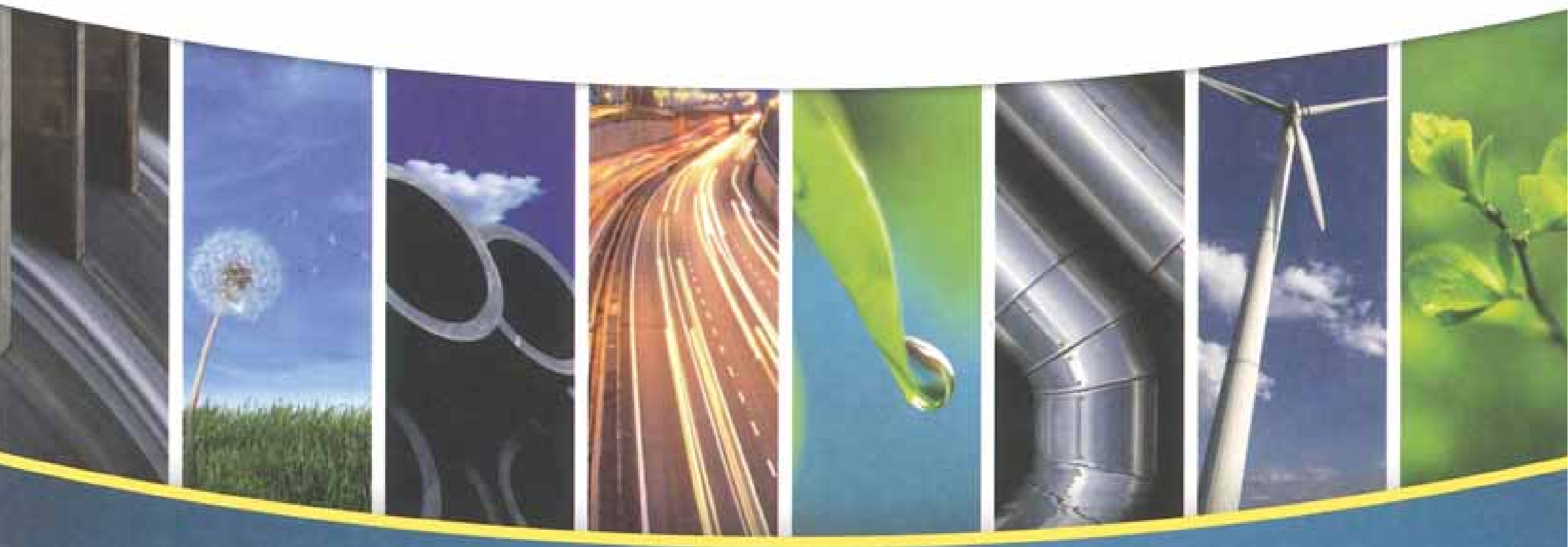
Effects of Flood Protection Activities on Aquatic and Riparian Ecology in the Hutt River

Prepared for Greater Wellington Regional Council (Flood Protection)

December 2016



MWH

QUALITY STATEMENT

PROJECT MANAGER	PROJECT TECHNICAL LEAD
Tom Kerr	David Cameron

PREPARED BY		
David Cameron		20/12/2016
CHECKED BY		
Kristy Hall		
REVIEWED BY		
Pip Lee (Independent Consultant)		
APPROVED FOR ISSUE BY		
Laurie Gardiner		

WELLINGTON
Level 13, 80 The Terrace, Wellington 6011
PO Box 9624, Te Aro, Wellington 6141
TEL +64 4 381 6700, FAX +64 4 473 1982

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 Hutt River system ("the application area"):

- a 28km length of the Hutt River, from Gillespies Road at Birchville to the Estuary Bridge at Petone;
- the end reach of the Akatarawa River, from 100m upstream of the Hutt River confluence to the confluence;
- the lower 1600m of Stokes Valley Stream, from its confluence with Tui Glen Stream to its confluence with the Hutt River;
- Te Mome Stream, from Bracken Street to the Hutt River confluence at Waione Street, and
- the lower 100m of Speedy's Stream from the SH2 culvert upstream to just beyond the Speedy's Stream debris arrestor.

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 recommendations of this report have been taken into consideration in the development of the Code and EMP.

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. These recommendations have formed the basis for the monitoring proposed in GWRC's EMP.

The Hutt River begins under indigenous forest in the Tararua Ranges and then flows out into the pastoral and urban areas of the Hutt Valley, which contains the application area. The Hutt River and tributaries within the application area support a diverse fish fauna including the threatened (Nationally Vulnerable) lamprey and seven species considered to be at risk (Declining). Brown trout are found throughout the river system and constitute a valued trout fishery. The river system also supports two small breeding populations of the shorebird pied stilt considered to be at risk (Declining) as well as two small colonies 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 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. However a more recent study conducted in the Hutt River at Belmont

shows that bed disturbance over a 200m to 250m 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 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 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 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.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

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 a 28km length of the Hutt River, from Birchville to the Estuary Bridge at Petone. The end reaches of the Akatarawa River (lower 100m) and Stokes Valley Stream (lower 1600m), as well as Te Mome Stream and the riverbed and banks at the debris arrester on Speedy's Stream are also included in the applications. These reaches, shown on Figure 1-1 as a blue line, are referred to in this report as the Hutt River "application area". Consent is sought for 35 years.

The new consents are intended to replace existing consents that currently allow for flood protection activities on these watercourses within the area forming the Hutt River flood protection scheme area. 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) (GWRC, working draft 2015), which is intended to monitor and guide how all flood protection and erosion controls are undertaken. The recommendations of this report have been taken into consideration in the development of the Code and EMP.

.

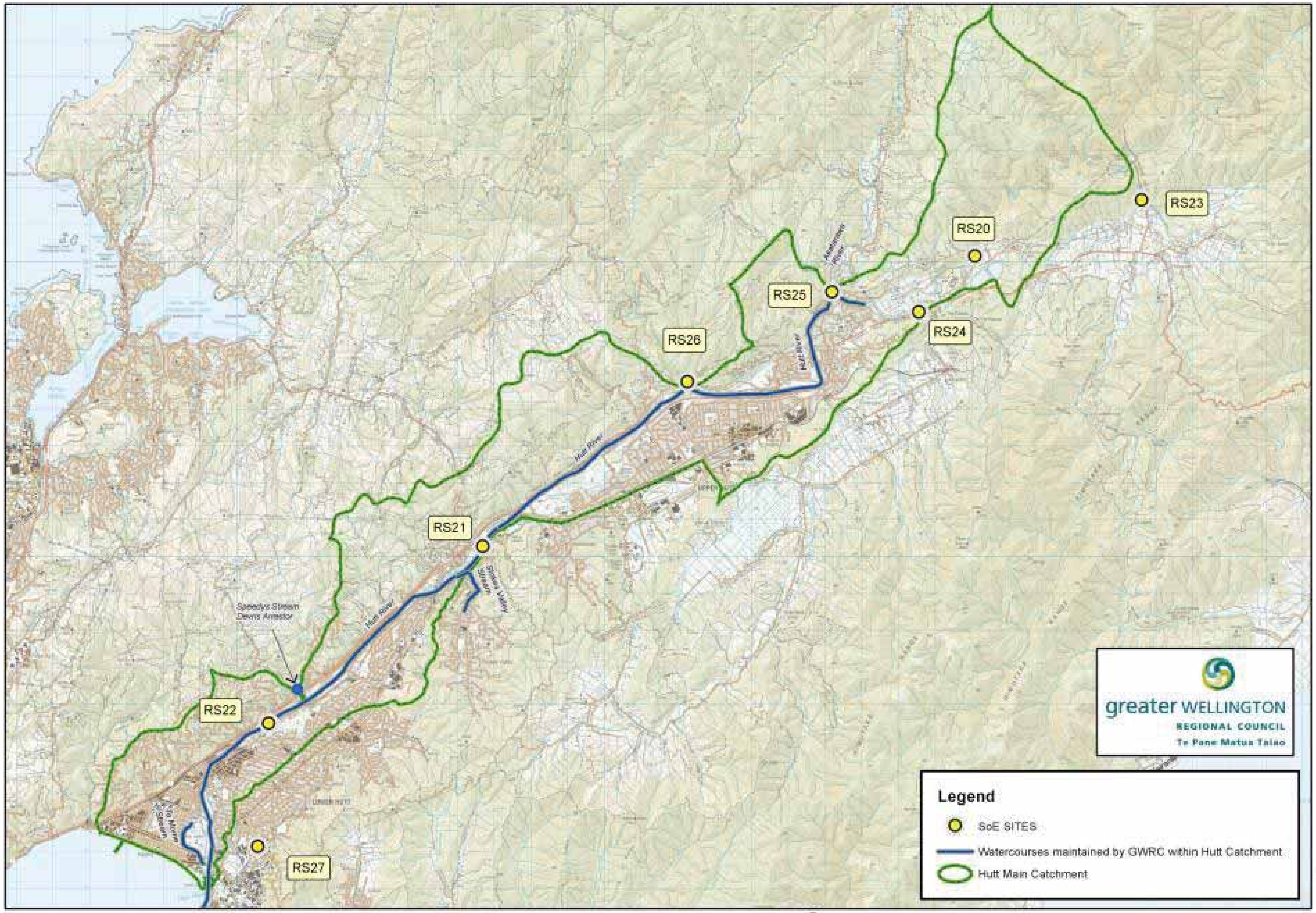


Figure 1 - 1 : HUTT MAIN CATCHMENT
Indicating SoE Sites & Watercourses Maintained by GWRC

File ref : Hutt Catchment.mxd

2 Information Sources

Information on the water quality and biology of the Hutt River system 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*
Cameron (2015)	Habitat quality, periphyton and macroinvertebrates	5 sites on the Hutt River from Kaitoke Weir to Birchville	GWRC river low flow annual monitoring for water take consents, 2014/15
Cameron (2015)	Habitat quality, water quality and fish	3 sites on the Hutt River	Before-After-Upstream-Control assessment of FP channel re-alignment works
Cameron (2015)	Habitat quality, periphyton and macroinvertebrates	3 sites on the Hutt River at Te Marua	Wellington Water, Te Marua Water Treatment Plant, annual monitoring.
Cameron (2015)	Habitat quality	Te Mome Stream, Speedy's Stream and Stokes Valley Stream	Site walkover, July 2015
Death & Death (2013)	Habitat quality, deposited sediment, periphyton macroinvertebrates and fish	3 sites on 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 Hutt River application area	Database accessed August 2015 + Trent Bell, unpublished data
Fish & Game drift dive data	Trout	14 sites on Hutt River	Drift dive data 1999 to 2014
Leathwick *et al* 2010	Freshwater Ecosystems of New Zealand (FENZ) Geodatabase	River of New Zealand	Predicted invertebrate and fish distributions
GWRC data	GWRC water quality, periphyton, macroinvertebrates, landcover, land use	Eight SOE sites on the Hutt River system	January 2004 to March 2015
GWRC maps	Application area, GWRC assets, RSoE sites, inanga spawning areas, riparian vegetation	Entire application area	
New Zealand Freshwater Fish Database (NZFFD)	Fish	30 sites within and upstream of the application area	Data 1960 to 2015
NIWA NRWQN sites	Invertebrates	Hutt River sites at Kaitoke and Boulcott	1999 to 2006
McArthur, Payle and Govella (2013)	Birds	Otaki, Waikanae and Hutt Rivers	Surveys between October and December 2012
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
McArthur and Lawson (2013)	Birds	Review of sites with significance for rare or threatened 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	Eight SOE sites on the Hutt River system	Monthly data from July 2008 to June 2014.
Perrie (2009, unpublished draft)	Habitat quality, periphyton macroinvertebrates and fish	4 sites on the Waingawa River	Before-After-Upstream-Control assessment of FP activities (instream)
Perrie (2013); Cameron (2013)	Habitat quality, macroinvertebrates and fish	3 sites on the Hutt River at the Harcourt-Werry beaches	Before-After assessment of FP gravel extraction works

3 Description of Existing Environment

GWRC undertakes flood protection operations and maintenance activities on the Hutt River from Birchville to the Estuary Bridge at Petone, a river length of 28km. It also actively manages the end reaches of the Akatarawa River (lower 100m) and Stokes Valley Stream (lower 1600m), as well as Te Mome Stream (1300m) and the riverbed and banks at the debris arrestor on Speedy's Stream (Figure 1-1). The Council also maintains the outlet of Opahu Stream, a tidally influenced arm of the Hutt River opposite Sladden Park, which is separated from the main river stem by a long training bank.

A detailed aerial view of the Hutt River application area is shown in GWRC Map Series HR-5407 (Maps 1a to 41a), attached as Appendix A. The aerial photographs were flown in 2013 and are drawn at an A3 scale of 1:2,500.

3.1 Freshwater habitats

3.1.1 Physical characteristics

3.1.1.1 Hutt and Akatarawa Rivers

The Hutt River is a steep gravel-bearing river which originates in the indigenous forest covered slopes of the southern Tararua Ranges and flows some 50 km to Wellington Harbour at Seaview. It has a catchment area of 655 km^2 and median flow of approximately 12.6 m^3/sec at Birchville. It's main tributaries are the Pakuratahi, Mangaroa, Akatarawa and Whakatiki Rivers. The bed gradient reduces at Kennedy Good Bridge, and again at the Ewen Bridge as the river approaches Wellington Harbour. The gravel bed load material drops out along this reach, from about Belmont, and in the Harbour adjacent to the river mouth.

The present condition of the Hutt River within the Upper Hutt and Lower Hutt basins of the valley is very different from what it was prior to European settlement. Early surveys of 1852 and 1867 show large meandering loops and split channels in the basins, and a substantial estuary at the river mouth, with three main channels entering the estuary. These channels would have been relatively shallow and mobile, with floodwaters spreading out over the lower basin (Williams, 2013).

The Hutt Valley has been uplifted by earthquakes around 1420 and in 1855 which have raised the valley, causing the river to degrade into the alluvial material and become more entrenched. Over time the river channel has been progressively straightened and confined, with the extraction of gravel bed material being used to define and confine the river. The river has thus become substantially entrenched into the alluvial materials of the two basins (Williams, 2013).

The Akatarawa River flows into the Hutt River at Birchville near Upper Hutt. It is situated on the northern part of the Hutt Catchment, between the Whakatikei and Waikanae catchments. It drains a steep and predominantly indigenous forest catchment of approximately 116 km^2, and includes some pine plantation forestry in the lower catchment. Of the four Hutt River tributaries within the application area, the Akatarawa River is by far the largest; however only the lower 100m reach of the river is located within the application area. To date the only flood protection activities undertaken in the Akatarawa River have been limited to the immediate vicinity of the confluence with the Hutt River. The extent of the application area within the Akatarawa River is shown in Figure 3-1 to 3-3.

The application area on the Akatarawa River lies within an incised gorge with steep banks flanked by mature indigenous vegetation. The riverbed substrate consists mostly of boulders, cobble and coarse gravels, and contains very little fine sediment. The bed includes a variety of hydraulic components including deep pools, rapids, riffles, fast runs and slow runs which provide an abundance of good quality habitat for invertebrates and fish. The GWRC habitat rating for state of the environment river monitoring site (RSoE) Site RS25, located within this reach, indicates excellent instream conditions (Table 3-2).

In addition to the Akatarawa River monitoring site noted above, GWRC maintains seven other state of the environment river monitoring sites in the Hutt catchment, three of which are on the main-stem of the Hutt River (Figure 1-1). The upper-most site at Te Marua (RS20) is located upstream of the application area while the middle and lower Hutt sites and the Akatarawa site (RS21, RS22 & RS25) are located within the application area. Details of river characteristics at the RSoE sites within and upstream of the application area are included in Table 3-1. GWRC habitat assessments scores are presented in Table 3-2.

Hutt River at Te Marua is slightly negatively impacted as a result of nearly 6% of its upstream catchment land-use being in production pasture. The Hutt River application area, having its upstream extent at the northern urban edge of Upper Hutt, is affected by a variety of land-uses including the large urban area extending throughout the Hutt Valley and the state highway adjacent to the river, as well as significant areas of low and high producing pasture. The Akatarawa site RS25, located within the application area, has retained excellent habitat quality.

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

Site no.	*Site name*	*Site type*	*Habitat grade*	*Indigenous forest and scrub (%)*	*Exotic forest (%)*	*Pasture (high prod.) (%)*	*Pasture (low prod.) (%)*	*Urban (%)*	*Other (%)*
RS20	Hutt R. at Te Marua intake	Impacted	good	90.9	3.1	3.9	1.9	0.1	0.2
RS21	Hutt R. at Manor Park G.C.	Impacted	fair	72.6	11.7	5.0	6.3	4.2	0.3
RS22	Hutt R. at Boulcott	Impacted	good	70.7	11.0	4.7	7.3	6.1	0.3
RS25	Akatarawa R. @Hutt R. con.	Impacted	Excellent	83.5	14.1	0.8	1.4	0.0	0.2

Note: sites within the area potentially affected GWRC flood protection activities (the application area) are shaded grey.

Table 3-2: Habitat scores for SOE sites assessed in summer/autumn 2014 (from Heath, Perrie, & Morar, 2014)

Site no.	*Site name*	*Fine sediment*	*Inverte-brate habitat*	*Fish cover*	*Hydraulic hetergen -eity*	*Bank stability*	*Bank vege-tation*	*Riparian buffer*	*Riparian shade*	*Channel alteratio n*	*Total habitat score*
RS20	Hutt R. at Te Marua	20	38	32	18	13.5	13.5	18	12	20	185
RS21	Hutt R. at Manor Park	10	24	24	11	11.5	9	16	7	1	113.5
RS22	Hutt R. at Boulcott	15	16	26	11	13	11	14	9	1	116
RS25	Akatarawa R. @Hutt R.	20	40	34	20	16	17	19	17	20	207

Figure 3-1: View of the lower reach of Akatarawa River at its confluence with the Hutt River

Figure 3-2: View of the lower Akatarawa River, looking upstream from Bridge Road.

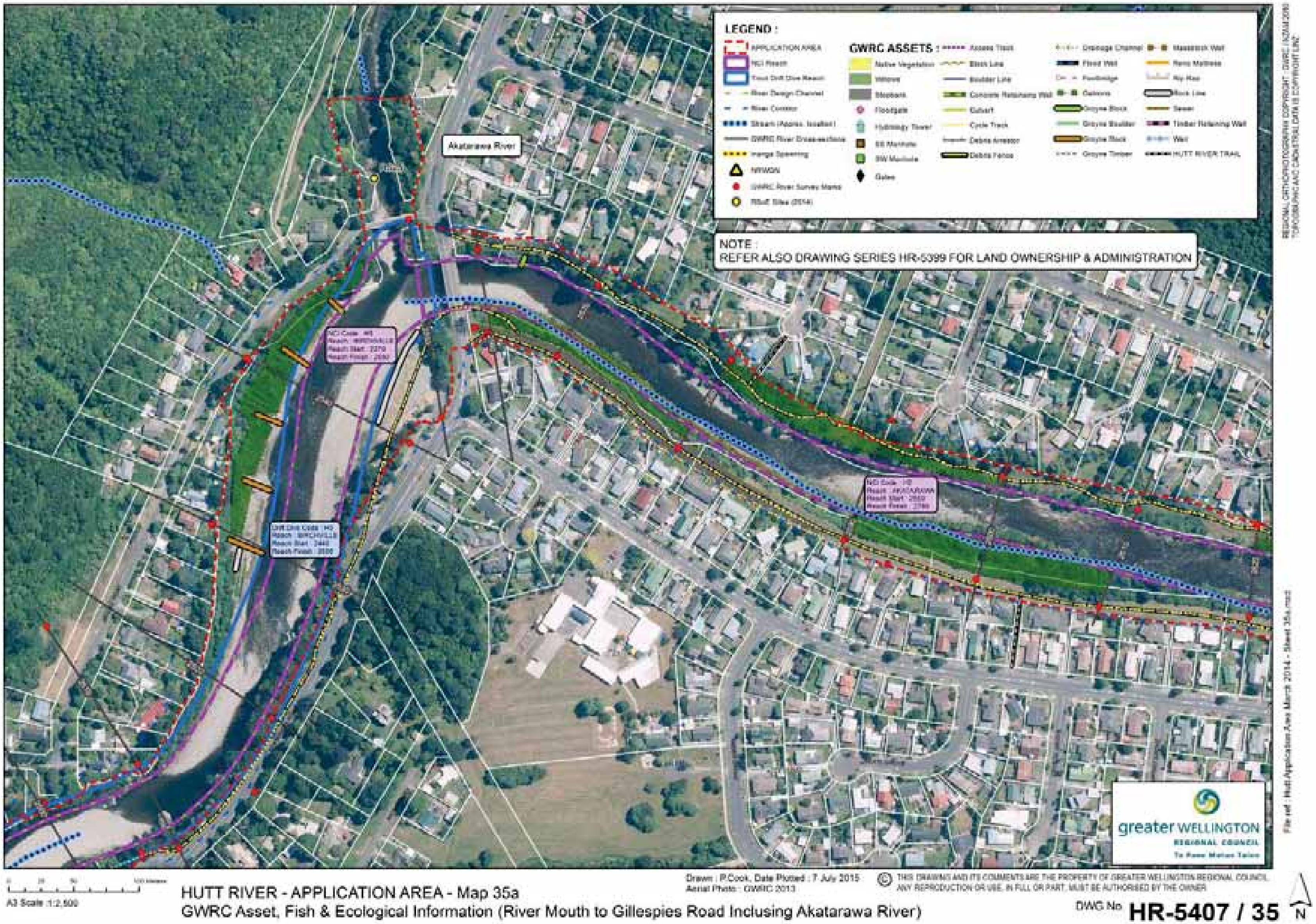


Figure 3-3: Map of application area at the confluence of the Hutt and Akatarawa Rivers

3.1.1.2 Stokes Valley Stream

Stokes Valley Stream begins as a relatively natural watercourse in regenerating bush in the upper valley but once it enters the valley floor it becomes channelised, straightened and is enclosed by culverts at a number of locations, including the reach passing under the Stokes Valley Shopping centre. The stream re-surfaces downstream of the shopping centre at Bowers Street but is contained within a concrete lined channel (Figure 3-4). The Tui Glen tributary stream, also contained within a concrete lined channel, joins Stokes Valley Stream approximately 700m downstream of Bowers Street, the confluence marking the upper extent of the application area. The stream runs a further 300m through the concrete channel to a stilling basin at the Stokes Valley Road Bridge (Figure 3-5). Beyond Stokes Valley Road the stream bed substrate takes on a more natural character of cobbles, gravels and fine sediment (Figure 3-6). It retains, however, a straightened ‘engineered’ channel with sloping grassed banks throughout the lower reach to its confluence with the Hutt River (Figure 3-7 and 8-8). The extent of the application area in the Stream is shown in Figure 3-9.

The results of a habitat assessment conducted in the reach downstream of Stokes Valley Road during July 2015, summarised in Table 3-3 and 3-4, show that the stream is in a degraded condition due to extensive urbanisation of its catchment causing loss of forest cover, modifications to its channel and removal to riparian vegetation, loss of shade and cover over the streambed, loss of connectivity to the flood plain, loss of hydraulic complexity and loss of woody inputs to the stream. These factors contribute to a low abundance and diversity of habitat for invertebrates and fish.

Figure 3-4: View of Stokes Valley Stream downstream of Bowers Street, 700m upstream of the application area

Figure 3-5: View of concrete lined channel and stilling basin at Stokes Valley Road, within the application area

Figure 3-6: View of modified straightened stream channel downstream of Stokes Valley Road, within the application area

Figure 3-7: Lower Stokes Valley Stream beside the Hutt River stop bank, within the application area

Figure 3-8: Confluence of Stokes Valley Stream and the Hutt River, within the application area

Table 3-3: Stream channel characteristics of tributary streams in the application area (MWH, 4/7/15)

Habitat Parameter	*Sampling Site*		
	Te Mome Stream	*Speedy's Stream*	*Stokes Valley Stream*
Location	Jackson Street	DS debris arrestor	Thomas Street
NZTM Ref	E1758934; N5433903	E1761627; N5438426	E1766410; N5441398
Time sampled	12:00am	9:50am	11:00am
Mean wetted width (m)	30	3.9	3.0
Mean thalweg depth (m)	1.0	0.31	0.40
%fine sediment cover	50	20	40
Dominant substrate	gravel/sand/silt	cobble/gravel/sand	gravel/sand/silt
Water temperature (^oC)	7.57	4.9	7.42
Electrical conductivity (mS/cm)	4668	100	97
pH	6.74	6.79	6.75
DO (%sat)	109	105	105
DO (mg/L)	12.78	13.46	12.68
Periphyton %cover			
Filamentous >2cm long	<5	<5	<5
Cyanobacteria >1mm thick	<5	<5	<5
All mats >3mm thick	30	<5	40
Macrophytes %cover Dominant taxa	5; *Carex, sp.* *Juncus* sp. Raupo	0	5; *Persicaria hydropiper*, *Glyceria maxima* *Mimulus guttatus*

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

Habitat parameter	*Sampling Site*		
	Te Mome Stream	*Speedy's Stream*	*Stokes Valley Stream*
Deposited sediment	3	6	4
Invertebrate habitat diversity	3	7	3
Invertebrate habitat abundance	3	7	3
Fish cover diversity	5	6	3
Fish cover abundance	5	5	2
Hydraulic heterogeneity	3	6	3
Bank erosion	9	7	7
Bank vegetation	4	7	1
Riparian width	4	9	1
Riparian shade	2	8	3
Habitat quality score (of 100)	41	70	30

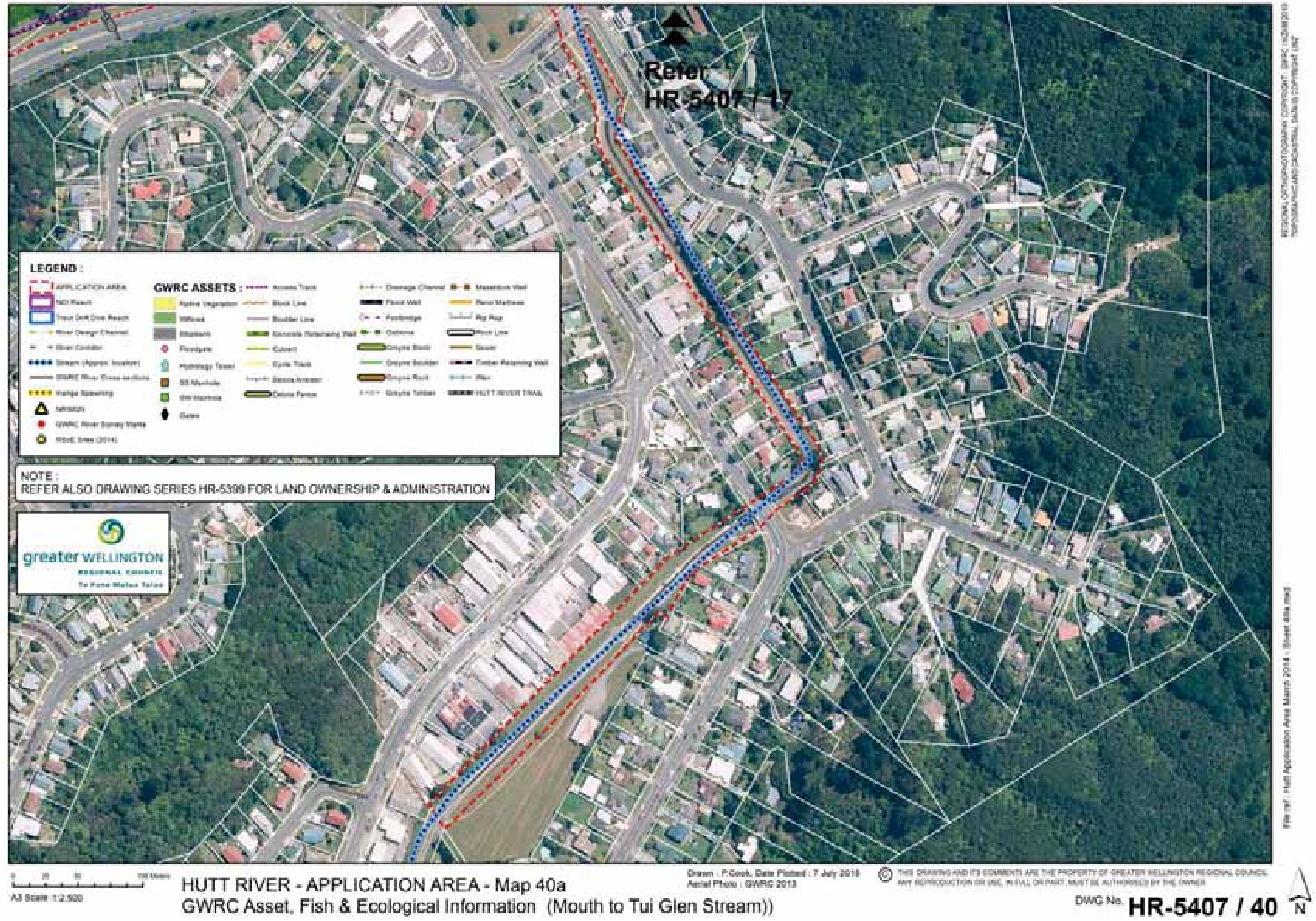


Figure 3-9: Map of application area within Stokes Valley Stream, from the Hutt River confluence to Tui Glen Stream

3.1.1.3 Speedy's Stream

Speedy's Stream drains a small steep forested catchment on the western side of the Hutt River valley adjacent to the suburb of Kelson, and joins the Hutt River on its true right bank immediately downstream of the Kennedy Good Bridge. The watercourse is well entrenched into the greywacke base rock, and confined at the bottom of steep sided valleys. The flood protection scheme reach has been modified and enclosed by road culverts, but upstream of SH2 the stream retains most of its natural character, supporting significant areas of regenerating native vegetation on both banks (Figure 3-10).

The riverbed substrate consists mostly of cobbles and coarse gravels, and occasional boulders, including introduced rock for bank protection (Figure 3-11). The bed contains little fine sediment and includes a variety of hydraulic components including small pools, riffles, runs and matted roots, which provide some good quality habitat for invertebrates and fish.

A rapid habitat assessment scored this reach 70/100, indicating good instream conditions and reflecting the relatively low level of channel modification (Table 3-4). However, the culvert under SH2 is likely a barrier to the upstream migration of fish species such as inanga and smelt, which are weak swimmers and have no climbing ability, and to trout which require a greater depth of water than is available in the culvert.

GWRC maintains the bed and banks around the Speedy's Stream Debris Arrester (Figure 3-12 and 3-13).

Figure 3-10: View of Speedy's Stream downstream of the debris arrester

Figure 3-11: View of the bed substrate in Speedy's Stream

Figure 3-12: View of the debris arrester on Speedy's Stream

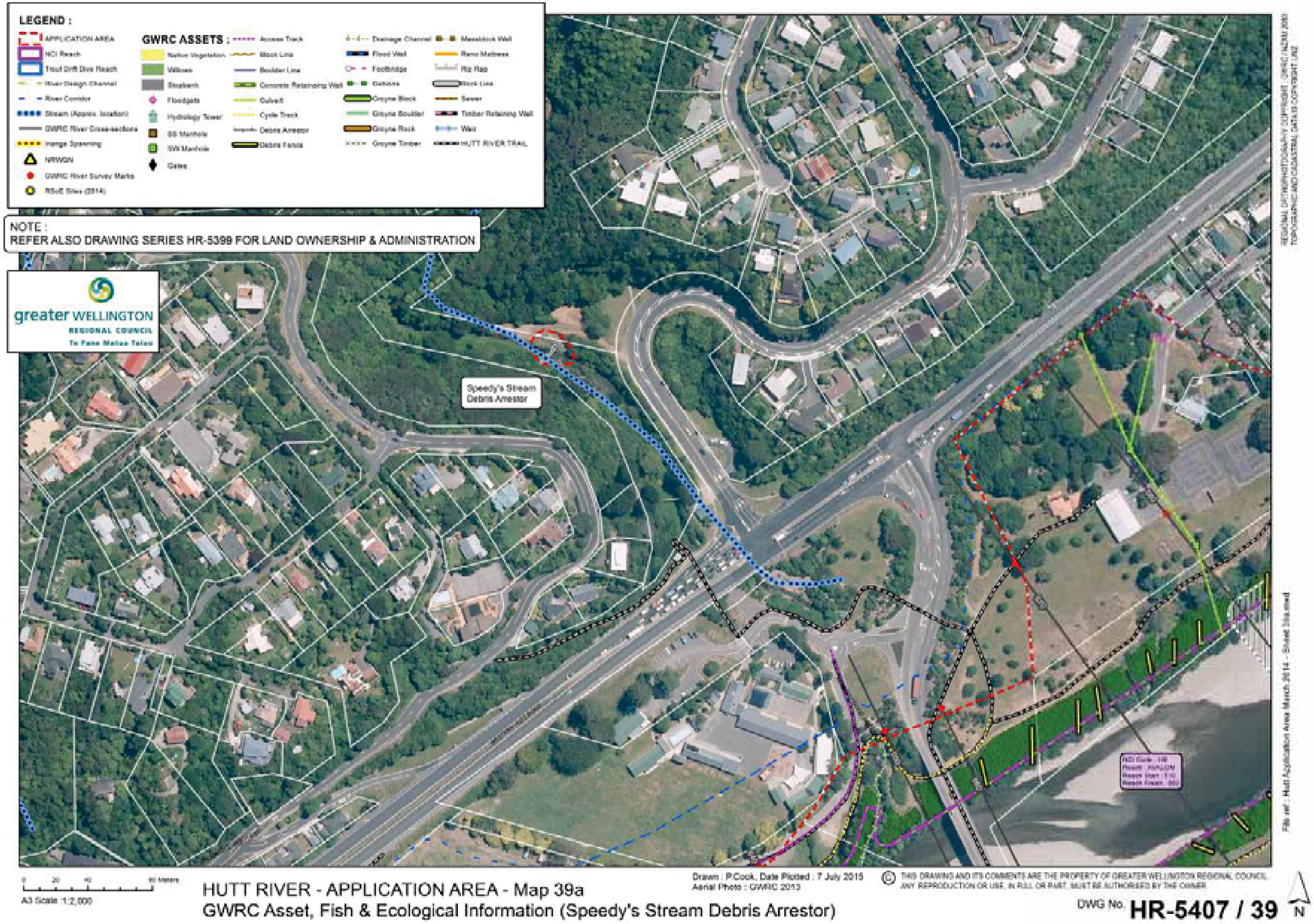


Figure 3-13: Map of application area within Speedy's Stream, showing location of debris arrester

3.1.1.4 Te Mome Stream

Te Mome Stream is a tidally influenced former channel of the Hutt River which runs around the Shandon Golf Club to join the Hutt Estuary via a flood-gated culvert under Waione Street, approximately 100m west of the Estuary Bridge (Figure 3-14). The hydrology of the watercourse was radically altered in the early 1900's when its northern connection to the Hutt River was blocked off. The stream is 1.5km long, up to 40m wide and 1.5m deep, with a tidal range of about 0.5m (Figure 3-15 and 3-16).

The surrounding catchment includes the suburbs of Ava, Petone and Alicetown, which contribute urban stormwater including runoff from industrial sites. Stormwater and historic industrial discharges have resulted in heavy metal contamination of stream sediments, similar to those found in Waiwhetu Stream (Figure 3-16). As a consequence the Environment Ministry and GWRC have identified Te Mome Stream as a priority site for remediation.

The main flood protection activities undertaken are occasional dredging to remove silt and tidal debris, including removal of debris from around the flood gate to ensure their efficient operation.

Figure 3-14: Waione Street culvert which connects the Te Mome Stream to the Hutt River

Figure 3-15: The tidal reach of Te Mome Stream beside Shandon Golf Club

Figure 3-16: One of many stormwater outlets discharging to Te Mome Stream

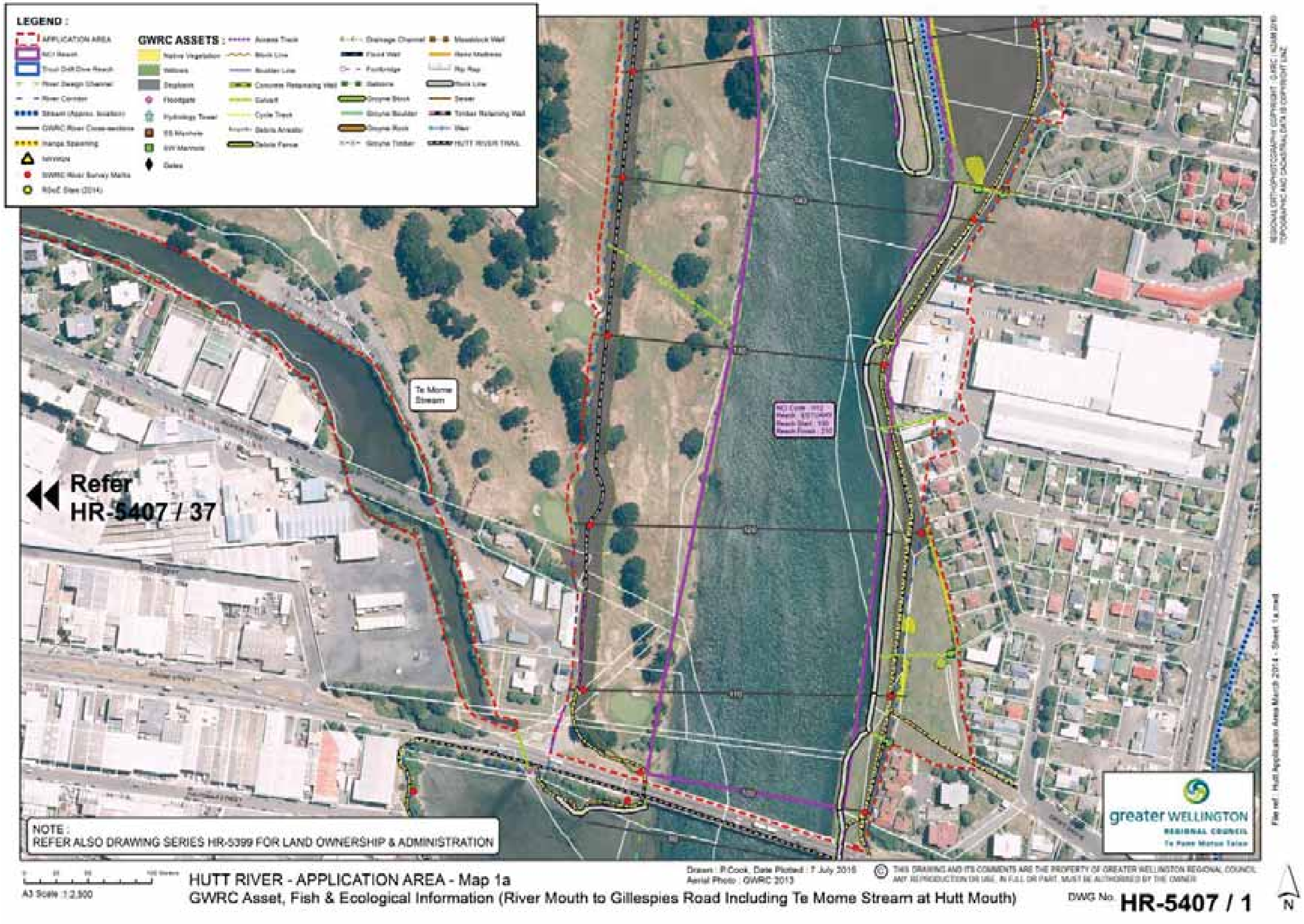


Figure 3-17: Map of application area within Te Mome Stream

3.1.2 Water Quality

3.1.2.1 Hutt and Akatarawa Rivers

Surface water quality is routinely monitored by GWRC at three RSoE sites on the main-stem of the Hutt River and one on the Akatarawa River (Figure 1-1). The upper-most site at Te Marua (RS20) is located upstream of the application area while the middle and lower Hutt sites and the Akatarawa site (RS21, RS22 & RS25) are located within the application area.

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, Perrie, & Morar, 2014) graded the Hutt River sites at Te Marua as "good", while Manor Park and Boulcott were both rated as having "fair" water quality. All three sites had less than optimal visual clarity while the Manor Park and Boulcott sites also had elevated *E. coli* values. These sites were ranked 22nd, 28th, and 26th, respectively, of the 55 RSoE sites monitored in the Wellington Region. The low water clarity recorded during much of 2014 is attributed to a major slip in the Hutt River headwaters upstream of the Kaitoke Weir (John Duggan, Wellington Water, pers. com.). There has been evidence from time to time that flood protection activities may occasionally contribute to reduced water clarity (i.e., Perrie *et al* 2012). It is noted also that water quality within the application area is influenced by multiple factors associated with a variety land-uses. The Akatarawa River near the Hutt River confluence was rated as "Excellent" and was ranked 10th out of 55 RSoE sites. Of the other major tributaries to the Hutt included in the RSoE programme, the Whakatikei River (RS26) was rated as having "excellent" water quality, while the Pakuratahi (RS23) and the Mangaroa (RS24) rivers were "fair".

Median 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 or low flows. TSS and turbidity values are typically lower and visual water clarity correspondingly higher in low flow conditions.

Results of selected variables at sites RS20 and RS22 are summarised by annual boxplot for the years 2004 to 2015 to show trends over time (Appendix C). The data indicate that dissolved nitrogen and phosphorus concentrations declined in the earlier part of that period at both sites, however, Perrie *et al* (2012) noted that a change in the analytical laboratory early in 2006 resulted in a 'step change' in some water quality variables, confounding trend assessments. The trend analysis reported by Perrie *et al* (2012) was therefore restricted to the five year period from July 2006 to June 2011. Over that period the following statistically significant changes were detected: total phosphorus declined in the Hutt River at RS20, total nitrogen declined at RS25, and *E.coli* declined at both RS22 and RS25. Perrie *et al* (2012) also reported a significant increase in dissolved reactive phosphorus at the National River Water Quality Network (NRWQN) site at Kaitoke (an upstream reference site) over that period.

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 an upstream reference sites (unshaded) from monthly samples collected from July 2013 to June 2014 (Heath, Perrie, & Morar, 2014)

Site	Site name	Water quality grade	Rank (of 55)	Guideline compliance (median values)					
				DO	Clarity	E. coli	NNN	Amm. N	DRP
RS20	Hutt R. at Te Marua intake	Good	22	✓	✗	✓	✓	✓	✓
RS21	Hutt R. at Manor Park G.C.	Fair	28	✓	✗	✗	✓	✓	✓
RS22	Hutt R. at Boulcott	Fair	26	✓	✗	✗	✓	✓	✓
RS25	Akatarawa R. @Hutt R. con.	Excellent	10	✓	✓	✓	✓	✓	✓

Table 3-7: Summary of water quality data at Hutt River and Akatarawa River sites sampled monthly between Jan 2010 and March 2015 (n=63). Median values that did not meet a guideline are shown in bold font (GWRC data). The Te Marua site is located upstream of the reach managed by GWRC (Flood Protection), while the other sites (shaded) are located within the managed reach.

Determinand	*Hutt River at Te Marua (RS20)*			*Hutt River at Manor Park (RS21)*			*Hutt River at Boulcott (RS22)*			*Akatarawa R at Hutt R confluence (RS25)*			*Guideline value**
	median	*min*	*max*	median	min	max	*median*	*min*	*max*	*median*	*min*	*max*	
Water temp. (°C)	11.1	7	17.35	13.8	8.5	21.4	14.2	8.27	21.52	11.6	6.8	17.49	≤19
DO (%saturation)	101	92	110	105	96	127	103	96	126	102	95	114	≥80
pH	7.27	6.51	7.79	7.29	6.58	8.51	7.26	6.57	8.23	7.33	6.65	7.87	6.5-9.0
Visual clarity (m)	3.23	0.31	7.73	1.75	0.05	6.83	1.59	0.04	7.5	3.66	0.07	7.97	≥1.6
Turbidity (NTU)	0.8	0.3	23	1.8	0.3	220	2.1	0.3	230	0.6	0.2	191	≤5.6
Suspended solids (mg/L)	<1	<1	33	<1	<1	440	<1	<1	470	<1	<1	370	--
Conductivity (µS/cm)	70	46	87	97	71	136	91	67	116	84	54	102	--
TOC (mg/L)	2.4	0.8	11.4	2.7	0.3	16.2	2.7	0.8	9.8	1.8	0.8	13.9	--
NNN (mg/L)	0.074	0.026	0.167	0.191	0.050	0.890	0.172	0.044	0.560	0.079	0.001	0.620	≤0.444
Ammoniacal N (mg/L)	0.005	0.003	0.005	0.005	0.003	0.045	0.005	0.003	0.01	0.005	0.003	0.033	≤0.021
Total N (mg/L)	0.162	0.055	0.420	0.330	0.140	1.96	0.310	0.120	1.83	0.160	0.055	1.38	≤0.614
DRP (mg/L)	0.002	0.002	0.007	0.005	0.001	0.011	0.004	0.001	0.011	0.002	0.002	0.008	≤0.010
Total P (mg/L)	0.006	0.002	0.032	0.01	0.002	0.38	0.009	0.002	0.39	0.006	0.002	0.3	≤0.033
E. coli (cfu/100ml)	20	1	300	100	4	4000	80	10	3600	42	11	2600	≤550

*Guideline values are those used by GWRC as described in Perrie et al (2012).

Table 3-8: Median water quality values at Hutt River and Akatarawa River sites at times when river flow is less than median from monthly samples collected between 2004 and 2009 (n=31) provided by GWRC. The Te Marua site is located upstream of the reach managed by GWRC (Flood Protection), while the other sites (shaded) are located within the managed reach.

Determinand	*Hutt River at Te Marua (RS20)*	*Hutt River at Manor Park (RS21)*	*Hutt River at Boulcott (RS22)*	*Akatarawa R. at Hutt R confluence (RS25)*	*ANZECC guideline*
Water temp. (°C)	13.5	17.0	16.8	14.6	≤19
DO (%saturation)	101	106	105	99.9	≥80
pH	7.59	7.6	7.42	7.52	6.5-9.0
Visual clarity (m)	3.77	2.70	2.67	4.13	≥1.6
Turbidity (NTU)	0.43	0.72	0.92	0.48	≤5.6
Suspended solids (mg/L)	<1	<1	<1	<1	--
Conductivity (µS/cm)	76	100	95.6	85	--
TOC (mg/L)	3.8	1.6	1.8	1.6	--
NNN (mg/L)	0.101	0.212	0.199	0.054	≤0.444
Ammoniacal N (mg/L)	<0.005	<0.005	<0.005	<0.005	≤0.021
Total N (mg/L)	0.150	0.3	0.25	0.12	≤0.614
DRP (mg/L)	<0.005	0.006	<0.005	0.006	≤0.010
Total P (mg/L)	0.008	0.009	0.009	0.006	≤0.033
E. coli (cfu/100ml)	20	120	70	62	≤550

3.1.2.2 Tributary Streams

Te Mome, Speedy's and Stokes Valley streams are not included in the GWRC RSoE monitoring programme and consequently routine water quality data are not available for these watercourses. The results of field measurements of water temperature, pH conductivity and dissolved oxygen made during a habitat assessment in July 2015 are included in Table 3-3.

3.1.3 Periphyton

GWRC monitors periphyton cover and biomass at eight state of the environment river monitoring sites in the Hutt catchment, including three on the main-stem of the Hutt River and one on the Akatarawa River. 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 year to June 2010, 2011, 2012, 2013 and 2014 are summarised in Table 3-10. Monthly observations of filamentous and mat forming periphyton cover 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 (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 Hutt River at Te Marua (upstream of the application area) and the Akatarawa River site at the confluence complied with the MfE guidelines for periphyton cover and biomass on all sampling occasions. Over the same five year period the Hutt River at Manor Park exceeded the periphyton cover guidelines on one monthly sampling occasion, and twice exceeded the periphyton biomass guideline (in 2010 and 2012). The Hutt River at Boulcott exceeded the periphyton cover guidelines on two monthly sampling occasions, and twice exceeded the periphyton biomass guideline (in 2010 and 2012).

At both the Manor Park and Boulcott monitoring sites the periphyton cover is typically dominated by mat-forming cyanobacteria of the genus *Phormidium* which blooms annually along the middle and lower reach of the Hutt River. *Phormidium* is known to produce a number of neurotoxic compounds which have been linked to dog poisonings, including a number on the Hutt River. Heath *et al* (2012) found that *Phormidium* was present throughout the river during February 2012, but that mat coverage increased in a downstream direction, possibly in response to nutrient concentrations and ratios. The authors suggest that elevated nitrogen levels and phosphorus limitation may play critical roles in regulating *Phormidium* proliferations in the Hutt River. Water quality monitoring during flood protection works in the Hutt River in July 2015 shows that mechanical disturbance of the riverbed caused localised increases in total nitrogen and total phosphorus but did not influence the availability of dissolved nutrients, and is therefore unlikely to influence periphyton growth rates (refer Section 5.2)

Regular periphyton monitoring is not undertaken on the minor tributary streams, however the results of a bankside visual assessment undertaken as part of the habitat assessment are included in Table 3-3.

Table 3-10: Summary of streambed peripyton biomass at RSoE in the Hutt River application area (grey) and upstream (unshaded), from 2009 to 2014 (after Perrie *et al,* 2011; Perrie and Conwell, 2013; and 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*
RS20	Hutt River at Te Marua intake	0.9	0.4	35.97	3.52	0.48
RS21	Hutt River at Manor Park Golf Club	**59.8**	1.6	**189.58**	7.20	6.55
RS22	Hutt River at Boulcott	**119.3**	20.6	**208.88**	30.83	38.43
RS25	Akatarawa River at Hutt R. confluence	0.3	7.8	46.34	0.86	0.09

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 (grey) and upstream (unshaded) 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)	
				Max	n>30% cover	Max	n>60% cover
2010	RS20	Hutt River at Te Marua intake	8	0	0	0	0
	RS21	Hutt River at Manor Park Golf Club	10	7	0	58	0
	RS22	Hutt River at Boulcott	7	2	0	51	0
	RS25	Akatarawa River at Hutt R. confluence	11	0	0	0	0
2011	RS20	Hutt River at Te Marua intake	10	0	0	0	0
	RS21	Hutt River at Manor Park Golf Club	9	15.5	0	**88**	**1**
	RS22	Hutt River at Boulcott	8	8	0	**100**	**1**
	RS25	Akatarawa River at Hutt R. confluence	10	0	0	9	0
2012	RS20	Hutt River at Te Marua intake	11	0	0	12	0
	RS21	Hutt River at Manor Park Golf Club	11	20	0	38	0
	RS22	Hutt River at Boulcott	11	17	0	**82**	**1**
	RS25	Akatarawa River at Hutt R. confluence	11	0	0	21	0
2013	RS20	Hutt River at Te Marua intake	11	0	0	4	0
	RS21	Hutt River at Manor Park Golf Club	10	7	0	15	0
	RS22	Hutt River at Boulcott	8	**60**	**1**	52	0
	RS25	Akatarawa River at Hutt R. confluence	11	0	0	17	0
2014	RS20	Hutt River at Te Marua intake	4	0	0	0	0
	RS21	Hutt River at Manor Park Golf Club	3	1	0	0	0
	RS22	Hutt River at Boulcott	3	22	0	16	0
	RS25	Akatarawa River at Hutt R. confluence	10	8	0	8	0

3.1.4 Macrophytes

No nationally threatened aquatic or semi-aquatic plant species are known to be associated with the Hutt River (P. Crisp, GWRC, *pers. comm.*) Observations from bankside inspections of the Hutt River and tributary streams in July 2015 include the following:

- the Hutt River at Te Marua and Belmont was virtually free of aquatic marophytes (and being a fast flowing gravel bed river, macrophytes are not expected to be a significant feature of the river ecology);
- the Stokes Valley Stream supported a number of aquatic macrophytes at the stream margins, predominantly water pepper (*Persicaria hydropiper*), monkey musk (*Mimulus guttatus*) and read sweet grass (*Glyceria maxima*). While the majority of the channel was clear of aquatic plants, it is noted that this survey was undertaken in winter and that more extensive aquatic plant growth is likely during the spring and summer;
- Speedy's Stream in the vicinity of the debris arrester was virtually free of aquatic plants due to its stony cobble bed, steep gradient and extensive shade provided by regenerating indigenous vegetation at the riparian margin.
- Te Mome Stream adjacent to the Shandon Golf Course supported sedges (*Carex* sp.) rushes (Juncus sp.) and raupo (*Typha orientalis*) at the margins.

3.1.5 Riparian Vegetation

The Hutt River application area is bounded by the urban areas of Upper Hutt and Lower Hutt cities to the east and by State Highway 2 to the west. The development of these areas over the last 100 years has resulted in an almost complete removal of the original indigenous vegetation from the riparian margins, followed by establishment of grasses and planted willows. Of the total 56 km of bank length within the application area it is estimated that 32km (or 57%) has been planted in willows as vegetative bank protection. The riparian vegetation includes small isolated stands of remnant and planted indigenous species, but these are often set back behind a front line of willows.

Vegetation within the Hutt River riparian margins is shown in GWRC Map Series HR-5407 (Maps 1a to 41a), 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 Macroinvertebrate community

3.1.6.1 Hutt and Akatarawa Rivers

GWRC undertakes annual monitoring of macroinvertebrates at seven RSoE sites in the Hutt River catchment including three on the main stem of the Hutt River (Te Marua, Manor Park and Boulcott) and one on the Akatarawa River (i.e., Perrie *et al* 2012; Heath, *et al*, 2014). Results from the RSoE sites (February 2014) and from an upstream reference site (Cameron, 2015) are included in Appendix D and summarised in Table 3-12, together with predictions of invertebrate species distribution from the FENZ database (Freshwater Ecosystems of New Zealand, Leathwick *et al,* 2010). Macroinvertebrate composition by relative abundance is illustrated in Figure 3-18.

While the macroinvertebrate community is dominated by the mayfly *Deleatidium* at all five sites, there are changes in community composition as the river progresses downstream. Notably, the stonefly *Zelanderperla* sp. is common in the Hutt River at Kaitoke and Te Marua, uncommon at Manor Park, and rare in the River at Boulcott. Conversely the Orthoclad midges are rare in the upper reaches in the forested catchment but abundant at lower river sites where production pasture makes up more 10% of the catchment. These changes are reflected in Macroinvertebrate Community Index (MCI) and Quantitative Macroinvertebrate Community Index (QMCI) scores which indicate "excellent" quality classes at the Kaitoke and Te Marua sites and "good" quality class in the lower river at Manor Park and Boulcott (Table 3-13).

The downstream decline is largely explained by the transition from the indigenous forest cover of the upper river to the urban areas of the Hutt Valley and the increasing proportion of production pasture and urban land-use at the downstream sites. Perrie *et al* (2012) in a review of the macroinvertebrate data for the Wellington Region found that mean MCI scores were strongly positively correlated with indigenous forest cover and negatively correlated with the proportion of pastoral land-cover. The authors noted that stream health declines with increasing intensity of urban land use, and that as little as 10% impervious cover within a catchment can reduce stream health. Reducing altitude and gradient are also related a reduction in biotic index scores (i.e., Stark 2009).

3.1.6.2 Limitations of the data

All of the macroinvertebrate monitoring data assessed as part of this investigation has been collected from wadeable areas in riffle or fast-run habitat. That includes RSoE monitoring, monitoring required by GWRC/Wellington Water consents for water supply, and monitoring at the NRWQN sites on the Hutt River at Kaitoke and Boulcott. The reason for this is that standard protocols for sampling macroinvertebrate in New Zealand have focused on wadeable habitats in flowing water (ie, Stark, et al, 2001; Stark & Maxted, 2007). Sampling in deeper, swifter rivers (non-wadeable) requires alternative techniques, possibly including grab samplers, SCUBA and boats, and is seldom undertaken.

It is recognised that sedimentation effects are likely to be more pronounced in pools and slow runs and that the effects on the macroinvertebrate habitats of those habitats have not been assessed.

Similarly, we have not sighted any specific information on the macroinvertebrate fauna that live within the gravel substrate of the Hutt 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.

The conservation status of freshwater invertebrates in New Zealand has been assessed by Grainger, *et al* (2014). We note, however, that many of the invertebrate results available for the Hutt catchment do not include identification to species level and consequently their conservation status has not been determined.

