6.2.2 Wastewater

In the past Lake Okareka sewage has been managed using individual septic tanks and disposal fields. However, in October 2010 a reticulated wastewater system for the settlement area was commissioned. Each house has a small wet sump and a low pressure pump connecting it to the wastewater pump station. The Okareka wastewater network discharges to one main collection well and transfer pump station. From the transfer pump station wastewater is pumped to the Rotorua wastewater treatment plant. Hence the potential for stormwater or lake water microbial contamination due to human wastewater has been significantly reduced with the introduction of reticulated wastewater.

A telemetry system operates, warning RDC of any potential overflow from the main wastewater wet well and ensuring the potential for overflow from the wastewater network to the stormwater network is minimised.

6.3 Regionally Significant Infrastructure

The presence of regionally significant infrastructure in the Lake Okareka Settlement area has been investigated from records held by utility providers and within RDC District Plan. A fire station is designated within the Lake Okareka Settlement area as well as three water reservoirs. There is no other regionally significant infrastructure within the subject catchment.

6.4 Topography

6.4.1 Lake Okareka Catchment

The larger Lake Okareka Catchment topography is characterised by volcanic landforms and depositional features typical of the region. The northern and eastern extents of this catchment are delineated by steeply sloping ridge lines while the areas to the south and southwest are characterised by broad rhyolitic dome features. This elevated terrain gives way to low-lying ground of gently sloping to even grade along the lake fringes.

The low-lying areas are more extensive along the west-southwest shores of the lake which include the main settlement, but their presence extends from the northern to the southern lake tip along the western shores. They are likely to be the result of a historical low energy depositional environment channeled along the existing valleys linking Lakes Tikitapu and Rotokakahi to the southwest, Lake Rotorua to the northwest and Lake Okataina to the northeast, and to the east of the main settlement area which juts out to Taumaihi Point.

Elevation between the surrounding area and the lakeshore generally falls from around RL 500 to 600 m down to around RL 350 m along the lake edge. A steeply sloping ridge line delineates the eastern lake edge as well as the catchment boundary and this ridgeline forms the northern extent of a saddle between Lake Okareka and Lake Tarawera to the east-southeast. The northern extent of the catchment is defined by an amphitheatre-shaped ridgeline surrounding a hill knob.

6.4.2 Lake Okareka Settlement Catchment

The urban settlement area is found on the Western and South Western edge of Lake Okareka. Most of the settlement is found on relatively easy contoured land below the 400 m level. The Wash, an ephemeral stream constructed into a drain of around 400 m is located at the northern end of the settlement. The Wash drains an area of 167 ha up to a maximum elevation of 500 m. In the settlement area The Wash catchment drains relatively flat areas of residential land. There is some steeper contoured land located on the true right of The Wash around Steep Street and Okareka Loop Road. In the headwaters of The Wash, where land use is generally farmland or native, elevations exceed 400 m and the land is steep.

6.5 Geology and Soils

As noted in the LOCMP (Appendix B) Lake Okareka occupies a valley that has eroded into an ignimbrite plateau on the western margin of the Horohoro Caldera that lies within the Okataina Volcanic Centre. The valley originally drained into Lake Tarawera but was truncated by lava associated with the Te Rere eruptive episode.

Geology and soil features of the study catchment are divided into two zones (refer to Figure 4 of the LOCMP within Appendix B).

The high western surfaces are underlain by volcanic ignimbrites and lake sediments of Pleistocene age (from 1.8 M years ago to 11,000 years ago). The soil is described as a shallow sandy loam. Hydraulic conductivity of these layers is high.

The lower lying surface, where the settlement is located, is composed from lacustrine deposits, Waiowhiro Sand, which is strongly gleyed. Therefore the subsurface layer is poorly drained.

6.6 Groundwater

There is little site specific information on groundwater quantity and quality around the Lake Okareka Settlement. The streams draining the Lake Okareka Settlement, including the largest stream (The Wash), are all ephemeral and contain little or no base flow during periods of dry weather. From observations made during fieldwork for this CSCA however, groundwater spring recharge is suspected at the wetland area near the corner of Acacia Bay Road and Okareka Loop Road. This spring is likely to be part of the ephemeral waterway draining farmland above Benn Road in stormwater catchment 08. Otherwise it appears that groundwater and surface water interactions within the settlement area are minimal.

