NZ TRANSPORT AGENCY
WAKA KOTAHI

Roads of national significance

16 20

Western Ring Route – Waterview Connection

Assessment of Freshwater Ecological Effects

Boffa Miskell

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1. Introduction

1.1 Background

In 2009 the New Zealand Transport Agency (NZTA) confirmed that the Waterview Connection Project (the Project) would be lodged with the Environmental Protection Agency (EPA) as a Proposal of National Significance. The Project includes works previously investigated and developed as two separate projects, being the SH16 Causeway Project and the SH29 Waterview Connection. A detailed description of the elements associated with the Project is given in section 4 of the Assessment of Environmental Effects report. The key elements of the Project are:

- Completing the Western Ring Route (which extends from Manukau to Albany via Waitakere);
- Improving resilience of the SH16 causeway between the Great North Road and Rosebank Interchanges to correct historic subsidence and "future proof" it against sea level rise;
- Providing increased capacity on the SH16 corridor (between the St Lukes and Te Atatu Interchanges);
- Providing a new section of SH20 (through a combination of surface and tunnelled road) between Great North Road and Maioro Street Interchange; and
- Providing a cycleway throughout the surface road elements of the Waterview Connection Project corridor.

1.2 Purpose

The purpose of this report is to provide an assessment of the effects of the Project on freshwater habitats that are present within and adjacent to the Project area, and to provide an assessment of the significance of these effects.

Where this report identifies potential adverse effects on the freshwater environment that are more than minor, it identifies measures to avoid, remedy or mitigate those effects. Where there is uncertainty regarding the likely effects or the significance of effects, this report identifies an approach for monitoring and response.

1.3 Project Description

The Project has been divided into 9 Sectors (Figure 1). These include Sectors 1, 2, 3, 4, 5 and 6 between Te Atatu and St Lukes Interchange on SH16, and Sectors 5, 7, 8 and 9 between the Great North Road Interchange and the Maioro Street Interchange on SH20 (Sector 5 is the Great North Road Interchange where the two highways will connect).

A detailed description of the elements associated with the Project is given in section 4 of the Assessment of Environmental Effects report. However, in summary, the Project includes the following elements):

- Sector 1 involves significant improvements to the Te Atatu Interchange;
- Sector 2 involves enlargement of the existing Whau River Bridge;
- Sector 3 involves the reconfiguration of the existing Rosebank Interchange and Patiki off-ramp bridge, and the widening of SH16 to provide 4 lanes in both directions;
- Sector 4 involves reclamation within the coastal marine area to raise and enlarge the existing Causeway and Causeway Bridge to accommodate additional lanes;
- Sector 5 involves a new interchange at the Great North Road Interchange (GNRI) ;
- Sector 6 involves the widening of SH16 from the GNRI to the St Lukes Interchange;
- Sector 7 involves two cut-and-cover tunnel that run from the northern portal at Waterview Park, cross beneath Great North Road in a southerly direction, and then connect with the deep tunnels (Sector 8) in the vicinity of Waterview Downs;
- Sector 8 involves the Avondale Heights Tunnels, which continue from the cut-and-cover sections in Sector 7 (in 2 deep tunnels at a maximum 30m depth) in a southerly direction through to Alan Wood Reserve, passing beneath Avondale Heights, the North Auckland rail line and New North Road; and
- Sector 9 involves the Alan Wood Reserve tunnel portals and the continuation of the 2 carriageways through the reserve at surface (running alongside and overlapping with the existing land set aside for rail [i.e. the Avondale Southdown Line Designation]) for a length of around 900m. Richardson Road will be bridged across the State Highway, which will join up with the existing motorway section at the Maioro Street Interchange.

Streams that are located within the Project footprint are Oakley Creek (Sectors 5, 7, 8 and 9), a tributary stream of Oakley Creek (the Stoddard Road tributary – Sector 9), Pixie Stream (Sector 1) and Meola Creek (Sector 6). The location and catchments of these are shown in Figure 2. The freshwater effects of the Project on that part of the Stoddard Road tributary within the Project footprint are described in this report[1], as well as the effects on Oakley Creek, Pixie Stream and Meola Creek.

In Sector 1, at the Te Atatu Interchange, during the construction phase the Project will involve the discharge of treated stormwater from Sediment Retention Pond (SRP) 1C into Pixie Stream. During the operational phase of the Project there will be the discharge of treated stormwater from the Jack Colvin Park Pond into the Coastal Marine Area (CMA) downstream of the mouth of Pixie Stream. The freshwater component of this stream will not be directly impacted upon by this discharge, although its brackish portion may, from time to time, receive diluted stormwater discharges (i.e. on flood tides when the pond is actively discharging). The existing culvert that conveys Pixie Stream beneath the existing SH16 carriageway will need to be extended to accommodate the new highway lanes. However, only the downstream section is still an actual stream, with the upstream section being entirely piped. The additional loss of functional stream habitat here will be 23m.

[1] Consents are already held for works in relation to SH20 affecting the Stoddard Road tributary upstream of the Project footprint (ie. in the Maioro Street Interchange area).

Figure 1 – Western Ring Route: Waterview Connection (SH16/SH20) Sector Map

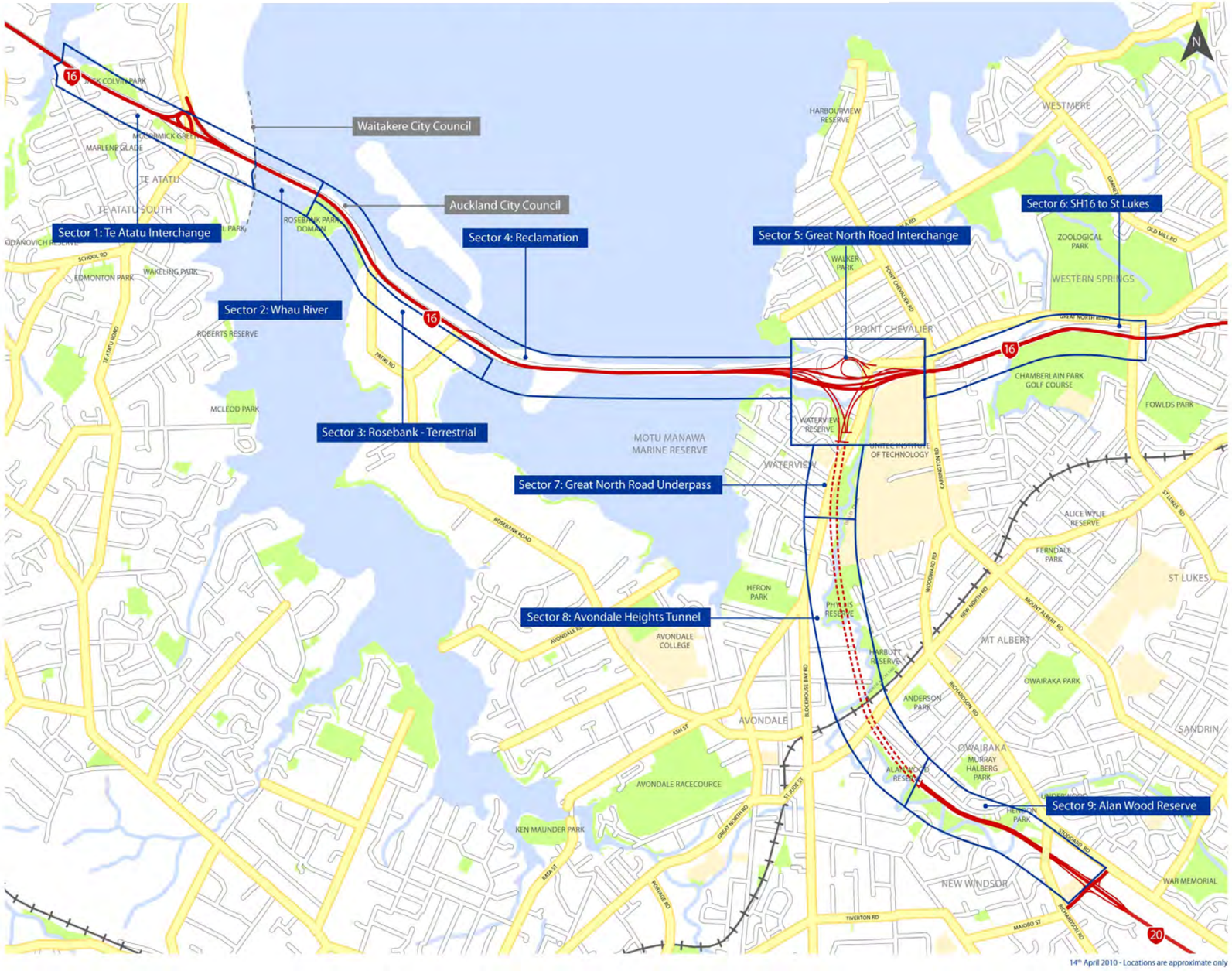
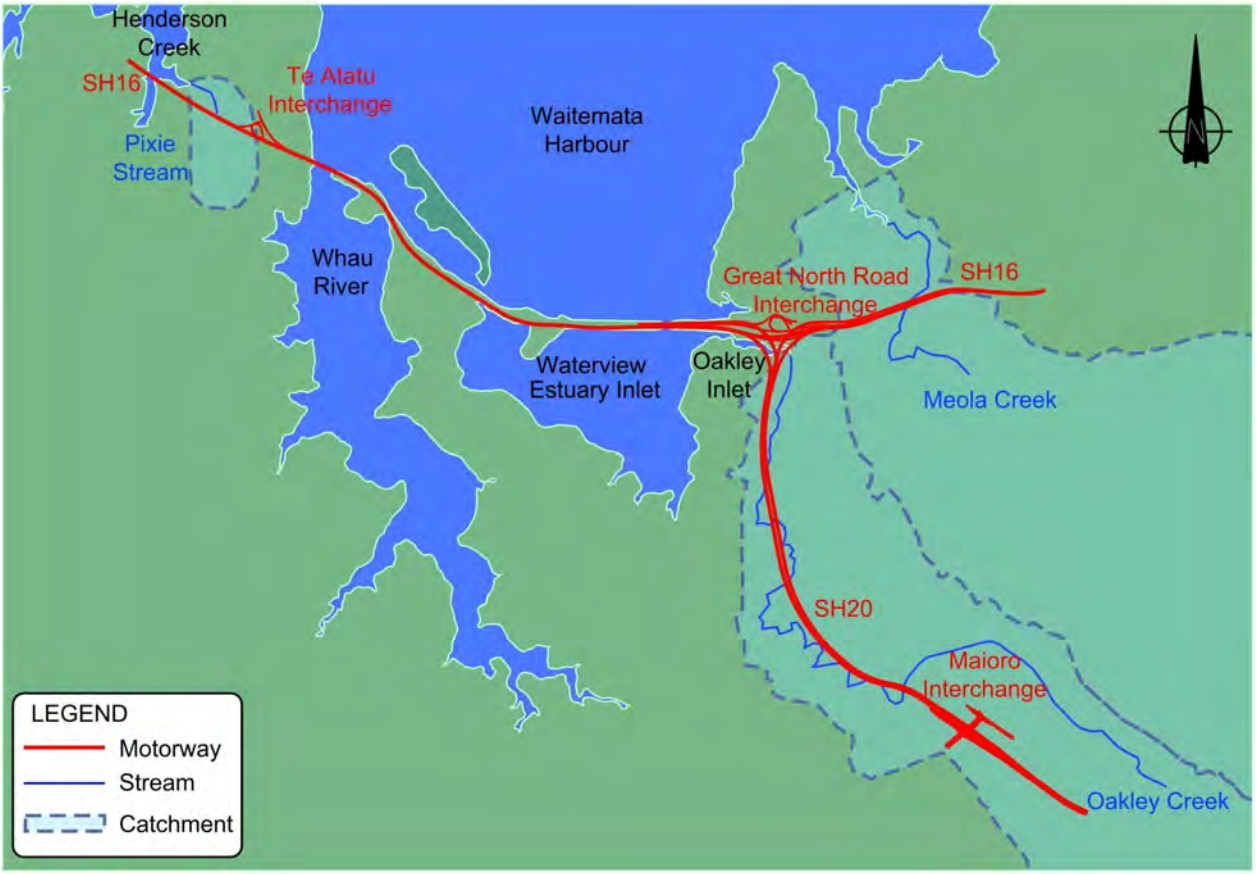


Figure 2. Freshwater Streams in the Project Area



In Sector 6, at the St Lukes end of SH16, the Project will involve the discharge of treated stormwater to Meola Creek (in both the construction phase and operational phase). No extensions to the existing Meola Creek culvert that conveys this waterway beneath the existing SH16 carriageway are required as part of the upgrade works in this sector.

Sector 5, at the Waterview Interchange, will involve earthworks in the vicinity of the Oakley Creek stream mouth. These earthworks are associated with construction of the interchange with various connections between SH20 and SH16 eastbound and westbound. Discharges from this area will be direct to the CMA rather than the creek, in both the construction and operational phases of the Project.

Sector 7, at Great North Road, involves construction of two cut and cover tunnels. During the construction phase there will be discharges of treated stormwater to Oakley Creek in this section, specifically from Stormwater Retention Pond (SRP) 7A.

Sector 8, (Avondale Heights Tunnels), is a section of deep tunnels that pass under Oakley Creek north of New North Road. There will be no surface disturbance here. However, water from groundwater pumping will be discharged to the stream, with low-turbidity water going directly to the stream and high turbidity water being treated before discharge.

Sector 9, at Alan Wood Reserve, is a section of surface highway between Richardson Road and New North Road. Works in this Sector will produce treated stormwater discharges to Oakley Creek in both the construction and operational phases of the Project, as well as physical effects on the stream channel as a result of stream realignments.

2. Catchment Characteristics

2.1 Oakley Creek and Tributaries

Oakley Creek is an 11.3km stream with its headwaters in the vicinity of Keith Hay Park in Hillsborough (Suren, 2001). It flows through Mt Roskill, Wesley and Owairaka to its mouth at Waterview, where it enters the Waitemata Harbour. It has a catchment area of 12.3km^2 and a maximum altitude of 134m, and has an estimated 84% of its catchment urbanised.

The freshwater environment of Oakley Creek is defined as the area upstream of the CMA boundary, which is located at the Great North Road culvert. Below this culvert the Creek is an estuarine environment and becomes an arm of the Waterview Inlet. There appears to be minimal tidal or saline influence upstream of this culvert.

For much of its length Oakley Creek flows through parks and reserves, and is the largest stream in Auckland City. It has a substantial waterfall (approximately 6m high) in its downstream section approximately 900m above its mouth. It has a predominantly urban (residential) land-use, although there is a small area of industrial and commercial land-use located at Stoddard Road, Mt Roskill. Its catchment is relatively long and narrow, so most of its tributaries would have been small and most are now piped. Non-piped tributaries occur at and around Keith Hay Park and at Stoddard Road.

2.2 Pixie Stream

Pixie Stream is a tributary of Henderson Creek and flows along the northern boundary of Jack Colvin Park, Te Atatu South, before discharging to the estuarine reaches of Henderson Creek. It has a predominantly urban (residential) land-use. The majority of the stream has been piped, with the only stretch of open channel being confined to the reaches downstream of the existing SH16 carriageway. The approximate length of this stream is 320m (including its tidally influenced downstream section).

2.3 Meola Creek

Meola Creek is a 2.6km stream with its headwaters entirely piped above the Chamberlain Park Golf Course. It flows alongside Western Springs Park on the western side of Motions Road, to its mouth at the Meola Reef Reserve, where it enters the Waitemata Harbour. It has a catchment area of 16.5 km^2 and a maximum altitude of 196m. It is characterised by an estimated 94% impervious surface area. It has a predominantly urban (residential) land-use.

2.4 Other Freshwater Environments

No other freshwater streams, rivers or wetlands are affected by the Project. The Whau River and Henderson Creek are within the Project area but are marine environments.

3. Auckland Regional Council Stream Classifications

3.1 Introduction

This section presents the Auckland Regional Council (ARC) stream classifications for Oakley Creek, Meola Creek and Pixie Stream. The ARC classifies streams to help it achieve its regional environmental management objectives. These classifications describe the general values of these watercourses and provide context for the more detailed investigations which are described subsequently in this report.

3.2 Oakley Creek

Oakley Creek is classified as a Permanent Stream with respect to stream flow under the proposed Regional Plan: Air, Land and Water (ALWP; ARC, 2009). It is an Urban Stream Management Area under Section 3.5 of the ALWP. This provides for stream reaches to be classified primarily by the percentage of impervious surface area and the percentage of artificial streambed material (such as concrete).

Oakley Creek is primarily a Type 4 stream (i.e. Highly Disturbed Urban Stream), with some Type 5 (i.e. Artificial or Concrete Channelised Urban Stream) reaches in the upper catchment (e.g. Underwood Park and Keith Hay Park). The area of tidally-influenced Type 1 stream (i.e. Stream Mouth) is negligible as the transition between freshwater and marine environments occurs over a very short distance coinciding with the Great North Road culvert.

The ALWP recognises that because of the need to use resources to accommodate regional growth, streams outside urban areas have a higher level of protection than those within urban areas, and that development within urban areas cannot occur without adverse environmental effects (Section 3.5.2.1). The ALWP states that the management of urban streams shall recognise this categorisation, provide for use and development, and where practicable avoid adverse effects and maintain and enhance stream values (Section 3.5.4.4).

ARC Technical Publication No.232 "*Framework for Assessment and Management of Urban Streams in the Auckland Region*" (ARC, 2004) further gives management priorities for each Stream Type. High priorities for Type 5 streams (or stream reaches) are improving water quality (including water temperature), managing flood risk and enhancing fish passage where the reach is a migration corridor. Type 4 streams also include enhancing amenity values as a High Priority, and enhancing instream values as a Medium Priority.

Technical Publication No.304 "*Summary of the Ecological Health of Auckland Streams Based on State of the Environment Monitoring 2000-2004*" (ARC, 2005) also recognises that water quality is a limiting factor in relation to the ecological values of urban streams, and suggests that habitat enhancement and shading to control water temperatures would be appropriate management goals.

Oakley Creek is not listed in the Regional Policy Statement (ARC, 1999) as an area of Significant Natural Heritage value (Map 2, sheet 2), nor as an Area of High Ecological Value Vulnerable to Degradation (Map 5, sheet 4), although its marine receiving environment is. Meola Creek is listed as a Degraded Urban Stream

(requiring greater emphasis on avoidance and mitigation of adverse effects of water quality; map 5, sheet 2). However, Oakley Creek is not.

3.3 Pixie Stream

Pixie Stream is a Permanent Stream with respect to flow, and is classed as a Type 4 (Highly Disturbed) Urban Stream due to the high percentage of impervious catchment (ALWP; ARC, 2008). The ALWP notes that these stream types typically have lower natural values, but may allow fish passage to upstream habitats. In the case of Pixie Stream, however, there is no open channel habitat upstream of the motorway, and the stream is not a significant corridor for fish passage.

The management priorities for this type of stream also include public amenity, hydrology and water quality (ARC TP232, 2004). The lower reaches of the stream enter the mangroves of the Whau River, and this section would be classified as a Stream Mouth (Type 1 Urban Stream), for which management of inanga spawning areas is an additional priority.

3.4 Meola Creek

Meola Creek is a Permanent Stream with respect to flow, and is also classified as a Type 4 (Highly Disturbed) Urban Stream due to the high percentage of impervious catchment (ALWP; ARC, 2008). The ALWP notes that these stream types typically have lower natural values, but may allow fish passage to upstream habitats. Meola Creek has a substantial length of habitat upstream of the motorway and maintaining fish passage should be a priority. The management priorities for this type of stream also include public amenity and hydrology and water quality (ARC TP232, 2004). The receiving environment is the Meola Creek estuary, an inlet of the Waitemata Harbour east of Point Chevalier.

Meola Creek is listed as a Degraded Urban Stream in the Auckland Regional Policy Statement (ARPS, Map 5), and the stream mouth is identified as an area of localised sediment contamination. The ARPS provides that areas identified in Map 5 require additional emphasis on avoidance and mitigation of adverse effects. The coastal receiving environment is a General Management Area in the Auckland Regional Plan: Coastal.

4. Methods

4.1 Review of Existing Literature and Data

A review of existing literature and data was undertaken. Table 1 lists the numerous surveys undertaken in different parts of Oakley Creek. Table 2 and Table 3 list the data sources for Pixie Stream and Meola Creek that were identified as a result of the literature review.