Table 3-12: Hutt 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)*
Hutt River at Kaitoke Weir	Indigenous forest 100% Upstream of application area	*Deleatidium>Zelandoperla>Aoteapsyche>Olinga>Coloburiscus* *(Deleatidium>Aoteapsyche>Olinga>Beraeoptera>Coloburiscus>Zelandoperla)*
Hutt River at Te Marua (RS20)	Indigenous forest 90.9% Pasture 5.8% Urban 0.1% Upstream of application area	*Deleatidium>Zelandoperla>Aoteapsyche>Nesameletus>Olinga>Elmidae* *(Deleatidium>Aoteapsyche>Olinga>Beraeoptera>Coloburiscus>Zelandoperla)*
Hutt River at Manor Park (RS21)	Indigenous forest 72.6% Pasture 11.3% Urban 4.2% Within application area	*Deleatidium>Tanytarsini>Orthocladiinae>Aoteapsyche>Hydrobiosis>Olinga* *(Deleatidium>Aoteapsyche>Olinga>Aprophila>Hydrobiosis>Oligochaeta)*
Hutt River at Boulcott (RS22)	Indigenous forest 70.7% Pasture 12% Urban 6.1% Within application area	*Deleatidium>Orthocladiinae>Elmidae>Olinga* *(Deleatidium>Aoteapsyche>Olinga>Aprophila>Hydrobiosis>Oligochaeta)*
Akatarawa River (RS25)	Indigenous forest 83.5% Pasture 2.2% Urban 0% Within application area	*Deleatidium>Olinga>Aoteapsyche>Zelandoperla>Coloburiscus* *(Deleatidium>Aoteapsyche>Olinga>Beraeoptera>Coloburiscus>Zelandoperla)*

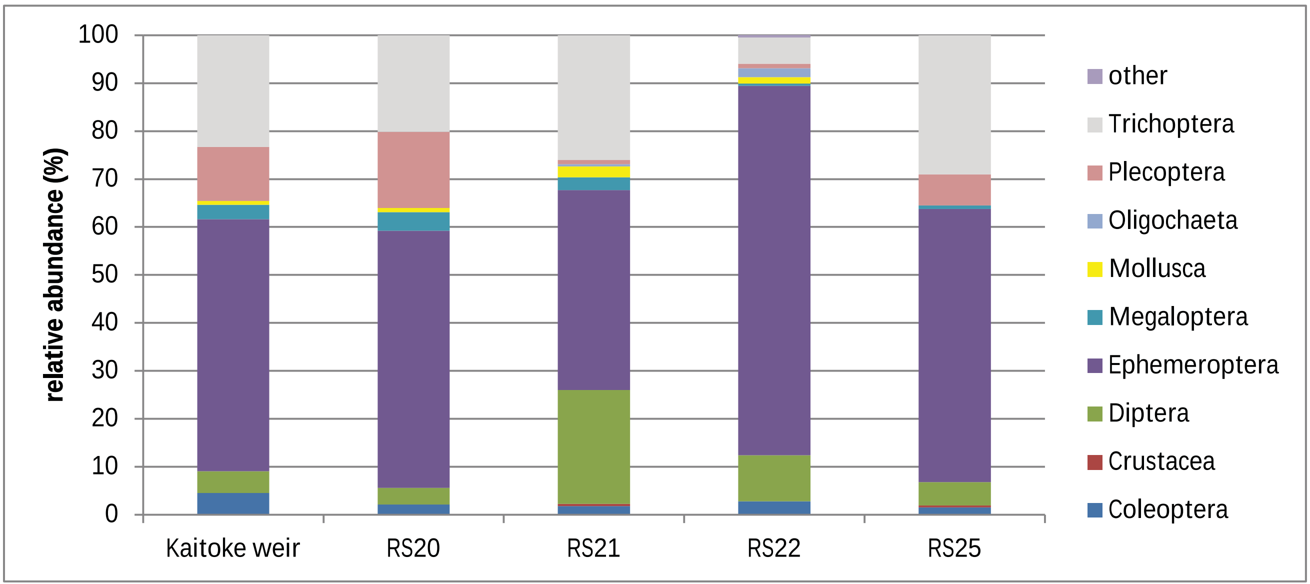


Figure 3-18: Macroinvertebrate community composition by relative abundance

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

Site no.	*Site name*	*MCI*	*QMCI*	*N. Taxa*	*%EPT indiv.*
Kaitoke	Hutt River above Kaitoke Weir[1]	140.6 (7.5) Excellent	8.00 (0.265) Excellent	16 (3)	86.7 (10.4)
RS20	Hutt River at Te Marua intake	134.5 (5.0) Excellent	8.03 (0.33) Excellent	25 (1.3)	91.3 (1.12)
RS21	Hutt River at Manor Park Golf Club[2]	119.1 (10.0) Good	5.62 (1.28) Good	23 (2.1)	55.1 (23.3)
RS22	Hutt River at Boulcott[2]	106.6 (6.9) Good	5.49 (1.47) Good	19 (3)	52.8 (24.9)
RS25	Akatarawa River at Hutt R. confluence[2]	129.9 (3.9) Excellent	7.19 (0.63) Excellent	26 (0.8)	79.5 (12.4)

Notes: [1]Kaitoke Weir data from GWRC (Cameron, 2015)
[2]Sites within the FP application area are shaded grey.

3.1.6.3 Comparison between the application area and upstream reaches

The Hutt River application area of the Hutt River begins at the sea and extends 28km through the urban areas of Petone, Lower Hutt City and Upper Hutt City, to an elevation 80m above sea level. The river upstream of the application area is by contrast relatively undeveloped, beginning at the outer urban edge of Upper Hutt, and passing beside the Te Marua Golf Course before entering the forested area of Kaitoke Regional Park in the foothills of the Tararua Range.

As described earlier, the longitudinal changes in macroinvertebrate community composition are largely explained by the transition from indigenous forest cover of the upper river to the urban areas of the Hutt Valley and the increasing proportion of production pasture and urban land-use at the downstream sites. A comparison of the invertebrate fauna of the application area and upstream reaches aimed at determining the effects of flood protection activities will be confounded by these underlying differences in macroinvertebrate habitat and would be meaningless 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.

3.1.6.4 Tributary Streams

Macroinvertebrate surveys have not been undertaken in the Te Mome Stream, Speedy's Stream or Stokes Valley Stream as part of this investigation. In the absence of monitoring data we have relied on FENZ predictions of macroinvertebrate species occurrence to describe the core community composition. The taxa with an occurrence probability>0.5 are listed in Table 3-14.

Table 3-14: FENZ predictions of macroinvertebrate species occurrence (Leathwick, *et al*, 2010)

Site name	Catchment land-use	FENZ predictions of species occurence (p>0.5)
Te Mome Stream	Urban	*Potamopyrgus>Deleatidium>Austrosimulium>Oligochaeta>Elmidae*
Speedy's Stream	Forest remnant/urban	*Deleatidium>Coloburiscus>Elmidae>Aoteapsyche>Olinga>Austrosimulium>Potamopyrgus*
Stokes Valley Stream	Urban	*Deleatidium>Elmidae>Austrosimulium>Orthocladiinae>Potamopyrgus>Aoteapsyche>Olinga*

3.1.7 Fish Communities

The New Zealand Freshwater Fish Database (NZFFD) was queried for records of sites sampled within the Hutt River catchment over the period 1960 to 2015 (93 records). This database was then reduced to sites within the Hutt River main-stem, the Akatarawa River, Stokes Valley Stream, Speedy's Stream, Opahu Stream and Te Mome Stream. In total 12 NZFFD sites are located within the application area and a further 18 sites are located on affected watercourses outside (upstream) of the application area. The tributary stream reaches included in the application area are relatively short stream lengths for which very limited fish data is available. The number of survey sites within and upstream of the application area is listed in Table 3-15.

Table 3-15: Number of NZFFD fish survey sites in each river sampled for freshwater fish (1960-2015)

Watercourse	Number of sites/records within application area	Number of sites/records upstream of application area	Sampling period
Hutt River	9	10	1962 to 2005
Akatarawa River	0	6	1968 to 2005
Stokes Valley Stream	1	2	1997 to 2004
Speedy's Stream	2	0	1961 to 1962
Opahu Stream	0	0	none
Te Mome Stream	0	0	none

3.1.7.1 Hutt River

Twelve species of fish have been recorded within the application area, including eleven native fish and the introduced brown trout (Table 3-16).

The distributions of key species are shown in Figure 3-19 to 3-25. One fish species recorded in the Hutt River, the lamprey, has a conservation status of threatened (Nationally Vulnerable) and seven species are considered to be at risk due to declining numbers nationally (Goodman, et al., 2014). The most commonly recorded fish species in the Hutt River application area are redfin bully (55% of survey sites), shortfin eel (44%), bluegill bully (44%) brown trout (44%) and longfin eel (33%). 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.

Targeted investigations of Hutt River habitats affected by flood protection activities have recently been undertaken by Perrie (2013) and Cameron (2015). The 2013 study is comprehensive, covering deep pools, deep runs, shallow runs and riffle habitats in a reach affected by gravel extraction (see Tables 3-14 and 3-15). The 2015 study was focused on wadeable habitat upstream, within and downstream of a zone affected by channel re-alignment (the full report is included in Appendix G). The fish species recorded in those surveys are consistent with those reported previously, indicating that the species list is reasonably complete. The results demonstrate the habitat preferences of key species in the Hutt River: common bully, koaro, smelt and small eels were more common in the shallower, slow flowing edges of riffle habitat, bluegill bully were mostly collected in the swifter sections of riffles while larger trout and eels were more likely to be recorded in deep pools.

Overall these results indicate a relatively diverse and abundant fish fauna in the Hutt River main-stem reaches within the application area, dominated by shortfin eel, longfin eel, bluegill bully, redfin bully, common bully and brown trout. Other species such as inanga, koaro and banded kokopu are likely to be seasonally abundant but not necessarily resident in these reaches.

Most of the indigenous fish species recorded in the catchment, except upland bully, Crans Bully, and 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 E and include the following:

- Peak periods of upstream migration of juvenile galaxiid species (whitebait), bluegill bully 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.
- Juvenile lampreys migrate upstream during winter, from June to September.

None of the introduced species have an obligatory migration phase. 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 many trout in the Hutt River system simply move from the main-stem to a headwater tributary to spawn 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 in any given 10km reach. Recommendations for the protection of indigenous fish are provided in Section 7.5.

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

- Inanga spawning habit is located in tidal estuary edge vegetation and occurs during March, April and May. Despite the general unsuitability of the Hutt River main-stem for inanga spawning, there are records of inanga spawning in areas in the tidal reach where bank armouring is absent (see Figure 3-35). These include observations near the Sladden Park boat ramp in Petone, at Te Mome Stream and Opahu Stream (Taylor & Kelly, 2001).
- Other galaxiid species including koaro, banded 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).
- 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 areas in the Hutt catchment include parts of the Mangaroa, Whakatikei, Akatarawa and Pakuratahi Rivers as well as other headwater streams (Strictland and Quarterman 2001). It is thought that the main-stem of the Hutt River within the reach managed by GWRC does not provide important trout spawning habitat due to the generally coarse nature of bed substrate (Appendix H). The lower 100m reach the Akatarawa River which may potentially include trout spawning habitat should therefore be left undisturbed during May, June and July if that habitat is to be protected. Further recommendations for the protection of trout spawning habitat are given in Section 7.5.

An assessment of the ecological effects of channel re-alignment in the Hutt River (Cameron, 2015) is included as Appendix G.

Table 3-16: Summary of the NZFFD records for the Hutt River as of June 2015 (n=93). FENZ predictions of occurrence inside and outside of the application area are also provided (see Leathwick, et al., 2010).

Scientific name	Common name	%Occurrence			Migratory species	Threat status (Goodman *et al* 2014)
		Recorded within application area (n=9)	Recorded outside application area (n=10)	Predicted within/ upstream (FENZ)		
Anguilla australis	Shortfin eel	44	0	100/10	yes	Not threatened
Anguilla dieffenbachii	Longfin eel	33	40	100/100	yes	At risk (declining)
Galaxias argenteus	Giant kokopu	22	0	30/0	yes	At risk (declining)
Galaxias brevipinnis	Koaro	22	30	10/30	yes	At risk (declining)
Galaxias divergens	Dwarf galaxias	0	30	10/10	no	At risk (declining)
Galaxias maculatus	Inanga	22	0	100/10	yes	At risk (declining)
Galaxias fasciatus	Banded kokopu	0	0	30/10	yes	Not threatened
Geotria australis	Lamprey	33	0	20/10	yes	Threatened (Nationally Vulnerable)
Gobiomorphus basalis	Crans bully	11	40	10/50	No	Not threatened
Gobiomorphus cotidianus	Common bully	11	0	100/20	yes	Not threatened
Gobiomorphus gobioides	Giant bully	11	0	40/0	yes	Not threatened
Gobiomorphus hubbsi	Bluegill bully	44	30	50/60	yes	At risk (declining)
Gobiomorphus huttoni	Redfin bully	55	80	100/100	yes	At risk (declining)
Retropinna retropinna	Common smelt	*	0	80/0	yes	Not threatened
Salmo trutta	Brown trout	44	70	50/90	yes	Introduced/naturalised

*Not listed in the NZFFD but recorded by Perrie (2013)

Table 3-17: Summary of fish survey results (number & size range; or present ✓) for two non-wadeable sites in the Hutt River within an area affected by flood protection activities (from Perrie 2013).

Species	Deep water - Site 1 (XS 770)		Deep water - Site 2 (XS 970)
	Fyke nets& minnow traps	*Spotlighting*	*Fyke nets & minnow traps*
Longfin eel	2 (450 to 550 mm)	✓	
Shortfin eel	11 (350 to 600 mm)		
Cran's bully	7	✓	
Common bully	16 (45 – 111 mm)	✓	10 (70 to 114 mm)
Giant bully	-		1 (175 mm)
Unidentified bully	8	✓	2
Inanga	28 (50 to 80 mm)		-
Koaro	1 (50 mm)	✓	2 (51 to 56 mm)
Whitebait (unidentified sp)	1 (47 mm)	✓	-
Brown trout		4 (400 to 500 mm)	2 (50 to 52 mm)
Shrimp	17	✓	16

Table 3-18: Species, abundance (n) and selected densities of fish and koura caught across Hutt River sites upstream, downstream and with a zone affected by gravel extraction, before, immediately after gravel extraction and seven weeks after gravel extraction (from Perrie 2013)

Species	Downstream (XS 590)			Impact (XS 740)			Upstream (XS 840)			Total (n)
	before	*immediately after*	*7 weeks after*	*before*	*immediately after*	*7 weeks after*	*before*	*immediately after*	*7 weeks after*	
Longfin eel	-	-	-	-	-	-	-	-	1	1
Shortfin eel	-	4	-	1	3	-	-	-	-	8
elver (unid.)	-	-	-	-	2	-	-	-	1	3
Bluegill bully	48	67	51	77	26	9	52	4	17	351
Redfin bully	5	2	-	-	11	1	1	1	-	21
Cran's bully	-	-	-	-	-	-	-	1	-	1
Common bully	-	1	-	-	-	-	1	-	-	2
Unidentified bully	-	-	5	-	-	3	3	1	3	15
Smelt	1	2	-	3	2	-	48	-	-	8
Koaro	89	6	-	41	2	-	48	-	-	186
Whitebait (unidentified sp)	-	-	-	-	1	-	-	-	-	1
Brown trout	1	1	3	-	-	1	3	1	1	11
Koura	-	-	-	-	-	-	-	-	1	1
Fish per m^2	0.435	0.234	0.305	0.339	0.077	0.054	0.316	0.020	0.108	-
Fish per m^2 (excluding koaro)	0.166	0.217	0.305	0.255	0.074	0.054	0.175	0.020	0.108	-
Bluegill bullies per m^2	0.145	0.189	0.263	0.214	0.042	0.035	0.146	0.010	0.080	-

3.1.7.2 Comparison between the application area and upstream reaches

The Hutt River application area begins at the sea and extends 28km through the urban areas of Petone, Lower Hutt City and Upper Hutt City, to an elevation 80m above sea level. River reaches upstream of the application area not affected by flood protection activities are by contrast relatively undeveloped, beginning at the outer urban edge of Upper Hutt, and passing beside the Te Marua Golf Course before entering the forested area of Kaitoke Regional Park in the foothills of the Tararua Range.

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

In addition to geographical changes, the transition from an indigenous forest catchment of Kaitoke Regional Park to the urban areas of the Upper Hutt and Lower Hutt Cities has caused a range of habitat changes associated with the reduced integrity of riparian vegetation, increased agricultural and urban development, increase inputs of nutrients (especially nitrogen), and increased occurrence of pest species.

While it would be possible to compare the fish data from the application area with an area unaffected by flood protection activities, such a comparison would be meaningless in the context of this assessment because the main differences between the fish communities in these two areas are driven by geographical, geomorphological and land-use factors. Due to these confounding factors it would is not possible to draw any conclusions about the influence of flood protection activities on the distribution of fish in the Hutt catchment 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.

3.1.7.3 Tributary Streams

Fish species recorded in the Akatarawa River, Stokes Valley Stream, Speedy's Stream and Te Mome Stream are summarised in Table 3-19. As very little data are available for these watercourses, 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 core fish communities are as follows:

- Akatarawa River: longfin eel, redfin bully, koaro and brown trout. While the application area extends only 100m into the Akatarawa River, all four species have a high probability of occurrence in that reach.
- Stokes Valley Stream: longfin eel, shortfin eel, redfin bully, common bully, banded kokopu and brown trout.
- Speedy's Stream: longfin eel, shortfin eel, redfin bully, common bully, banded kokopu and brown trout.
- Te Mome Stream: longfin eel, shortfin eel, common bully, banded kokopu and inanga.

Table 3-19: Fish species recorded in the Akatarawa River, Stokes Valley Stream, Speedy's Stream and Te Mome Stream from NZFFD (2015) and Taylor and Kelly (2001). FENZ predictions of occurrence inside and outside of the application area are also provided (see Leathwick, et al., 2010).

Common name	Akatarawa River			Stokes Valley Stream			Speedy's Stream			Te Mome Stream		
	%Occurence			%Occurence			%Occurence			%Occurence		
	Within Area (n=0)	Outside Area (n=6)	Predicted In/out (FENZ)	Within Area (n=1)	Outside Area (n=2)	Predicted In/out (FENZ)	Within Area (n=2)	Outside Area (n=0)	Predicted In/out (FENZ)	Within Area (n=0)	Outside Area (n=0)	Predicted In/out (FENZ)
Longfin eel	0	83	100/100	100	100	100/100	50	0	100/100	0	0	80/80
Shortfin eel	0	17	20/20	0	50	90/50	50	0	100/30	0	0	100/100
Lamprey	0	13	10/10	0	0	10/10	50	0	10/10	0	0	10/10
Bluegill bully	0	38	10/10	0	0	10/10	50	0	10/10	0	0	10/10
Redfin bully	0	67	100/100	0	0	50/40	50	0	100/60	0	0	30/30
Common bully	0	0	20/20	100	0	60/20	50	0	30/10	0	0	60/60
Giant bully	0	0	10/10	0	0	10/10	50	0	10/10	0	0	60/10
Crans bully	0	17	10/10	0	0	10/10	0	0	10/10	0	0	10/10
Banded kokopu	0	13	20/20	0	50	30/50	50	0	60/60	0	0	60/60
Giant kokopu	0	0	10/10	0	50	20/10	50	0	20/10	0	0	20/50
Koaro	0	67	60/60	0	0	10/10	0	0	10/20	0	0	10/10
Inanga	0	0	10/10	0	0	80/60	0	0	90/30	100*	100	100/100
Dwarf galaxias	0	17	1010	0	0	10/10	0	0	10/10	0	0	10/10
Brown trout	0	50	100/100	100	50	50/30	100	0	50/50	0	0	30/30

Not listed in the NZFFD but reported by Taylor and Kelly (2001)

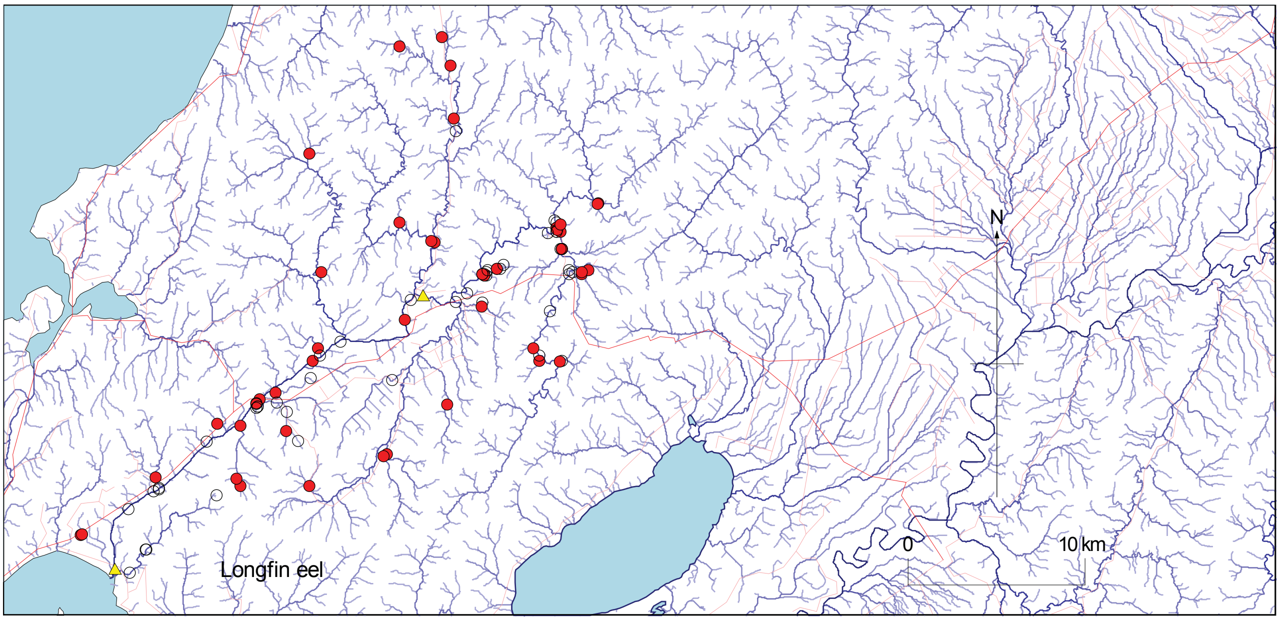


Figure 3-19: Longfin eel records for the Hutt River and tributaries (presence indicated as red dots, absence by a circle; the upstream and downstream extent of the Hutt River application area is indicated by yellow triangles). Data is from NZFFD as of June 2015.

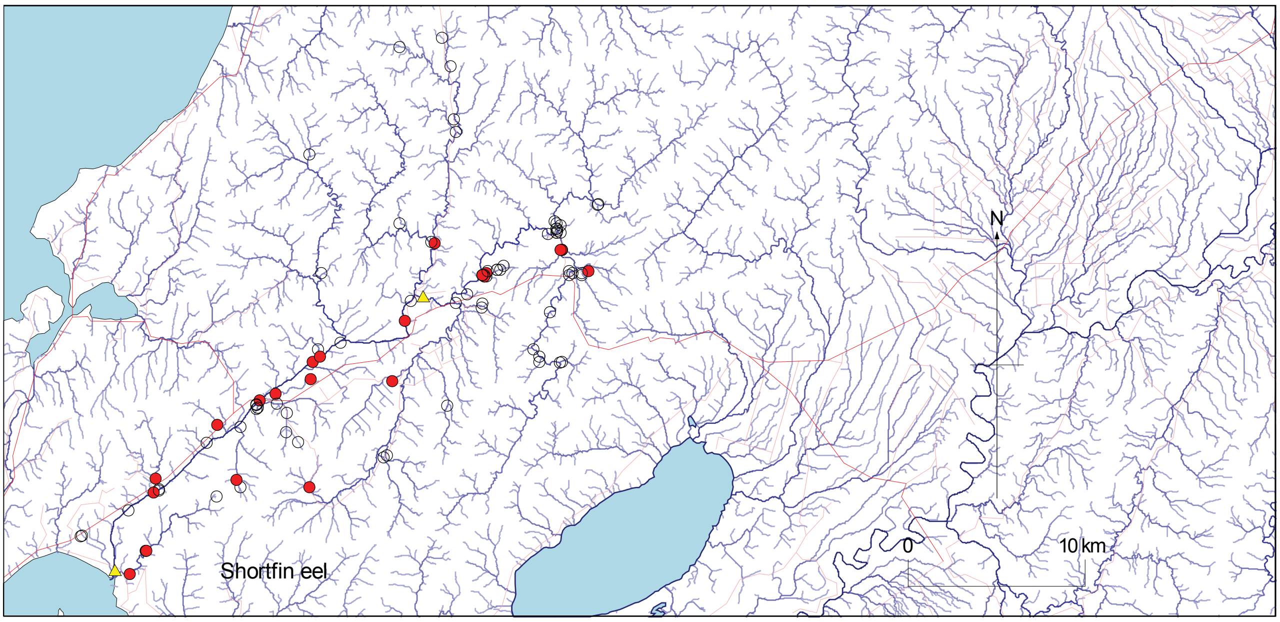


Figure 3-20: Shortfin eel records for the Hutt River and tributaries (presence indicated as red dots, absence by a circle; the upstream and downstream extent of the Hutt River application area is indicated by yellow triangles). Data is from NZFFD as of June 2015.

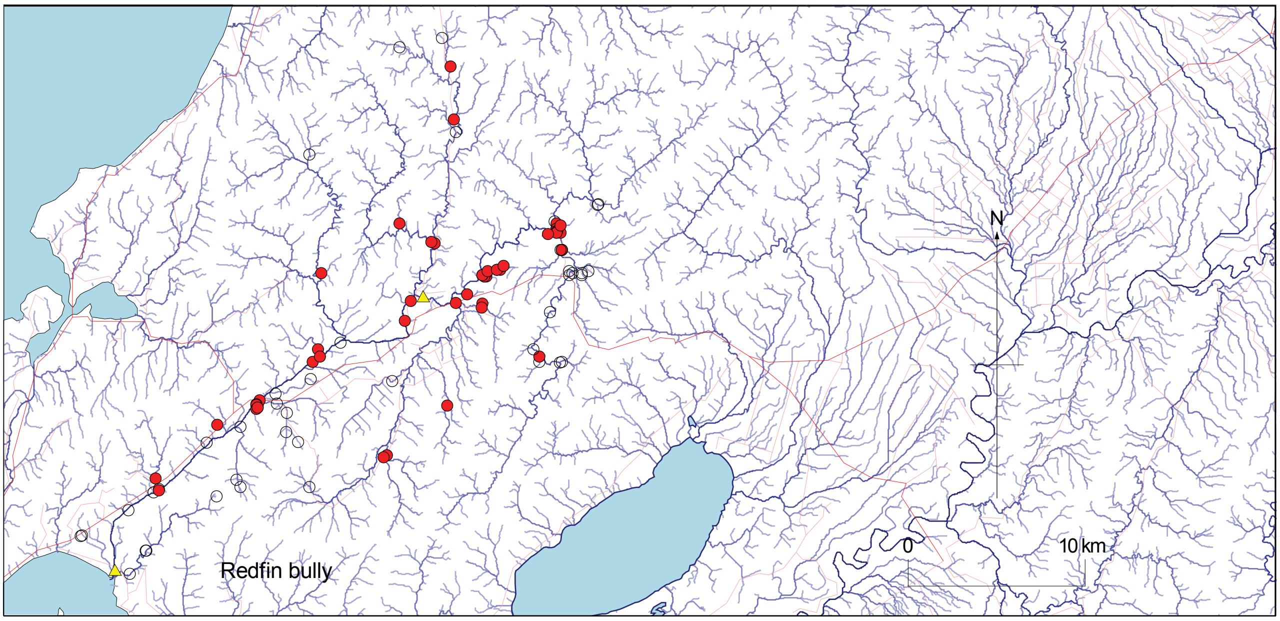


Figure 3-21: Redfin bully records for the Hutt River and tributaries (presence indicated as red dots, absence by a circle; the upstream and downstream extent of the Hutt River application area is indicated by yellow triangles). Data is from NZFFD as of June 2015.

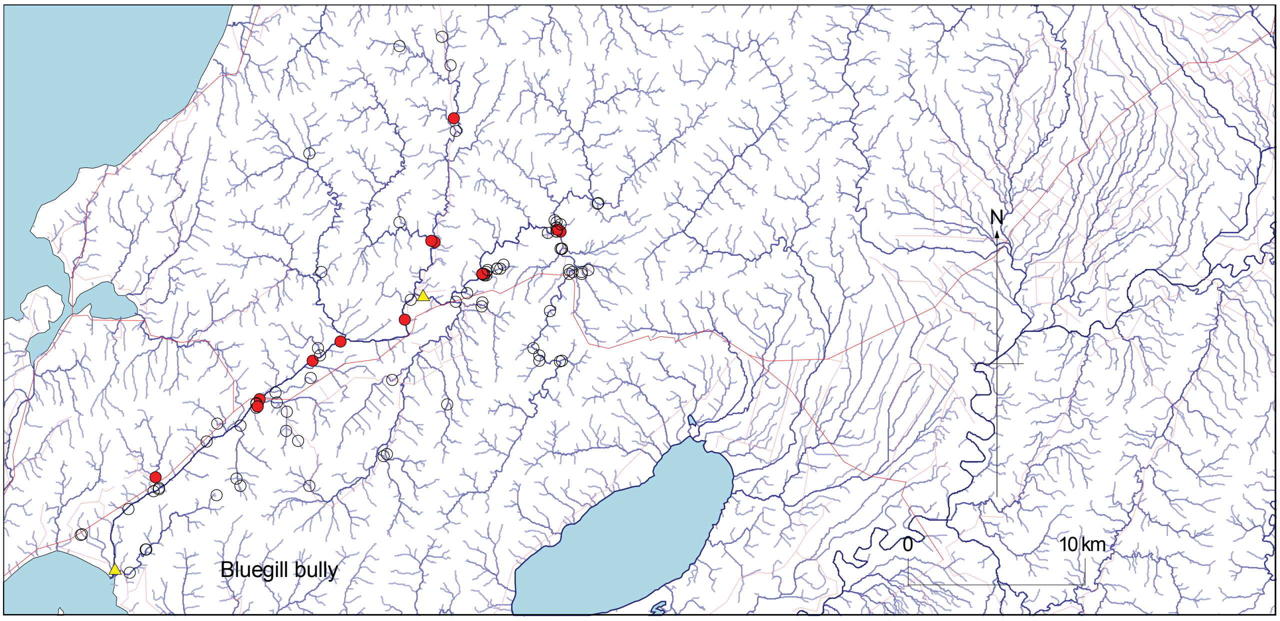


Figure 3-22: Bluegill bully records for the Hutt River and tributaries (presence indicated as red dots, absence by a circle; the upstream and downstream extent of the Hutt River application area is indicated by yellow triangles). Data is from NZFFD as of June 2015.

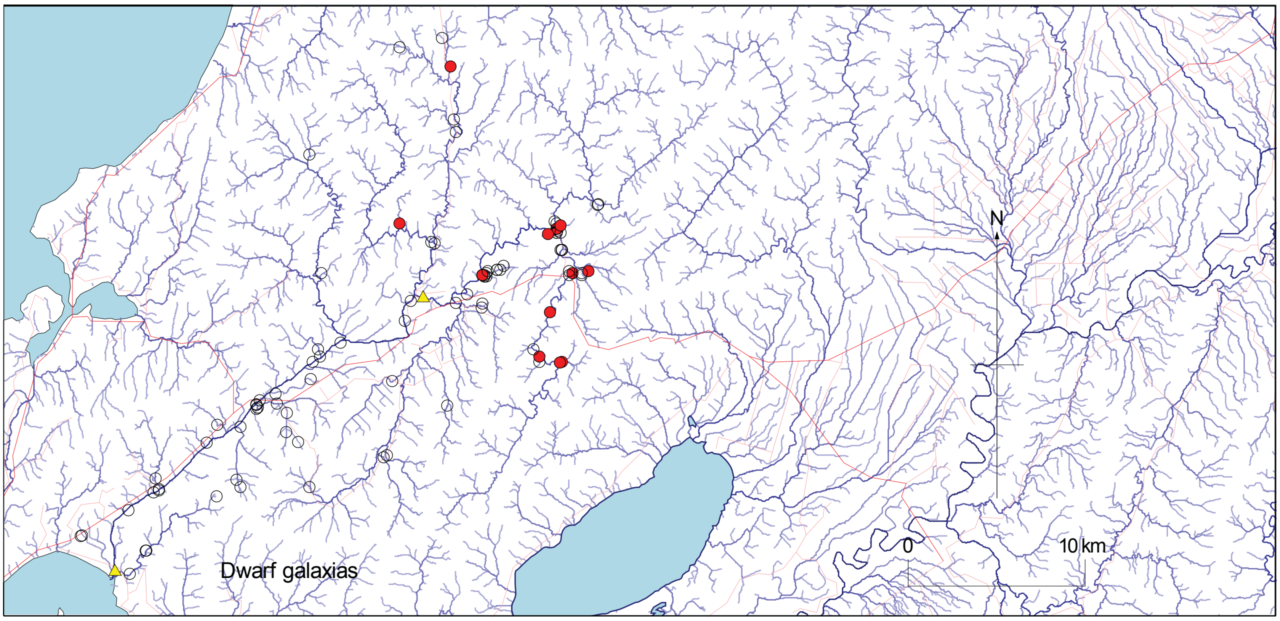


Figure 3-23: Dwarf galaxias records for the Hutt River and tributaries (presence indicated as red dots, absence by a circle; the upstream and downstream extent of the Hutt River application area is indicated by yellow triangles). Data is from NZFFD as of June 2015.

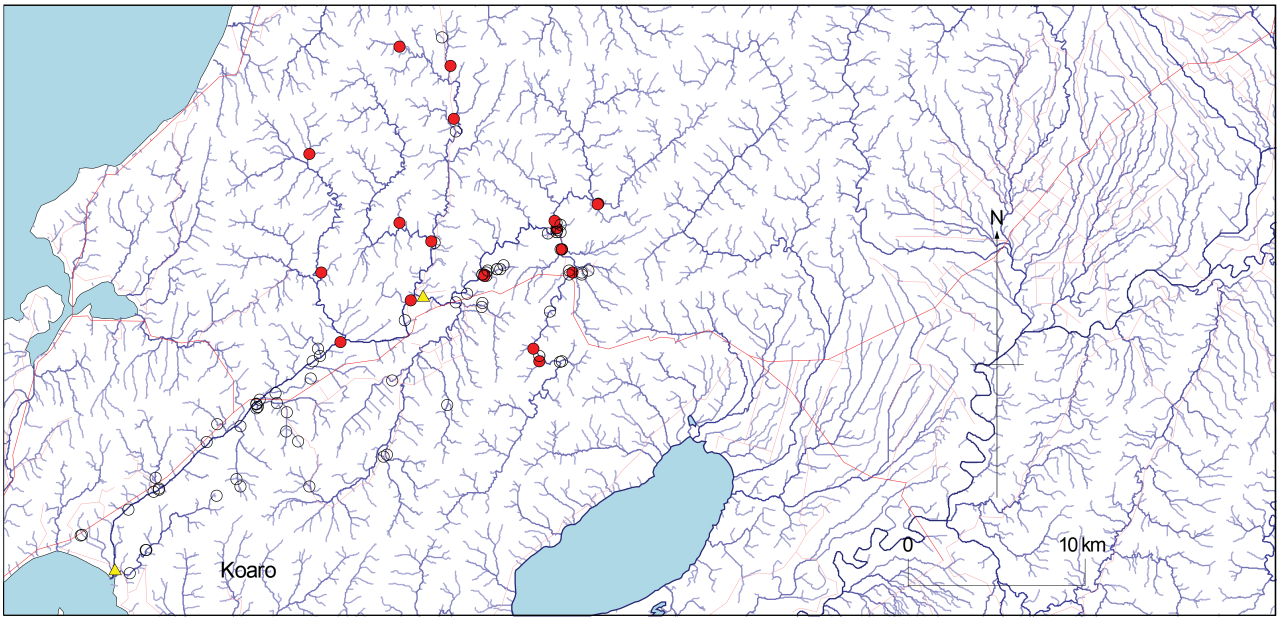


Figure 3-24: Koaro records for the Hutt River and tributaries (presence indicated as red dots, absence by a circle; the upstream and downstream extent of the Hutt River application area is indicated by yellow triangles). Data is from NZFFD as of June 2015.

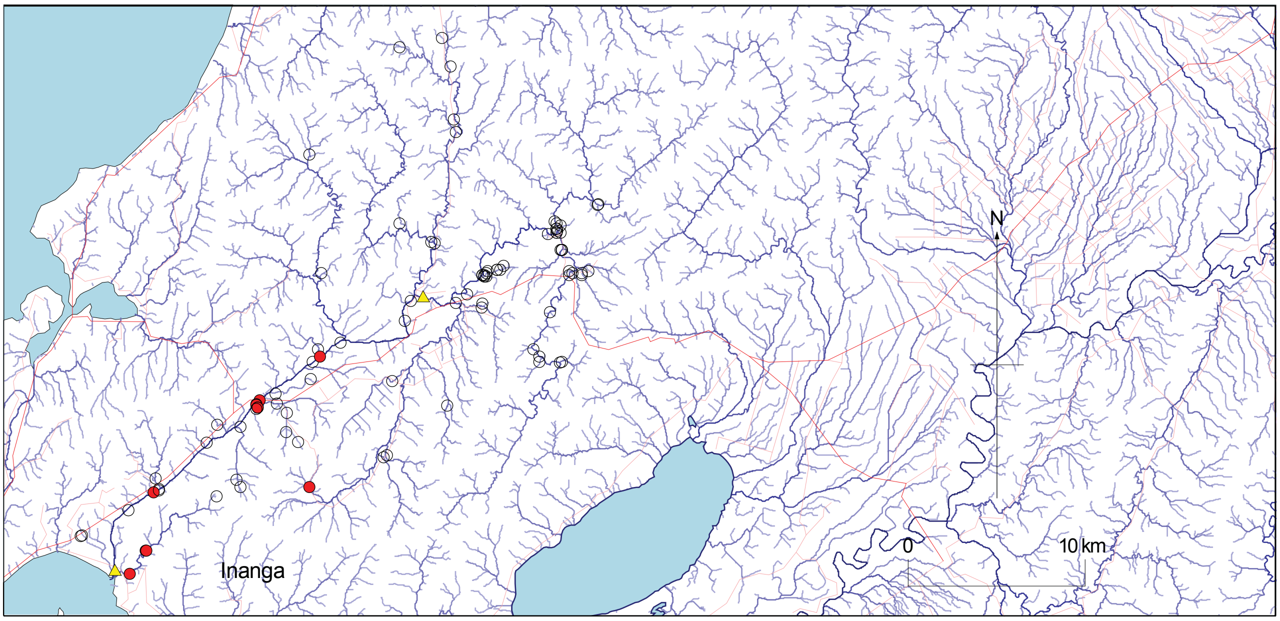


Figure 3-25: Inanga records for the Hutt River and tributaries (presence indicated as red dots, absence by a circle; the upstream and downstream extent of the Hutt River application area is indicated by yellow triangles). Data is from NZFFD as of June 2015.

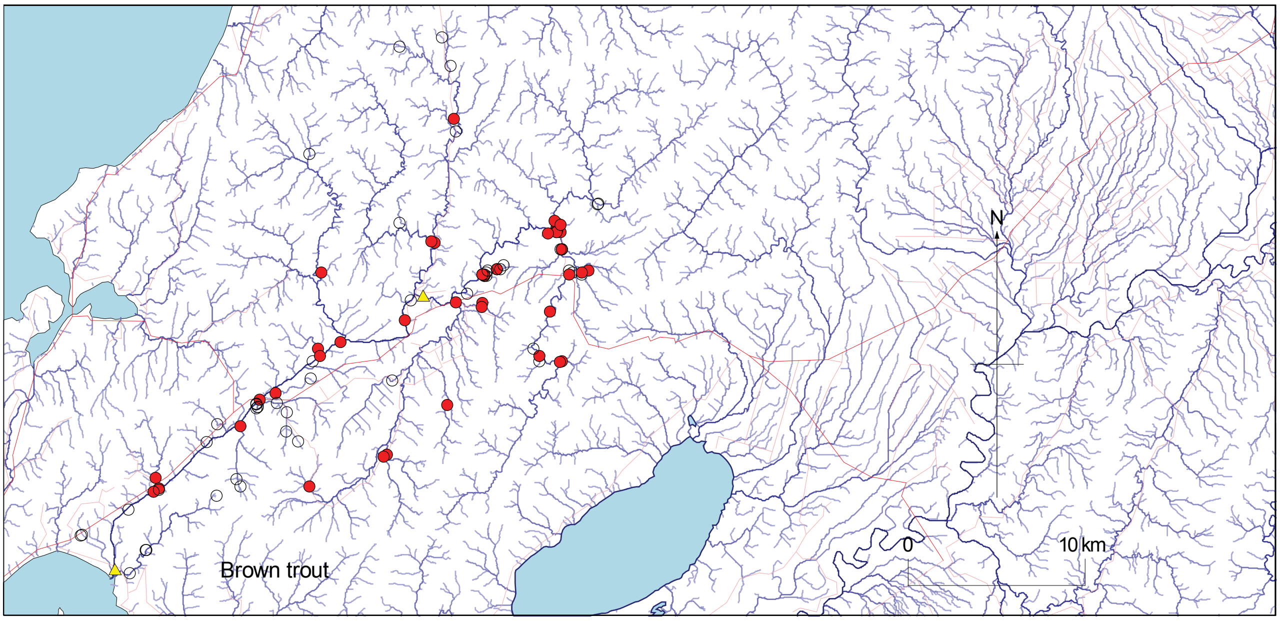


Figure 3-26: Brown trout records for the Hutt River and tributaries (presence indicated as red dots, absence by a circle; the upstream and downstream extent of the Hutt River application area is indicated by yellow triangles). Data is from NZFFD as of June 2015.

3.1.7.4 The recreational trout fishery

Brown trout were originally introduced to the Hutt River in 1874 and now provide the basis for a valued recreational trout fishery. The abundance of trout has been monitored annually by Fish and Game NZ since 1999 in order to explore the relationship between trout abundance and the frequency and extent of river control works. GWRC agreed, via a Memorandum of Understanding (MOU), to fund the annual survey in the Hutt River (and also Waikanae River) over the fifteen year term of the resource consents granted in 1998, in recognition of concerns by Fish and Game that some flood protection activities may compromise the preferred habitat requirements of brown trout.

The results of this monitoring programme indicate that trout are generally most abundant in the lower reaches of the Hutt River at Melling, and less abundant in the upper river, at Kaitoke. However, trout numbers vary considerably year to year, within a broad cyclic pattern. The results for 2014, reported by Pilkington (2014), show that:

- The mean number of trout per km was 118.7 (standard error 31) compared with 155.3 (standard error 45.6) for the 2013 survey, a difference which is not regarded as statistically significant.
- The number of medium and large brown trout per km for the 16 years between 1999 and 2014 increased, on average by 4% per year (refer Figure 3-27).
- Trout numbers are typically highest in the lower river at Melling, Taita and Whakatikei within the application area) and lowest in the upper river at Te Marua and Kaitoke, upstream of the application area (Figure 3-28).

Pilkington (2014) noted that:

> "*The long term (sixteen-year) trend is in the positive. The increased number of medium sized fish counted during this years' drift dive is indicative of good recruitment and survival during the last few years when no major flood have occurred.*"

The author goes on to note that the severity of spring floods is believed to reduce trout recruitment (i.e., Hayes, 1995). In an earlier report Pilkington (2012) notes that correlating flood data against the number of medium trout counted 1.5 years later shows a reasonably strong negative correlation, and that the negative correlation increased with severity of the flood. However, it was also noted in that report that where cross blading (i.e. bed re-contouring) had been undertaken recently at the Melling site, there was virtually no invertebrate life visible and no trout of any size class observed. These observations suggest that while bed re-countering and gravel extraction is likely to influence trout abundance at impacted sites in the short term, broader scale climatic factors are likely to be important in the longer term.

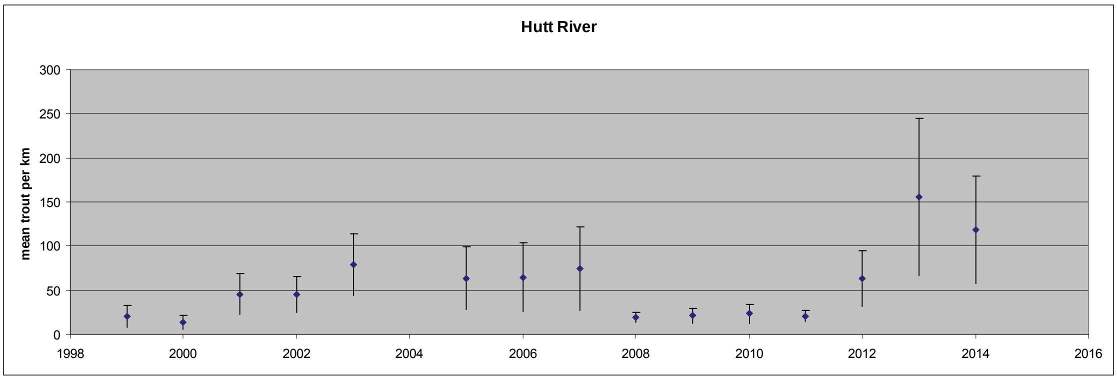


Figure 3-27: Mean large and medium trout per km, Hutt River (from Pilkington 2014)

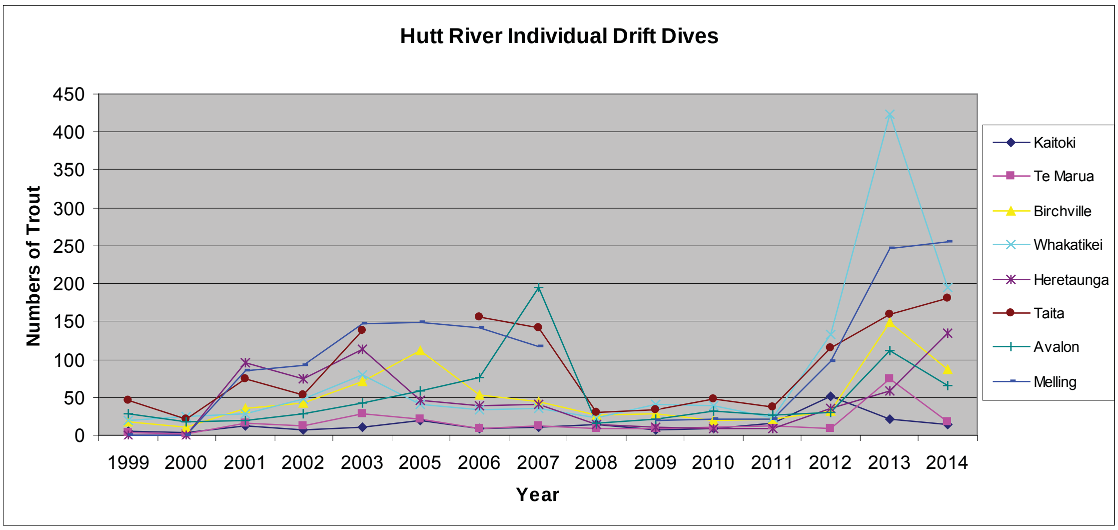


Figure 3-28: Mean number of trout over each individual reach

Investigations that specifically focused on the effects of gravel extraction in the Hutt River upstream of Kennedy Good Bridge during the 2012/13 summer include a Fish and Game assessment of trout abundance by drift dives (refer Appendix H). Surveys were undertaken both within and upstream of the reach affected by gravel extraction. The first survey was undertaken on 1 November 2012 prior to gravel extraction. On that occasion visibility was only moderately good (black disc distance was 3.6m), and the bottom of several deep holes could not be seen. As a consequence trout counts are expected to have underestimated the number of trout present. The second survey, after the works, was undertaken on 1 March 2013 during a period of stable low river flow when water clarity was much higher (black disc distance was 6.3m). Trout counts are expected to be relatively accurate on that occasion.

Gravel extraction started on 26th of November 2012 and continued until 19 December 2012. Approximately 16,000m^3 of gravel was extracted from a river length of approximately 400m. Both the “impact” and “control” reaches were both approximately 1400m in length, but the works did not extend through the entire 1400m “impact” reach as originally planned. The trout counts are summarised in Table 3-20.

Table 3-20: Hutt River trout counts above Kennedy Good Bridge (from Wellington Fish & Game)

Reach	*Date*	*Large brown trout*	*Medium brown trout*	*Small trout*
Control	1/11/2012	32	18	present
Impact (before disturbance)	1/11/2012	35+	24+	present
Control	1/3/2013	47	90	none seen
Impact (after disturbance)	1/3/2013	34	289	none seen

Fish and Game noted that: “*Trout numbers in both the undisturbed and disturbed areas appear very similar despite the works, and are relatively high*”. These results indicate that the gravel extraction operation had no lasting impact on trout numbers or distribution, and indeed that fish numbers are very high in this reach. Divers did, however, notice an absence of green algae and higher silt load in the disturbed reach than elsewhere. Fish and Game also noted the entire Hutt River has seen a large increase in trout numbers this year [2013], suggesting very good recruitment.

3.1.8 River birds

3.1.8.1 Introduction

GWRC has recognised that 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 of Practice and Environmental Monitoring Plan (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 Hutt 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*), is a recent addition to the New Zealand avifauna, having self-colonised from Australia in the early 1950s. Although the black-fronted dotterel is not ranked as either Threatened or ‘At Risk’, the southern North Island is currently a stronghold for this species in New Zealand.

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 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, counts of 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.

3.1.8.2 Riverbird nesting shorebirds

McArthur *et al* (2015) reported that only one species of shorebird (pied stilt) was observed using the exposed gravel habitats along parts of the Hutt River during the 2012-2015 surveys. Although no nests or chicks were located, the presence of territorial pairs in suitable habitat during this species breeding season suggests that these birds are likely to be breeding in the Hutt River.

On average 20 pied stilts were recorded along the 31.5 km of river surveyed each year, or 0.6 brids per km of river. As illustrated in Figure 3-29, these birds were concentrated in two discrete reaches of the river, between XS1310 and XS2270 (within the application area, from the Silverstream Weir to the eastern end of Awa Kairangi Park) and between XS2730 and XS2900 (upstream of the application area, alongside the Te Marua Golf Course).

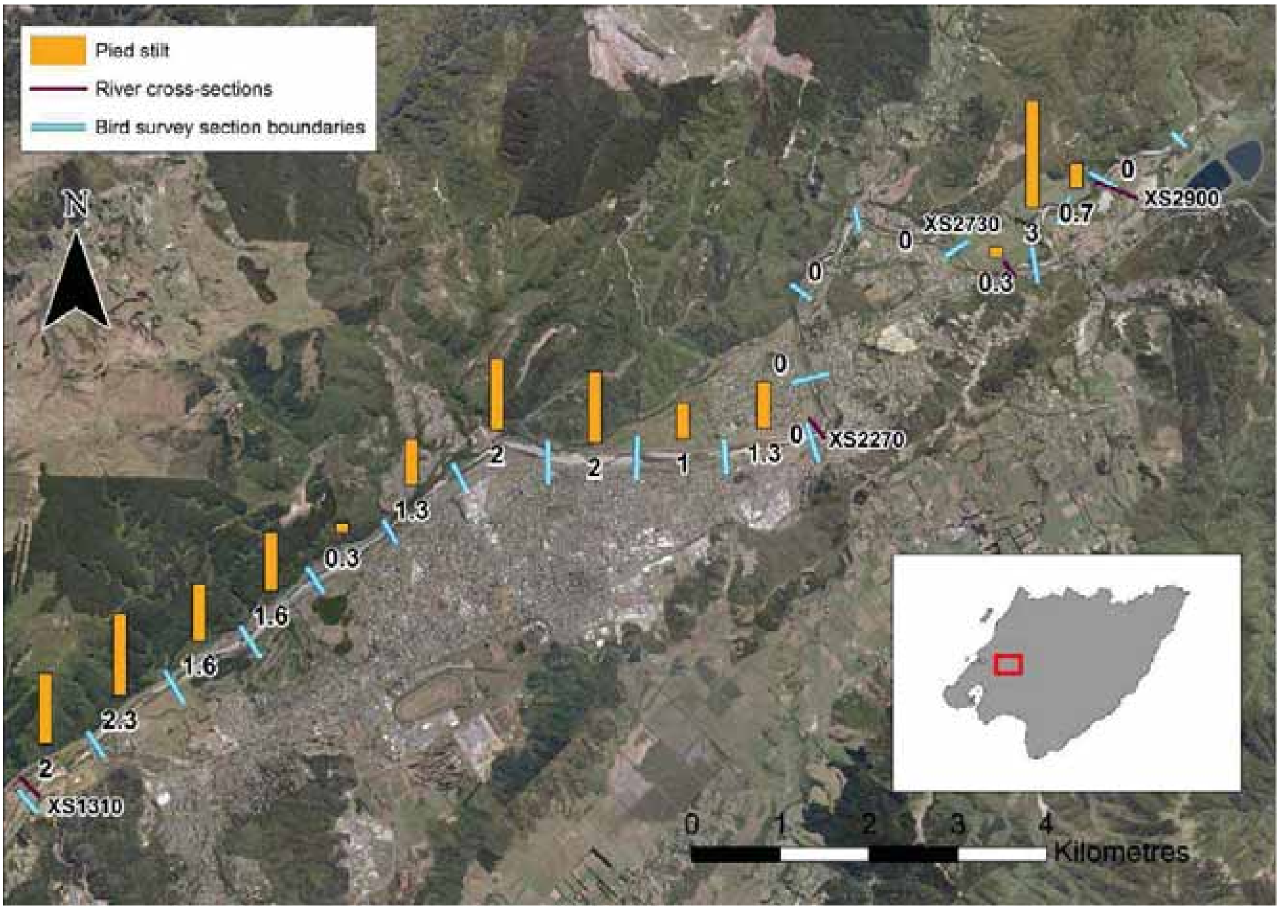


Figure 3-29: Map of the Hutt River showing the spatial pattern in the relative abundance of pied stilts (from McArthur *et al,* 2015). Coloured bars and adjacent values represent the mean number of birds counted along each 1 km survey section during three annual surveys between 2012 and 2015.

3.1.8.3 Spatial patterns in bird species diversity

McArthur *et al* (2015) recorded a total of 44 bird species during the 2012-15 bird surveys, including 26 native species and 18 introduced species. Of the native species, seven were ranked as Nationally Threatened or 'At Risk' under the New Zealand Threat Classification System (Robertson, et al., 2012). The authors note that in addition to the 44 birds species observed during the 2012-15 surveys, a further

18 species (all native) have been recorded on the Hutt River since 1997, bringing the total number of bird species recorded on the Hutt River to 62.

Both the total number of species and the ratio of native to introduced species encountered within each 1km survey section varied little along the 31.5 km of the Hutt River that was surveyed (Figure 3-30). A slightly higher proportion of Threatened or 'At Risk' species were recorded between XS1310 and XS2270 (within the application area, from the Silverstream Weir to the eastern end of Awa Kairangi Park) and between XS2730 and XS2900 (upstream of the application area, alongside the Te Marua Golf Course), due to the presence of both pied stilts and black shags on the riverbed in these reaches. The total number of species recorded, the ratio of native to introduced species and the proportion of threatened and 'at risk' species all increased with increasing distance downstream of XS540. McArthur et al (2015) concluded that this change was due to the presence of greater numbers of predominantly coastal bird species such as red-billed gulls (*Larus novaehollandiae*), royal spoonbills (*Platalea regia*), pied shags and variable oystercatchers in this lower reach of the Hutt River.

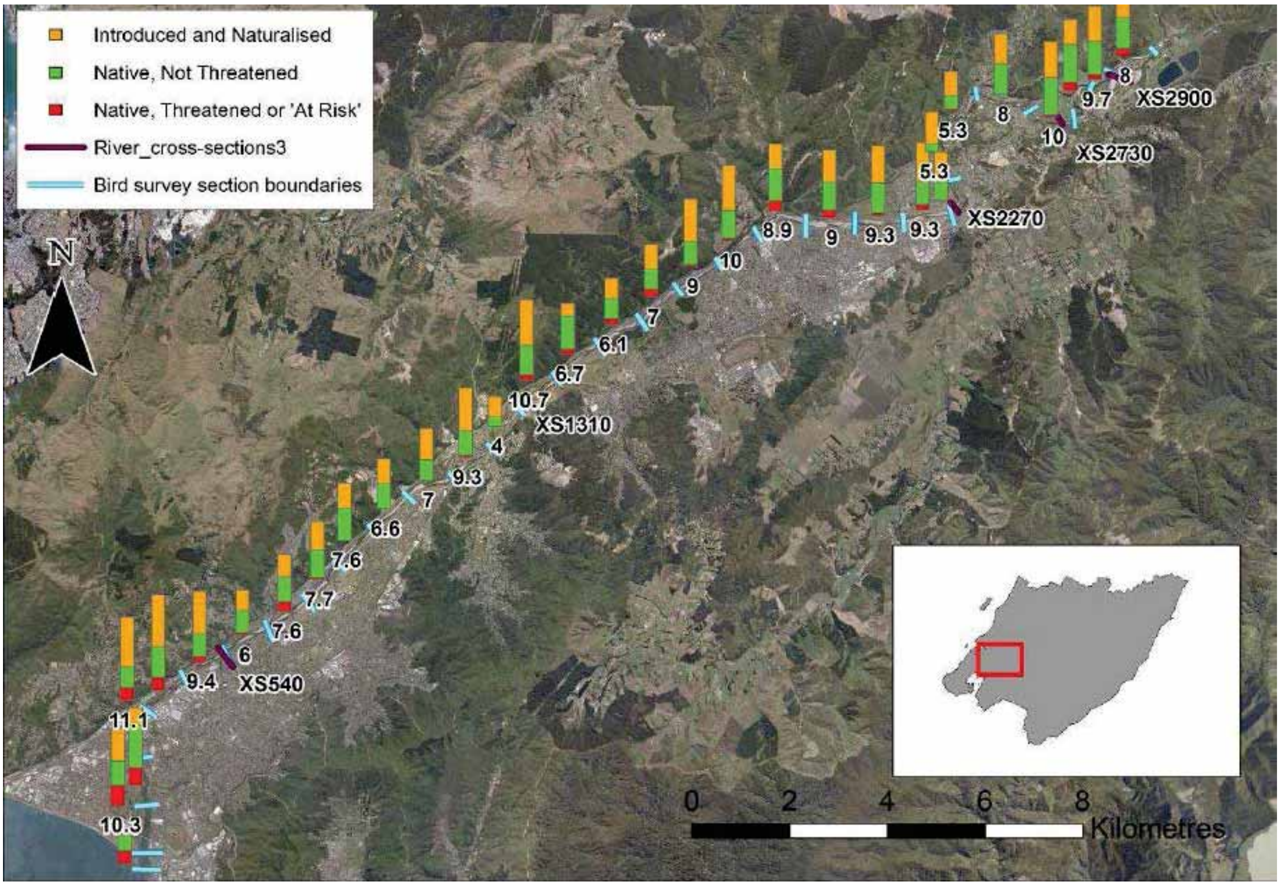


Figure 3-30: Map of the Hutt River showing the spatial patterns in bird species diversity (from McArthur et al, 2015). Coloured bars and adjacent values represent the mean number of species detected along each 1 km survey section during the three annual surveys between 2012 and 2015.