Morgenstern et al. (2004) provide information on the geohydrology of an area of the lake just north of the settlement and also provide background information on the settlement. The authors summarise information on bore logs in the area of the Okareka Settlement. Bore logs in Okareka township suggest that a layer of pumice/sand overlies the unit considered to be Pokopoko Pyroclastics. Interpretation of the bore logs suggests that the Pokopoko Pyroclastics are described as rhyolite/ignimbrite in the driller's logs. The surface pumice/sand layer probably supports localised aquifers, from which groundwater is likely to flow into the deeper fractured aquifer system (the pyroclastics).

The piezometric map of the Lake Okareka township area, which is approximately 1 km south of the Morgenstern et al. (2004) study area, shows that the direction of groundwater flow is towards Lake Okareka. In general, groundwater flow follows local topography, with groundwater levels high on the ridge, and low groundwater levels in the valleys.

6.7 Water Quantity

6.7.1 Stormwater runoff calculations

Stormwater runoff calculations were computed in the LOCMP (RDC 2010). Design storms for 10 year, 50 year and 100 year return period were produced. The pipe network capacity has been assessed using the Rational Method to compute design flows through the pipe network reaching the lake and an Intensity Duration Frequency graph is provided in the LOCMP (RDC 2010).

In accordance with RDC policy, all primary stormwater systems (i.e., all open drains and pipes within the road reserve) are designed to carry surface water resulting from a 1 in 10 year return period storm (10% Annual Exceedance Probability). As noted in the LOCMP (RDC, 2010) discharge flows from the stormwater network have been calculated as between 148 and 2,672 L/s (RDC 2010).

6.7.2 Flooding

The LOCMP notes that historical RDC records as well as anecdotal evidence from local residents suggest that flood issues have occurred at particular properties on Miller Road and the left bank of The Wash between the road bridges. Local flood issues have also arisen on Calder Road, Summit Road and 1 1-3 Lake Okareka Loop Road near the lake edge.

RDC have noted flooding has occurred at the following sites, with the following explanations[3]:

- The Okareka Hall (71 Okareka Loop Road) and at the neighbouring property (69 Okareka Loop Road) in very heavy rainfall events. Both of these properties are very low lying and have steep driveways down from the road.
- Properties on the upper side of Branch Road can on occasions, cause problems to properties on the lower lying side of Branch Road during heavy rainwater events. Stormwater is uncontrolled here, but over time, minor improvements will be made to reticulate flood flows. This will only be done in conjunction with other works (e.g., road improvements).
- The Wash has had flooding issues in the past but these are now under control.

BoPRC investigated Lake Okareka lake level control[4], current and historical lake levels in February 1999 and produced a map (Appendix E) of historical lake levels with suggested restrictions on land development. However, RDC have confirmed that development restrictions for flooding have not been formally implemented through the Rotorua District Plan[5].

Recent personal communication with a local resident[6] during the site visit for this CSCA provided more anecdotal evidence of localised flooding when the lake levels were high, but that this was a rare event.

Overall it appears that flooding is predominantly a function of the Lake Okareka outlet being unable to clear high lake levels during storm events. As a consequence BoPRC have begun a process of planning and surveying for an upgrade of the lake level outlet. If implemented, this work will reduce the frequency of future flood events in the area of the Lake Okareka Settlement[7].

6.8 Water Quality

6.8.1 Introduction

RDC monitored water quality in the discharge from drainage pipe 5 (DP5), on five occasions in 2010. The samples from 21-Jan-10 and 24-Mar-10 were presented in the LOCMP. Since this report was prepared, a further three samples have been collected from this site.

In addition, Golder collected lake water quality samples from locations close to drainage pipes 6, 7 and 8 (DP6-8) and sediment quality samples from close to drainage pipes 2, 7 and 8 (DP2, DP7 and DP8) on 9 March 2011.

6.8.2 Water quality guidelines

In this section, the stormwater and baseflow water quality are compared to water quality guidelines. This is typically carried out to gauge the water quality relative to its potential to have effects or elicit responses in biological communities or to assess its suitability for various uses (recreation, public health etc.).

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[3] Justine Randell pers comm. with previous Land Drainage Manager RDC, email to Golder 17 March 2011.

[4] Lake Okareka level control EBoP Operations Report 98/10, February 1999.

