks and amongst established trees. This is most commonly used where large areas of planting are required.
- Planting using a digger. Willow poles (large cuttings of 3 m long or more) are planted in a trench dug and backfilled by the excavator. This method is used where willows are planted in very dry areas or immediately adjacent to fast flowing water.
- Planting using a mechanical auger to prepare holes for stakes or poles (Figure 5-4).

Figure 5-4: Willow pole planting (note native plantings in foreground)

Potential effects

Short term construction effects are expected to be negligible because the works involve minor disturbance and occur outside of the active river channel.

A recent review of effects of willows on stream ecosystems in Australia and New Zealand concluded that riparian willows at moderate density are more beneficial to trout and benthic macroinvertebrates when compared with riparian pasture reaches (Wagenhoff & Young, 2013). Most of those benefits are related to functions such as the provision of shade and shelter, control of water temperature, and control of sediment and nutrient levels. Mitchell (1997) observed that a chaotic tangle of fallen willow trunks, undercut banks and root mats, with the river eddying and cutting scour holes, provides deep water and many opportunities for cover for eels in particular but also for a range of other fish species.

On the other hand the widespread use of willows along river margins in New Zealand has, in many cases, reduced the natural biodiversity of the river ecosystem. Wagenhoff and Young (2013) found that, when compared with native vegetation, willow reaches supported fewer terrestrial invertebrate and bird species and lower bird numbers. It is recognised also that use of willow plantings and other bank protection methods to train and hold the river channel in a design alignment could result in restriction or reduction of habitat diversity unless the design alignment also provides for preservation of habitat diversity through deliberate measures.

It is evident that willow management is complex and context dependent, and that factors such as stream size, geomorphology, hydrology and catchment land-use may influence the outcome. We note that the use of willows forms the keystone of much of GW's (and other regional council's) flood protection work and if it were to be discontinued it would need to be associated with quite significant shifts in both river management policy and practice and in the community's use of the land beside the rivers. Consideration of this matter is beyond the scope of the current application.

On balance, the approach adopted by GW, including the continued use of willows as front line river bank protection, in conjunction with an active programme of planting native trees in the river corridor, may provide a reasonable compromise. Such an approach is likely to enhance some forms of fish habitat without undue adverse effects within the riparian margin, and the overall effect on native fish and trout populations is likely to be positive.

5.10.2 Maintenance of willow plantings and removal or layering of old trees

Description of activity

Maintenance of willow plantings on the river edge would generally involve removal of unstable trees, replanting with new poles, or layering and tethering of mature trees.

Layering is achieved by partially cutting through the trunk of large willow or poplar trees and obliquely felling the trees towards the river in a downstream direction. The intent is to allow the willows to sucker from the branches lying on the ground once they become covered in silt and gravel. The tree is wired to the stump to prevent it breaking off during a flood event. In a stand of willows, it is common for only the front two or three rows to be layered in any one year.

In some instances large unstable trees would be completely removed, but this would normally be followed by replanting for bank stabilisation and to re-instate bird roosting and aquatic ecology values.

Potential effects

Short term effects of layering trees are expected to be negligible. However the removal of old trees may result in the immediate loss of fish habitat (see below), and possibility a temporary and localised increased sediment inputs to the stream via stormwater runoff.

Willow layering for edge protection can benefit the aquatic ecology due to the creation of shade, cover and the supply of woody debris to the river as discussed in the previous section. Willow trunks layered over the bank into the channel may provide many opportunities for cover for eels and other fish species.

On the other hand the removal of trees may result in the loss of good quality fish habitat. While re-planting would normally be undertaken following tree removal, a delay of 10 – 15 years may occur before the full benefits of riparian planting are realised.

Wagenhoff and Young (2013) noted in their review that the potential risks of reach-scale willow removal are related to the influence willows have on geomorphic processes and the consequences of their removal. These include changes to the stream channel, pool-riffle sequences or channel migration associated with stream bank and floodplain erosion with further consequences for stream biota.

The review also showed that risks of willow removal are associated with the loss of the important functions riparian vegetation fulfils. These include increase in water temperature, sediment and nutrient levels, decrease in dissolved oxygen levels, organic matter input, shade and shelter, changes in periphyton community structure and stream metabolism, and eutrophication with direct negative effects on sensitive macorinvertebrate and fish species or indirect food-wed mediated effects associated with reduced detrital food sources (Wagenhoff & Young, 2013).

In some smaller water courses where there is little in-stream cover in the form of logs or undercut banks, willows may constitute a crucial habitat element (Dr Mike Joy, *pers. com*.). Given the paucity of focused information about the effects of willow removal on fish habitat it may be appropriate for a targeted study to be undertaken in a selected watercourse where this activity is likely to be required on a large scale, as part of an environmental monitoring plan.

In summary, the removal of one or two rows of a stand of willows, or of isolated unstable trees, is unlikely to have significant long term effects on river ecology, whereas willow removal at the reach-scale may have significant adverse effects, particularly in smaller watercourses.

5.11 Channel maintenance

5.11.1 Removal of woody vegetation

Description of activity

Willows or other tree species may be removed from the channel or adjacent banks, so as to minimise potential for blockages during floods, or to prevent dislodged willows re-growing in the channel. Trimming of willows on the bank edges is also required to clear survey sight lines and to maintain recreational access to the river. Clearance may be done by excavator and/or by hand.

Potential effects

The effects of willow removal are as described in the preceding section..

5.11.2 Removal of aquatic vegetation and silt

Description of activity

This activity includes the clearance of aquatic macrophytes (aquatic plants) and silt from low gradient watercourses so as to maintain channel capacity. High densities of these plants can increase sediment deposition, reduce flows and potentially flood surrounding land. Clearance may be done by mechanical or manual extraction of plant material. The Pahiko and Katihiku drains are typically cleared by hydraulic excavator around once each year; excavated vegetation and silt is placed on the banks (Figure 5-5). Clearing of parts the Rangiuru and Ngatoko Streams is also undertaken from time to time.

Potential effects

Clearance of aquatic macrophytes and silt from the Rangiuru/Ngatoko Stream or Pahiko/Katihiku drains is likely to result in significant short term disturbance (refer Section 5.3). Hand clearance is the least disruptive method but may not be viable in these watercourses. Mechanical excavation can result in the immediate loss of a high proportion of the available plant cover. Potential adverse effects of vegetation removal listed by Greer (2014) include the following:

- *Loss of fish spawning habitat.* Inanga spawn along banks of tidal reaches of these watercourses. Eggs are deposited in vegetation on a spring tide and develop out of the water. Removal of vegetation immediately prior to spawning limits availability of suitable habitat. If excavation is conducted while eggs are developing they may be crushed or removed.

- *Stranding of fish and removal of invertebrates during digger operation.* Many native fish species are nocturnal and utilise macrophyte stands as cover during the day. During weed harvesting and mechanical excavation, fish within macrophyte stands can be removed from the waterway alongside the vegetation. Although eels can sometimes make their own way back to the channel most stranded fish either die from desiccation or bird predation. Macro-invertebrates are also removed in large numbers during weed harvesting and mechanical excavation.

- *Suspended sediment causing fish mortality.* If sediment suspended by mechanical excavation has a large organic component, dissolved oxygen in the water column can be reduced. Sustained oxygen depletion can be lethal to fish.
- *Non-lethal effects of suspended sediment impacting fauna.* Suspended sediment concentrations are increased by the physical process of mechanical excavation and the resulting reduction in bed and bank stability. Suspended sediment concentrations can remain elevated for an extended period of time following large drain clearing operations. A persistent increase in suspended sediment concentrations reduces macro-invertebrate prey availability, impairs the feeding ability of some fish species, and impairs respiration. Most native fish and trout avoid high sediment environments; long term increases in suspended sediment reduces abundance. High suspended sediment concentrations and turbidity can affect upstream migrations of native fish and trout. High levels of fine sediment released during excavation can smother benthic fish and invertebrates when deposited in downstream receiving environments, causing death. Sediment released during drain clearing may reduce benthic fish habitat suitability in receiving environments by clogging interstitial spaces. Population densities can be reduced as a result.
- *Fish and invertebrate populations affected by changes in habitat structure.* Invertebrate community structure is strongly influenced by benthic habitat and is likely to be negatively affected by riffle disturbance and coarse substrate removal during excavation. Macrophytes and woody debris provide important habitat for invertebrates in soft-bottomed low-land streams. Therefore, the removal of these structures during excavation may have a significant impact on invertebrate populations. Nocturnal fish species such as the giant kokopu and the longfin eel spend daylight hours in cover provided by macrophytes, woody debris and undercut banks. Disturbance of these structures during drain cleaning may reduce their suitability as habitat. Disturbance of riffles and the removal of course substrates during excavation decreases population densities of some fish species and reduces spawning habitat availability for bullies and trout.
- *Changes in channel morphology and hydrology*. Channel morphology and hydrology can be altered by excavation of macrophytes which can have an impact on habitat availability for aquatic organisms. The removal of macrophytes and deposited sediment decreases water depth, increases current velocity and increases channel depth. However, repeated cleaning can over widen and deepen channels, slowing water movement. Removal of riparian vegetation and alterations to bank shape during excavation can decrease bank stability. This increases the risk of bank collapse which can affect the shape, path and hydrology of the waterway.

Greer (2014) proposed a series of strategies aimed at mitigating the adverse effects of watercourse clearing, noting that not all of these strategies will be successful or necessary all of the time. Those strategies that are applicable to the Otaki catchment are listed in Section 7.5.

Figure 5-5: Vegetation and silt clearing on the Pahiko Drain

5.11.3 Beach ripping and scalping

Description of activity

Beach scalping involves mechanical clearance of woody and herbaceous weeds and grasses from gravel beaches. Mechanical clearance is typically performed using a bulldozer, large excavator or front end loader to strip the vegetation and thus remove vegetative obstacles in the channel that might lead to gravel deposition in floods and consequent shifts in the desired channel alignment. The vegetation is crushed and left to break down or become light flood debris.

Ripping involves loosening of the gravel armouring layer by dragging a tine through it. This facilitates the mobilisation of the gravel during floods (Figure 5-6).

Both activities involve excavation or disturbance of bed material but do not typically result in a discharge of sediment to the flowing channel.

Figure 5-6: Beach ripping, Hutt River.

Potential effects

These activities are unlikely to have any immediate downstream effects on water quality or aquatic habitat. Beach ripping will,

however, loosen the beach gravels so that in the next flood, gravels and interstitial sand will be more readily mobilised, possibly causing additional siltation and gravel accumulation in the reach downstream. These processes already occur during floods and consequently river biota are well adapted to a dynamic, mobile bed environment. In this context the additional silt and gravel from lengths of loosened beaches is unlikely to be important.

Clearing areas that are in the process of becoming more stable and covered by pioneer weeds creates more open gravels. There is evidence that removing weeds has considerable value for those birds which roost and breed on open riverbeds (i.e., Rebergen 2011 & 2012). McArthur, et al (2015) identified that virtually the entire length of the application area provides breeding habitat for regionally-significant populations of both banded and black-fronted dotterels, and for a relatively large local breeding population of pied stilts. In addition, the lower reach of the Ōtaki River between XS90 and XS170 appears to be utilized by banded dotterels as a post-breeding staging area prior to migration.

In light of this information McAthur made a number of recommendations for the protection of breeding colonies on the Otaki River, which are included in Section 7.2 of this report and are incorporated in the Code. Recommendations about further monitoring to be carried out to provide quantitative data to describe ongoing trends in the distribution and abundance of river birds are included in Section 8 (and the Code).

5.11.4 Clearance of flood debris

Description of activity

Flood debris is material deposited on the river bed as a result of wreckage or destruction resulting from flooding. It can include trees, slip debris, collapsed banks, the remains of structures, and other foreign material including abandoned vehicles, but does not include the normal fluvial build-up of gravel.

Removal of flood debris is necessary because blockages reduce channel cross-sectional area which result in higher flood levels. In addition, if allowed to occur, build-up of obstacles may deflect flood flows into banks, causing lateral erosion.

Removal of flood debris covers only the minimal amount of work needed to clear the bed or structures within the bed of flood debris; any beach or bed contouring completed at a location where debris removal occurs is accounted for as beach or bed recontouring.

This activity may also be undertaken in the minor tributaries from time to time, including the Rangiuru, Ngatoko and Waimanu Streams, the Pahiko and Katihiku Drains, and Chrystalls Lagoon.

Potential effects

Mitchell (1997) notes that debris clearance has implications for fish living in large open rivers. Trees and debris stranded in the river channel by a flood event will have formed local disruptions to flow. Turbulence results in scour around the debris and there can be a subsequent range of habitats formed. During flood events, debris clusters can provide shelter for fish where they could otherwise be swept downstream. In normal flows these same areas can provide feeding lies for trout if they remain at least partially submerged and are beside the main flow. Small fish are attracted to the cover provided beneath debris in shallow, slow-flowing water (biologists will head for these areas during electric fishing surveys because of the high probability of finding fish in this type of habitat).

Overall, there is little doubt that flood debris can increase the range of water depth and velocities which in turn provide for a variety of habitat preferences for fish, although Jowett & Richardson (1995) suggest that flood debris are not sufficiently abundant to influence fish distribution to any great extent. It seems therefore that where there is opportunity to leave flood debris that presents no apparent risk to structures or public safety, it would be beneficial to enhancement of available habitat for fish.

As parts of the Rangiuru Stream and Pahiko/Katihiku drains are known to provide inanga spawning habitat, the timing of any works in these areas will be important. Disturbance of these areas should be avoided during spawning, from March to May, inclusive and, if practicable, should not occur when the whitebait return from the sea to run up the river (the whitebait season) from 15 August to 30 November. (refer Section 7.6).

5.11.5 Gravel extraction

Description of activity

Gravel bed material is extracted from the river in order to maintain bed levels within a design envelope of maximum and minimum levels. The aim is to maintain a balance between flood capacity (reduced by high bed levels) and the threat of undermining bank protection works (increased by lower bed levels).

To date practice in the Wellington Region has been to limit gravel extraction to areas outside the wetted width of the river, that is, from beaches above the active channel (‘dry extraction’). Gravel is pushed up into stock piles by an excavator and then loaded onto trucks for removal. Trucks may need to cross the river in some instances but in general the disturbance of riverbed materials within the active channel is relatively minor. GWRC proposes to continue this activity at some locations.

GWRC also proposes that gravel bed material will be extracted from the Otaki River using the methodology developed for wet extraction in the Hutt River. This involves working in the low flow channel, with a lower channel being formed beach by beach to a meander pattern with a pool and riffle form. The intention is to maintain a well-defined low flow channel with a ‘natural’ slope to the beach and well-formed pools and riffles, so as to provide good quality habitat for invertebrates and fish. This approach is intended to avoid the creation of a uniform straight, shallow channel, which had been observed to occur in the lower Otaki River as a result of extracting gravel only from beaches above the active channel. The aim is to improve both the natural character of the lower river and the quality of habitat for invertebrates and fish.

GWRC proposes to continue to extract approximately 53,500m^3 of gravel annually which is the estimated volume required to maintain design bed levels (Gardiner, 2011). The majority of this is expected to be taken downstream of Chrystalls Bend.

An additional 35,000m^3 of material is available for removal from a large gravel bar known as "Mangahenene Island" adjacent to the CMA boundary (see Figure 3-17). GWRC proposes to remove scrub, weeds and gravel from a dry beach on the northern edge of the Island, between XS 30 and XS 80, to achieve the design channel alignment through this reach. This action would remove the erosive pressure on the true right (north) bank.

Potential effects in Otaki River

(i) Disturbance of birds

McArthur, *et al* (2015) identified four sites of value for native birds on the Ōtaki River:

- Virtually the entire length of the application area provides breeding habitat for regionally significant populations of both banded and black-fronted dotterels, and for a relatively large local breeding population of pied stilts.
- A nesting colony of black shags on the escarpment on the true right of the Ōtaki River at XS970. Although the colony itself is situated on the escarpment well above the bed of the Ōtaki River, both adult black shags and recently-fledged juveniles from the colony were observed using the adjacent river channel and riverbed for foraging and roosting.
- The lower reach of the Ōtaki River between XS90 and XS170 appears to be utilized by banded dotterels as a post-breeding staging area prior to migration. In late summer (January), a relatively high number of non-territorial adult and juvenile dotterels roost in this downstream reach of the river before departing on migration.
- The Ōtaki Estuary supports a relatively high total number of bird species, a relatively high number of Nationally Threatened and 'At Risk' species, and a higher ratio of native to introduced bird species than any other reach of the Ōtaki River

Gravel extraction from beaches above the active channel (in the dry) may have implications for river bird roosting and breeding habitat. McAthur made a number of recommendations for the protection of breeding colonies on the Otaki River, which are included in Section 7.2 of this report and are incorporated in the Code. Recommendations about further monitoring to be carried out to provide quantitative data to describe ongoing trends in the distribution and abundance of river birds are included in Section 8 (and the Code)

(ii) Disturbance of Herpetofauna

One species of lizard, the northern grass skink, has been recorded within the Otaki River flood corridor. Gravel extraction from dry beaches may affect the margins of the northern grass skink population, however lizards are likely to be, at best, sparsely distributed on these beaches, which are regularly innundated by flood flows. Accordingly the potential impact on lizard populations is assessed as negligible and no specific mitigation measures are considered to be necessary.

(iii) Fine sediment mobilisation and deposition

Gravel extraction from the dry is likely to have minimal effects on water quality of the Otaki River, although in those cases where trucks are required to cross the river there is potential for minor temporary discharge of suspended sediment (refer Section 5.2) and disturbance of bed material. This can be managed by requiring vehicles to use designated crossing points.

There is evidence from a study of the Pohangina River that gravel extraction in the dry can lead to the accumulation of fine sediment on the river bank at locations where it can be carried into the river during a small fresh (Death *et al,* 2011). That is likely to be a consequence of the mudstone geology and high fine sediment content of gravels in the Pohangina River, which is not the case for the Otaki catchment which has hard-sedimentary geology, and where the fine sediment content of gravels is low. It is noted however that Perrie (2013) reported a reduction in substrate size on dry beaches of the Hutt River, where gravel had been previously stockpiled and then removed.

Gravel extraction which involves working in the active channel, as is proposed in the Otaki River, entails extensive disturbance of bed material and significant release of suspended sediment into the water column. Monitoring of river water quality indicates that this activity generates suspended solids concentrations in the river immediately downstream of the works of up to 800 mg/L, or about the same order as an annual flood (Section 5.2). Monitoring results also indicate that suspended solids concentrations decrease with distance downstream, and return to near ambient levels within an hour of the completion of works. Consequently, if works in the actively flowing channel are limited to no more than 12 hours each day the aquatic biota downstream of the works would have the benefit of normal water quality for half of each 24 hour period, including night time when much of the native fish feeding activity occurs.