Table 1. Oakley Creek Information Sources

Section	Habitat	Fish	Invertebrates	SEV	Water Quality	Sediment Quality
Great North Road - waterfall	BML 2001, 2003, 2008a; Suren 2001, 2005	BML 2001, 2003, 2008a; Suren 2001	BML 2001, 2003, 2008a; Suren 2001	BML (unpub)	ARC 2010;Suren 2001, 2005	Suren 2005
Waterfall - New North Road	BML 2001, 2003, 2008a; Suren 2001, 2005; Bioresearches 1998, 1999	BML 2001, 2003, 2008a; Suren 2001; Bioresearches 1998, 1999	BML 2001, 2003, 2008a; Bioresearches 1998, 1999		Suren 2001, 2005; Bioresearches 1998	Suren 2005
New North Road - Richardson Road	BML 2001, 2003, 2008a; Suren 2001, 2005; Bioresearches 1998, 1999	BML 2001, 2003, 2008a; Allibone et al 2001; Suren 2001; Bioresearches 1998, 1999	BML 2001, 2003, 2008a; Allibone et al 2001; Bioresearches 1998, 1999	BML, 2009b	Suren 2001, 2005; Beca (unpub); Bioresearches 1998, 1999	Suren 2005; Beca (unpub)
Richardson Road - May Road	Suren 2001, 2005	Suren 2001	Suren 2001	-	Suren 2001, 2005	Suren 2005
May Road - Keith Hay Park	BML 2001, 2003, 2008a; Suren 2001, 2005	BML 2001, 2002, 2003, 2005, 2006, 2007,2008a, 2009a; Suren 2001	BML 2001, 2002, 2003, 2005, 2006, 2007,2008a, 2009a' Suren 2001		Suren 2001, 2005	Suren 2005
Headwater tributaries	BML 2001, 2003, 2008a; Suren 2001, 2005	BML 2001, 2002, 2003, 2005, 2006, 2007,2008a, 2009a; Suren 2001	BML 2001, 2002, 2003, 2005, 2006, 2007,2008a, 2009a; Suren 2001		Suren 2001, 2005	Suren 2005

Table 2 Pixie Stream Information Sources

	Habitat	Fish	Invertebrates	SEV	Water Quality
Pixie Stream	Bioresearches 2009	Bioresearches 2009; BML 2004, 2005, 2006, 2007, 2008b, 2009	BML 2004, 2005, 2006, 2007, 2008b, 2009; Bioresearches 2009	Bioresearches 2009	Bioresearches 2009

Table 3 Meola Creek Information Sources

	Habitat	Fish	Invertebrates	SEV	Water Quality
Meola Creek	Bioresearches 1998; Suren 2001	Bioresearches 1998; Allibone et al 2001; FFDB records	Bioresearches 1998; Allibone et al 2001	-	Bioresearches 1998; Suren 2001

To summarise the above tables, fish and macroinvertebrate surveys have been extensively undertaken throughout Oakley Creek as part of this and other projects, except in the concrete section between Richardson Road and May Road, which would be expected to have minimal ecological values. Water quality has been monitored by the ARC in the lower Oakley Creek for a period of 10 years. Sediment quality data has been recently added in some areas to complement environmental data. The Stream Ecological Valuation (SEV) (ARC, 2008) has also been undertaken at several sites within Oakley Creek, primarily to evaluate the effects of piping or diverting sections of the creek between New North Road and the Maioro Street Interchange.

4.2 Field Sampling : Oakley Creek

A number of organisations have undertaken field investigations in Oakley Creek (see Figure 3), including many by Boffa Miskell Ltd (BML). The macroinvertebrate surveys undertaken by BML have followed the Stark et al. (2001) methodology, typically Protocol C1 (hard-bottomed, semi-quantitative). Composite samples comprised of five sample units (e.g. 0.1 - 0.2m^2 of stream bed) were collected with a 0.5mm mesh dip net, with identification to taxonomic level required for the Macroinvertebrate Community Index (MCI), using with semi-quantitative abundance estimates (i.e. using defined abundance classes rather than full counts of individuals).

This information was then used to calculate a Macroinvertebrate Community Index (MCI), based on sensitivity scores for taxa in hard-bottomed streams (MCI-hb) (Stark, 1998). For all MCI, scores of ≥ 120 are indicative of excellent habitat quality, scores of 100 - 119 are indicative of good habitat quality, scores of 80 – 99 are indicative of fair habitat quality, and scores of < 80 are indicative of poor quality habitat.

Fish surveys within Oakley Creek were typically surveyed with two fyke nets and five Kilwell bait traps per site. Backpack electrofishing with an EFM300 machine was also used where depth permitted. All fish captured were identified, counted and measured before being returned to their habitats. An Index of Biotic Integrity (IBI) was calculated for each site based on fish species present, altitude and distance inland (Joy and Henderson, 2004).

Stream Ecological Valuation (SEV) surveys at Oakley Creek and its Stoddard Road tributary were undertaken in accordance with the ARC Technical Publication No.302, the "SEV Manual" (ARC, 2008.

4.3 Field Sampling : Pixie Stream

BML has undertaken annual surveys within Pixie Stream in two sampling reaches, both downstream of the existing SH16 carriageway, as part of an annual Freshwater Fisheries Monitoring Programme for Waitakere City Council (WCC). Bioresearches Group Ltd (BGL) surveyed the lower reaches of Pixie Stream in 2009, immediately upstream of the tidal portion of Henderson Creek, and completed a SEV for this reach

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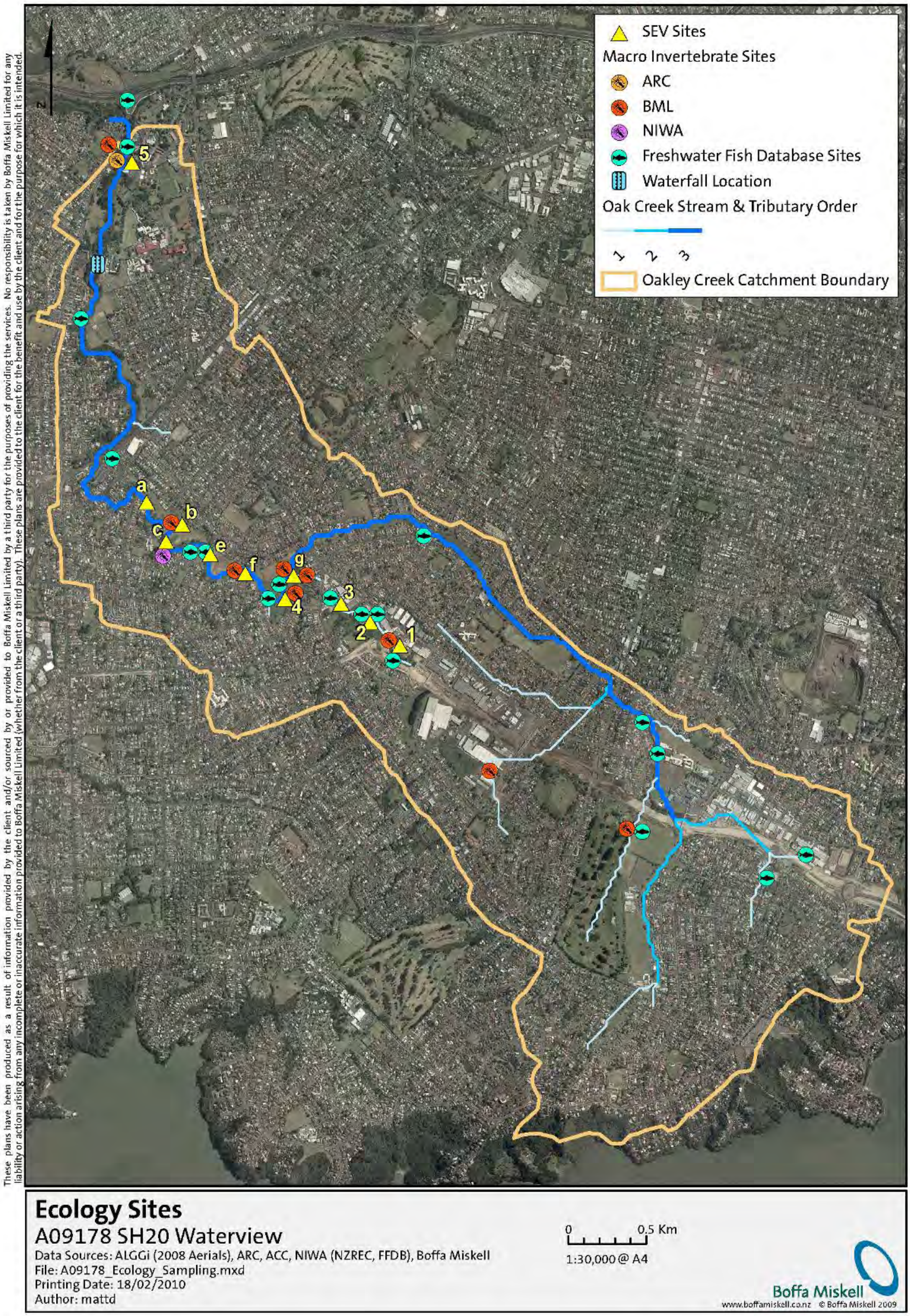
Figure 3: Ecological Sampling Sites, Oakley Creek



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As a result of the surveys described above, both macro-invertebrate and fish communities have been sampled, and the general ecological condition of the stream habitat has been evaluated. Spot measurements of basic water quality parameters (i.e. temperature, dissolved oxygen & conductivity) were undertaken in the BGL (2009) study, with these being measured using a portable meter. Clarity was measured to the nearest 1cm using a 'turbidity tube'.

Macroinvertebrates were sampled in all studies in accordance with Protocol C1 (Stark et al., 2001), and were identified to the lowest practicable level and counted to enable biotic indices to be calculated.

To sample fish communities, an approximate 40m reach of the waterway was electric fished using an EFM 300 backpack electric fishing machine in the BGL 2009 and BML 2010 studies. Fish traps and fyke nets were also routinely used in the majority of the BML studies.

4.4 Field Sampling : Meola Creek

BGL (1998) investigated the riparian and in-stream characteristics of Meola Creek together with its fish and macro-invertebrate communities. BML undertook a verification survey of the riparian and in-stream characteristics of the creek below the existing SH16 carriageway in 2010, and completed a SEV survey of the reaches immediately below the existing SH16 culvert in this stream in 2010. In addition, New Zealand Freshwater Fish Database (FFDB) records for the Creek were sourced, with information being found to be available for the period between 1998 - 2004.

5. Results

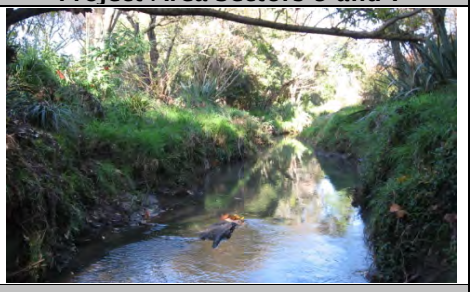
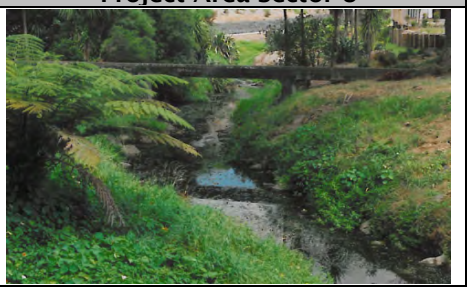
5.1 Physical Habitats

5.1.1 Oakley Creek

The River Environment Classification (REC) (Snelder et al., 2004) provides information at stream segment scales which can be used to compare stream characteristics. The REC indicates that large-scale factors influencing stream environments are relatively similar throughout Oakley Creek. From Keith Hay Park to the stream mouth at Waterview the stream is classified as 3rd order, with a low gradient and miscellaneous geology. This indicates that local-scale features and human influences are most important in determining habitat quality along the stream length, rather than underlying large-scale geographical characteristics.

The physical characteristics of Oakley Creek are summarised in Table 4, where the stream has been divided into 6 sections, each with different fish access, instream habitat and riparian characteristics (see also Figure 4).

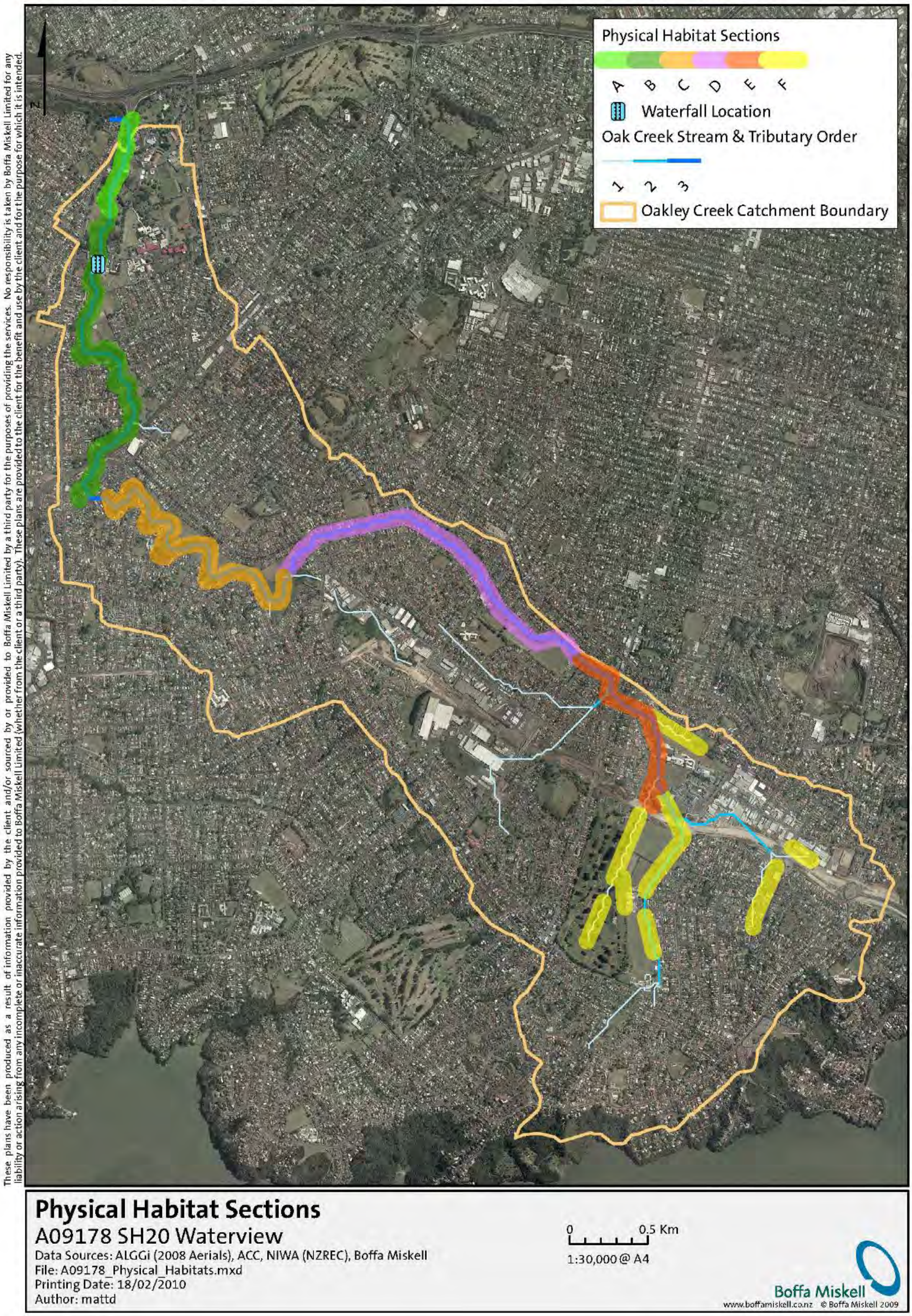
Table 4. Physical Habitat Characteristics of Oakley Creek.

Section A.	Great North Road to Waterfall	Project Area Sectors 5 and 7
Modification:	low (unchannelised)	
Riparian veg.:	riparian trees and shrubs	
Overhead shade:	good, partial canopy	
Substrate:	soft sediment	
Fish habitat:	good (undercut banks, pools)	
Fish access:	good, no downstream barriers	
Water quality:	poor (stormwater, CSO's[2])	
Section B.	**Waterfall to New North Road**	**Project Area Sector 8**
Modification:	moderate (unchannelised)	
Riparian veg.:	riparian trees and shrubs	
Overhead shade:	good, partial canopy	
Substrate:	soft sediment, boulder sections	
Fish habitat:	good (undercut banks, pools)	
Fish access:	poor (downstream waterfall)	
Water quality:	poor (stormwater, CSO's)	

[2] CSO's : Combined Sewer Overflows (i.e. involving both sanitary and stormwater sewer overflows).

Section C.	New North Road to Richardson Road	Project Area Sectors 8 and 9
Modification:	moderate (channelised sections)	
Riparian veg.:	grass with some riparian trees/shrubs	
Overhead shade:	poor, no canopy	
Substrate:	soft sediment, boulder sections	
Fish habitat:	moderate (substrate, bank vegetation)	
Fish access:	poor (downstream waterfall)	
Water quality:	poor (stormwater, CSO's)	
Section D.	**Richardson Road to May Road**	**Outside Project Footprint**
Modification:	high (concrete channel)	
Riparian veg.:	Grass	
Overhead shade:	poor, no canopy	
Substrate:	concrete, boulder sections	
Fish habitat:	poor (concrete)	
Fish access:	poor (downstream waterfall)	
Water quality:	poor (stormwater, CSO's)	
Section E.	**May Road to Keith Hay Park**	**Outside Project Footprint**
Modification:	moderate (straightened but unlined)	
Riparian veg.:	Grass	
Overhead shade:	poor, no canopy	
Substrate:	soft sediment, boulder sections	
Fish habitat:	moderate (bank vegetation)	
Fish access:	poor (downstream waterfall)	
Water quality:	poor (stormwater, CSO's)	
Section F.	**Headwater tributaries**	**Outside Project Footprint**
Modification:	moderate (channelised)	
Riparian veg.:	grass, some shrubs	
Overhead shade:	poor, generally no canopy	
Substrate:	soft sediment	
Fish habitat:	poor (bank vegetation)	
Fish access:	poor (downstream waterfall)	
Water quality:	poor (stormwater, CSO's)	

Figure 4: Physical Habitat Sections, Oakley Creek



5.1.2 Pixie Stream

The riparian vegetation of Pixie Stream generally comprises tall shading exotic vegetation and weed species, including willow, gorse, rank grasses and wandering jew that provides moderate to dense shading along the streambed. The stream is on average 1m wide and generally shallow (average water depth of 0.2m), with some deeper pooled habitat (maximum depth of 0.6m) (Table 5). The substrate is comprised of mixed gravel and soft mud. Physical characteristics of Pixie Stream below the existing SH16 carriageway are summarised in Table 5.

Table 5. Physical Habitat Characteristics of Pixie Stream Below the SH16 Carriageway.

	Pixie Stream	
Modification:	Moderate (unchannelised)	
Riparian veg.:	riparian trees and shrubs	
Overhead shade:	good, partial canopy	
Substrate:	gravel and soft sediment	
Fish habitat:	Moderate	
Fish access:	Good	
Water quality:	poor (stormwater, CSO's)	

5.1.3 Meola Creek

The riparian vegetation of Meola Creek below SH16 consists of tall shading exotic vegetation (primarily willows) with a ground cover of weed species (e.g. wandering jew, nasturtium) and rank grasses. This provides moderate to dense shading along the streambed. The stream is swiftly flowing, very clear and quite deep (up to 0.8m in places). The substrate is dominated by mud and bedrock. Physical characteristics of Meola Creek below the existing SH16 carriageway are summarised in Table 6.

Table 6. Physical Habitat Characteristics of Meola Creek Below the SH16 Carriageway.