[5] Tracey May, Planning Manager, RDC pers. com., 6 April 2011.

[6] John Roper.

[7] Comments on LOCMP from EBoP dated 16 March 2011 noted EBoP has begun work on the lake outlet.

To assess the potential for effects in freshwater biological communities, water quality data is compared against well know regulatory water quality values. These values can take a number of forms depending on where they have been produced. They include chronic and acute water quality criteria (USEPA 2000) or targets (ANZECC 2000). Although the ANZECC (2000) targets and USEPA chronic criteria are generally similar, the ANZECC (2000) trigger values are based on no ecological effects concentrations (NOECs) and the USEPA criteria were developed to protect 90% of all species present in a community. As such, the ANZECC (2000) concentrations are typically lower than the USEPA concentrations. Both have been utilised in New Zealand over the years but, the ANZECC (2000) trigger values are typically used throughout New Zealand in regional planning documents. As such these are used in this assessment.

The water quality data collected is compared in the following sections with ANZECC (2000) water quality triggers. The comparison is made to the trigger values for slightly to moderately disturbed ecosystems. Although these trigger values apply to receiving waters following reasonable mixing, and are not intended to be applied directly to discharges, such an approach will highlight any parameters for which some dilution is required to lower the concentration in the discharge below the relevant standard; and as such will provide a preliminary screen of water quality data. This dilution will be available when stormwater mixes with water in Lake Okareka.

6.8.3 Stormwater quality

Discharge sample point DP5 collects stormwater runoff from sub-catchment 5 (refer Figure 3), a 5.2 ha residential catchment in the Lake Okareka Settlement. The quality of stormwater in five samples collected from DP5 is summarised in Table 2. Comments in the LOCMP (RDC 2010) suggest that previously collected samples (21-Jan-10 and 24-Mar-10) were first flush samples, whereas the more recent samples did not capture the first flush, and represent stormwater quality later in the rain event. Further discussion of potential effects is provided in Section 8.2.

Suspended solids and clarity

The concentration of total suspended solids (TSS) was high in first flush samples (200 to 360 g/m^3), whereas TSS concentrations were relatively low in the more recent samples of post-first flush stormwater (median 23 g/m^3 range 10 to 57 g/m^3).

The higher concentrations are similar to the 50%ile concentration reported for urban stormwater identified by Williamson (1993). The first flush data is higher than the median concentrations reported for urban residential areas in Rotorua (33 g/m^3), Kaikorai Dunedin (86.9 g/m^3) and Pakuranga in Auckland (41.4 g/m^3) (refer summary in Kennedy (2003). The relative significance of the TSS data is discussed again in Section 8.3.

Metals/metalloids

The concentration of total and dissolved metals and metalloids were measured on the collected samples. The total metal concentrations reflect the concentration of TSS in each sample. As such, dissolved concentrations are discussed below. The following comments can be made about the data collected:

- The concentrations of dissolved arsenic, cadmium, chromium and nickel are low or below the detection limit.
- Lead concentrations were measured in four of five samples (the fifth had a higher detection limit preventing a concentration being reported). Measured concentrations ranged from 0.00044 to 0.00062 g/m^3.
- The concentration of dissolved copper ranged from 0.0010 g/m^3 to 0.0046 g/m^3.
- The concentration of dissolved zinc in stormwater ranged from 0.031 to 0.11 g/m^3.

Table 2: Stormwater discharge quality from discharge point 5 (DP5).