Boubee *et al* (1997) demonstrated, in laboratory tank studies, that some juvenile migratory native fish, particularly banded kokopu, are sensitive to suspended solids concentrations and avoid turbid waters much over 25 NTU (about 120 mg/L suspended solids). Koaro and inanga were found to be less sensitive than banded kokopu, with avoidance response at 70 and 420 NTU, respectively. Short fin and longfin elvers and redfinned bullies showed no avoidance behaviour, even at the highest turbidity tested of 1100 NTU. Subsequently, experiments in a natural stream determined that the rate of movement of migrant banded kokopu declined as turbidity levels exceeded 25 NTU (Richardson *et al*, 2001). Of the native fish species present in the Otaki River, banded kokopu is likely to be the most sensitive to suspended solids.

Death *et al* (2013) found that bed recontouring on Waingawa River, using a similar method to that applied during gravel extraction, resulted in a marked increase in levels of deposited sediment downstream of the works but that effect was temporary, with a return to ambient levels after the first fresh. Extensive bed recontouring works on the Hutt River at Belmont caused a conspicuous sediment plume while machines were operating in the river (up to 770 mg/L) but two weeks after completion (and after a minor flood flow) fine sediment cover in riffle habitat 750m downstream of the works was no higher than upstream of the works (Cameron, 2015).

In summary, gravel extraction works have typically caused a marked increase in water column suspended solids, but this effect is temporary and does not continue much beyond the cessation of works. The works have also caused increased rates of sediment deposition in downstream river habitats, but this effect seldom extends much beyond the first fresh.

(iv) Disturbance of benthic habitats

Habitat mapping studies undertaken in the Waingawa River during channel re-alignment (Perrie, 2009), the Hutt River during gravel extraction and the Hutt River during channel re-alignment (Cameron, 2015) show that these works can cause a major change in the relative areas of in-stream habitat types, often resulting in a reduction of pool and swift riffle habitat and an increase in run habitat; and nearly always with an associated loss in hydraulic complexity. In some instances the river quickly reverted to a more natural form after the first fresh in the river, but this is not always the case. In some instances the re-establishment of specific habitat types may require a series of high flow events over several months. The time required for recovery can be reduced by incorporation of an engineered channel design, with a well-defined low flow channel with a ‘natural’ slope to the beach, and creation of well-formed pools and riffles as part of the works (refer Section 7.4).

(v) Disturbance of macroinvertebrate communities

Gravel extraction in the Otaki River is expected to create major mechanical disturbances of benthic habitats and sedimentation effects immediately downstream. Fenwick, *et al* (2003) found that despite the major disturbance created by in-stream gravel extraction operations, in large braided rivers like the Waimakariri River, which are characterised by frequent floods and discoloured waters, gravel extraction from the active channel does not appear to have a major effect on the benthic fauna downstream of the works area, although some changes in invertebrate faunal composition occurred.

There is strong evidence that macroinvertebrate re-colonisation of shallow riffle areas disturbed by in-stream works is rapid and that any impacts are likely to be short lived, i.e., Perrie (2009); Sagar (1983); Perrie (2013b) and Death *et al* (2013). The majority of these studies identified clear impacts on macroinvertebrate communities immediately after the works but found that recovery to the pre-works condition had occurred rapidly, within seven or eight weeks, typically after the first significant fresh has passed through and re-worked the river gravels. This is likely to be the case in the Otaki River where a healthy and diverse benthic community in the river upstream of the works area would be available to re-colonise disturbed reaches (as already occurs after major floods). It is noted however, that where the area of mechanical disturbance involves multiple riffles the overall productivity of that reach will be reduced, potentially reducing food supplies for fish.

(vi) Disturbance of fish communities

Perrie (2013a) undertook a 'before and after' survey of fish abundance by EFM in three shallow riffle habitat sites on the Hutt River where gravel extraction occurred. One site was located in the immediate area of the gravel extraction activity, a second site was located 1.2 km downstream and a third 1.2 km upstream. The results show that juvenile koaro were abundant at all three sites in the first survey in November but numbers decreased at all three sites in second survey in December and no koaro were caught in the final survey in February. The author concluded that this reflected the annual upstream migration (whitebait run) of this species to upstream habitat. Redfin bullies were also juveniles likely to be migrating upstream. Bluegill bullies were the most abundant species and were sufficiently abundant to be compared between sites and across sampling occasions (and are expected to be resident in this part of the river system). Perrie (2013a) observed that:

> *"Overall, given that a reduction in bluegill bully densities occurred at the upstream site, it is not conclusive that the gravel extraction caused the decline observed in the impact site. However given that the gravel extraction changed the habitat at the impact site from that considered ideal for bluegill bullies (riffles) to that considered less favourable (run), it seems highly plausible that the gravel extraction contributed at least in some way to the decline in density at this site. Further work is clearly required to better understand how gravel extraction from the wetted channel may be affecting bluegill bully populations in the Hutt River."*

More recently an investigation was conducted in the Hutt River at Belmont before and after channel re-alignment works over a 220m river length (Cameron, 2015). The results of that study showed that the re-alignment works caused a major change in habitat characteristics. The channel was straightened and simplified by removal of a meander and gravel bar. Several areas of swift riffle habitat were lost and had not been re-established seven weeks after completion of works. The loss of swift riffle habitat had implications for the local bluegill bully population which were the most abundant fish species in this reach. The abundance of bluegill bullies declined at the works site as a result of river engineering activities, and had not recovered seven weeks after completion of the works. It was evident that the bullies had not returned to the engineered reach because there was no good quality habitat for them there.

Death et al (2013) found that bed re-contouring on Waingawa River temporarily affected fish numbers, but, provided suitable habitat was available, the fish fauna recovered rapidly, usually after the first fresh. The authors concluded in relation to the Wairarapa Rivers that:

> *"…the weight of evidence provides no indication that any fish (except for trout in the Waingawa) were adversely affected by the engineering activities, in fact eels and/or bullies in some of the rivers increased in abundance".*

Surveys of trout numbers undertaken by Fish & Game divers before and three months after disturbance by gravel extraction in the Hutt River found that trout were relatively abundant at both disturbed and undisturbed reaches, indicating that any adverse effects that had occurred were relatively short-lived (Cameron, 2015).

Fenwick *et al* (2003) found that juvenile torrentfish and bullies in the Waimakariri were more abundant and had more food in their guts downstream of gravel extraction than at the control site. One explanation for this is that the in-channel disturbance caused by gravel extraction dislodged benthic invertebrates and increased drift downstream. As a result, the fish may have preferred the riffle downstream of the digger because of the increased food availability. The mayfly *Deleatidium* spp. comprised a major proportion of the foods found in the guts of juvenile torrentfish (a species that is typically a nocturnal feeder) and is probably susceptible to dislodgement and drifting downstream from in-channel gravel extraction activities. The possibility of greater availability of food for fish with in-channel disturbance is evident in the fact that some anglers prefer to fish for trout downstream of active extraction sites because of greater catch rates, believed to be due to increased feeding by fish at such sites (Fenwick *et al,* 2003).

It is our recommendation that where there is a potential for loss of important habitat due to river engineering works, consideration should be given to options for avoiding or mitigating any such loss, for instance by incorporating a design meander pattern into the works, with a focus on creation of riffle, pool and/or backwater habitat. For large scale works affecting a long length of river and multiple riffles, consideration should also be given to leaving some riffles (perhaps every second riffle) untouched so as to maintain sufficient reserves in the local fish population to enable the efficient recolonization of the engineered reaches (refer Section 7.4).

(vii) Disruption of fish spawning and/or migration

As described in Section 3.1.7 the Otaki River application area provides spawning habitat for a variety of fish, as follows:

- Inanga spawning habit is located in tidal estuary edge vegetation and occurs during March, April and May. While the main-stem is not suitable for inanga spawning, the Rangiuru Stream and the Pahiko/Katihiku drain offer good habitat for inanga spawning.
- Other galaxiid species including koaro, banded kokopu, shortjaw kokopu and giant kokopu, spawn in vegetation or cobbles at the riparian margin between April and August. Spawning habitat is generally thought to occur near typical adult habitats which, for most of these species will be minor watercourses upstream of the application area.
- Bullies spawn in riverbed substrate, often under large rocks, between August and February. Some spawning habitat will occur within the application area.
- Torrentfish spawn in riverbed substrate, probably in the lower river near the coast, within the application area, mostly between January and April.
- Trout move into headwater tributaries to spawn during May and June. Trout spawning habitat in the Otaki appears to be limited to upper tributaries (Strickland & Quarterman, 2001); it is thought that the main-stem of the Otaki below the gorge does not provide important trout spawning habitat due to the generally coarse nature of the bed substrate.

(viii) General comments

Gravel extraction activities have the potential to cause significant adverse effects on the river ecology, at least in the short term. Bed disturbance and discharge plumes have the potential to interfere with juvenile fish migration and to disrupt spawning of inanga, bullies and torrentfish. These effects could, however, be avoided or mitigated by limiting the amount of bed disturbance that can occur during periods of peak upstream migration & spawning, as specified in Section 7.6 (summarised in Table 5-8).

Table 5-8: Recommended constraints of works in the wetted river channel – Otaki River

<table>
<tr><th></th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td>Otaki River</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4" rowspan="3">No more than 3 day's work per site or 15 days per 10km</td></tr>
<tr><td>Otaki Estuary</td><td></td><td></td><td colspan="3">No works near inanga spawning habitat</td><td></td><td></td><td></td></tr>
<tr><td>Rangiuru/Ngatoko Streams and Pahiko/Katihiku drains</td><td></td><td></td><td colspan="3">No works near inanga spawning habitat</td><td></td><td></td><td></td></tr>
</table>

Information currently available for the lower Otaki River downstream of SH1 indicates that it, both in terms of its geomorphological characteristics and in terms of the diversity and abundance of fish, is in relatively poor condition. Gravel extraction from dry beaches has very likely contributed to the formation of a uniform shallow channel in the lower river. The proposed use of wet gravel extraction to maintain the design bed level and to establish and maintain a meander pattern with a pool and riffle form, has the potential to improve in-stream habitat quality of the lower river in the longer term.

Potential effects in Otaki Estuary

(i) Birds

The Otaki River mouth is identified as a “habitat of significance for indigenous birds in the Wellington Region” (McArthur, Robertson, Adams, & Small, 2015). This site achieved a category one score in respect of the RPS Policy 23 criteria for diversity, and category three scores for rarity and ecological context. Seven threatened or ‘at risk’ species are known to be resident or regular visitors to this site: Royal spoonbill, black shag, pied shag, banded dotterel, pied stilt, red billed gull and white fronted tern. The authors found that there are no critical times of the year during which key or threatened or ‘at risk’ bird species present at the site are particularly susceptible to human related impacts.

GWRC has indicated that a large gravel bar known as “Mangahenene Island” encroaches well into the design alignment and that gravel extraction is likely to be required in order to widen the river channel in that area. This is likely to include the partial removal of the gravel bar at its northern extent. While the operation of heavy machinery in this area may disturb feeding and roosting activity in the immediate vicinity of the works, this effect is likely to be localised and temporary. Nevertheless, consideration should be given to minimising the level of disturbance to resident and migratory bird species as part of the pre-works planning. In the longer term the proposed removal of scrub and weeds from the gravel bar will potentially improve habitat for banded dotterel, pied stilt and black-fronted dotterel.

(ii) Sediment Discharge and Deposition

The proposed gravel extraction activity at Mangahenene Island is likely to result in a temporary increase in the deposition of fine sediment in habitats downstream of the works site. The Otaki Estuary is a “shallow tidal river mouth” type estuary, dominated by river flows and well flushed, with a residence time of less than one day. Consequently it is considered to have a low susceptibility to sedimentation issues (Robertson & Stevens, 2007). It is likely that gravel extraction would temporarily increase the risk of sediment related impacts such as poor water clarity and muddy intertidal substrates, which tend to favour mud tolerant invertebrate taxa. However, in a well flushed system it is expected that such effects would be relatively minor and temporary, lasting only until the next flood event.

(iii) Disruption of inanga spawning

Inanga spawning habitat located on tidal estuary edge vegetation in the Rangiuru Stream and the Pahiko/Katihiku drain and occurs during March, April and May. Recommendations for the protection of inanga spawning habitat juvenile fish migration are provided in Section 7.6 and summarised in Table 5-8 above.

5.12 Channel shaping and realignment

5.12.1 Beach re-contouring

Description of activity

Beach recontouring can be undertaken on its own, and also in conjunction with the removal of vegetation from beaches, establishment of structures or in association with bed recontouring. It is undertaken in the dry bed, away from the flowing channel. The purpose is to streamline the beaches to avoid any future obstructions to flow that may lead to unexpected and unwanted shifts in channel alignment.

Potential effects

Beach recontouring may have implications for river birds and, when done in conjunction with clearing of vegetation from beaches, may improve the quality and/or quantum of river bird roosting and breeding habitat. McArthur *et al* (2015) identified four sites of value for native birds on the Otaki River including breeding colonies banded and black-fronted dotterels, and pied stilts, a nesting colony of black shag, a post breeding staging colony of pied stilts. The author made a number of recommendations for the protection of river bird breeding colonies which are included in Section 7.2 of this report. Recommendations about further monitoring to be carried out to provide quantitative data to describe on-going trends in the distribution and abundance of river birds are included Section 8.

As this work is undertaken in the dry bed, away from the active channel, there is little risk of short term construction impacts on water quality or aquatic ecology. There is no evidence of negative impacts in the long term.

5.12.2 Bed recontouring

Description of activity

Bed recontouring is mechanical shaping of the active channel to realign the low flow channel so as to reduce erosion (typically at the outside of a bend) or to prepare the bed for construction or planting works. In general, straightening of the channel and removing sharp bends increases the hydraulic efficiency of a reach and thereby reduces flood levels.

Bed recontouring to realign a channel bend is done by cutting a new channel through a dry beach on the inside of a bend, leaving a bund at both ends to minimise silt discharges. Excavated material is placed at the outside edge of the new channel. When the new channel is completed, the end bunds are removed, and the excavated material pushed across the old channel alignment to the required finished profile.

Bed recontouring may also be done in conjunction with gravel extraction in order to establish a design meander pattern, and in that case it will not necessarily shorten or straighten the channel (see previous section).

An analysis of the length of river bed affected by recontouring over the duration of the current consents is summarised in Table 5-7. (Note that the table does not include bed re-contouring associated with gravel extraction works on the Hutt River).

Table 5-9: Lineal lengths of river bed affected by re-contouring over 13 years to January 2012

	Otaki	Hutt	Waikanae
Total lineal length (m)	9620	7050	2580
Average per year (m)	740	542	184
Permitted by existing consent: Total (m) per year	1200	800	600

Potential effects

Bed recontouring involves mechanical working in the active channel and entails extensive disturbance of bed material and significant temporary release of suspended sediment into the water column. The short term construction effects on water quality, macroinvertebrate and fish populations are likely to be similar to those described above for wet gravel extraction because the two processes are very similar. However, when used to realign the low flow channel, the extent and duration of works in the active channel may be less than required for wet gravel extraction (days rather than weeks) because much of the work can be completed in the dry.

Bed re-contouring, where it is used to straighten the channel, is likely to result in loss of channel complexity and a reduction in aquatic habitat diversity. Mitchell (1997) observed that major channel re-alignment involves the direct loss of habitat and offers few direct ecological benefits apart from greater channel stability. Mitchell concluded that channel realignment was the flood protection practice most likely to have significant impacts on the environment (but noted that, overall, the river management approaches used on Wairarapa Rivers should result in an enhancement of biological activity). Perrie (2009) observed that channel realignment on the Waingawa River resulted in significant straightening of the river channel in the study reach and had a clear impact on the diversity of habitat types. In particular deep runs were reduced in overall extent and pools were completely removed, while the proportion of shallow run and riffle habitats increased. Perrie considered this to be a net reduction in the overall diversity of habitat in this reach because of the relative scarcity of deep water habitat and because of the higher complexity of that habitat type relative to shallow water habitats.

In summary the medium to long term effects on the aquatic ecology of bed re-contouring, where it is used to straighten the channel, are negative, and the significance of those effects for the river ecology at the reach scale will depend on the quantum of bed re-contouring undertaken over time. It is possible that this activity could be undertaken at a rate that balances the destabilising effects of floods, without on-going loss of habitat complexity, provided measures are in place to ensure the number of pools and riffles within a specified reach are maintained.

There is however an opportunity to mitigate many of these adverse effects by applying the principles developed for the Hutt River gravel extraction programme, whereby the works are designed to form a well-defined low flow channel with a 'natural' slope to the beach and well-formed pools and riffles, which provide good quality habitat for invertebrates and fish. The maintenance or creation of backwaters as part of these works should also be considered. These additional design elements would minimise the loss of habitat diversity (refer Section 7.4).

5.12.3 Channel diversion cuts

Description of activity

A channel diversion cut consists of cutting a new channel through the dry beach on the inside of a bend, leaving a bund at both ends to minimise silt discharges. Excavated material is placed at the outside edge of the new channel or is processed by a gravel extractor contractor. The entire process is undertaken outside of the active channel. Bunds are left in place in such a way that the river is able to divert through the new channel during the next significant flood event.

Potential effects

Diversion into the new channel occurs during a flood event of sufficient magnitude to breach the bund. This will result in the mobilisation of gravels and interstitial silt as the diversion takes place, possibly causing additional siltation and gravel accumulation in the reach downstream. These processes already occur during floods and consequently river biota are well adapted to a dynamic environment. In this context the additional silt and gravel from the diversion cut is unlikely to be important.

In most respects this process resembles the impact of a flood and a resulting course change, and may include the loss of habitat due to channel shortening. Diversion cuts which involved the loss of large areas of riffle habitat could impact local fish production, as described above for bed re-contouring. Similarly the loss of other high value habitat may reduce carrying capacity at the reach scale. Habitat loss could be mitigated to some extent by the maintenance or creation of riffles, pools or backwaters as part of these works.

5.12.4 Wet ripping

Description of activity

Mechanical ripping of the bed in the wet channel is a technique used in some rivers to improve the low flow channel form and alignment through the riffle zones in particular.

The activity involves dragging a tine that is mounted on a bulldozer or excavator through riffle sections of the active channel, in order to encourage the mobility of bed material. Mobilisation of bed material occurs naturally in flood events. The wet ripping activity is intended to facilitate that process by loosening bed material in target areas, leaving the river move the bed material. The intention is to mitigate any sharp directional changes in the channel at such points and thus maintain a more regular channel meander pattern.

Potential effects

Wet ripping involves mechanical disturbance of the riverbed, with associated aquatic habitat disturbance and release of sediment to the water column, however the activity is generally less extensive and can be completed more quickly than bed recontouring and thus the scale of effects is relatively less than with bed recontouring. These works cause some disruption to periphyton, invertebrate and fish communities. Nevertheless, as described above for bed-recontouring, re-colonisation is rapid and the impact is generally short lived.

5.13 Flood Protection Activities in the CMA

5.13.1 Otaki River mouth realignment

Description of activity

A diversion cut is excavated at Otaki River mouth in response to predefined “trigger points”. These trigger points are:

- when the channel outlet migrates either 300m south or north of the centre line of the river measured 700m upstream; or
- when the river mouth closes; or
- when the Rangiuru flood gates are unable to be effectively operated due to high water levels.