	Meola Creek	
Modification:	moderate (unchannelised)	
Riparian veg.:	riparian trees and shrubs	
Overhead shade:	good, partial canopy	
Substrate:	bedrock and soft sediment	
Fish habitat:	moderate (instream vegetation)	
Fish access:	good, no downstream barriers	
Water quality:	poor (stormwater, CSO's)	

5.2 Aquatic Vegetation

5.2.1 Oakley Creek

Three species of macrophyte are present in the stream, being the introduced *Egeria densa* (oxygen weed) and *Potamogeton crispus* (pondweed), and the native *P. cheesemanii* (Suren, 2001). Oxygen weed in particular forms dense growths during stable summer conditions, which is recognised as a Class B Noxious Plant. Aquatic mosses (mainly *Leptodictyum riparium*) are also common.

A small amount of the Nationally Endangered aquatic moss *Fissidens berteroi* has previously been reported from the Stoddard Road tributary flowing through Hendon Park (Dr. R. Gardner, *pers. comm.*). However, recent surveys (2010) indicate that this species is no longer present here (refer to the Assessment of Terrestrial Vegetation Effects report (BML, 2010a) for details).

5.2.2 Pixie Stream

Macrophytes are relatively abundant here, with dense beds of *Elodea canadensis* recorded from the upper sections of the reach. Starwort (*Callitriche* sp.) is also present in small isolated patches.

5.2.3 Meola Creek

Meola Creek is characterised by thick growths of the introduced macrophyte *Vallisneria gigantean*, interspersed with oxygen weed (*Egeria densa*), starwort and *Nitella hookeria.* The Nationally Endangered aquatic moss *Fissidens berteroi* Is also present in Meola Creek in the vicinity of the Great North Road culvert (i.e. downstream and outside of the Project footprint – see the Assessment of Terrestrial Vegetation Effects report (BML, 2010a)).

5.3 Aquatic Invertebrates

5.3.1 Oakley Creek

Surveys of aquatic macroinvertebrates (small animals such as insects, snails and worms) in Oakley Creek over the past decade have included BML surveys in 2001, 2003 and 2008; ARC Long Term Baseline Monitoring in section A; sampling by Allibone et al. (2001) in section A; sampling by Bioresearches (1998 and 1999); and annual SH20 Mt Roskill Monitoring from 2002 to 2009 upstream of the Project Area (BML, 2002 - 2009).

In the macroinvertebrate surveys undertaken by BML, biological metrics indicative of ecological health have been generally similar between survey years (Table 7). These metrics have included taxonomic richness (the total number of taxa recorded); insect richness (the number of insect taxa recorded); EPT abundance (the relative abundance of pollution-sensitive EPT taxa in a sample, these being Ephemeroptera or mayflies, Plecoptera or stoneflies and Trichoptera or caddisflies); and MCI/SQMCI scores (Macroinvertebrate Community Index and its Semi-Quantitative derivative).

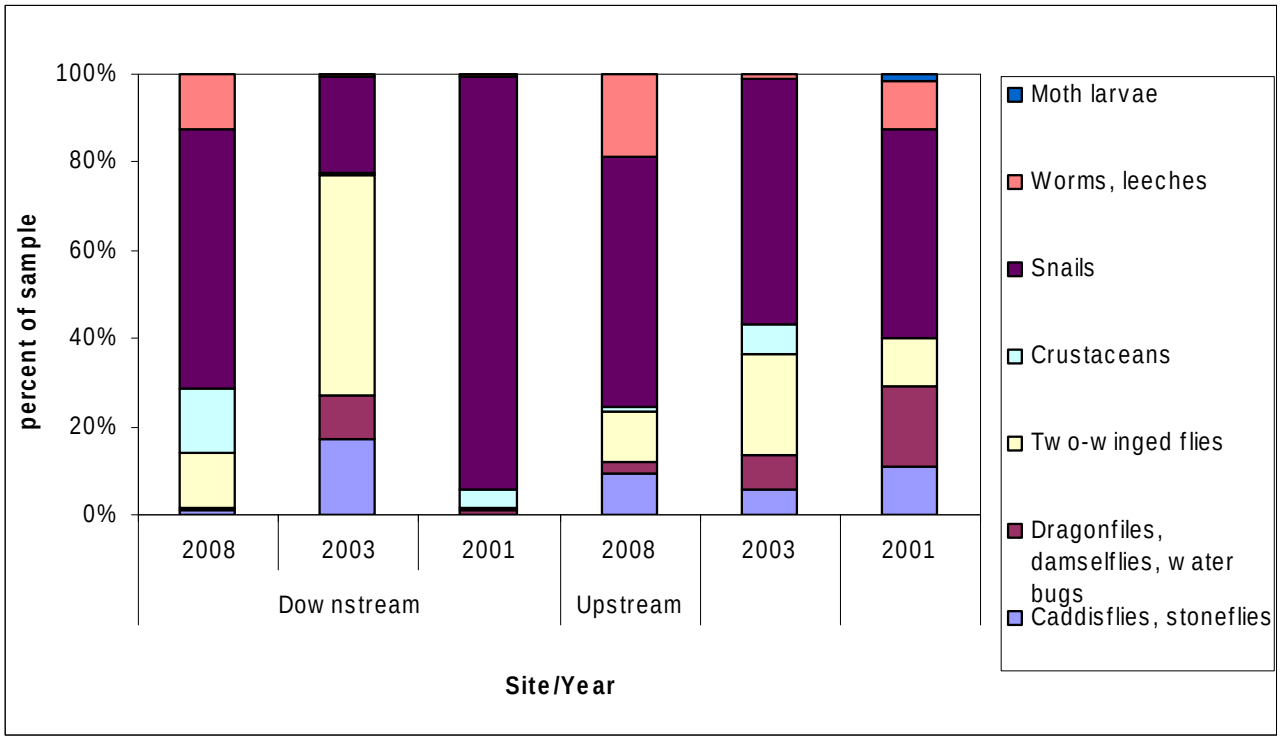
Taxonomic richness has ranged from 11 to 15 taxa, number of insect taxa ranged from 5 to 6, EPT taxa were absent or rare (*Triplectides* and rarely *Acroperla* being recorded), and MCI and SQMCI scores were low, indicating that pollution-tolerant taxa were dominant.

Table 7. Results of the Boffa Miskell 2008, 2003 and 2001 Macroinvertebrate Surveys.

	Sector 7 and 8 Waterview to New North Road			Sector 9 Alan Wood Reserve			
	2001	2003	2008	2001	2003	2008	2009(mean)
Taxonomic richness	15	11	12	12	11	11	7
No. of Insect Taxa	6	5	6	7	5	4	3
EPT	1	0	2	1	0	0	0
MCI	50	50	70	62	50	65	56
SQMCI	2.2	2.1	2.9	3.2	2.1	3.2	3

Figure 5 summarises the macroinvertebrate community structure (i.e. the relative abundance of different taxonomic groups) for Oakley Creek over the sampling periods 2001, 2003 and 2008.

Figure 5 : Oakley Creek Macroinvertebrate Community Structure 2001, 2003 and 2008



Allibone *et. al.* (2001) sampled in the lower creek between the waterfall and New North Road (Section B – Table 2 (Sector 8)), recording 14 taxa but only one EPT taxon (being the caddis *Triplectides* sp., which is not a particularly pollution-sensitive species). This was similar to the BML results in Table 7.

BML commenced monitoring the effects of the SH20 Mt Roskill Extension on Oakley Creek and its tributaries in 2002. Although the sampling locations are outside of the Project footprint, these results also help characterise the ecological characteristics of the Creek.

Six pre-construction surveys were undertaken between 2002 and 2005, and four construction-phase surveys between 2006 and 2008. Two post-construction surveys have been completed, in February and December 2009 respectively.

Upstream of the Project area a total of 35 taxa of aquatic macro-invertebrate were recorded during the SH20 Mt Roskill monitoring surveys between 2002 and 2009 (BML, 2009) (not including December 2009). The most common taxa were leeches, segmented worms and orthoclad midges. There were no Ephemeroptera (mayflies) or Plecoptera (stoneflies) recorded, and only two Trichoptera (caddisflies), these being *Triplectides* and *Oxyethira*.

A relatively high proportion of taxa (12 [i.e.34%]) were non-insect taxa, which are typically more pollution-tolerant than insects. Eight taxa (23%) were only recorded once. The low number of taxa per sample (i.e. taxonomic richness), coupled with the predominance of pollution-tolerant taxa and the absence of most pollution-sensitive taxa indicate that water quality is low in the upper Oakley Creek.

5.3.2 Pixie Stream

The macroinvertebrate community surveyed by BGL (2009) had moderate diversity, with eleven taxa recorded. The community was dominated by *Potamopyrgus* snails, which comprised 78% of the total sample. With the exception of the damselfly larvae *Xanthocnemis zealandica*, all other taxa were considered to be common or rare (less than 10 individuals). The MCI score was 76, which is indicative of 'poor' instream habitat quality (Stark and Maxted, 2007a).

5.3.3 Meola Creek

BGL (1998) surveyed the invertebrate fauna of Meola Creek immediately below the SH16 carriageway and found a total of 10 taxa. The fauna was dominated by Amphipods and the snail *Potamopyrgus*, with the snail *Physa* and damsel fly *Xanthocnemis* also being common. No sensitive macro-invertebrates (i.e. those with a MCI score of >6 out of 10, a score of 10 being the most sensitive) were present. The only caddisfly found at this site was *Oxyethira*, a pollution-tolerant taxa. Communities with a low taxonomic richness are typical of urban streams and reflect the high degree of habitat modification and low water quality in these streams.

Allibone et al. (2001) report very similar results to those of the BGL (1998) survey, with a total of 10 taxa and a community dominated by Amphipods and *Potamopyrgus*. No EPT were recorded and the only caddisfly present being *Oxyethira*.

5.4 Fish

5.4.1 Oakley Creek

Records in the New Zealand Freshwater Fish Database (FFDB) list the following five species downstream of the waterfall: longfin and shortfin eel, common smelt, inanga and common bully. Upstream of the waterfall, the following five species are recorded: longfin and shortfin eels, goldfish, mosquitofish and banded kokopu (with only the single record of a solitary specimen for the latter species – indicating that this species does not constitute a population in the creek above the waterfall).

Longfin and shortfin eels are common throughout the stream above the waterfall, and are the only native fish with resident populations here. Longfin eels are considered to be an 'at risk' species, being in Gradual Decline on a national basis (Hitchmough et al., 2007).

In their 2001 survey, in addition to the five species previously recorded in the New Zealand Freshwater Fish Database, BML also recorded redfin bully, giant bully and torrentfish below the waterfall. This indicates that this section of the stream (i.e. below the waterfall) is accessible to fish and provides suitable habitat for the species that are present. Their absence from subsequent records (including the 2008 BML verification survey) is probably due to lower sampling intensity at that time, but nevertheless does suggest that these five species occur less commonly here within the lower section of Oakley Creek.

Table 8 summarises the results of the 2001 and 2008 fish surveys in Oakley Creek undertaken by Boffa Miskell. The diversity of fish in the section of creek below the waterfall is considered to be relatively high (i.e. 7 species within the creek itself, together with an additional 2 species in the mouth of the creek (being smelt and yelloweye mullet)).

Table 8. Results of the Fish Surveys in 2008 and 2001.

	Downstream				Upstream			
	2008		2001		2008		2001	
	No.	Size range (mm)	No.	Size range (mm)	Density per m2	Size range (mm)	Density per m2	Size range (mm)
Common bully	2	58 - 115	1	75	-	-	-	-
Elvers	-	-	-	-	-	-	0.10	50 - 250
Gambusia	-	-	-	-	0.02	-	-	-
Giant bully	-	-	1	150	-	-	-	-
Inanga	46	50 - 100	16	50 -75	-	-	-	-
Longfin eel	3	400 - 700	-	-	0.08	280 - 500	-	-
Redfin bully	-	-	1	55	-	-	-	-
Torrentfish	-	-	2	25 - 80	-	-	-	-
Shortfin eel	-	-	2	500 - 600	0.28	140 - 520	0.25	250 - 650
Total abundance	51	-	23	-	0.38	-	0.36	-
Diversity	3	-	5	-	3.00	-	1.00	-

5.4.2 Pixie Stream

A small range of native fish species was recorded, including both shortfin and longfin eel, inanga and common bully. The NIWA Freshwater Fisheries Database also includes records of banded kokopu as being present. Small shoals of whitebait, most likely inanga, were observed within the pooled habitat at the upper extent of the estuary and also throughout the surveyed reach. The Fish Index of Biotic Integrity (IBI) score for this site was 40, indicative of 'good' habitat quality or connectivity for fish migrations (Joy and Henderson, 2004).

The presence of longfin eel is of note, given that this is an 'at risk' species, being in Gradual Decline on a national basis (Hitchmough et al., 2007). No other rare or sensitive taxa were recorded.

5.4.3 Meola Creek

The fish fauna reported by Bioresearches (1998) consisted of only 2 species, being shortfin eel and common bully. The NIWA Freshwater Fisheries Database also lists records of banded kokopu, inanga and torrentfish, together with two marine wanderers at the stream mouth (being yellow-eyed mullet and cockabully. These species are common in a variety of habitats, especially in streams with gentle to moderate flows with a good cover of rocks, vegetation and instream debris, and as such the specimens observed probably obtained shelter from the macrophytes (aquatic plants) in this stream.

Allibone et al. (2001) also recorded the presence of both longfin and shortfin eels in this creek, with the shortfin eels being common in occurrence but with the longfin eels being rare. The presence of longfin eel is of note, given that this is an 'at risk' species, being in Gradual Decline on a national basis (Hitchmough et al., 2007). No other rare or sensitive taxa were recorded.

5.5 Sediment Quality

5.5.1 Oakley Creek

Suren (2005) analysed a number of sediment quality parameters for Oakley Creek, including zinc, copper, lead and poly-aromatic hydrocarbons (PAHs). The metal concentrations in the sediments were generally below Australian and New Zealand Environment and Conservation Council (ANZECC) 95% protection thresholds, although occasional exceedances were recorded in some headwaters and tributaries, indicating that adverse ecological effects may occur at these locations.

More recently, a sediment quality sampling programme has been initiated by BCHF, with sampling at five sites along the creek at 6 monthly intervals (Figure 6). One sampling run has been undertaken to date (February 2010). These data will be reported on after 12 months. In addition, a separate set of samples analysed for concentrations of lead has been collected from several sites along the stream, in relation to groundwater contamination studies. These ongoing investigations will form part of the Project's monitoring programme.

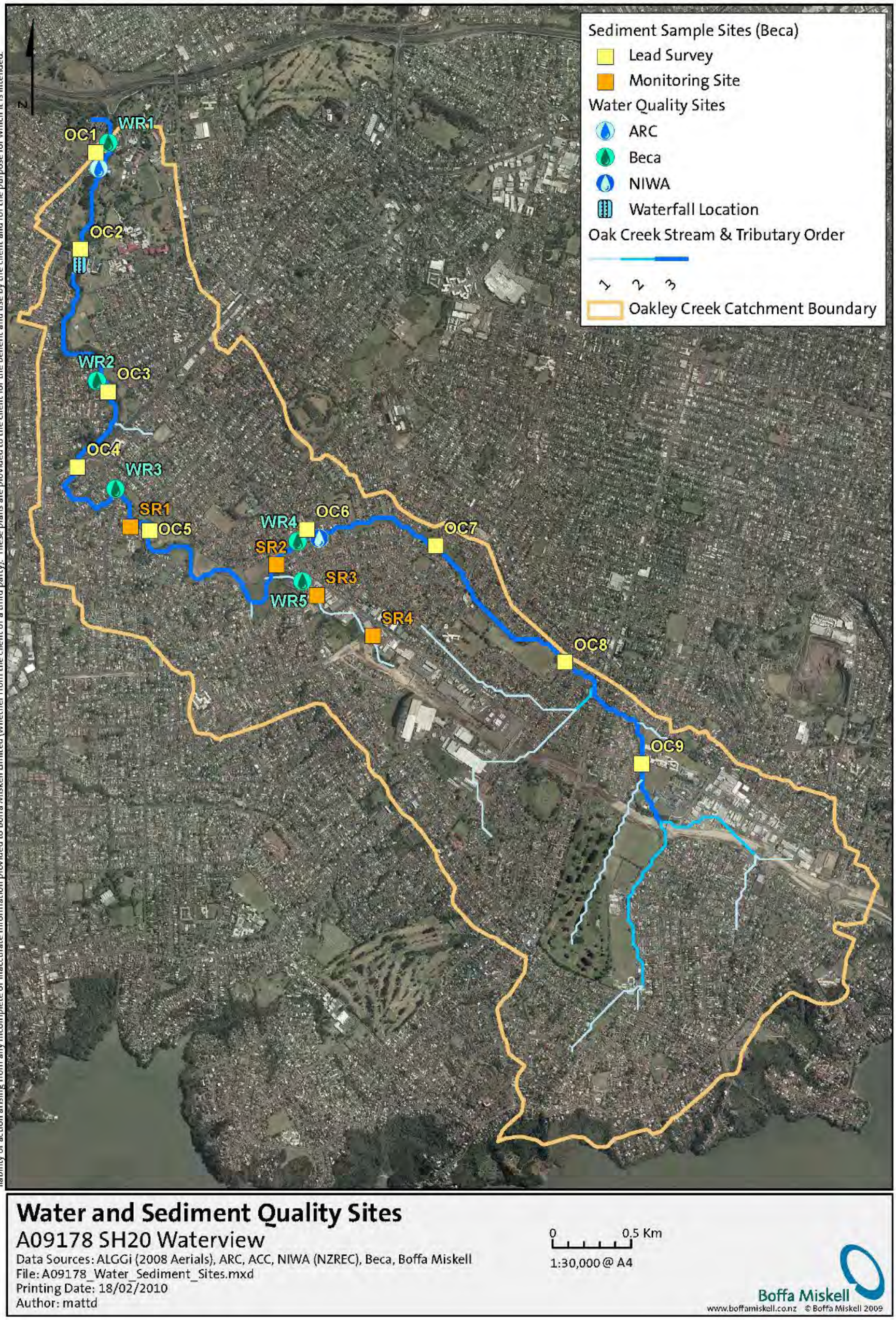
5.5.2 Pixie Stream

No sediment quality analyses have been undertaken in relation to Pixie Stream. The upstream catchment is residential, and contaminant concentrations in streambed sediments are unlikely to be outside the range of similar urban sites. The streamworks (i.e. earthworks within the stream channel or adjacent floodplain) here are small in scale, and the risk of significant toxicity effects resulting from disturbance of contaminated sediments is therefore low.

5.5.3 Meola Creek

No sediment quality analyses have been undertaken in relation to Meola Creek. The upstream catchment is residential and contaminant concentrations in streambed sediments are unlikely to be outside the range of similar urban sites. The only streamworks here will be the construction of the outlet structure of the Sector 6 stormwater treatment pond within Meola Creek, which will not result in significant disturbance of the stream bed. The risk of significant toxicity resulting from disturbance of contaminated sediments is therefore low.

Figure 6: Water and Sediment Quality Sites, Oakley Creek



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5.6 Water Quality

5.6.1 Oakley Creek

A rainfall-event based sampling programme was undertaken at a site upstream of Richardson Road by NIWA (2004). Up to 184 samples were collected by automated samplers for six events between January and March 2003. The results indicated that water quality in the Oakley Creek was similar to other residential catchments, with most contaminants being lower than representative industrial catchments. Dissolved phosphorus concentrations were higher than other mainly-residential catchments, possibly due to detergents used in industrial and commercial premises.

Oakley Creek was ranked 8th out of 16 soft-bottomed streams tested for water quality by the ARC, based on ranking scores derived from dissolved oxygen, nutrients, suspended solids and faecal coliforms collected monthly from 1992 to 2003 (ARC, 2005; TP 304). In this ranking, Oakley Creek was the best of six urban streams and was assessed as having better water quality than two rural streams.

Despite these levels being moderate compared to other urban streams, the NIWA (2004) data indicates that ANZECC (2000) water quality guidelines for 95% protection of aquatic life are frequently exceeded in the stream (Table 9). Over 50% of event-based samples (i.e. samples collected during and after rainfall events) exceeded guideline levels for selected metals and nutrients. Low water quality is therefore relatively "normal" for this waterway, and is likely to be exerting an adverse effect on aquatic life here.