3.1.8.4 Sites of value for indigenous birds

McArthur *et al* (2015) identified six sites of value for native birds on the Hutt River including two reaches that that are likely to provide breeding habitat for pied stilt - see Figure 3-31. The surveys also confirmed two small nesting colonies of black shags on the Hutt River, one near XS2920 (outside of the application area, opposite the Te Marua Golf Course) and one near XS490 (within the application area, near the Melling Bridge). Although both colonies are situated on escarpments well above the bed of the Hutt River, both adult black shags and recently-fledged juveniles from the colonies were observed using the adjacent river channel and riverbed for foraging and roosting. These colonies are two of only eight black shag nesting colonies known to be active in the Wellington Region at the present time (McArthur et al, 2015).

The authors have observed that a large gravel island that is exposed at low tide near XS190 (just downstream of the Ava railway bridge) provides an important roost site for a number of threatened shorebird species including royal spoonbills, black shags, little black shags (*Phalacrocorax sulcirostris*), pied shags, variable oyster catchers, pied stilts and Caspian terns (*Hydroprogne caspia*). Gravel beaches either side of the Silverstream road bridge (XS1400) are also used as a roost site by large numbers of black-backed gulls (*Larus dominicaus*), however black-backed gulls lack legal protection and are classified as 'Not Threatened' (Robertson, et al., 2012). This, and the fact that their presence at this location is more likely to be a consequence of the proximity of the Silverstream Landfill has led McArthur et al (2015) to consider that this latter roost site should not be considered as a "site of value" for native birds.

The authors concluded that the Hutt Estuary, upstream to XS150 supports 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 Hutt River.

3.1.8.1 Comparison between the application area and upstream reaches

While it would be possible to compare the data from three years of annual surveys from the Hutt River from Birchville to the Hutt Estuary (the application area) and six years of bird survey data from the Hutt Water Collection Area (an area unaffected by flood protection activities), such a comparison would be meaningless in the context of this assessment as the main differences between the bird communities in these two areas are driven by differences in vegetation cover and river geomorphology rather than the presence/absence of flood protection activities (Nikki McArthur, pers.com.)

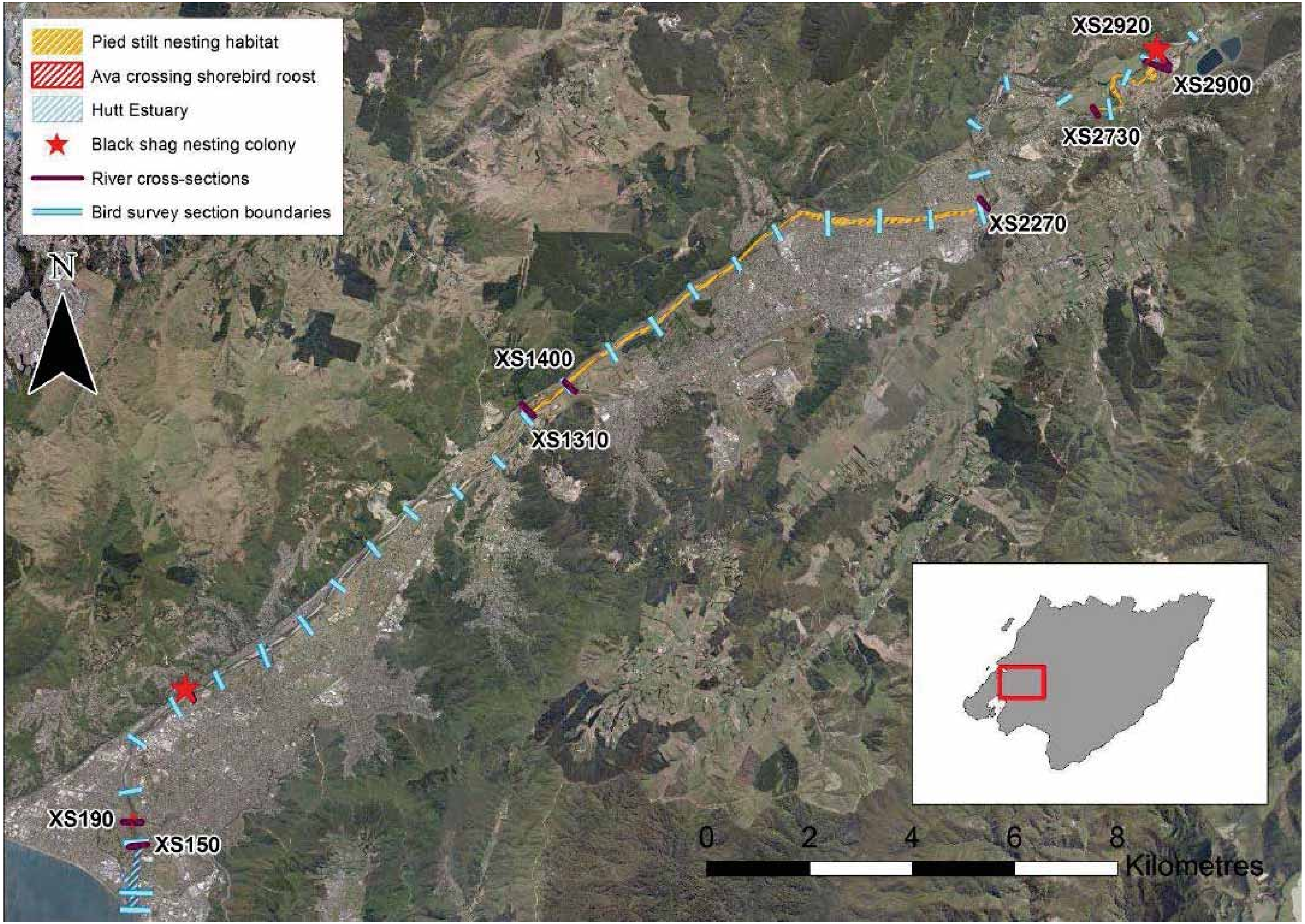


Figure 3-31: Map of the Hutt River showing birds sites of value identified in the 2015-15 surveys (from McArthur et al 2015)

3.1.9 Herpetofauna

A search of lizard and frog records within a corridor extending 1km either side of the Hutt River channel centreline (i.e., the search area extends well beyond the application area which has a typical width of only 200 to 300m) was undertaken via the Department of Conservation BioWeb Herpetofauna database and unpublished data (Trent Bell, unpub. data, trent@ecogecko.co.nz).

Several lizard species and two frog species are recorded within the Hutt Valley search corridor (Table 3-21 and Figure 3-32). These are the Ngahere gecko, barking gecko, Raukawa gecko, copper skink, northern grass skink and ornate skink, and two introduced frogs. A further species, the Pacific gecko, *Dactylocnemis pacificus* (At Risk - Relict), is sparsely recorded at Silverstream (more than one kilometre from the flood corridor). This is the species' southernmost range and may potentially be found in primary or secondary forest existing within the flood corridor (but is less likely to be found within the application area).

Flood protection activities may affect the margin of some lizard populations in the Hutt Valley. However lizards are likely to be sparsely distributed in areas that are frequently flooded, and rare in built-up urban areas where the population is likely to be represented only by northern grass skink. However, the upstream reaches of the application where there are steeper river banks, boulders, rank grassland, scrub and forests, may include a greater diversity of species, potentially including ngahere geckos, barking geckos and Raukawa geckos, as well as northern grass skinks..

Table 3-21: Herpetofauna records within the Hutt Valley 2km wide search corridor. Reptile threat classification obtained from Hitchmough *et al.* (2012) and frog threat classifications from Newman *et al.* (2013).

Species	*Common name*	*Threat Classification*	*No. of records*	*Species habitat preference*	*Likelihood of presence*
Mokopirirakau "southern North Island"	Ngahere gecko	At Risk - Declining C (2/1)	40	Macro: Primary and secondary forest, and scrubland. Micro: Rock or wood piles, tree hollows and canopy.	Moderate upstream within preferred habitat; Low elsewhere.
Naultinus punctatus	Barking gecko	At Risk - Declining C (2/1)	6	Macro: Primary and secondary forest, and scrubland. Micro: Canopy.	Moderate upstream within preferred habitat; Low elsewhere.
Oligosoma aeneum	Copper skink	Not Threatened	2	Macro: Primary and secondary forest, scrubland and wasteland with debris. Micro: Waste piles, dense leaf litter, wood piles, rock piles and compost.	Moderate
Litoria raniformis	Growling grass frog	Introduced and Naturalised (Threatened Overseas)	2	Macro: Forest, scrubland, grassland, wetland and stream banks. Micro: Rock piles, wood piles and dense rank grass.	Moderate
Woodworthia maculata	Raukawa gecko	Not Threatened	1	Macro: Primary and secondary forest, and scrubland. Micro: Canopy (night), tree hollows, wood piles and rock piles.	Moderate upstream; Low downstream
Oligosoma polychroma	Northern grass skink	Not Threatened	1	Macro: Grassland and scrubland. Micro: Dense rank grass, wood piles, rock piles.	High upstream; Low downstream
Litoria ewingii	Whistling tree frog	Introduced and Naturalised	1	Macro: Primary and secondary forest, scrubland, grassland, wetland and stream banks. Micro: Rock piles, wood piles and dense rank grass.	Moderate

Notes: Threat classification criteria: C (2/1) = very large population and low to high ongoing or predicted decline, total area of occupancy > 10 000 ha (100 km^2), predicted decline 10–70%.

Figure 3-32: Herpetofauna records within a 1km radius of the Hutt River application area centreline

3.1.10 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, bankfull 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 measure 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. The first NCI assessment was completed in 2013 and referenced against the earliest available aerial photographs for these rivers (1941 for the Hutt River) and is reported in Williams (2013). A summary of results for the Hutt River is provided in Table 3-22. The locations of the 12 NCI reaches 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. It is noted that high NCI scores recorded in the lower river at XS 200 –XS 100 reflect that fact that major flood protection works had already been constructed on the lower river by 1941, i.e., the reference condition includes significant modification, and that little further change has occurred since then.

Table 3-22: NCI assessment for the Hutt River (from Williams, 2013)

Reach Cross section	Sinuosity	Pools	Natural Floodplain width to:			Overall NCI
			Active	Bank-full	Permitted	
XS 2780 – XS 2560	1.00		0.98	0.73	0.22	**0.73**
XS 2540 – XS 2410	1.00		1.13	1.03	1.00	**1.04**
XS 2400 – XS 2270	0.87	1.00	0.78	0.50	0.98	**0.83**
XS 2260 – XS 1920	0.98	0.33	0.64	0.47	0.28	**0.54**
XS 1910 – XS 1780	1.00	0.758	0.65	0.56	0.59	**0.71**
XS 1770 – XS1350	0.99	0.43	0.79	0.73	0.54	**0.70**
XS 1340 – XS 1090	0.98	0.00	0.89	0.59	0.28	**0.55**
XS 1080 – XS 850	0.98	0.80	0.72	0.81	0.09	**0.68**
XS 840 – XS 510	0.89	1.00	0.95	0.57	0.17	**0.72**
XS 500 – XS 370	0.99	2.00	1.21	1.06	0.44	**1.14**
XS 360 – XS 210	1.00	1.00	0.95	0.91	0.98	**0.97**
XS 200 – SX 100	0.95	2.00	0.71	0.90	0.98	**1.11**
Average	*0.97*	*0.93*	*0.87*	*0.74*	*0.55*	***0.81***

3.2 Hutt Estuary

3.2.1 Physical characteristics

The Hutt Estuary is a moderate sized (3km long) “tidal river mouth” type estuary which drains into Wellington Harbour at Petone. It has been extensively reclaimed and modified, and the banks clad with large rip-rap boulders (Robertson & Stevens, 2007). Saltwater extends up to 3km, nearly as far as Ewen Bridge (and well upstream of the Estuary Bridge). The estuary is highly modified from its original state. In 1909 it was much larger and included several large lagoon arms and extensive intertidal flats and saltmarsh vegetation. Over the next 50 years, most of the intertidal flats and lagoon areas were re-claimed and the estuary was trained to flow in one channel between rock rip-rap lined banks. The terrestrial margin, which was originally vegetated with coastal shrub and forest species, was replaced with urban and industrial land-use (Robertson & Stevens, 2011).

The application area extends downstream to the Estuary Bridge, well into the upper part of the estuary. The river mouth downstream of the Estuary Bridge which is not within the application area is regularly dredged (under a separate consent) to maintain flood capacity.

3.2.2 Ecological values

As a result of modifications over the last 100 years, including loss of most of the intertidal flats, lagoon areas and much of its riparian vegetation, the estuary now has low habitat diversity. High value habitats such as tidal flats, saltmarsh and sea-grass beds are virtually absent. Instead, the estuary is dominated by lower value, sub-tidal sands and muds and artificial sea walls (Robertson & Steven, 2011).

Nevertheless, parts of the estuary are considered to be important areas for juvenile flatfish and significant feeding/refuge areas for wading and non-wading birds (Weir, 2010; Stevens, Robertson, & Robertson, 2004; McArthur *et al*, 2015).

3.2.3 Macroalgae

Macroalgal monitoring has been undertaken annually in Hutt Estuary from 2010 to 2014 and is reported by Stevens & Robertson (2014). The authors note that *Ulva intestinalis* grows on almost every part of the intertidal habitat with an extensive cover extending from the railway over bridge to the Hutt River mouth. *Gracilaria* and the green alga *Ulva* (sea lettuce) is largely confined to the lower intertidal reaches. Despite the high cover, nuisance conditions (rotting macroalgae and poorly oxygenated and sulphide rich sediments) are not widespread in intertidal areas. Regular flushing of the estuary appears to currently restrict the presence of nuisance conditions to localised areas on intertidal flats, and in subtidal areas near the Hutt River mouth. The distribution of macroalgae on 22 January 2014 is illustrated in Figure 3-33.

3.2.4 Sediments

The results of annual sediment monitoring in the Hutt Estuary from 2010 to 2014 are reported by Stevens & Robertson (2014). Measurement of depths to four concrete plates buried in intertidal sediment in 2010 was undertaken to assess the sedimentation rate. Redox potential discontinuity (RPD) depth and sediment grain size were assessed to indicate sediment condition. The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. It is an effective ecological barrier for most but not all sediment-dwelling species. A rising RPD will force most macrofauna towards the surface to where oxygen is available.

The results show that the overall mean sedimentation rate across the four years of monitoring was a decrease of 4.2mm/yr. Regular dredging of sediment from the channel in the lower estuary, and scouring of the tidal flats during high river flows, are likely reasons for the low mean annual deposition rate. In the 2014 survey the sediment mud content was 21.9%, reflecting firm muddy sands and the average RPD depth was 1.5cm. The authors concluded that: “*The sedimentation rate over the past 4 years showed slight erosion, but the high sediment mud content and shallow RPD depth indicate the estuary is susceptible to sediment related impacts from poor clarity and muddy intertidal substrates, with a macrofaunal community dominated by mud tolerant species – a common situation in NZ tidal river estuaries*”.

The results of fine scale monitoring in 2010, 2011 and 2012 show that, as may be expected for such a heavily modified estuary and developed catchment, the subtidal sediments had a relatively high mud content, moderate levels of sediment oxygenation, and moderate nutrient levels. Perhaps less expected, given the exposure to urban runoff, were low concentrations of potential toxicants (heavy metals and PAH's) in all three years of baseline monitoring (Robertson & Stevens, 2012).

The authors noted that overall, while the greatest impact to the estuary has undoubtedly been from the extensive historical loss of high value natural vegetated margin, saltmarsh, sea-grass, and intertidal habitat, the findings indicate that the estuary currently:

- is moderately enriched with nutrients (mesotrophic),
- has elevated muds but low sedimentation rates, and
- has low levels of toxicity.

Figure 3-33: Map of intertidal macroalgal cover in the Hutt Estuary (from Stevens & Robertson, 2014)

3.2.5 Macroinvertebrates

Fine scale monitoring reported by Robertson & Stevens (2012) includes survey of infauna from sediment core samples collected at two Hutt Estuary sites (A & B) in 2010, 2011 and 2012. In all three years the macroinvertebrate community was found to have low-moderate numbers of species at both sites. In terms of abundance, the results show a large reduction at both sites between 2010 and 2012. Compared with other NZ tidal river estuaries the abundances were relatively low.

The mud tolerance of the Hutt Estuary macroinvertebrate community was in the "moderate-high" category in 2012, a slight improvement from the previous two years (Figure 3-34). The results show that the community was dominated by species that prefer mud rather than those that prefer sand.

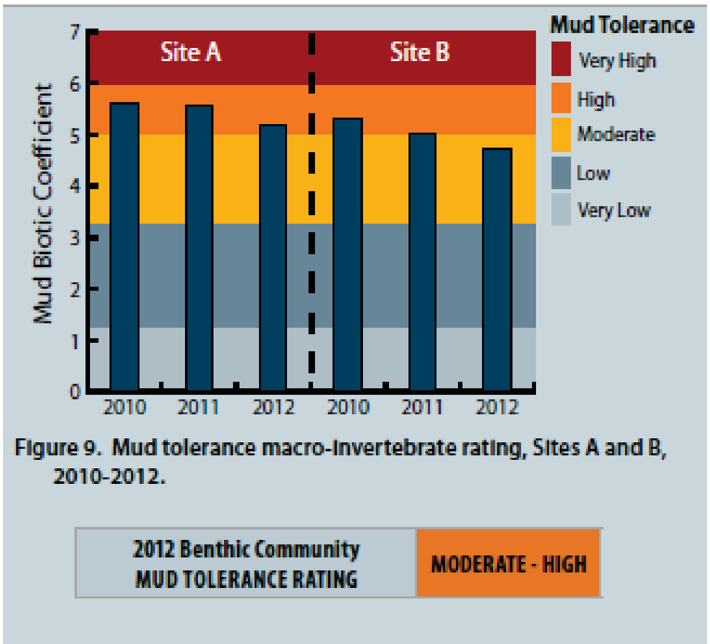


Figure 3-34: Mud tolerance macroinvertebrate rating, sites A and B, 2010-2012

Overall, the sediment results indicate that macroinvertebrate diversity and abundance is likely to be adversely affected by the sediment mud content, and that fine sediments have reached levels where both sites and nearly all sensitive species are affected. However, there is evidence that some improvement occurred between 2010 and 2012.

Weir (2010) noted that the river mouth downstream of the Waione Street Bridge is regularly dredged to maintain flood capacity and that the "extraction zone" benthos is sparsely distributed in that area. Weir also observed that the south-western seawall consists of man-made materials positioned along the true left bank as protection from flooding and erosion, which forms intertidal habitat dominated by green algae (*Ulva)* and *Enteromorpha intestinalis* and the blue mussels *Mytilus galloprovincialis,* with patches of necklace seaweed (*Hormosira banksii*).

3.2.6 Fish

Migratory freshwater fish species listed in Table 3-16 rely on the estuary zone to provide unimpeded access from the open harbour waters to the upper reaches of the river (or *vice versa*) for the purposes of spawning. Additionally a number of marine species venture into the estuarine area to breed or feed, including yellow-eyed mullet (*Aldrichetta forsteri)*, sand flounder *(Rhombosolea plebia)* and kahawai *(Arripis trutta)*, and in particular the estuary is considered to be an important nursery area for juvenile sand flounder (Weir & Haddon, 1992; Weir, 2010).

Despite the general unsuitability of the main-stem for inanga spawning, there are records of inanga spawning in areas in the tidal reach where bank armouring is absent. These include observations near the Sladden Park boat ramp in Petone, at Te Mome Stream and Opahu Stream (Taylor & Kelly, 2001). In recent years GWRC has undertaken works to enhance inanga spawning habitat in the lower Opahu Stream, as part of flood protection upgrade works in the Ava to Ewen reach. Potential inanga spawning habitat identified by Taylor and Kelly (2001) is shown in Figure 3-35.

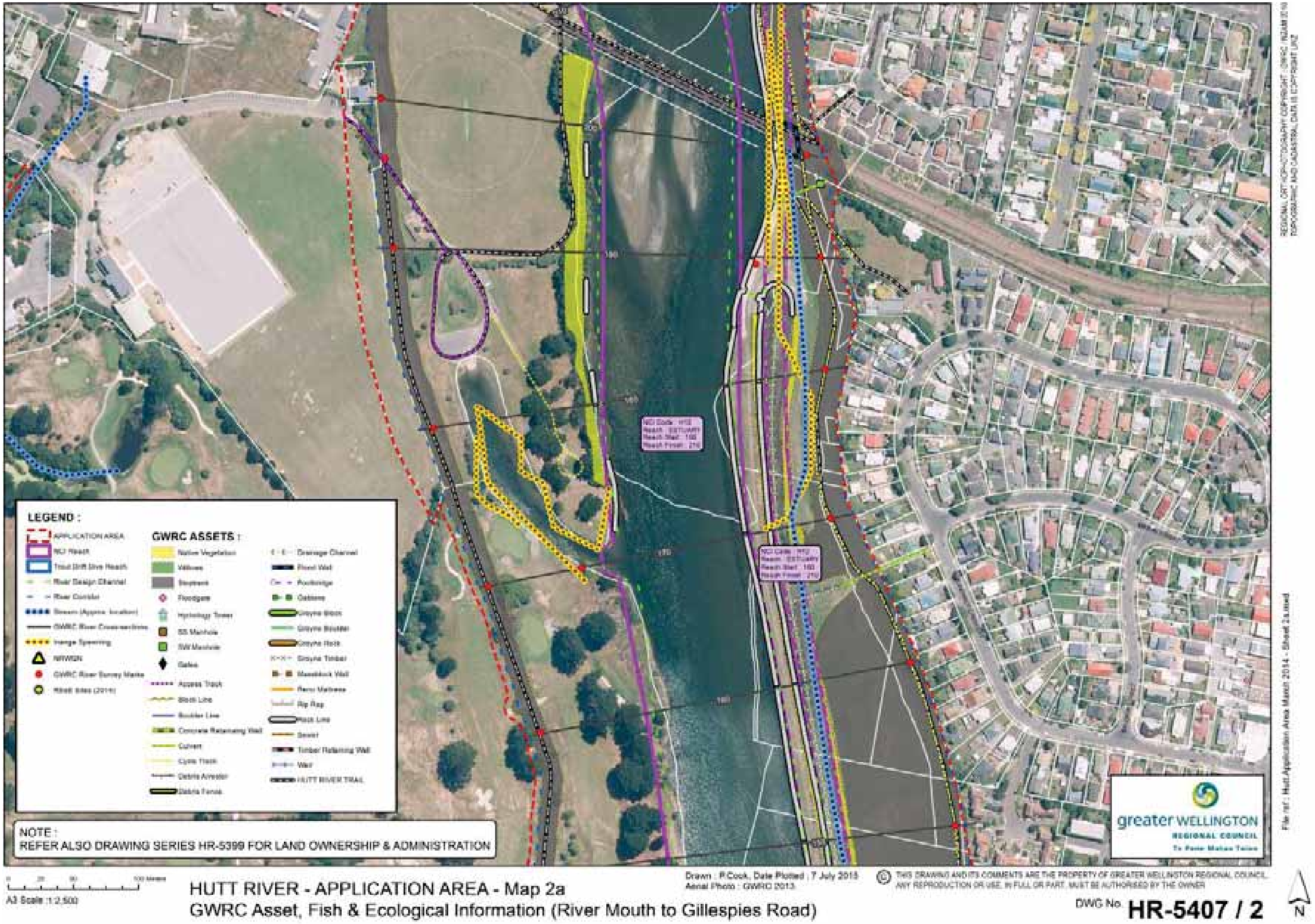


Figure 3-35: Potential inanga spawning habitat in the Hutt Estuary is indicated by yellow/red dotted lined (from Taylor and Kelly, 2001)

3.2.7 Birds

The western arm tidal flat of the Hutt Estuary is an important roosting, wading and feeding area for a number of birds, including the variable oystercatcher, black shag, little black shag, royal spoonbill, reef heron, mallards and grey ducks, red-billed gulls, and terns (Wear & Haddon, 1992; McArthur, Robertson, Adams, & Small, 2015).

GWRC has identified the Hutt River reach from the river mouth to 1.3 km upstream of the mouth as a site of significance for indigenous birds (McArthur and Lawson, 2013). The ecological context is that "this site provides seasonal or core habitat for black shag, little black shag, royal spoonbill, variable oyster catcher and red-billed gull". Present threats identified in that report include disturbance caused by recreational users, dogs and vehicles, disturbance and habitat modification caused by flood protection activities.

4 Flood Protection Activities

4.1 Purpose

As described in the Resource Consent Applications for Operations and Maintenance Activities in the Hutt 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 Hutt 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 listed above, GWRC currently undertakes a wide range of flood protection activities in the Hutt River, as listed below in Table 4-1.

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)

4.2.2 Maintenance of channel capacity

The main activities currently used to maintain channel capacity are:

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

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 stopbanks.

Table 4-1: Summary of operations and maintenance activities undertaken in the Hutt 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)	New stormwater drainage channels associated with cycleway/walkway construction New stormwater culverts associated with cycleway/walkway construction Footbridges associated with cycleways/walkways Fences Access roads Floodwalls
Demolition and removal of existing structures on & in the river bed	Formation of access-way (where required) – removal of vegetation, reshaping of bank, temporary placement of gravel. River crossing by machinery Demolition by mechanical and/or hand methods. Removal of material from river bed.
Maintenance of existing structures on & in the river bed	Formation of access-way (where required) – removal of vegetation, reshaping of bank, temporary placement of gravel. Structural repairs and maintenance to: • Existing erosion protection structures in the river bed • Existing culverts and outlet structures that discharge directly to the Hutt River
Structural maintenance work outside the river bed	Structural repairs and maintenance to: • Stopbanks & training banks • Flood walls • Stormwater culverts • Stormwater drainage channels • Footbridges located on the river berms • Fences located on the river berms • Berms
Development of vegetative bank protection	Tree planting, willow layering, cabling & tethering
Maintenance of vegetative works	Trimming of trees 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 recontouring Mechanical bed recontouring Mechanical ripping in the wetted channel
Channel maintenance	Removal of vegetation Beach ripping Clearance of flood debris Gravel extraction Dredging of Lower Opahu Stream isolated arm
Non-structural maintenance works outside the river bed	Mowing stopbanks & berms (not involving machinery in river bed) Mowing stopbanks & berms – Stokes Valley Stream (machinery in river bed) Planting & landscaping
Contingency works	Any of the above undertaken in response to a flood or emergency situation

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 instream 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 Hutt catchment, and others in the Wellington Region, where the river has been progressively straightened and confined to allow for residential and commercial development, there may be little realistic prospect of substantially widening the river channel or increasing connectivity to the floodplain. 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 water quality and ecology of the Hutt River and specified tributaries. While all of the listed activities are potentially available for use in the tributaries covered by the current application, in practice and based on past experience, there is only a relatively small number of activities that are regularly undertaken in these streams; these are listed below in Table 5-1.

Table 5-1: Flood protection activities likely to be required in Hutt River tributaries

Watercourse	Activities likely to be undertaken in the future
Akatarawa River	GWRC maintains only a very short (100m) section of the river at the Hutt confluence and activities are primarily focused on keeping the stream clear from obstructions, including: • Removal of vegetation (including trees) and • Clearance of flood debris
Stokes Valley Stream	• Mowing stopbanks & berms (tractor access along streambed) • Planting & Landscaping • Maintenance of existing structures (in & out of bed) • Removal of vegetation • Clearance of flood debris • Clearance of stilling basin
Speedy's Stream	• Removal of debris from the arrester. • Maintenance of debris arrestor. • Ability to rebuild arrestor.
Opahu Stream outlet	• Dredging of outlet reach (silt and tidal debris) • Maintenance of plantings. • Additional planting and landscaping.
Te Mome Stream	• Dredging (to remove silt and tidal debris) • Removal of debris from flood gates.

5.2 Water Quality

The primary effects on water quality associated with mechanical disturbance of the 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 re-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 routine flood protection activities discussed in this report. Maximum turbidity and suspended solids values of 306 NTU and 207 mg/L, respectively, were recorded in the River near the Kennedy Good Bridge during bulldozer operation. It is noted also that turbidity levels ranging from 70 to 163 NTU were recorded in the River 1400m downstream of the works over the same period (Alton Perrie, *pers. com*.).

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.

The results in Table 5-2 and 5-3 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.

Suspended solids concentrations as high as 780 mg/L occur in the Hutt River 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 (see Appendix G). 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. The particulate material in the discharge plume may also harbour microbiological contaminants, but the results of this study indicate that any increase in indicator bacteria in the water column is likely to be intermittent and localised.

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 in the Hutt River as water velocities during subsequent minor flood flows are sufficient to remove most of the fine sediment from the affected reach (Appendix F).

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;
- 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 (410m^3/s @ Birchville on 19/11/96)	780	-	-
	High river flow event (160m^3/s @ Birchville on 8/10/2007)	397	-	-
	High river flow event (80m^3/s @ Birchville on 5/2/2013)	65	-	
Waikanae	Placement of rip-rap	<2	98	68
	Truck crossing	<2	<2	11
	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

	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	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	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 Stokes Valley Stream

GWRC maintains the lower 1.6km of the Stokes Valley Stream from the confluence with the Hutt River to the confluence with Tui Glen Stream. The main activities undertaken in Stokes Valley Stream are the mowing of berms and removal of rubbish and debris (including from the stilling basin shown in Figure 3-5), with some structural repairs as required. Mowing of the berms involves tractor operation within the stream (see Figure 5-1), which includes some disturbance to the streambed and a temporary release of sediment.

As described in Section 3.1.1.2, Stokes Valley Stream is enclosed by culverts under the Stokes Valley Shopping Centre, and is concrete lined downstream as far as Stokes Valley Road. The lower reach, from Stokes Valley Road to the Hutt River has a more natural bed substrate consisting of gravel, silt and sand, however the channel retains the straightened and simplified character and has generally degraded habitat quality, particularly in respect of bank vegetation, riparian width and fish cover. FENZ predictions of macroinvertebrate distribution indicate a moderately degraded fauna which might include the mayfly *Deleatidium*, but is likely to be dominated by more tolerant taxa such as freshwater snails and Orthoclad midges (Table 3-14). A single fish record within the application area, together with FENZ predictions indicates that the core fish fauna of the lower stream is likely to consist of shortfin eel, longfin eel, redfin bully, common bully, juvenile trout and inanga. However, due to limited habitat availability the abundance of fish may be low.

Given the highly modified condition of the lower stream, neither the macroinvertebrate nor fish fauna are likely to be sensitive to the type of disturbance caused by the occasional passing of a tractor along the channel or the operation of a digger bucket to remove debris. It is noted however, that the practice of mowing right down to the waters' edge has reduced the quality and quantity of habitat for invertebrates and fish. Habitat could be improved by restoring stands of native vegetation at selected locations along either bank so as to increase the amount of shade and cover over the stream bed and to provide refuges for fish

No river nesting bird species are likely to be found on Stokes Valley Stream. Those birds that are found adjacent to the stream are terrestrial species that are common and widespread in the surrounding landscape and are unlikely to be affected by the very limited flood protection activities that occur in this watercourse.

Figure 5-1: Mowing stop-banks in Stokes Valley Stream

5.3.2 Speedy's Stream

GWRC maintains the lower 100m of Speedy's Stream from State Highway 2 upstream to just beyond the Speedy's Stream debris arrester (Figure 3-12). This involves the periodic removal of logs and other debris which may accumulate during a flood event.

Upstream of State Highway 2 the stream has retained much of its natural character; it supports regenerating indigenous vegetation at the riparian margins, and provides good quality habitat for benthic macroinvertebrates and fish. Site observations together with FENZ predictions indicate that it will support a moderately diverse macroinvertebrate fauna including mayflies (*Deleatidium and Coloburiscus*) caddisflies (*Aoteapsyche* and *Olinga*), freshwater snails (*Potamopyrgus*) and beetles (Elmidae). The core fish community is likely to consist of shortfin eel, longfin eel, redfin bully, and banded kokopu (Table 3-19). We consider this stream to be of relatively high value due its diversity of invertebrates and fish.

The potential for adverse effects caused by the periodic removal of logs from the debris arrester is low because the level of physical disturbance is low, and involves only very localised disturbance of the bed due to operation of machinery at the site of the arrester; the main effect consists of a brief release of suspended sediment to the water column in the short reach downstream of the structure.

No river nesting bird species are likely to be found on Speedy's Stream. Those birds that are found adjacent to the stream are terrestrial species that are common and widespread in the surrounding landscape and are unlikely to be affected by the very limited flood protection activities that occur in this watercourse.

5.3.3 Te Mome Stream

GWRC maintains the lower 1300m of Te Mome Stream from Bracken Street to Waione Street (Figure 3-17). The main flood protection activities undertaken are occasional dredging to remove silt and tidal debris, including removal of debris from around the flood gates to ensure their efficient operation.

Te Mome Stream is a tidally influenced former channel of the Hutt River approximately 1500m long and up to 40m wide. Based on site observations and FENZ predictions, the core fish fauna upstream of the tidal influence is expected to include long and shortfin eel, common bully, banded kokopu and inanga.

The western arm tidal flat of the Hutt Estuary, including parts of Te Mome Stream is an important roosting, wading and feeding area for a number of birds, including the variable oystercatcher, black shag, little black shag, royal spoonbill, reef heron, mallards and grey ducks, red-billed gulls, and terns (Wear & Haddon, 1992; McArthur, Robertson, Adams, & Small, 2015).

As this watercourse contains habitat of relatively high value for both fish and waterfowl, the periodic removal of accumulated silt and organic material does present some risks to this habitat which need to be effectively managed. The potential adverse effects associated with silt and vegetation removal from Te Mome Stream are outlined in Section 5.11.2 and a possible mitigation strategy is provided in Section 7.5.

5.3.4 Opahu Stream

GWRC maintains the outlet from Opahu Stream, which is tidally influenced arm of Hutt River opposite Sladden Park, and which is separated from the main flow of the Hutt River by a long training bank (Figure 3-35). The flood protection activities undertaken here include the occasional dredging of the outlet reach, maintenance of plantings, and periodically undertaking additional planting and landscaping.

The reach of the Hutt River beside the training bank has been identified by Taylor and Kelly (2001) as potential inanga spawning habitat. GWRC have undertaken works to enhance this habitat as part of flood protection upgrade works in the Ava to Ewen reach. The potential adverse effects associated with silt and vegetation removal from Opahu Stream 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.

GWRC work records for the Hutt River from 1999 to 2013 show that 45 rock groynes have been constructed within the flood protection scheme area, at an average of 3 per year. The application area is 28m in length, meaning that there is 56km of river bank witin the area. On average each year approximately 30m lineal length of river bank would be affected by new construction, which is approximately 0.05% of the total length of river banks within the application area. In total approximately 0.8% of the lineal length of river bank within the application area has been affected by rock groyne construction over the 14 year period. Rock groynes are not likely to be used in the smaller tributary streams.

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 increase 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 (refer Tables 5-2 to 5-4). Monitoring in the Hutt River has confirmed that turbidity and suspended solids concentrations return rapidly to near ambient levels once the in-stream activity ceases, usually within 1 hour. These results indicate that even during intense and sustained periods of in-stream channel works the aquatic biota throughout the reach would have the benefit of normal or near 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 Hutt River provided key habitat types such as swift riffles are retained.

McArthur *et al* (2015) identified six sites of value for native birds on the Hutt River including 2 breeding colonies of pied stilt, two small nesting colonies of black shag and two roosting/feeding sites (near the Silverstream Bridge and the Ava Rail Bridge). 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 pre-works planning prior to any construction activity in the Hutt River.

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. As observed in the Hutt River upstream of the Kennedy- Good Bridge (see Figure 5-2 and 5-3), the presence of groynes often results in deep pools associated with the toe of the structure, and water sheltered from the current downstream of the structure (refer Habitat Mapping Report in Appendix F). This combination of fast water, sheltered water, deep pools and large crevices amongst the boulders can potentially provide a variety of habitat potentially available for both native fish and trout. Perrie (2013a) recorded shortfin eel, longfin eel, koaro, inanga, crans bully, common bully, giant bully, brown trout and shrimp in deep water habitat associated with groynes on the Hutt River near Kennedy Good Bridge. The longfins 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. Death *et al* (2013) noted in respect of the Waiohine and Ruamahanga Rivers that the creation of boulder groynes would probably increase the availability of good habitat for many fish. A recent Fish & Game survey in the Hutt River near Kennedy Good Bridge shows that trout numbers through this reach are relatively high, and that many were located in deep holes associated with the rock groynes (Appendix H).

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 Hutt Rivers is likely to range from neutral to positive.

Figure 5-2: Rock groynes on the Hutt River upstream of Kennedy Good Bridge

Figure 5-3: Rock groyne on the Hutt River

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 5-4). Hydraulic excavators are used to contour 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 shaped 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 are used extensively in the Hutt River where 25% of the total bank length within the flood protection scheme area has a rock rip-rap lining. By comparison, this is more extensive than that on the Waikanae, Wainuiomata and Otaki Rivers, as indicated in Table 5-6.

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
Hutt	56km	13.8km	25%
Waikanae	14km	1.6km	11%
Wainuiomata	9.6km	0.015km	0.2%
Otaki	22.2km	4.3km	19%

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 Sladden Park, Te Mome Stream or Opahu Stream, construction of rip-rap rock lining could potentially destroy inanga spawning habitat. 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 behind the rock lining has the potential to provide overhanging cover, which may improve fish habitat in some instances.

Overall this activity would appear to have a neutral to negative 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 cover and woody inputs;
- Provision of fish refuges, for instance by imbedding concrete pipes within the structure; and
- Inclusion of additional boulders protruding out from the wall to break up the uniform flow.

Figure 5-4: Rock rip-rap lining against deep water on the Hutt River

Figure 5-5: Construction of rock rip-rap lining on the 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 protruding 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 arrester, 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 help create or re-establish a willow buffer zone along the edge of the river channel, and so maintain channel alignment. The structures afford protection to willow plantings 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 mounted on a large excavator (Figure 5-6).

Figure 5-6: Completed debris fence (Otaki River)

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. GWRC maintains a debris arrester in Speedy's Stream, approximately

400m upstream of the Hutt River. These structures are used at relatively few locations in the Hutt catchment, but remain a useful tool in the right situation.

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.

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 Table 5-2. 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 arresters may cause a temporary release of sediment and other material into the stream, but any discharge is likely to be of short duration and is unlikely to have any lasting adverse effect on downstream aquatic biota (refer to Section 5.3.2 regarding the debris arrester in Speedy's Stream).

Debris fences act 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 timber groyne ages, willows and other plants can begin to grow from the trapped debris, until the structure eventually becomes largely obscured and outflanked by the establishment of vegetation. If the fence achieves its purpose, this will result in the accumulation of gravels around the structure and causing the river channel to shift away from it, 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 one or two days per year in each of the large rivers. It is unlikely to have any significant long term impact on macroivertebrate 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 stop-banks such and mowing and riparian planting.

It may also include 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 7.1. Subject to the provisions in Section 7.1, 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 and 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 by 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.

It is noted however that GWRC does not plan to significantly extend the total area of willow plantings in the Hutt River corridor in the future. It is also noted that GWRC also undertakes significant planting of native trees including almost 16,000 assorted native plants in the Hutt River corridor (i.e. behind the 'front line' willow defence plantings) over the past thirteen years.

As indicated in Table 5-7, over half of the total river bank length within the Hutt River flood protection scheme area has vegetative protection. This is similar to vegetative bank protection in the Waikanae and Wainuiomata, but less than in the Otaki scheme.

Table 5-7: Summary of vegetative bank protection lineal lengths

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

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 1 – 1.5 m long and approximately 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 (Figure 5-7); 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 5-7: Planting willow poles using a digger

Potential effects

Short term construction effects are expected to be negligible because the level of physical disturbance is small and the works occur outside of the active river.

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 and 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 a number of 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).

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 macroinvertebrate and fish species or indirect food-wed mediated effects associated with reduced detrital food sources (Wagenhoff and Young 2013).

In summary, the removal of one or two rows of a stand of willows, or of isolated unstable trees, is unlikely to have a noticeable effect on river ecology in a large watercourse such as the Hutt River, whereas willow removal at the reach-scale may have significant adverse effects.

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 above in the preceding section. They may include reduced habitat heterogeneity, and the addition of wood and carbon sources to the river.

5.11.2 Removal of aquatic vegetation and silt

Description of activity

This activity includes the clearance of aquatic macrophytes (aquatic weeds) and silts 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 area covered by the Hutt River consent application includes a number of stormwater drains which are mechanically cleared from time to time. These appear to be of marginal ecological value, but nevertheless may potentially provide habitat for eels or other fish (refer Figure 5-8).

Dredging of the lower Opahu and Te Mome streams around the floodgates and clearance of the Stokes Valley stilling basin also falls into this activity type.

Potential effects

Clearance of aquatic macrophytes and silt from lowland streams and drains is likely to result in significant short term habitat disturbance. Hand clearance is the least disruptive method but may not be viable for large reaches of stream. Mechanical excavation can result in the immediate loss of a high proportion of the available plant cover. Potential adverse effects listed by Greer (2014) include the following:

- *Loss of fish spawning habitat.* Inanga spawn along banks of tidal reaches of creek and drains. 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 long periods of time in some watercourses (but probably not those in the Hutt River application area). 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 drain clearing, noting that not all of these strategies will be successful or necessary all of the time. Those strategies that are applicable to clearing low gradient streams and drains in the Hutt catchment are listed in Section 7.5.

Figure 5-8: Stormwater drain clearing in the Hutt catchment

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 thegravel armouring layer by dragging a tine through it. This lfacilitates the mobilisation of the gravel during floods (Figure 5-9).

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

Figure 5-9: Beach ripping in the Hutt River

Potential effects

This activity is unlikely to have any immediate downstream effects on water quality or aquatic habitat as it occurs on dry beaches out of the active channel. It 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 river beds (i.e., Rebergen, 2012). McArthur *et al* (2015) identified six sites of value for native birds on the Hutt River including 2 breeding colonies of pied stilt, two small nesting colonies of black shag and two roosting/feeding sites (near the Silverstream Bridge and the Ava Rail Bridge). In light of this information McArthur made a number of recommendations for the protection of the pied stilt 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.

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; GW has advised that any beach or bed contouring completed at a location where debris removal occurs is accounted for as beach or bed recontouring in work records.

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.

Regarding occasional dredging of Opahu Stream, this area has been identified as supporting potential inanga spawning habitat, therefor the timing of any works is critical; disturbance of the bed or banks of these areas should not occur during spawning from March to April inclusive.

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 stockpiles 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.

However, the gravel extraction methodology used in the Hutt River since 2006 has been focused on deliberate lowering the active bed in the reach from around Belmont down to Melling Bridge. This is within the natural aggradation zone for the river, where the river gradient lessens and the sediment load carried by the river is deposited on the bed. To achieve the comprehensive lowering of the bed that is required it has been necessary to work in the low flow channel, with a lower channel being formed beach by beach using a combination of gravel extraction and bed recontouring (see Section 5.12.1). The work has included working the new channel to a meander pattern with a pool and riffle form (Figure 5-10). The intention is to maintain a well-defined and relatively regularly winding 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.

This approach is intended to avoid the creation of a uniform straight, shallow channel, which had been observed to occur in the Hutt River as a result of extracting gravel only by the dry extraction method, which relies heavily on the natural river processes to rework the river channel to a new form post extraction.

Figure 5-10: Gravel extraction; shaping of a new low flow channel with meander pattern

Potential effects in the Hutt River

(i) Birds

McArthur *et al* (2015) identified six sites of value for native birds on the Hutt River including 2 breeding colonies of pied stilt, two small nesting colonies of black shag and two roosting/feeding sites (near the Silverstream Bridge and the Ava Rail Bridge). McArthur made a number of recommendations for the protection of the pied stilt 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.

(ii) Herpetofauna

Several lizard species and two frog species are recorded within the Hutt Valley flood corridor. These are the Ngahere gecko, barking gecko, Raukawa gecko, copper skink, northern grass skink and ornate skink, and two introduced frogs. Flood protection activities may affect the margin of some lizard populations in the Hutt Valley, however lizards are likely to be sparsely disturbed in those areas where flooding occurs frequently; and rare in built-up urban areas. They may be represented only by northern grass skink in these cases. Accordingly, the risk to herpetofauna associated with flood protection activities in the riverbed are 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 Hutt River, although in those cases where trucks are required to cross the river there is potential for minor 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 Hutt catchment which has hard-sedimentary geology, and where the fine sediment content of gravels is low. An assessment of riverbed sediment in the Hutt River near Kennedy Good Bridge indicates that clay/silt and sand make up approximately 1% and 7% of the total substrate, respectively (refer habitat assessment in Appendix A). Nevertheless, Perrie (2013a) 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 Hutt River, entails extensive disturbance of bed material and significant release of suspended sediment into the water column over an extended period of some weeks. 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 fairly rapidly 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 required to cease by 5:00pm each day the aquatic biota downstream of the works would have the benefit of normal water quality for more than 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). Koara 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 Hutt River, banded kokopu is likely to be the most sensitive to suspended solids.

Death *et al* (2013) found that bed re-contouring 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 it declined dramatically after the first fresh. Extensive bed re-contouring 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 there was no increase in fine sediment cover in riffle habitat 750m downstream of the works Cameron (2015a).

In summary, these works cause a major increase in water column suspended solids, but this effect is temporary and does not continue much beyond the cessation of works. The works also caused increased rates of sediment deposition in downstream river habitats but this effect was also short-lived, seldom extending 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 (Cameron, 2015d) and the Hutt River during channel re-alignment (Cameron, 2015a) 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 (Figure 5-11 and 5-12). 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 well-formed pools and riffles (refer Section 7.4).

(v) Disturbance of macroinvertebrate communities

Gravel extraction in the Hutt 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 Hutt River where a healthy and diverse benthic community in the river upstream of the works area would be available to resource the re-colonisation of 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, potential reducing food supplies for fish.

Figure 5-11: Riffle on 20th December 2012 near Kennedy Good Bridge, one day after completion of gravel extraction and channel shaping works, showing simplified channel structure and reduced substrate particle size (compared with pre-works)

Figure 5-12: Riffle on 14th February 2013 near Kennedy Good Bridge, having been re-worked by three high river flow events, showing increased channel complexity and increased substrate coarseness.

(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 (Death & Death, 2013). 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 (refer Appendix H). The Fish & Game surveys from 1999 to 2014 also show the trout abundance is highest in the lower river within the reach affected by a range of flood protection activities than it is higher in the catchment, upstream of the reach managed by GWRC.

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 Hutt 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. Despite the general unsuitability of the Hutt River main-stem for inanga spawning, there are records of inanga spawning in areas in the tidal reach where bank armouring is absent. These include observations near the Sladden Park boat ramp in Petone, at Te Mome Stream and Opahu Stream.
- Other galaxiid species including koaro, banded 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 in minor water courses outside (upstream) of the application area.
- 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. Some spawning habitat will occur within the application area
- Trout move into headwater tributaries to spawn during May and June. The lower 100m reach the Akatarawa River is the only reach within the application area which may potentially include trout spawning habitat. Recommendations for the protection of trout spawning habitat are given in Section 7.6.

The proposed 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, torrentfish and brown trout. 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 (and summarised in Table 5-8).

Table 5-8: Recommended constraints of works in the wetted river channel – Hutt 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>Hutt River</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="3" colspan="4">No more than 3 day’s work per site or 15 days per 10km</td></tr>
<tr><td>Akatarawa River</td><td></td><td></td><td></td><td></td><td colspan="3">No works in the trout spawning reach</td><td></td></tr>
<tr><td>Hutt Estuary</td><td></td><td></td><td colspan="3">No works near inanga spawning habitat</td><td></td><td></td><td></td></tr>
</table>

Potential Effects in the Hutt Estuary

Mobilisation of fine sediments from gravel extraction works in the river has the potential to increase sedimentation rates further downstream in the estuary. Monitoring undertaken between 2010 and 2014 indicates low sedimentation rates in the Hutt Estuary (Stevens & Robertson, 2014), despite a gravel extraction works being undertaken in the Hutt River over that period. Nevertheless the sub-tidal sediments have relatively high mud content and shallow RPD indicating that the estuary may be susceptible to sediment related impacts for poor clarity and muddy substrates.

In light of these factors it is recommended that gravel extraction from the active channel in the Hutt River should be subject to the restrictions listed in Section 7.6. These restrictions, in combination with the expected return to ambient water quality each night, provide to a reasonable extent for the peak sensitivity periods of indigenous fish (i.e., McDowell 1995).

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 (refer Section 5.9.2). McArthur *et al* (2015) identified six sites of value for native birds on the Hutt River including 2 breeding colonies of pied stilt, two small nesting colonies of black shag and two roosting/feeding sites (near the Silverstream Bridge and the Ava Rail Bridge). In light of this information McArthur made a number of recommendations for the protection of the pied stilt 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 (Figure 5-11). 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.

In the Hutt River bed recontouring is also 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. (TNote 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 the 13 years to January 2012

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

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 (refer to 10.5). 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 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 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.

Short term and long term 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 recountering 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.

6 Cumulative Effects

The potential for effects of GWRC operations and maintenance activities to be increased by other similar activities undertaken in the catchment by other parties is low, principally because there are only two other granted consents of relevance, both held by NZTA to extend or maintain existing culverts and to undertake associated disturbance of the beds of watercourses

There may be a cumulative effect resulting from the extension of permanent works (i.e. rip-rap linings). However, recent surveys of native fish and trout numbers in the Hutt River at Belmont where river banks are extensively lined with rip-rap indicate a relatively diverse and abundant fish fauna, 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 lower river affected by flood protection activities that in the river upstream of the managed reach.

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 Code and 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 and Monitoring Plan 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 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 Hutt River from flood protection activities on gravel beaches, including the following changes to the Code:

- The wording of the Code should be modified to specify that flood protection activities causing disturbance to dry gravel beaches on the Hutt River should be programmed outside of the shorebird nesting season 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 should be updated to reflect the new information on the presence of a breeding population of pied stilts on the Hutt River between XS1310 and XS2270 and between XS2731 and XS2900. A restriction period applicable to these two reaches should be added to Table 6 of the Code, specifying that works on dry gravels between 1 August and 28th Feb such work should be avoided where possible. When such work must be carried out during the shorebird nesting season, they should be preceded by a survey for pied stilt nests and chicks, carried out by an appropriately experienced ornithologist.
- If nests or chicks are found during pre-works surveys, exclusion zones should be maintained at 75 metres from nests and 50 metres from chicks during any activities causing continuous disturbance to habitat (e.g. beach re-contouring or gravel extraction). Exclusion zones can be reduced to 25 metres for both nests and chicks for any activity causing periodic disturbance (e.g. passing machinery).
- In addition, an appropriate trigger level for the Hutt River pied stilt population should be added to the EMP to provide a mechanism by which the Flood Protection department can devise an appropriate responses to any future decline observed in this population. That trigger level is "*50% or more decline in the average number of breeding pairs detected between one 3-year set of surveys and the next*".

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,
- give consideration to the protection of high-value areas of riparian native vegetation where such areas are threatened by erosion, and
- for smaller watercourses such as Stokes Valley Stream, where current practice is to mow right down to the waters' edge, give consideration to improving instream habitat by restoring riparian edge vegetation at selected locations.

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 recolonise.

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

- planting downstream of 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, 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 and between 1 May and 30 September avoid clearing waterways identified as trout 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 any 10 km of river length.
- 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 the Akatarawa River during the trout spawning period between 1 May and 31 July.

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 twelve Hutt 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 Hutt 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, some habitats in which flood protection activities can occur, including deeper water habitats, which are difficult to survey by electric fishing methods, are not well represented in the database. A recent survey conducted by GWRC (Perrie, 2013) covered both shallow and deep water habitats in the Hutt River near the Kennedy-Good Bridge, by backpack electric fishing, trapping and spotlighting, going some way towards addressing these information gaps.

It is recommended that further investigations of this type be undertaken at three yearly intervals in selected reaches of the Hutt 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 will be continued using drift dive methodology, at eight reaches on the Hutt River as described in Pilkington (2014). If possible it would be desirable to align drift dive reaches with NCI survey reaches (Table 3-13)

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 Hutt 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 Hutt 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, 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 Hutt 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 Hutt Valley 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 managed by GWRC 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 200m to 250m 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.

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

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.

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. (2014). *GWRC Flood Protection Operations and Maintenance Consents - Habitat Assessment Forms.* Report prepared for Greater Wellington Regional Council.

Cameron, D. (2015). *Hutt River Benthic ecology Monitoring, November 2014 to April 2015.* Prepared for Wellington Water.

Cameron, D. J. (2015). *Ecological Effects of Flood Protection Activities in the Hutt River.* Prepared for Greater Wellington Regional Council.

Cameron, D. J. (2015). *Te Marua Water Treatment Plant, Annual Benthic Biota Survey - Hutt River.* Report prepared for Wellington Water.

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

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. (2012). *Wairarapa River Management and their Fish Communities.* Prepared for Greater Wellington Regional Council.

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.

Golder Associates. (2012). *Fish Passage at Pipeline Crossing of the Hutt River.* Report prepared for Hutt City Council.

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 2014). *Environmental Code of Practice and Monitoring Plan for Flood Protection Activities.* Greater Wellington Regional Council.

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.

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

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.

Hudson, H. R. (2005). *Sustained drainage management: Coarse Sediment Trap.* NZWERF.

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.

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., Playle, S., & Govella, S. (2013). *Diversity, abundance and distribution of birds on selected rivers in the Wellington Region.* Greater Wellington Regional Council.

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.

Milne, J. R. et al. (2010). *Mangatarere Stream catchment water quality investigation. Greater Wellington Regional Council report GW/EMI-T-10/72.*

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.

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.

Reidy, G. (2007). *Waiohine, Upper Ruamahanga and Waipoua River Morphology Report - Covering the period 2000 to 2006.* 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 Coasts and Wellington Harbour. Risk Assessment and Monitoring Recommendations.* Prepared for Greater Wellington Regional Council.

Robertson, B., & Stevens, L. (2011). *Hutt Estuary: Fine Scale Monitoring 2010/11.* Report prepared for Greater Wellington Regional Council.

Robertson, B., & Stevens, L. (2012). *Hutt Estuary: Fine Scale Montoting 2011/12.* Report prepared for Greater Wellington Regional Council.

Robertson, C., Dowding, J., Elliot, G., Hitchmough, R., Miskelly, C., O'Donnell, C., et al. (2012). *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.*

Sim, D. (1997). *Effect of gravel extraction on the banded dotterel (Charadius bicinctus).* Unpublished report, Wellington Regional Council.

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.

Stevens, L., & Robertson, B. (2014). *Hutt Estuary: Intertidal Macroalgal Monitoring 2013/14.* Report prepared for Greater Wellington Regional Council.

Stevens, L., & Robertson, B. (2014). *Hutt Estuary: Intertidal sediment monitoring summary, 2013/2014.* Summary report prepared for Greater Wellington Regional Council.

Stevens, L., Robertson, B., & Robertson, B. (2004). *Broad Scale Habitat Mapping of Sandy Beaches and River Estuaries - Wellington Harbour and South Coast.* Prepared for Greater Wellington Regional Council.

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

Taylor, & Kelly. (2001). *Inanga spawning habitats in the greater Wellington Region.* Report prepared for Greater Wellington Regional Council.

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

Tonkin and Taylor. (2015). *Resource Consent Applications - Hutt River/Te Awa Kaririani.* Report prepared for Greater Wellington Regional Council.

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.

Weir, R., & Haddon, M. (1992). *Summary of Marine Ecological and environmental studies in Wellington Harbour and environs.* Coastal Marine Reearch Unit Report No. 17. Victoria University of Wellington.