The alignment of the cut is directly in front of the main river channel. A trench is excavated through the foreshore and beach to form a pilot channel for the new river mouth (Figure 5-7). Sand from the excavation is used to block off the active river channel and prevent flow to the sea. This work begins at low tide when the sand is firmer and the machinery does not have to work in water. The block is left until sufficient water has ponded in the lower river. At the following low tide the top of the pilot channel is opened to release the ponded water into the new channel and out to sea. The sudden release of water scours the new channel deeper and wider than the original excavation.

This work is usually undertaken at spring tides when the tidal variation is greatest. The operation usually takes a maximum of 24 hours to complete and involves the use of up to six earth moving machines. This would typically include two hydraulic excavators, one large dump truck for the long hauling of sand and three rubber tyre loaders for short hauls. This activity was been undertaken five times under since 1998, on July 2002, August 2002, August 2005, September 2009, and July 2011 (note, this is currently a permitted activity).

Figure 5-7: Diversion cut, Otaki River Mouth

Potential effects

The excavation cut would disturb the foreshore and beach immediately in front of the river channel. The foreshore can develop into a sand-spit extending from either side of the river. This area is naturally unstable, being periodically removed by flood flows and frequently eroded or submerged by wave action during high tides and storm surges. As the pilot channel is opened, ponded water scours a channel through to the sea, mobilising large quantities of sand. This creates a visible discharge plume in near shore coastal waters similar to that generated by a large flood event. Much of the scoured material is deposited within the surf zone and then gradually dispersed by wave action and tidal currents. Finer material is likely to remain in suspension causing a temporary reduction in visual clarity in coastal water in the vicinity of the cut, especially during the first few hours of the breach.

Birds such as gulls and terns in particular spend time resting, bathing and preening in the Otaki Estuary, and the foreshore provides a relatively safe resting place for sea and water birds. The excavation cut may remove a small portion of this habitat, but as this habitat is readily available all along the coast, no adverse effects on bird populations are likely. Mouth re-alignment is not expected to affect habitat quality elsewhere within the estuary, which is dominated by river flows and is well flushed.

5.13.2 Removal of flood debris from the CMA

As already discussed in Section 5.10.4 for the river above the CMA, effects are expected to be minor provided a balanced approach is undertaken, whereby flood debris is left in the river/estuary where it presents no immediate risk. The works should be undertaken in such a way that disturbance of inanga spawning habitat is avoided and , if practicable should not occur during the whitebait fishing season.

5.13.3 Removal of gravel from dry beaches in the CMA

As discussed in Section 5.11.5, the proposed gravel extraction programme includes widening of the river channel adjacent to 'Mangahenene Island', including the removal of scrub, weeds and gravel from a dry beach on the northern side of the island, some of which lies within the CMA. The assessment provided in Section 5.11.5 also applies to the area within the CMA.

5.13.4 Maintenance of existing structures in the CMA

Currently no flood protection structures are located within the CMA (a large rock groyne on the true right bank at XS 70 is located nearly 200m outside the CMA boundary).

6 Cumulative Effect

The potential for the effects of GWRC operations and maintenance activities to be increased by other similar activities undertaken in the Otaki catchment by other parties is low, principally because there is only one other granted consent of relevance, which is for a private individual to extract stones from the river (by hand) for building purposes.

There may be a cumulative effect resulting from the extension of permanent works (i.e. rip-rap linings) however the extent of such structures is relatively low in the Otaki River, Furthermore, there is evidence that fish abundance and diversity can be relatively high in river reaches that are intensively managed (for instance the Hutt River at Belmont), suggesting that the cumulative effect of flood protection activities on the riverine ecology may be relatively minor. Indeed, trout abundance is consistently higher in the Hutt River at the Melling – Belmont reach compared with unmanaged reaches upstream of the application area.

It is acknowledged, however, that the cumulative effects of multiple flood protection activities have not been systematically monitored in the past and, in the absence of suitable information, there remains some uncertainty around the long term cumulative effects of these activities.

The monitoring programme outlined in Section 8 and detailed in the EMP is intended to establish a long term monitoring framework covering both geomorphological and biological measures of river health. It includes the development of a natural character index (NCI) which, it is expected, will provide a measure of the cumulative effects of river-channel activities on river morphology, and by inference on habitat quality. Further investigations will need to be undertaken to better establish the link between NCI scores and ecological condition, and is noted that the applicability of this approach has yet to be tested.

7 Mitigation

7.1 Overview

Many of the flood protection activities assessed here are identified as having potential adverse effects on the river ecology due to changes that they cause to water quality, riverine or riparian habitat, or due to direct impacts on river bird, benthic macroinvertebrate or fish communities. In many cases the adverse effects of individual works will be temporary, or can be avoided or mitigated by the application of good practice methods, and by scheduling the works so as to avoid periods of peak sensitivity at specific locations, such as river-bird nesting, fish spawning and peak fish migrations.

GWRC has prepared an Environmental Code of Practice (Code) and Monitoring Plan (EMP) in support of the flood protection consent applications which are intended to guide and monitor how all flood protection and erosion control activities are done across the Region. It is intended that flood protection activities will be conducted in accordance with the Code, using methods selected from the Code, that monitoring of the effects of those activities will be conducted in accordance with the EMP, and that the results of monitoring will feed into a regular review process. Over time this process will facilitate the adaptive management of flood protection activities, with the objective of avoiding unacceptable adverse effects and mitigating other negative effects while still enabling the conduct of flood protection activities for the public good.

Specific measures which have been identified in this report as being important considerations for the avoidance or mitigation of adverse effects in the Otaki River and minor tributaries within the application area are outlined in the following sections.

7.2 River Bird Habitat

McArthur,*et al* (2015) made a number of recommendations to minimise the risk to nesting bird populations of the Otaki River from flood protection activities on gravel beaches, including the following changes to the Code:

- The wording of the Code [at section 3.3.5] should be modified to specify that flood protection activities causing disturbance to dry gravel beaches on the Otaki River should be programmed outside of the shorebird nesting season (August to February) whenever possible. Where this is not possible, these works should be preceded by a survey carried out by an appropriately experienced ornithologist to identify the presence of shorebird nests or chicks.

The Code [at Section 3.2.2] specifies a monitoring programme and trigger levels for changes in the average number of breeding pairs of banded dotterel, pied stilt and black fronted dotterel. Exceedance of trigger levels would require investigation into the cause of any change. Where a causal link is evident between a decline in bird numbers and a FP activity this would result in a modification of that activity (or offset of habitat loss by creation of new habitat elsewhere) via the review process. In the event that the cause of the population decline is not obvious, the appropriate response would be to initiate a more targeted investigation of the species in question in order to quantify survival and nesting success and to identify the cause(s) of the decline. In addition, should an increase in population sizes of indicator species be observed, GWRC will review the trigger levels and revise them downwards if appropriate.

7.3 River Edge Biodiversity

For vegetative bank protection where willows are used as front line river bank protection, give consideration to:

- provision of an active programme for the planting and maintenance of native trees in the river corridor,
- seek to integrate native and willow planting where appropriate,
- as far as is practicable avoid disturbance of existing areas of native vegetation,
- protection of high-value areas of riparian native vegetation which are threatened by erosion.

7.4 Habitat of Benthic Biota and Fish - Rivers

Various flood protection activities have been identified as having the potential to adversely affect the habitat of macroinvertebrates and fish. In particular, bed recontouring, channel realignment and wet gravel extraction can involve extensive mechanical disturbance of the wetted riverbed, causing considerable short term impacts on invertebrate and fish communities.

For the maintenance or enhancement of in-stream habitat during in-channel works it is recommended that works should be undertaken in accordance with a 'design channel alignment' which aims to achieve:

- optimum flood carrying capacity,
- a stable channel alignment,
- a well-defined low flow channel with a 'natural' slope to the beach, and
- well-formed pools and riffles providing good quality habitat for macroinvertebrates and fish to re-colonise.

For construction of new rock rip-rap bank protection or significant extension of existing rip-rap, consider the following:

- planting above rip-rap where this is likely to provide bankside cover and overhanging vegetation,
- provision of fish refuges, for instance in spaces between large rocks within the structure, and
- inclusion of additional boulders protruding out from the wall to break up the uniform flow.

For the clearance of flood debris:

- Adopt a balanced approach whereby flood debris (trees, logs, etc) is left in the river unless it presents an apparent risk.

7.5 Habitat of Benthic Biota and Fish – streams and drains

In small soft bedded streams and drains where macrophyte or silt removal is required (such in the Rangiuru/Ngatoko Streams and Pahiko/Katihiku drains), develop a mitigation strategy that should include most, but not necessarily all, of the following:

1. Return stranded mega fauna (fish, crayfish, shellfish etc.) to the waterway;
2. Encourage the digger operator to ensure the bucket is submerged at the end of each cut (to give fish an opportunity to escape);
3. Distribute spoil in such a way that it cannot slump or be washed back into the waterway;
4. Distribute spoil so that stranded eels can make their own way back to the waterway;
5. Use a weed rake rather than a conventional bucket in gravel bottom waterways;
6. Use a conventional bucket rather than a weed rake where large amounts of fine sediment are present;
7. In heavily silted waterways prevent suspended sediment moving downstream by using artificial or natural filters;
8. Recover distressed fish from the disturbed waterway and relocate them upstream;
9. Do not return recovered fish to highly turbid water.
10. Maintain beneficial plant refuges by only partially clearing plants from the waterway (leaving the margins or entire sections of waterway un-cleared);
11. Maintain ecological refuges by not cleaning all waterways in a catchment or property at once;

12. Replace lost habitat complexity with reinstated artificial structures (such as artificial refuse structures made of PVC piping, cinderblocks or bogwood);
13. Between 1 March and 30 May avoid clearing waterways identified as potential inanga spawning habitat.
14. Preserve specific important habitats such as riffles, if they exist;
15. Avoid removing course gravel and cobble substrates, if it is present;
16. Where practicable maintain variability in stream bed depth and contours.

7.6 Protection of Fish Life

For the protection of indigenous fish it is recommended that:

- Disturbance of the wetted channel (by bed re-contouring, channel realignment or wet gravel extraction) should not be undertaken between 1 September and 31 December, inclusive, for more than three days at any works site or for more than 15 days over the 12 km of river length within the application area.
- Disturbance of the wetted channel should not be undertaken when the river flow has receded below the minimum flow specified in GWRC's Regional Plan (for water allocation purposes), unless it can be demonstrated that the work is urgent and necessary, and appropriate approval is obtained.
- Works should not block the channel in such a way that fish passage is prevented at any time.
- Any fish that are stranded during dewatering of any channel shall be immediately placed back into the flowing channel.

For the protection of inanga spawning habitat:

- Avoid works in the bed or river banks in the immediate vicinity of inanga spawning areas during spawning from 1 March to 30 May.

For the protection of trout spawning habitat it is recommended that:

- No work shall be undertaken in the wetted channel of Waimanu Stream during the trout spawning period between 1 May and 30 September.

8 Monitoring

8.1 Overview

Monitoring the effects of flood protection activities on geomorphology, river nesting birds and aquatic ecology is proposed by GWRC to be undertaken in accordance with the EMP, which is included in Section 2 of the Code. The EMP proposes a programme of baseline monitoring and specific event monitoring. Baseline monitoring will consist of regular (three yearly) measurement of geomorphological and biological variables in each of the seven Otaki River reaches defined for the NCI, which would be used to assess the cumulative effects of flood protection activities over time.

The Code specifies trigger levels for each monitoring component which, if exceeded, will be used as inputs to the regular review process prescribed by the Code. That review could, where appropriate, result in a modification of a specific activity, and require some other measures (such as offset of habitat loss by creation of new habitat elsewhere) to be implemented.

Event monitoring for moderate scale works would consist of before/after habitat assessments and for large scale works would include comprehensive before/after/control/impact investigations of water quality habitat quality, biological monitoring and calculation of NCI (definitions for 'moderate' and 'large' scale works are given in Section 8.3).

8.2 Baseline Monitoring

8.2.1 Riparian vegetation

Vegetation types within the riparian margins of rivers in the application area will be broadly mapped using aerial photography (or LiDAR survey) supported by selected site visits to confirm interpretation. It is intended that these surveys would be completed within three years of the consents being granted and at 9-year intervals thereafter and that this will enable any changes in the extent and composition of riparian vegetation to be tracked over time.

8.2.2 River birds

Baseline river bird monitoring was undertaken during 2012, 2013 and 2014 on the Otaki River. It is proposed that three year sets of annual surveys are repeated on a regular basis, with a gap of 5 years between surveys (i.e., in years 2012, 2013, 2014, 2020, 2021, 2022, etc.).

8.2.3 Fish communities

The New Zealand Freshwater Fish Database (NZFFD) contains a significant amount of information about freshwater fish communities in the Wellington Region. However, the fish communities of the lower Otaki River are not well characterised.

It is recommended that further investigations be undertaken at three yearly intervals in selected reaches of the Otaki River for the duration of the consent (or until modified by review of the EMP). It is further recommended that these reaches should be coordinated with those defined for NCI assessment and to include reference and impact sites (to the extent that is possible within the application area), so as to provide information on the relationship between fish populations and natural character of the river.

8.2.4 Trout abundance

Annual monitoring of trout abundance is proposed, using drift dive methodology, at two reaches on the Otaki River. If possible it would be desirable to align drift dive reaches with NCI survey reaches (drift dive reaches are shown in Appendix A).

8.2.5 River bed level surveys

Monitoring of riverbed levels is important due to their impact on flood capacity and channel stability. GWRC currently undertakes riverbed surveys at five yearly intervals on the Otaki River. Survey data are used to analyse trends in gravel movement and to determine river management policies for the succeeding five year period.

8.2.6 Aerial photography

Aerial photographs provide a useful tool for river management planning and allow quantification of river morphology and depiction of changes in this over time. Aerial photography mosaics will be produced at least once every three years over the reaches of the Otaki River managed by GWRC to ensure that up to date data for management planning and a regular record of river morphology for potential use in assessment of effects of river works is available over the life of the new consents.

8.2.7 Pool and riffle counts

The numbers of pools and riffles in a river is a measure of the diversity of aquatic habitat and morphological complexity of a river, which in turn can be used as an indicator of the overall ecological health of the river (particularly when considered in conjunction with other aquatic survey data). Pool and riffle counts will be conducted at least once every three years in each of the reaches identified for calculation of NCI. It is intended that counts will be undertaken by representatives of Wellington Fish and Game and GWRC according to an agreed methodology using aerial photography mosaics flown no more than 12 months prior to the count.

8.2.8 Deposited sediment

The amount of deposited sediment on the river bed can be used as an indicator of aquatic habitat quality, and changes in the amounts of deposited sediment can also be used to indicate changes in habitat quality over time. Deposited sediment measurements will be undertaken once every three years in each of the reaches identified for calculation of NCI to allow comparison of the resultant data. These measurements will also be co-ordinated, as far as is practicable, with the 3-yearly aerial photography outlined above, for the same reason. The measurements will include visual estimates of fine sediment cover and assessment of substrate grain size by Wolman pebble count, in accordance with the protocols provided in Clappcott *et al* (2011).

8.2.9 Riverbank undercutting and overhanging vegetation

River bank undercutting and overhanging vegetation provide opportunities for aquatic habitat diversity, which in turn may contribute to overall aquatic ecological health. Length of riverbank undercutting and overhanging vegetation will be measured once every three years in each of the reaches identified for calculation of NCI to allow for this parameter to be included in the overall NCI calculation.

8.2.10 Natural character index

GWRC is proposing to further investigate the use of a natural character index (NCI), currently under development by Massey University researchers, to monitor the degree of departure from a reference condition of geomorphological characteristics in the selected rivers on a regular basis.

Wave amplitude (from aerial photography), pool and riffle counts, deposited sediment levels, substrate grain size, length of undercutting, and length of overhanging vegetation would be assessed and selected variable used as input to the NCI (details to be confirmed). It is intended that the NCI be used as part of the baseline monitoring programme to assess departure from an historic reference condition at each of the NCI reaches defined for these rivers (refer Williams 2013). It is anticipated that this will provide a measure of the cumulative effects on river morphology for specific river reaches.

It is also intended that NCI would form part of any site specific monitoring programme to be developed for larger flood protection works (see Event Monitoring below). The geomorphological variables would be assessed at the works reach and a similar length of river upstream before and after the works. The ratio of these variables (expressed as a combined index of before to after) would be calculated for the works and upstream reaches (i.e. to produce a ‘works reach’ NCI and an ‘upstream reach’ NCI).

It should be noted that this science is relatively new and that further work is required to develop and refine the NCI for use in the rivers of the Wellington Region. Further investigations will need to be undertaken to better establish the link between NCI scores and ecological condition before the NCI could be confidently used as an indicator of ecological condition, or as a trigger for mitigation action.

8.3 Event Monitoring

In the first instance, event monitoring will focus on those activities deemed to have the most potential for adverse effects, namely wet gravel extraction and bed recontouring. The need for inclusion of other activities would be identified through the Code review process. For the purpose of determining an appropriate level of monitoring for these riverbed disturbance events, activities have been categorised as minor, moderate and large scale, as described in the following sections.

8.3.1 Minor scale works in the wetted riverbed

Minor scale works are defined as those affecting less than 175m lineal length of wetted riverbed and/or no more than 3 days of in-river works.

Baseline monitoring at each NCI reach will be undertaken as described in 8.2 above. Over time the baseline monitoring results would be used detect cumulative change, either by aggregation of a range of habitat measures via the NCI or as individual components of habitat quality.

No site specific monitoring is proposed for work sites in this category.

8.3.2 Moderate scale works in the wetted riverbed

Moderate scale works are defined as those affecting between 175m and 800m lineal length of wetted riverbed and/or between 3 days and 8 days of in-river works.

In addition to the baseline monitoring as described in Section 8.2, site specific before/after habitat assessments will be undertaken at each work site by the operations supervisor using the habitat assessment template included in Appendix 2 of the Code.

8.3.3 Large scale works in the wetted riverbed

Large scale works are defined as those affecting more than 800m of wetted riverbed length and/or more than 8 days of in-river works. This will include large scale wet gravel extraction or bed re-contouring works which occur relatively infrequently but which result in extensive riverbed disturbance.

At these works, in addition to the baseline monitoring as described in Section 8.2, a site specific EMP will be developed prior to the commencement of work by a suitably experienced aquatic ecologist. The site specific EMP is likely to include some or all of the following, and where possible would be based on a before/after/control/impact design:

- Water quality monitoring (suspended solids, turbidity, Total-Nitrogen, Total-Phosphorus)
- Deposited sediment monitoring (sediment cover and substrate size)
- Habitat mapping at impact and reference sites
- Macroinvertebrate re-colonisation
- Survey of fish populations
- NCI calculated for the works and upstream reaches (i.e. to produce a ‘works reach’ NCI and an ‘upstream reach’ NCI)

8.3.4 Mechanical weed removal from perennial streams

During the first three year period under the new consents, fish surveys will be undertaken on all perennial streams affected by mechanical clearance of aquatic weeds (Rangiuru/Ngatoko Streams and Pahiko/Katihiku drains), before and after the clearance operation. Fish surveys will be undertaken by backpack electric fishing (and where appropriate by trapping and/or spotlighting) in general accordance with the New Zealand Freshwater Fish Sampling Protocols (Joy, David and Lake 2013). The need for further monitoring of fish populations in these watercourses will be determined at the first five yearly review of the Monitoring Plan.