Table 9. Comparison of Water Quality Results to ANZECC Guidelines

		NIWA, 2004	ANZECC/MFE	
		50% percentile value	Guidelines level	Exceedance
Dissolved copper	g/m^3	0.0043	0.0014	YES
Dissolved zinc	g/m^3	0.01	0.008	YES
E. coli	per 100ml	7450	550	YES
total dissolved nitrogen	g/m^3	0.79	0.614	YES
total dissolved phosphorus	g/m^3	0.04	0.033	YES

More recently, a water quality monitoring programme has been initiated by BCHF, consisting of monthly sampling at five sites along the creek, plus event-based sampling (Figure 6). Three sampling runs have been undertaken to date (February 2010). These data will be reported on after 12 months.

5.6.2 Pixie Stream

The water quality sampling undertaken by BGL (2009) recorded a water temperature of 15°C, with moderate levels of dissolved oxygen (7.7 mg/L & 76% saturation). Visual clarity was excellent (> 1m) and conductivity was 112 µS/cm. This data indicates that water quality is fair under baseflow conditions. However, this limited data is insufficient to characterise water quality in the stream due to the limited number of parameters and samples. Intermittent pulses of low quality water typically occur in urban streams at the onset of rainfall events, and this pattern would be expected in Pixie Stream.

5.6.3 Meola Creek

Suren (2001) measured a number of water quality parameters, as shown in Table 10 below.

Table 10. Summary of Water Quality Parameters in Meola Creek Below SH16

Site	Conductivity ($\mu S\ cm^{-1}$)	pH	Temperature	Dissolved O_2 ($mg^{/-1}$)	Turbidity (NTU's)
Meola Creek	261	7.3	17.5	8.3	3

The temperature was relatively cool, most likely reflecting the amount of overhead vegetation, as well as its relatively large and deep nature which would have given it a relatively high degree of thermal resistance to solar radiation. The relatively low pH and dissolved readings reflects the fact that at most sites photosynthesis would have been relatively low (although these variables would change diurnally, especially at sites where macrophytes covered a large area of streambed). Under such conditions, dissolved O_2 levels in the stream may drop to very low values during the night as the macrophytes and associated detritus begins to respire. Turbidity readings at this site were very low.

Suren (2005) analysed a number of other water quality parameters for Meola Creek, including baseflow dissolved copper (g/m^3), baseflow dissolved zinc (g/m^3), baseflow maximum temperature (Celsius) and baseflow minimum DO (g/m^3). The baseflow concentrations of copper and zinc were below the ANZECC 95% protection threshold, indicating that the concentrations of these contaminants in Meola Creek were unlikely to be causing any adverse ecological effects.

5.7 Stream Ecological Valuation (SEV) Assessments

5.7.1 Introduction

Using the data described in the preceding sections, an SEV assessment in Oakley Creek was undertaken in July 2008. The SEV is a method for determining the integrity of a stream's ecological functions. It is described in ARC TP 302 (Rowe et al. 2008), and summarised in Appendix A of this report. For the SEV assessment, parameters relating to hydrological functions, biochemical functions, habitat provision and biodiversity are assessed. A total of sixteen stream function parameters are used (Table 11). These are scored and an overall average score ranging from 0 to 1 is calculated, the higher the score the better the stream condition. Sites scoring less than 0.4 are considered to have low functional values while those scoring above 0.8 have high values.

The SEV also provides a methodology for determining the level of Environmental Compensation (EC) appropriate when performing works in a stream which have adverse effects that cannot be mitigated within that reach. The SEV parameters are adjusted to reflect the future effects of works and mitigation, respectively. Ecological losses and gains are then compared to determine the level of remediation required to offset the impact of works. This is expressed as an Environmental Compensation Ratio (ECR), which is the length of stream requiring remediation per unit area of works (Rowe et al. 2008). This is discussed further (with the EC associated with the Project being determined) in Section 6.7 of this report.

Table 11. Ecological Functions in the SEV and Their Relative Importance (Rowe *et al*,. 2008)

	Ecological Function	Overall Relative Importance
	Hydraulic Functions	
1.	Natural flow regime maintained	High
2.	Connectivity to flood-plain maintained	Medium
3.	Connectivity for species migrations exists	Low
4.	Connectivity to groundwater maintained	Low
	Biogeochemical Functions	
5.	Water temperature control maintained	High
6.	Dissolved oxygen levels maintained	Medium
7.	Organic matter input maintained	Medium
8.	In-stream particle retention maintained	Medium
9.	De-contamination of pollutants maintained	Medium
10.	Flood-plain particle retention maintained	Low
	Habitat Provision Functions	
11.	Fish spawning habitat intact	High
12.	Habitat for aquatic fauna intact	High
	Biotic Provision Functions	
13.	Fish fauna intact	High
14.	Invertebrate fauna is intact	High
15.	Aquatic biodiversity intact	High
16.	Riparian vegetation intact	High

5.7.2 Oakley Creek

Stream Ecological Valuation assessments have undertaken over a period of time at a number of sites within Oakley Creek, in accordance with the protocols described in ARC TP 302. The results from a recent SEV assessment for 3 representative sites from along the length of the creek are presented in Table 12 (maximum score of 1). The overall SEV scores for these 3 sites were 0.39 (Stoddard Road tributary), 0.34 (Hendon Park) and 0.45 (lower Oakley Creek), which indicates that the stream is predominantly of low ecological value (i.e. as represented by sites 1 and 2), although the lower reaches are of moderate ecological value (i.e. site 3).

Several SEV surveys were also undertaken along the length of Oakley Creek within Alan Wood Reserve and Hendon Park, targeting the full range of habitat types present here (e.g. rocky stream bed vs soft stream bed, blockwork walls vs natural stream banks, pools vs runs/riffles, etc). The results of this are shown in Appendix B. These SEV scores ranged between 0.30 – 0.49, with moist below 0.4. These are consistent with the representative SEV assessment for the Hendon Park site described in the preceding paragraph.

5.7.3 Pixie Stream

A SEV assessment was also undertaken within Pixie Stream (Bioresearches 2009). The results are recorded in Table 13 below. The overall SEV score for the stream was 0.67 (maximum score of 1), which indicates that the tributary is of moderate ecological value and has been impacted by both catchment and instream changes.

The major limiting factors for this stream were the impervious upper catchment, the patchy riparian cover and the presence of some anaerobic sediments, all of which may have contributed to the limited macroinvertebrate diversity (11 taxa recorded).

Table 12. SEV Results for Representative Sites Within Oakley Creek

Ecological Function	Relative Importance	Site 1	Site 2	Site 3
		Stoddard Road	Hendon Park	Lower Oakley Creek[3]
Hydraulic Functions				
Natural flow regime maintained	High	0.05	0.08	0.00
Connectivity to flood-plain maintained	Medium	0.60	0.05	0.05
Connectivity for species migrations exists	Low	0.05	1.00	1.00
Connectivity to groundwater maintained	Low	0.90	0.50	1.00
Hydraulic function mean score		**0.40**	**0.41**	**0.51**
Biogeochemical Functions				
Water temperature control maintained	High	0.42	0.30	0.50
Dissolved oxygen levels maintained	Medium	0.42	0.61	0.65
Organic matter input maintained	Medium	0.12	0.02	0.26
In-stream particle retention maintained	Medium	0.08	0.08	0.08
De-contamination of pollutants maintained	Medium	0.81	1.00	0.76
Flood-plain particle retention maintained	Low	0.59	0.13	0.29
Biogeochemical function mean score		**0.41**	**0.36**	**0.42**
Habitat Provision Functions				
Fish spawning habitat intact	High	1.00	0.50	0.50
Habitat for aquatic fauna intact	High	0.30	0.26	0.38
Habitat provision function mean score		**0.65**	**0.38**	**0.44**
Biotic Provision Functions				
Fish fauna intact	High	0.17	0.47	0.47
Invertebrate fauna is intact	High	0.00	0.03	0.03
Aquatic biodiversity intact	High	0.25	0.39	0.54
Riparian vegetation intact	High	0.45	0.03	0.77
Biodiversity function mean score		**0.22**	**0.23**	**0.45**
Sum of scores (maximum value 16)		**6.20**	**5.45**	**7.26**
Overall mean SEV score (maximum value 1)		**0.39**	**0.34**	**0.45**

[3] Below the waterfall

Table 13. SEV for Pixie Stream
(Source : Bioresearches 2009)

Ecological function	Function score	
	Pixie Stream	Mean of SEV reference sites (Papakura; n=3)
Hydraulic Functions		
1. Natural flow regime	0.30	0.87
2. Connectivity to flood-plain	0.75	0.57
3. Connectivity for migrations	1.00	1.00
4. Connectivity to groundwater	1.00	0.93
Biogeochemical Functions		
5. Water temperature control	0.75	0.86
6. Dissolved oxygen maintained	0.45	1.00
7. Organic matter input	0.43	0.83
8. Instream particle retention	0.72	0.98
9. Decontamination of pollutants	1.00	0.95
10. Flood-plain particle retention	0.73	0.71
Habitat Provision Functions		
11. Fish spawning habitat	0.88	0.79
12. Habitat for aquatic fauna	0.50	0.96
Biotic Provision Functions		
13. Fish fauna intact	0.67	0.95
14. Invertebrate fauna intact	0.15	1.00
15. Aquatic biodiversity intact	0.72	0.98
16. Riparian vegetation intact	0.62	1.00
Overall mean SEV score	**0.67**	**0.90**

5.7.4 Meola Creek

The Project will not involve any stream works or stream loss in relation to Meola Creek. Notwithstanding this, an SEV was undertaken here, in order to compare the relative merits of applying the Environmental Compensation directly No SEV assessments were undertaken within Meola Creek, given that the only potential adverse effect would be the discharge of treated stormwater into it.

5.8 Synopsis of Freshwater Values Within the Project Area

5.8.1 Oakley Creek

Oakley Creek is a significant watercourse in Auckland City. Parts of this waterway are substantially modified and the entire creek receives urban stormwater runoff from the surrounding catchment. In its downstream section a 6m high natural waterfall prevents passage of most native fish species.

Ecological investigations have indicated that environmental conditions within Oakley Creek are poor, probably due to low water quality. The primary indicators of this poor water quality were the macro-invertebrate communities, which were characterized by low numbers of taxa and the absence of pollution-sensitive taxa. In particular, Oakley Creek near New North Road provided physical habitat conditions favourable to a range of sensitive species (eg. stony substrate and oxygenated water), and their absence therefore suggested that water quality was the main limiting factor. Other sites sampled within the Creek also lacked pollution-sensitive taxa, and generally had few insect taxa of any sort.

Relatively high abundance of midge larvae and axehead caddis larvae at the Oakley Creek sites suggested the presence of productive algal slimes on the rocky substrate, which indicates nutrient enrichment.

In terms of physical habitat, Oakley Creek is a large stream with a large volume of habitat, deep pools suitable for large eels and permanent flows. Downstream of New North Road it has a relatively low level of channel modification, although hydrological changes resulting from urbanization have probably affected channel form.

Freshwater fish communities within Oakley Creek above the waterfall are of very low diversity, with only shortfin eels (in super-abundance) and (less commonly) longfin eels, and the introduced pest mosquitofish being recorded. Given this it is evident that the waterfall in Oakley Creek near UniTec (downstream of the Phyllis Street reserve) is a significant barrier to migrating native fish.

In comparing the earlier freshwater fish studies (BML, 2001; 2003) with the most recent one (BML, 2008), there are a number of similarities but also a number of differences. The results were similar above the waterfall, where in all surveys eels were the only native taxon recorded. These were also captured in almost identical densities, and size distributions were also similar between the years. While longfin eels and mosquitofish were not recorded in 2001, their low numbers in the 2008 dataset suggests that this was due to sampling error.

Below the waterfall the results for different surveys were similar in some respects (i.e. with inanga being the most abundant species and of similar size range, and with common bullies being present in similar numbers), but different in others. In particular, species diversity was very different, with only three species recorded in 2008 compared to five in 2001. These differences between surveys below the waterfall are considered to be due to differences in sampling effort between the surveys and/or natural temporal variation. This supposition is supported by the macroinvertebrate data and upstream fish data demonstrating that no significant changes have occurred between the surveys (see below).

In comparing the earlier aquatic macroinvertebrate studies (BML, 2001; 2003) with the most recent one (BML 2008), results were broadly similar between sites and surveys, with all assessed parameters except abundance being generally comparable. Variation in this parameter was largely due to differences in the abundance of snails, which probably does not reflect significant changes in environmental quality in the stream (since a significant effect would be consistent across a range of taxa and other metrics in addition to abundance).

Overall, Oakley Creek within the Project footprint has relatively low ecological health, particularly in terms of its physical habitat modification and low diversity and sensitivity of macroinvertebrates. Water quality here is also low, but is similar to other urban catchments. The SEV scores in the parts of the stream directly affected by the Project (ie. Stoddard Road and Hendon Park) are generally low (0.39 and 0.34 respectively). However, outside of the Project area, in the lower reaches of the stream (below the waterfall), the SEV score is higher (0.45), reflecting greater ecological values downstream compared to upstream.

5.8.2 Pixie Stream

Pixie Stream is a small stream with most of its catchment area piped, with the remaining area of open channel being entirely confined to the reaches below the existing SH16 carriageway. The riparian vegetation here generally comprises tall shading exotic vegetation and weed species. The stream is generally shallow but with some deeper pools present. The substrate comprises soft mud.

The macroinvertebrate community has moderate diversity (11 taxa), dominated by snails (78%). The MCI score was 76, which is indicative of 'poor' instream habitat quality.

A small range of native fish species was recorded, including shortfin eel, longfin eel, inanga and bullies. The Fish IBI for this site was 40, indicative of 'good' habitat quality or connectivity for fish migrations.

The SEV score for this stream was 0.67, indicating that it was of moderate ecological value.

5.8.3 Meola Creek

Meola Creek is a moderately long stream (2.6km) with its headwaters entirely piped. The riparian vegetation below the SH16 carriageway consists of tall shading exotic vegetation (primarily willows) with an understory / ground cover of weed species. The stream is swiftly flowing, very clear and quite deep (up to 0.8m in places). The substrate is dominated by mud and bedrock.

Thick growths of the introduced macrophyte *Vallisneria gigantean*, interspersed with oxygen weed, fill all but the swiftest flowing areas of Meola Creek immediately downstream of the existing SH16 culvert. Small amounts of starwort are also present. It is noteworthy that the Nationally Endangered aquatic moss *Fissidens berteroi* is present in Meola Creek in the vicinity of the Great North Road culvert (i.e. downstream and outside of the Project footprint).

The invertebrate fauna of Meola Creek immediately below the SH16 carriageway supports 10 taxa, dominated by amphipods and snails. No sensitive macroinvertebrates are present. Such a low taxonomic richness (i.e. few species)is typical of that of other Auckland urban streams, and reflects the high degree of habitat modification and low water quality in these streams.

The fish fauna is relatively depauperate, consisting of longfin eels, shortfin eels and common bullies. Of these, the shortfin eel is the only commonly occurring species.

Water quality parameters indicate that the concentrations of contaminants in Meola Creek are unlikely to be causing any adverse ecological effects.

6. Assessment of Effects on Freshwater Environments

6.1 Introduction

This section presents an assessment of the freshwater ecological effects that may occur during the construction and operational phases of the Project.

The activities that may result in adverse effects include the discharge of sediment and contaminants (affecting water quality), changes to impermeable surface area and drainage (affecting water quantity and flow characteristics), ground settlement over the tunnels, physical disturbance to stream channels (e.g. realignment), and loss of stream habitat due to piping or shortening. The impact of these activities on stream biota within the Project area is assessed below.

Mitigation measures have been discussed in other technical reports relating to Project design and construction, including the Assessment of Stormwater and Streamworks Effects, Groundwater Management Plan, Ecological Management Plan and Construction Environmental Management Plan. This report assumes that these measures will be implemented and addresses the residual effects on freshwater ecological values.

The effects of loss of stream habitat, and an evaluation of environmental compensation to off-set these effects, are presented in Section 6.6 and Sections 7 and 8 of this report.

6.2 Construction Phase Sediment

6.2.1 Oakley Creek

6.2.1.1 Proposed Works

The proposed construction phase works within the Oakley Creek catchment include surface earthworks and structures in Sector 5 (linking the northern portals of the cut-and-cover tunnels with the Great North Road Interchange); tunnelling in Sectors 7 and 8; and surface earthworks (connecting the Waterview Connection to the existing SH20 Mt Roskill extension at the Maioro Street Interchange), structures (the southern portals of the driven tunnels and the Oakley Creek bridge) and stream diversions in Sector 9.

The surface works in particular have the potential to generate large volumes of sediment, in particular the earthworks but also the excavations associated with constructing the tunnel portals and constructing the stream realignments.

6.2.1.2 Proposed Controls

(a) <u>Erosion and Sediment Control Approach</u>

All stormwater runoff from areas disturbed by construction activities will be managed in accordance with the Erosion and Sediment Control Plan (ESCP) (Ridley Dunphy Environmental, 2010), which sets out the principles and specific methods that will be applied in each sector.

Under this plan, ***avoidance*** of effects is the first priority (for example by minimising stream works and avoiding discharges to sensitive areas), followed by ***erosion control*** to minimise the generation of sediment. The third level in the hierarchy is ***sediment control***, which will remove sediment prior to discharges to the receiving environments.

Sediment control will be based on Sediment Retention Ponds (SRP's) with chemical flocculation (i.e. the ponds are treated with chemicals that cause fine suspended particles to clump together and sink to the bottom, increasing sediment removal efficiency). These SRP's will be based on the Technical Publication (TP) 90 design with 3% volume criteria for pond size. These will be supported by a range of other stormwater management controls such as Decanting Earth Bunds, Super Silt Fences and Silt Fences. These devices and technical terms are explained more fully in the ESCP (Ridley Dunphy, 2010).

One of the key methods of erosion control is progressive stabilisation, which will minimise the duration of exposure of unstabilised soils. For example, all Contractors Working Areas (CWAs) will be sealed with compacted gap65 metal once the platforms have been completed.

It is also notable that a substantial portion of the earthworks are related to the tunnel portals, in Sectors 5 and 9 respectively. These are effectively holes in the ground from which discharge is totally controlled by pumping, with high levels of control including chemical treatment together with pH and turbidity monitoring which will further reduce actual sediment discharge from the potential levels that have been calculated (G.Ridley, *pers comm*.).

A risk assessment has also been undertaken as part of the ESCP to identify higher-risk areas and ensure that erosion and sediment controls are appropriate. This is discussed further in section 6.2.1.2 (d) below.

(b) <u>Pond Discharge Locations</u>

The location of SRP's and their discharge points, together with pond sizes and contributing catchment areas is shown in Appendix F of the ESCP.

A total of five SRP's will be located at the northern tunnel portals and associated Contractors Working Areas (Sectors 5 and 7). These consist of two SRP's within the Waterview interchange loop (SRP 5B and 5D), two in the Waterview Park area (SRP 5A and 5C), and one at the bored tunnel north portal (SRP 7A).

All of the Sector 5 SRP's will discharge directly to the coastal marine area, thereby avoiding effects on Oakley Creek[4]. The only SRP discharge into Oakley Creek north of the tunnel portals will be from SRP 7A.

At the southern end of the Project (Sector 9) extensive surface earthworks will be undertaken associated with the southern tunnel portals, surface motorway and Contractors Working Areas. There are three SRP's here, being 9A, 9B and 9D, with additional sediment retention to be provided by the Hendon wetland pond if necessary. These ponds will discharge into the adjacent section of Oakley Creek.

[4] While the mouth of Oakley Creek is tidal it is believed that the small but regular stream level fluctuations that occur immediately upstream of the mouth are caused by stream water ponding in front of the incoming tides as opposed to any actual penetration of saline water through the existing Great North Road culvert. In this way it is unlikely that sediment-laden saline water (as a result of stormwater pond discharges at the mouth of Oakley Creek) will flow upstream on flood tides through the culvert and enter the lower creek.

There will also be two SRPs between the Maioro Street interchange and Richardson Road, discharging to the adjacent Stoddard Road tributary, which joins Oakley Creek in Hendon Park (approximately 500m downstream).

(c) Sediment Volumes

After treatment in the SRPs, residual sediment will be discharged to Oakley Creek. This will occur during and after rainfall, together with some continuous discharge during tunnel construction as a result of groundwater seepage. Sediment discharge will therefore vary seasonally with rainfall. Most earthworks will be undertaken in the Earthworks Season of October to April to avoid times of peak rainfall (note that this season may be subject to extension and some earthworks and activities such as tunnel boring may continue where risk is assessed as low).

The Project will also seek to minimise the duration of exposure of unstabilised soils. Therefore, the earthworks area indicated in the plans will only be unstable for a short period in relation to the overall project duration.