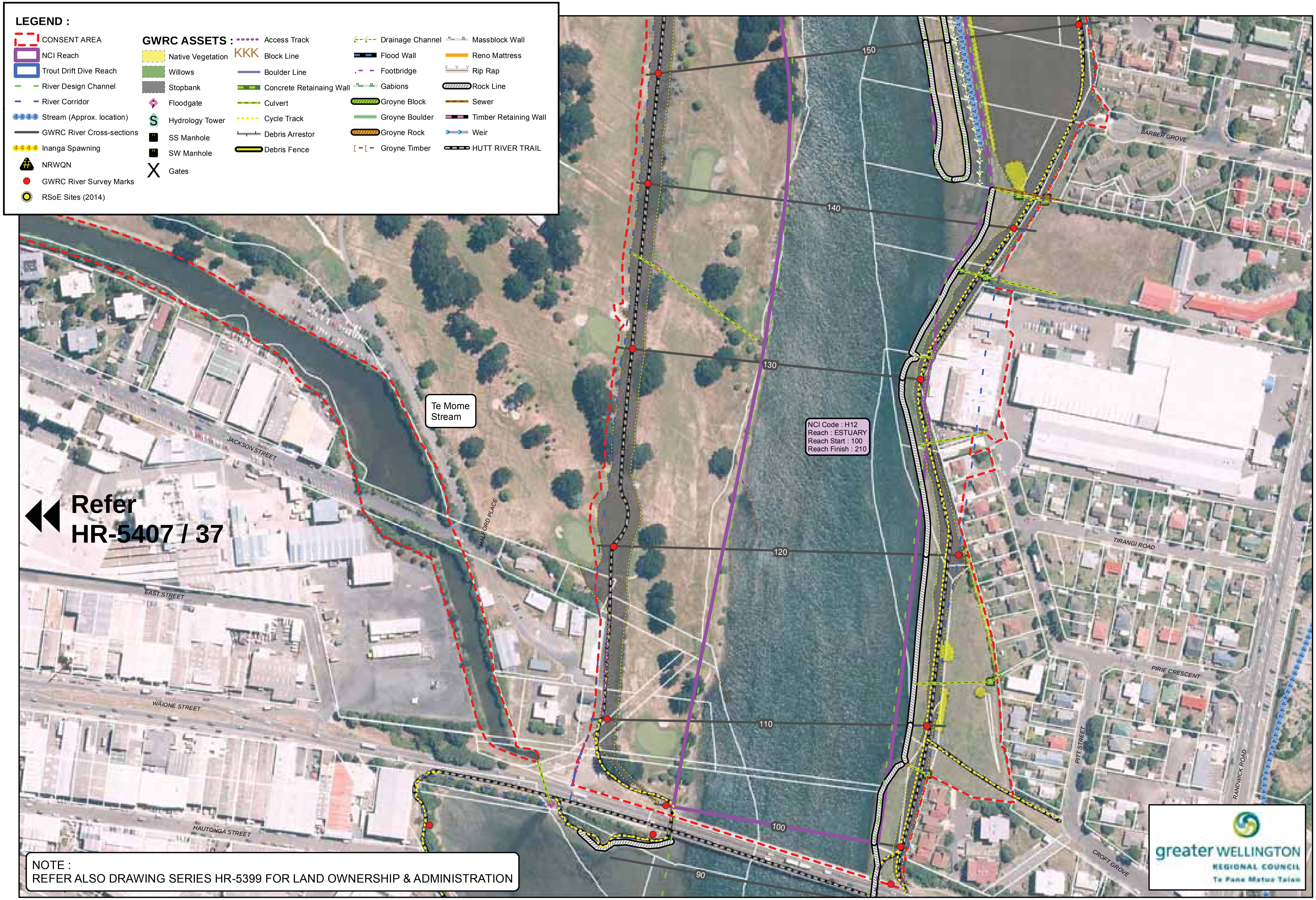
Weir, R. (2010). *Shingle Extraction and By-product Disposal in Wellington Harbour: Environmental Effects Assessment in relation to a Resource Consent Application.* Report prepared for Greater Wellington Regional Council.

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 Hutt River Application Area



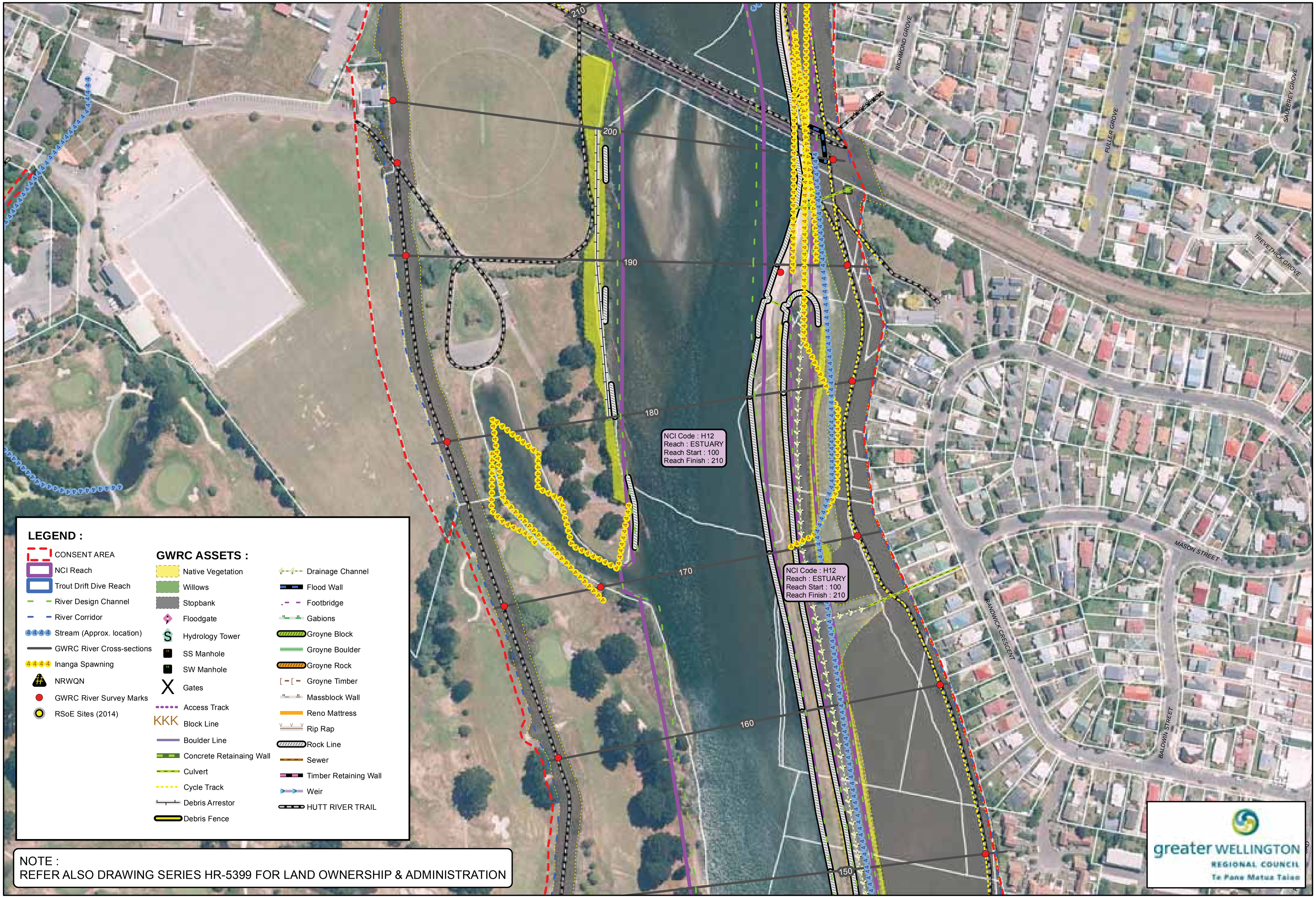
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 1a

GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road Including Te Mome Stream at Hutt Mouth)

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

DWG No. HR-5407 / 1



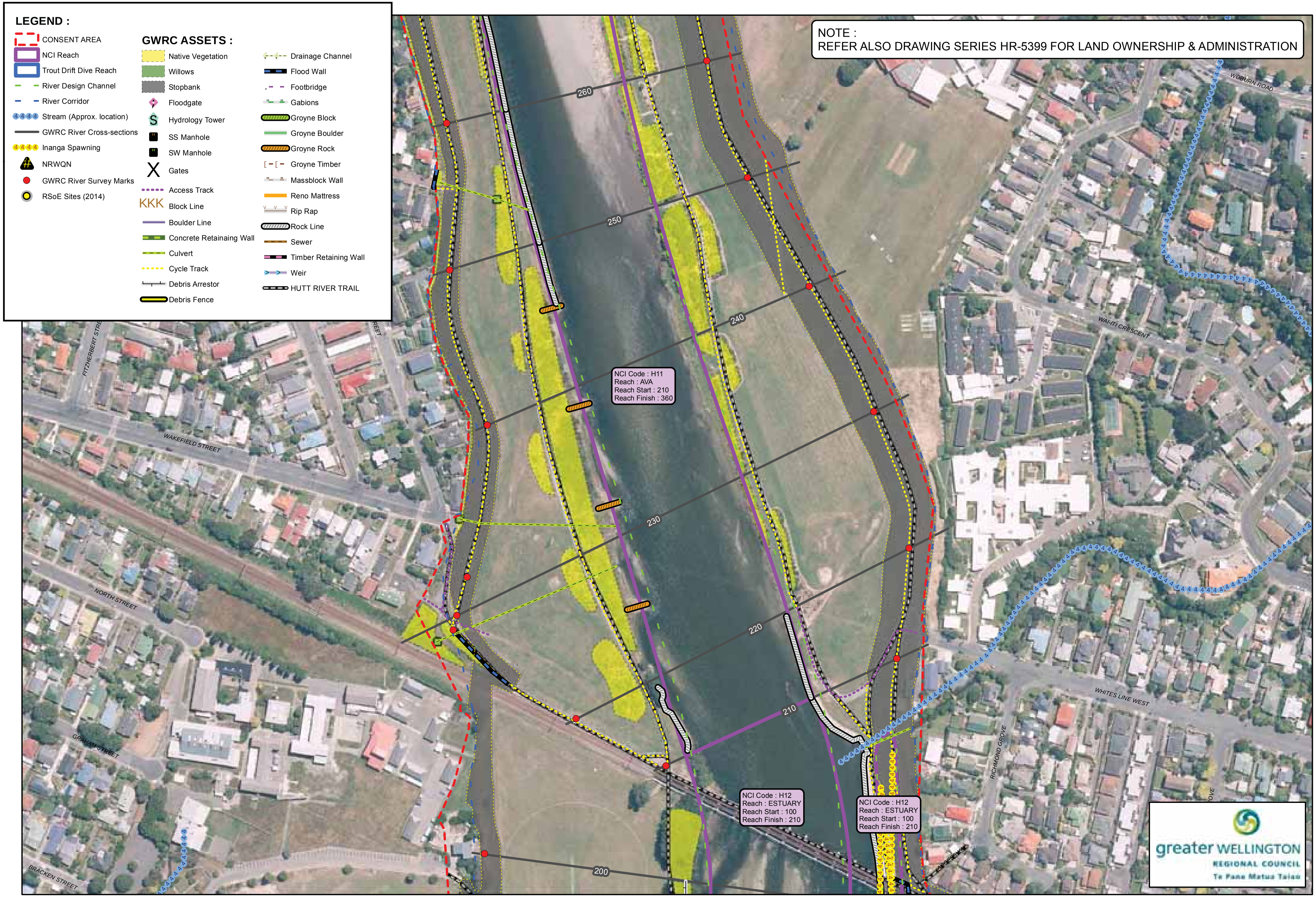
File ref : Hutt Application Area March 2014 - Sheet 2a.mxd

A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 2a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 2**



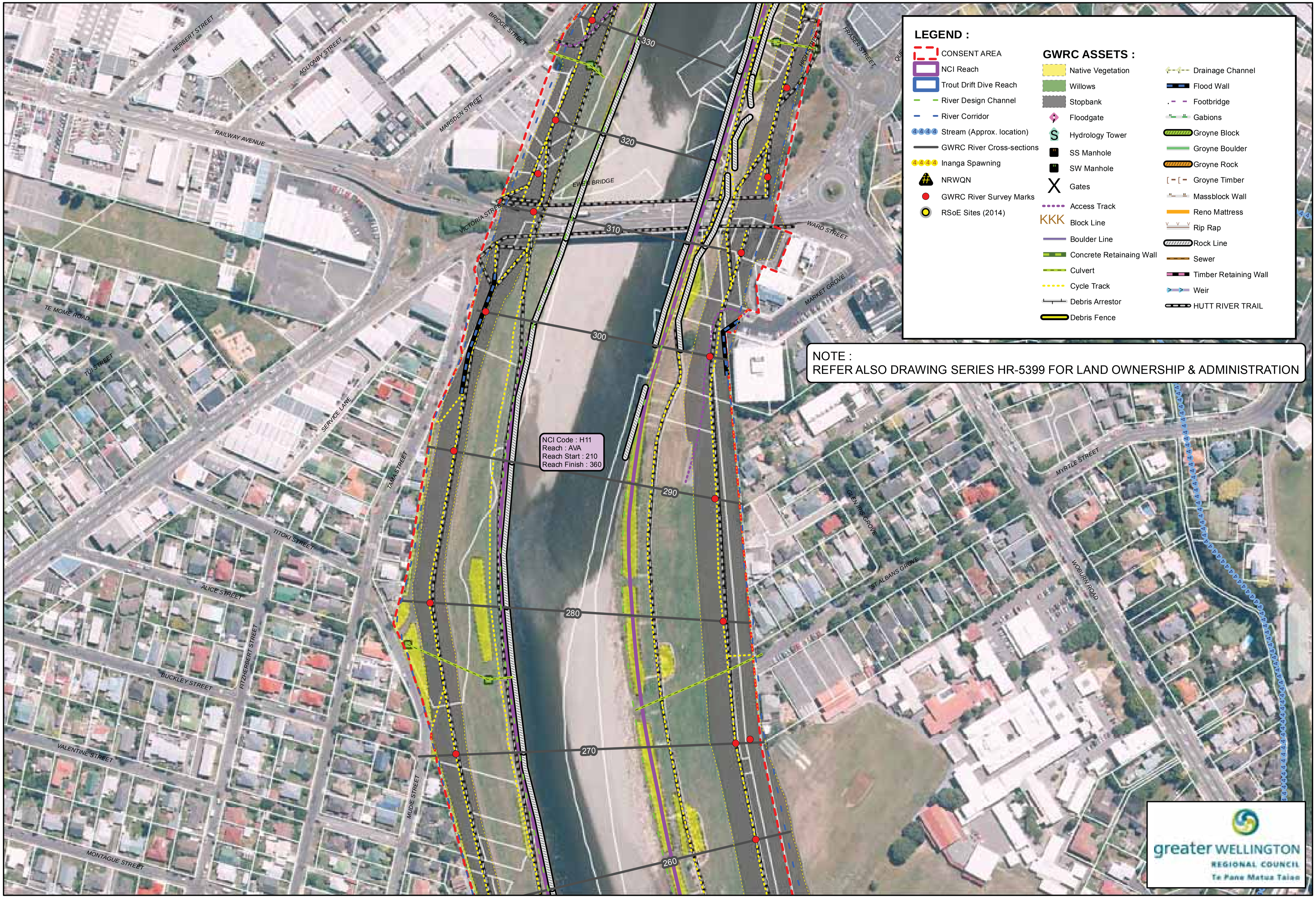
HUTT RIVER - CONSENT AREA - Map 3a

GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 3**

File ref : Hutt Application Area March 2014 - Sheet 3a.mxd



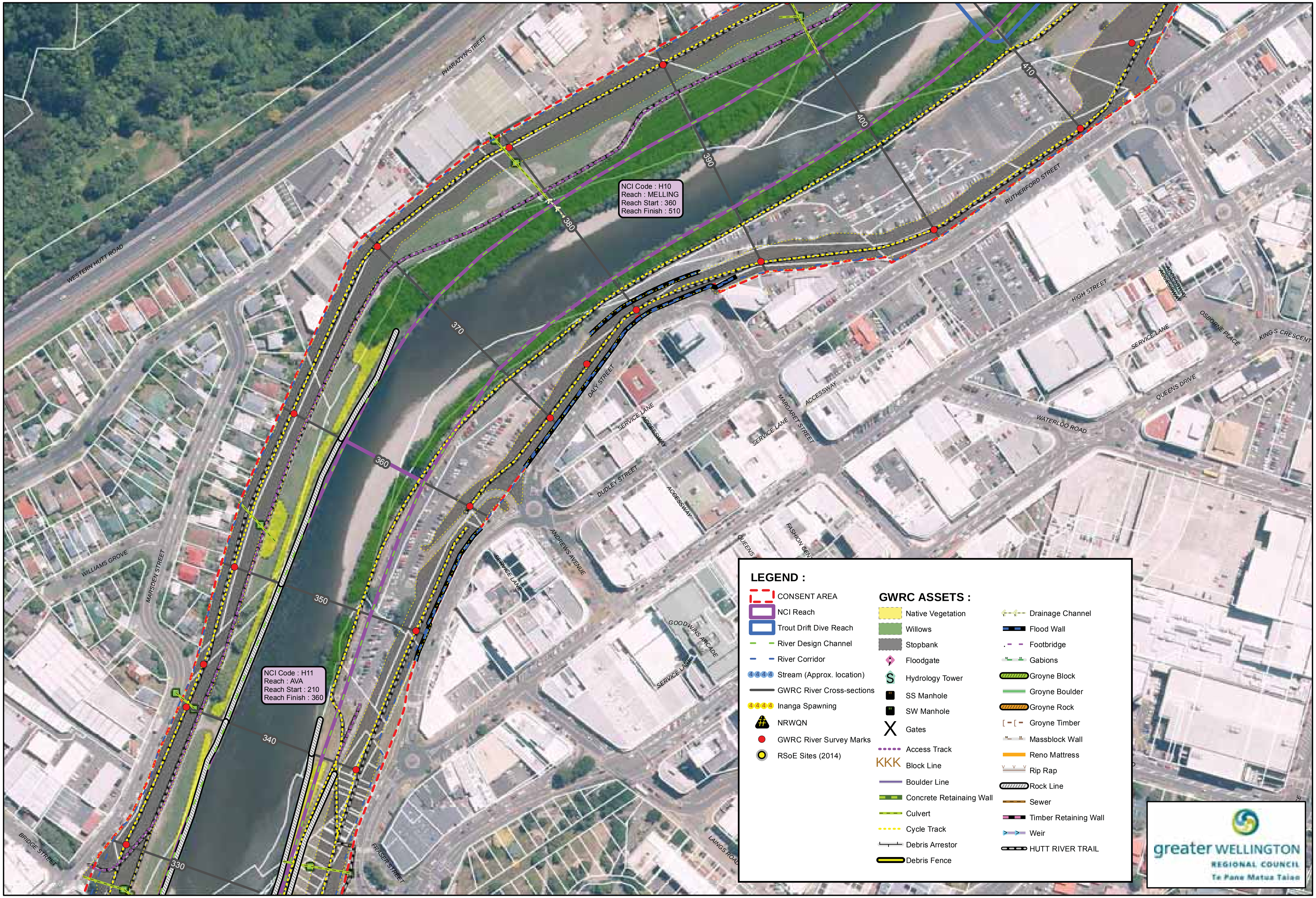
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 4a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 4**

File ref : Hutt Application Area March 2014 - Sheet 4a.mxd



File ref : Hutt Application Area March 2014 - Sheet 5a.mxd

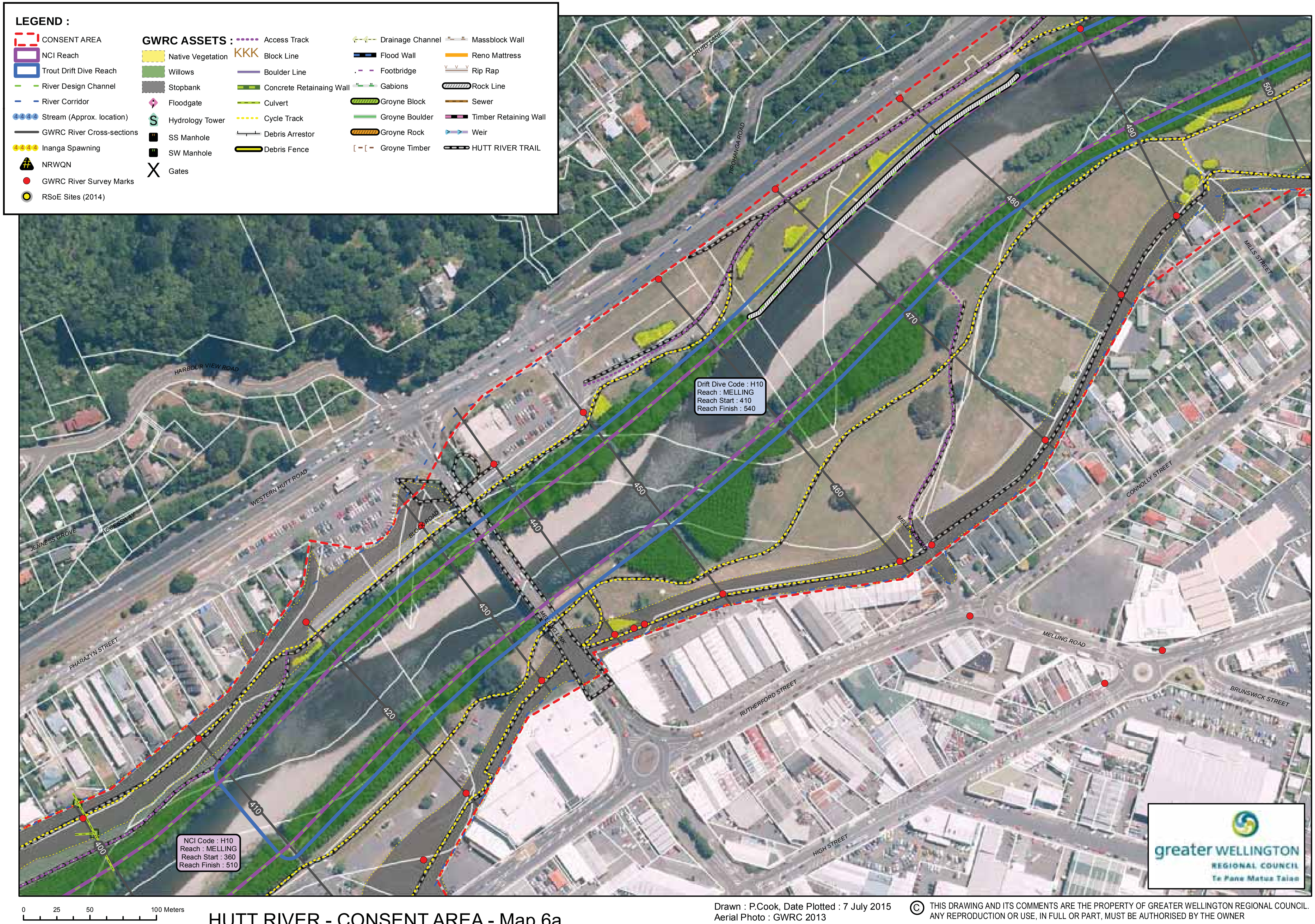
greater WELLINGTON REGIONAL COUNCIL Te Pane Matua Taiao

A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 5a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 5**



A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 6a

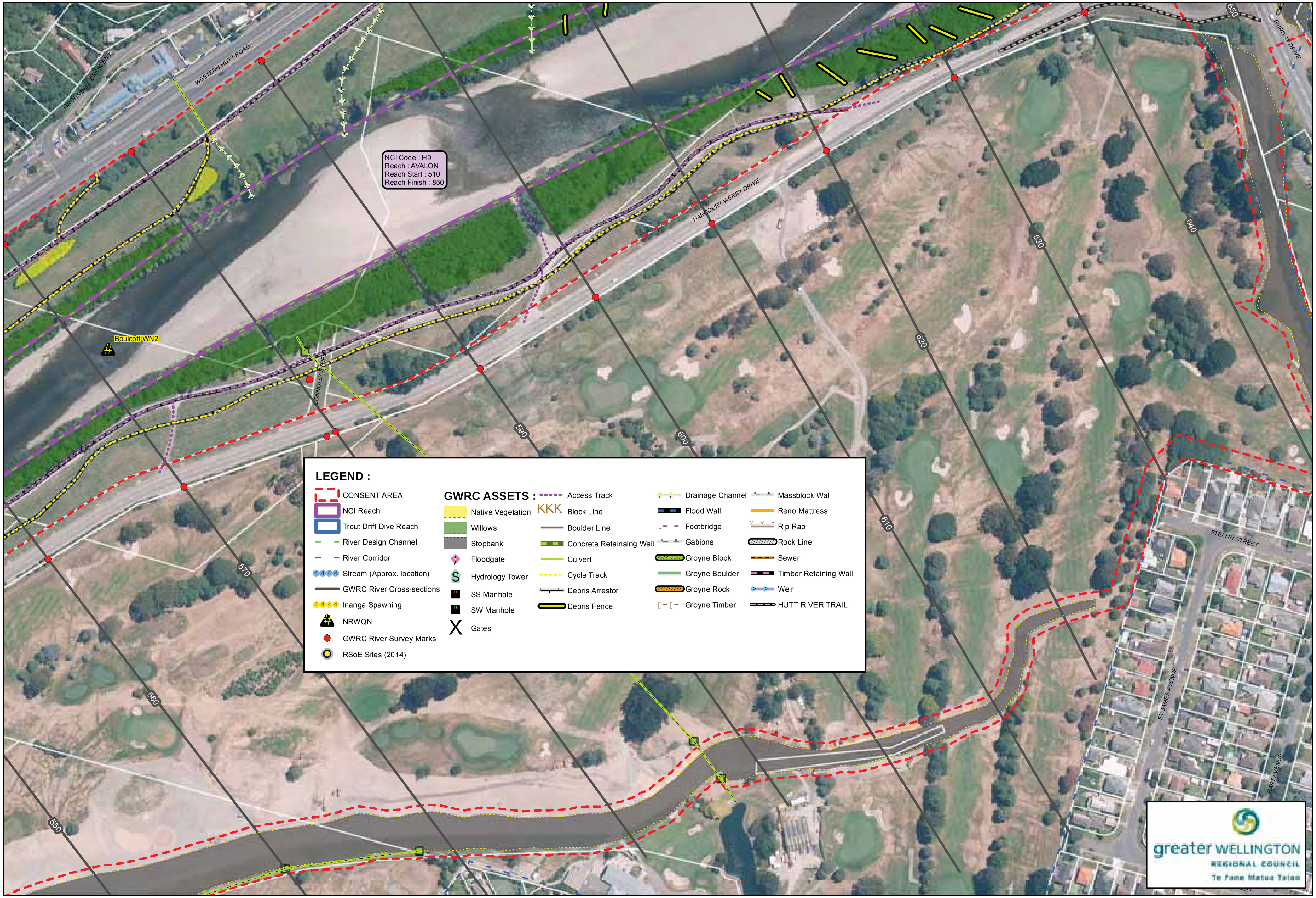
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 6**

greater WELLINGTON REGIONAL COUNCIL Te Pane Matua Taiao

File ref : Hutt Application Area March 2014 - Sheet 6a.mxd



A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 8a

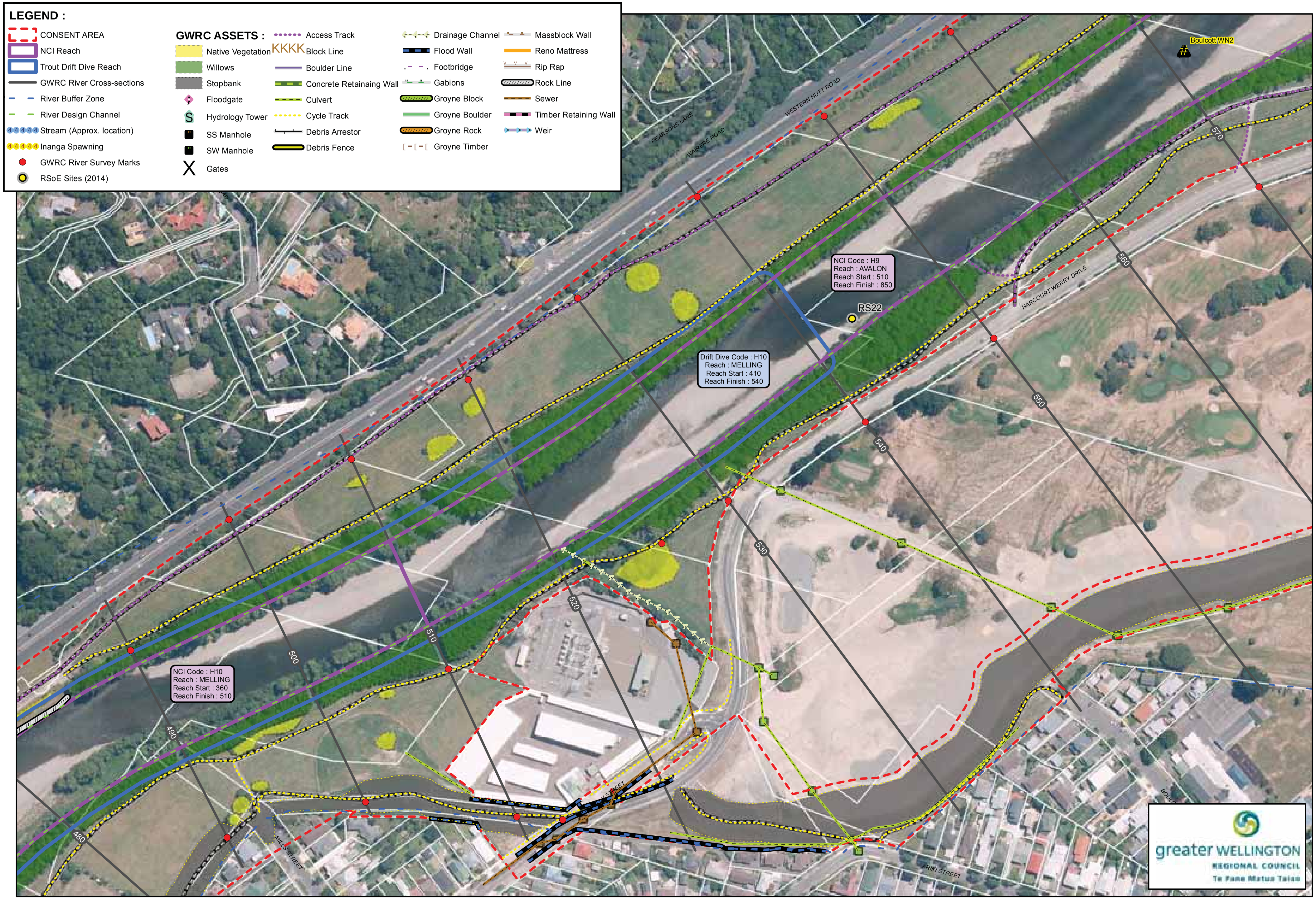
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. HR-5407 / 8

greater WELLINGTON REGIONAL COUNCIL Te Pane Matua Taiao

File ref : Hutt Application Area March 2014 - Sheet 8a.mxd



HUTT RIVER - CONSENT AREA - Map 7a

GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

greater WELLINGTON REGIONAL COUNCIL Te Pane Matua Taiao

DWG No. **HR-5407 / 7**

File ref : Hutt Application Area March 2014 - Sheet 7a.mxd

File ref : Hutt Application Area March 2014 - Sheet 9a.mxd

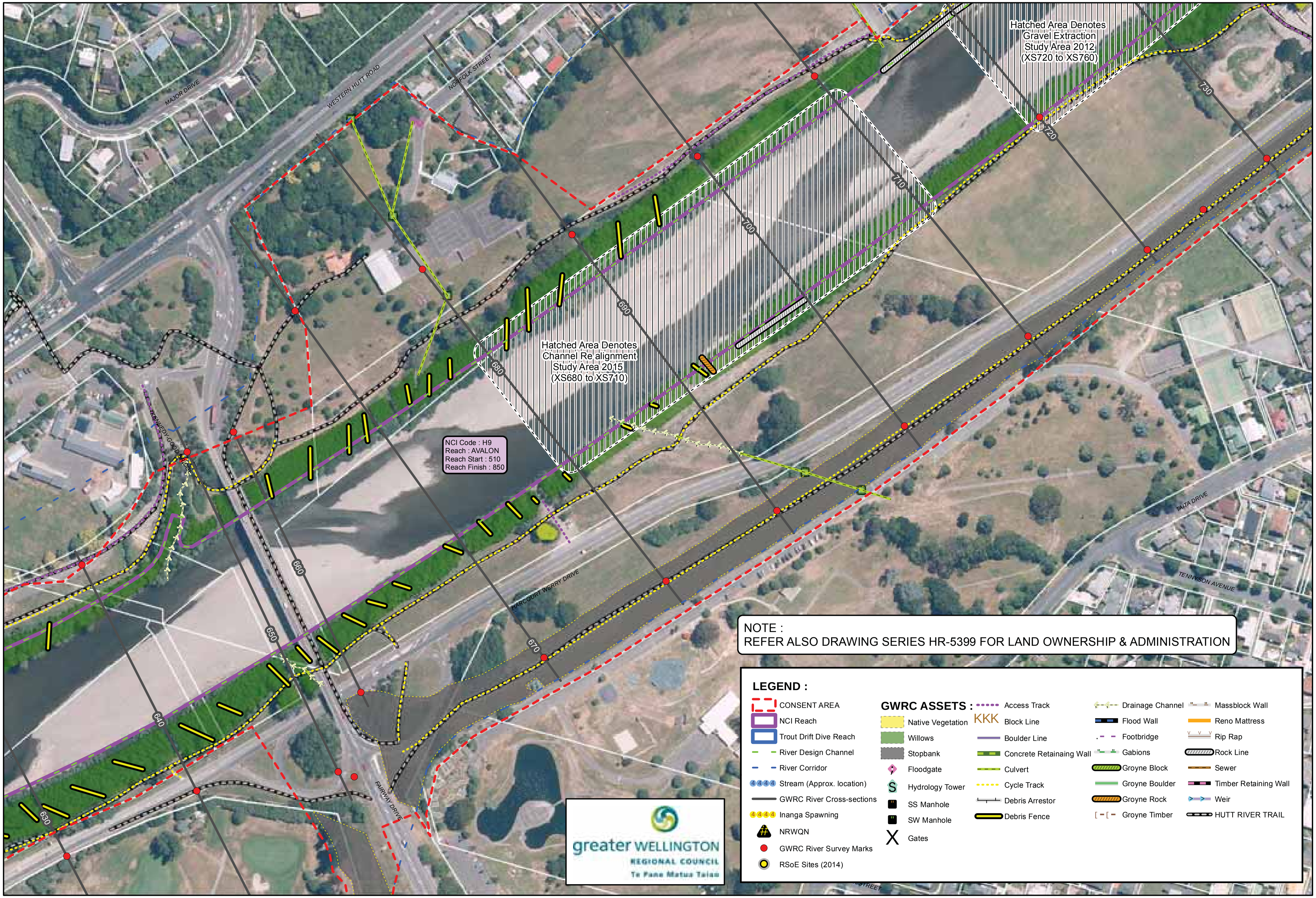
0 25 50 100 Meters

A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 9a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 9**



File ref : Hutt Application Area March 2014 - Sheet 10a.mxd

0 25 50 100 Meters

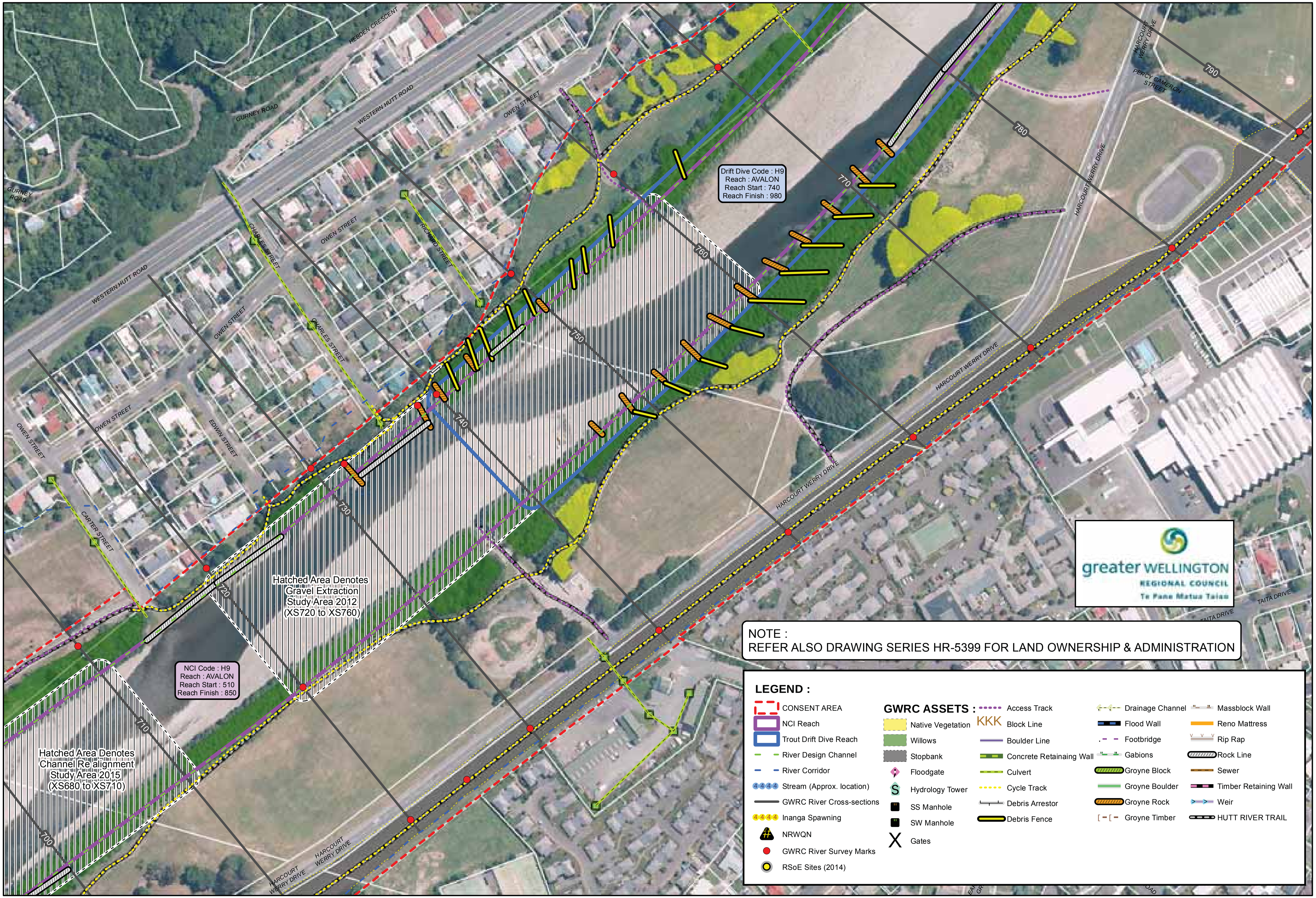
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 10a

GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 10**



REGIONAL ORTHOPHOTOGRAPHY COPYRIGHT : GWRC / NZAM 2010
TOPOGRAPHIC AND CADASTRAL DATA IS COPYRIGHT LINZ

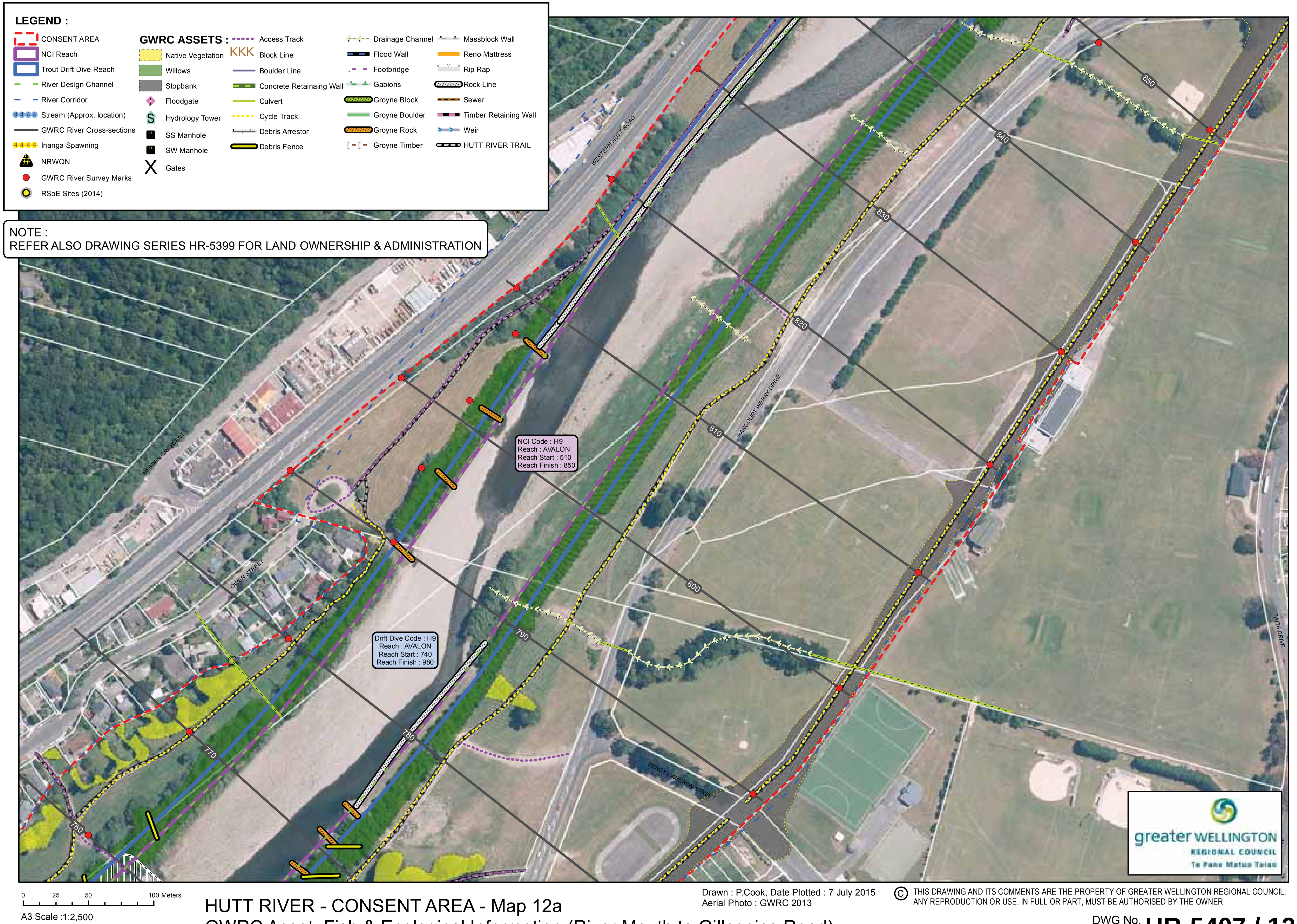
File ref : Hutt Application Area March 2014 - Sheet 11a.mxd

0 25 50 100 Meters
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 11a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. HR-5407 / 11

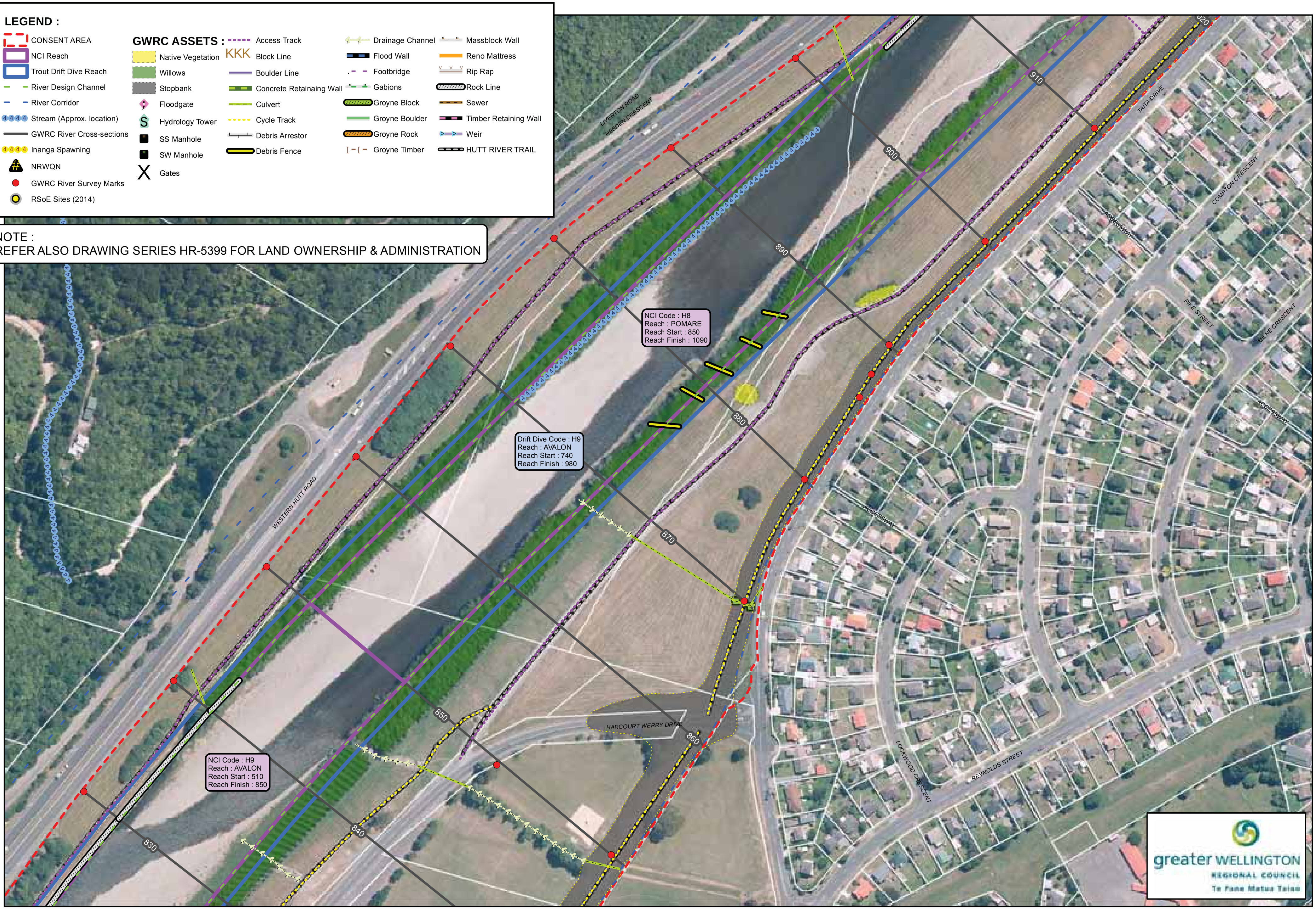


File ref : Hutt Application Area March 2014 - Sheet 12a.mxd

HUTT RIVER - CONSENT AREA - Map 12a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 12**



REGIONAL ORTHOPHOTOGRAPHY COPYRIGHT : GWRC / NZAM 2010
TOPOGRAPHIC AND CADASTRAL DATA IS COPYRIGHT LINZ

File ref : Hutt Application Area March 2014 - Sheet 13a.mxd

greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

0 25 50 100 Meters

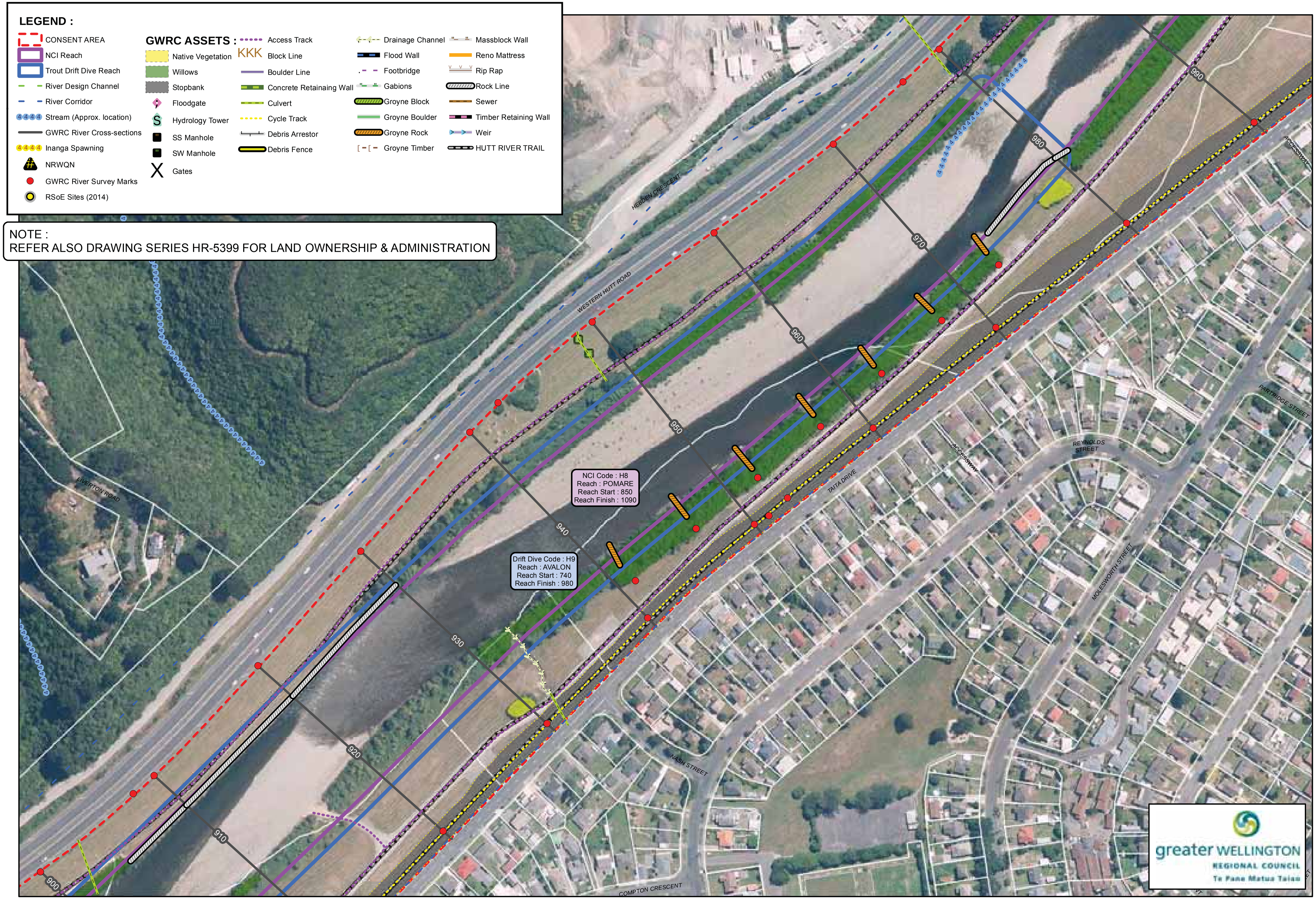
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 13a

GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 13**



NOTE :
REFER ALSO DRAWING SERIES HR-5399 FOR LAND OWNERSHIP & ADMINISTRATION

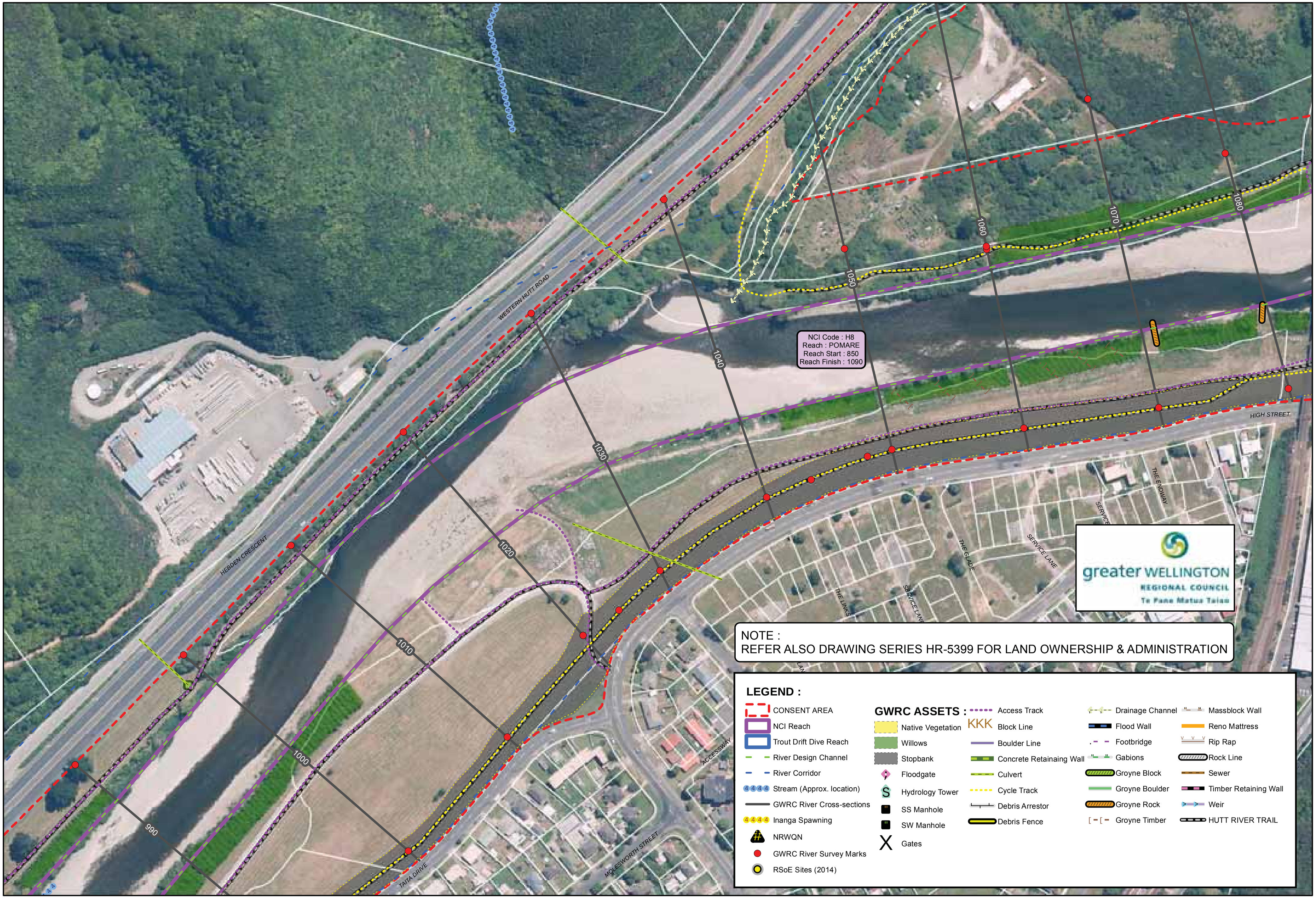
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 14a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 14**

File ref : Hutt Application Area March 2014 - Sheet 14a.mxd



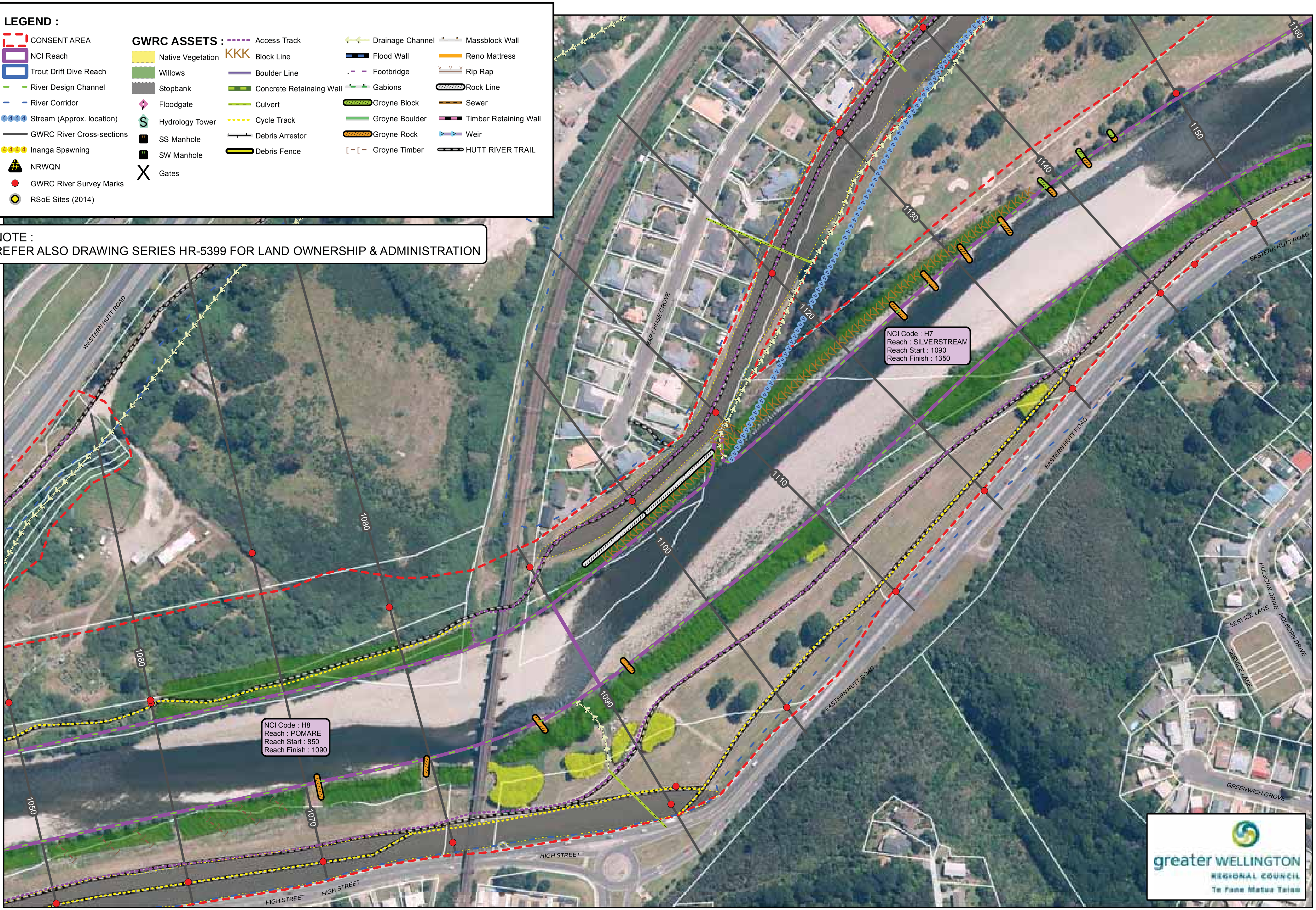
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 15a

GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

File ref : Hutt Application Area March 2014 - Sheet 15a.mxd

DWG No. **HR-5407 / 15**



A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 16a

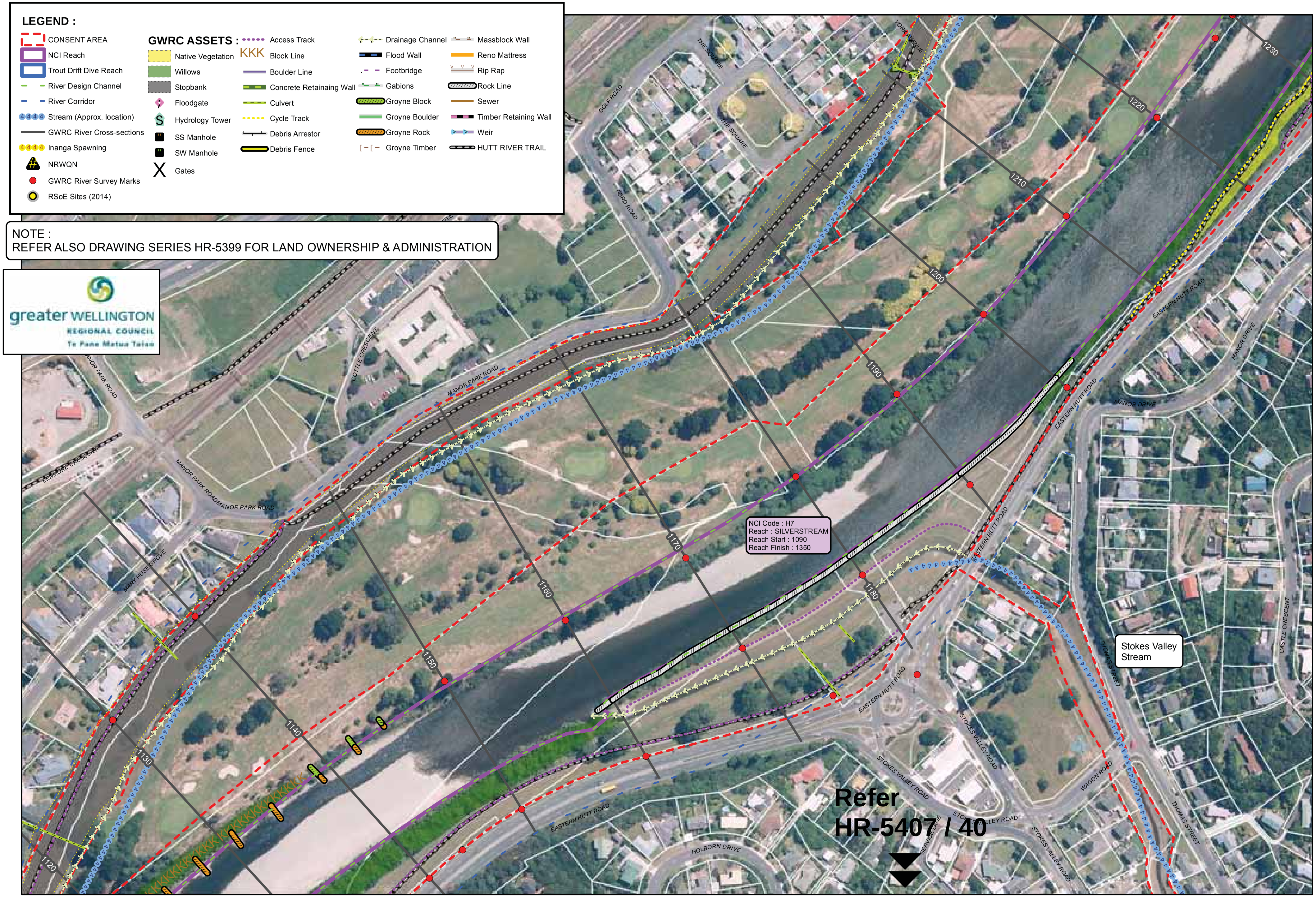
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

Drawn : P.Cook, Date Plotted : 7 July 2015

Aerial Photo : GWRC 2013

DWG No. HR-5407 / 16

File ref : Hutt Application Area March 2014 - Sheet 16a.mxd



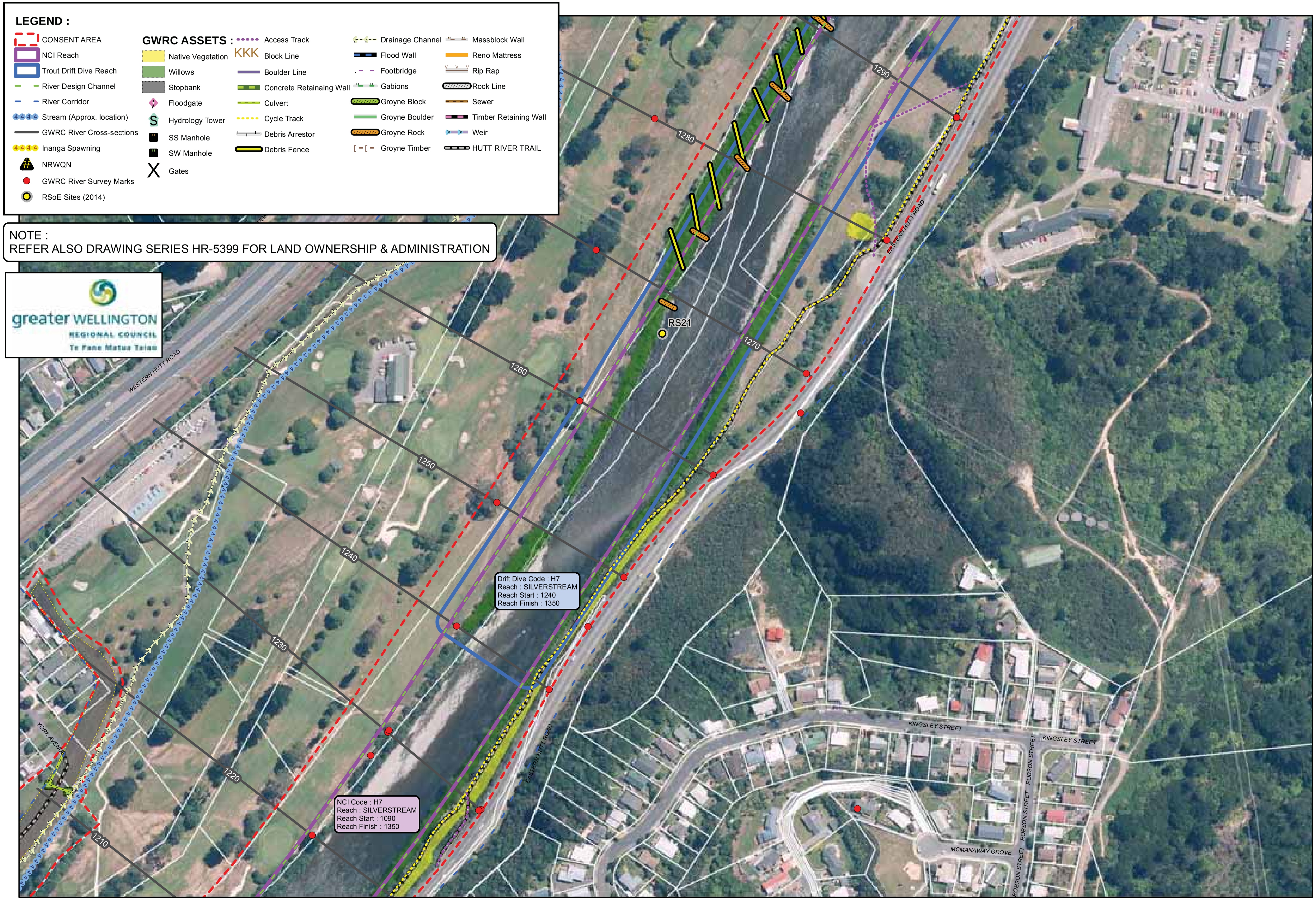
HUTT RIVER - CONSENT AREA - Map 17a

GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road inclusing Stokes valley Stream

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

DWG No. HR-5407 / 17

File ref : Hutt Application Area March 2014 - Sheet 17a.mxd



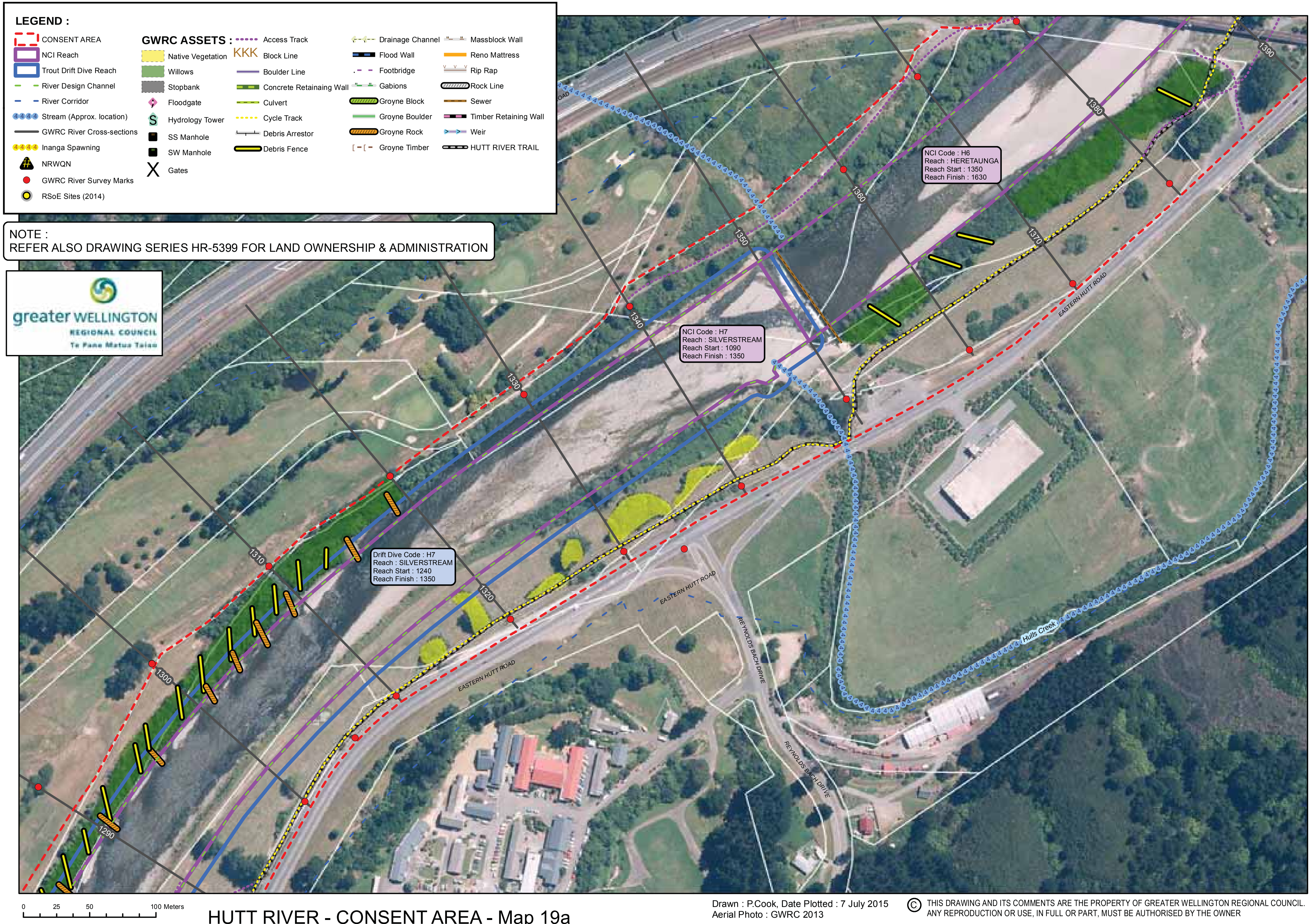
File ref : Hutt Application Area March 2014 - Sheet 18a.mxd

A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 18a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 18**



greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

HUTT RIVER - CONSENT AREA - Map 19a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 19**

File ref : Hutt Application Area March 2014 - Sheet 19a.mxd

LEGEND :

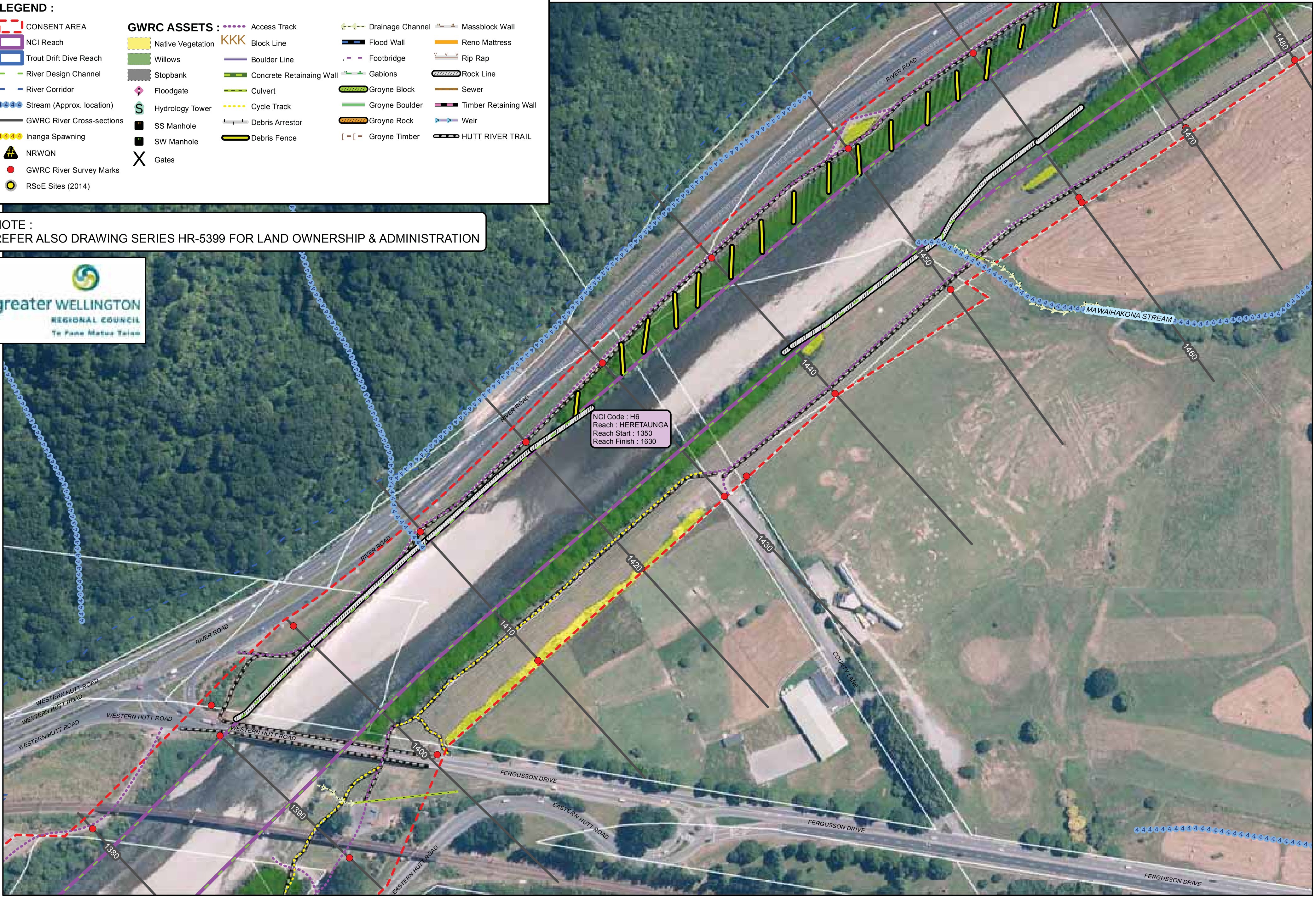
CONSENT AREA
NCI Reach
Trout Drift Dive Reach
River Design Channel
River Corridor
Stream (Approx. location)
GWRC River Cross-sections
Inanga Spawning
NRWQN
GWRC River Survey Marks
RSoE Sites (2014)

GWRC ASSETS :

Native Vegetation
Willows
Stopbank
Floodgate
Hydrology Tower
SS Manhole
SW Manhole
Gates
Access Track
Block Line
Boulder Line
Concrete Retainaing Wall
Culvert
Cycle Track
Debris Arrestor
Debris Fence
Drainage Channel
Flood Wall
Footbridge
Gabions
Groyne Block
Groyne Boulder
Groyne Rock
Groyne Timber
Massblock Wall
Reno Mattress
Rip Rap
Rock Line
Sewer
Timber Retaining Wall
Weir
HUTT RIVER TRAIL

NOTE :
REFER ALSO DRAWING SERIES HR-5399 FOR LAND OWNERSHIP & ADMINISTRATION

greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao



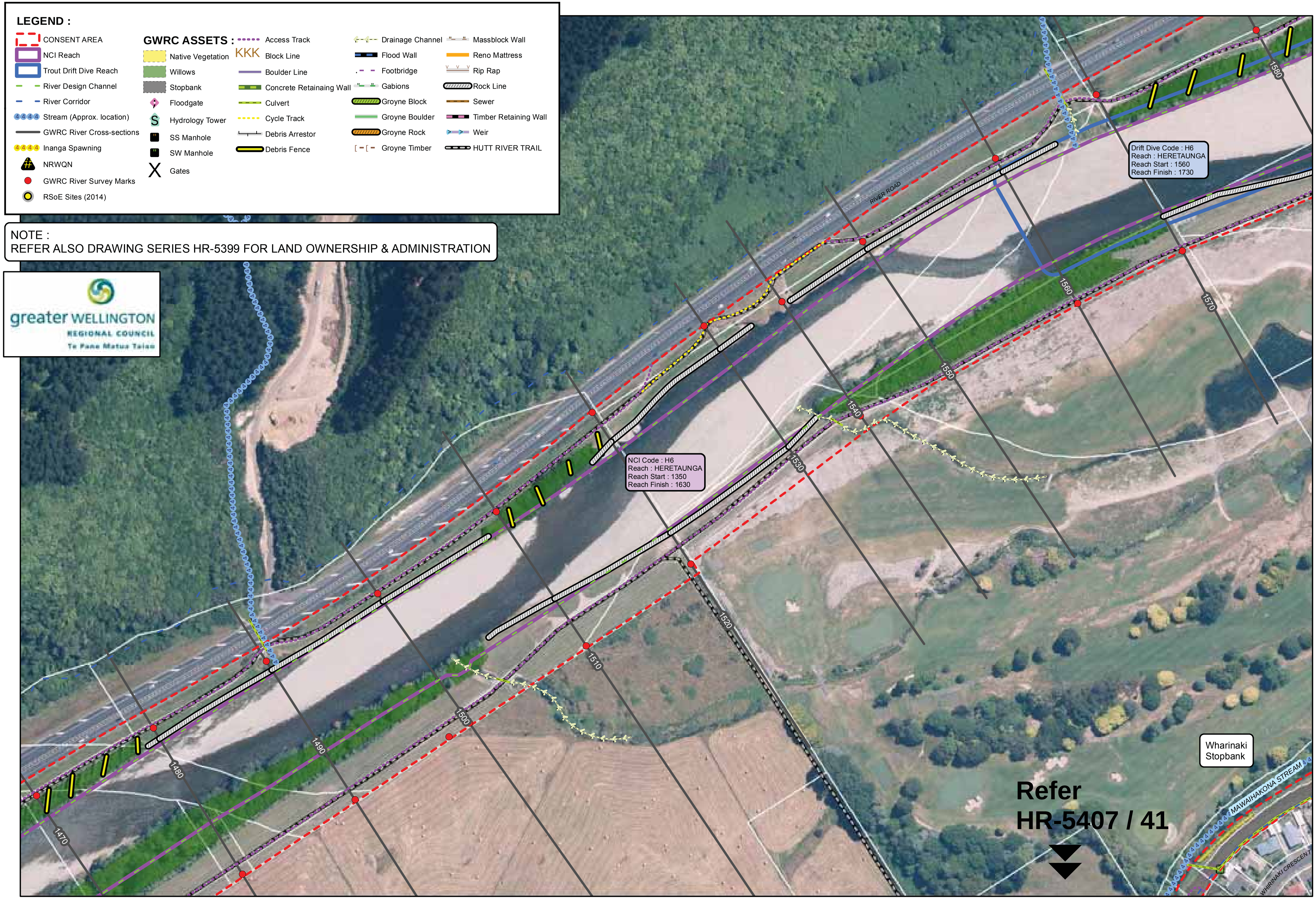
File ref : Hutt Application Area March 2014 - Sheet 20a.mxd

0 25 50 100 Meters
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 20a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. HR-5407 / 20



REGIONAL ORTHOPHOTOGRAPHY COPYRIGHT : GWRC / NZAM 2010
TOPOGRAPHIC AND CADASTRAL DATA IS COPYRIGHT LINZ

File ref : Hutt Application Area March 2014 - Sheet 21a.mxd

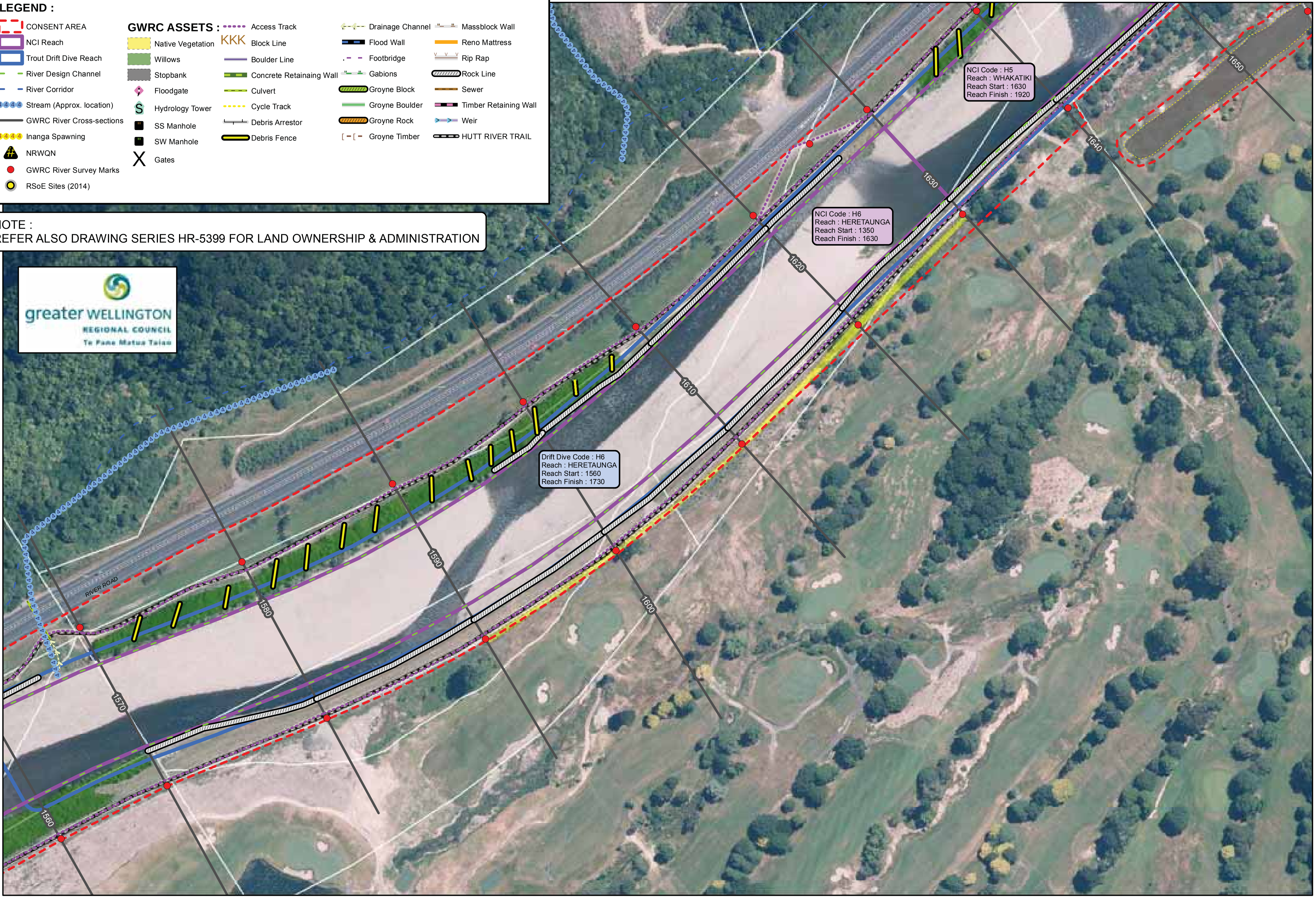
0 25 50 100 Meters

A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 21a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. HR-5407 / 21



LEGEND :

- CONSENT AREA
- NCI Reach
- Trout Drift Dive Reach
- River Design Channel
- River Corridor
- Stream (Approx. location)
- GWRC River Cross-sections
- Inanga Spawning
- NRWQN
- GWRC River Survey Marks
- RSoE Sites (2014)

GWRC ASSETS :

- Native Vegetation
- Willows
- Stopbank
- Floodgate
- Hydrology Tower
- SS Manhole
- SW Manhole
- Gates
- Access Track
- Block Line
- Boulder Line
- Concrete Retaining Wall
- Culvert
- Cycle Track
- Debris Arrestor
- Debris Fence
- Drainage Channel
- Flood Wall
- Footbridge
- Gabions
- Groyne Block
- Groyne Boulder
- Groyne Rock
- Groyne Timber
- Massblock Wall
- Reno Mattress
- Rip Rap
- Rock Line
- Sewer
- Timber Retaining Wall
- Weir
- HUTT RIVER TRAIL

NOTE :
REFER ALSO DRAWING SERIES HR-5399 FOR LAND OWNERSHIP & ADMINISTRATION

greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

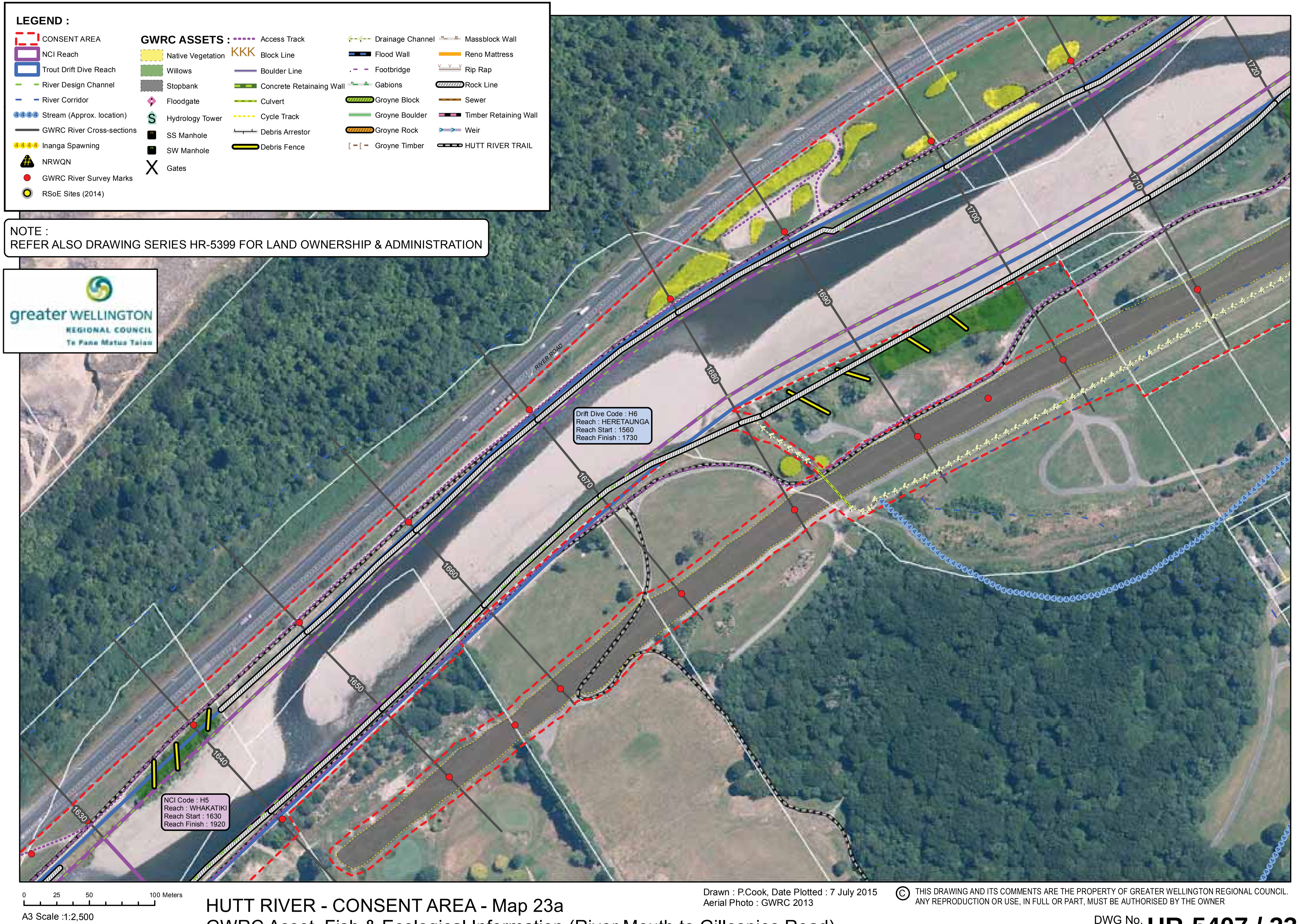
File ref : Hutt Application Area March 2014 - Sheet 22a.mxd

0 25 50 100 Meters
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 22a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 22**



NOTE :
REFER ALSO DRAWING SERIES HR-5399 FOR LAND OWNERSHIP & ADMINISTRATION

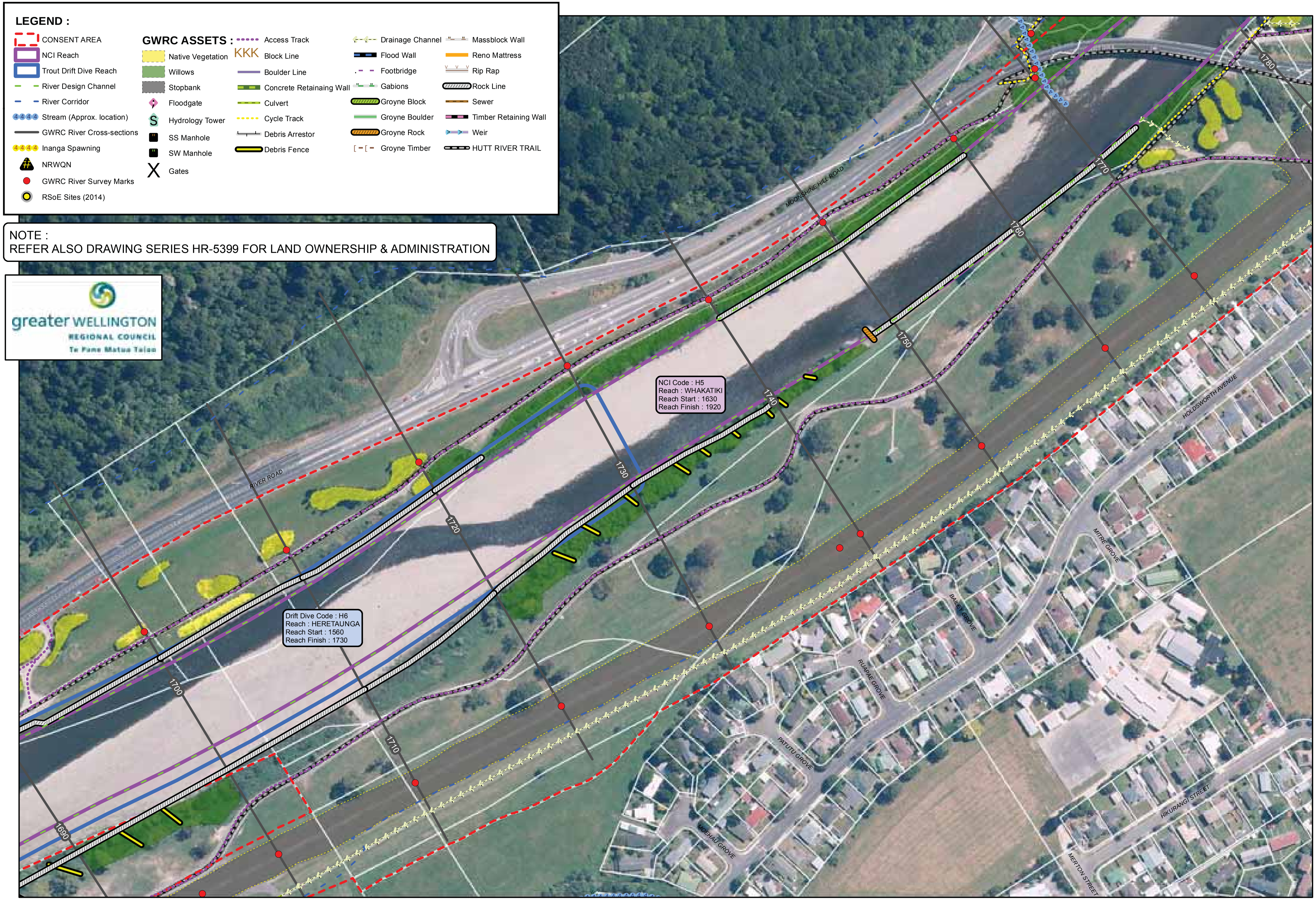
greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

File ref : Hutt Application Area March 2014 - Sheet 23a.mxd

HUTT RIVER - CONSENT AREA - Map 23a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. HR-5407 / 23



NOTE :
REFER ALSO DRAWING SERIES HR-5399 FOR LAND OWNERSHIP & ADMINISTRATION

greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

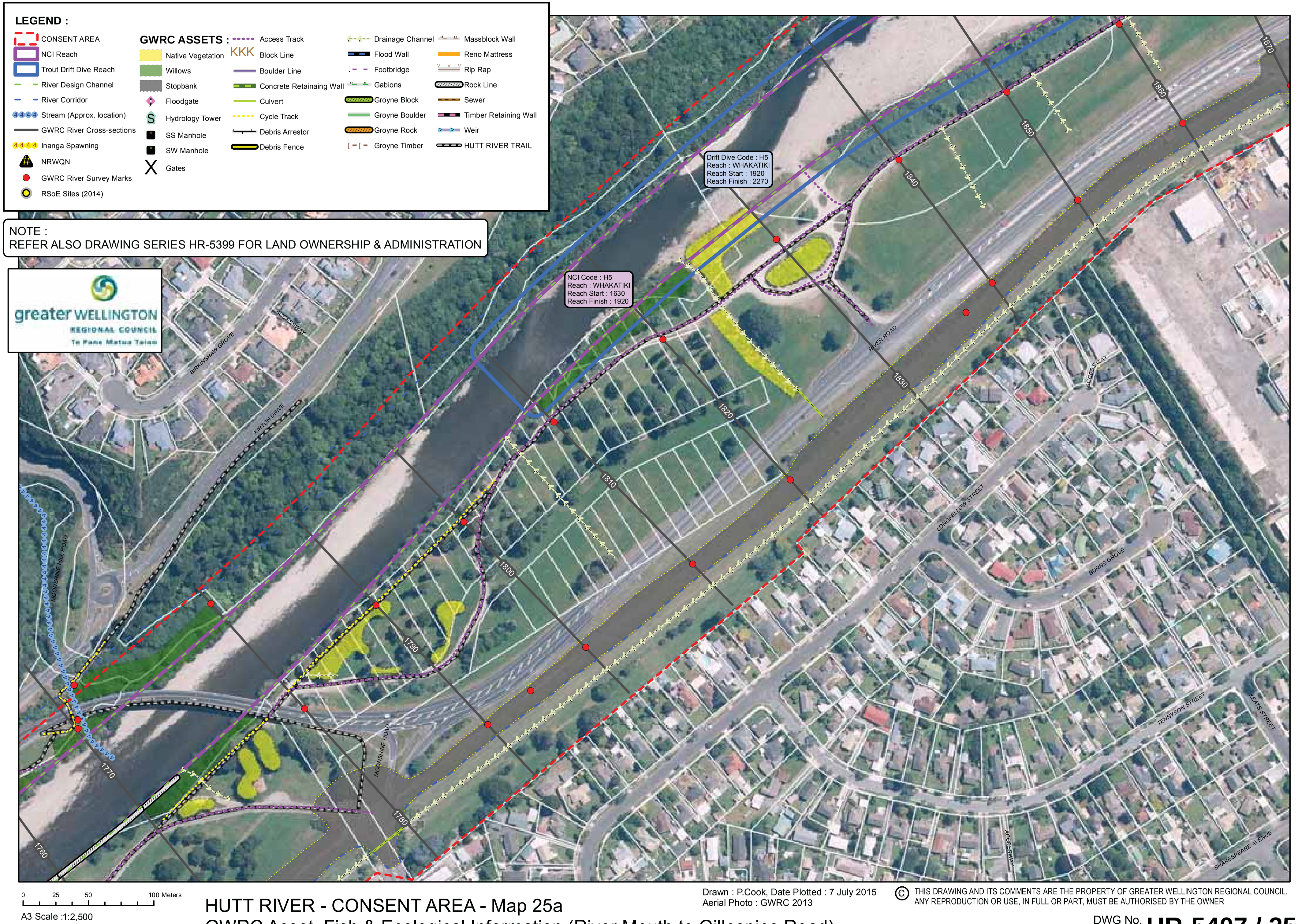
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 24a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. HR-5407 / 24

File ref : Hutt Application Area March 2014 - Sheet 24a.mxd



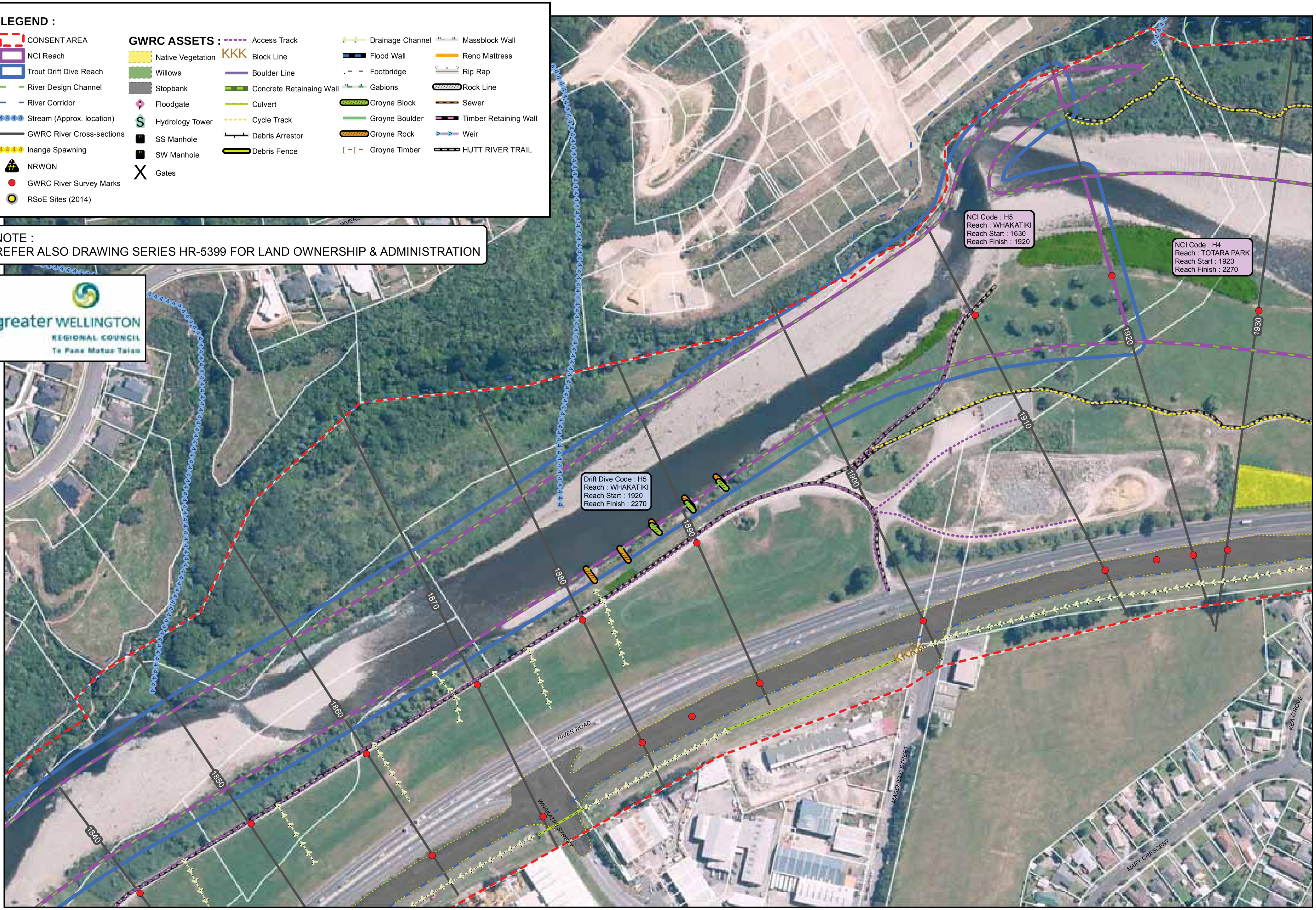
HUTT RIVER - CONSENT AREA - Map 25a

GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 25**

File ref : Hutt Application Area March 2014 - Sheet 25a.mxd



NOTE :
REFER ALSO DRAWING SERIES HR-5399 FOR LAND OWNERSHIP & ADMINISTRATION

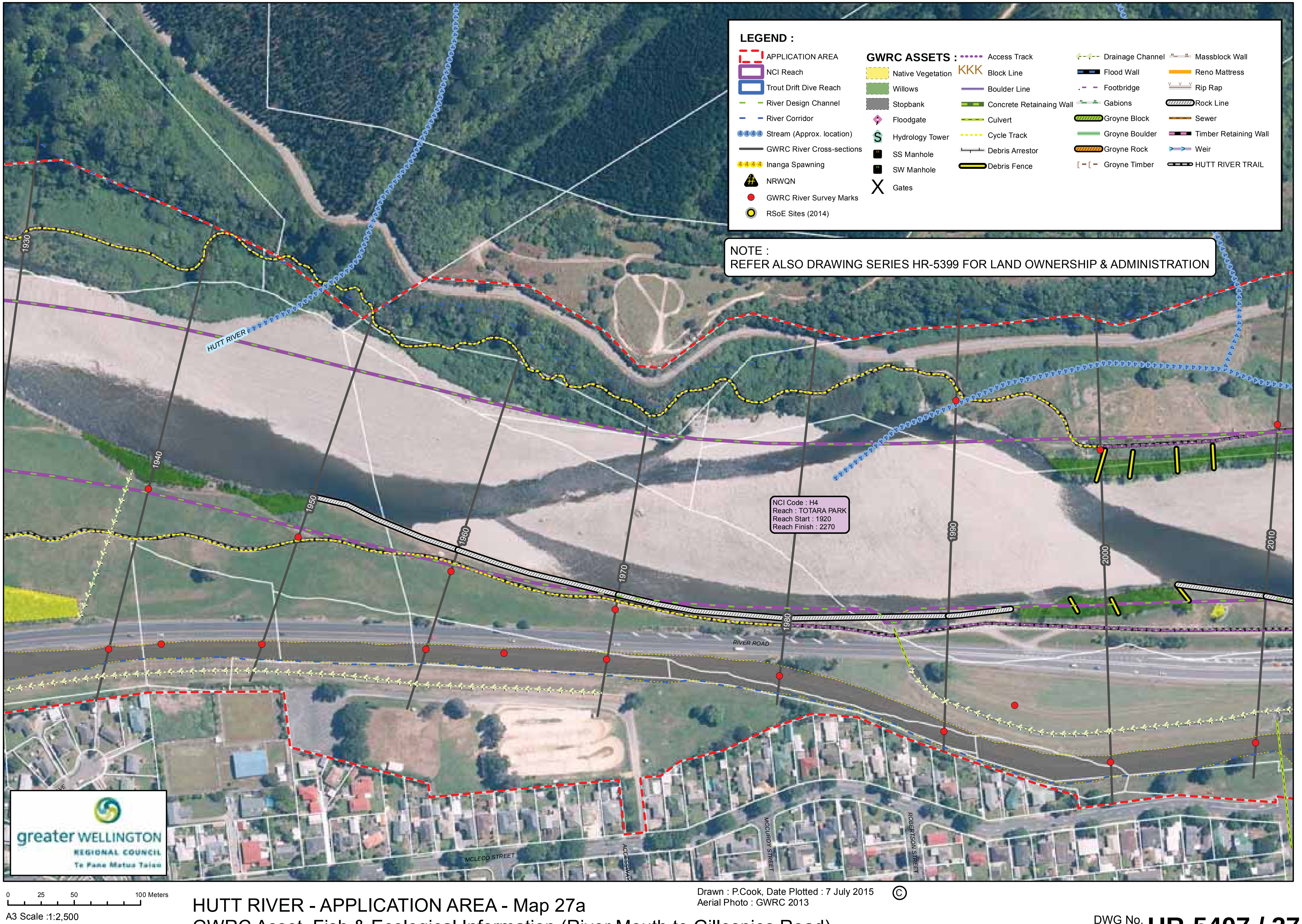
greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

File ref : Hutt Application Area March 2014 - Sheet 26a.mxd

HUTT RIVER - CONSENT AREA - Map 26a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. HR-5407 / 26



HUTT RIVER - APPLICATION AREA - Map 27a

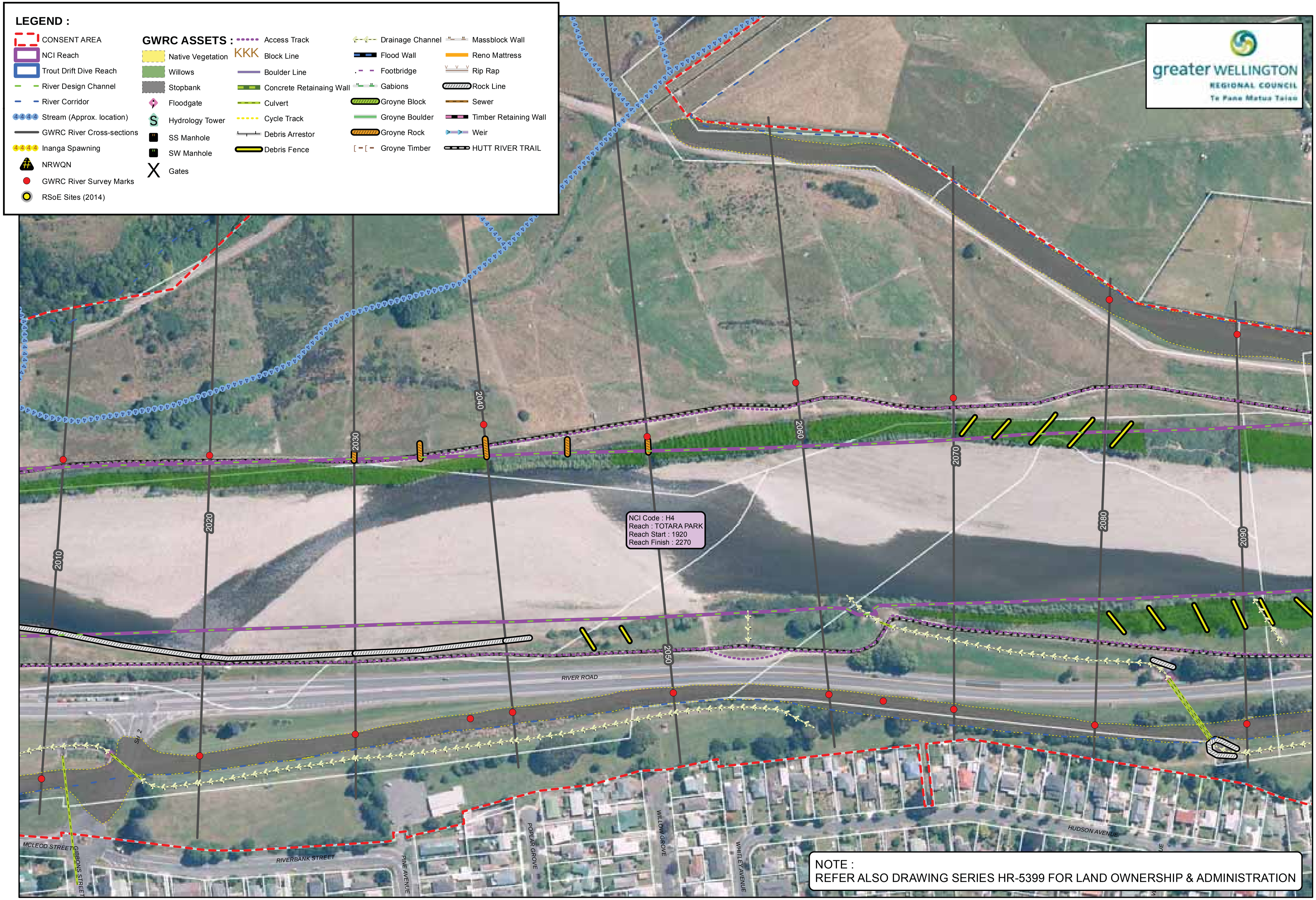
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

©

DWG No. **HR-5407 / 27**

File ref : Hutt Application Area March 2014 - Sheet 27a.mxd



File ref : Hutt Application Area March 2014 - Sheet 28a.mxd

NOTE :
REFER ALSO DRAWING SERIES HR-5399 FOR LAND OWNERSHIP & ADMINISTRATION

0 25 50 100 Meters

A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 28a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 28**

File ref : Hutt Application Area March 2014 - Sheet 29a.mxd

0 25 50 100 Meters

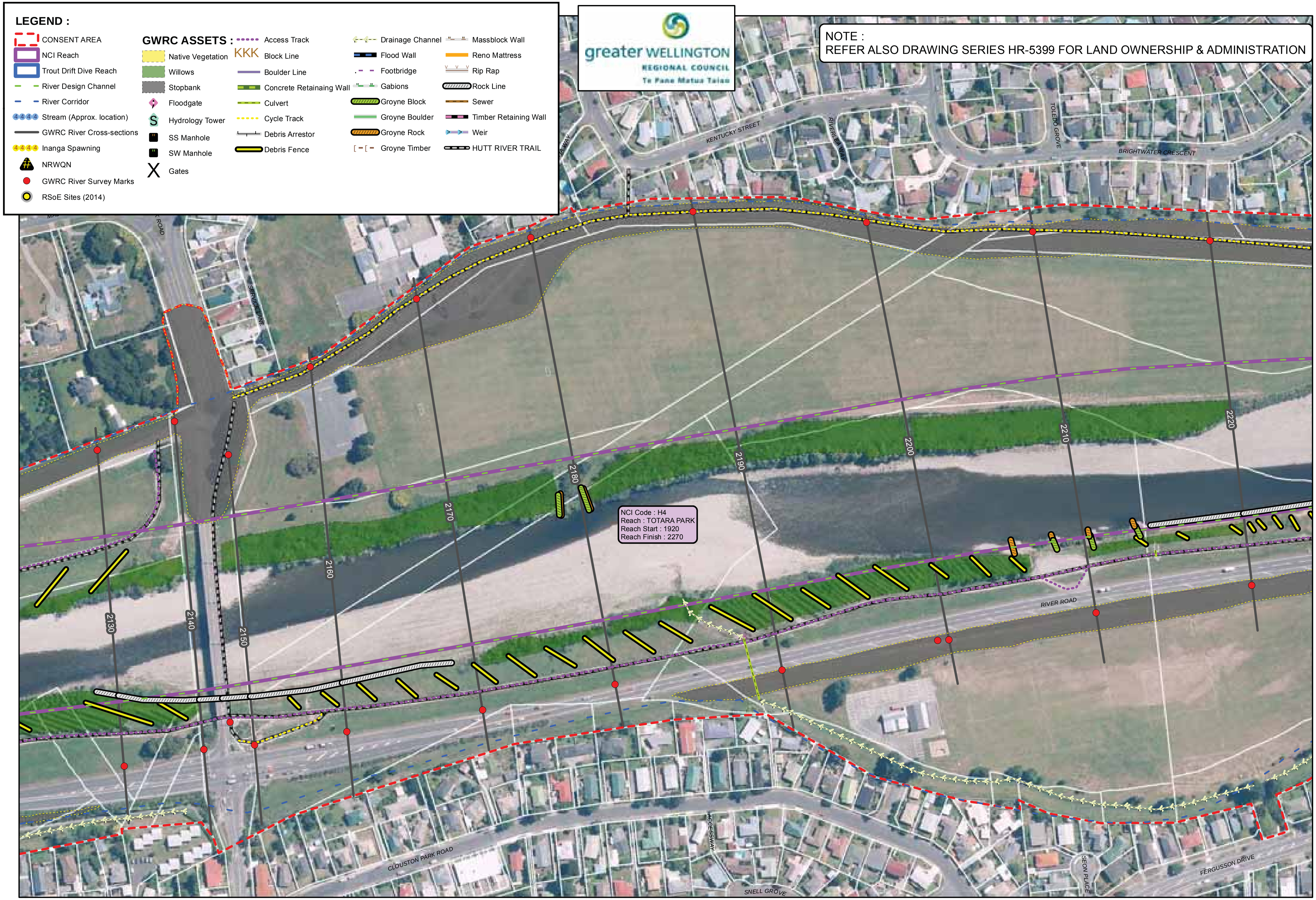
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 29a

GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 29**

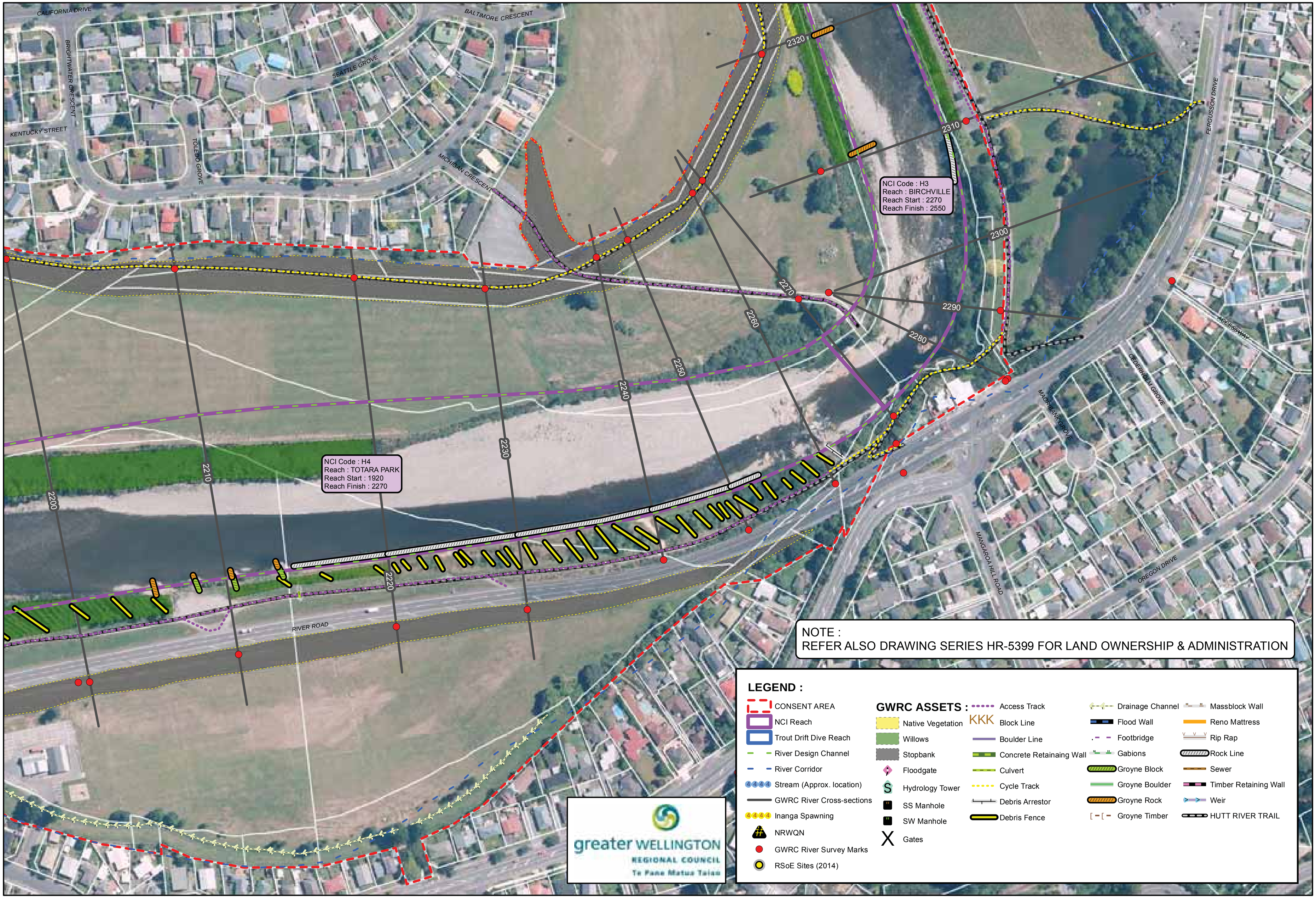


HUTT RIVER - CONSENT AREA - Map 30a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 30**