	21-Jan-10	24-Mar-10	14-Apr-10	2-Aug-10	9-Sept-10	Trigger Levels[1]
pH (unitless)	5.7	6.3	6.8	6.2	6.6	-
Total suspended solids	200	360	10	57	23	-
Total arsenic	0.0073	0.0055	0.0018	0.0041	0.0016	-
Dissolved arsenic	0.0031	0.0014	0.0015	0.0027	0.0010	0.013
Total cadmium	0.000093	0.00011	<0.000053	0.00011	<0.000053	-
Dissolved cadmium	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.00020
Total chromium	0.0048	0.0050	0.00077	0.0013	0.0011	-
Dissolved chromium	0.00084	<0.00050	<0.00050	<0.00050	0.00070	0.0010
Total copper	0.024	0.023	0.0037	0.0042	0.0038	-
Dissolved copper	0.0042	0.0040	0.0030	0.0010	0.0046	0.0014
Total nickel	0.0019	0.0018	<0.00053	0.00054	<0.00053	-
Dissolved nickel	<0.00050	<0.00050	<0.00050	<0.00050	0.0011	0.011
Total lead	0.015	0.019	0.0015	0.0042	0.0027	-
Dissolved lead	0.00059	0.00062	0.00040	<0.0010	0.00044	0.0034
Total zinc	0.28	0.14	0.11	0.059	0.26	-
Dissolved zinc	0.031	0.084	0.11	0.041	0.048	0.0080
Dissolved cadmium	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.00020
Total nitrogen	0.55	1.1	0.67	0.62	0.65	0.61
Total Kjeldahl nitrogen	0.50	0.95	0.58	0.55	0.59	-
Nitrate-N+Nitrite-N	0.050	0.19	0.090	0.070	0.060	0.44
Total ammoniacal-nitrogen	0.10	0.080	0.040	0.080	0.040	
Total phosphorous	0.34	0.55	0.13	0.15	0.19	0.033
Dissolved reactive phosphorous	0.090	0.22	0.070	0.030	0.040	0.010
Total petroleum hydrocarbons	<0.70	<0.70	<0.70	<0.70	<0.70	-

Notes: All data g/m^3 unless otherwise stated. All data rounded to two significant figures. [1]ANZECC (2000) trigger levels for slightly-moderately disturbed ecosystems. [2]At a pH of 6.0.

Table 3 summarises and compares the DP5 Okareka stormwater quality data with some New Zealand residential stormwater data. Overall, the cadmium, chromium, copper and nickel concentrations were lower than measured in other urban areas. Lead concentrations are detectable but low, reflecting that lead was removed from petrol more than 10 years ago (but is still present in soils adjacent to roads etc.). Zinc concentrations were similar to those measured in stormwater from urban areas such as Rotorua.

Nitrogen and phosphorous

Nitrogen and phosphorous concentrations in the stormwater samples is summarised in Table 2. The key points arising are:

- Concentrations of total oxidised nitrogen, which is equivalent to the sum of nitrate nitrogen (NO_3-N) and nitrite nitrogen (NO_2-N), ranged from 0.050 to 0.19 g/m^3.
- Ammoniacal nitrogen (NH_4-N) concentrations, which ranged from 0.040 g/m^3 to 0.10 g/m^3.
- Soluble inorganic nitrogen concentrations in the samples (sum of nitrate and ammoniacal-nitrogen) were generally low (0.10 to 0.3 g/m^3).
- Total nitrogen (TN) concentrations ranged from 0.55 to 1.1 g/m^3. Typically, the TN concentration and the total Kjehldahl nitrogen concentrations were very similar. With a low ammoniacal-nitrogen concentration, the data suggests some organic nitrogen in the samples.

- Dissolved reactive phosphorus (DRP) stormwater concentrations ranged from 0.030 g/m^3 to 0.22 g/m^3, while total phosphorus (TP) concentrations ranged from 0.13 g/m^3 to 0.55 g/m^3. Concentrations of DRP were typically a small proportion of total phosphorous.

Table 3: Residential stormwater quality (median, range).

Location	Lake Okareka Settlement	Rotorua	Pakuranga, Auckland	Kaikorai Valley, Dunedin
Dissolved cadmium	<0.00005	0.00006 (<0.00005-0.011)	0.00018	-
Dissolved chromium	<0.00050 (<0.0005-0.00084)	<0.0005	-	-
Dissolved copper	0.004 (0.003-0.0046)	0.0041 (0.0014-0.0077)	0.0032	0.0097 (0.0041-0.0157)
Dissolved lead	0.00044 (0.0004-0.00062)	0.0033 (0.0002-0.0074)	0.00021	0.0029 (0.0003-0.0165)
Dissolved nickel	<0.0005 (<0.0005-0.0011)	<0.0005 (<0.0005-0.0008)	-	-
Dissolved zinc	0.048 (0.031-0.11)	0.033 (0.016-0.075)	0.170, 0.113	0.107 (0.0742-0.243)
Total Kjeldahl nitrogen	0.58 (0.50-0.95)	0.541 (0.431-0.814)		2.055 (1.065-4.035)
Nitrate-nitrite nitrogen	0.07 (0.05-0.19)	0.06 (0.027-0.072)		0.833 (0.281-1.839)
DRP	0.07 (0.03-0.22)	0.027 (0.011-0.038)		0.038 (0.016-0.090)
Total phosphorus	0.19 (0.13-0.55)	0.118 (0.084-0.174)		0.118 (0.064-0.352)
	RDC (median data refer Table 2)	Macaskill et al. (2003)	ARC 1992 (1994)	Mosley & Peake (2001)

Hydrocarbons

The concentration of total petroleum hydrocarbons (TPH) was below the detection limit (<0.70 g/m^3) in all DP5 stormwater samples.