Concentrations of sediment in Oakley Creek during the construction phase will vary with rainfall. However, the natural dilution of sediment within the creek waters coupled with the capacity of the creek to transport sediment downstream (and out of the freshwater environment) will tend to be greatest during and immediately after rainfall events, which will tend to reduce the potential for sedimentation to occur within the creek.

NIWA have estimated the sediment yield for the Project using the GLEAMS model, based on a 12 month total construction period within each sector. They have also estimated the background sediment yield using the Contaminant Load Model (CLM). The model estimates are based on the highway footprint only and do not include construction yards, ponds or other components of the construction footprint that are regarded as having relatively low sediment-generating potential.

The Oakley Creek catchment has a total area of 1,231ha, while the motorway will have an area of 12ha or approximately 1% of catchment area (Table 13). The surface area of the motorway will be approximately 6% of the existing road network surface area. The GLEAMS model estimated that the Project would generate 16.8 tonnes of sediment per year from Sectors 7 – 9 during construction, which will discharge to Oakley Creek. This represents 4.7% of current background sediment levels.

Table 13. Oakley Creek Catchment Areas and Sediment Loads

	Oakley Creek current	Project Area	Percent
Contributing Area (ha)	1,231	12.1	1.0
Road Surface Area (ha)	204	12.1	5.9
Construction Annual Sediment Load (tonnes)	359.5	16.8	4.7
Operational Annual Sediment Load (tonnes), 2016 scenario	359.5	1.7	0.5
Operational Annual Sediment Load (tonnes), 2026 scenario	359.5	1.9	0.5

While this does not include the area of construction yards and the like, it over-estimates the duration of exposure of disturbed soils as it does not factor in progressive stabilisation. Overall, this estimate suggests that the increase in background sediment loads will be minor. By targeting high-risk areas with specific sediment controls, as described in the ESCP, it is expected that this estimated total can be reduced further.

(d) Erosion and Sediment Control Risk Assessment

The Erosion and Sediment Control Plan includes a risk assessment based on estimates of sediment yield calculated by the Universal Sediment Loss Equation (USLE) and the GLEAMS model. The purpose of this analysis was to identify areas with relatively high sediment yield potential where more stringent sediment control measures should be put in place. This analysis identified Sectors 1, 6 and 9 as the highest sediment-producing sectors. Because of ease of erosion and sediment control in Sector 6 (which simply involves motorway shoulder widening) the actual risk here has been assessed in the ESCP as not being significant. Sector 9 treatment devices discharge to Oakley Creek, and this sector has been identified as an area requiring significant emphasis on sediment control. Further risks identified in the Risk Assessment include works within watercourses, works within 1% AEP floodplain areas, and failure of the pump system associated with the tunnel portal excavations. These risks are specifically addressed in the ESCP.

(e) Instream Works

Instream works will be undertaken in Sector 9. These consist of:

- stream realignments in Alan Wood Reserve/Hendon Park that are necessary to physically accommodate the new highway here[5];
- stream realignments between Richardson Road and the Maioro Street Interchange that are necessary to physically accommodate the new highway here; and
- stream realignments at the confluence of Oakley Creek with the Stoddard Road tributary that are necessary to physically accommodate the new highway and the future rail alignment here.

In addition to these realignments, there are a number of places along Oakley Creek where stream rehabilitation is proposed. All of these rehabilitation sites are located within Alan Wood Reserve, Hendon Park and the Goldstar Block. The rehabilitation will involve reshaping the existing stream channel (with some associated minor realigning of the stream bed) to a more natural cross section (as opposed to the existing vertical blockwork wall)[6]. This is discussed further in Section 8. The purpose of these rehabilitation works is to enhance stream functional values as well as to improve the amenity, landscape and recreational values of these reserves. An added benefit of the channel reshaping will be an increase in the volume capacity of the creek in this area in relation to the conveyance of flood waters.

These stream realignments avoid the need for any new culverts within Oakley Creek. They have furthermore been designed to minimise loss of stream length, as well as to maintain fish passage and enhance instream habitat quality (for example, by allowing for variation in stream width, depth and velocity, and by planting riparian vegetation).

[5] These realignments will be undertaken in general accordance with the "*Western Ring Route - Maioro Street Interchange and Waterview Connection: Oakley Creek Realignment and Rehabilitation Guidelines*" (BML, 2010b). – see Appendix C

[6] These rehabilitation works will be undertaken in general accordance with the *Western Ring Route - Maioro Street Interchange and Waterview Connection: Oakley Creek Realignment and Rehabilitation Guidelines*" (BML, 2010b) – see Appendix C

However, notwithstanding their merits, they have also been identified as potential erosion risk features in the ESCP. Their construction methodology is described in detail in Section 7.3 of that report. The key component in relation to erosion control is their intended construction outside of the stream itself. Sediment generation during their construction will be contained and treated via the SRP system. Stream flows will be diverted into the newly formed realignments progressively, once the channel banks have been stabilised.

Once the realignments have come "on-line" there is expected to be a visible increase in suspended sediment below them for several days. However, the actual loads are likely to be low. The stream dimensions will be similar to the existing stream and should therefore have a similar capacity to accept a range of flows without any increased erosion risk.

The piers that will support the Oakley Creek bridge will be set back from the stream banks and there should be no requirement for instream works for their construction. Sediment generated during bridge construction will be diverted away from the stream into the sediment control system and treated in the local SRPs.

6.2.1.3 Extent and Sensitivity of the Oakley Creek Receiving Environment

The extent of Oakley Creek within the Project footprint is approximately 6.5km, extending from the Maioro Street Interchange to its mouth at the Waterview Inlet. It includes a 100m long culvert beneath Richardson Road, a 200m long culvert under New North Road and a 30m long culvert beneath Great North Road. The distance from the waterfall to the Great North Road culvert is approximately 1k.

There would be no discharges from the SRP's to Oakley Creek in Sector 5. There would also be no discharges in Sector 8 (being the bored tunnels sector), with sediment generated from this area being managed in the Sector 5 and Sector 9 SRP's, respectively. Sediment discharges to Oakley Creek would therefore only occur in Sectors 7 and 9. The sensitivity of freshwater communities in these two sectors is relatively low (as it is generally in relation to the entire creek, as described in earlier sections of this report). Macroinvertebrate communities comprise common, pollution-tolerant species throughout the steam, and have relatively low ecological values. The only native fish with permanent populations above the waterfall are shortfin and longfin eels, which are tolerant of a wide range of adverse environmental variables, including elevated levels of suspended sediment.

Conversely, fish communities below the waterfall (Sector 7) are relatively diverse, reflecting the proximity to the sea for juvenile migrants. Populations here are likely to fluctuate each year in response to instream conditions, and annual recruitment of juveniles to the population here would provide resilience to the freshwater community to recover from intermittent effects, such as those that would be associated with the construction of the Project. The few kilometres of stream lying between Sector 9 and the waterfall would also provide a significant dilution role and tend to reduce the magnitude of effects felt below the waterfall as a result of upstream sediment discharges.

6.2.1.4 Assessment of Effects

Oakley Creek is considered to be a high-risk area in terms of potential adverse freshwater effects resulting from the construction of the Project. There is a combination of relatively high sediment generating potential from Sector 9. The stream is a contained environment in that there is no lateral dispersal of sediment, with all sediment discharged increasing the creek's base load and potentially affecting the downstream environment all the way to the stream mouth.

Notwithstanding this, Sector 9 has low gradients (being generally flat), and therefore will generate relatively low volumes of sediment which can be effectively contained and treated. Progressive stabilisation of earthworks will also ensure that soils are exposed for the minimum duration. The ESCP has identified and addressed hot spots. These measures should ensure that sediment loads in the stream are less than 5% of background levels.

The biological communities in the stream are characterised by common, pollution-tolerant macroinvertebrate taxa and low fish diversity above the waterfall. These communities will generally have a low sensitivity to the predicted increases in suspended sediment.

Effects are likely to be limited to localised decreases in abundance of some species, but there are not expected to be any significant decreases in taxonomic richness or changes in characteristic fauna within Oakley Creek. The existing biological communities in the creek are adapted to fluctuating flows and water quality, and are expected to have a high resilience or capacity to recover from the predicted (or even worse) increases in suspended sediment.

In support of the above, it is noted that regular monitoring of Oakley Creek (2004 - present) that has been associated with the SH20 Mount Roskill Extension Project has shown that even when sediment deposition increased significantly at the sampling sites there were very little corresponding adverse effects on the bio-metrics of the instream community.

Hence, even in a worst-case scenario where suspended sediment concentrations may become substantially elevated above base loads and where sedimentation of the bed of Oakley Creek may occur as a result of the Project, based upon the SH20 Mt Roskill results it would appear that the effects on instream fauna are more likely to be of a localised and short term nature rather than anything catastrophic and permanent.

6.2.2 Pixie Stream

6.2.2.1 Proposed Works

Pixie Stream is located in Sector 1 on SH16, near the western end of the Project area. It runs from SH16 for approximately 320m around Jack Colvin Park to discharge into the Henderson Creek estuary. It is entirely piped south (upstream) of SH16. Works here consist of widening the existing shoulders of SH16, with a consequential extension of the existing SH16 Pixie Stream culvert by 34m (23m on its northern side (intruding into the remaining stream channel) and 11m on its southern side (replacing an existing culvert)).

6.2.2.2 Proposed Controls

A temporary sediment retention pond (SRP 1C) will be constructed on the eastern side of Pixie Stream close to its maximum upstream extent (on the southern side of SH16), and will discharge treated stormwater into it. Additional sediment control measures in the vicinity of Pixie Stream will include silt fences, super silt fences, decanting earth bunds, and clean and dirty water diversion bunds (these measures are fully explained in the ESCP). Progressive stabilisation of the earth-worked areas will minimise the exposure period of all disturbed soils.

6.2.2.3 Extent and Sensitivity of the Pixie Stream Receiving Environment

The extent of Pixie Stream below SH16 that will be potentially affected by elevated levels of suspended sediment during the construction phase works is 320m. The upstream catchment (above SH16) is entirely piped. The stream is culverted at the road entrance into Jack Colvin Park, and upstream of this culvert it takes the form of a straightened channel. Below the culvert access for migrating juvenile fish is good. However, the culvert impedes the upstream passage of all fish with the exception of eels.

The long grass around the stream mouth may potentially be inanga spawning habitat. Ecological surveys indicate that stream health is not high, with the macroinvertebrate community being characterised by a low taxonomic richness and dominated by pollution-tolerant species. Notwithstanding this, it is noted that the SEV score suggests moderate ecological value. The existing instream communities within Pixie Stream have low sensitivity, while the potential inanga spawning habitats at the mouth of the stream would have high sensitivity to sediment deposition.

6.2.2.4 Assessment of Effects

The proposed works in the vicinity of Pixie Stream have a moderate risk of affecting this small waterway. The culvert extension in the active stream channel will release sediment, although these works will be of short duration and will be undertaken in a period without preceding rainfall.

The small size of this stream means it has a relatively low capacity to dilute discharges from SRP 1C and flush them out of the stream system. As a result, visible deposits of sediment may occur below the SRP. These elevated sediment loads could reduce the abundance of macroinvertebrates and fish during the construction period, and may also reduce spawning success (assuming the stream mouth is an active spawning site).

Notwithstanding the above, the stream habitats and communities are expected to recover relatively rapidly once construction is completed. Additionally, sediment control measures, chemical treatment and culvert construction methods have a high probability of preventing significant sediment effects (G.Ridley, *pers comm.*). While some effects are likely to be evident they are not likely to be ecologically significant, given the existing compromised nature of the stream and its generally poor health, provided that the works (and associated sediment discharges) are of a relatively short duration.

6.2.3 Meola Creek

6.2.3.1 Proposed Works

Meola Creek is located in Sector 6, approximately 700m west of the St Lukes Interchange. The Project here involves the widening of SH16, construction of Contractors Working Area 5 (CWA5), and construction of a permanent stormwater treatment pond at the same location as CWA5. No instream works are required.

6.2.3.2 Proposed Controls

The ESCP proposes that motorway margins be protected by silt fences, and the approaches to Meola Creek by super silt fences. These will feature “returns” at 60m intervals to slow longitudinal flows and trap sediment, and will be backed up by two Decanting Earth Bunds (DEB 5A and 5B). Runoff from CWA5 will be treated by Decanting Earth Bunds before discharge to Meola Creek.

The footprint of the construction phase works within this catchment will be small. The low gradient of the affected areas (being generally flat) and the containment of disturbed ground within a narrow strip support the prediction that erosion and sediment controls will be entirely effective here. Progressive stabilisation of earthworks along the motorway, and of CWA5 immediately after construction, will minimise exposure of disturbed soils to a maximum duration of one month.

6.2.3.3 Extent and Sensitivity of the Meola Creek Receiving Environment

Meola Creek extends for approximately 1.4km from SH16 to the upper extent of mangroves near Meola Road. The Creek currently receives stormwater and combined stormwater sewer overflows from a predominantly residential catchment, and the stream channel is extensively modified both above and below SH16. Ecological surveys have recorded macroinvertebrate communities characterised by common, pollution-tolerant taxa. A reasonable diversity of fish are present. These communities are adapted to fluctuating flows and water quality conditions and are characterised as resilient with regard to their sensitivity to minor or moderate increases in sediment loads The Nationally Endangered aquatic moss *Fissidens berteroi* Is also present in Meola Creek in the vicinity of the Great North Road culvert (i.e. downstream and outside of the Project footprint).

6.2.3.4 Assessment of Effects

The Project works will discharge stormwater containing elevated levels of sediment to Meola Creek. This will occur during and after rainfall events. The footprint of the works here is relatively small within the context of the catchment, and the actual area of exposed soils during any rainfall event will be further reduced by progressive stabilisation. The sediment discharged to the Creek is expected to be a small percentage of background sediment loads from the upstream catchment.

The fish and macroinvertebrate communities downstream of the works have relatively low ecological values in terms of biodiversity, reflecting the conditions found in urban streams, and would have a low sensitivity to minor increases in sediment loads. While some localised effects are likely, such as decreases in abundance of macroinvertebrates in the vicinity of the DEB discharge points, the freshwater communities will recover after completion of the works.

No significant effects on fish communities or their spawning habitats are expected due to the relatively small volume of sediment and the flushing effect of flood flows, and the resilience of most New Zealand fish species to intermittent increases in suspended sediment. Sediment is likely to be well diluted by the time it reaches the location of the rare aquatic moss, and unlikely to result in smothering effects. In conclusion, effects on freshwater habitats and communities in Meola Creek are unlikely to be ecologically significant.

6.3 Groundwater Drawdown and Oakley Creek Base Flows

Drawdown of groundwater in the vicinity of Oakley Creek to facilitate tunnel and portal construction might alter the contribution of groundwater that naturally flows towards Oakley Creek. This may result in changes to the base flows in Oakley Creek. It might also increase the volume of water that naturally discharges through the floor of the Creek to recharge the underlying groundwater system. These potential issues are discussed and addressed in the Assessment of Groundwater Effects report (BCHF, 2010c). In that report four long term groundwater drainage scenarios for the tunnels and portals are evaluated as follows:

1. Tunnels and portals drained during construction but sealed long term (except in the basalt at the southern portal which is permanently drained);
2. Tunnels and portals drained during construction, with the cut-and-cover and driven tunnels sealed long term and with the southern portal fully drained;
3. Tunnels and portals drained during construction, with the driven tunnel sealed long term but with the cut-and-cover tunnels and portals being fully drained;
4. Tunnels and portals drained long term.

In relation to scenarios 1-3, the modelling suggests that during the construction phase the excavation dewatering associated with the northern portals (with a maximum open driven tunnel length of 400m) will have a negligible effect (1% reduction in flows) on groundwater leakage to and from Oakley Creek. The modelling also suggests that during the construction phase at the southern portals, drainage of the basalt and consequent lowering of the water table would result in an 8% reduction in flows when the entire length of basalt is open and dewatered.

In relation to the long term steady state, the modelling suggests a reduction in stream base flow of around 9% for scenario 1 and 10% for scenarios 2 and 3 if a permanent basalt drain at the southern portals is in place. A lesser reduction of around 4% could be expected if the southern portals were to be fully sealed. The effects of these reductions in terms of changes in the base flows of Oakley Creek range from negligible (at the northern portals) to minor (at the southern portal).

In relation to scenario 4, at most locations the floor of the tunnels is at a lower elevation than Oakley Creek, and therefore it is likely that drawdown of groundwater at the tunnels could result in a reduction in the volume of groundwater that flows to the creek, or could result in the loss of water through the bed of the creek. This effect will be greatest where the tunnels are closest to the creek.

The modelling suggests that stream base flow could be reduced by up to 21% due to long term leakage into the tunnels and consequent groundwater lowering. This would be a significant reduction in base flows, and from an ecological perspective the adverse effects associated with this scenario would be high.

In its conclusions, the Assessment of Groundwater Effects report (Beca, 2010a) recommends a number of excavation construction strategies that will minimise the extent of groundwater drawdown and changes in base flows to Oakley Creek. In terms of the long term steady state the report recommends that the northern portals and approaches be undrained, that the tunnels be sealed, and that a permanent drain be placed in the basalt at the southern portals (to relieve pressure on the retaining walls here). The report concludes that with adoption of these recommendations the potential effects of dewatering will be less than minor.

6.4 Tunnel Settlement Effects on Oakley Creek

Drawdown of groundwater at the tunnels will result in a cone of depression of the groundwater table(s) that extends outwards from the tunnels. The drawdown of groundwater below its normal seasonal variation can cause settlement of the ground, with the degree of potential settlement being highest for land that is situated above the tunnels. This process of ground settlement will affect the bed of Oakley Creek where the tunnels pass in close proximity beneath it. This issue is addressed in the Assessment of Ground Settlement Effects (BCHF, 2010c). Table 15 provides calculations of creek bed settlement along the length of the tunnels.

Table 15 : Total Predicted Settlement Along Oakley Creek

Chainage	Location	Distance from Creek[7]	Settlement (m)
1780	Alan Wood Reserve	-220m	0.000
1860	Alan Wood Reserve	-28m	0.012
2160	Alan Wood Reserve	-75m	0.001
2450	Pak n' Save	-200m	0.000
2750	Harbutt Reserve	95m	0.016
3200	Phyllis Street Reserve	-108m	0.046
3400	Phyllis Street Reserve	-16m	0.265
3785	UniTec	40m	0.000
3880	Oakley Creek Walkway	38m	0.025
3940	Oakley Creek Walkway	115m	0.003
4160	Oakley Creek Walkway	111m	0.002

The reach of Oakley Creek most affected by settlement is at chainage 3400, where the bed of the stream is predicted to settle by 0.265m (i.e. 26.5cm). Between chainage 3400 and 3785 the slope of settlement will be 0.07%, while the existing slope of the creek bed here is 1%; settlement will produce an average 7% change in stream slope.

To further investigate the potential impact of settlement, effects on water velocity were estimated by Tonkin & Taylor engineers using the FlowMaster model, utilising cross-section data collected for the MIKE11 flow model. A cross-section was taken from the MIKE11 flow model at stream chainage 10,637m, which is the closest cross section to our point of interest at motorway chainage 3400 (the MIKE cross-section was only 18m from motorway chainage 3400).

For this cross-section the stream velocities were calculated for different flows and gradients. Flows from 1m^3/s up to 9 m^3/s (the water quality event flow) were used as well as three different gradients: the existing gradient of the stream (approximately 1%) and the gradients resulting from the settlement of 0.265m at motorway chainage 3400 (1.1% and 0.93%). The mannings number used was 0.045 which is the value prescribed for natural streams, weedy by FlowMaster. The results are shown in Figure 6.