File ref : Hutt Application Area March 2014 - Sheet 30a.mxd



File ref : Hutt Application Area March 2014 - Sheet 31a.mxd

HUTT RIVER - CONSENT AREA - Map 31a

GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

DWG No. HR-5407 / 31

File ref : Hutt Application Area March 2014 - Sheet 32a.mxd

greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

HUTT RIVER - CONSENT AREA - Map 32a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. HR-5407 / 32

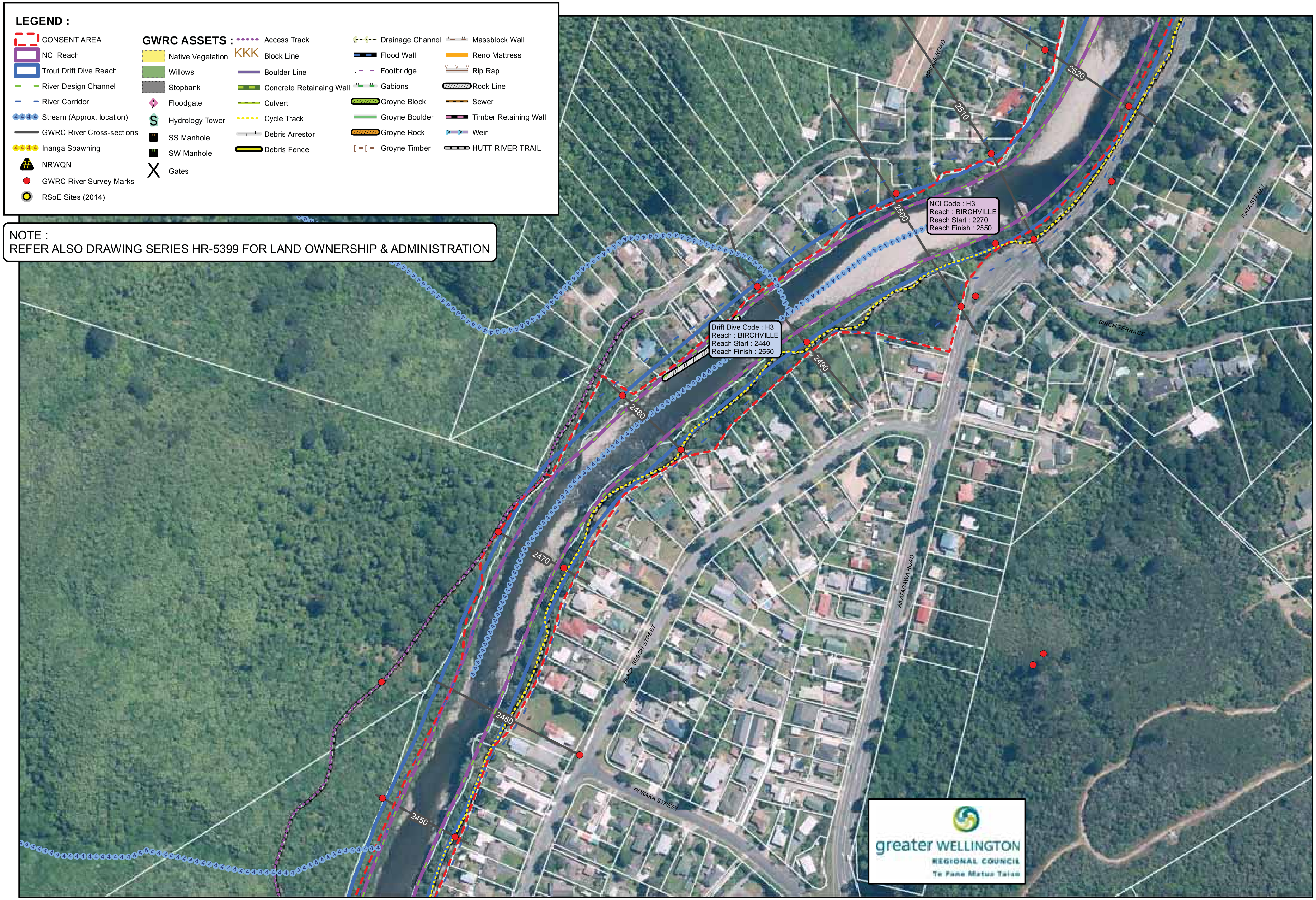
A3 Scale :1:2,500

File ref : Hutt Application Area March 2014 - Sheet 33a.mxd

HUTT RIVER - CONSENT AREA - Map 33a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 33**



NOTE :
REFER ALSO DRAWING SERIES HR-5399 FOR LAND OWNERSHIP & ADMINISTRATION

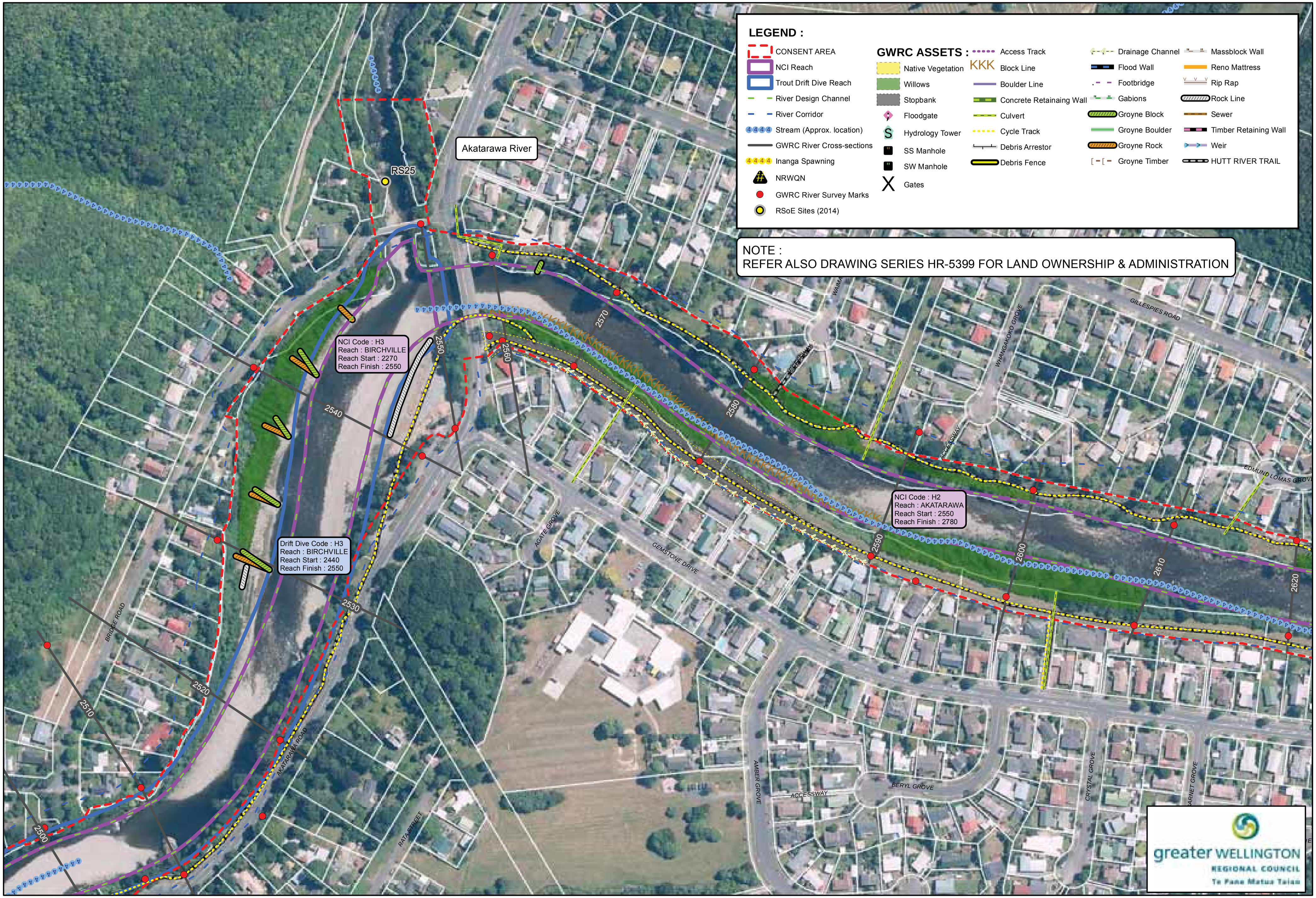
File ref : Hutt Application Area March 2014 - Sheet 34a.mxd

A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 34a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

DWG No. **HR-5407 / 34**



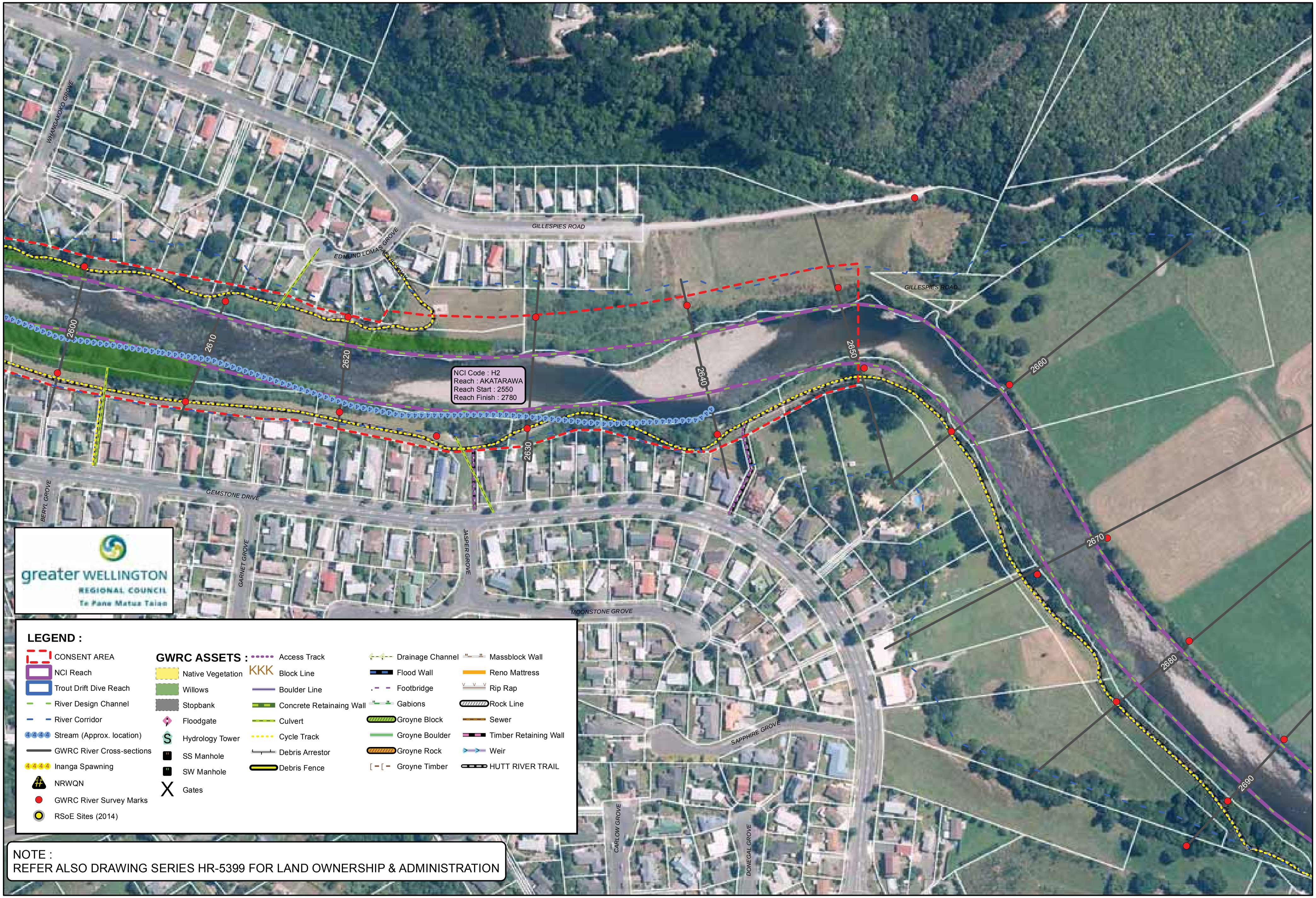
File ref : Hutt Application Area March 2014 - Sheet 35a.mxd

0 25 50 100 Meters
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 35a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road Inclusing Akatarawa River)

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

DWG No. **HR-5407 / 35**



File ref : Hutt Application Area March 2014 - Sheet 36a.mxd

greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

LEGEND :

- CONSENT AREA
- NCI Reach
- Trout Drift Dive Reach
- River Design Channel
- River Corridor
- Stream (Approx. location)
- GWRC River Cross-sections
- Inanga Spawning
- NRWQN
- GWRC River Survey Marks
- RSoE Sites (2014)

GWRC ASSETS :

- Native Vegetation
- Willows
- Stopbank
- Floodgate
- Hydrology Tower
- SS Manhole
- SW Manhole
- Gates
- Access Track
- Block Line
- Boulder Line
- Concrete Retainaing Wall
- Culvert
- Cycle Track
- Debris Arrestor
- Debris Fence
- Drainage Channel
- Flood Wall
- Footbridge
- Gabions
- Groyne Block
- Groyne Boulder
- Groyne Rock
- Groyne Timber
- Massblock Wall
- Reno Mattress
- Rip Rap
- Rock Line
- Sewer
- Timber Retaining Wall
- Weir
- HUTT RIVER TRAIL

NOTE :
REFER ALSO DRAWING SERIES HR-5399 FOR LAND OWNERSHIP & ADMINISTRATION

0 25 50 100 Meters
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 36a
GWRC Asset, Fish & Ecological Information (River Mouth to Gillespies Road)

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

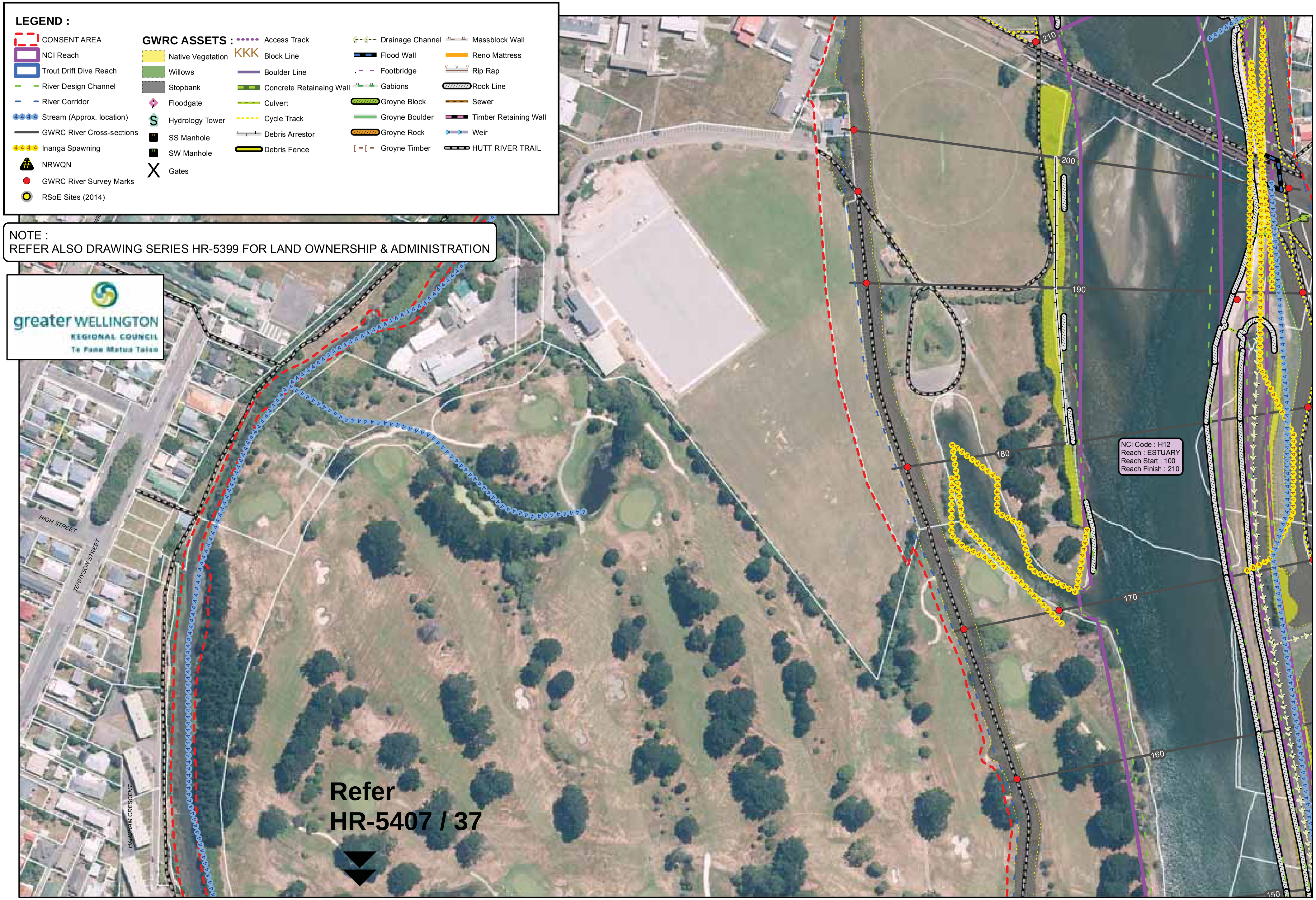
DWG No. **HR-5407 / 36**

HUTT RIVER - CONSENT AREA - Map 37a

GWRC Asset, Fish & Ecological Information (Te Mome Stream Mouth to Bracken Street)

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

DWG No. **HR-5407 / 37**



0 25 50 100 Meters

A3 Scale :1:2,500

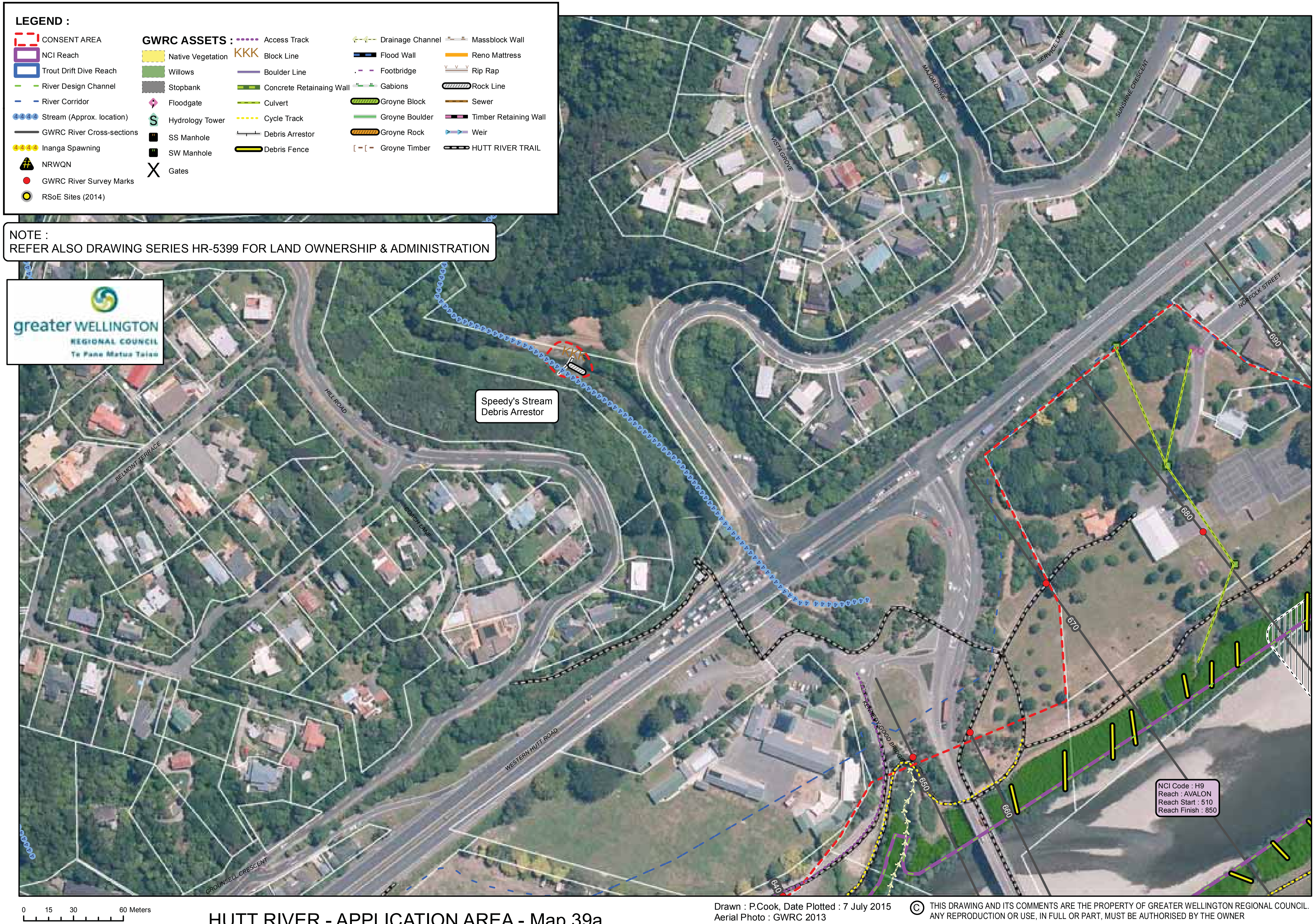
HUTT RIVER - CONSENT AREA - Map 38a

GWRC Asset, Fish & Ecological Information (Te Mome Stream Mouth to Bracken Street)

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

DWG No. **HR-5407 / 38**

File ref : Hutt Application Area March 2014 - Sheet 38a.mxd



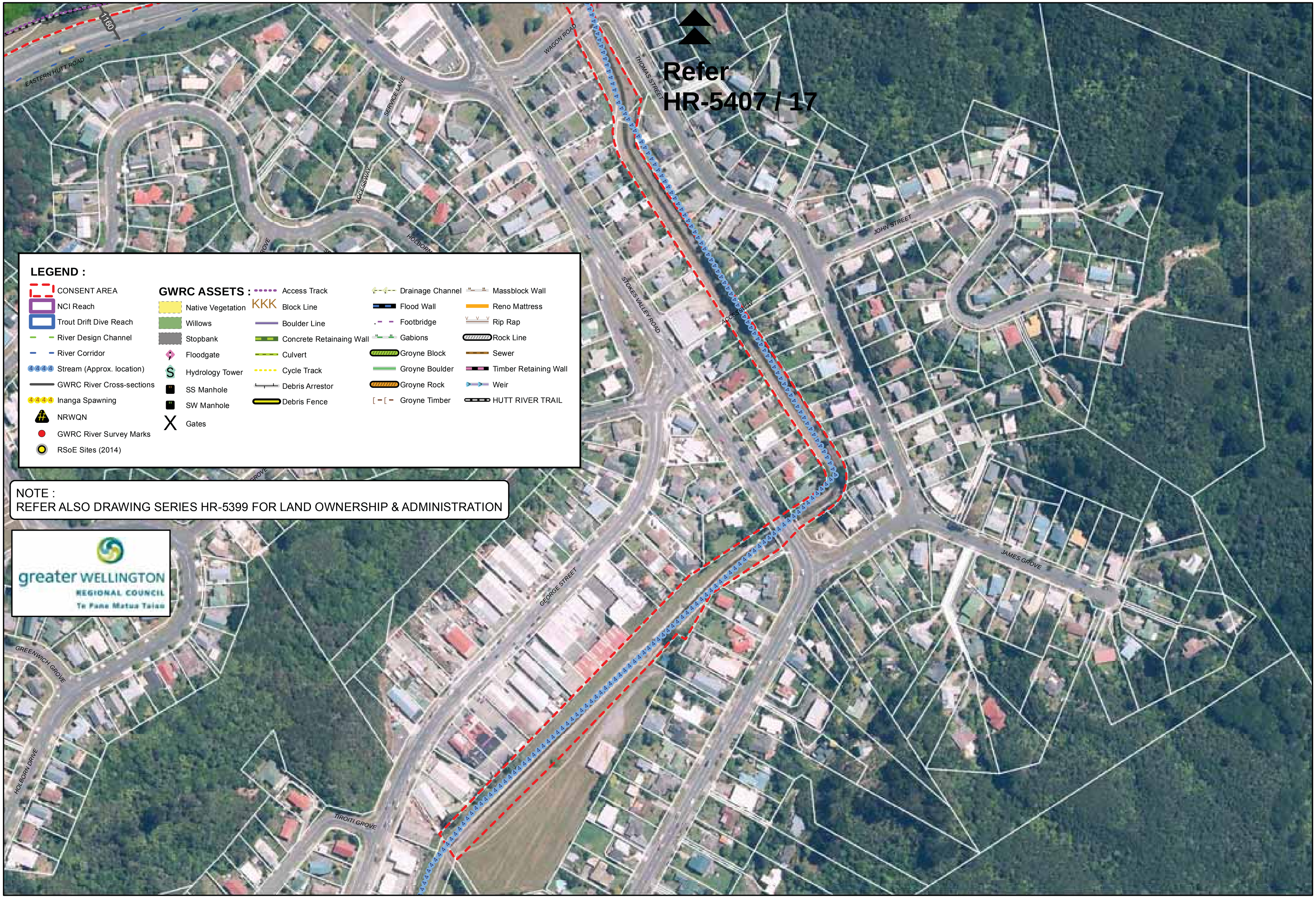
File ref : Hutt Application Area March 2014 - Sheet 39a.mxd

A3 Scale :1:2,000

HUTT RIVER - APPLICATION AREA - Map 39a
GWRC Asset, Fish & Ecological Information (Speedy's Stream Debris Arrestor)

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

DWG No. **HR-5407 / 39**



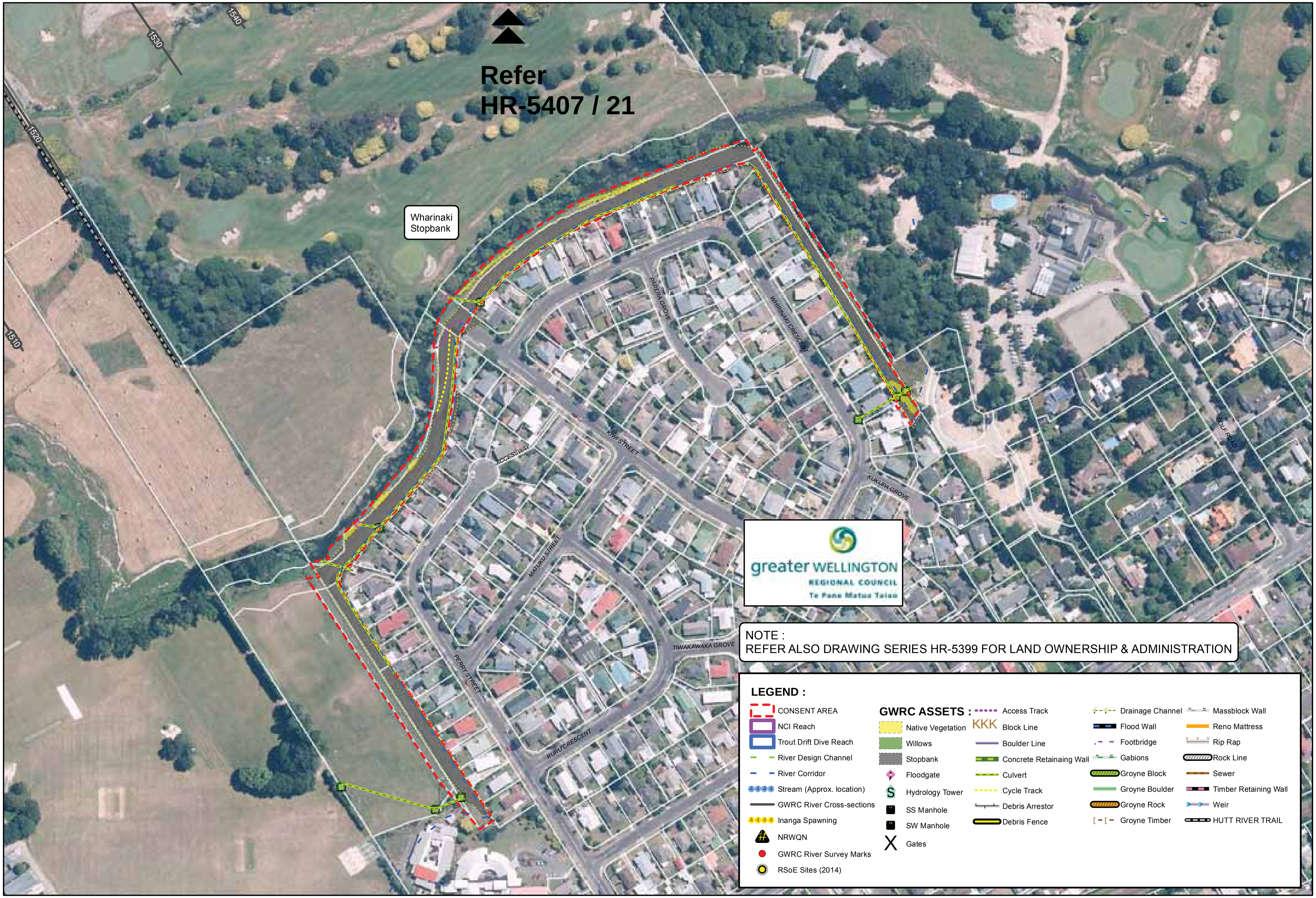
0 25 50 100 Meters
A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 40a
GWRC Asset, Fish & Ecological Information (Mouth to Tui Glen Stream))

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

DWG No. HR-5407 / 40

File ref : Hutt Application Area March 2014 - Sheet 40a.mxd



File ref : Hutt Application Area March 2014 - Sheet 41a.mxd

A3 Scale :1:2,500

HUTT RIVER - CONSENT AREA - Map 41a
GWRC Asset, Fish & Ecological Information (Whirinaki Stopbank, Upper Hutt)

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

DWG No. HR-5407 / 41

Appendix B Habitat characteristics of Stokes Valley, Speedy's and Te Mome Streams

Surveys of channel characteristics and habitat quality were undertaken within the application areas of Te Mome, Speedy's and Stokes Valley streams on 7 July 2015. These surveys were conducted outside of the summer growing season, which limits their representativeness as regards periphyton and macrophyte cover.

Stokes Valley Stream has been significantly degraded by the urbanisation of its catchment, modifications to its channel and removal to riparian vegetation, resulting in a loss of shade and cover over the streambed, a loss of connectivity to the flood plain, loss of hydraulic complexity and loss of woody inputs to the stream. These factors contribute to a low abundance and diversity of habitat for invertebrates and fish.

By comparison, Speedy's Stream is relatively unmodified and has retained most of its ecological functions in the reach upstream of SHW2. However the culvert under SHW2 is likely a barrier to the upstream migration of fish species such as inanga and smelt, which are weak swimmers and have no climbing ability, and to trout which require a greater depth of water than is available in the culvert.

The catchment of Te Mome Stream is highly urbanised and nearly all indigenous vegetation, including most of the riparian vegetation, has been removed. In addition the hydrology of the watercourse was radically altered in the early 1900's when its northern connection to the Hutt River was blocked off.

Table A1: Stream channel characteristics of tributary streams in the application area (4/7/15)

Habitat Parameter	*Sampling Site*		
	Te Mome Stream	*Speedy's Stream*	*Stokes Valley Stream*
Location	Jackson Street	DS debris arrestor	Thomas Street
NZTM Ref	E1758934; N5433903	E1761627; N5438426	E1766410; N5441398
Time sampled	12:00am	9:50am	11:00am
Mean wetted width (m)	30	3.9	3.0
Mean thalweg depth (cm)	1.0	0.31	0.40
%fine sediment cover	50	20	40
Dominant substrate	gravel/sand/silt	cobble/gravel/sand	gravel/sand/silt
Water temperature (^{o}C)	7.57	4.9	7.42
Electrical conductivity (mS/cm)	4668	100	97
pH	6.74	6.79	6.75
DO (%sat)	109	105	105
DO (mg/L)	12.78	13.46	12.68
Periphyton %cover			
Filamentous >2cm long	<5	<5	<5
Cyanobacteria >1mm thick	<5	<5	<5
All mats >3mm thick	30	<5	40
Macrophytes %cover Dominant taxa	5; *Carex, sp.* *Juncus* sp.	0	5; *Persicaria hydropiper*, *Glyceria maxima* *Mimulus guttatus*

Table A2: Rapid habitat assessment results summary (using a protocol from Clapcott, 2015)

Habitat parameter	*Sampling Site*		
	Te Mome Stream	*Speedy's Stream*	*Stokes Valley Stream*
Deposited sediment	3	6	4
Invertebrate habitat diversity	3	7	3
Invertebrate habitat abundance	3	7	3
Fish cover diversity	5	6	3
Fish cover abundance	5	5	2
Hydraulic heterogeneity	3	6	3
Bank erosion	9	7	7
Bank vegetation	4	7	1
Riparian width	4	9	1
Riparian shade	2	8	3
Habitat quality score (of 100)	41	70	30

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

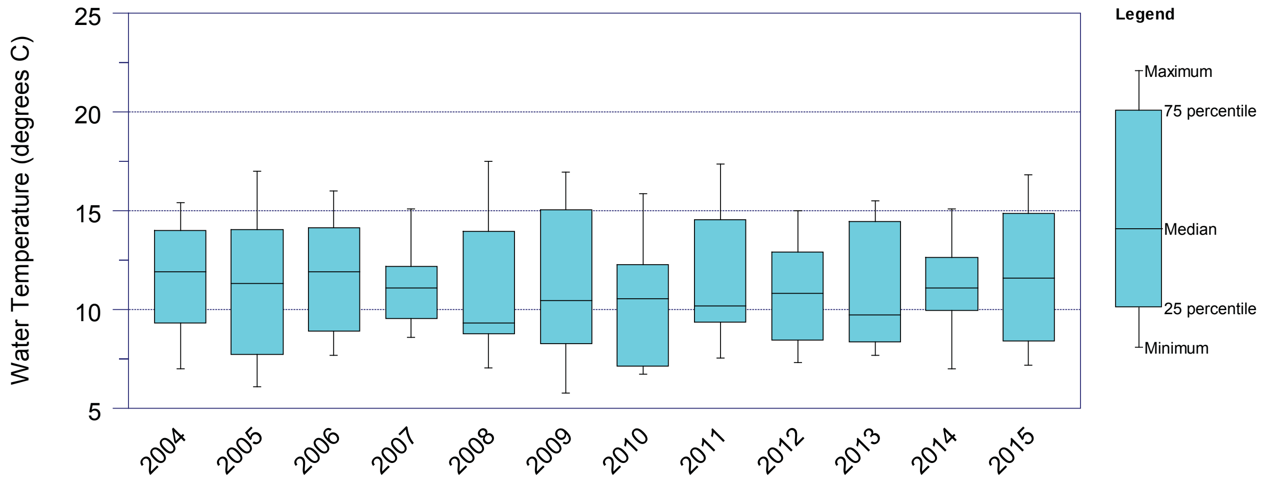


Figure B1: Temperature (°C) by year in the Hutt River at Te Marua

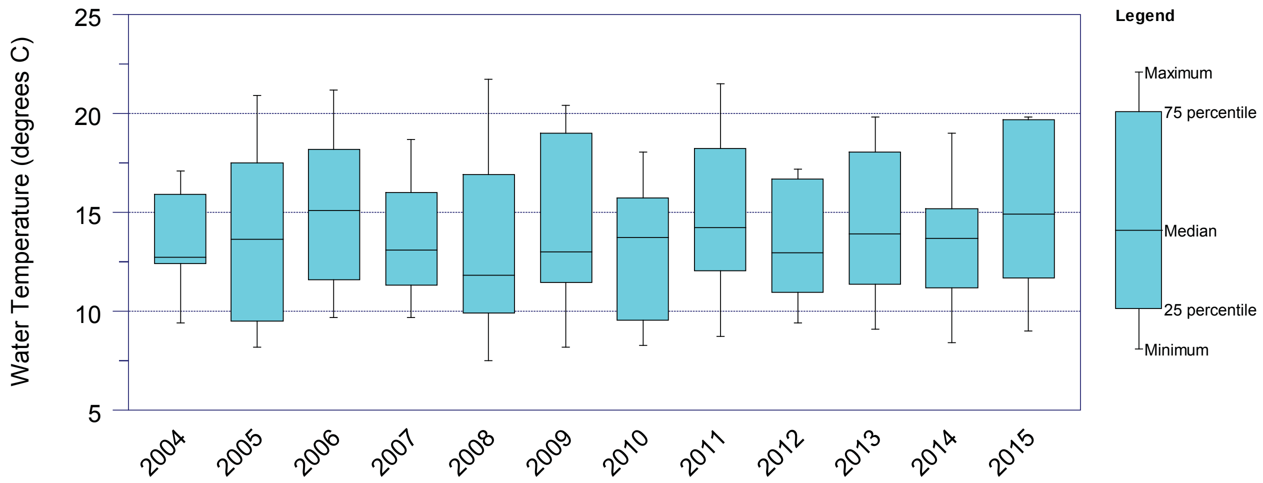


Figure B2: Temperature (°C) by year in the Hutt River at Boulcott

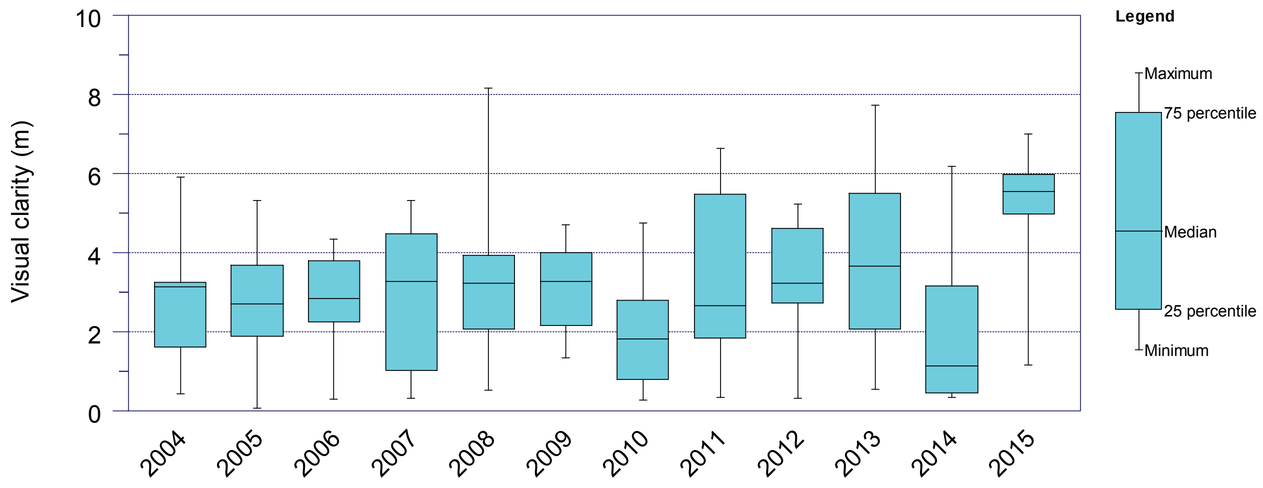


Figure B3: Visual clarity (m) by year in the Hutt River at Te Marua

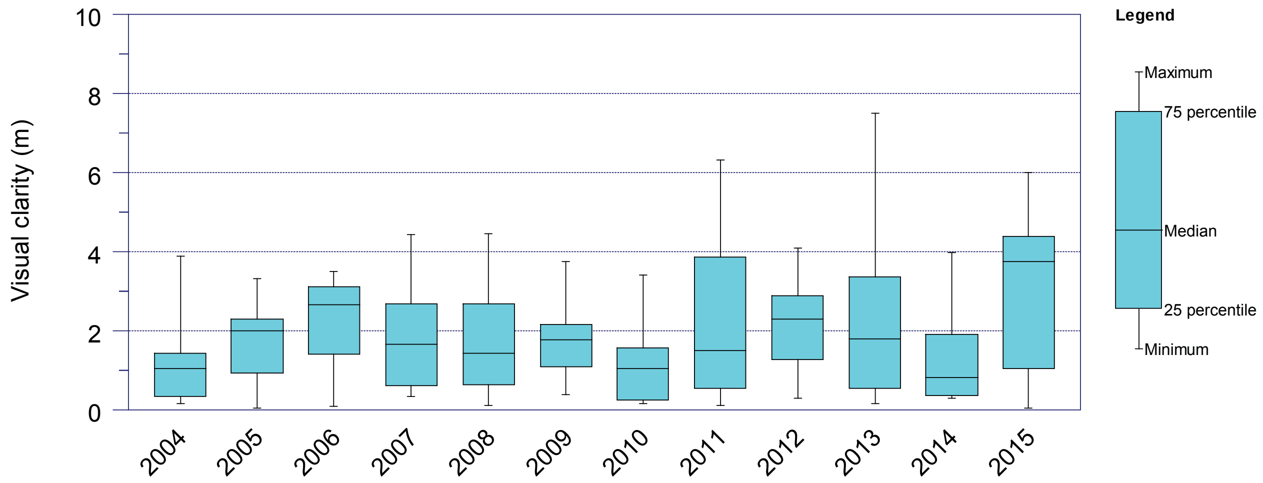


Figure B4: Visual clarity (m) by year in the Hutt River at Boulcott

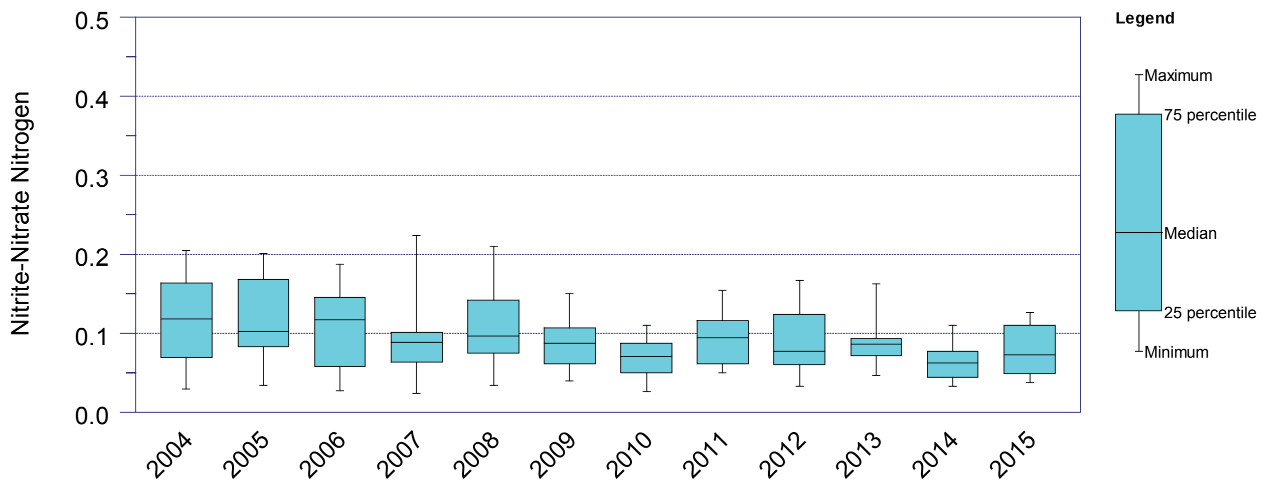


Figure B5: **Nitrate + Nitrite Nitrogen (mg/L) by year in the Hutt River at Te Marua**

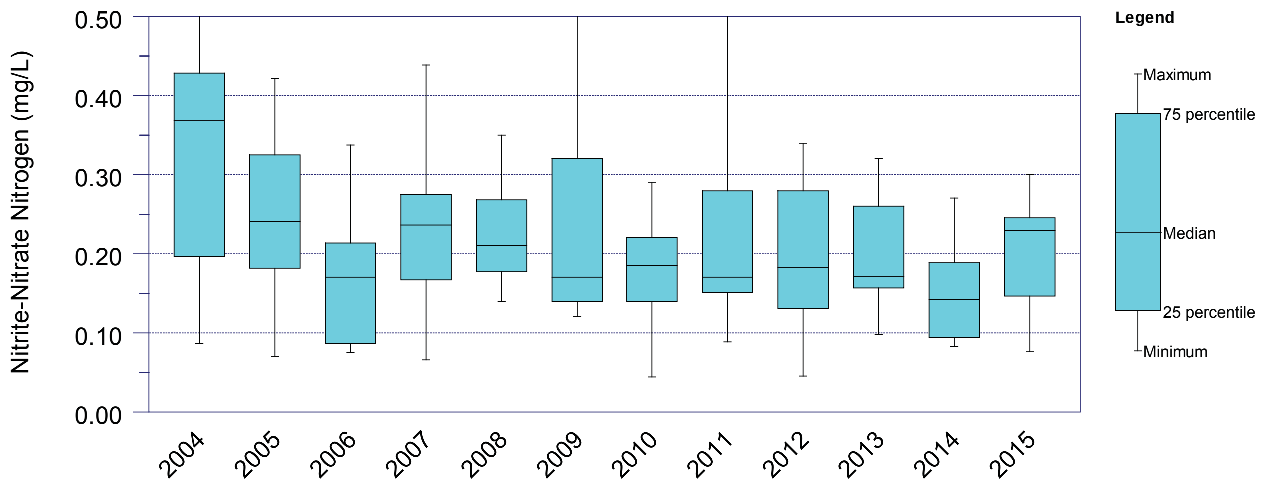


Figure B6: **Nitrate + Nitrite Nitrogen (mg/L) by year in the Hutt River at Boulcott**

Figure B7: **Dissolved reactive phosphorus (mg/L) by year in the Hutt River at Te Marua**

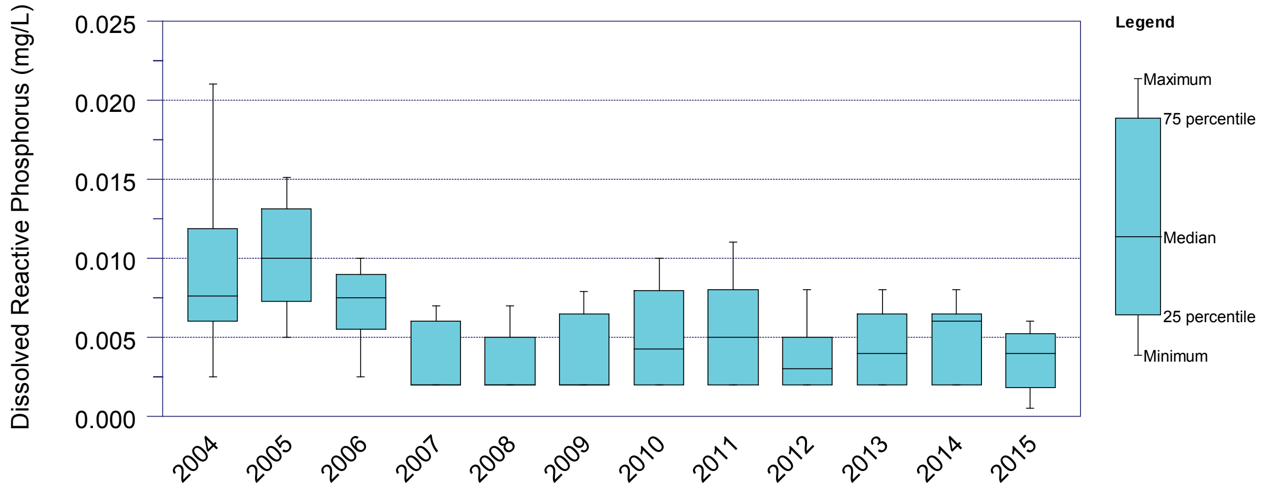


Figure B8: **Dissolved reactive phosphorus (mg/l) by year in the Hutt River at Boulcott**

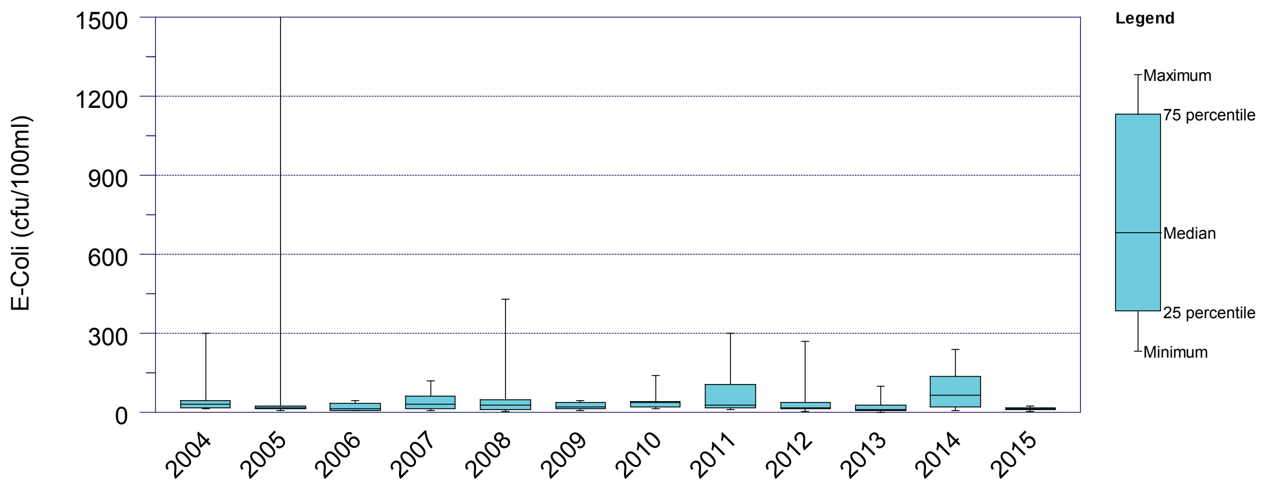


Figure B9: E. coli (cfu/100ml) by year in the Hutt River at Te Marua

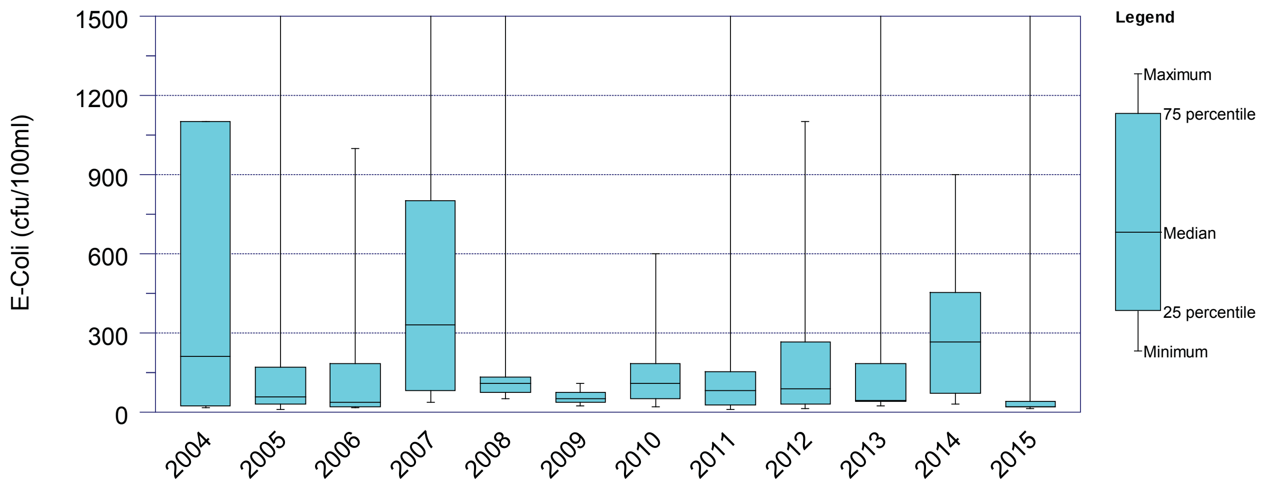


Figure B10: E. coli (cfu/100ml) by year in the Hutt River at Boulcott

Appendix D Macroinvertebrate results for 2014

2014 SOE and Additional Data	Site No	Kaitoke Weir	RS20	RS21	RS22	RS25
	Site Name	Hutt River at Kaitoke Weir	Hutt River at Te Marua Intake Site	Hutt River Opposite Manor Park Golf Club	Hutt River at Boulcott	Akatarawa River at Hutt Confluence
	EOS ID	n.a.	I140629	I140630	I140593	I140596
	Date sampled	27/02/2014	28/02/2014	28/02/2014	28/02/2014	3/02/2014
Generic Grouping	MCI-level taxa					
Acari	Acari					
Coelenterata	Hydra					
Coleoptera	Antiporus					
	Berosus					
	Elmidae	4	4	3	5	4
	Enochrus					
	Hydraenidae	2	1	1	1	
	Hydrophilidae					
	Liodessus					
	Ptilodactylidae					
	Scirtidae					
Collembola	Collembola					
Crustacea	Amphipoda					
	Amphipoda					
	Cladocera					
	Copepoda					
	Isopoda					1
	Ostracoda			1		
	Paracalliope					
	Paraleptamphopus					
	Paranephrops					
	Paratya					
Diptera	Aphrophila	1	1	1	1	5
	Austrosimulium		1	1	2	1
	Ceratopogonidae					
	Chironomidae		1			2
	Chironomus					
	Corynoneura					
	Empididae					
	Ephydridae					
	Eriopterini		1	1		1
	Harrisius					
	Hexatomini					
	Maoridiamesa		1		1	
	Mischoderus					
	Muscidae					
	Neocurupira					
	Orthocladiinae		2	19	14	3

2014 SOE and Additional Data	Site No	Kaitoke Weir	RS20	RS21	RS22	RS25
	Site Name	Hutt River at Kaitoke Weir	Hutt River at Te Marua Intake Site	Hutt River Opposite Manor Park Golf Club	Hutt River at Boulcott	Akatarawa River at Hutt Confluence
	Paralimnophila	5				
	Psychodidae					
	Sciomyzidae					
	Stictocladius					
	Stratiomyidae					
	Tabanidae					
	Tanypodinae			3		
	Tanytarsini		1	28	3	1
	Zelandotipula					
Ephemeroptera	Acanthophlebia		2			1
	Ameletopsis			1		
	Austroclima					
	Coloburiscus	3	15	9		11
	Deleatidium	62	107	82	167	134
	Ichthybotus					1
	Neozephlebia					
	Nesameletus	5	1		1	3
	Oniscigaster					
	Rallidens					
	Zephlebia			1		1
Hemiptera	Anisops					
	Microvelia					
	Sigara					
Hirudinea	Hirudinea					
Lepidoptera	Hygraula					
Megaloptera	Archichauliodes	4	9	6	1	2
Mollusca	Ferrissia					
	Gyraulus					
	Physa				1	
	Potamopyrgus	1	2	5	2	
	Sphaeriidae					
Nematoda	Nematoda				1	
Neuroptera	Kempynus					
Odonata	Anisoptera					
	Antipodochlora					
	Austrolestes					
	Xanthocnemis					
Oligochaeta	Oligochaeta			1	4	
Platyhelminthes	Platyhelminthes					
Plecoptera	Acroperla					
	Austroperla	1	1	1		2
	Megaleptoperla					
	Spaniocerca					

2014 SOE and Additional Data	Site No	Kaitoke Weir	RS20	RS21	RS22	RS25
	Site Name	Hutt River at Kaitoke Weir	Hutt River at Te Marua Intake Site	Hutt River Opposite Manor Park Golf Club	Hutt River at Boulcott	Akatarawa River at Hutt Confluence
	Stenoperla		2		1	1
	Zelandobius					1
	Zelandoperla	14	34	1	1	13
Polychaeta	Polychaeta					
Trichoptera	Aoteapsyche	13	11	11	1	31
	Beraeoptera	2	3			4
	Costachorema		1			1
	Helicopsyche			1		1
	Hudsonema					
	Hydrobiosella					
	Hydrobiosis	2	6	19	3	3
	Hydrochorema					
	Neurochorema					
	Oecetis					
	Oeconesidae					
	Olinga	11	24	17	5	35
	Orthopsyche					
	Oxyethira					
	Paroxyethira					
	Plectrocnemia			1		
	Polyplectropus			1		
	Psilochorema	3	1	6	3	2
	Pycnocentria					
	Pycnocentrodes		1	2		
	Triplectides					
	Fixed Count	133	233	223	218	265
	Squares counted		2	7	4	3
		Kaitoke Weir	RS20	RS21	RS22	RS25
Metrics based on MCI-level data	TOTAL	1521	3664	997	1712	2795
	TAXA Richness	26	25	26	20	26
	MCI-hb	133.7	128.00	127.69	111.00	134.62
	MCI-sb	-	129.12	127.31	113.00	140.31
	EPT Richness	18	14	14	8	17
	Hydroptilid EPT	0	0	0	0	0
	EPT (- Hydropts)	18	14	14	8	17
	QMCI-hb	7.90	7.99	6.24	7.20	7.51
	QMCI-sb	-	6.70	5.75	5.48	6.36
	% EPT	92	90.76	68.76	84.03	92.37
	% Hydropts	0.00	0.00	0.00	0.00	0.00

Appendix E Peak periods for upstream fish migration and spawning

B1: Periods of peak sensitivity for upstream fish migration (dark grey) and range (light grey) in the Hutt 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												
Banded kōkopu	juvenile												
Common bully	juvenile												
Redfin bully	juvenile												
Bluegill bully	juvenile												
Lamprey	adult												
Common smelt	juvenile												
Torrentfish	juvenile												
Black flounder	juvenile												
brown trout	adult												

B2: Periods of peak sensitivity for fish spawning (dark grey) and range (light grey) in the Hutt 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												
Banded kōkopu	margins												
Common bully	bed												
Redfin bully	bed												
Bluegill bully	bed												
Lamprey	upper reaches												
Common smelt	Lower reaches												
Torrentfish	bed												
Dwarf galaxias	?												
Upland bully	bed												
Cran's bully	bed												
brown trout	bed												

Appendix F Hutt River gravel extraction - habitat mapping

Hutt River Gravel Extraction - Habitat Mapping

Rev. No.	Date	Description	Prepared By
1	8/3/13	Draft report	David Cameron
2	10/3/13	Final report	David Cameron

1 Introduction

A habitat mapping study has been undertaken to coincide with the November-December 2012 round of wet gravel extraction in the Hutt River at Belmont.