6.8.4 Discharges below catchments 06-08

DP6 and DP8 collect stormwater runoff from residential catchments 06 and 08 respectively in the Lake Okareka Settlement (refer Figure 3; DP6 11 ha, DP8 4.3 ha). DP8 is spring fed and as such provide a base flow to the DP8 discharge point. DP7 collects stormwater runoff from a 123 ha rural catchment, which is predominantly native bush and pasture (refer Figure 3). A single grab sample was collected from each of DP6, DP7 and DP8 during dry weather. This data is presented in Table 4.

Table 4: Dry weather water quality in DP6-8.

	DP6	DP7	DP8	Morgenstern et al. (2004) catchment groundwater[3]	Trigger Levels[1]
Turbidity (NTU)	11	7.2	11	-	-
Total suspended solids	<3.0	15	56	-	-
Dissolved copper	<0.00050	<0.00050	0.00060	-	0.0014
Dissolved lead	<0.00010	<0.00010	<0.00010	-	0.0034
Dissolved zinc	0.0030	0.0045	0.0062	-	0.0080
Total nitrogen	0.37	1.2	2.4	-	0.61
Total Kjeldahl nitrogen	0.14	0.94	0.35	0.1, <0.1, 1.6	-
Total ammoniacal nitrogen	<0.010	0.026	<0.010	<0.01, 0.02, 0.02	0.9[2]
Nitrite-nitrogen	<0.002	<0.002	<0.002	All <0.002	-
Nitrate-nitrogen	0.23	0.29	2.1	3.84, 0.101, 1.80	-
Nitrate-N+Nitrite-N	0.23	0.29	2.1	3.84, 0.101, 1.80	0.44
Dissolved reactive phosphorous	0.0060	0.011	0.0090	0.015, 0.585, 0.041	0.010

Notes: All data g/m^3 unless otherwise stated. All data rounded to two significant figures. [1]ANZECC (2000) trigger levels for slightly-moderately disturbed ecosystems. [2]A freshwater high reliability trigger value of 0.90 g/m^3 total ammonia-N was calculated at pH 8.0 using the statistical distribution method with 95% protection (protection from toxicity). [3] The samples provided are a shallow open well (1.6 m deep), a deep well (43 m) and spring.

For comparison, data is presented for groundwater collected from two wells and a spring to the north (500 m and 1.5 km respectively) of the Lake Okareka Settlement (Morgenstern et al. 2004).

The data in Table 3 and 4 provides the following information:

- Turbidity was relatively constant in the samples compared to TSS.
- Dissolved copper and lead concentrations were low (at or below detection) in all three samples.
- Dissolved zinc was measureable and above detection even in DP7 which was predominantly rural.
- Soluble inorganic nitrogen concentrations varied with low to non-detectable ammoniacal-nitrogen, low nitrate in two samples of three.
- Total nitrogen concentrations varied with low concentrations in DP6, moderate in DP7 and in relative terms high in sample DP8. The cause of the high total nitrogen in DP8 was an elevated concentration of nitrate-N at that site.
- DRP concentrations were consistently low in all samples.

The data collected at sites DP6-8 did not display any characteristics that would indicate any identifiable influence of the Okareka Settlement (low urban trace metal concentrations). The data did show that the water contained low concentrations of DRP but elevated concentrations of nitrogen. The water quality results obtained are in part comparable to data presented by Morgenstern et al. (2004) for groundwater/spring water quality in the catchment. That data showed that groundwater was variably enriched in nitrogen (probably due to catchment farming activity) with the shallow groundwater and spring data showing elevated nitrate-nitrogen. Given that sites such as DP8 have rural catchments and the base flow is spring fed, this is not surprising.