8.3.5 Disturbance of terrestrial vegetation at the river margins

Any flood protection activities likely to involve disturbance of large areas of indigenous forest or scrublands should be preceded by a lizard survey within the affected area. Such surveys will be designed to determine the presence or absence of lizard species within the works area and indicate the severity of potential impacts on any populations. If lizards are found and a severe impact is predicted, a lizard management plan should be prepared for the area.

9 Summary and Conclusions

GWRC Flood Protection department undertakes a range of river management activities within the Otaki River application area in order to maintain the river channel within its design alignment, maintain the flood capacity of the river channel, and maintain the integrity and security of existing flood defences which provide for the safety and well-being of the Otaki communities. Many of the flood protection activities assessed here are identified as having potential adverse effects on the river ecology due to changes in water quality, riverine or riparian habitat, or due to direct impacts on river bird, benthic macroinvertebrate or fish communities. In many cases the adverse effects of individual works will be temporary, or can be avoided or mitigated by the application of good practice methods as specified in the Code, and by scheduling the works so as to avoid periods of peak sensitivity at specific locations, such as river-bird nesting, fish spawning and peak fish migrations.

Some practices such as the establishment of vegetative buffer zones, willow planting and layering, and construction of rock groynes, will have mostly positive effects on river ecology, while other activities involving a greater level of disruption to benthic habitats will tend to have more negative effects. Bed recontouring, channel realignment and gravel extraction are identified as having the greatest potential for adverse effects on river ecology in the short term. These activities involve major mechanical disturbance of benthic habitats, and create a visible discharge plume as well as increased rates of fine sediment deposition downstream. Research conducted on rivers in the northern Wairarapa Valley shows that individual works on short reaches (100m to 150m lineal length) do not have a lasting effect on benthic ecology or fish communities, and that adverse effects are not likely to last much beyond the first fresh. However a more recent study conducted in the Hutt River at Belmont shows that bed disturbance over a 220 m lineal length resulting in a loss of swift riffle habitat can have a more lasting effect, probably requiring a series of high river flow events to re-establish good riffle habitat. This could have been improved if the channel realignment had been based on creation of a meander pattern (which it was not) and reconstruction of some channel complexity had been incorporated into the works.

The potential effects of larger scale in-channel works, for instance where mechanical disturbance of the river bed extends over river lengths of greater than 800m, are less well characterised, mainly because works on this scale occur infrequently and the opportunity to assess the effects of such activities has not arisen in recent years. It is assumed that the scale of effects could increase roughly in proportion with the scale of works but that hypothesis is yet to be tested. For this reason the EMP proposes a tiered ‘event’ monitoring approach, with increasing monitoring effort required for larger scale works sites.

It is recognised that information on the cumulative effects of multiple small works undertaken at different locations and at different times is currently limited. Effects of this type are more difficult to identify and will not necessarily be detected by monitoring focused on individual works sites. For this reason, in addition to the proposed event monitoring, an ongoing baseline programme is proposed to detect changes in geomorphological characteristics at specified river reaches over time, utilising a natural characteric index to combine these various monitoring results. Baseline monitoring will also include biological variables and it is anticipated that, in the longer term, the monitoring programme will provide an improved understanding of the relationship between natural character and ecological health.

It is proposed also that the results of monitoring under the EMP will feed into a regular review of the activities and processes specified in the Code with the aim of improving environmental and other outcomes over time.

References

Adams, M., Gilliland, B., & Watson J. (1987). *The water resources of the Otaki River.* Manawatu Catchment Board (unpublished report).

Australian and New Zealand Environment and Conservation Council. (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.*

Biggs, B. (2000). *New Zealand periphyton Guideline - Detecting Monitoring and Managing Enrichment of Streams.* Prepared for Ministry for the Environment.

Boffa Miskel Partners. (1992). *Otaki River Floodplain Management Plan - Environmental Investigations.* Prepared for Wellington Regional Council.

Boffa Miskell. (2001). *Lower Otaki River Ecological Survey, 2001.* Report prepared fro Kapiti Coast District Council.

Boubee, J., Dean, T., West, D., & Barrier, R. (1997). Avoidance of suspended sediment by the juvenile migratory stage of six New Zealand native fish species. *New Zealand Journal of Marine and Freshwater Research 31:61-69*.

Cameron, D. (2015). *Effects of Flood Protection Activities on Aquatic and Riparian Ecology in the Hutt River.* Prepared for Greater Wellington Regional Council.

Champion, P., Rowe, D., Smith, B., Wells, R., Kilroy, C., & de Winton, M. (2013). *Freshwater Pests of New Zealand.* NIWA Fact Sheets.

Clapcott, J. (2015). *National Rapid Habitat Assessment Protocol Development for Streams and Rivers.* Prepared for Northland Regional Council.

Clapcott, Young, Harding, Matthaei, Quinn, & Death. (2011). *Sediment Assessment Methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values.*

Death , A., Death, R., & Death F. (2011). *Is gravel extraction in the dry the best for instream ecology?* Short presentation to NZFSS.

Death, R., & Death, F. (2013). *Ecological effects of flood management activities in Wairarapa Rivers.* Report prepared for Greater Wellington Regional Council.

Death, R., Death, A., Fuller, I., & Jordan, C. (2015). *A technique (eNCI) for Assessing Natural Character Impacts of River Management Activities.* Massey University, Palmerston North, NZ.

Fenwick, Mckerchar, & Glova. (2003). *Gravel extraction from New Zealand Rivers and its in-stream ecological effects.* Report prepared by NIWA CHC2003-057.

Gardiner, M. (2011). *Otaki River Gravel Analysis 1991- 2011.* GWRC Technical Report.

Goodman, J., Dunn, N., Ravenscroft, P., Allibone, R., Boubee, J., David, B., et al. (2014). *Conservation Status of New Zealand freshwater fish, 2013.* New Zealand Department of Conservation.

Grainger, N., Collier, K., Hitchmough, R., Harding, J., Smith, B., & Sutherland, D. (2014). *Conservation status of New Zealand freshwater invertebrates, 2013.* Department of Conservation.

Greater Wellington Regional Council. (2002). *Erosion and sediment Control Guidelines for the Wellington Region.*

Greater Wellington Regional Council. (Working Draft, March 2015). *Environmental Code of Practice and Monitoring Plan for Flood Protection Activities.* Greater Wellington Regional Council.

Greer, M. (2014). *Memorandum regarding drain clearance best management practice.* Prepared for Environment Canterbury.

Groundtruth. (2013). *Restoration plan for Katihiku.* Report prepared for Greater Wellington Regional Council.

Hamer, M. (2007). *The freshwater fish spawning and migration calendar report.* Environment Waikato Technical Report 2007/11.

Harding, C. Q. (2009). *Stream Habitat Assesment Protocols for wadeable rivers and streams in New Zealand.*

Hayes, J. (1995). Spatial and temporal variation in the relative density and size of juvenile brown trout in the Kakanui River, North Otago. *New Zealand Journal of Marine and Freshwater Research, 29; 393-407.*

Heath, Brasell, Young, Wood, & Ryan. (2012). *Hutt River Phormidium Habitat Suitability Criteria and Hydraulic Habitat Assessment.* Report prepared for Greater Wellington Regional Council.

Heath, M., Perrie, A., & Morar, S. (2014). *Rivers State of the Environment monitoring programme. Annual data report, 2013/14.* Greater Wellington Regional Council GW/ESCI-T-14/118.

Hicks, & Griffiths. (1992). *Waters of New Zealand (Chapter 13; Sediment Load).* Edited by Paul Mosley for New Zealand Hydrological Society.

Jowett, I., & Duncan. (1990). Flow variability in New Zealand rivers and its relationship to in-stream habitat and biota. *New Zealand Journal of Marine and Freshwater Research 24*, 429-440.

Jowett, I., & Richardson, J. (1995). *Habitat preferences of common riverine New Zealand native fishes and implications for flow management.* New Zealand Jounal of Marine and Freshwater Research 29: 13-23.

Joy, M., David, B., & Lake, M. (2013). *New Zealand Freshwater Fish Sampling Protocols: part 1 Wadeable Rivers and Streams.* Massey University.

Leathwick, J. R., West, D., Gerbeaux, P., Kelly, D., Robertson, H., Brown, D., et al. (2010). *Freshwater Ecosystems of New Zealand (FENZ) Geodatabase - User Guide.*

Lloyd, D. (1987). Turbidity as a water quality standard for salmonid habitats in Alaska. *North American Journal of Fisheries Management 7; 18-33.*

McArthur, N., Robertson, H., Adams, L., & Small, D. (2015). *A review of coastal and freshwater habitats of significance for indigenous birds in the Welington region.* Environmental Science Department, Greater Wellington Regional Council.

McArthur, N., Small, D., & Govella, S. (2015). *Baseline monitoring of the birds of the Otaki, Waikanae and Hutt Rivers, 2012-2015.* GWRC, Environmental Science Department.

McDowall, R. M. (1995). *Seasonal pulses in migration of New Zealand diadromous fish and the potential impacts or river mouth closure.* New Zealand Journal of Marine and Freshwater Research.

McDowell, R. M. (1990). *New Zealand Freshwater Fishes. A Natural History Guide.* Heinemann Reed.

Miskelly, Dowding, Eliot, Hitchmough, Powlesland, Robertson, et al. (2008). *Conservation status of New Zealand birds, 2008.* Notornis 46:101-122.

Mitchell, C. (1997). *Effects of River Control Works on Aquatic and Riparian Ecology in the Upper Ruamahanga River.* Report prepared for Wellington Regional Council.

Morar, S., & Perrie, A. (2013). *River State of the Environment Monitoring. Annual data report, 2012/13.* Greater Wellington Regional Council GW/ESCI-T-13/114.

Ohau Plants Ltd. (2009). *Fish recovery pilot report for the Waimeha Stream.* Report prepared for Greater Wellington Regional Council.

Perrie, A. (2013a). *Effects of gravel extraction from the wetted channel on the aquatic ecosystem of the Hutt River: a summary of two Environmental Science investigations undertaken in 2012/2013. GWRC internal memo.* GWRC.

Perrie, A. (2013b). *The effects of gravel extraction from the wetted channel on the aquatic ecosystem of the Hutt River: a summary of macroinvertebrate data collected befor and after gravel extraction.* Greater Wellington Regional Council Internal Memo.

Perrie, A., & Conwell, C. (2013). *Annual freshwater quality monitoring report for the Wellington Region, 2011/12.* Greater Wellington Regional Council GW/ECI-G-13/32.

Perrie, A., Morar, S., Milne, J., & Greenfield, S. (2012). *River and stream water quality and ecology in the Wellington Region - State and Trends.* Wellington: Greater Wellington Regional Council.

Phillips et al. (2009). *Native planting for river edge protection: analysis of trials. Report prepared for Greater Wellington Regional Council.*

Pilkington, S. (2014). *Hutt and Waikanae Rivers Sportsfish Monitoring Results 1999-2014.*

Rebergen, A. (2012). *Birds on Wairarapa Rivers and Coast in 2011-12 Breeding Season.* Report prepared for Greater Wellington Regional Council.

Richardson, J., & Fuller, I. (2010). *Quantitation of channel planform change on the lower Rangatikei River, New Zealand, 1949-2007: response to management?* Geoscience 2010/2.

Richardson, J., Rowe, D., & Smith, J. (2001). Effects of turbidity on the upstream movement of migratory banded kokopu (Galaxias fasciatus) in a small agricultural stream. *New Zealand Journal of Marine and Freshwater Research 35; 191-196.*

Richardson, Teirney, & Unwin. (1984). *The relative value of Wellington Rivers to New Zealand Anglers.* FRD, NZ Ministry of Agriculture and Fisheries.

Robertson, B., & Stevens, L. (2007). *Kapiti, Southwest, South Coast and Wellington Harbour. Risk Assessment and Monitoring Recommendations.* Prepared for Greater Wellington Regional Council.

Robertson, C., Dowding, J., Elliot, G., Hitchmough, R., Miskelly, C., O'Donnell, C., et al. (2013). *Conservation status of New Zealand birds, 2012.* New Zealand Threat Classiification Series 4, Department of Conservation, Wellington.

Rowe, D., Dean, T., Williams, E., & Smith, J. (2003). Effects of turbidity on the ability of juvenile rainbow trout, Oncorhynchus mykiss, to feed on limnetic and benthic prey in laboratory tanks. *New Zealand Journal of Marine and Freshwater Research. 37: 45-52*.

Sagar, P. (1983). Invertebrate recolonisation of a previously dry channel in the Rakaia River. *New Zealand Journal of Marine and Freshwater Research, 17.*

Smith, J. (2015). *Freshwater Fish Spawning and Migration Periods.* MPI Technical Paper No: 2015/17, prepared for MPI by NIWA.

Stark, & Maxted. (2007). *A Users Guide for the Macroinvertebrate Community Index.* Report prepared for Ministry for the Environment.

Stark, J., Boothroyd, I., Harding, J., Maxted, J., & Scarsbrook, M. (2001). *Protocols for sampling macroinvertebrates in wadeable streams.* Prepared for the Ministry for the Environment.

Strickland, R., & Quarterman. (2001). *Review of freshwater fish in the Wellington Region.* Nelson: Cawthron Institute.

Taylor, & Kelly. (2003). *Inanga spawning habitats in the greater Wellington Region.* Report prepared for Greater Wellington Regional Council.

Thompson, M. (2011). *Otaki River instream values and minimum flow assessment.* Greater Wellington Regional Council GW/EMI-T-11/133.

Tonkin and Taylor. (2015). *Resource Consent Applications - Otaki River.* Report prepared for Greater Wellington Regional Council (Flood Protection.

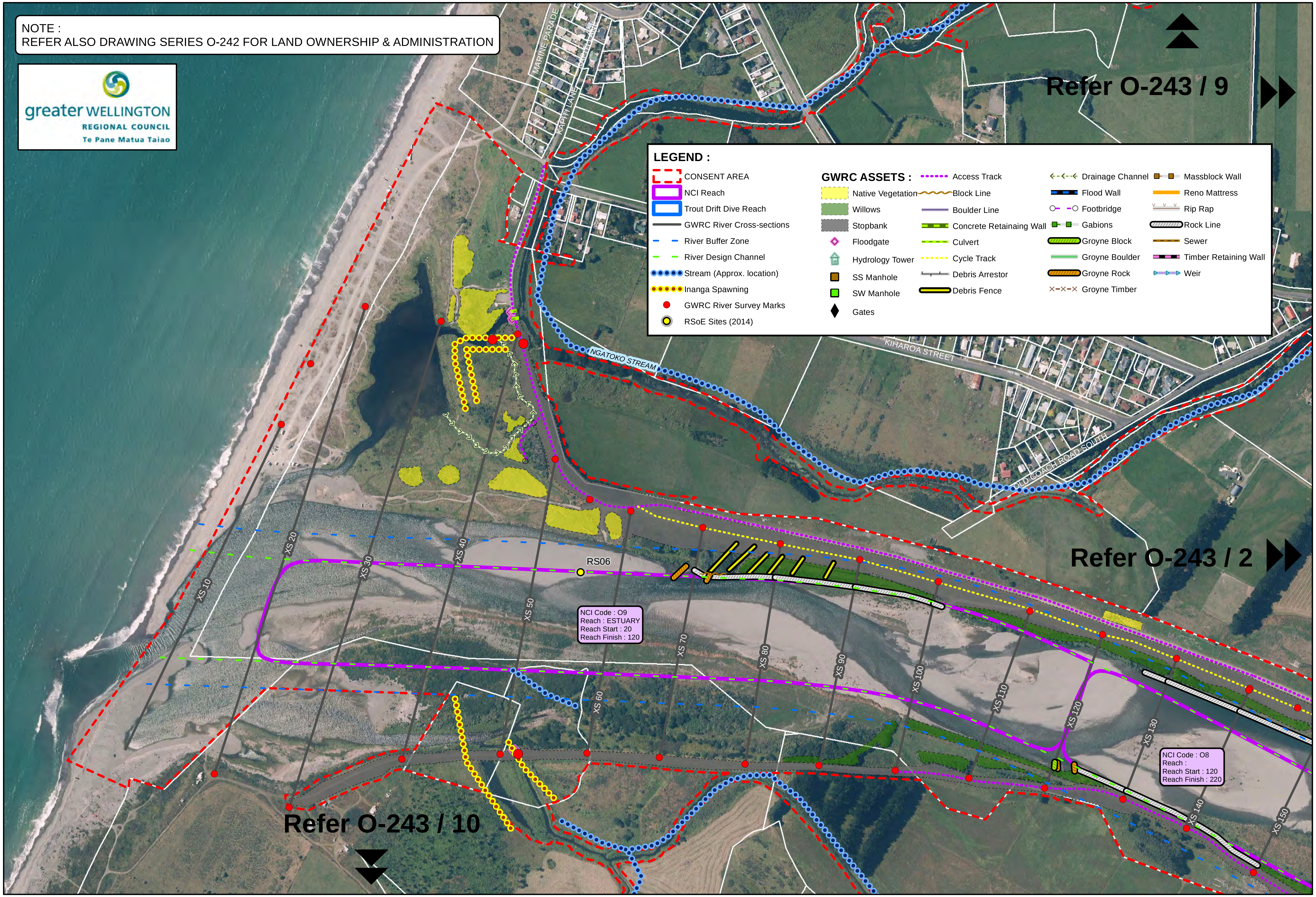
Wagenhoff, A., & Young, R. (2013). *Effects of willow removal on Australian and New Zealand Stream ecosystems - a literature review of the potential risks and benefits. .* Cawthron Institute report prepared for MBIE Project CO1X1002: Maintenance and Rehabiliation of Aquatic Ecosystems.

Williams, G. (2013). *Western River Schemes. Report on the Natural Character of the Rivers and an Assessment od Natural Character for Scheme Monitoring.* Report prepared for Greater Wellington Regional Council.

Winterbourn, M., & Wright-Stow, A. (2003). *Depth distribution of stream invertebrates in the hyporheic zone: diel and life history effects.* Department of Zoology, Universtity of Canterbury.

Wood, S., Hamilton, D., Paul, W., Safi, K., & Williamson, W. (2009). *New Zealand Guidelines for Cyanobacteria in Recreational Freshwaters - Interim Guidelines.* Prepared for the Ministry for the Environment.