The gravel extraction method developed by GWRC for the Hutt River under consent WGN 060334[25362] is focused on the deliberate formation of a meander pattern in the low flow channel. Condition 18 of the consent states that:

"*Gravel extraction operations and subsequent river bed channel reshaping works undertaken in the vicinity of the Owen Street and Harcourt Werry beaches shall be undertaken in accordance with Plan No. HR-5263 entitled "Hutt River – Indicative Plan of Proposed Gravel Extraction August 2006" lodged with the Wellington Regional Council on 16 August 2006, and shall restore, as far as is practicable, the pool and riffle habitat through this reach such that 6 pools and 5 riffles are in place on expiry of this consent. If this is not achieved on expiry of the consent, the consent holder must supply a detailed written explanation as to why this could not be achieved and an action plan that demonstrates how it will be achieved in the future.*"

A count of pools and riffles within the affected reach is currently undertaken using aerial photographs which shows the requisite number of pools and riffles are maintained (and exceeded), however it is recognised that a simple pool count provides little information about the quality of that habitat.

This study aims to address that shortfall by mapping the proportion of river habitat types at the local scale, before and after gravel is extracted from a defined reach. The objectives of this study are:

(a) To determine whether the riverine habitat created by gravel extraction is different than the existing habitat, and to characterise any differences,

(b) If changes occur, measure time for recovery to pre-works conditions.

2 Study Reach

Most of the Hutt River reach consented for gravel extraction has been recently worked and is therefore unsuitable for the type of study proposed here. The one exception is a 1,400m long stretch at the upstream extent of the consented area, upstream of the Kennedy-Good Bridge (cross sections 720 to 860), from which gravel was previously extracted in 2006. No significant in-river works have been under taken there since 2006 but gravel extraction works were programmed for this reach in November and December 2012. For the purpose of this study this 1400m length has been named the 'impact reach'.

Another 1400m reach located immediately upstream of the impact reach, which would not be affected by gravel extraction, has been named the 'control reach' (refer Figures 2-1 and 2-2). This provides a before-after-control-impact (BACI) design.

Figure 2-1: Location of the Hutt River ‘control reach’. Cross river transects are located at approximately 100m intervals. The red bar denotes a representative sediment assessment site.

Figure 2-2: Location of the Hutt River ‘impact reach’ which is immediately downstream of the control site. Cross river transects are located at approximately 100m intervals. The red bar denotes a representative sediment assessment site. The area within the dotted line was affected by gravel extraction activities.

3 Methods

3.1 Timing of mapping survey's

Gravel extraction works began in the impact reach on 26th November 2012 and were completed on 19th December. River habitat was mapped on two occasions prior to commencement of gravel extraction, once immediately after the works were completed, and again some eight weeks after completion of the works, after a series of significant high flow events had passed through. One of these events, on 4 February 2013, was a significant flood event which extensively re-worked river bed materials. The dates of the surveys, the river flow on the survey date and days since last large flow event are summarised in Table 3-1. The river hydrograph for this period is shown in Figure 3-1.

Table 3-1: Habitat mapping surveys

Mapping Survey	Date	River flow on survey day (m^3/s)	Weeks since completion of gravel extraction works
1 Pre-works	25 October 2012	12.3	n/a
2 Pre-works	9 November 2012	7.9	n/a
3 Post works	20 December 2012	12.6	<1
4 Post works	14 February 2012	7.1	8

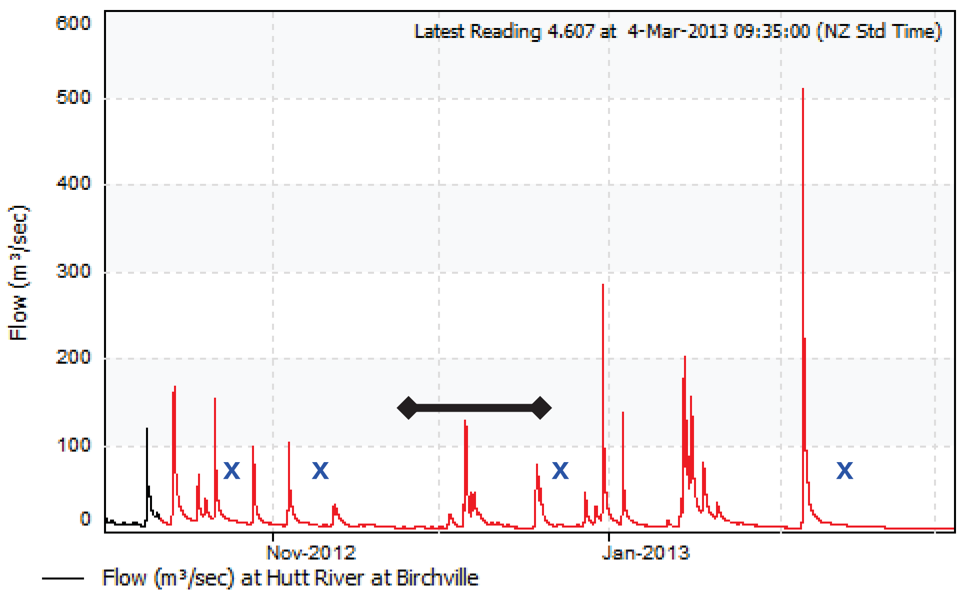


Figure 3-1: Hutt River flow hydrograph at Birchville. The timing of the gravel extraction works is indicated by the bar and the timing of mapping surveys are indicated by X.

River flows were reasonably well matched across all four surveys, as indicated in Table 3-1. This was important because the proportions of some habitat types are partially flow dependent, for instance a "riffle" during low flow may become a "shallow-run" at higher flows, and vice versa.

3.2 Habitat mapping

An aerial photograph of the river reach was marked up with cross river transects at 100m intervals to provide a habitat map template. Each of the mapping surveys were undertaken by walking the true left bank of the river. At each cross river transect the wetted width was measured by laser rangefinder (to an accuracy of ± 1 metre) and the current location of the active channel was marked on the map template. In addition the river channel was delineated into one of five bedform types, which were also marked up on the map template.

The bedform or habitat types are generally based on descriptions from Harding *et al* (2009), as follows:

- *(R) Rapid* – shallow to moderate depth, swift flow and strong currents, surface broken with white water.
- *(RI) Riffle* – shallow depth, moderate to fast water velocity, with mixed currents, surface rippled but unbroken.
- *(SR) Shallow Run* – habitat in between that of riffle/rapid and pool, slow to moderate water velocity, uniform-slightly variable current, surface unbroken, smooth to rippled, shallower than average depth.
- *(DR) Deep Run* - habitat in between that of riffle/rapid and pool, slow to moderate water velocity, uniform-slightly variable current, surface unbroken, smooth to rippled, deeper than average depth.
- *(P) Pool* – deep, slow flowing with a smooth water surface, usually where the river widens and deepens. Generally about 1.5 times the average depth.
- *(B) Backwater* – slow or no flow zone away from the main flowing channel that is a surface flow deep-end; although flow could down-well or up-well from groundwater.

On each sampling occasion the following sediment assessments were undertaken at a representative run selected in both the control and impact reaches:

- Visual assessment of bankside sediment cover were undertaken at those sites using protocol **SAM1** (Clapcott *et al* 2011).
- Particle size distribution was undertaken by Wolmen pebble count as per **SAM3** (Clapcott *et al* 2011).

3.3 Calculation of habitat areas

On completion of each mapping survey the hand drawn maps were digitized using MapInfo which is a windows based mapping and geographic information system. Areas of each habitat type were calculated directly by MapInfo.

3.4 Statistical analysis

The statistical difference of habitat variable results was compared using an equivalence test in the software 'Time Trends'. Equivalence tests incorporate both testing of means (using a student t-test) and testing of a meaningful change (interval testing).

4 Results

In practice the gravel extraction works were less extensive than planned, affecting only 400m of the 1400m impact reach (refer Figure 2-2) . This included one crossover sequence (shallow-run/riffle/deep-run/pool) but two other crossovers sequences in this reach were not affected. This was unfortunate in terms of the study design, because the ability to distinguish between normal variation and meaningful change caused by gravel extraction works was reduced. Nevertheless this study has been useful in that it has provided a detailed description of local scale habitat in river reaches affected by a range of flood protection activities including gravel extraction.

4.1 Sediment Assessment

4.1.1 Sediment cover

A bankside visual estimate of the surface area of streambed covered by fine sediment (<2mm) was made in accordance with SAM1 (Clapcott *et al* 2001). The assessment was limited to representative shallow runs located on each of the control and impact reaches. This was done in conjunction with Wolman pebble count described in the following section. The visual assessment results indicate that between 10 and 25% of the bed had some fine sediment cover and that the proportion decreased gradually through the summer, possibly as a result of a series of freshes which passed through river over that period (Figure 4-1). The impact site appeared to have marginally higher sediment cover than the control site, but the difference was negligible (Figure 4-1). At both locations the fine sediment was predominantly sand (>80% sand) and clay/silt was scarce.

We note that neither of the sediment assessment sites were affected by gravel extraction activities.

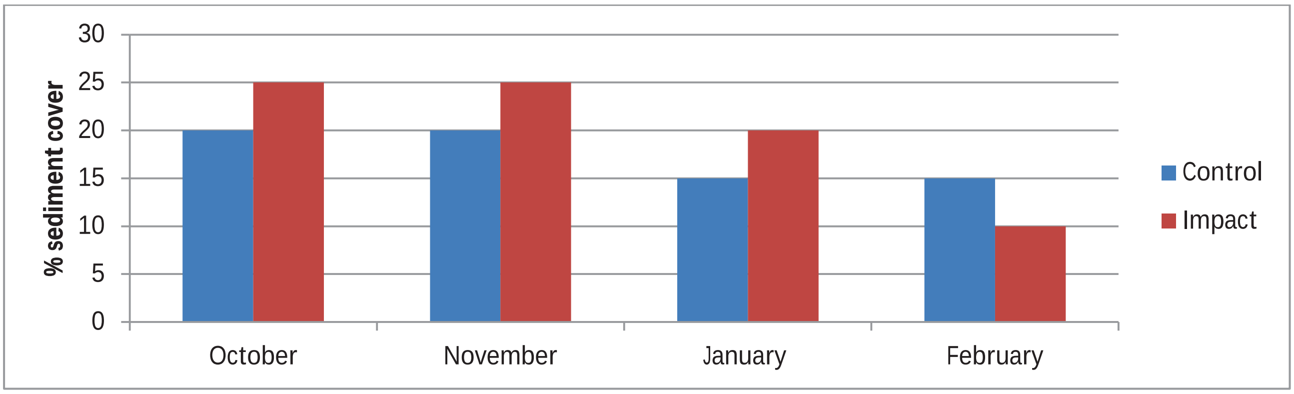


Figure 4-1: Bankside visual estimate of sediment cover at control and impact sites

4.1.2 Particle Size Distribution

Particle size distribution was assessed by Wolman pebble count at representative shallow-runs on both control and impact reaches (both located upstream of gravel extraction activities). The results summarized in Figure 4-2 and 4-3 describe the substrate particle distribution for both reaches during each of the four survey days. The predominant size classes were 'large cobble', 'small cobble', and 'large gravel' in that order, and the results show relatively little variation between survey days.

A comparison between the mean particle distributions for the control and impact reaches indicates a high degree of similarity, which would be expected given the similar morphologies of the two reaches (refer Figure 2-1 and 2-2).

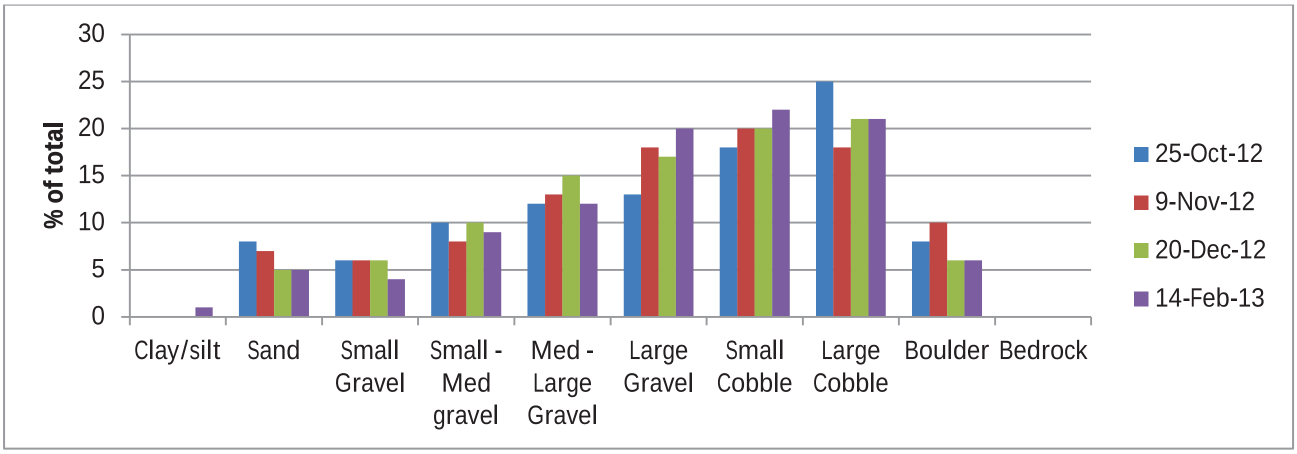


Figure 4-2: Substrate particle size distribution at a representative shallow run in the control reach

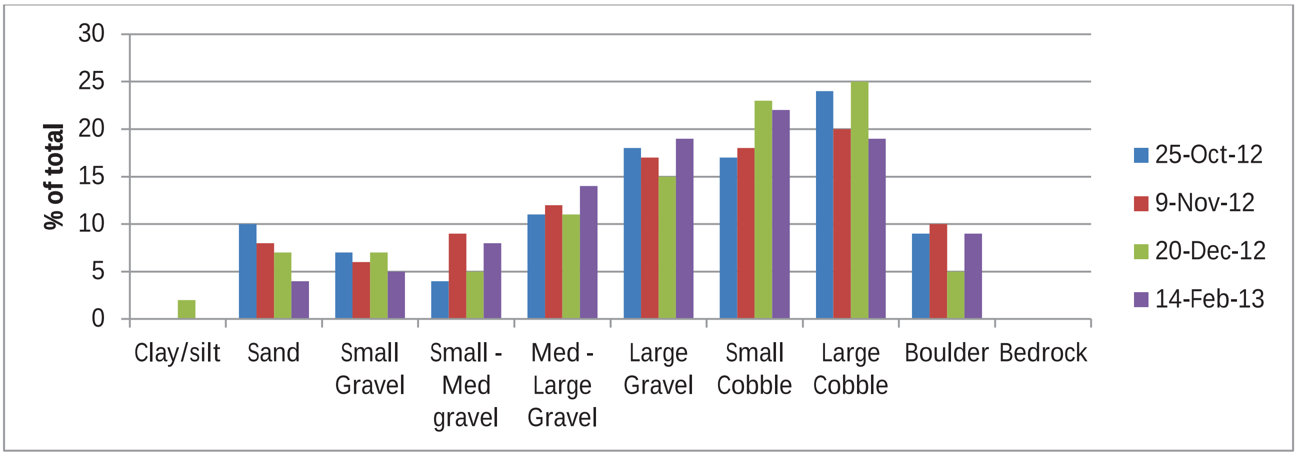


Figure 4-3: Substrate particle size distribution at a representative shallow-run in the impact reach

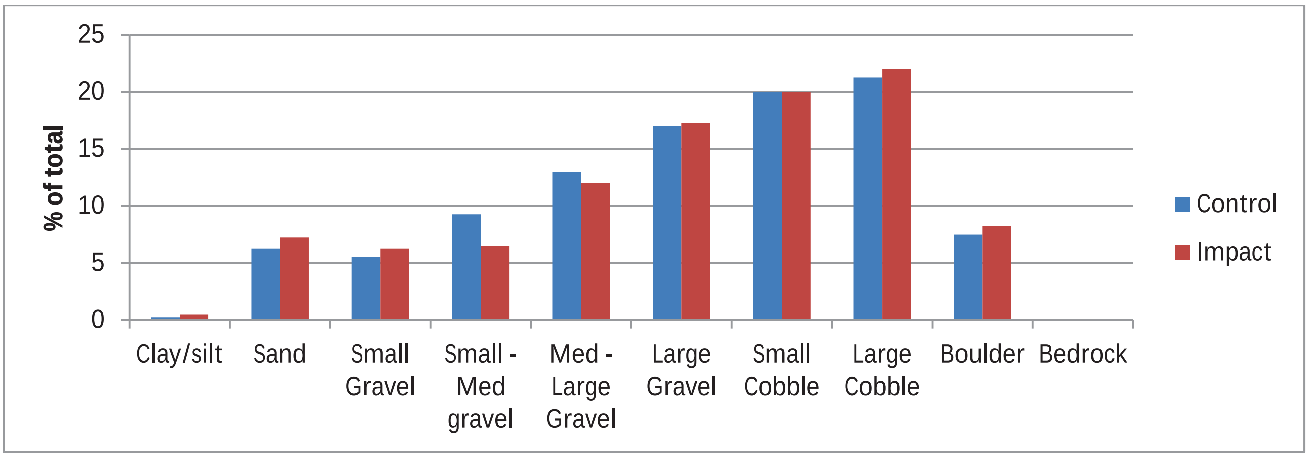


Figure 4-4: Comparison of mean particle sizes for control and impact reaches

4.2 Habitat Mapping

4.2.1 Control reach

Habitat mapping at the control reach on four occasions indicates that shallow runs predominate at nearly 60 percent of total habitat (Table 4-1). Riffles and rapids made up approximately 25 percent of the total; deep-runs typically made up 13 percent, while pools and backwaters were scarce (<3%). All of the pools in this reach, 5 in total, were associated with rock stub groynes along the true left bank. One of the pools was greater than 3m deep in low flow conditions while the others were smaller, from 1 to 2m deep. The deep-run habitat is either located in fast water beside rip-rap lined banks, or in center channel where the flow is pushed out from the banks by stub groynes. Backwaters were fairly stable during the first three surveys, but had largely dried up in the February survey.

The most variable component appeared to be the balance between shallow-runs and riffles, with large shifts from one to the other depending on river flow. There were also large variations in these components at the same river flow, i.e., the area of riffle increased 100% between the October and December surveys which were conducted at nearly the same flow. While inaccuracies in the habitat mapping method account for some variation, other factors such as gravel movement in high flow events are likely to be having some influence.

The proportions of habitat types recorded in the February survey differed from the earlier surveys in that much of the deep-run, pool and backwater area had been lost while shallow runs had increased. That is partly attributed to reduced river flows however a large flood event on 4 February had clearly caused extensive bed movement and may have contributed to the observed changes.

A comparison of habitat values for the first two runs (Oct, Nov) against the second two runs (Dec, Feb) by equivalence test found no evidence of any meaningful change for any variable. This was the expected result given no gravel extraction works had been undertaken in this reach.

Table 4-1: Habitat variables in the control reach

Date	*Flow (m^3/s)*	*Wetted width (mean)*	*Total wetted area (ha)*	*% of total habitat*					
				Rapid	*Riffle*	*Shallow Run*	*Deep Run*	*Pool*	*Backwater*
25 Oct 12	12.3	41.5	622	2.5	15.3	63.4	14.5	1.5	2.9
9 Nov 12	7.9	37.7	611	1.8	21.9	57.3	14.9	1.6	2.6
20 Dec 12	12.6	38.9	592	3.3	29.2	47.3	16.0	1.8	2.5
14 Feb 13	7.1	36.7	544	4.1	23.3	66.3	5.4	0.9	0.1
Mean	10.0	38.7	592.3	2.9	22.4	58.6	12.7	1.5	2.0
st.dev.	2.5	1.8	29.9	0.9	4.9	7.3	4.3	0.3	1.1
Equivalence test	inconclusive	inconclusive	inconclusive	inconclusive	inconclusive	inconclusive	inconclusive	inconclusive	inconclusive

*Equivalence test assumes +/- 20% difference and p-values significant if <0.05

Habitat maps for the control reach (see Figure 4-5) indicate that river alignment has remained relatively stable throughout the survey period despite seven high flow events (>100m^3/s) occurring between the first and last survey.

River morphology elements of particular relevance to the aquatic ecology include the first crossover (at the far right of the figure) where a shallow-run feeds into a riffle/rapid sequence and then sweeps past a rip-rap lining and rock groynes on the true left bank. High water velocities maintain deep water while sheltered pools have developed on the lee of the rock groynes. These structures provide potentially high quality feeding lies for trout and a variety of habitat for native fish species.

The second crossover in the middle of the reach forms a broad complex braided riffle with numerous strands which feed into a high energy rapid as the flow hits the rock rip-rap lining and is diverted sharply downstream. High water velocities maintain deep water against the rip-rap lining, potentially providing cover and good quality habitat for larger fish amongst rip-rap boulders. The braided riffle is likely to provide good quality habitat for bluegill bully which are abundant in this area (Perrie 2013).

The large backwater towards the downstream end of this reach, which receives some cover from overhanging vegetation, may also provide sheltered rearing habitat for small fish, and possibly day-time cover for larger fish including eels, although this feature had disappeared during the last survey.

25 October 2012, flow = 12.3 m^3/s

9 November 2012, flow = 7.9 m^3/s

20 December 2012, flow = 12.6 m^3/s

14 February 2013, low = 7.1 m^3/s

Figure 4-5: Habitat maps of the Hutt River control reach (R= rapid, RI = riffle, SR = shallow-run, DR = deep-run, P= pool and b = backwater

4.2.2 Impact reach

Habitat mapping at the impact reach indicates that most habitat types are present at similar proportions to those described for the control reach, being dominated by shallow-runs which make up approximately 60 percent of total habitat (refer Table 4-2 and Figure 4-6). However, the impact reach generally had more pool habitat and less deep-run and backwater habitat than the control site. All of the pools in the impact reach, including two large pools >3m deep and four to five smaller pools, were associated with rock stub groynes. The deep-run habitat was nearly all generated by fast water pushing up against rip-rap lined banks.

As noted for the control reach, the most dynamic feature of the impact reach was the shifting balance between shallow-run and riffle habitat, which appeared to be driven by at least three factors including:

- changes in river flow rates,
- changes in river morphology, possibly resulting from gravel movement during preceding flood events, and
- gravel extraction works.

An equivalence test comparison of habitat values in the impact reach for the first two runs 'before' gravel extraction against the second two 'after' the works gave inconclusive results for all variables except for the proportion of pool habitat, for which the data showed strong evidence of a practically important decrease following the in-river works (Table 4-2). As can be seen in Figure 4-7 no clear before/after pattern is evident for any habitat type other than pool.

Table 4-2 Habitat variables in the impact reach (post gravel extraction results are in bold)

Date	*Flow (m^3/s)*	*Wetted width (mean)*	*Total wetted area (ha)*	*% of total habitat*					
				Rapid	*Riffle*	*Shallow Run*	*Deep Run*	*Pool*	*Backwater*
25 Oct 12	12.3	36.5	552	5.6	17.1	61.5	11.1	4.4	0.2
9 Nov 12	7.9	34.1	480	4.6	9.1	72.9	7.5	5.4	0.6
20 Dec 12	**12.6**	**32.7**	**462**	**2.9**	**37.0**	**41.8**	**16.2**	**2.0**	**0.1**
14 Feb 13	**7.1**	**34.3**	**495**	**4.4**	**18.1**	**64.7**	**10.7**	**2.0**	**0.1**
Mean	10.0	34.4	497.3	4.4	20.3	60.2	11.4	3.5	0.3
st.dev.	2.5	1.4	33.7	1.0	10.2	11.4	3.1	1.5	0.2
Equivalence test	inconclusive	inconclusive	inconclusive	inconclusive	inconclusive	inconclusive	inconclusive	strong	inconclusive

*Equivalence test assumes +/- 20% difference and p-values significant if <0.05

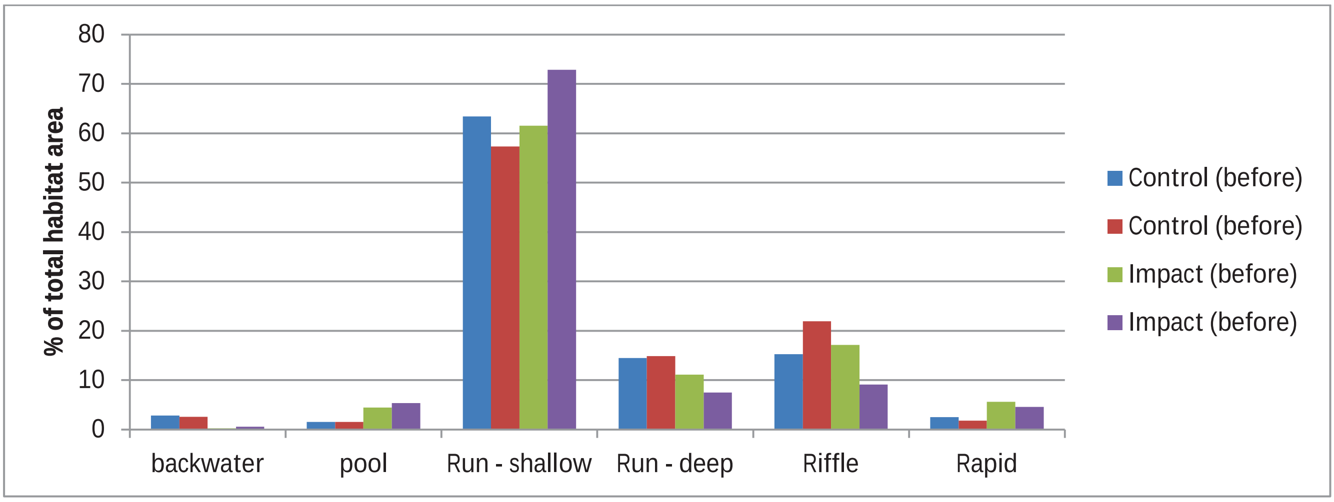


Figure 4-6: Proportion of habitat types in control and impact reaches prior to gravel extraction works

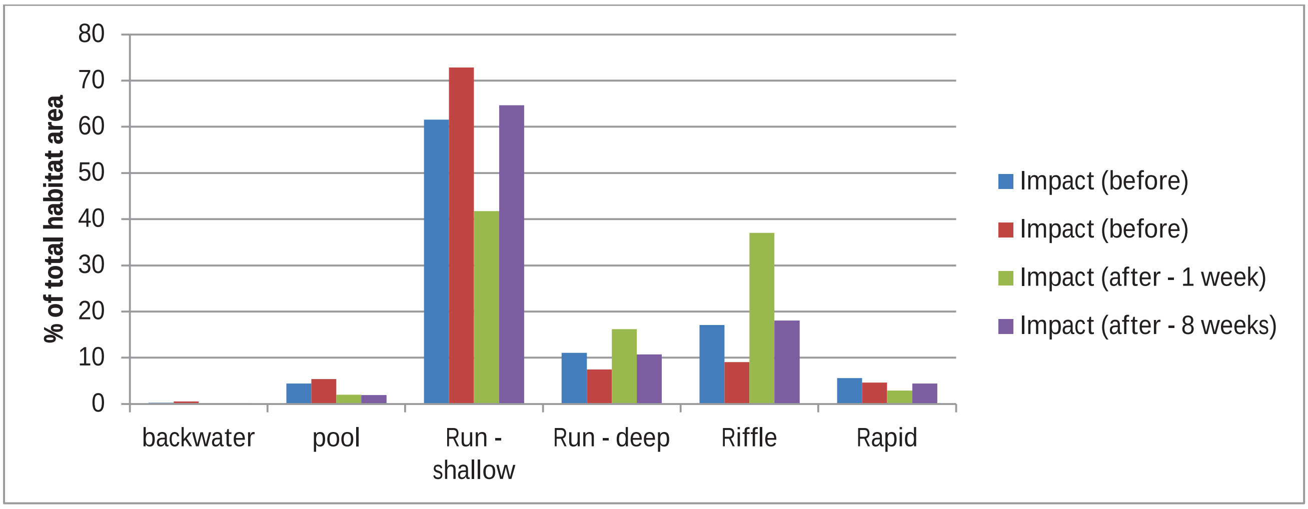


Figure 4-7: Proportion of habitat types in the impact reach before and after gravel extraction works

The impact reach habitat maps in Figure 4-8 show very similar characteristics to the control reach, both having three crossovers where a shallow-run feeds into a riffle/rapid/deep-run sequence. The crossover in the middle of the Figure 4-8 is of particular interest as it generates a complex morphology with water flowing fast over a riffle and rapid into a narrow deep channel which then sweeps hard against a riprap lined wall on the true left bank. A series of rock groynes push the main flow out from the bank and in doing so create a series of deep pools linked by a deep-run. Deep sheltered water occurs in the lee of each groyne providing a series of good quality feeding lies for trout. Overall, this combination of structures potentially provides a variety of high quality habitats for invertebrates and fish.

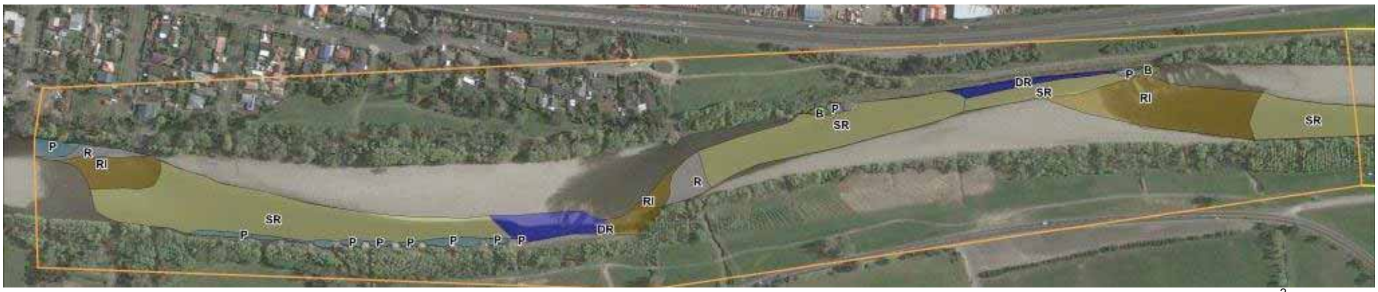
The gravel extraction works affected the downstream 400m of the reach. As shown in Figure 4-8 the works transformed the shallow-run/riffle/rapid/pool sequence shown on the far left into a narrower, more channelised structure, with greater area of deep-run and much reduced shallow-run. The large pool was reduced in size and the riffle changed from a complex braided structure into a longer narrower, more channelised structure (refer Figure 4-4).

From an ecological perspective the loss of complexity of the braided riffle and the loss of much of the large pool are likely to have reduced habitat quality, however this was offset to some extent by the conversion of a uniform broad shallow-run into a well-defined low flow channel with increased area of deep-run habitat. It may also have been offset but other changes elsewhere in the reach unrelated to the works, including a large increase in riffle area at the most upstream crossover.

There was evidence of significant short term impacts including direct fish mortality, suspension and deposition of fine sediments in the works area and further downstream, and reduction in particle size within the modified riffle (pers.com. Alton Perrie).

Eight weeks later, after the passage of three large flood events which had extensively re-worked the gravels in this part of the river, the lower part of the reach had changed again and had partially reverted to the pre-works structure. The large pool had been fully reinstated and the riffle had again become braided and had a normal (cobble) substrate composition. Recovery, at least in terms of physical habitat, was therefore fairly rapid in this instance, but was largely dependent on the occurrence of high flow events of sufficient magnitude to re-work the gravels.

Before Works: 25 October 2012, flow = 12.3 m^3/s



Before Works: 9 November 2012, flow = 7.9 m^3/s

Immediately After Works: 20 December 2012, flow = 12.6 m^3/s

Eight Weeks After Works: 14 February 2013, low = 7.1 m^3/s

Figure 4-8: Proportion of habitat types in the impact reach

5 Discussion and conclusions

Normal practice in the Wellington Region is to limit gravel extraction to areas outside the wetted width of the river, that is, from beaches above the active channel. Gravel is pushed up into stock piles by an excavator and then loaded onto trucks for removal. However, in a river such as the Hutt, which is tightly constrained by development adjacent to the river corridor, that practice has tended to result in the creation of a uniform straight, shallow channel with little morphological complexity, few pools and poor quality habitat for fish.

In response to this concern, GWRC has, in consultation with Fish and Game NZ, developed a different method of gravel extraction (coupled with bed recontouring) for the Hutt River which involves working in the low flow channel. This is centred on the deliberate formation of a meander pattern with a pool and riffle form so as to provide better in-stream habitat for invertebrates and fish.

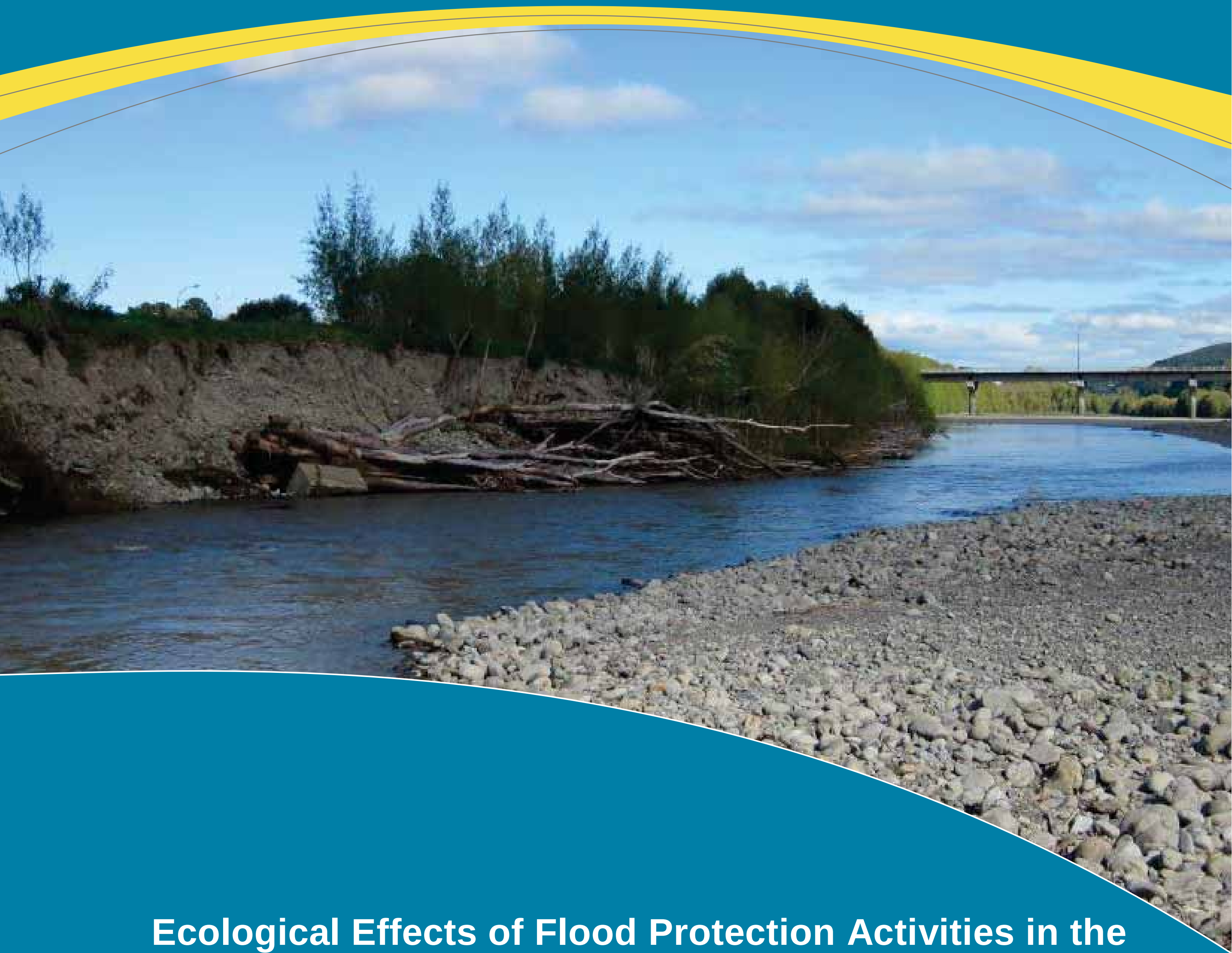
This habitat mapping study has assessed the implications of this approach in terms of the relative abundance of six main habitat types. The following observations can be made:

- Work within the low flow channel invariably caused short term impacts including direct fish mortality, suspension and deposition of fine sediments, and temporary loss of invertebrate production from relatively large areas of riffle habitat.
- In terms of physical habitat the works tended to result in a deeper more confined channel, with less shallow-run and more deep-run, and reduction in the area of pool habitat. A loss of complexity and reduced substrate particle size within the riffle habitat was also noted.
- Recovery was well underway within eight weeks of completion of works. The riffle had increased in complexity by re-formation of a braided character and increased particle size. The pool which had been reduced in size by the works had been scoured out by flood waters and was now very large, possible 4 to 5 meters deep.
- In this case the net change in the impact reach was relatively small, probably within the normal variation for this part of the river, but this is partly due to the reduced scope of works.
- A key finding of this investigation is that both the control reach and the impact reach contained relatively large areas of high quality habitat for invertebrates and fish and would be expected to support a moderately diverse fish population. This is despite the relatively extensive flood protection works including rock rip-rap linings, rock stub groynes, vegetative bank protection and gravel extraction.

Appendix G Ecological Effects of Channel Re-alignment in the Hutt River

MWH

BUILDING A BETTER WORLD



Ecological Effects of Flood Protection Activities in the Hutt River

Prepared for Greater Wellington Regional Council

July 2015

This document has been prepared for the benefit of Greater Wellington Regional Council. No liability is accepted by this company or any employee or sub-consultant of this company with respect to its use by any other person.

This disclaimer shall apply notwithstanding that the report may be made available to other persons for an application for permission or approval to fulfil a legal requirement.

QUALITY STATEMENT

PROJECT MANAGER

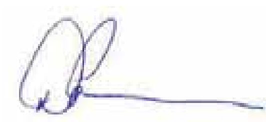
Tom Kerr

PROJECT TECHNICAL LEAD

David Cameron

PREPARED BY

David Cameron



.... 25/07/2015

REVIEWED BY

Kristy Hall

.... 25/07/2015

APPROVED FOR ISSUE BY

Laurie Gardiner

WELLINGTON
Level 13, 80 The Terrace, Wellington 6011
PO Box 9624, Te Aro, Wellington 6141
TEL +64 4 381 6700, FAX +64 4 473 1982

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 Introduction

1.1 Background

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 for a number of other purposes including the maintenance of aquatic ecosystem health. GWRC has recently undertaken a series of investigations designed to assess the effects of flood protection activities on river ecology around the region. These studies include investigations of fish and invertebrate re-colonisation following gravel extraction in the Hutt River (Perrie, 2013), and investigations of changes in sediment deposition, periphyton biomass, invertebrate re-colonisation, and fish re-colonisation following three types of flood protection activities in the Waingawa, Waiohine and Ruamahanga Rivers (Death & Death, 2013). These studies have identified that flood protection works involving extensive disturbance of the riverbed have the potential to adversely affect the benthic ecology and fish communities by:

- Changes to stream channel shape and geomorphology,
- Changes to the compaction and size distribution of the stream substrate,
- Mobilisation, re-suspension and increased deposition of fine sediment and associated effects on water clarity and benthic habitat,
- Physical disturbance of, or change of in-stream and riparian habitat,
- Physical destruction of plants and animals
- Disruption of fish spawning and/or migration.

1.2 Hutt River Flood Protection Works

A reach in the Hutt River at Belmont, at GWRC cross sections XS690 to XS710, was identified by GWRC as an area where flood protection works would be required due to severe erosion of the true left bank. The proposed works include bed re-contouring which would be required over a river length of 220m with a total surface area of approximately 6,800 m^2 to achieve a new channel alignment and to repair the eroded bank.

1.3 Purpose of this Report

The purpose of this report is to provide an assessment of the effects of channel re-alignment and associated bed re-contouring on aquatic habitat characteristics, water quality and fish communities of the Hutt River at Belmont.

2 Methodology

2.1 Survey Design

A Before-After-Control-Impact design was selected in order to account for differences between the sites and to focus the assessment, as far as is practicable, on the effects of flood protection activities. The method adopted for the assessment of habitat quality and fish communities was to visit each site on three occasions, once prior to works being carried out (on 23 April 2015), once within two weeks of completion of the works (on 16 June 2015) and once four to five weeks later, following a fresh (on 23 July 2015). Ideally two pre-works surveys would have been undertaken so as to characterise natural variation, but on this occasion there was insufficient lead time for this to be implemented. Water quality monitoring was undertaken at the three sites twice prior to commencement of work (4th and 11th May 2015) and twice while bulldozers were operating in the active river channel (26th and 29th May, 2015).

2.2 Monitoring Sites

Three aquatic ecology monitoring sites were established in order to monitor the effects of the flood protection works. The sites were the works site itself, and similar reaches located 1,000m upstream and 750m downstream of the works. The intention was to select upstream and downstream reaches that were similar to the works reach in terms of hydrology, geomorphology and habitat types, and that were in reasonably close proximity, to act as control sites.

The three survey reaches upstream (H-US), downstream (H-DS) and impact (H-IM) are listed in Table 2-1 and their locations are shown in Figure 2-1. All three sites are located in areas where river meanders have eroded the true left bank. At the upstream site the river flowed in a single channel whereas at the impact and downstream sites the river had split into two channels forming a central gravel bar. (Note the aerial photograph shown in Figure 2-1 does not show the river form at the time of the survey but does indicate its general location).

Table 2-1: Location of Hutt River aquatic ecology monitoring sites

Site Code	Location	Easting	Northing
H-US	1000m upstream of river works	2672993	6000694
H-IM	River works impact site	2672293	6000046
H-DS	630m downstream of river works	2671686	5999634

Figure 2-1: Locations of Hutt River Aquatic Ecology Monitoring Sites (red) and works site (yellow)

2.3 Physical Habitat

Physical habitat characteristics were assessed over study reaches of 200m length at each of the three sites, once prior to commencement of works, once two weeks after completion of works and once seven weeks after completion. The assessment included the following:

- Wetted width measured by laser rangefinder at six locations equally spaced along the 200m reach.
- Thalweg water depth measured at six locations equally spaced along the 200m reach.
- Lineal length of bank undercutting measured on both banks along the 200m reach
- Lineal length of overhanging vegetation was measured on both banks along the 200m reach.
- Particle size distribution determined by Wolman pebble count at one representative riffle and one shallow run at each site. The results were used to calculate the median particle diameter (d50) at each location.
- Embeddedness was subjectively assessed as loose, moderate or tight at one representative riffle and one shallow run at each site.
- Channel characteristics were noted at each site (i.e., single channel, split channel).
- Habitat types were mapped and surface area calculated at each site (as rapid, riffle, shallow run, deep run, pool and backwater)

2.4 Water Quality

At each of the three sites, spot water quality testing was undertaken on two separate days before commencement of works and on two days while the works were in progress (when two bulldozers were operating in the wetted channel). The following water quality variables were measured:

- Turbidity
- Total suspended solids,
- Total phosphorus and dissolved reactive phosphorus,
- Total nitrogen, nitrate + nitrite nitrogen, total ammonia nitrogen, and
- *E. coli.*

The sampling location at the impact site was approximately 100m downstream of the active works area.

Water samples were collected on site and sent for analysis at Hills Laboratory.

2.5 Fish Communities

Single pass electric fishing was conducted at each site using a Kainga EFM300 battery powered backpack electric fishing machine (EFM), following an adaptation of the New Zealand freshwater fish sampling protocols (Joy, David, & Lake, 2013). The New Zealand freshwater fish sampling protocols are designed for wadeable streams at locations where at least 90% of the site is less than 0.6m deep and the mean wetted width is less than 12m. Neither of these conditions were met on the Hutt River and it was not feasible to survey a continuous 150m reach as recommended by the protocols. Instead sampling was undertaken on between 650 and 850 m^2 of wadeable habitat, mostly in riffle habitat and in shallow runs, and occasional backwater habitat. Deep unwadable sections of the river were not surveyed due to health and safety issues.

One limitation of this approach is that it may not detect taxa which prefer deep run or pool habitat which in this part of the river might include common bully, cran's bully, giant bully, shortfin eel, longfin eels and trout (refer Perrie, 2013). It is noted also that water temperatures became progressively cooler during the course of the study and that low temperatures on the two post works surveys (7 to 9 ^oC) may have reduced fish capture rates compared with the pre-works survey (14 to 16 ^oC).

All fish caught were identified and a selection of fish were measured (total length) before being released back into the river at the end of the survey.

3 Results

3.1 Flood Protection Works

The river re-alignment works were designed to arrest erosion on the true left bank of Hutt River at Belmont by realigning the river channel. The works extended over a river length of approximately 220m and width of 65m, creating a channel through a gravel beach (Figure 3-1).

The works commenced on Friday 22nd May 2015 and were completed eight days later on Saturday 30th May 2015, after approximately 100 hours of bulldozer operation. Initially a single bulldozer was used but a second bulldozer joined the works on 26th May, and both continued to completion. The following observations were made during site visits on 22nd and 26th May:

- Bed material was first pushed from mid channel to form a large windrow near the true left bank.
- The river was allowed to flow along the middle channel while the realignment was completed by a second push of material into the eroded true left bank, initially at the upstream end, working in downstream direction. Fish located near the left bank were at risk during this activity, however an escape route was maintained at the downstream end of this reach.
- Fish that sought shelter in the bed substrate or under cover against the left bank are likely to have been killed during construction. No dead fish were observed during a site walkover immediately after the works, however that inspection did not include searching for fish beneath cobbles.

Figure 3-1: Erosion site on the true left bank of the Hutt River at Belmont, and proposed new channel alignment (indicative)

3.2 River flow conditions during the study

The pre-works habitat assessment and fish survey was undertaken in 23 April 2015, shortly before the works were due to commence. A series of high river flow events delayed the start of works until 22 May, and completion until 30 May (see Figure 3-2). The post-works habitat assessment and fish surveys were undertaken on 16 June and 23 July 2015. The initial fish survey was undertaken while the river flow was very low, at 4.759 m^3/s. River flow became progressively higher during the second and third surveys at 9.446 m^3/s and 14.999 m^3/s, respectively. The differences in river flows may have influenced fish densities and fish 'catchability' as discussed later in this report.

High river flow events on 14 May and 18 June were of sufficient magnitude to cause some changes in river form at some locations (including removal of a central gravel bar at the downstream site H-DS).

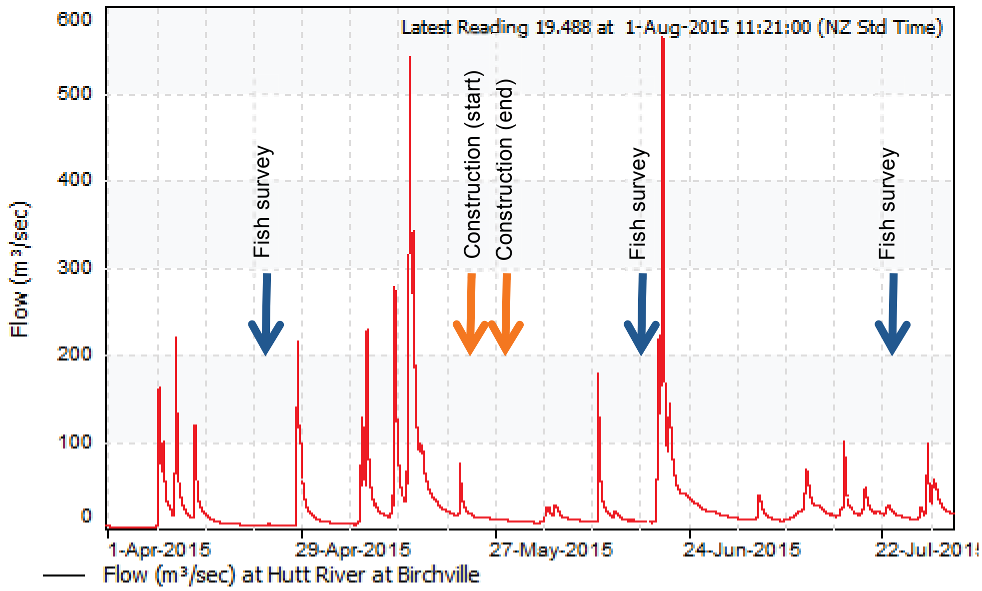


Figure 3-2: Hydrograph of Hutt River for the study period show the beginning and end of river works (orange arrows) and the three fish surveys (blue arrows)

3.3 Habitat characteristics

The habit characteristics recorded at the three Hutt River sites are presented in Table 3-1 and the results for selected variables are illustrated as bar graphs in Figure 3-3 to 3-10. Pre-works and post works photographs of the three sites are included as Appendix A and habitat maps used to calculate habitat areas of are included as Appendix B.

The upstream site included a broad shallow run which swung towards the true left bank and narrowed into a swift shallow riffle, then a rapid, pushing up against an armoured rip-rap bank where it transitioned into a fast deep run. The predominant habitat was shallow run (67%) followed by deep run (19%), and riffle (14%), with no significant areas of backwater or pool. The substrate was predominantly large cobbles in riffles (the median diameter or d50 was 62mm) and small cobbles and gravel in runs (d50 = 38mm). The substrate was relatively loose (not tightly embedded). The mean wetted width was 15m at low flow and the mean thalweg depth was 1m. The reach did not include any undercut banks or vegetation overhanging the active channel.

The works site, where channel re-alignment was to be carried out, included a broad shallow run which swung towards the true left bank and split into two channels around a central gravel bar. Each of the channels formed swift shallow riffles at the upper and lower ends, with a shallow run between. The two channels recombined near the true left bank near the active erosion zone. This reach included a rapid and pool followed by deep run and shallow run. The predominant habitat type was shallow run (68%) followed by riffle (15%), deep run (14%), and pool (3.6%), with no significant area of backwater. The substrate was predominant large and small cobbles in riffles (d50 = 49mm) and small cobbles and gravel in runs (d50 = 30mm), and was loosely embedded. The mean wetted width was 17m at low flow and the mean thalweg depth was 1.15m. The site included 20m of undercut bank length and 60 of vegetation overhanging the active channel.

The downstream site had a very similar form to the works site. It included two channels flowing around a central gravel bar, recombining near the true left bank forming a rapid in the region of active erosion on the left bank, followed by a deep pool and a long deep run. The predominant habitat site was shallow run (66%) followed by deep run (20%), riffle (10%), and pool (3%), and backwater (1.5%). The substrate was predominantly cobble/gravel in riffles (d50 = 34mm) and gravel in runs (d50 = 16mm). The mean wetted width was 22m at low flow and the mean thalweg depth was 0.63m. The site included 60m of undercut bank length and 100 of vegetation overhanging the active channel.

Changes identified at the upstream site across the three surveys appear to be largely due to progressively higher river flows in the later surveys, which greatly increased the area of shallow run, thereby reducing the proportion of deep run and riffle area. Moderate flood events on 14 May and 18 June 2015 do not appear to have greatly altered the riverbed at the upstream site, but significantly altered the downstream site by removing the central bar and increasing the total area of riffle

Changes at the impact site caused by the river engineering works were significant. The channel was straightened and simplified by removal of a meander and gravel bar. Two weeks after completion of works the following changes were identified:

- reduction of riffle habitat from 13.4 to 1.9% of total area (remaining riffle deeper and slower),
- reduction of deep run habitat from 13.9 to 1.0% of total area,
- reduction of pool habitat from 3.6 to 0.9% of total area,
- increase in shallow run habitat from 68 to 96% of total area,
- increase in substrate embeddness in both runs and riffles, and
- overhanging vegetation reduced from 60m to 40m of bank length.

The works did not greatly alter the median diameter of substrate (d50) or %fine sediment, but it is noted that a minor flood event prior to the first post-works survey may have removed much of the fine sediment deposited during the works. The works did not change the proportion of undercut bank.

By the second post-works survey the proportion of habitat types was little different from the first post works survey, despite a significant high flow event in the intervening period. In particular the swift shallow riffle habitat that was lost as a result of the works had not been re-established by river processes.

It can be seen in Figure 3-3 that while the proportion of riffle reduced at the impact site, it increased at the downstream site. When assessed across all three sites the proportion of riffle area shows a minor but progressive reduction through the three surveys, which is attributed to a combination of factors including:

- loss of riffle area at the impact site because of engineering works,
- gain of riffle area at the downstream site by conversion of gravel bar riffle by a high flow event, and
- reduction of riffle area at all three sites due to higher flow levels during the two post works surveys.

The pronounced reduction in riffle area at the impact site compared with the relatively minor loss when assessed at the reach scale underscores the importance of scale both in terms of the area affected and the frequency of works when considering the potential adverse effects associated with habitat loss.