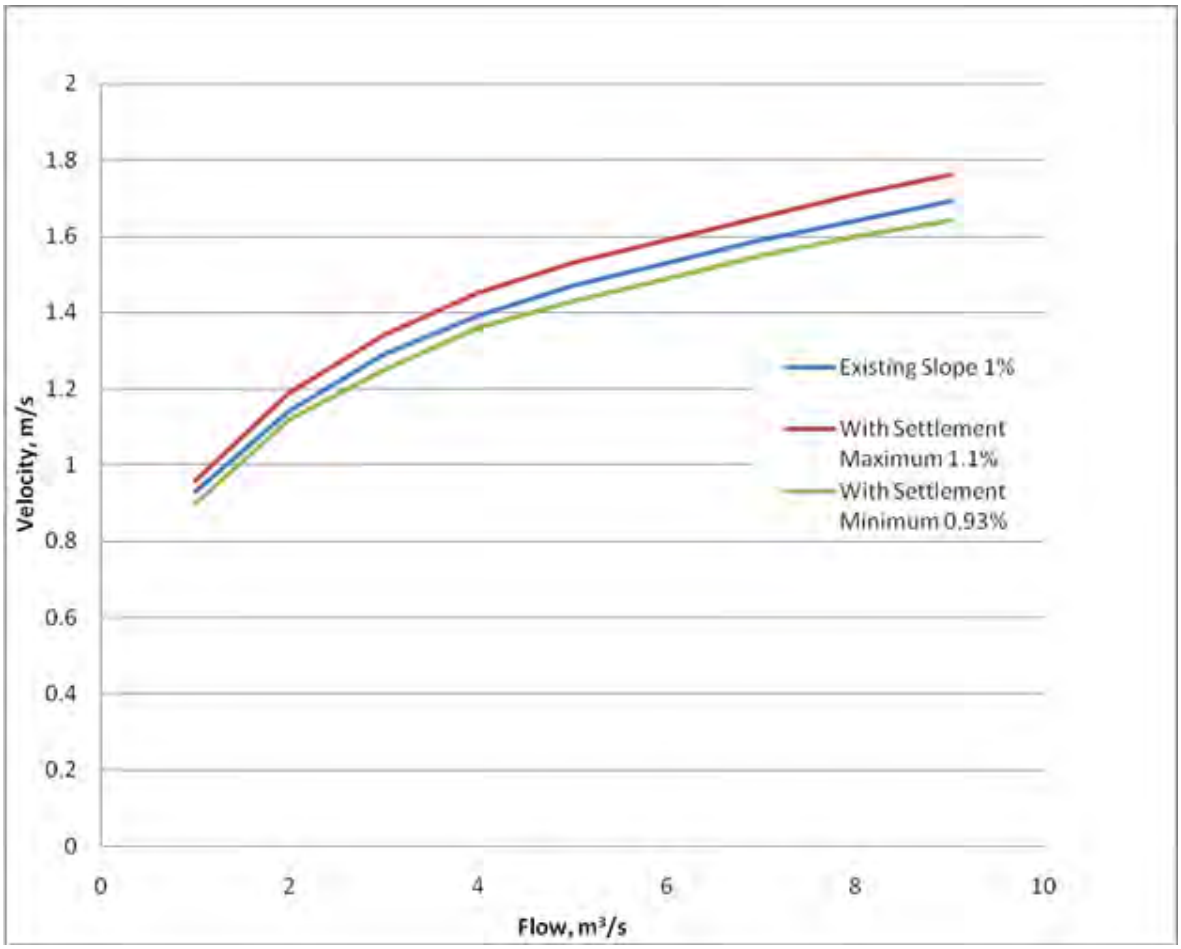
When the stream gradient was increased to 1.1% by the settlement the stream velocities for the range of flows increased by between 3.3% and 4.4% (Figure 6). When the stream gradient was decreased to 0.93% by the settlement the stream velocities decreased by between 1.8% and 3.2%.

This model indicates that change in average velocity will be less than 0.1m/s. This is a minor change within the context of natural variation in water velocity within a stream section (velocity will vary with factors such as flow, changing gradient along the stream, stream cross-sectional area, distance from stream bed and banks, and instream features such as boulders, logs and weed beds). A change in velocity of this magnitude would have no significant effect on instream habitats, such as additional erosion or deposition.

[7] Distances with a "-" indicate that the creek is to the south of the tunnels, while distances without this "-" indicate that the creek is positioned to the north of the tunnels.

It is expected that the resident biota here are already adapted to a range of velocity conditions, and it is concluded that effects of this magnitude would not significantly alter instream environmental conditions and would thus not have significant effects on the stream ecology.

Figure 6. Effects of Stream Channel Slope Change on Water Velocity



6.5 Contaminated Sites

6.5.1 Oakley Creek

Disturbance of the streambed or surrounding land could potentially release contaminants which may have adverse effects in the downstream receiving environment. Routes for the transport of terrestrially derived contaminants include surface flow in stormwater and groundwater seepage. An extensive survey programme has been undertaken along the alignment to identify contamination and assess environmental risks. These surveys are described in the Assessment of Land and Groundwater Contamination report (BCHF, 2010b).

The Assessment of Land and Groundwater Contamination report (BCHF, 2010b) concluded that while "*several areas were identified where ecological guidelines were exceeded by specific heavy metals...all were within background concentrations in the Auckland Region and so are not considered to pose a significant threat to ecological receptors*".

Soil samples from within the Great North Road Interchange (Sector 5) were identified in the Assessment of Land and Groundwater Contamination report (BCHF, 2010b) as exceeding the Permitted Activity criteria for lead, nickel, various individual PAH compounds, benzo(a)pyrene equivalent and 4-nitrophenol. However, these levels were only found at isolated locations and most of the soils here are considered to be free from contamination. Furthermore, the majority of this area does not drain to Oakley Creek but instead either drains to the mouth of the creek (within the coastal marine area) or directly to the Waitemata Harbour.

In the Assessment of Land and Groundwater Contamination report (BCHF, 2010b), after initial exceedance of assessment criteria for dissolved lead, copper and volatile hydrocarbons in groundwater samples collected from Sector 8, further testing has established that groundwater contamination is not significant, with all contaminants analysed being below their guideline value or below laboratory detection thresholds. Contaminated soil was found in the historic landfill in the Phyllis Street Reserve (with the Permitted Activity criteria being exceeded for lead, zinc and PAH compounds) and with zinc above its ANZECC guideline value in groundwater here. Contaminated groundwater was also found in the historic landfill at Harbutt Reserve, with zinc above its ANZECC guideline value. Notwithstanding the presence of these contaminated sites within Sector 8, the Assessment of Land and Groundwater Contamination report (BCHF, 2010b) concluded that the potential for contaminated inflows into the tunnel was considered to be very low.

In Sector 9, within the Alan Wood Reserve area no contaminants exceeded Permitted Activity criteria. However, in the vicinity of the Maioro Street Interchange, while contaminants were below their guideline values in groundwater the levels of copper, zinc, nickel and lead in soils exceeded their Permitted Activity criteria. However, these exceedances were only at isolated locations here. Land disturbance activities within the vicinity of these locations would require a discharge consent under Rule 5.5.44 of the PARP:ALW. Appropriate methods for the excavation, handling and disposal of these contaminated soils will be dealt with by way of resource consent conditions as well as the Contaminated Sites provisions of the Contractors Environmental Management Plan.

As the areas of significant contamination are relatively localised and well-defined, these specific management practices for land disturbing activities should ensure that the risk of significant discharges of contaminants is minimised and significant adverse effects avoided. In addition, effects on the aquatic receiving environment will be monitored, with response measures in place to mitigate any effects that may occur. As these effects should be no more than minor, and furthermore cannot be quantified, no "off-setting" mitigation is proposed. The monitoring and response measures are described in the CEMP (BCHF, 2010d).

6.5.2 Pixie Stream

The Assessment of Land and Groundwater Contamination report (BCHF, 2010b) concluded that there were no land contamination issues in Sector 1. Given this there would be no water contamination issues in relation to Pixie Stream.

6.5.3 Meola Creek

The Assessment of Land and Groundwater Contamination report (BCHF, 2010b) identified that the Permitted Activity criteria for various metals and individual PAH compounds were exceeded at four locations within the Meola stormwater pond area. Land disturbance activities here would therefore require discharge consents under Rule 5.5.44 of the Proposed Auckland Regional Plan : Air, Land and Water (PARP:ALW).

Appropriate methods for the excavation, handling and disposal of these contaminated soils will be dealt with by way of resource consent conditions as well as the Contaminated Sites provisions of the Contractors Environmental Management Plan.

6.6 Operational Phase Stormwater Contaminants

6.6.1 Oakley Creek

6.6.1.1 Proposed Works

Stormwater generated by the motorway will contain pollutants from vehicles such as heavy metals, suspended solids and hydrocarbons. The change in land use will increase the impervious surface area, increasing the volume of runoff from the catchment and potentially the peak flow during flood events unless mitigation is provided. Stormwater management for the Project is described in the Assessment of Stormwater and Streamworks Effects report (Tonkin & Taylor, 2010). NIWA has also undertaken contaminant load modelling.

6.6.1.2 Proposed Controls

All discharges to Oakley Creek will be treated. Stormwater from Sector 5 (Great North Road Interchange) will be discharged after treatment into the mouth of the creek (which is within the coastal marine area), thereby avoiding any effects on its upstream (freshwater) part. While the mouth of the creek is tidal it is believed that the small but regular stream level fluctuations that occur immediately upstream of the mouth are caused by stream water ponding in front of the incoming tides as opposed to any actual penetration of saline water through the existing Great North Road culvert. Because of this it is unlikely that discharges from the Sector 5 treatment pond will flow upstream on flood tides through the culvert and enter the lower creek.

Sector 7 (the cut and cover tunnels) and Sector 8 (the Avondale Heights tunnels) will generate limited quantities of contaminated water, mainly from groundwater seepage into the tunnel lining, which will be collected and pumped to the northern portal wetland for treatment prior to discharge into the mouth of Oakley Creek (with contingency for removal by tanker trucks for off-site treatment if it is found to be highly contaminated). Operational phase stormwater generated in Sector 9 will be treated by wetland ponds located in Alan Wood Reserve.

The proposed treatment devices have been selected using a Best Practicable Option (BPO) approach and include a combination of wetlands, filter strips, swales and cartridge filters (see Assessment of Stormwater and Streamworks Effects report (Tonkin & Taylor, 2010) for details). The BPO approach incorporates low impact design principles, discharge of water within the catchment in which it originates, minimising structures such as outlets located in the receiving environment, and consideration of the overall effects of discharges.

Devices were assessed against criteria for erosion control, water quality treatment, overland flow provision and flood attenuation (Tonkin & Taylor, 2010 - Table 4.1). These devices will treat stormwater to the level required in the Auckland Regional Council Proposed Air, Land and Water Plan. The design of these devices is based on ARC TP10 "*Stormwater Management Devices Design Guidelines Manual*" (2009), and will provide at least 75% removal of suspended solids and associated contaminants, as well as providing amelioration of peak flood flows by way of detention.

Given that most of the Project footprint will be underground (thereby not generating stormwater run-off from impervious surfaces) and that all of the stormwater generated in Sector 5 will discharge (after treatment) directly below the mouth of Oakley Creek, the potential adverse effects of the operational phase stormwater discharges on the ecological values of the creek will be significantly reduced. Surface runoff discharges to Oakley Creek will be almost entirely generated in Sector 9.

The Oakley Creek catchment has a total area of approximately 1,231ha and has 84% urban surface cover (Tonkin & Taylor, 2010). This indicates a total impervious surface area of approximately 1,033ha. While this includes a high proportion of low-pollution generating surfaces such as house roofs, it is also of a generally untreated nature. The new motorway will be approximately 12ha in extent, and will represent approximately a 1% increase in impervious surface area discharging to the creek. While it will have a relatively high contaminant load, this will be treated before discharge to attain ARC TP10 standards. Furthermore, the existing motorway catchment in Sector 5 is presently untreated. Both the new and the existing motorway in this sector will be treated, which will benefit the biota resident or otherwise utilising the habitat present at mouth of Oakley Creek.

Overall, it appears unlikely that the motorway discharges will significantly increase stormwater contaminant loads in Oakley Creek. NIWA have estimated that the current or baseline annual load of zinc (Zn) is 729kg per year and copper (Cu) is 87kg per year for the entire Oakley Creek catchment. The future load from Sector 9 represents approximately 6% of the current load.

NIWA modelling results for the long-term operational sediment and contaminant annual loads (based on projected traffic numbers in 2016 and 2026) for Oakley Creek are given in Table 16 below.

Table 16 : Sector 9 Long-Term Operational Sediment and Contaminant Loads

Sector	Annual Load (kg year[8])					
	2016			2026		
	TSS	Zn	Cu	TSS	Zn	Cu
9	1,671	36	4	1,920	42	5

[8] These annual load values represent the operational road area only, and do not include the surrounding catchment area.

6.6.1.3 Extent and Sensitivity of the Receiving Environment

The sensitivity of the biological communities in Oakley Creek is relatively low. Macro-invertebrate communities comprise common, pollution-tolerant species throughout the steam. The only native fish with permanent populations above the waterfall are shortfin and longfin eels, which are tolerant of pollution. Fish communities below the waterfall are relatively diverse, reflecting the proximity to the sea for juvenile migrants. Populations here are likely to fluctuate each year in response to instream conditions, and annual recruitment here would provide resilience for the freshwater community to recover from intermittent effects, such as discharges from stormwater treatment wetlands.

6.6.1.4 Assessment of Effects

Approximately 9ha of new highway surface area will generate stormwater runoff that will be discharged, after treatment, to Oakley Creek and its mouth. The total catchment area of the creek is approximately 1,230ha, of which 84% is urban. The additional contaminant load is therefore likely to be a small percentage of the total contaminant loads generated within this urban catchment.

The total length of stream potentially affected is approximately 6km. Ecological health and values are relatively low, with macroinvertebrate communities characterised by common, pollution-tolerant taxa and only shortfin and longfin eels being present above the waterfall. A greater range of fish species have been recorded below the waterfall, and this section therefore has higher ecological values. Ecological communities both above and below the waterfall are considered to be tolerant of a wide range of water quality conditions, which currently vary periodically between moderate to very poor.

The predicted minor increase in contaminant concentrations as a result of the Operational phase of the Project is unlikely to significantly affect water quality in Oakley Creek, and significant adverse effects on biological communities are therefore unlikely to occur.

6.6.2 Pixie Stream

6.6.2.1 Proposed Works

The project will generate additional stormwater from shoulder widening.

6.6.2.2 Proposed Controls

The volume of additional stormwater that will be generated as a result of shoulder widening is not large. It will be treated in a wetland located west of Jack Colvin Park, which will discharge to the coastal marine area at Henderson Creek. This treatment device will also provide treatment for the stormwater generated from the existing SH16 carriageway, which is presently untreated. NIWA modelling results for the long-term operational sediment and contaminant annual loads (based on projected traffic numbers in 2016 and 2026) for Sector 1 (which includes Pixie Stream) are given in Table 17 below.

6.6.2.3 Extent and sensitivity of the Receiving Environment

Pixie Stream is approximately 320m long. It has poor ecological health and low sensitivity to minor increases in contaminant loads.

Table 17 : Sector 1 Long-Term Operational Sediment and Contaminant Loads

Sector	Annual Load (kg year[9])					
	2016			2026		
	TSS	Zn	Cu	TSS	Zn	Cu
1	4,590	97	11	5,136	111	12

6.6.2.4 Assessment of Effects

As the stormwater wetland will discharge into the coastal marine area rather than the stream itself, any effects on Pixie Stream from the operation of the Project will be largely avoided. The only potential for treated discharges to enter the stream would be in situations where the wetland was discharging on an in-coming tide. Notwithstanding this, the stormwater will be treated to ARC TP10 standards and shouldn't result in effects that are any worse than those currently being experienced as a result of the existing untreated discharges from this part of SH16. Indeed, the diversion of presently untreated stormwater at this section of SH16 into the treatment wetland should result in a net improvement in the quality of the discharges here despite the small increase in volumes.

6.6.3 Meola Creek

6.6.3.1 Proposed Works

Works in Sector 6 affecting operational phase stormwater consist of shoulder widening.

6.6.3.2 Proposed Controls

Stormwater treatment for Sector 6 will be provided by way of a wetland, which will discharge into Meola Creek on the northern side of the motorway. This wetland will also treat some of the currently untreated local SH16 stormwater.

NIWA modelling results for the long-term operational sediment and contaminant annual loads (based on projected traffic numbers in 2016 and 2026) for Sector 6 (which includes Meola Creek) are given in Table 18.

6.6.3.3 Extent and Sensitivity of the Receiving Environment

Meola Creek extends for approximately 1.4km from SH16 to its mouth. The stream is affected by stormwater discharges from its large urban catchment above SH16. Biological communities are characterised by pollution-tolerant species and have a relatively low sensitivity.

[9] These annual load values represent the operational motorway surface area only, and do not include the surrounding catchment area.

Table 18 : Sector 6 Long-Term Operational Sediment and Contaminant Loads

Sector	Annual Load (kg year[10])					
	2016			2026		
	TSS	Zn	Cu	TSS	Zn	Cu
6	3,608	58	8	3,777	61	8

6.6.3.4 Assessment of Effects

The additional impervious area here will be a very small percentage of the wider catchment area. Stormwater will be treated, and any resultant adverse effects will be mitigated by the additional treatment that will be provided to currently untreated motorway runoff. The biological communities are pollution-tolerant and currently exposed to a range of pollution levels, which fluctuate with rainfall. These communities will not be sensitive to minor increases in contaminant loads.

6.7 Loss of Instream Habitat

6.7.1 Oakley Creek

6.7.1.1 Realignments and Stream Loss

Sections of Oakley Creek within Alan Wood Reserve, Hendon Park and the Goldstar Block will be realigned to allow the construction of the motorway. These are described in the Assessment of Stormwater and Streamworks Effects (Tonkin & Taylor, 2010).

The realignments consist of Stream Realignments A, B and C (in Alan Wood Reserve, Hendon Park and the Goldstar Block), realignment of the Oakley Creek main stem to facilitate the highway bridge crossing of this waterway, realignment of the Stoddard Road tributary at its confluence with Oakley Creek to facilitate the future railway corridor in this area, and the Stoddard tributary realignment east of Richardson Road. The location of these is shown in Figure 7, being the stream reaches highlighted in orange.

A total of (approximately) 217m of the Stoddard Road tributary and 790m of Oakley Creek will be realigned (with a combined overall length of approximately 1,007m). These realignments will result in a final stream length that is shorter than the existing watercourses, resulting in a total loss of stream length estimated at 137m (Table 19).

The realignments will be designed to provide multiple benefits for ecology, amenity and flood management. With respect to ecology, the aim is to ensure that the new channels provide better instream habitat opportunities than are currently present within the existing channels.

[10] These annual load values represent the operational road area only, and do not include the surrounding catchment area.