Appendix A Map series showing the Otaki Application Area



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Otaki Application Area March 2014 - Sheet 1a.mxd

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A3 Scale :1:5,000

OTAKI RIVER - CONSENT AREA - Map 1a
GWRC Asset, Fish & Ecological Information (River Mouth to Waihoanga Suspension Bridge
Including Rangiuru & Ngatoko Streams)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerials : GWRC 2013

DWG No. O-243 / 1

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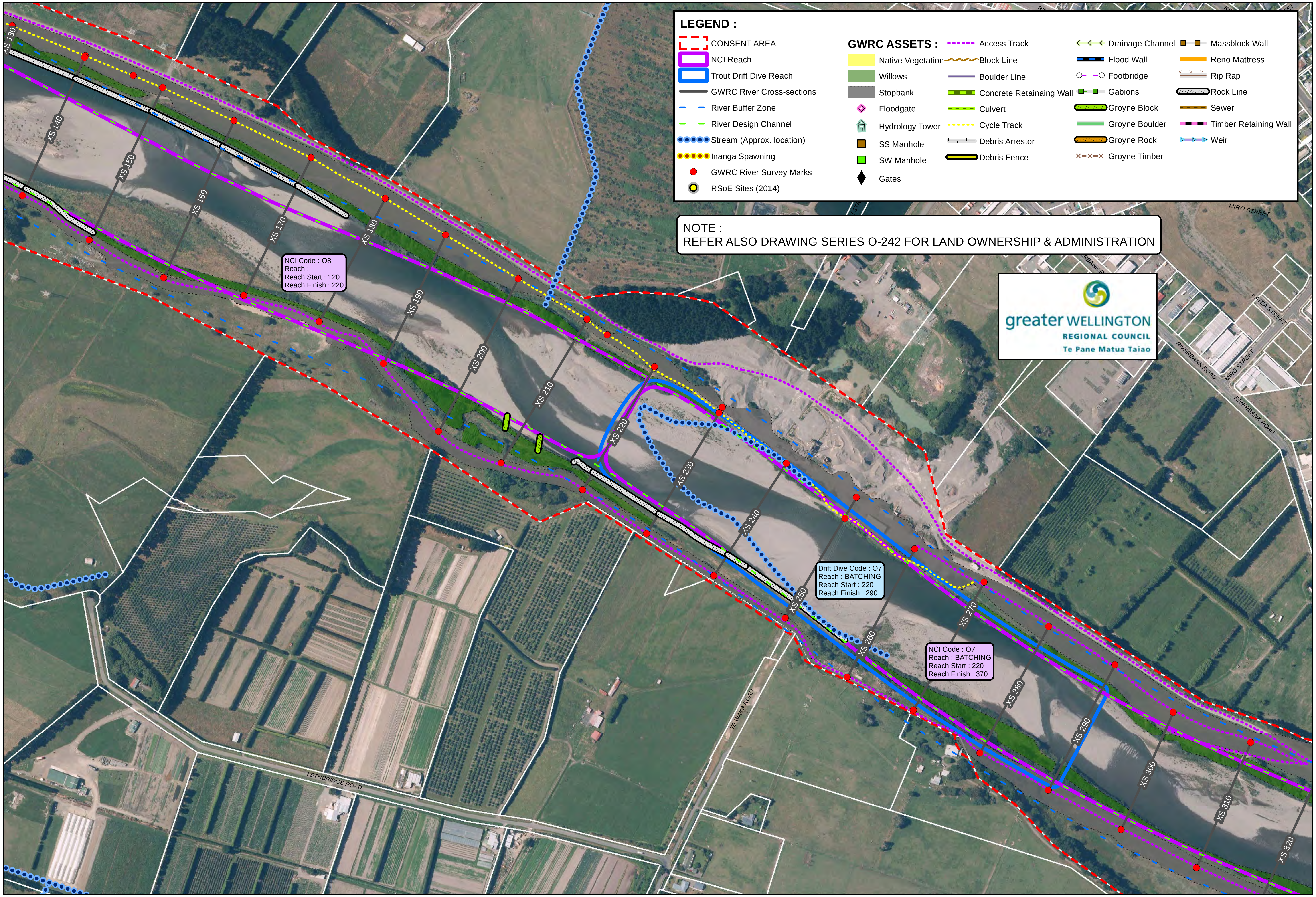

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OTAKI RIVER - CONSENT AREA - Map 2a
GWRC Asset, Fish & Ecological Information (River Mouth to Waihoanga Suspension Bridge)

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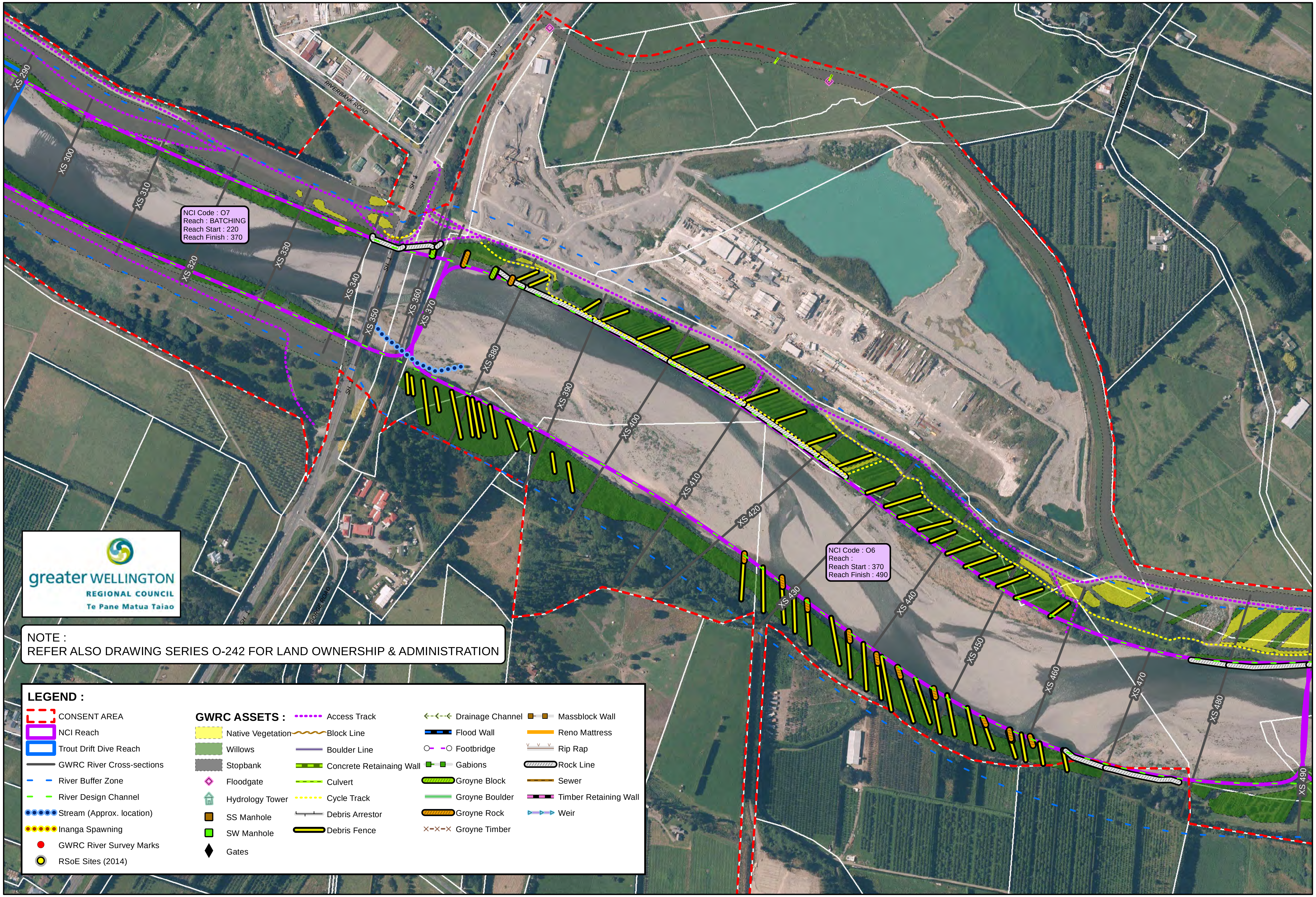

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OTAKI RIVER - CONSENT AREA - Map 3a
GWRC Asset, Fish & Ecological Information (River Mouth to Waihoanga Suspension Bridge)

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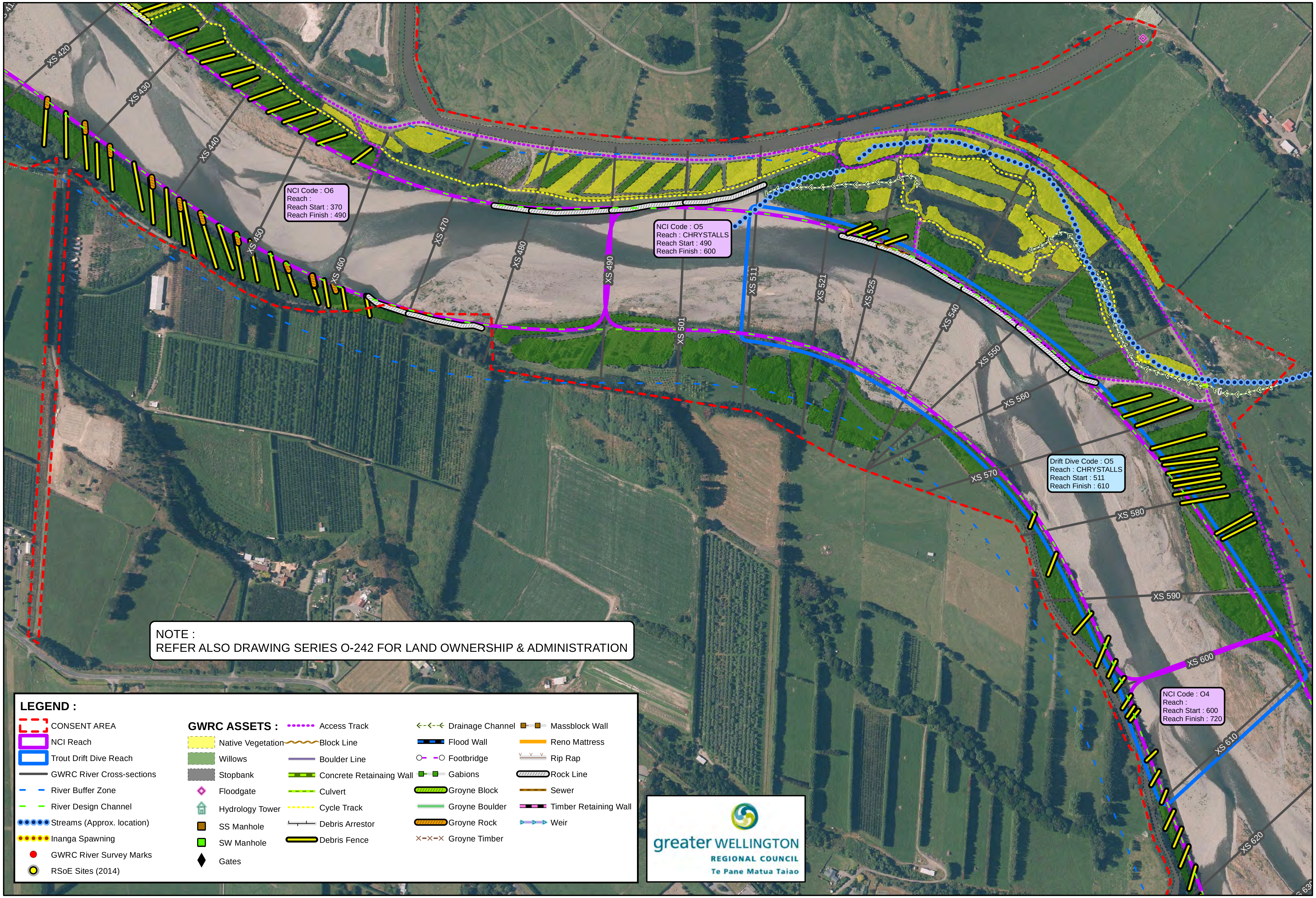

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OTAKI RIVER - CONSENT AREA - Map 4a

GWRC Asset, Fish & Ecological Information (River Mouth to Waihoanga Suspension Bridge)

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DWG No. **O-243 / 4**

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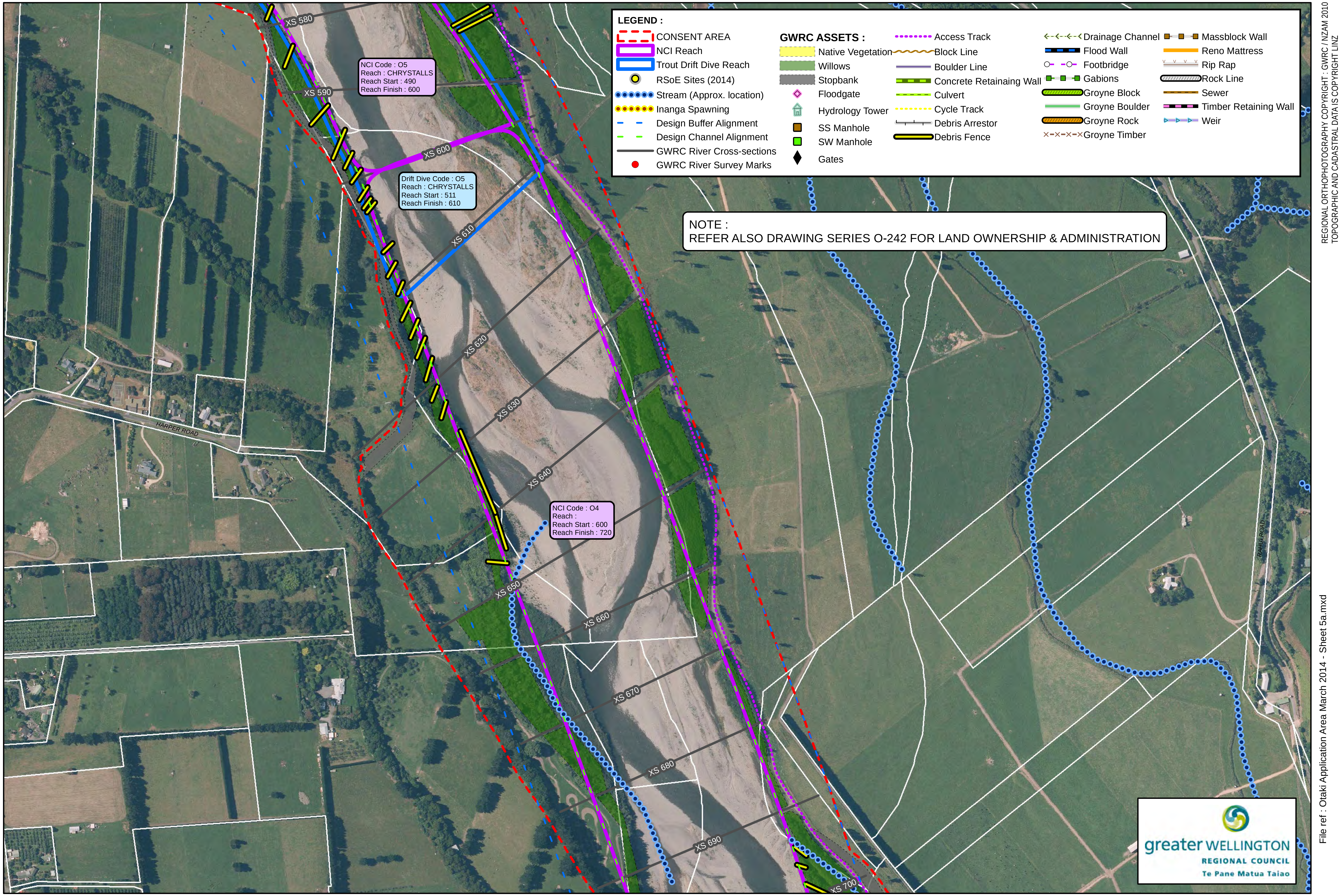

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OTAKI RIVER - CONSENT AREA - Map 5a

GWRC Asset, Fish & Ecological Information (River Mouth to Waihoanga Suspension Bridge)

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Aerials : GWRC 2013

DWG No. **O-243 / 5**

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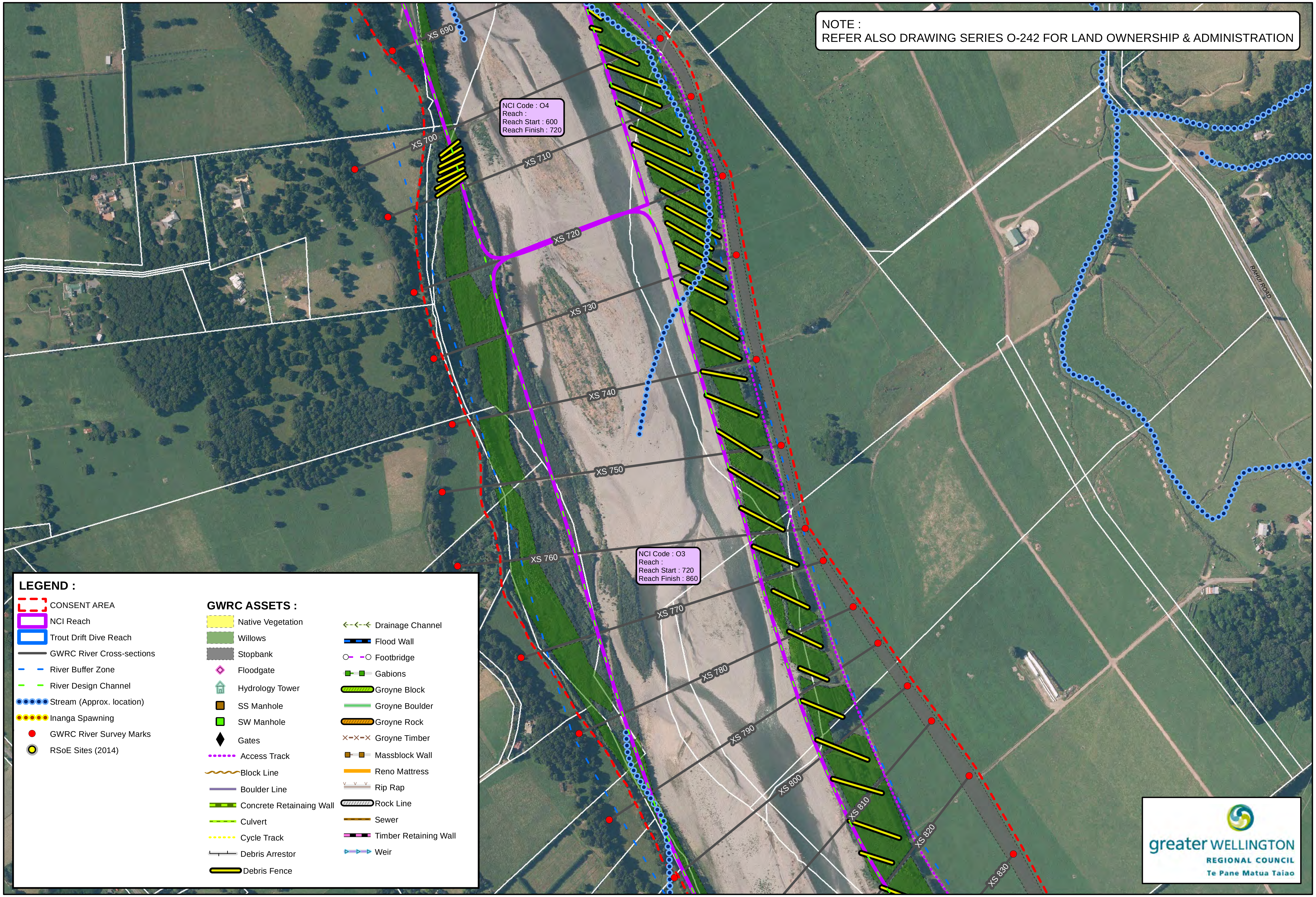