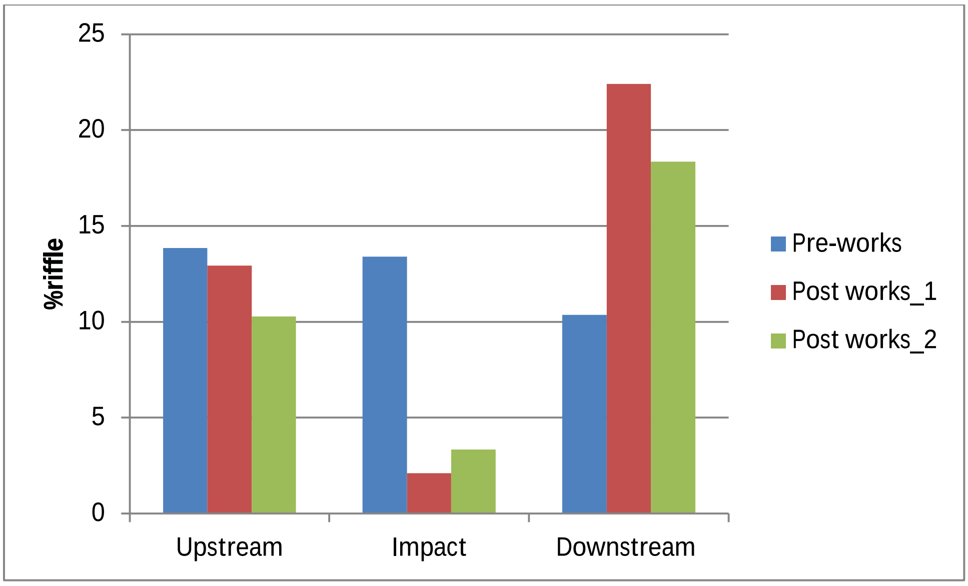


Figure 3-3: Proportion of riffle habitat at three sites in Hutt River before and after river works

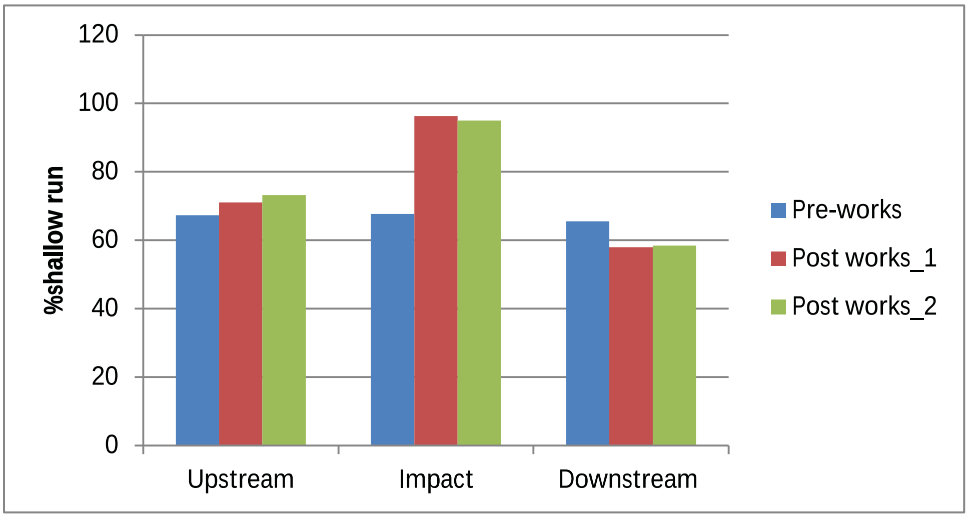


Figure 3-4: Proportion of shallow run at three sites in Hutt River before and after river works

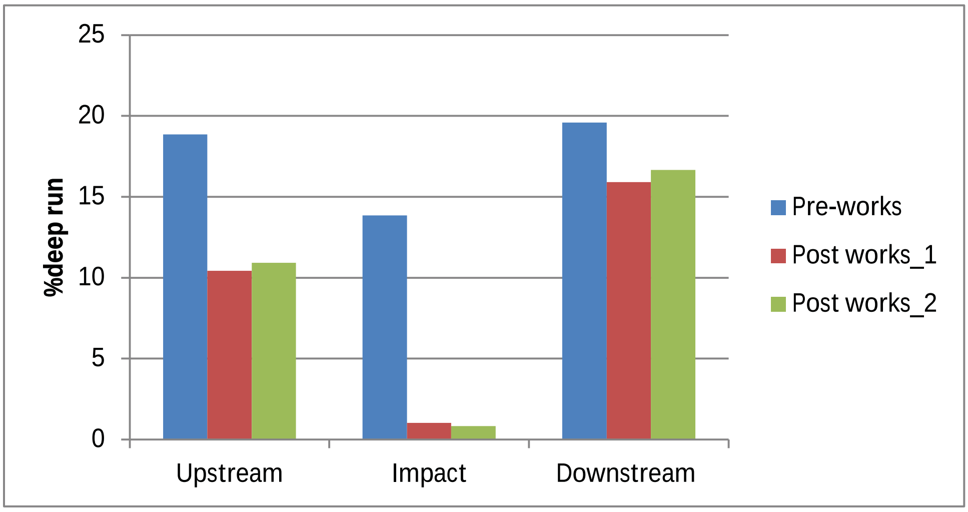


Figure 3-5: Proportion of deep run at three sites in Hutt River before and after river works

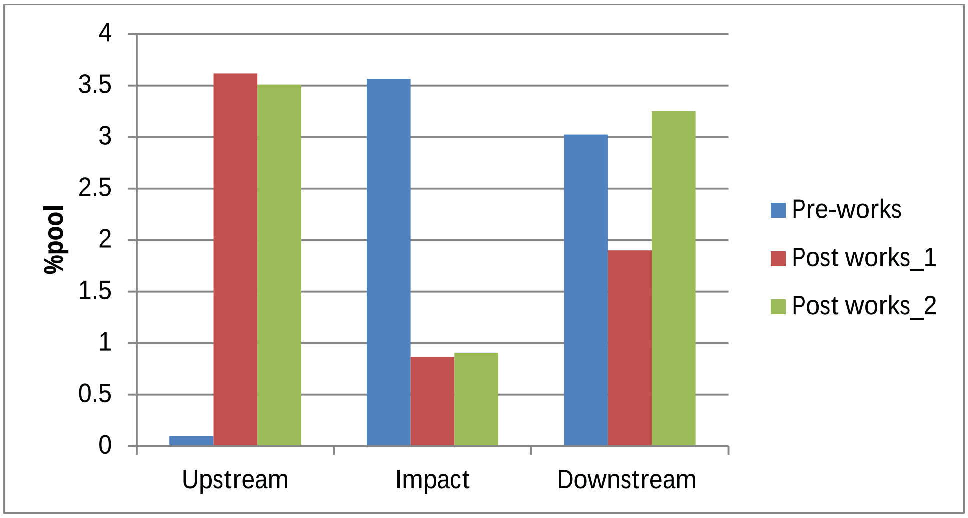


Figure 3-6: Proportion of pool habitat at three sites in Hutt River before and after river works

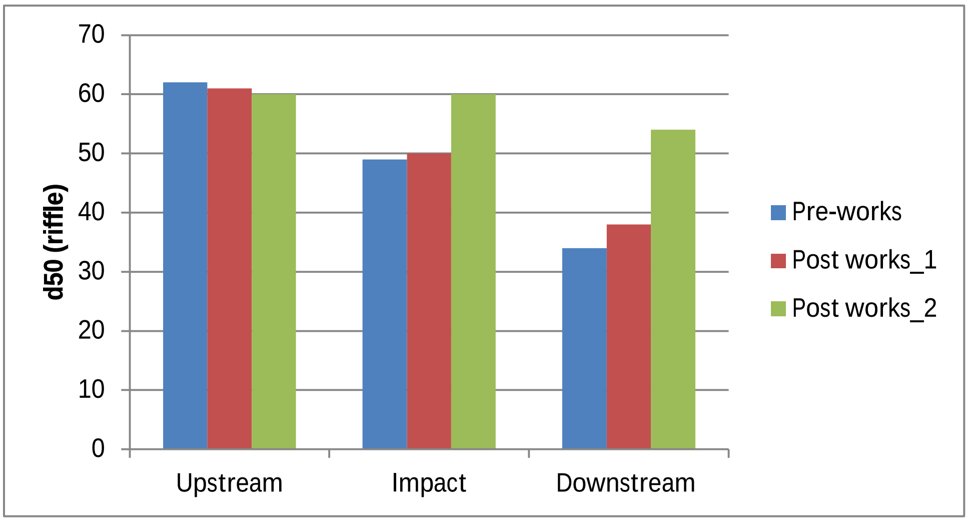


Figure 3-7: Median particle size mm (d50/riffles) three sites before and after river works

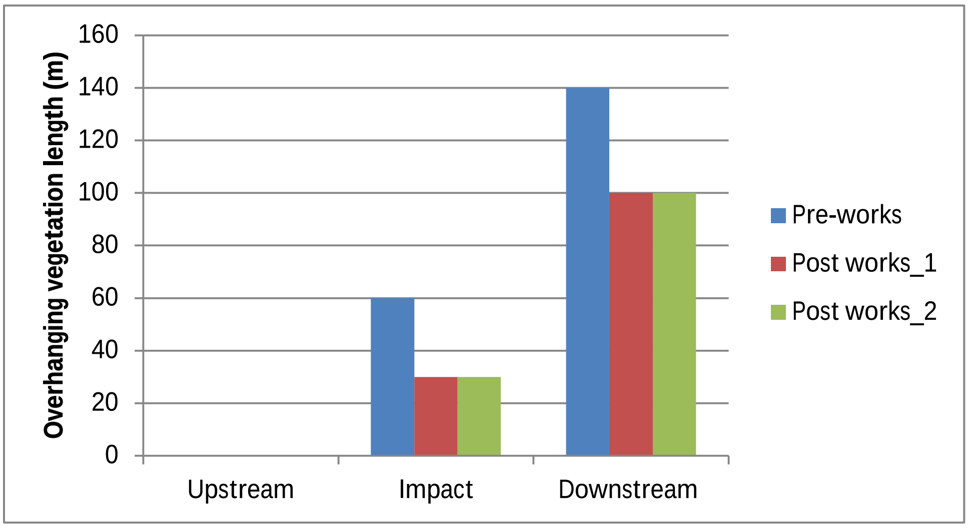


Figure 3-8: Length of overhanging vegetation at three sites before and after river works

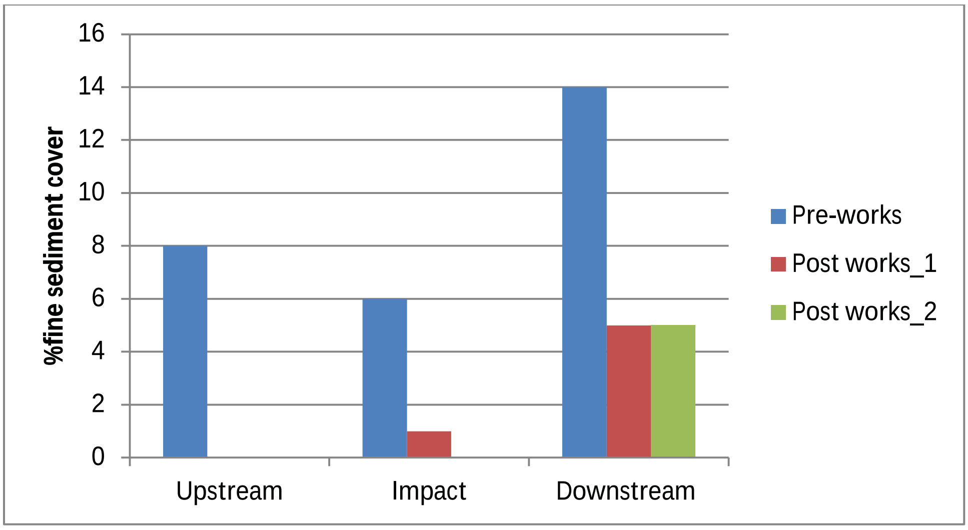


Figure 3-9: %fine sediment cover at three sites in the Hutt River before and after river works

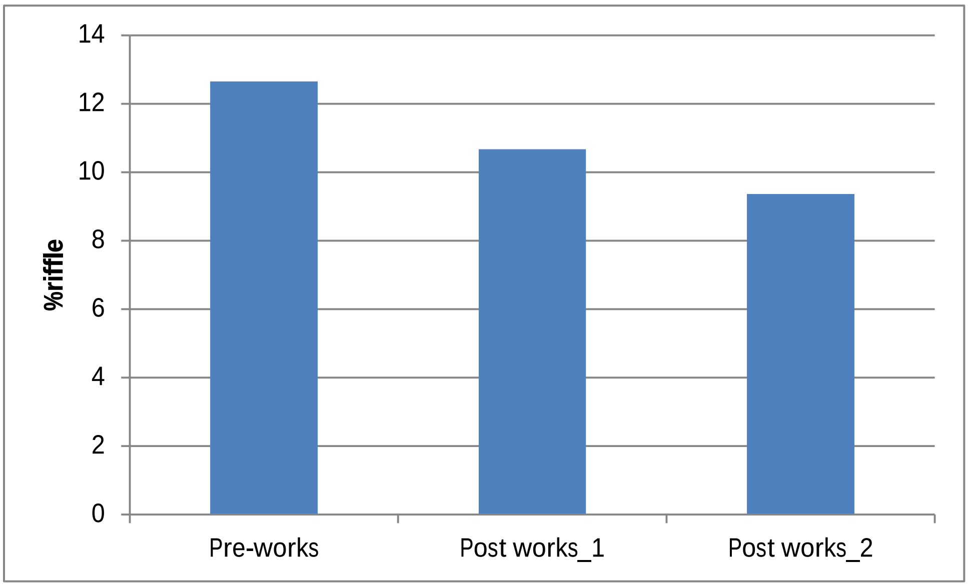


Figure 3-10: %riffle across three sites (upstream, impact, downstream) before and after works

Table 3-1: Habitat characteristics of sites sampled upstream, within and downstream of river works on the Hutt River

	Upstream H-US			Works Area H-IM			Downstream H-DS		
	Pre-works	Post-works#1	Post-works#2	Pre-works	Post-works#1	Post-works#2	Pre-works	Post-works#1	Post-works#2
Date sampled	23/04/2015	16/06/2015	23/07/2015	23/04/2015	16/06/2015	23/07/2015	23/04/2015	16/06/2015	23/07/2015
Time sampled	15:58	13:50	11:15	11:15	11:30	10:30	9:40	9:30	9:45
Easting	2672993	2672993	2672993	2672293	2672993	2672993	2671686	2672993	2672993
Northing	6000694	6000694	6000694	6000046	6000694	6000694	5999634	6000694	6000694
Water Quality									
Water temp (°C)	15.58	8.73	8.08	13.89	8.29	7.43	13.53	8.08	7.29
Conductivity (µS/cm)	86	63	60	82	62	58	81	71	61
DO (%sat)	104.3	95.8	107	101.8	97.1	108	93	91.9	109
DO (mg/L)	10.38	11.16	12.67	10.51	11.41	12.96	9.71	10.87	13.21
pH	7.04	6.83	7.02	7	6.75	6.8	6.96	6.8	6.91
Physical									
River flow (m^3/s)	4.759	9.446	14.996	4.759	9.446	14.996	4.759	9.446	14.996
Mean width (m)	14.8	49.3	56.8	16.6	50.3	62.3	21.8	34.2	42
Mean thalweg depth (m)	1	1.63	1.75	1.15	0.66	0.5	0.63	1.12	1.38
channel form	single	single	single	split	single	single	split	split	single
reach length (m)	200	200	200	200	200	200	200	200	200
wetted area (m^2)	5379	9210	9491	6877	11993	14499	5093	7897	8765
Habitat type									
% pool	0.0	3.6	3.5	3.6	0.9	0.9	3.0	1.9	3.3
% riffle	13.9	12.9	10.3	13.4	1.9	3.2	10.4	22.4	18.4
% shallow run	67.3	71.0	73.2	67.7	96.3	95.0	65.5	57.9	58.4
% deep run	18.9	10.4	10.9	13.9	1.0	0.8	19.6	15.9	16.7
% backwater	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.0	1.0
undercutting (m)	0	0	0	20	20	20	60	60	60
Overhanging veg. (m)	0	0	0	60	40	40	100	100	100

Table 3-2: Riverbed substrate characteristics of sites sampled upstream, within and downstream of river works on the Hutt River

	Upstream H-US						Works Area H-IM						Downstream H-DS					
	Pre-works		Post-works#1		Post-works#2		Pre-works		Post-works#1		Post-works#2		Pre-works		Post-works#1		Post-works#2	
Substrate	riffle	run	riffle	run	riffle	run	riffle	run	riffle	run	riffle	run	riffle	run	riffle	run	riffle	run
embeddedness	Loose	Loose	Loose	Loose	Loose	Loose	Loose	Loose	Mod.	Mod.	Mod.	Mod.	Loose	Loose	Loose	Loose	Loose	Loose
% clay/silt	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% sand	1	6	0	0	0	0	1	6	1	1	0	0	1	14	0	5	1	5
% small gravel	4	6	1	3	3	3	2	7	2	8	2	2	3	12	2	14	3	12
% small-med gravel	5	12	3	11	11	11	5	12	6	19	5	14	11	16	10	16	8	15
% med-large gravel	11	13	15	29	14	28	10	19	15	27	11	26	23	19	16	17	12	19
% large gravel	20	18	21	30	15	28	31	20	25	29	24	28	26	20	33	21	22	22
% small cobble	26	26	30	16	26	17	30	20	25	12	28	19	27	13	23	15	25	15
% large cobble	32	17	29	10	31	12	21	15	25	4	29	11	9	6	15	9	29	9
% boulder	1	0	1	1	0	1	0	1	1	0	1	0	0	0	1	3	0	3
% bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
%fine sediment	1	8	0	0	0	0	1	6	1	1	0	0	1	14	0	5	1	5
Median diameter (d50)	62	38	61	28	60	29	49	30	50	21	60	30	34	16	38	22	54	24

3.4 Water quality

The water quality results are summarised in Table 3-3 and are shown as bar graphs in 3-11 to 3-17.

Hutt River turbidity and suspended solids were similar at all three sites prior to works being undertaken but increased sharply at the works site and downstream of the works while bulldozers were operating in the active channel. At approximately 100m downstream of the operating bulldozers turbidity levels were up to 460 higher than pre-works, declining to 16 times higher than pre-works at 700m downstream. Suspended solids concentrations were up to 233 times higher at 100m and 18 times higher at 700m. A visible plume of turbid water was observed to extend some kilometres downstream of the works site while the bulldozers were operating.

Escherichia coli counts were similar at all three sites prior to the works but increased 10-fold at the works site during one of the two sampling occasions while the bulldozers were operating. Interestingly, on the second sampling event during works there was no increase at the works site. Seven hundred metres downstream of the works site there was no difference between pre-works and works *E. coli* counts.

Total nitrogen (TN) concentrations increased in a downstream direction prior the works, and increased up to 3-fold at the works site during bulldozer operation. There was no corresponding increase 700m downstream of the works, indicating that this effect was relatively localised. Dissolved inorganic nitrogen (DIN) also increased in a downstream direction prior to the works but unlike TN did not increase while the works were in progress.

Total phosphorus (TP) increased in a downstream direction prior the works, and increased up 64-fold at the works site during bulldozer operation. A slight increase (2-fold) occurred 700m downstream of the works, indicating that the effect of works on TP was quite localised. Dissolved reactive phosphorus (DRP) increased in a downstream direction prior to the works but did not increase while works were underway.

In summary, the works caused a marked increase in suspended solids and turbidity in the water column and an associated increase in nitrogen and phosphorus concentrations. The results show however that dissolved nutrients did not increase during the works, suggesting that the nutrients were bound to particulate material and would not necessarily be available for plant growth. It is noted that biochemical conditions inside *Phormidium*-dominated mats can, in some instance, be conducive to the release of loosely bound phosphorus, in which case phosphorus may become available for uptake by periphyton (Mark Heath, pers com.)

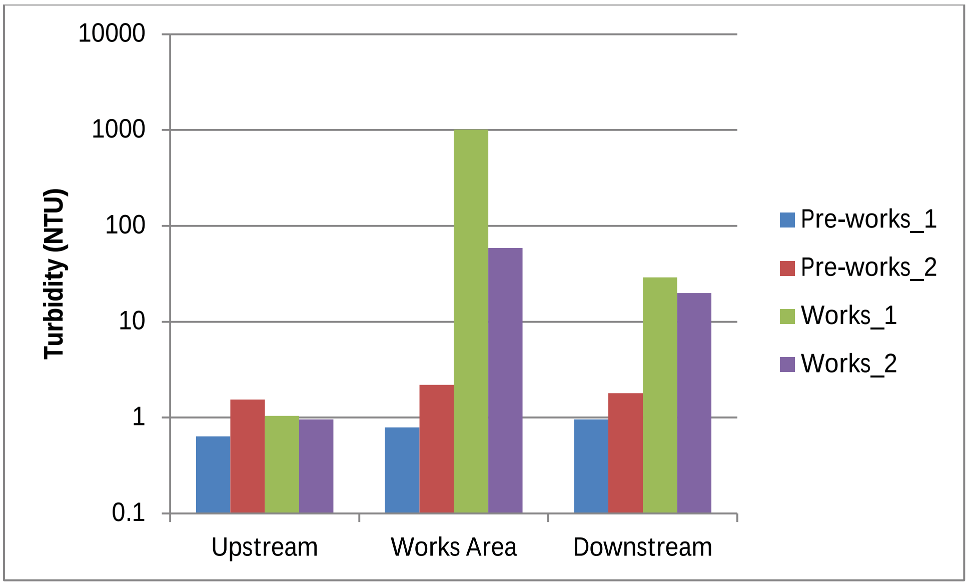


Figure 3-11: Turbidity (NTU) at sites sampled in the Hutt River in May 2015 (log scale)

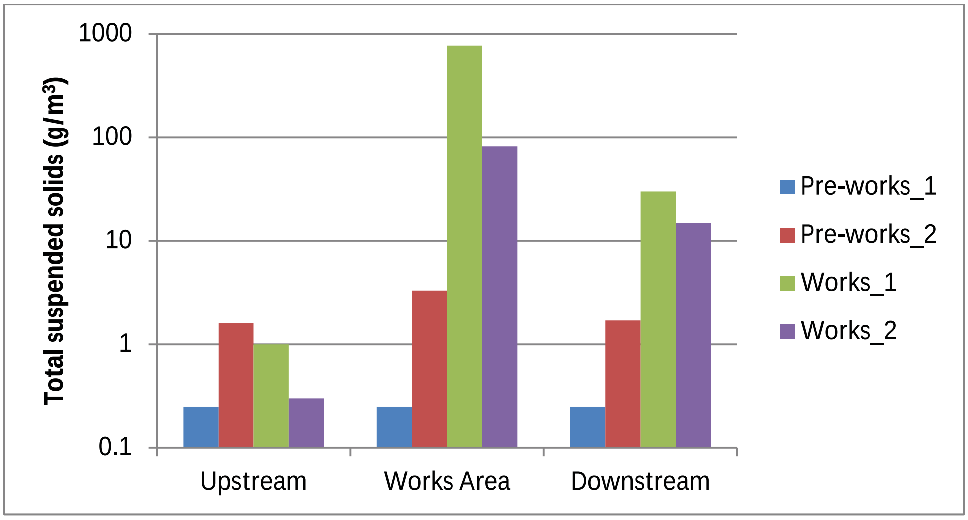


Figure 3-12: Total suspended solids (g/m^3) at sites sampled in the Hutt River in May 2015

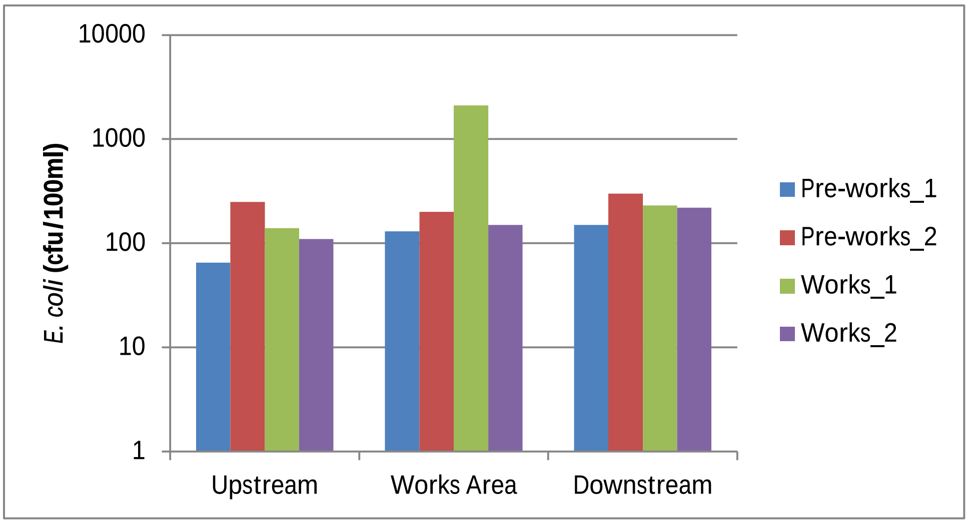


Figure 3-13: E. coli (cfu/100ml) at sites sampled in the Hutt River in May 2015

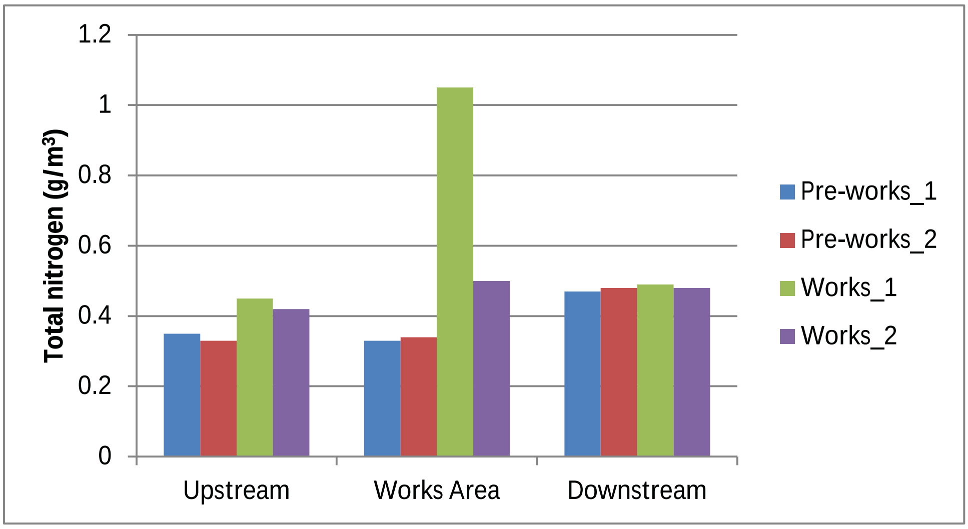


Figure 3-14: Total nitrogen (g/m^3) at sites sampled in the Hutt River in May 2015

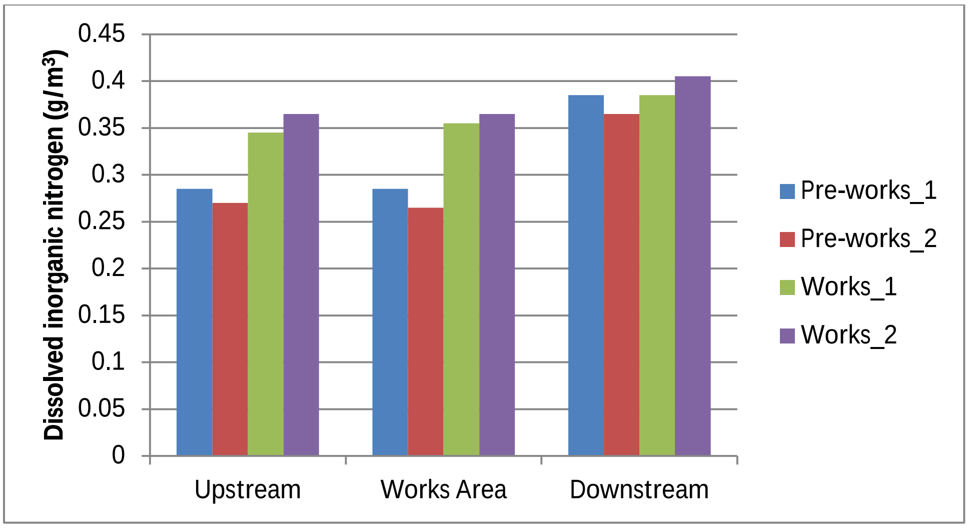


Figure 3-15: DIN at sites sampled in the Hutt River in May 2015

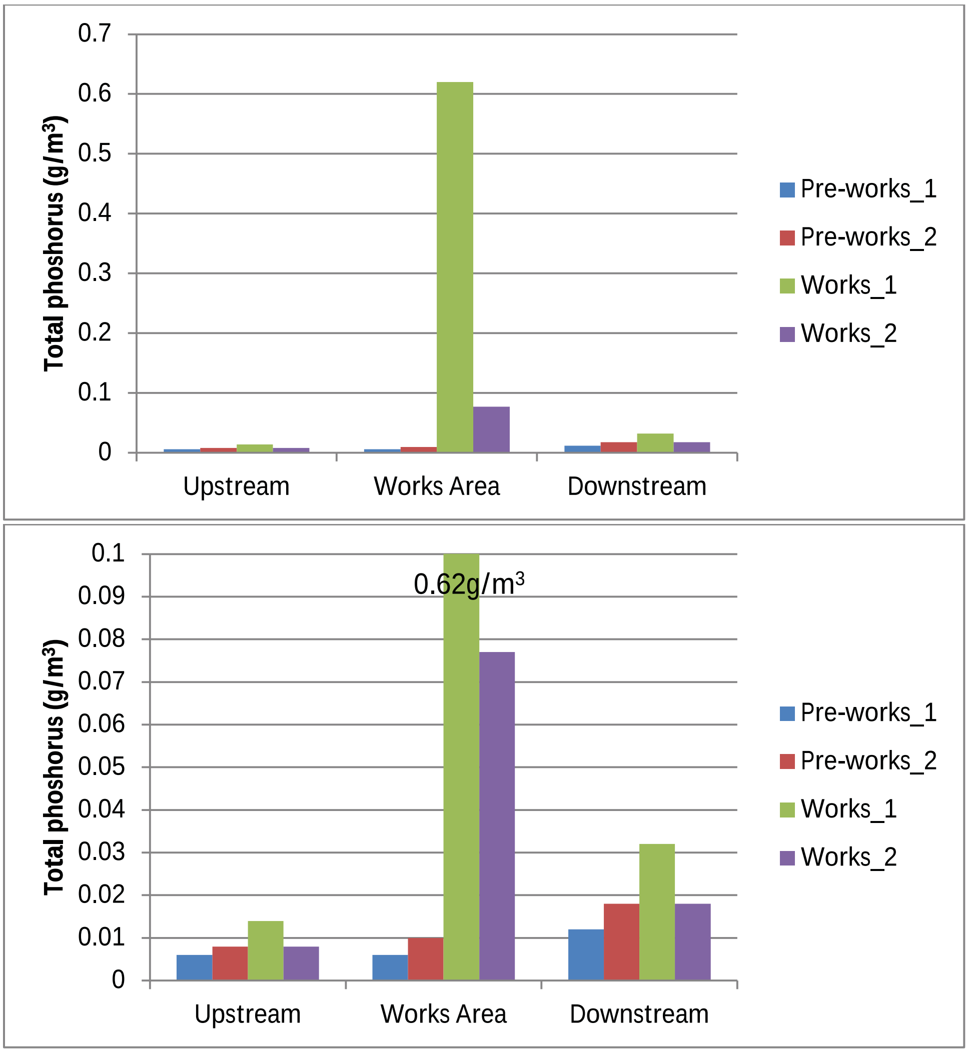


Figure 3-16: TP (g/m^3) at sites sampled in the Hutt River, May 2015 (full scale above, fine scale below)

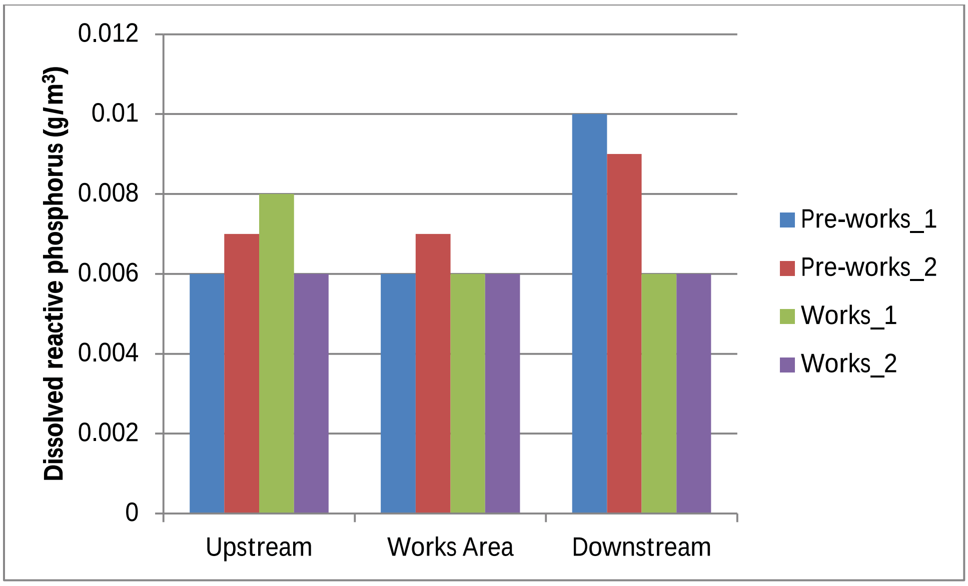


Figure 3-17: DRP (g/m^3) at sites sampled in the Hutt River in May 2015

Table 3-3: Water quality results at three sites on the Hutt River on two occasion prior to works and two occasions during works

	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	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	65	250	140	110	130	200	2100	150	150	300	230	220

3.5 Fish communities

Four fish species were recorded during the survey: bluegill bully (*Gobiomorphus hubbsi*), common bully (*G. cotidianus*), shortfin eel (*Anguilla australis*) and the exotic brown trout (*Salmo trutta*). Bluegill bully was the only species to be recorded at all three sites in significant numbers and made up more than 97% of the fish recorded (Table 3-4). A total of 377 bluegill bullies were collected across all sites and all sampling occasions. The great majority of bluegill bullies were adults ranging in length from 50 to 65mm, and are likely to be resident in this part of the river. The common bullies collected ranged in length from 50 to 91mm, while shortfin eels ranged from 250mm to 300mm, and the single brown trout collected was a juvenile of 146mm in length.

Prior to the works there was little difference in the total number of fish or the number of bluegill bullies collected across the three sites. The similarity in fish abundance across the three sites reflects their similar habitat characteristics (see Section 3.3), with each having a predominantly cobble and gravel bed and similar proportions of riffle habitat. The number of species varied between the sites, with three species present at the upstream site, one at the impact (bluegilled bullies) and two and the downstream site (Figure 3-18).

Fish abundance declined at all three sites across the three surveys, largely due to declines in bluegill bully numbers. Very few common bullies and eels were caught, and only one brown trout was caught, so these species did not influence the results across the three surveys.

Bluegill bullies declined in abundance over time at all three sites, with the most marked decline recorded at the works site. It is known that the upstream migratory urge for this species remains throughout life (see Atkinson & Joy, 2009), which may cause abundance to decline in the lower and middle river through autumn and winter, until the next upstream migration of juveniles begins in the spring. The decline in abundance may also be related to the higher river flows and lower water temperatures for the second and third surveys. Higher rivers levels allow fish more room to spread out across a wider river and can also make small fish such as bullies more difficult to observe capture. Lower water temperatures are known to reduce activity of freshwater fish and may also reduce the chance of capture by EFM. It is evident however that the engineering works caused an additional decline in the works area over and above any seasonal change, and that fish numbers had not recovered by the last survey, seven weeks after completion of works. Common bully, shortfin eel and trout were not sufficiently abundant at any site to allow conclusions to be drawn about the engineering effects on these species.

The lack of recovery in bluegill bully abundance at the works site after seven weeks, despite the occurrence of a high river flow in the period, is expected to be linked to the loss of riffle habitat caused by the works and the absence of any new riffle habitat formation by river processes since completion of the works.

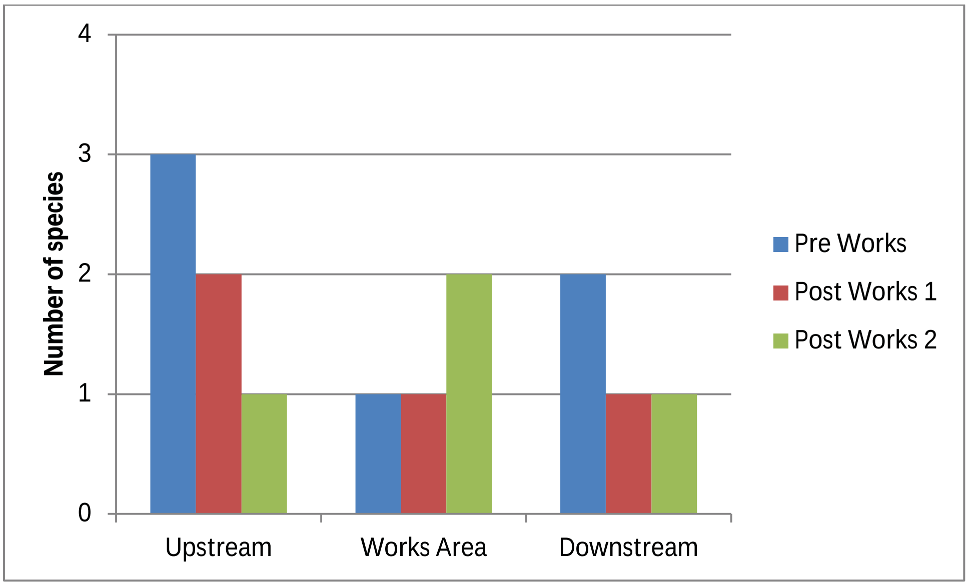


Figure 3-18: Number of fish species collected in the Hutt River, 2015

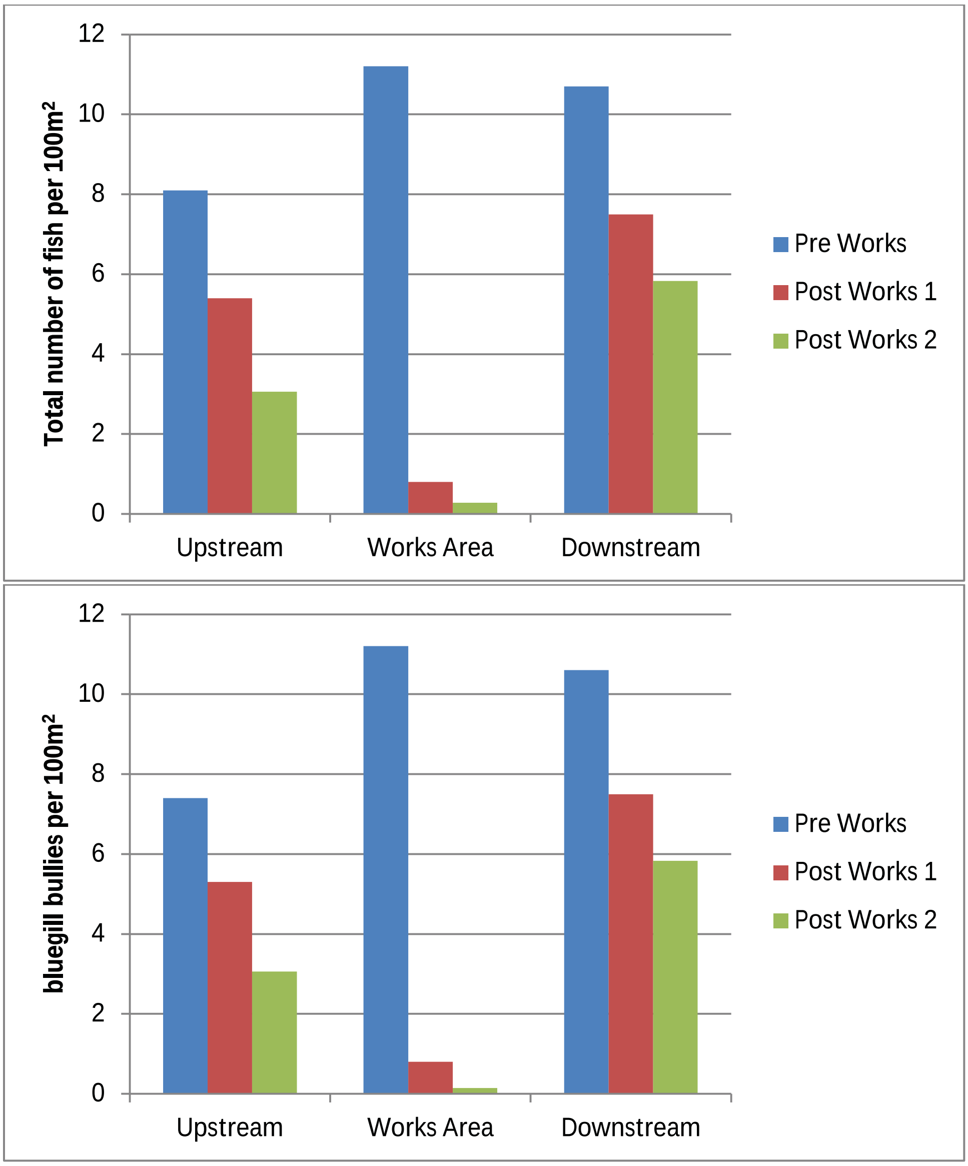


Figure 3-19: Total number of fish and number of bluegill bullies collected per $100m^2$ in the Hutt River

Table 3-4: Number of fish collected at sites upstream, within and downstream of river works on the Hutt River

	Pre-works			Post-works 1			Post-works 2		
Taxa	Upstream	Works area	Downstream	Upstream	Works area	Downstream	Upstream	Works area	Downstream
total area	755	730	653	800	850	875	620	700	600
shock time	25	21	32	24	27	31	18	20	19
blue gill bully	56	82	69	42	7	66	19	1	35
common bully	4	0	0	0	0	0	0	1	0
shortfin eel	1	0	1	0	0	0	0	0	0
brown trout	0	0	0	1	0	0	0	0	0
total number of fish	61	82	70	43	7	66	19	2	35
total number of species	3	1	2	2	1	1	1	2	1
total fish per 100m^2	8.1	11.2	10.7	5.4	0.8	7.5	3.1	0.3	5.8
blue gill bully per 100m^2	7.4	11.2	10.6	5.3	0.8	7.5	3.1	0.1	5.8

4 Assessment of Effects

The channel re-alignment works included a substantial mechanical disturbance to a 220m length of river bed, which produced large but temporary increases in river water column turbidity and suspended solids levels. An earlier study of the effects of gravel extraction in the Hutt River also reported elevated turbidity and suspended solids in the water column but found that these effects were short lived, typically returning to ambient levels within 1 hour of works completion (Cameron, 2015).

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. The river bed disturbance is therefore unlikely to have directly stimulated periphyton growth because the nutrients were not present in a form that can be readily taken up by aquatic plants. It is noted however that biochemical conditions within cyanobacteria mats can be conducive to the release of loosely bound phosphorus, potentially making it available for uptake by algae and cyanobacteria. The particulate material in the discharge plume may also harbour microbiological contaminants, but the results of this study indicate that any increase in indicator bacteria in the water column is likely to be highly localised.

The works caused a major change in habitat characteristics at the works site. 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 works caused some increase in substrate embeddedness, but no increase in fine sediment cover or any significant change in substrate particle size.

The loss of swift shallow riffles can have implications for the river ecology as these areas are important sites for benthic macroinvertebrate production and are the preferred habitat for bluegill bullies. The number 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. This result is similar to that previously reported on the Hutt River in relation to gravel extraction near Kennedy Good Bridge (Perrie, 2013), where riffle habitat was lost and bluegill bully numbers declined. However, in that study fish numbers also declined at the upstream reference site, suggesting that natural variability may have accounted for at least some of the reduction in bluegill densities. Similar investigations in three rivers in the Ruamahanga catchment indicate that fish fauna recovery can occur rapidly provided suitable habitat is available (Death & Death, 2013).

Where habitat is lost and is not reinstated as part of the works programme, the recovery of fish communities is expected to occur more slowly and will depend on the occurrence of high flow events in the river to re-work bed material.

5 Conclusion and Recommendations

The flood protection works at the Hutt River in Belmont resulted in short-term reductions in water quality during excavation activities, and a longer term loss of swift riffle habitat. The latter resulted in a localised reduction in blue gilled bully abundance. For any future works of this type the following steps are recommended to avoid or mitigate adverse effects:

- All 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 recolonise.
- Where the works are expected to affect multiple riffles, give consideration to leaving a proportion of habitat untouched (for instance every second riffle) to facilitate recolonization by invertebrates and fish.

- Disturbance of the wetted channel 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 any 10 km of river length.
- 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.

References

Atkinson, N., & Joy, M. (2009). *Longitudinal size distributions of bluegill bullies (Gobiomorphus hubbsi) and torrentfish (Cheimarrichthys fosteri) in two large New Zealand rivers.* New Zealand Journal of Marine and Freshwater Research, 643-651.

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

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

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

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

Perrie, A. (2013). *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.

Appendix A Survey sites before and after works

Figure 1: Upstream site H-US before floor protection works.

Figure 2: Upstream site H-US after works were undertaken

Figure 3: River works site H-IM before works were undertaken

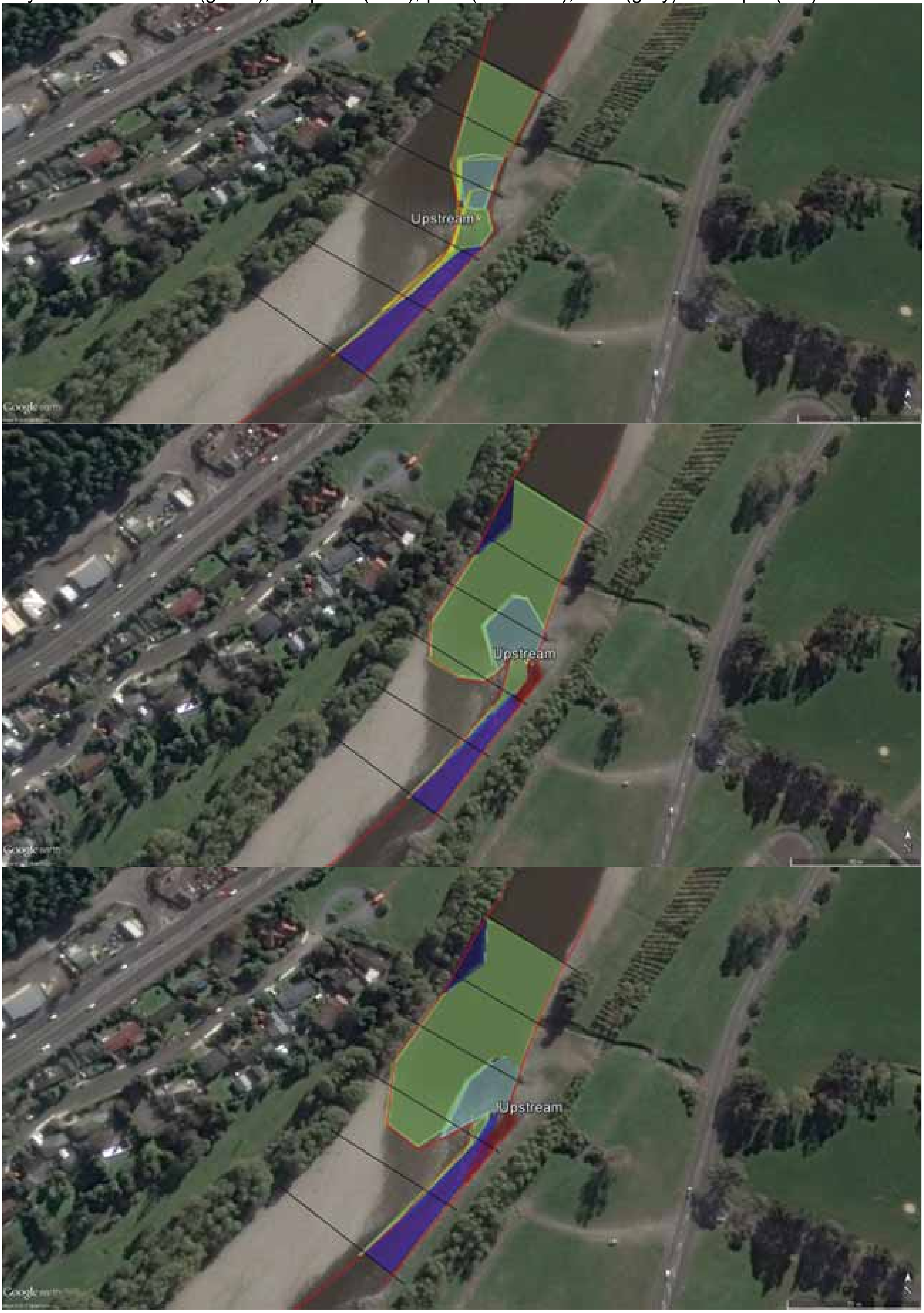
Figure 4: River works site H-IM after works were undertaken

Figure 5: Downstream site H-DS before works were undertaken

Figure 6: Downstream site H-DS, before (upper) and after (lower) works were undertaken

Appendix B Habitat maps before, 2 weeks after and seven weeks and after works

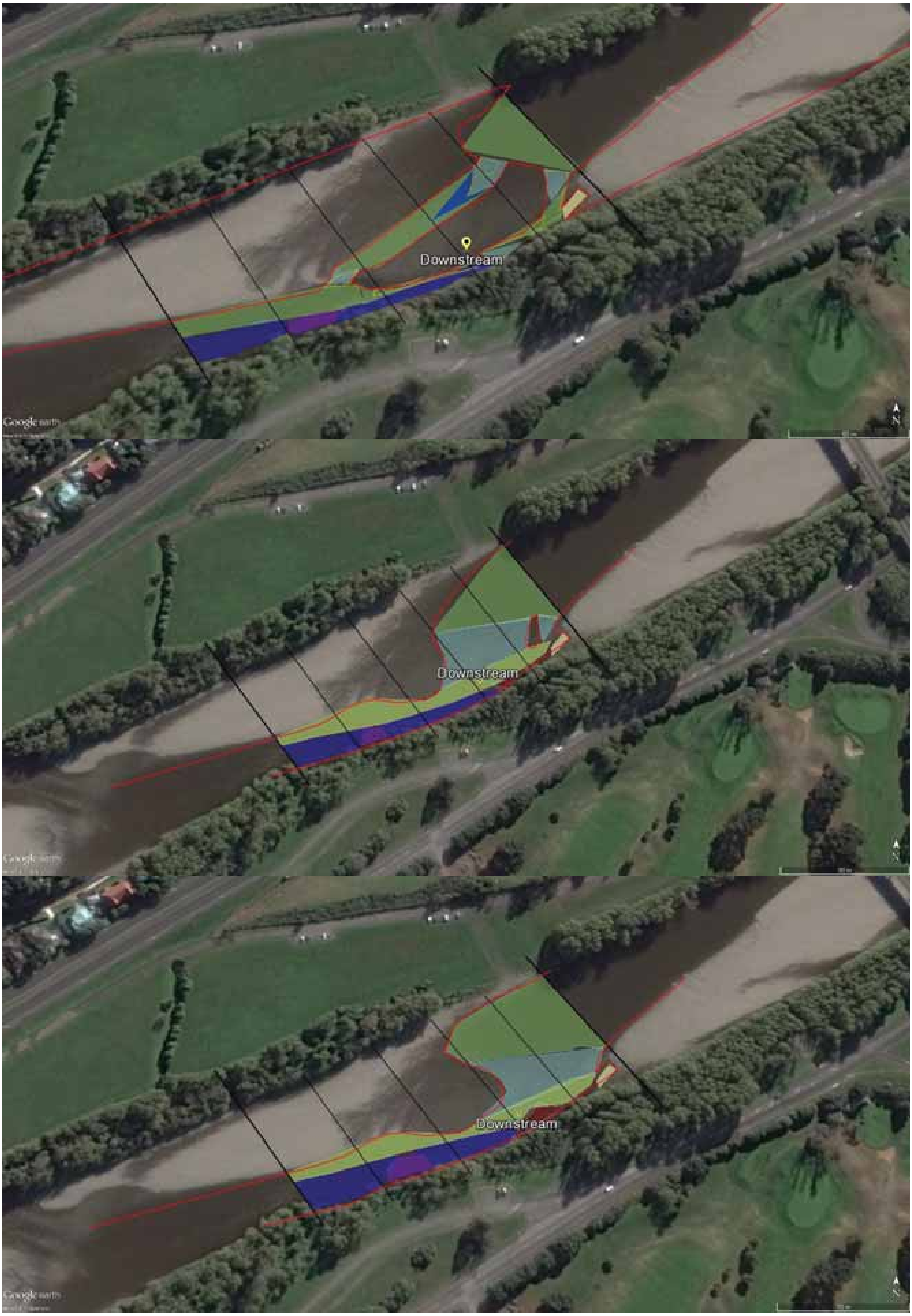
Key: Shallow run (green), deep run (blue), pool (dark blue), riffle (grey) and rapid (red)




Impact


Impact


Impact


Downstream
Downstream
Downstream

Appendix H Hutt River gravel extraction – drift dive survey of trout

Wellington Fish & Game, 27 March 2013

Brief Report on Hutt River Drift Dives

Five competent divers attempted to count the trout in the two areas outlined in the photo supplied to Fish and Game on November 1st 2012. Visibility was not the best (black disc distance was 3.6 m), and in some of the wider reaches of the river, adequate coverage of the complete cross section of the river was not possible with only the 5 divers. As a consequence, some fish will have eluded detection. In addition to this, in the site to be disturbed, there are three relatively deep holes which we could not see the bottom and hence trout numbers will inevitably also be less than what was present (in a previous deep hole a number of trout were observed on the bottom).

Given the above restrictions, we observed the following:

Upper Control Section		
Large Brown Trout	Medium sized brown trout	small trout
32	18	present
Site to be disturbed		
35 +	24 +	present

By driving between the start and end points and using the car odometer, it was estimated to be 4.6 km in distance.

Steve Pilkington
Wellington Fish and Game

Follow-up Friday 1st March 2013.

Seven competent divers redived the two areas.
River levels were lower than in December and as such the trout in the deep pools could be seen and thus the trout counts will be more reliable.

Upper Control Section		
Large Brown Trout	Medium sized brown trout	small trout
47	90	none seen
Site to be disturbed		
34	289	none seen

There was a MARKED demarcation in the vegetation between the upper control and lower "worked" section. Prior to the disturbed site there was a large amount of green algae attached to rocks. Below the works this was **totally** absent, and a higher silt load was evident. Visibility was 6.3 m with the black disc, and the temperature was 21°C.

Trout numbers in both undisturbed and disturbed areas appear very similar despite the works, and are "relatively" high. However, the entire Hutt River this year has seen an enormous increase in fish numbers, suggesting very good recruitment!

Appendix I Important trout spawning waters

(From Strickland and Quarterman 2001)

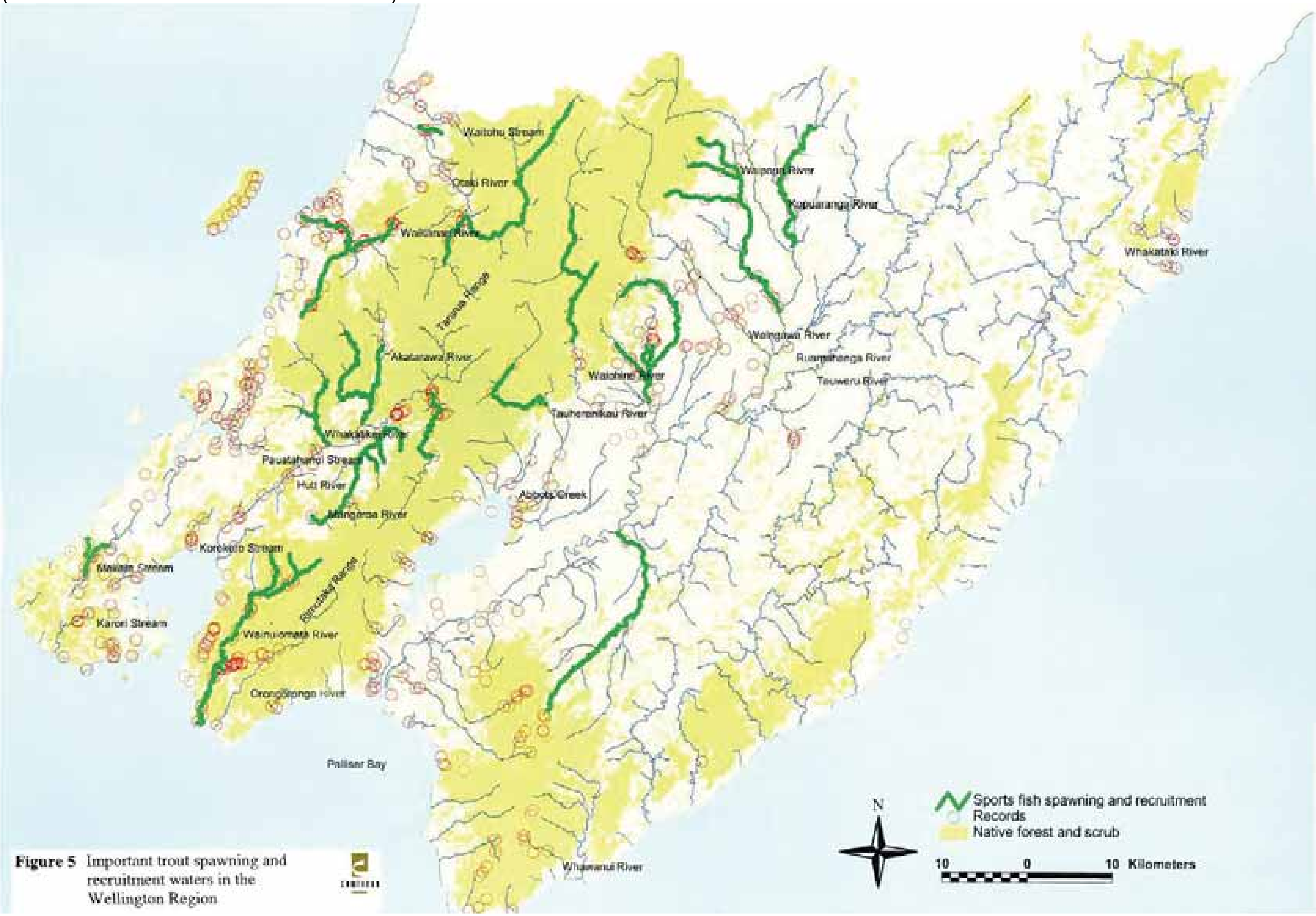


Figure 5 Important trout spawning and recruitment waters in the Wellington Region