Figure 7. Location of Stream Realignments, Oakley Creek

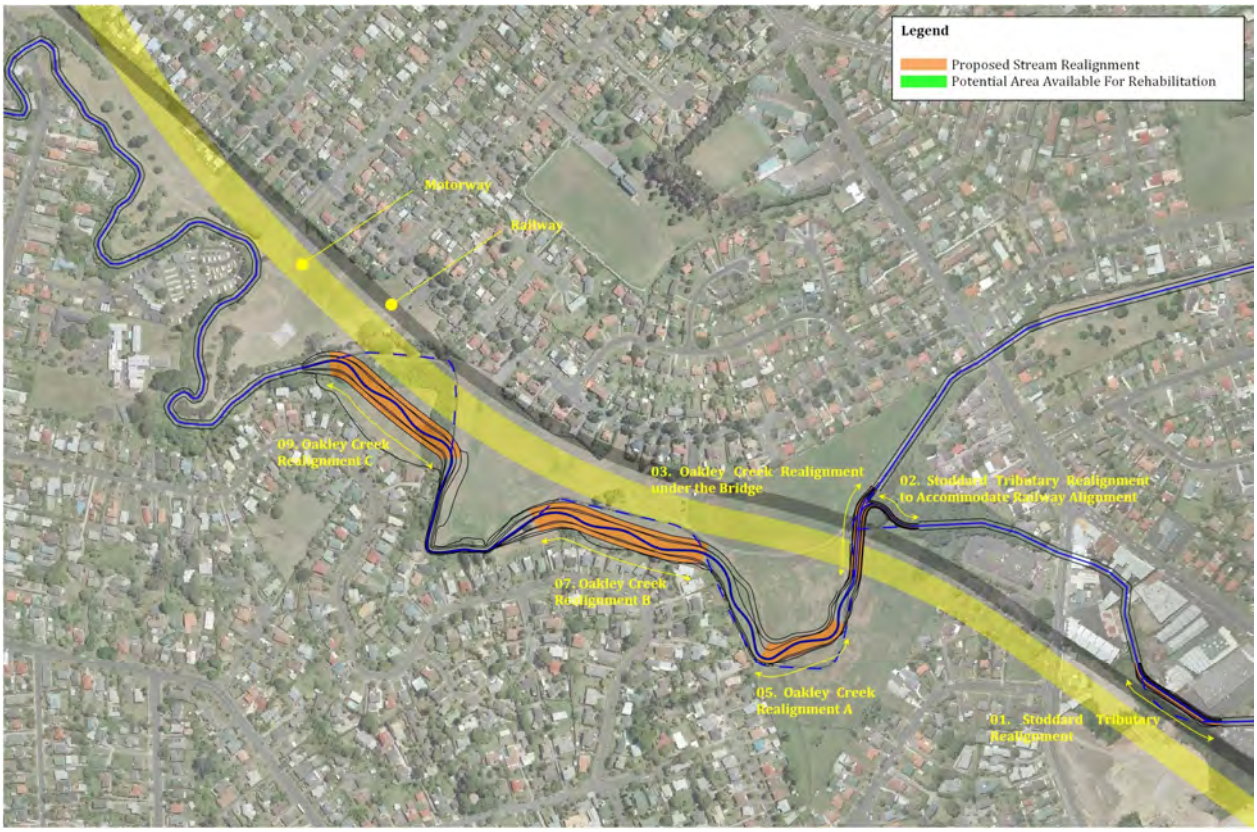


Table 19. Length of Oakley Creek Realignments and Calculated Loss of Streambed Habitat Area

Stream Realignment	Existing Creek Length (m)	Proposed Stream Length (m)	Net Stream length loss (m)	Stream width (m)	Streambed area lost (m^2)
Stoddard Tributary Realignment	138	127	11	1.7	19
Stoddard Tributary Realignment to Accommodate Railway Alignment	79	71	8	1.8	14
Oakley Creek Realignment under the Bridge	125	124	1	2.4	2
Oakley Creek Realignment A	148	114	34	2.1	71
Oakley Creek Realignment B	230	214	16	2.1	34
Oakley Creek Realignment C	287	220	67	2.1	141
Total	**1007**	**870**	**137**	**-**	**281**

This will be achieved by restoring more natural channel form and materials, incorporating greater instream habitat diversity, and restoring native riparian vegetation. Hydrological connections with groundwater, ecological connections along the stream (such as downstream drift of invertebrates and upstream movement of fish) and interactions with the riparian zone will be maintained or enhanced.

The realignments have been designed to ensure that the ecological goals of improving the stream and other goals relating to amenity values and flood management can be achieved. These are all described in the *WRR – Maioro Street Interchange and Waterview Connection : Oakley Creek Realignment and Rehabilitation Guidelines* (BML, 2010b) (see Appendix C). While these realignments will be an improvement on the present situation, it is recognised that the rehabilitation of their physical habitat will not address other factors that presently limit aquatic ecological values of the creek, specifically low water quality and poor fish access. However, the poor fish access is a natural phenomenon resulting from the presence of the waterfall in the lower Creek, while improvement of urban water quality is a long-term goal for the catchment, and cannot be addressed within this Project.

It is considered that the ecological attributes added into the design of these realignments represent good environmental practice and will off-set any temporary adverse effects likely to occur during construction and establishment. They will also deliver a net ecological benefit by improving upon the existing degraded freshwater habitat in this part of Oakley Creek, and this in itself is sufficient mitigation for the disturbance of the stream during their construction. Notwithstanding this however, as a result of the realignments there will be a net reduction in the length of stream in this locality (from 1,007m to 870m) and corresponding reductions in the area of streambed (in the order of 281m^2). Ecological compensation is required for this permanent loss of stream habitat, as discussed below.

6.7.1.2 Environmental Compensation for Stream Habitat Loss

The net loss of stream habitat needs to be compensated by way of stream rehabilitation at another appropriate location. The amount of Environmental Compensation required was calculated in accordance with ARC TP302 (2008), "*Stream Ecological Valuation (SEV): A Method for Scoring the Ecological Performance of Auckland Streams and for Quantifying Environmental Compensation*" (Rowe et al. 2008). This method aims to achieve "*no net loss*" of ecological values as quantified using the SEV methodology. An explanation of the SEV and ECR are given in Appendix 1. For these calculations it was assumed that the compensatory rehabilitation would consist of riparian revegetation along Oakley Creek within the Alan Wood Reserve/Hendon Park area (see Figure 8).

Calculation of the Environmental Compensation involved the following steps:

1. Quantification of the existing values of the stream at impact and mitigation sites using the SEV;
2. Estimation of potential loss of SEV values at the impact site and gain at the mitigation site;
3. Calculation of the Environmental Compensation Ratio (ECR);
4. Calculation of the streambed area affected, being stream length x stream width;
5. Multiplying the streambed area affected by the ECR to determine the streambed area requiring improvement by rehabilitation works;
6. Dividing this area by stream width to determine the length of stream rehabilitation required.

For this analysis the hypothetical mitigation site was in Alan Wood Reserve.

The current SEV values at the realignment sites were between 0.31 and 0.40, with potential values between 0.49 and 0.58 (Table 20). As stream habitat would be lost entirely, the post-impact SEV score of the affected reaches would be zero. The ratio of the loss at the impact site divided by the gain at the mitigation site, multiplied by a standard factor of 1.5 (to allow for time delays before ecological benefits are realised) produced ECR values of between 3.87 and 4.58.

Table 20. ECR Calculation, Oakley Creek and Stoddard Tributary Stream Loss

	Values at Realignment Site			Values at Mitigation Site		ECR Calculation		
	SEV current	SEV impact	SEV potential	Mitigation current	Mitigation potential	Loss at impact site	Gain at mitigation site	ECR
Stream Realignment	SEVi-C	SEVi-I	SEVi-P	SEVm-C	SEVm-P			
Stoddard Tributary Realignment	0.40	0	0.49	0.39	0.58	0.49	0.19	3.87
Stoddard Tributary Realignment to Accommodate Railway Alignment	0.40	0	0.49	0.39	0.58	0.49	0.19	3.87
Oakley Creek Realignment under the Bridge	0.34	0	0.58	0.39	0.58	0.58	0.19	4.58
Stream Realignment A	0.31	0	0.49	0.39	0.58	0.49	0.19	3.87
Stream Realignment B	0.31	0	0.49	0.39	0.58	0.49	0.19	3.87
Stream Realignment C	0.31	0	0.49	0.39	0.58	0.49	0.19	3.87

The streambed area lost was calculated and multiplied by the ECR to give an Environmental Compensation (EC) area of 1,098m^2 (Table 21). The stream width at the hypothetical mitigation area, being the northern end of Alan Wood Reserve, was 3.2m. The stream length to be rehabilitated to improve 1,098m^2 of streambed was therefore 343m.

Table 21. Environmental Compensation (EC) Calculation.

Stream Realignment	Streambed area lost (m^2)	ECR	EC area (m^2)
Stoddard Tributary Realignment	19	3.9	73
Stoddard Tributary Realignment to Accommodate Railway Alignment	14	3.9	56
Oakley Creek Realignment under the Bridge	2	4.6	11
Oakley Creek Realignment A	71	3.9	278
Oakley Creek Realignment B	34	3.9	131
Oakley Creek Realignment C	141	3.9	549
Total	**281**	-	**1,098**

6.7.2 Pixie Stream

Pixie Stream is a small stream that flows through Jack Colvin Park. Its headwaters (on the southern side of SH16) are entirely piped, and its present extent is limited to approximately 320m of open channel. The culvert under SH16 here will be extended, resulting in the loss of 23m of modified stream channel below the existing culvert outlet. The stream here is degraded and in poor health (although its SEV suggests it still retains moderate ecological values), and the effects of this relatively modest culvert extension would not be ecologically significant. Nevertheless, the stream will be shortened by 7% as a result of the Project, and the loss of this freshwater habitat will need to be mitigated.

An SEV assessment was undertaken here to determine the rehabilitation length required to compensate for the ecological functions lost as a result of this culvert extension. The SEV assessment and ECR calculations are shown in Table 22. For this assessment the hypothetical mitigation site was in Jack Colvin Park. The total length of Pixie Stream proposed to be piped is 23m, with the average width being 0.96m. The corresponding permanent loss of stream-bed will therefore be 22m^2. If riparian planting alone is to be undertaken as the mitigation, the ECR required is 9. This derives a required linear length of 207m of riparian stream-side revegetation (i.e. 23m x 0.96m =22.08m^2 x 9 / 0.96 = 207m).

Table 22. ECR Calculation, Oakley Creek and Stoddard Tributary Stream Loss

Stream Culverting	Values at Culvert Extension Site			Values at Mitigation Site		ECR Calculation		
	SEV current SEVi-C	SEV impact SEVi-I	SEV potential SEVi-P	Mitigation current SEVm-C	Mitigation potential SEVm-P	Loss at impact site	Gain at mitigation site	ECR
Pixie Stream	0.53	0.28	0.64[11]	0.58	0.64	0.36	0.06	9

Notwithstanding the above, it is noted that Pixie Stream has been the recipient of recent rehabilitation under the Twin Streams project, and there is unlikely to be any scope for additional riparian revegetation at this location. This is discussed in more detail in Section 7.2.

6.7.3 Meola Creek

Shoulder widening along the SH16 would not require extensions to the Meola Creek culverts, and there would therefore be no loss of stream habitat as a result. Given this, there is no need for any mitigation in relation to stream shortening in this sector.

[11] Upstream potential score with fish barrier removed.

7. Mitigation Options Analysis

7.1 Oakley Creek Mitigation Options

As described in Section 6.7.1.1 above, the stream realignments necessary within Oakley Creek and its Stoddard Road tributary will result in the net loss of 281m^2 of stream bed habitat (equivalent to 137m of linear stream length). Application of the ECR yields a compensatory requirement for this loss that is equivalent to the enhancement of 343m of stream length.

While the SEV assessment for Oakley Creek indicated that stream rehabilitation can produce ecological benefits within this waterway, this rehabilitation may nevertheless be constrained by low urban water quality and the presence of the waterfall in the lower stream (which impairs fish migration). Neither of these two issues can be addressed within the scope of Project. In recognition of these limitations, an assessment of the potential benefits of rehabilitation at various locations within and outside of the Oakley Creek catchment was undertaken. The results are presented below.

7.1.1 Within-Catchment Options Analysis

Oakley Creek is a large urban stream resource, and is important to local communities. Undertaking the required quantum of stream rehabilitation within this waterway would have the significant advantage of being in the same stream catchment as the affected stream reaches (i.e. the proposed realignments), thereby retaining ecological functions within the same stream system. These functions would be lost to Oakley Creek if the mitigation to be undertaken outside of the catchment.

Table 23 summarises the results of the rehabilitation options analysis in relation to locations within the wider Oakley Creek catchment. It shows that while the area below Alan Wood Reserve, Hendon Park and the Goldstar Block would not substantially benefit as a result of rehabilitation works, the area above it probably would.

Notwithstanding this however, the benefits associated with undertaking the rehabilitation works within Alan Wood Reserve, Hendon Park and the Goldstar Block were considered to represent the optimum. Within this large area of public open space there is high potential to realise multiple benefits through recreational, amenity and visual improvements to the creek, as well as realising habitat improvements that would be of benefit to aquatic invertebrate communities. While fish communities will always be limited by the downstream waterfall here, this is an issue that is common to all sites along Oakley Creek.

As a result of this analysis, it was concluded that were the required stream rehabilitation to be focused within the Oakley Creek catchment, then the optimum site for such would be the in the Alan Wood Reserve, Hendon Park and the Goldstar Block area.

Table 23. Evaluation of Mitigation Locations Within Oakley Creek.

Location	Negative factors	Positive factors
Lower Oakley below waterfall	Extensive existing riparian vegetation, therefore limited potential for further beneficial riparian restoration	Possible benefits to fish, but already good fish habitat present.
Lower Oakley above waterfall	Extensive existing riparian vegetation, therefore limited potential for further beneficial riparian restoration	Unlikely to benefit.
Alan Wood Reserve, Hendon Park & Goldstar Block	Security and maintenance issues with planting.	Minimal existing riparian vegetation, therefore high potential for beneficial riparian restoration. Security of delivery (i.e. within the Project area, therefore part of the Project works covered by Project consents). Rehabilitation proposals already well developed. Naturalising the stream would be of ecological benefit.
Underwood Park/War Memorial Park	Concrete removal may result in erosion. Security and maintenance issues with planting. Width may be constrained by sports fields.	Plenty of length available. Minimal existing riparian vegetation, therefore high potential for beneficial riparian restoration. Naturalising the stream would be of ecological benefit.
Keith Hay Park	Concrete removal may result in erosion. Security and maintenance issues with planting. Width may be constrained by sports fields.	Plenty of length available. Minimal existing riparian vegetation, therefore high potential for beneficial riparian restoration. Naturalising the stream would be of ecological benefit.

Hence, in summary the Project requires 343m of riparian rehabilitation, which will be undertaken within Alan Wood Reserve, Hendon Park and the Goldstar Block. In this context it is noteworthy that a quantum of additional rehabilitation works within Oakley Creek are already required of NZTA, by virtue of resource consent conditions associated with a related (but separate and already consented) project, being the SH20 Maioro Street Interchange Project. These rehabilitation works are also intended to be undertaken within Alan Wood Reserve, Hendon Park and the Goldstar Block. They will also be undertaken in accordance with the WRR – Maioro Street Interchange and Waterview Connection – Oakley Creek Realignment and Rehabilitation Guidelines (BML, 2010b). This allows the opportunity for the separate mitigation works packages associated with these two different Projects to be co-ordinated, in order to maximise the potential extent and range of benefits that might accrue to the local environment and community. This is discussed in more detail in Section 8.1.

7.1.2 Outside catchment Options Analysis

7.1.2.1 Meola Creek

Meola Creek is a large urban stream about 2km east of Oakley Creek. It is also affected by the Project (i.e. the SH16 widening). There is community support for improving the stream. The lower (estuarine) reaches include the Meola Reserve and MOTAT, the middle reaches includes Chamberlain Park Golf Course, and the upper reaches include Mt Albert Grammar School and Mt Albert Research Centre. The stream reaches within these private areas are generally highly modified. Notwithstanding this, there are potential opportunities to negotiate stream rehabilitation with these stakeholders. However, as with Oakley Creek, urban stormwater will be a factor that will continue to limit ecological values.

To further evaluate this option an SEV assessment was undertaken in this creek to produce an ECR and determine the length of stream that would have to be rehabilitated here to compensate for the loss of stream habitat within Oakley Creek. A site immediately upstream of Great North Road was surveyed. A comparison of the EC lengths calculated for Meola Creek compared to those associated with Avondale Creek (see Section 7.1.2.2 below) and Hendon Park is given in Table 24.

The SEV score here was 0.54 (compared to that of 0.34 for Oakley Creek). Some existing riparian vegetation was present (mainly willows, with little understorey), and as a result the benefits to the stream of additional planting would be relatively low, resulting in a higher ECR of 5.65 (the ECR for rehabilitation in Oakley Creek was 3.9). The site at Meola Creek was wider (4m, compared to 3.2m for Oakley Creek).

The length of stream rehabilitation required here to compensate for the loss of 281m^2 of stream bed (equivalent to 137m of stream length) in Oakley Creek would be 442m. This is approximately 30% more stream rehabilitation than the preferred option of rehabilitation within Alan Wood Reserve, Hendon Park and the Goldstar Block (involving 343m), and consequently rehabilitation within Meola Creek would be a more expensive and less efficient option.

7.1.2.2 Avondale Stream

The Avondale Stream is a large stream that passes through New Lynn and then branches towards Titirangi and Mt Roskill, respectively. Both branches have sections within golf courses. The estuarine section is located in Olympic Park, a reserve that has recently undergone considerable redevelopment. A wide range of fish species have been recorded in the stream, mainly in the lower reaches. There is strong community and council support for stream improvement. Water quality is probably less of a limiting factor than in Meola Creek and Oakley Creek. Much of the stream has some riparian vegetation, so planting here would provide less benefit to SEV functions per unit of stream length.

To further evaluate this option an SEV assessment was undertaken to produce an ECR and determine the length of stream that would have to be rehabilitated here to compensate for the loss of stream habitat within Oakley Creek. A site at Shadbolt Park was surveyed. A comparison of the EC lengths calculated for Avondale Stream compared to those associated with Meola Creek (see Section 7.1.2.1 above) and Hendon Park is given in Table 24.

The SEV score here was 0.63 (compared to that of 0.34 for Oakley Creek). As for Meola Creek, existing riparian vegetation was present here (mainly willows and pines, with some native understorey revegetation), and the benefits to the stream of additional planting would be relatively low, resulting in an ECR of 8.17. The Avondale Stream here was narrower (2m, compared to 3.2m for Oakley Creek), and so more planting would be required to compensate for the loss of stream habitat.

The length of stream rehabilitation required here to compensate for the loss of 281m^2 of stream bed (equivalent to 137m of stream length) in Oakley Creek would be 1,161m. This is over three times more stream rehabilitation than the preferred option of rehabilitation within Alan Wood Reserve, Hendon Park and the Goldstar Block (involving 343m), and consequently rehabilitation within Avondale Stream would be a more expensive and less efficient option.

Table 24 : EC for Stream area ('EC area') and Stream Length ('EC length') for Alternative Mitigation Sites

		Avondale Stream			Meola Creek			Hendon Park		
Stream Realignment	**Streambed area lost (m^2)**	**ECR**	**EC area (m^2)[1]**	**EC length (m)[2]**	**ECR**	**EC area (m^2)[1]**	**EC length (m)[2]**	**ECR**	**EC area (m^2)[1]**	**EC length (m)[2]**
Stoddard Tributary Realignment	19	8.2	155	78	5.7	107	30	3.9	73	22.8
Stoddard Tributary Realignment to Accommodate Railway Alignment	14	8.2	114	58	5.7	79	22	3.9	56	17.5
Oakley Creek Realignment under the Bridge	2	9.7	19	10	6.7	13	4	4.6	11	3.4
Oakley Creek Realignment A	71	8.2	580	293	5.7	401	112	3.9	278	86.9
Oakley Creek Realignment B	34	8.2	278	140	5.7	192	53	3.9	131	40.9
Oakley Creek Realignment C	141	8.2	1152	582	5.7	797	221	3.9	549	171.6
Total	**281**	**-**	**2298**	**1161**	**-**	**1591**	**442**	**-**	**1098**	**343**

[1]ECR area = area of streambed lost multiplied by ECR.
[2]ECR length = ECR area divided by mean stream width.

7.1.2.3 Streams Outside the Metropolitan Urban Limit (MUL)

As an alternative to the urban streams discussed above, a bush stream could be protected or a rural stream replanted somewhere else in the Auckland Region to compensate for the loss of stream habitat within Oakley Creek.

Streams without urban stormwater issues would have better potential for improvement of ecological values. This is recognised in the Urban Stream Management Framework (ARC, 2004). However, a result of pursuing this option is that functions would be permanently lost from Oakley Creek.

It is noted in the SEV manual that rehabilitation sites in proximity to the impacted sites are preferable, but "*the Regional Council may decide that environmental compensation may be performed off-site if there is greater environmental benefit for the region to be gained by doing so*". The low SEV values of around 0.4 or lower in Alan Wood Reserve, Hendon Park and the Goldstar Block do suggest that off-site mitigation could be appropriate.

However, while an off-site option might deliver greater ecological benefits to the region, it would fail to address the adverse effects of the Project on Oakley Creek, and is therefore not preferred.

7.1.3 Oakley Creek Mitigation Options Conclusions

The mitigation requirements associated with the loss of stream habitat within Oakley Creek could potentially achieve ecological benefits at virtually any stream location within the Auckland Region. However, the greatest benefit for physical habitat rehabilitation would be realised where water quality and fish passage are not factors limiting ecological potential – this is presently not the case in relation to Oakley Creek. However, most urban streams will have the same water quality issues as does Oakley Creek. It is also clear that any rehabilitation outside of the Oakley Creek (particularly at sites far removed) will fail to address the effects of the Project on the creek itself.

The analysis undertaken above indicates that rehabilitation within Alan Wood Reserve, Hendon Park and the Goldstar Block would achieve greater benefit per unit of stream length than mitigation works in either Avondale Stream or Meola Creek. In addition, the preferred option of rehabilitation within Alan Wood Reserve, Hendon Park and the Goldstar Block provides opportunities for multiple benefits by also improving amenity, recreational and landscape values, within a large area of public open space. These would be further enhanced (as would flood management capability) as a result of coordinating the rehabilitation works here with the channel reshaping works proposed for this same area under the rehabilitation requirements of the Maioro Street Interchange Project.