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OTAKI RIVER - CONSENT AREA - Map 6a
GWRC Asset, Fish & Ecological Information (River Mouth to Waihoanga Suspension Bridge)

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Aerials : GWRC 2013

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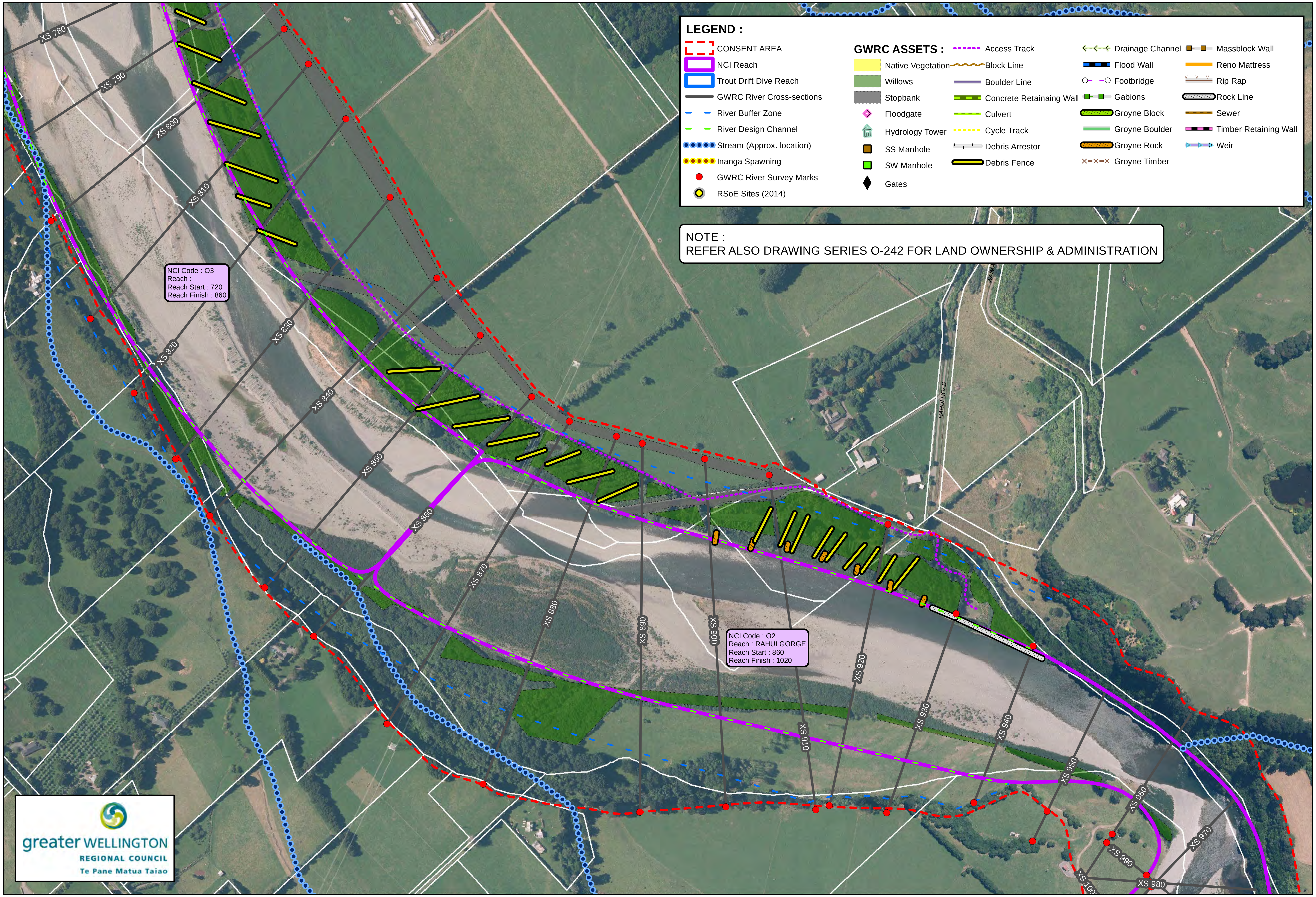

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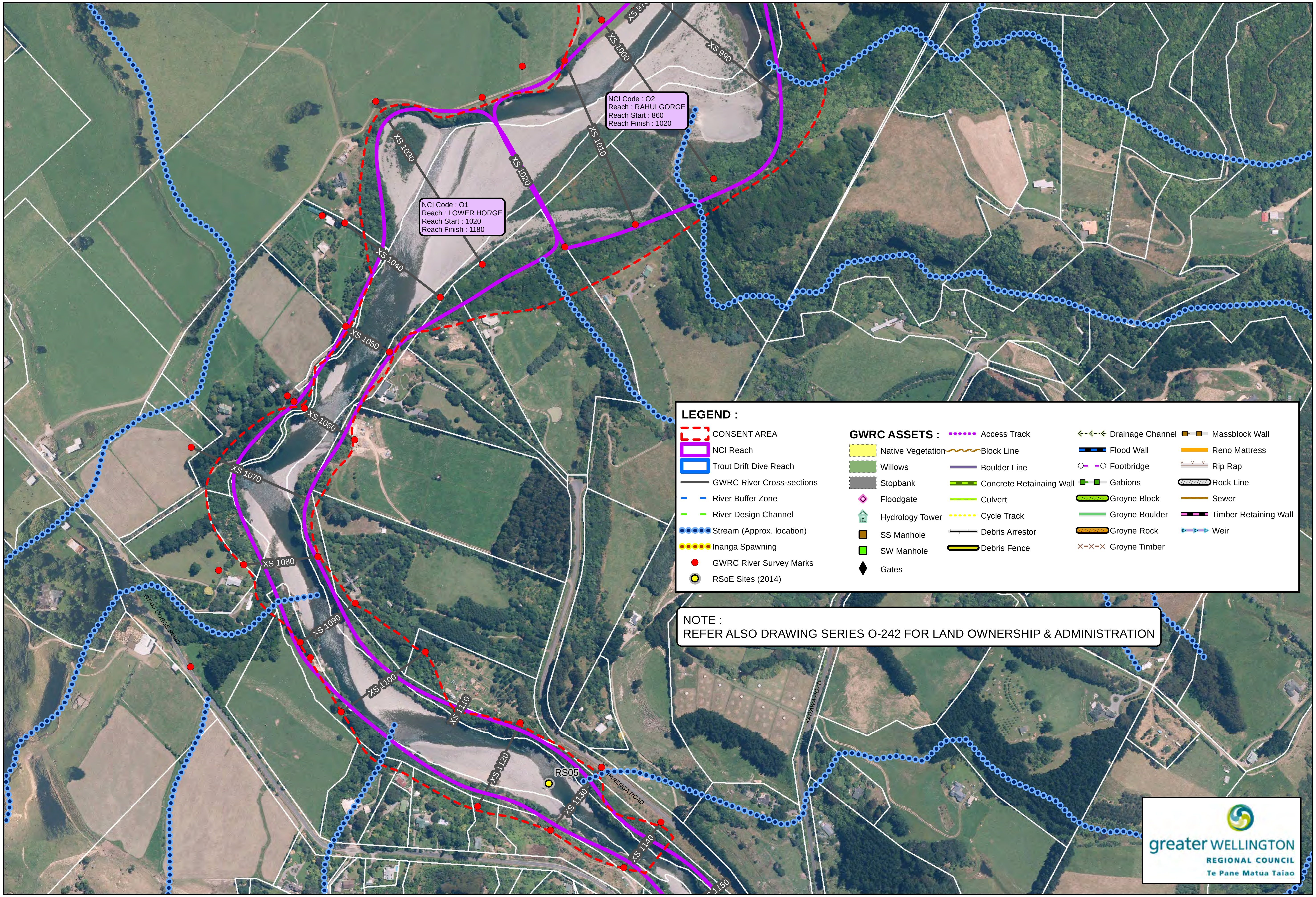
greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

A3 Scale :1:5,000

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerials : GWRC 2013

OTAKI RIVER - CONSENT AREA - Map 7a
GWRC Asset, Fish & Ecological Information (River Mouth to Waihoanga Suspension Bridge)

DWG No. **O-243 / 7**



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OTAKI RIVER - CONSENT AREA - Map 8a

GWRC Asset, Fish & Ecological Information (River Mouth to Waihoanga Suspension Bridge)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerials : GWRC 2013

DWG No. **O-243 / 8**

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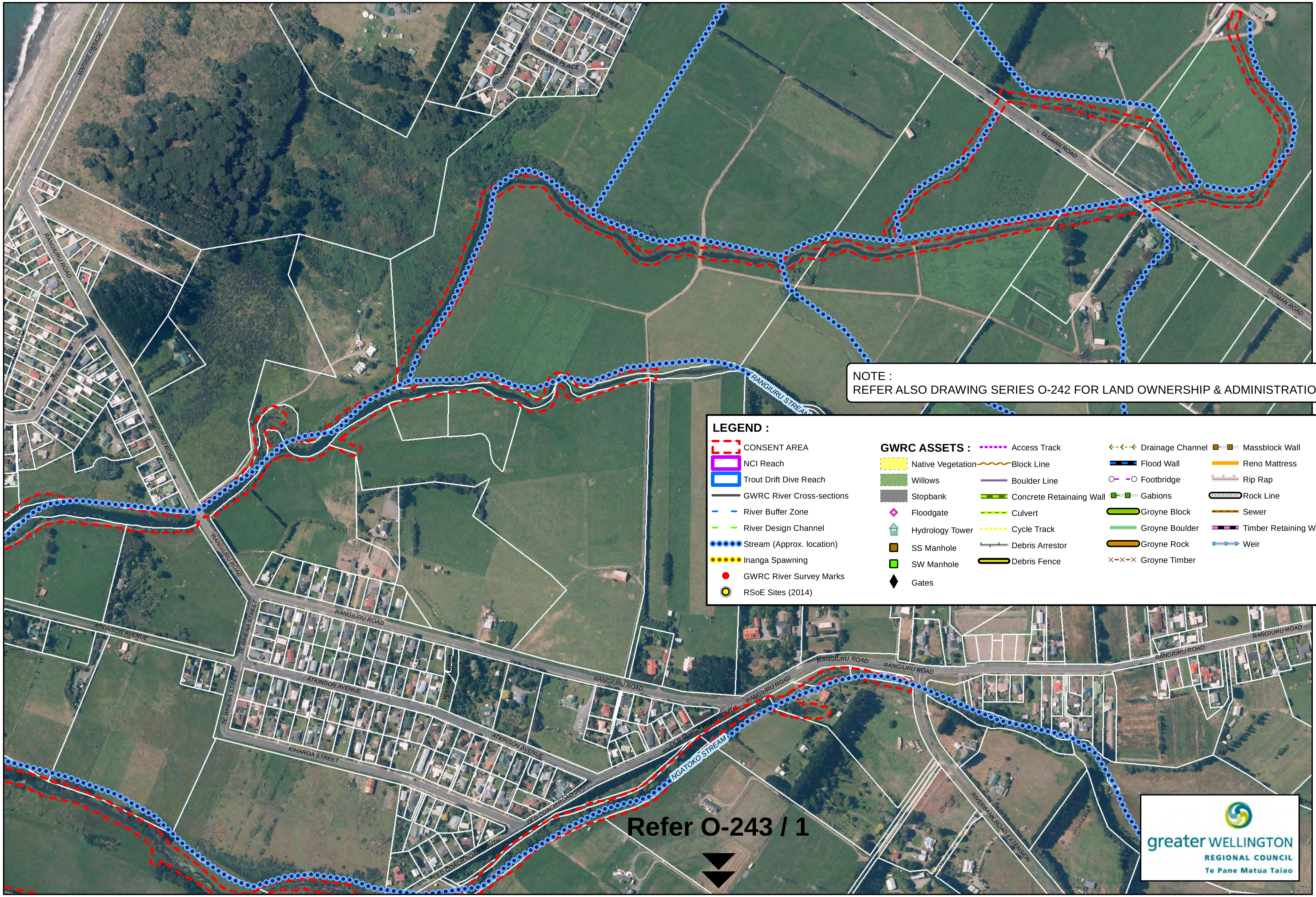

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Otaki Application Area March 2014 - Sheet 9a.mxd

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A3 Scale :1:5,000

OTAKI RIVER - CONSENT AREA - Map 9a

GWRC Asset, Fish & Ecological Information (Rangiuru & Ngatoko Streams)

Drawn : P.Cook, Date Plotted : 7 July 2015
Aerials : GWRC 2013

DWG No. **O-243 / 9**

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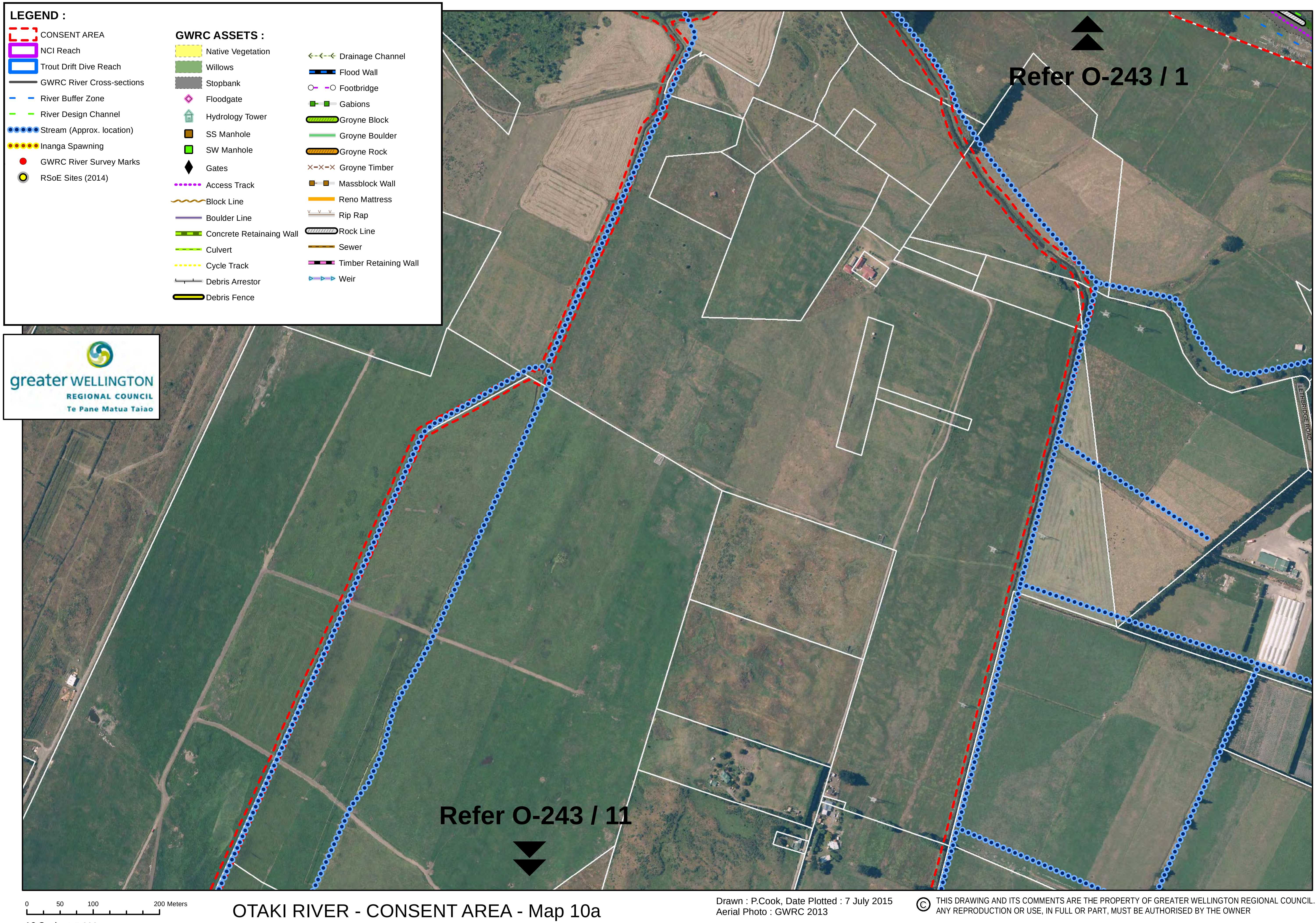

OTAKI RIVER - CONSENT AREA - Map 10a

GWRC Asset, Fish & Ecological Information (Katihuku & Pahiko Streams)

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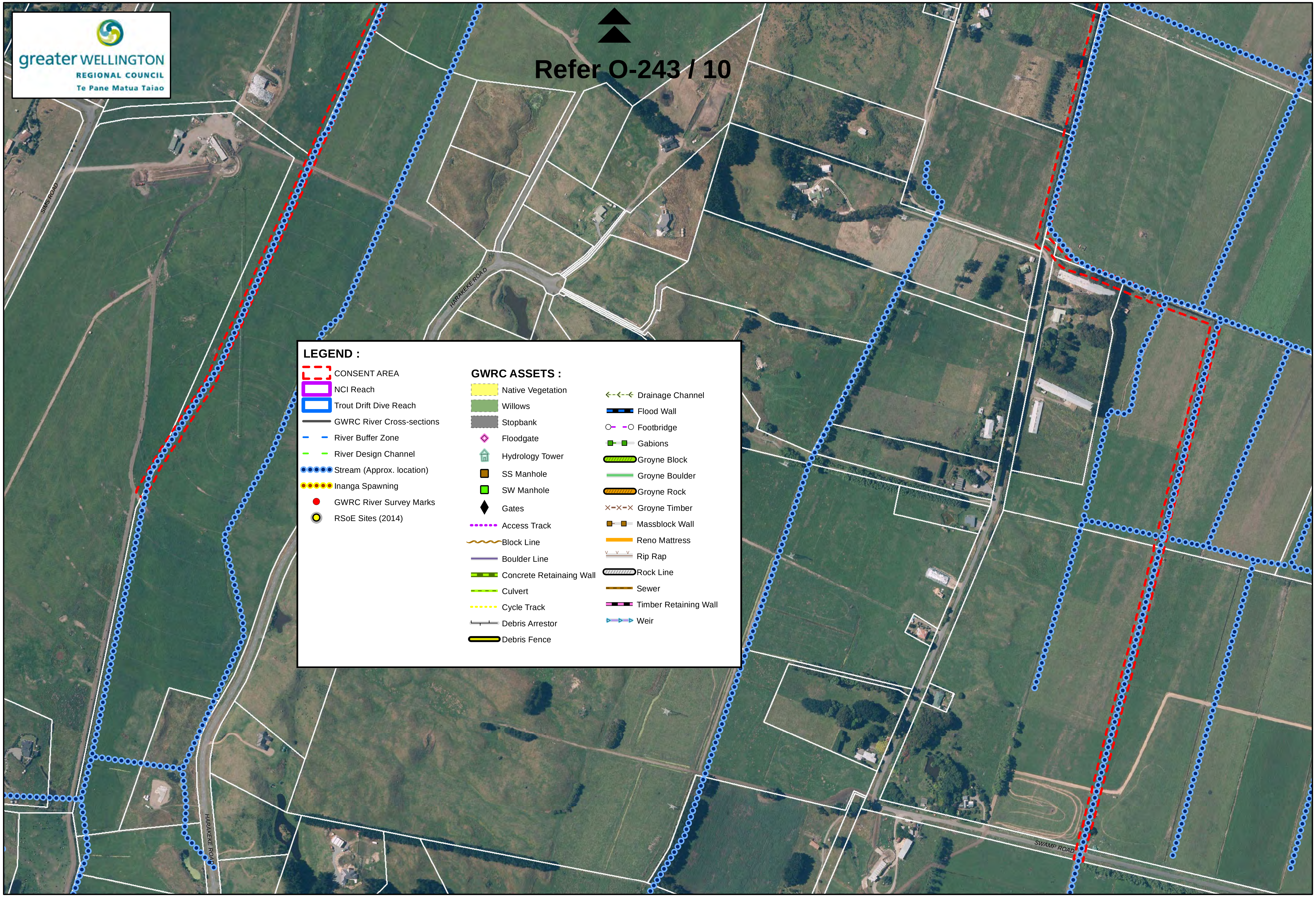
Aerial Photo : GWRC 2013