It is therefore concluded that, in relation to the Project, the preferred option is to undertake the required 343m of stream rehabilitation (comprised of riparian revegetation) within Alan Wood Reserve, Hendon Park and the Goldstar Block.

7.2 Pixie Stream Mitigation Options

7.2.1 Within Catchment Options Analysis

7.2.1.1 Riparian Planting

As described in Section 6.7.2 above, the Project will result in the loss of 23m of Pixie Stream. Application of the ECR yields a compensatory requirement for this loss that is equivalent to the enhancement of 199m^2 of stream bed, which in the case of Pixie Stream (being 0.96m wide) equates to 207m of stream length.

While there is sufficient length of Pixie Stream to accommodate the required 207m of riparian planting (with this stream being in the order of 320m long), there is little (if any) scope for restoration here given that the entire stream has already been planted under the Twin Streams project (a joint initiative between community groups and the Waitakere City Council). The present vegetation here is a mix of regenerating native plants with mature exotic trees (Figure 8) and presently provides all of the riparian benefits that the EC is designed to make available. There is also no scope for increasing the lateral extent of the existing plantings, since they are already at their maximum in relation to the spatial constraints associated with the adjacent sports fields and residential houses.

Figure 8. Pixie Stream Existing Vegetation

7.2.1.2 Alternative On-Site Works

A potential alternative to the riparian planting would the removal of an existing perched culvert associated with the entry bridge into Jack Colvin Park (Figure 9). This culvert is a barrier to fish passage. This is evident in the results of fish surveys here, with inanga, common bully and eels being present downstream, but with only eels being present upstream of this structure. Hence, it is apparent that only eels are able to access the section of stream above this culvert, restricting the value of this upper-most section of Pixie Stream as a freshwater habitat for native fish.

However, given that only an additional 40m (or so) of upstream habitat will become newly available to the fish community of the stream were this culvert to be removed (i.e. a 12.5% increase), the ecological benefits of culvert replacement with a fish-passage friendly structure here would be limited. Furthermore, removing the culvert would only reduce the ECR to 4.5, which would still require a length of 104m of stream to be rehabilitated. As described in Section 7.2.1.1 above, there is no scope for undertaking such rehabilitation on-site at Jack Colvin Park. Hence, an alternative site for the rehabilitation is required in this instance.

Figure 9. Pixie Stream Perched Culvert

7.2.2 Outside Catchment Options Analysis

The outside catchment option would involve an alternative location for the required 207m of stream side planting. While this option will fail to address the effects of the Project on Pixie Stream itself, and would not compensate the local community. However, there is no alternative. To this end NZTA will consult with the Council to identify an appropriate recipient site, and undertake a quantum of riparian planting that will rehabilitate 199m^2 of stream bed. It is assumed that Council will be keen on having this work implemented in reasonably close proximity to Pixie Stream, so that the wider local community enjoys the benefits.

7.2.3 Pixie Stream Mitigation Options Conclusions

The option involving the removal of the perched culvert in Jack Colvin Park is not supported. The option of rehabilitating Pixie Stream is not possible (due to its existing rehabilitated nature). Therefore, the only option available is to undertake the rehabilitation outside of the Pixie Stream catchment. The exact location of this rehabilitation will need to be worked through with Council.

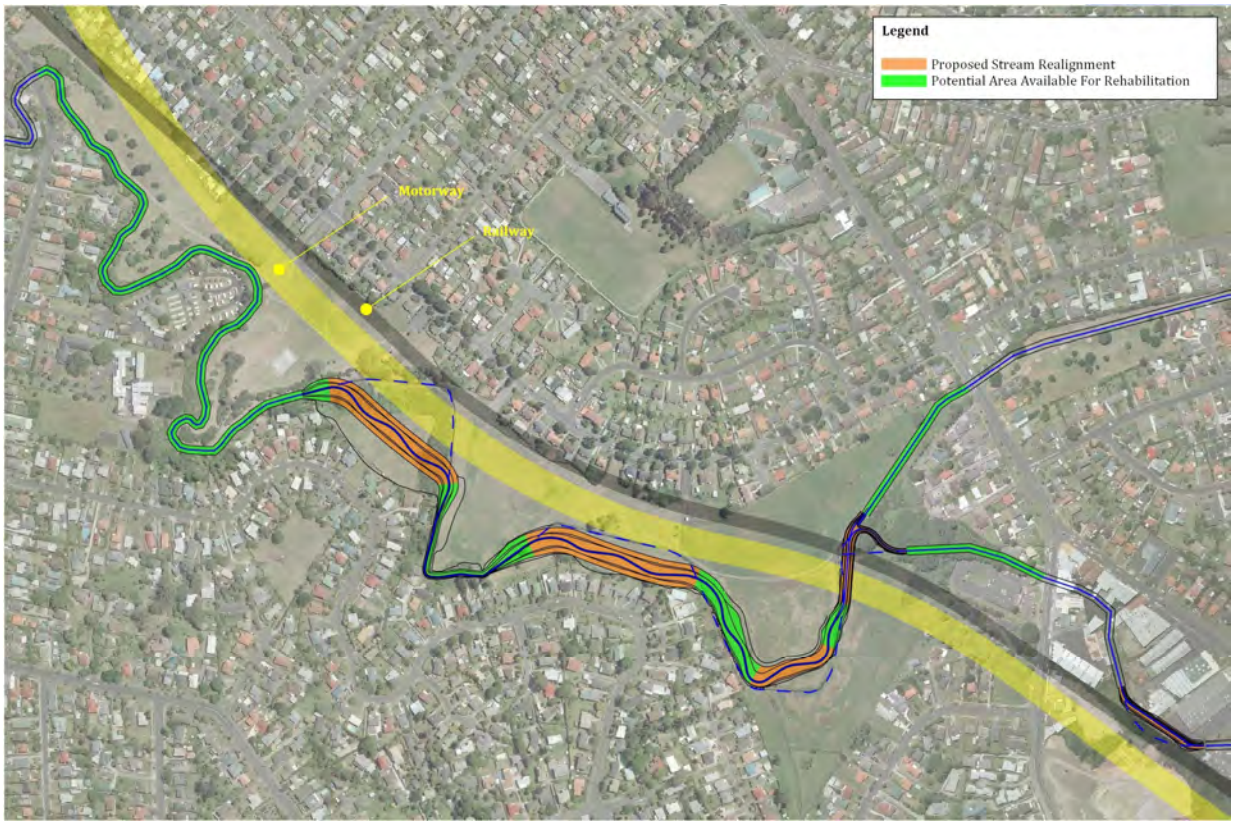
8. Recommended Mitigation

8.1 Oakley Creek

As identified in Section 7.1.3, the preferred option in relation to the required mitigation to compensate for the loss of stream habitat within Oakley Creek is the "within catchment" option, with this mitigation to be implemented within the Alan Wood Reserve, Hendon Park and the Goldstar Block area.

Figure 10 identifies the available potential rehabilitation area (shaded in green) within this area. In total the length of stream available for rehabilitation here (excluding the proposed realignments – shaded in orange) is 1,795m.

Figure 10 : Location of Potential Stream Rehabilitation Sites



The rehabilitation works associated with the Project will be restricted to the riparian planting of 343m of the Oakley Creek main stem within Alan Wood Reserve, Hendon Park and the Goldstar Block. These works will be undertaken in accordance with the *WRR – Maioro Street Interchange and Waterview Connection – Oakley Creek Realignment and Rehabilitation Guidelines* (BML, 2010b).

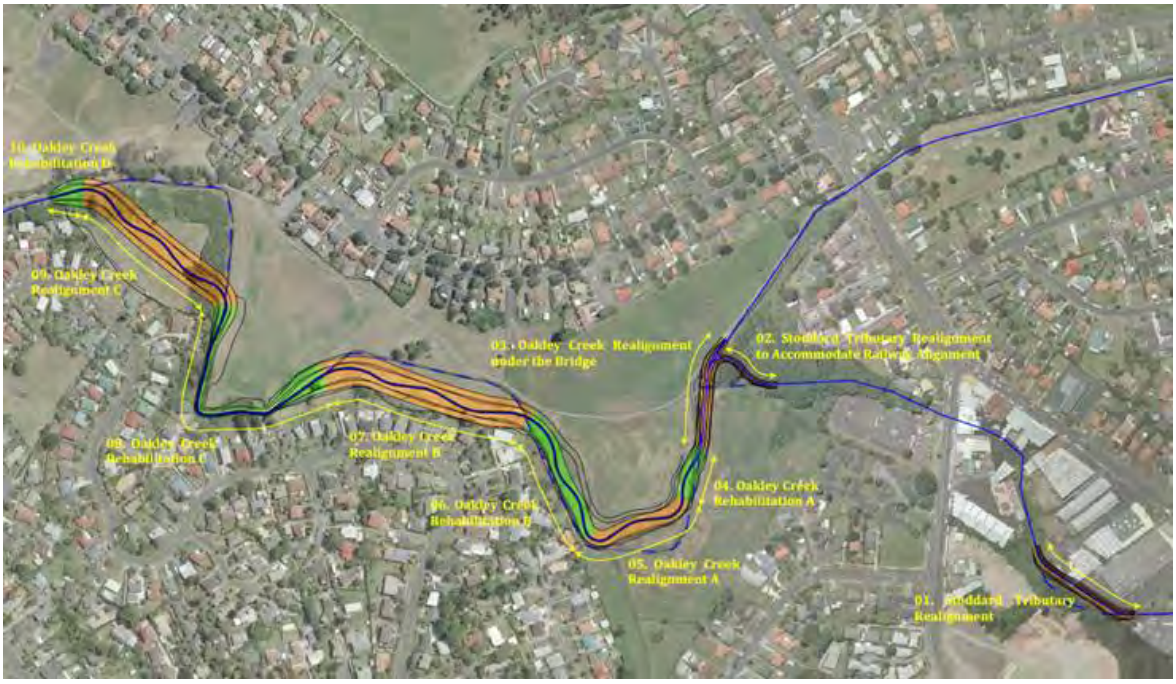
Further to the above, as noted in Section 7.1.1, in addition to the rehabilitation requirements of the Waterview Connection Project, a quantum of other (supplementary) rehabilitation works within Oakley Creek is already required of NZTA, by virtue of resource consent conditions associated with a related (but separate and already consented) project, being the SH20 Maioro Street Interchange Project. These supplementary rehabilitation works will also be undertaken within Alan Wood Reserve, Hendon Park and the Goldstar Block, and will also be in accordance with the *WRR – Maioro Street Interchange and Waterview Connection – Oakley Creek Realignment and Rehabilitation Guidelines* (BML, 2010b). However, unlike the Waterview Connection Project, the rehabilitation works associated with the Maioro Street Interchange Project will be a mix of riparian revegetation together with channel reshaping. The latter activity involves the replacement of the vertical blockwork channel walls that presently line much of Oakley Creek within this area with a more naturally contoured stream bank.

NZTA proposes to coordinate the required stream rehabilitation works associated with these two Projects (i.e. the Waterview Connection Project and the Maioro Street Interchange Project), in order to derive maximum environmental and community benefits. To this end, the 343m of riparian revegetation associated with the Waterview Connection Project will be undertaken in conjunction with the channel reshaping rehabilitation works associated with the Maioro Street Interchange Project, to produce 343m of reshaped stream channel with revegetated stream banks. This combined rehabilitation approach is shown in Figure 11.

Figure 11 goes further to illustrate the opportunity for integrating the proposed <u>realignments</u> in Alan Wood Reserve, Hendon Park and the Goldstar Block with the proposed <u>rehabilitation</u> in this same area, using the combined two projects (i.e. the Waterview Connection Project and the Maioro Street Interchange Project).

Figure 11. Proposed Oakley Creek Rehabilitation Concept

Rehabilitation reaches are shown in green - Stream realignments are shown in orange



This opportunity involves extending the reshaped (and revegetated) channels of the realignments to include the stream reaches that lie in between them, reshaping these channels and planting their riparian margins as well (all in accordance with the *WRR – Maioro Street Interchange and Waterview Connection – Oakley Creek Realignment and Rehabilitation Guidelines* (BML, 2010b). In this way a consistent, integrated and natural-looking stream system is created in this area, tying in with the more natural (non-channelised) section of Oakley Creek in the lower part of Alan Wood Reserve, and the majority of Oakley Creek in the Alan Wood Reserve, Hendon Park and the Goldstar Block area is rehabilitated.

The concept illustrated in Figure 11 covers an area of 448m of stream bank to be reshaped and planted (Table 25). Of this the Waterview Connection Project will contribute 343m of riparian planting. The Maioro Street Interchange Project will contribute all of the channel reshaping and the remaining 105m of planting. It is noted that the Maioro Street Interchange Project will also include additional rehabilitation works in other parts of Oakley Creek, but aside from the reshaping of the rehabilitated reaches as shown in Figure 11 these are not germane to the Waterview Connection Project, and are not discussed further in this report.

Table 25. Stream Rehabilitation Lengths

Stream Rehabilitation	Existing Stream Length (m)	Proposed Stream Length (m)
Oakley Creek Rehabilitation A	49	48
Oakley Creek Rehabilitation B	135	141
Oakley Creek Rehabilitation C	228	228
Oakley Creek Rehabilitation D	31	31
Total	**443**	**448**

It is noted that all of the land associated with the rehabilitation concept as shown in Figure 11 lies within the Project designation. As such it is within the control of NZTA, as opposed to being in other land ownership. Given this, there is a high degree of certainty associated with the concept as shown in this Figure. Notwithstanding this however, it is emphasised that if (for whatever reason) the proposed channel reshaping fails to materialise, the Project will still deliver 343m of riparian revegetation along the margins of Oakley Creek inside the designation within the Alan Wood Reserve, Hendon Park and Goldstar Block area.

The restoration of Oakley Creek through Alan Wood Reserve, Hendon Park and the Goldstar Block will improve riparian and in-stream habitat, providing benefits to the fish and macroinvertebrate communities present in these creek reaches. Although these improvements are difficult to quantify (Rowe et al., 2006), the benefits of riparian vegetation on aquatic ecology are widely published (e.g. ARC, 2001).

Riparian vegetation is beneficial for aquatic macroinvertebrates. Overhanging vegetation, leaves and fallen wood provide substrate on which macroinvertebrates feed, live and lay their eggs. It provides shade to the stream, reducing summer water temperatures and improving dissolved oxygen levels. Sensitive EPT taxa are more common in bush lined streams for these reasons. Riparian vegetation also provides suitable habitat for the adult stages of aquatic insects, which often require damp, humid conditions to survive and reproduce. Increased macroinvertebrate density and diversity also has flow-on benefits for fish fauna which prey on these species as food.

Oakley Creek has a depauperate fish fauna as a result of the presence of the waterfall in the lower reaches of the creek. This natural feature poses an impassable barrier to non-climbing fish species, with only longfin and shortfin eels forming resident populations upstream (gambusia and goldfish are non-migratory species which have been introduced by people). Shortfin eels are a common species tolerant of poor water and habitat quality, including slow flows and fine sediments, but longfin eel are a threatened species, more prevalent further inland and in higher elevation streams. Eel densities are positively correlated to the amount of in-stream and bank cover available, as both species use these areas as resting habitat during the day. Improving riparian vegetation will therefore improve habitat quality for both eel species within Alan Wood Reserve, Hendon Park and the Goldstar Block.

It is acknowledged that improvements to fish and macroinvertebrates in the creek will take several years or even decades to be realised as the vegetation matures. Further improvements to aquatic ecology in the stream will be achieved by improving stormwater quality before it enters Oakley Creek, but this is outside the scope of this project.

8.2 Pixie Stream

As identified in Section 7.2.3, *t*he only option available is to undertake the required rehabilitation outside of the Pixie Stream catchment. The exact location of this rehabilitation will need to be worked through with Council.

9. Freshwater Management and Monitoring

The means by which the ecological values of the Project Area will be managed and monitored over the course of the construction of the Project is specified in the Ecological Management Plan (ECOMP). The sections of the ECOMP relevant to freshwater are attached to this report as Appendix D.

10. Conclusions

10.1 Construction Effects

In relation to Oakley Creek, potential effects on freshwater environments from the construction phase of the Project include sediment discharge from SRP's and instream works; discharges of contaminants from contaminated soils or groundwater; effects of the Avondale Heights tunnel on stream base flows (as a result of groundwater drawdown); and ground settlement effects on the bed of Oakley Creek (again as a result of groundwater drawdown).

The large scale of the Project means there is significant potential for sediment generation. However, land-disturbing activities will be largely avoided in the tunnel sectors. A detailed Erosion and Sediment Control Plan (ESCP) has been prepared, describing how erosion will be minimised and sediment volumes reduced prior to discharge of stormwater to the receiving environments. These measures will meet or exceed ARC TP90 standards. The ESCP also describes how controls will be monitored to ensure they function effectively.

Sediment generated in Sector 1 and Sector 6 will be discharged (after treatment) to Pixie Stream and Meola Creek respectively. Stormwater from the Waterview Interchange area (Sector 5) and the driven tunnel section (Sector 8) will not discharge to the freshwater environment. Discharges from Sectors 7 and 9 could potentially increase loads in Oakley Creek by up to 6%. However, this amount will be significantly reduced by way of progressive stabilisation. It is also notable that a substantial portion of the earthworks are related to the two tunnel portals, in Sectors 5 and 9 respectively. These are effectively holes in the ground from which discharge is fully controlled by pumping, with high levels of control including chemical treatment which will further reduce actual sediment discharge from the potential levels that have been calculated (G.Ridley, *pers comm*.).

The stream realignments in Alan Wood Reserve are considered to be high risk areas in terms of sediment generating potential. However, a methodology for construction outside of the creek channel will minimise sediment mobilisation here.

Investigations of contaminated land suggest that such areas are limited in extent and can be avoided or managed to ensure no significant contamination of stream water occurs. Effects on stream flow and channel settlement will be negligible.

While temporary and localised adverse ecological effects are expected in the receiving environments, overall it is concluded that the measures described above should ensure that these are not significant (i.e. they will be less than minor).

10.2 Operational Effects

Permanent environmental effects of this Project will include discharge of additional stormwater to Oakley Creek, Meola Creek and Pixie Stream, and loss of stream length in Oakley Creek and Pixie Stream. However, the tunnel sectors will significantly reduce potential stormwater generation as these sectors will not increase impermeable surface area in the catchment.

Away from the tunnel sectors the increase in percentage of impermeable surface areas in each stream catchment will be small. Furthermore, all stormwater from new motorway surfaces will be treated, and some currently untreated areas will also be treated.

The biological communities resident in the receiving environments have relatively low ecological values and are characterised by species able to tolerate poor water quality conditions. The additional stormwater is unlikely to have significant adverse ecological effects.

Stream realignments will be undertaken in accordance with appropriate guidelines (BML, 2010b) and will result in an improvement over the existing situation, by replacing the present blockwork channel walls with more natural contours and planting the resultant riparian margins. These works will result in benefits to aquatic invertebrate communities, as well as benefits in relation to flood management, and will achieve significant enhancements in relation to amenity, landscape and recreational values within the realigned sections.

Loss of stream length within Alan Wood Reserve, Hendon Park, the Goldstar Block and Pixie Stream will be compensated for by stream rehabilitation to ensure no net loss of ecological values. The amount of rehabilitation required has been assessed using the ARC TP302 methodology, and rehabilitation guidelines prepared describing how such rehabilitation should be undertaken within Alan Wood Reserve, Hendon Park and the Goldstar Block. This will ensure that the Project is sustainable in terms of maintaining stream functional values.

10.3 Summary

It is considered that the above measures are comprehensive and represent current best practice environmental management for a highway infrastructure project. While the Project will generate some level of disturbance to freshwater habitats, the urban streams affected do not contain ecologically sensitive communities, and it is expected that, in the long term, there will be no significant loss of ecological values (such as significant decreases in the abundance or diversity of fish or aquatic invertebrates).

It is further considered that all reasonable measures to avoid, mitigate or remedy adverse effects on freshwater ecosystems have been adopted in the Project proposal. All in all it is concluded that provided these measures are conscientiously implemented, the net adverse freshwater ecological effects associated with the Project will be less than minor.

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