Otaki Application Area March 2014 - Sheet 10a.mxd

DWG No. **O-243 / 10**



Otaki Application Area March 2014 - Sheet 11a.mxd

OTAKI RIVER - CONSENT AREA - Map 11a

GWRC Asset, Fish & Ecological Information (Katihuku & Pahiko Streams)

DWG No. **O-243 / 11**

Appendix B Boxplots of water quality results by year, from 2004 to 2015

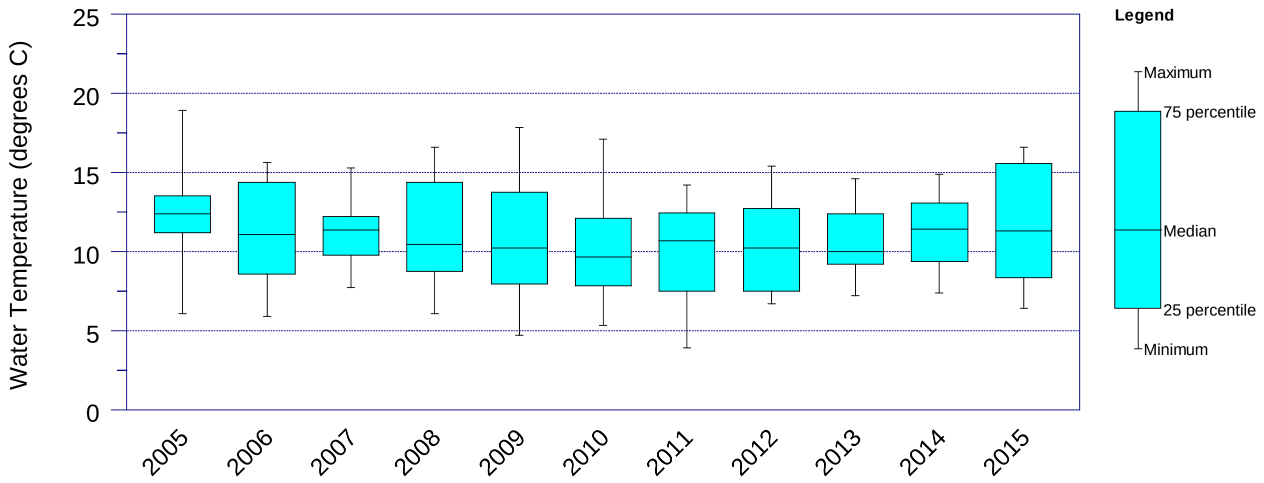


Figure B1: Temperature (ºC) by year in the Otaki River at Pukehinau

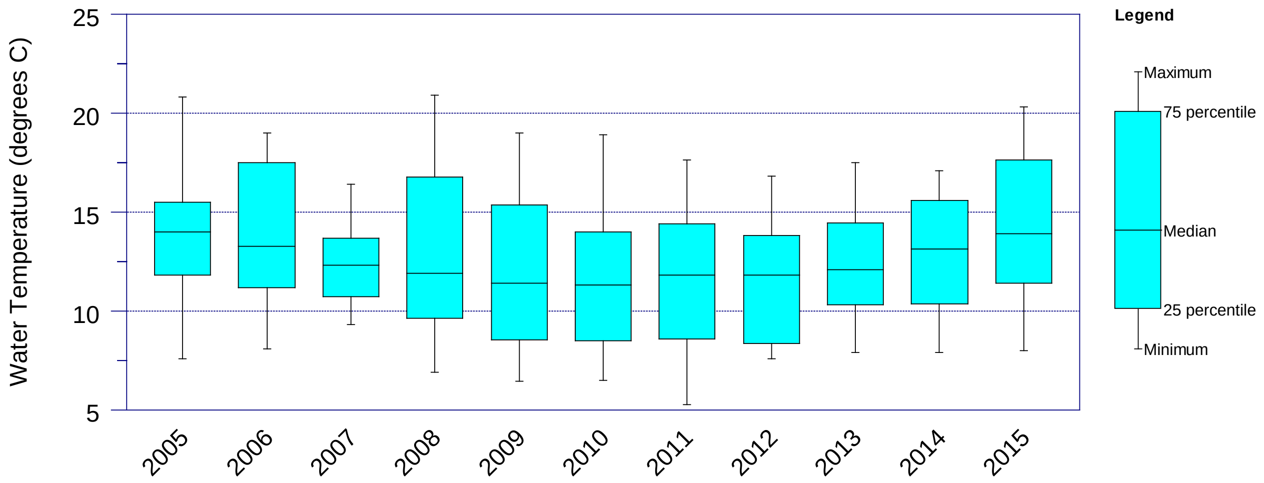


Figure B2: Temperature (ºC) by year in the Otaki River at Mouth

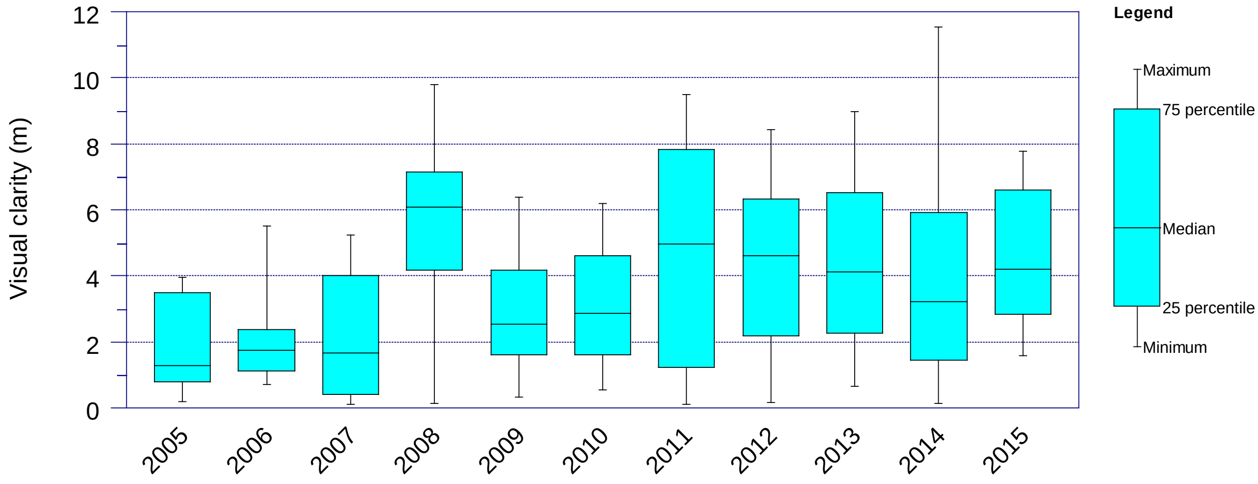


Figure B3: Visual clarity (m) by year in the Otaki River at Pukehinau (Mann-Kendall test shows increasing trend at 8.8% per year (p <0.001))

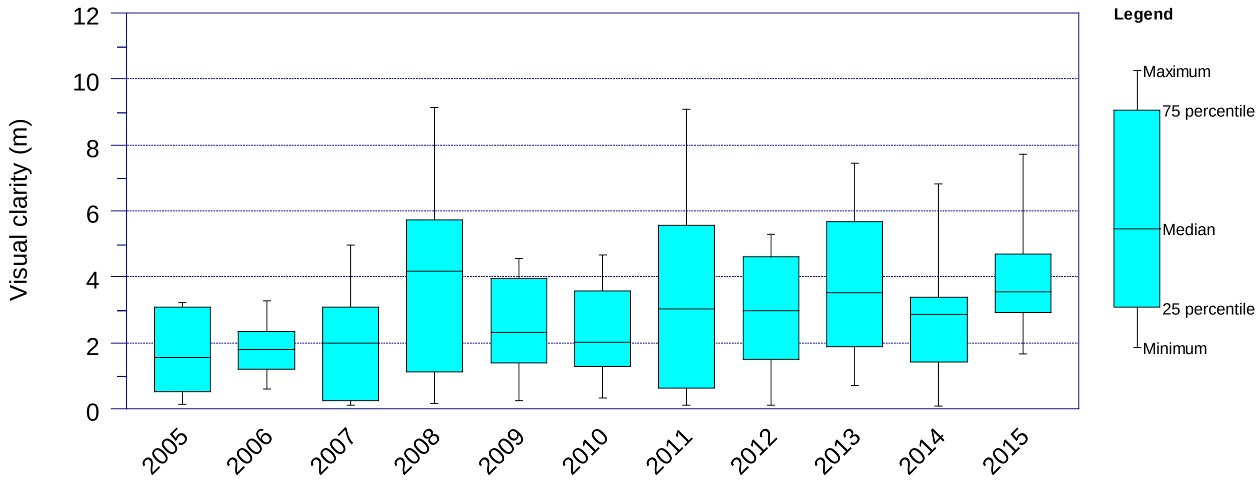


Figure B4: Visual clarity (m) by year in the Otaki River at Mouth (Mann-Kendall test shows increasing trend at 8.0% per year (p <0.001))

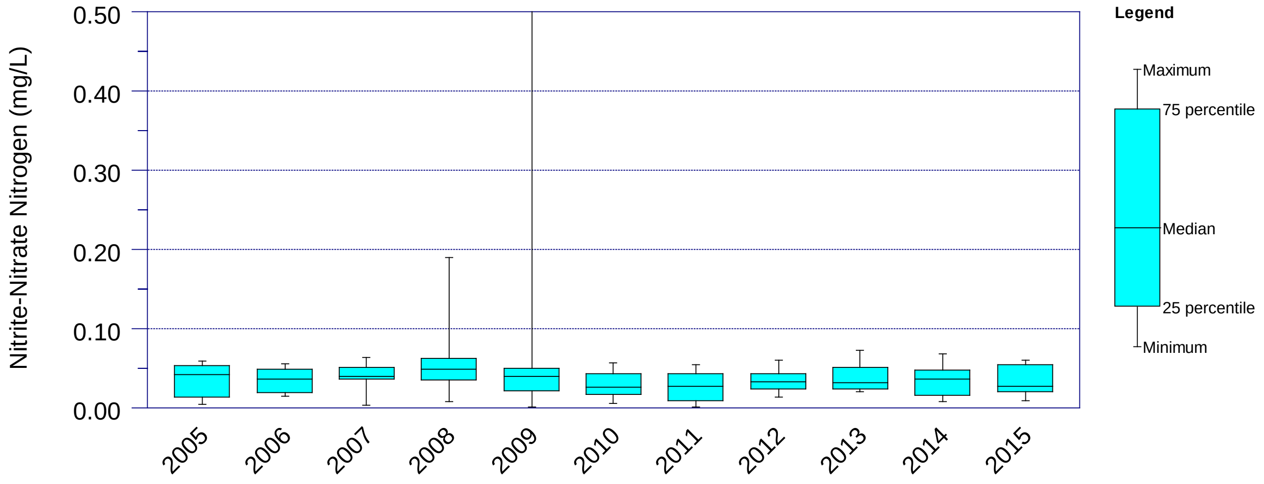


Figure B5: Nitrate + nitrite nitrogen (mg/L) by year in the Otaki River at Pukehinau

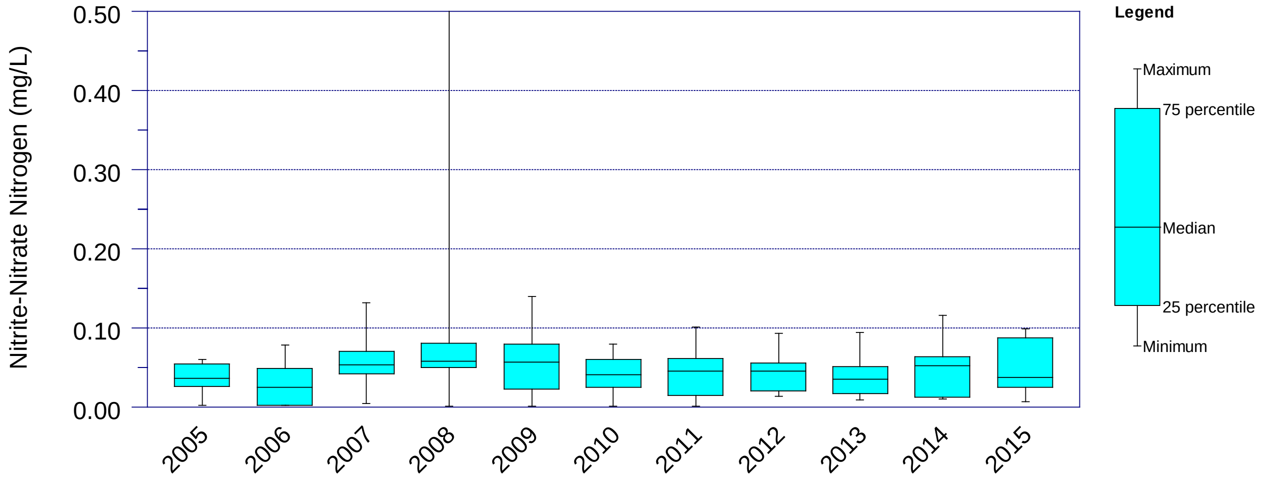


Figure B6: Nitrate + nitrite nitrogen (mg/L) by year in the Otaki River at Mouth

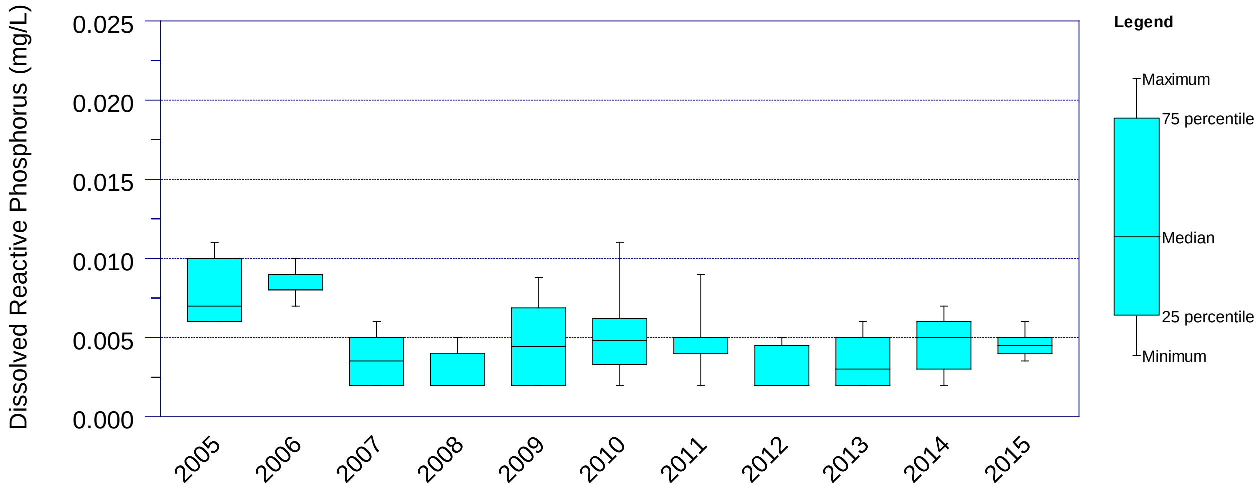


Figure B7: Dissolved reactive phosphorus (mg/L) by year in the Otaki River at Pukehinau (Mann-Kendall test shows decreasing trend at -2.9% per year (p = 0.002))

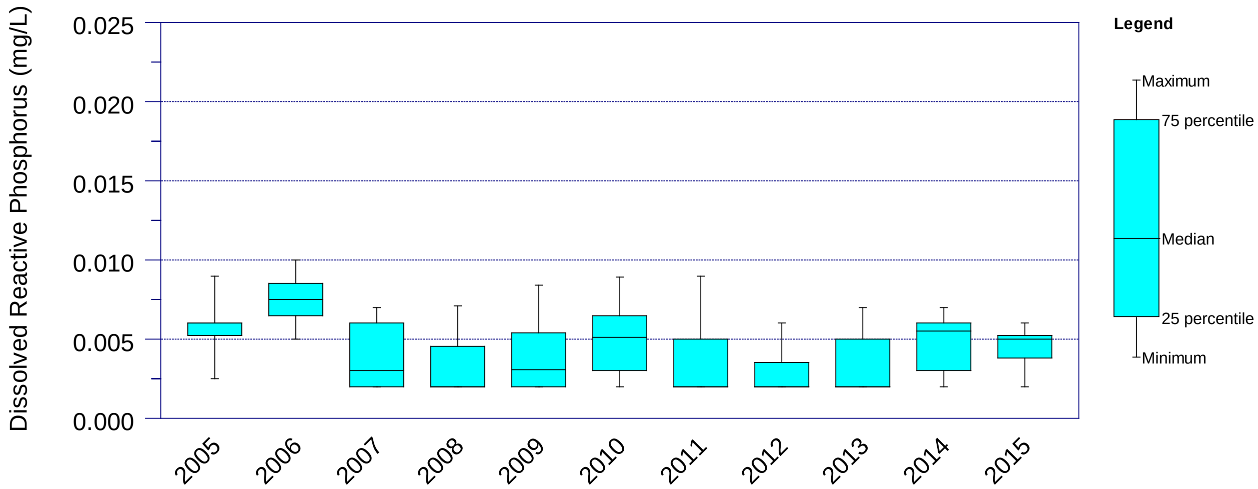


Figure B8: Dissolved reactive phosphorus (mg/L) by year in the Otaki River at Mouth

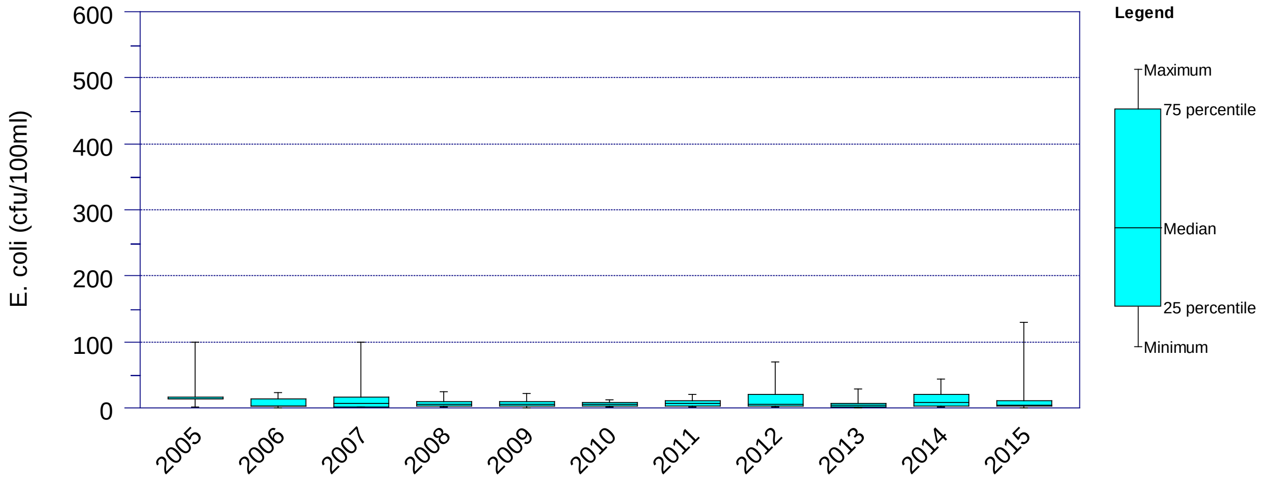


Figure B9: E. coli (cfu/100ml) by year in the Otaki River at Pukehinau

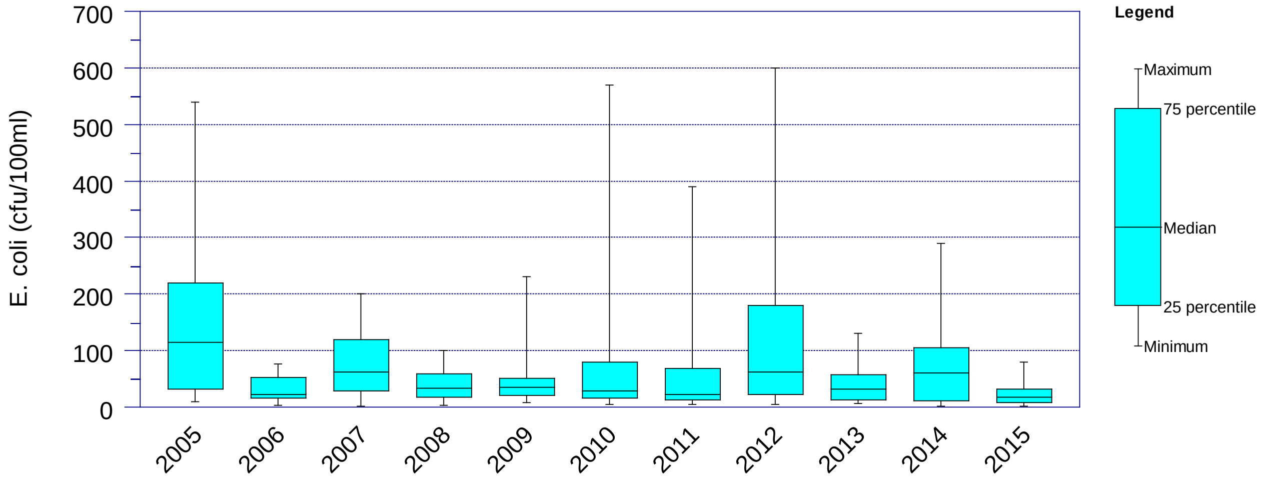


Figure B10: E. coli (cfu/100ml) by year in the Otaki River at Mouth

Appendix C Macroinvertebrate results for 2014/15

2014 SOE and Additional Data	Site No	R1 (MWH)	RS05	RS06
	Site Name	Rangiuru	Otaki River at Pukehinau	Otaki River at Mouth
	Date sampled	27/07/2015	13/02/2014	13/02/2014
Generic Grouping	MCI-level taxa			
Acari	Acari		1	1
Coelenterata	Hydra			
Coleoptera	Antiporus			
	Berosus			
	Elmidae		4	3
	Enochrus			
	Hydraenidae			
	Hydrophilidae			
	Liodessus			
	Ptilodactylidae			
	Scirtidae			
Collembola	Collembola			
Crustacea	Amphipoda			
	Amphipoda			
	Cladocera			
	Copepoda			
	Isopoda			
	Ostracoda	167		
	Paracalliope	2404	2	
	Paraleptamphopus			
	Phreatogpmmarus	286		
	Paranephrops			
	Paratya			
	Talitridae	1		
Diptera	Aphrophila			1
	Austrosimulium			
	Ceratopogonidae			
	Chironomidae		1	
	Chironomus	1		
	Corynoneura			
	Empididae			
	Ephydridae			
	Eriopterini		4	1
	Harrisius			
	Hexatomini			2
	Maoridiamesa		P	1
	Mischoderus			
	Muscidae			
	Neocurupira			

	Orthocladiinae	1	4	19
	Paradixa			
	Psychodidae			
	Sciomyzidae			
	Stictocladius			
	Stratiomyidae			
	Tabanidae			
	Tanypodinae	24		
	Tanytarsini			18
	Zelandotipula			
Ephemeroptera	Acanthophlebia			
	Ameletopsis			
	Austroclima			
	Coloburiscus		2	1
	Deleatidium	1	155	146
	Ichthybotus			
	Neozephlebia			
	Nesameletus		1	
	Oniscigaster			
	Rallidens			
	Zephlebia			
Hemiptera	Anisops			
	Microvelia			
	Sigara			
Hirudinea	Hirudinea	1		
Lepidoptera	Hygraula			
Megaloptera	Archichauliodes		5	1
Mollusca	Ferrissia			
	Gyraulus			
	Physa	48		
	Potamopyrgus	5069	1	
	Sphaeriidae	1		
Nematoda	Nematoda			
Neuroptera	Kempynus			
Odonata	Anisoptera			
	Antipodochlora			
	Austrolestes			
	Xanthocnemis	48		
Oligochaeta	Oligochaeta	1		5
Platyhelminthes	Platyhelminthes	1		
Plecoptera	Acroperla			
	Austroperla		1	
	Megaleptoperla			
	Spaniocerca			
	Stenoperla		3	
	Zelandobius			

	Zelandoperla		3	P
Polychaeta	Polychaeta			
Trichoptera	Aoteapsyche		21	8
	Beraeoptera			
	Costachorema		1	
	Helicopsyche			
	Hudsonema			
	Hydrobiosella			
	Hydrobiosis		2	4
	Hydrochorema			
	Neurochorema			
	Oecetis			
	Oeconesidae			
	Olinga		4	2
	Orthopsyche			
	Oxyethira			
	Paroxyethira			
	Plectrocnemia			
	Polyplectropus			
	Psilochorema		1	2
	Pycnocentria			
	Pycnocentrodes			
	Triplectides			
	Fixed Count		216	215
	Squares counted		4	5
Metrics	TOTAL	8054	1696	1350
	TAXA Richness	16	20	17
	MCI-hb		131.00	116.47
	MCI-sb	63.90	131.00	125.76
	EPT Richness	1	11	7
	Hydroptilid EPT		0	0
	EPT (- Hydropts)		11	7
	QMCI-hb		7.41	6.60
	QMCI-sb	3.20	5.85	5.37
	% EPT	6.00	89.59	77.04
	% Hydropts		0.00	0.00
	% EPT (- Hydropts)		89.59	77.04

Appendix D Peak periods for upsteam fish migration and spawning

Table F1: Periods of peak sensitivity for upstream fish migration (dark grey) and range (light grey) in the Otaki River system (compiled from McDowell, 1990; McDowall, 1995; and Hamer, 2007, and references therein)

		Summer		Autumn			Winter			Spring			Summer
Species	Life stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shortfin eel	juvenile												
Longfin eel	juvenile												
Inanga	juvenile												
Kōaro	juvenile												
Giant kōkopu	juvenile												
Shortjaw kopopu	juvenile												
Banded kōkopu	juvenile												
Common bully	juvenile												
Redfin bully	juvenile												
Lamprey	adult												
Torrentfish	juvenile												
Black flounder	juvenile												
brown trout	adult												

Table F2: Periods of peak sensitivity for fish spawning (dark grey) and range (light grey) in the Otaki River system (compiled from McDowell, 1990; McDowall, 1995; and Hamer, 2007, and references therein)

		Summer		Autumn			Winter			Spring			Summer
Species	Critical habitat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inanga	margin, estuary												
Kōaro	margin												
Giant kōkopu	margin												
Shortjaw kopopu													
Banded kōkopu	margins												
Common bully	bed												
Redfin bully	bed												
Lamprey	upper reaches												
Torrentfish	bed												
Dwarf galaxias	?												
Upland bully	bed												
Cran's bully	bed												
brown trout	bed												

Appendix E List of bird species recorded on the Otaki River, 2012- 2105

Data is from McArthur, et al, (2015). Threat rankings are as per Robertson et al (2013). Species names and taxonomic order are as per Gill et al (2010). Habitat use columns describe which habitats each species was observed using, or is likely to be using for feeding (F), roosting (R) and breeding (B) within the Ōtaki River corridor. Date ranges provided delimit the breeding season for each bird species observed or likely to be breeding in the river corridor, breeding season information was sourced from the New Zealand Birds Online website, accessed 30th July 2015.

Scientific name	Common name	Threat ranking	Habitat use	
			Dry gravels	Riparian vegetation
Phasianus colchicus	common pheasant	Introduced and Naturalised	F, R, B (Jul – Mar)	F, R, B (Jul – Mar)
Cygnus atratus	black swan	Not Threatened	R	Species unlikely to be using this habitat
Anser anser	greylag goose	Introduced and Naturalised	R	Species unlikely to be using this habitat
Tadorna variegata	paradise shelduck	Not Threatened	R, B (Aug – Feb)	B (Aug – Feb)
Anas gracilis	grey teal	Not Threatened	R, B? (Jun – Jan)	B? (Jun – Jan)
A. platyrhynchos	mallard	Introduced and Naturalised	R, B (Jul – Dec)	B (Jul – Dec)
A. rhynchotis	Australasian shoveler	Not Threatened	R	Species unlikely to be using this habitat
Cairina moschata	Muscovy duck	N/A[2]	R	Species unlikely to be using this habitat
Phalacrocorax melanoleucos	little shag	Not Threatened	R	R
P. carbo	black shag	At Risk, Naturally Uncommon	R	R
P. varius	pied shag	Nationally Vulnerable	R	Species unlikely to be using this habitat
Egretta novaehollandiae	white-faced heron	Not Threatened	R	R, B? (Jun – Apr)

[2] Muscovy duck is not included in the current checklist of the birds of New Zealand (Gill et al, 2010) and therefore has not been given a New Zealand Threat Classification System ranking (Robertson et al, 2013)

Scientific name	Common name	Threat ranking	Habitat use	
			Dry gravels	Riparian vegetation
Circus approximans	Australasian harrier	Not Threatened	F, R, B (Sep – Apr)	F, R
Porphyrio melanotus	pukeko	Not Threatened	F, R, B (all year around)	F, R, B (all year around)
Arenaria interpres	turnstone	Migrant	R	Species unlikely to be using this habitat
Haematopus unicolor	variable oystercatcher	At Risk, Recovering	R, B (Sep – Mar)	Species unlikely to be using this habitat
Himantopus himantopus	pied stilt	At Risk, Declining	F, R, B (Jun – Feb)	Species unlikely to be using this habitat
Charadrius bicinctus	banded dotterel	Nationally Vulnerable	F, R, B (Aug – Feb)	Species unlikely to be using this habitat
Elseyornis melanops	black-fronted dotterel	Coloniser	F, R, B (Aug – Mar)	Species unlikely to be using this habitat
Vanellus miles	spur-winged plover	Not Threatened	F, R, B (Apr – Nov)	Species unlikely to be using this habitat
Larus dominicanus	black-backed gull	Not Threatened	F, R	Species unlikely to be using this habitat
L. novaehollandiae	red-billed gull	Nationally Vulnerable	F, R	Species unlikely to be using this habitat
Hydroprogne caspia	Caspian tern	Nationally Vulnerable	R	Species unlikely to be using this habitat
Sterna striata	white-fronted tern	At Risk, Declining	R	Species unlikely to be using this habitat
Columba livia	rock pigeon	Introduced and Naturalised	F, R	Species unlikely to be using this habitat
Hemiphaga novaeseelandiae	New Zealand pigeon (kereru)	Not Threatened	Species unlikely to be using this habitat	F, R
Platycercus eximius	eastern rosella	Introduced and Naturalised	F	F, R, B (Sep – Mar)
Chrysococcyx lucidus	shining cuckoo	Not Threatened	F, R	F, R, B (Oct – Mar)
Todiramphus sanctus	kingfisher	Not Threatened	F, R	F, R, B (Oct – Jan)
Gerygone igata	grey warbler	Not Threatened	F, R	F, R, B (Aug – Feb)

Scientific name	Common name	Threat ranking	Habitat use	
			Dry gravels	Riparian vegetation
Prosthemadera novaeseelandiae	tui	Not Threatened	Species unlikely to be using this habitat	F, R
Gymnorhina tibicen	Australian magpie	Introduced and Naturalised	F, R	F, R, B (Jul – Jan)
Rhipidura fuliginosa	New Zealand fantail	Not Threatened	F, R	F, R, B (Aug - Mar)
Petroica macrocephala	tomtit	Not Threatened	Species unlikely to be using this habitat	F, R
Alauda arvensis	Eurasian skylark	Introduced and Naturalised	F, R, B (Aug – Jan)	Species unlikely to be using this habitat
Zosterops lateralis	silvereye	Not Threatened	F, R, B (Aug – Feb)	F, R, B (Aug – Feb)
Hirundo neoxena	welcome swallow	Not Threatened	R	Species unlikely to be using this habitat
Turdus merula	blackbird	Introduced and Naturalised	F, R, B (Aug – Feb)	F, R, B (Aug – Feb)
T. philomelos	song thrush	Introduced and Naturalised	F, R, B (Aug – Feb)	F, R, B (Aug – Feb)
Sturnus vulgaris	starling	Introduced and Naturalised	F, R	F, R, B (Sep – Dec)
Passer domesticus	house sparrow	Introduced and Naturalised	F, R	F, R, B (Sep – Mar)
Anthus novaeseelandiae	New Zealand pipit	At Risk, Declining	F, R, B (Aug – Feb)	Species unlikely to be using this habitat
Prunella modularis	dunnock	Introduced and Naturalised	F, R, B (Sep – Feb)	F, R, B (Sep – Feb)
Fringilla coelebs	chaffinch	Introduced and Naturalised	F, R, B (Sep – Feb)	F, R, B (Sep – Feb)
Carduelis chloris	greenfinch	Introduced and Naturalised	F, R (Oct – Mar)	F, R, B (Oct – Mar)
C. carduelis	goldfinch	Introduced and Naturalised	F, R, B (Oct – Mar)	F, R, B (Oct – Mar)
C. flammea	redpoll	Introduced and Naturalised	F, R	F, R, B (Oct – Mar)

Scientific name	Common name	Threat ranking	Habitat use	
			Dry gravels	Riparian vegetation
Emberiza citrinella	Yellowhammer	Introduced and Naturalised	F, R, B (Oct – Mar)	R, B (Oct – Mar)

Appendix F Important trout spawning waters

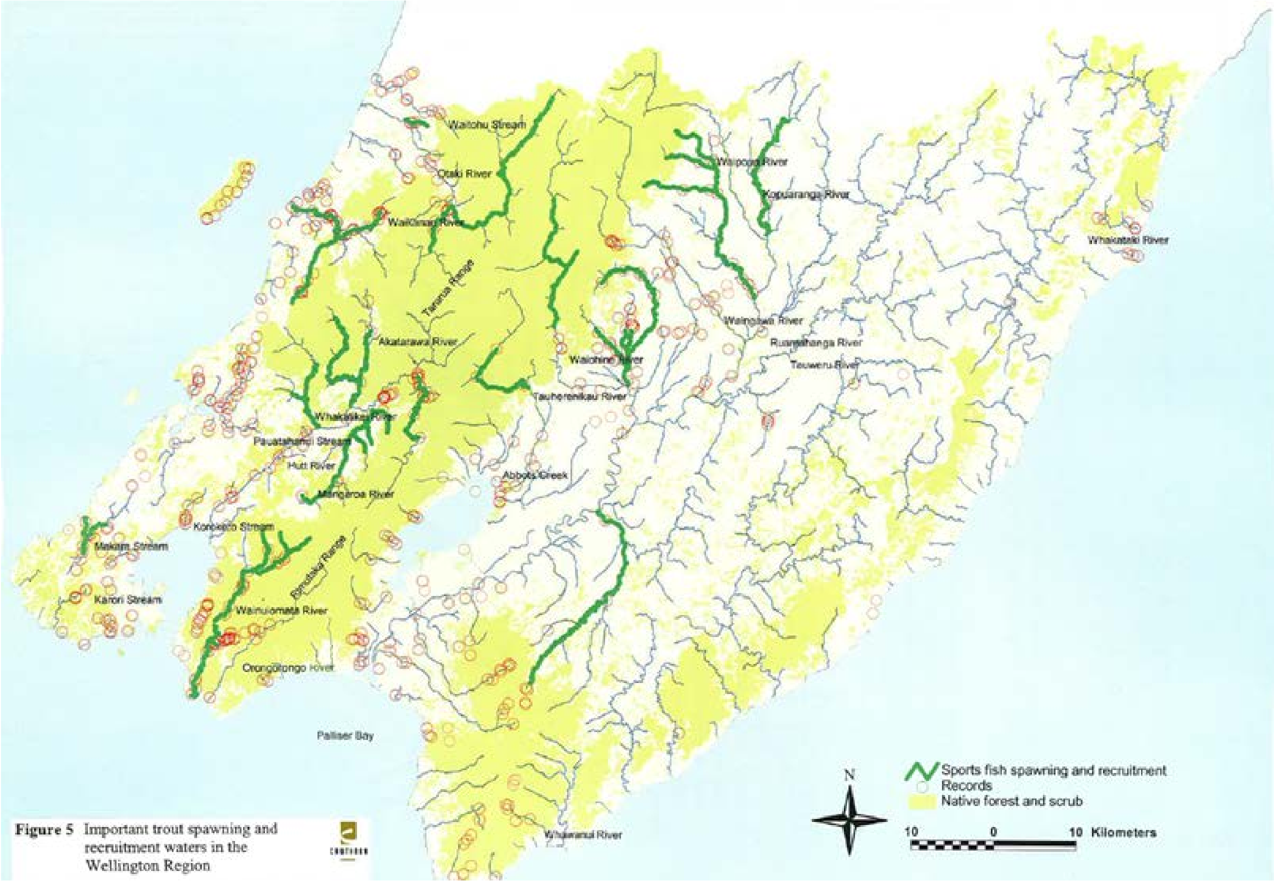


Figure 5 Important trout spawning and recruitment waters in the Wellington Region