6.8.5 Lake water quality

BoPRC monitors water quality in the Rotorua Lakes including Lake Okareka. BoPRC (2010) summarises lake water quality data and provides information on lake trophic status. Lake Okareka is classified as mesotrophic.

The BoPRC report card for Lake Okareka can be located at:

http://www.ebop.govt.nz/media/33628/RotoruaLakes-100827-LakeOkarekaReport.pdf

The BoPRC lake water monitoring site is located across the lake from the urban settlement. Lake Okareka typically stratifies in early October and becomes isothermal (fully mixed) in late May to early June (EBoP, 2009, BoPRC 2010).

Concentrations of TN measured in the lake have averaged 0.22 g/m^3 and TP 0.0069 g/m^3 (BoPRC 2010). BoPRC (2010) notes that since 2006 phosphorus concentrations have been decreasing in the hypoliminion (bottom waters) due to Phoslock applications (EBOP 2007) reducing phosphorus-release from the sediment. Nitrogen concentrations have stayed fairly constant. Although BoPRC (2009) note that there may be more phosphorus entering the lake from septic tank sources than previously thought wastewater from dwellings is now directed out of catchment and hence this source of phosphorous has been eliminated.

6.8.6 Summary

Sampling of stormwater from sub-catchment 05 in the Lake Okareka Settlement showed that the stormwater contained moderate concentrations of suspended sediment in first flush and generally low concentrations post-first flush (comparable to concentrations seen in urban centres such as Rotorua).

Concentrations of dissolved urban metals such as copper and zinc were comparable to those seen elsewhere with dissolved zinc the common contaminant. As is typical in most urban areas, concentrations of dissolved copper and zinc were higher than ANZECC (2000) trigger values.

6.9 Sediment Quality

A single sediment sample was collected adjacent to the three sampled stormwater discharge points from sites DP2, DP6 and DP8, which drain catchments 02, 06 and 08 respectively to assess whether discharge from those locations was having any identifiable effect on sediment quality.

As described above, DP6 and DP8 collect stormwater runoff from residential catchments of 11 and 4.3 ha respectively. DP2 collects runoff from a large rural catchment (catchment 03; 168 ha), and a smaller residential catchment (catchment 02; 9.8 ha) located close to the edge of Lake Okareka.

The results of this sampling are presented in Table 5. The sediment samples were generally coarse in nature being sandy with significant amounts of fine pumice. The <500 µm fraction of the samples was used to measure key metal concentrations (very little <63 µm fraction was evident). The concentration of total recoverable copper in the <500 µm sediment fraction ranged from 1.4 to 7.7 mg/kg. The concentration of total recoverable lead ranged from 2.0 to 7.9 mg/kg and the concentration of total recoverable zinc ranged from 9.3 to 31 mg/kg. All of these concentrations are considered low relative to typical concentrations measured in urban stormwater sediments (Kennedy 2003), and all are below the ANZECC (2000) ISQG-low trigger value. Comparison is made to the ANZECC (2000) interim sediment quality guidelines (ISQG), as they are commonly used for assessments of sediment quality in New Zealand. The ISQG-low guideline is adapted from the effects range-low used in the National Oceanographic and Atmospheric Administration (NOAA) listing. The ISQG-low, which is equivalent to a “trigger value”, represents a ~15% probability of adverse effects.

Table 5: Total recoverable metals in the <500 µm sediment fraction from discharge points 2, 6 and 8.

	DP2	DP6	DP8	Trigger Levels[1]
Total recoverable copper	7.7	1.4	4.3	65
Total recoverable lead	7.9	2.0	4.3	50
Total recoverable zinc	31	9.3	17	200

Notes: All data mg/kg unless otherwise stated. All data rounded to two significant figures. [1]ISQG-low from ANZECC (2000).

Overall, concentrations of copper, lead and zinc in sediments collected adjacent to the three sampled stormwater discharge points shows low concentrations in sediment. The results displayed some range in concentration, some of which may be attributable to the physical characteristics of the sediments. With roadways and human activity within the catchment some addition of contaminants will occur to sediments. The higher concentration at DP2 may reflect a greater contribution from the catchment at this site; however the concentrations at all three sites were low and would not be likely to be having adverse effects on aquatic organisms inhabiting the sediments.

6.10 Description of the Receiving Environment within the Lake Okareka Settlement

6.10.1 Catchment streams assessment

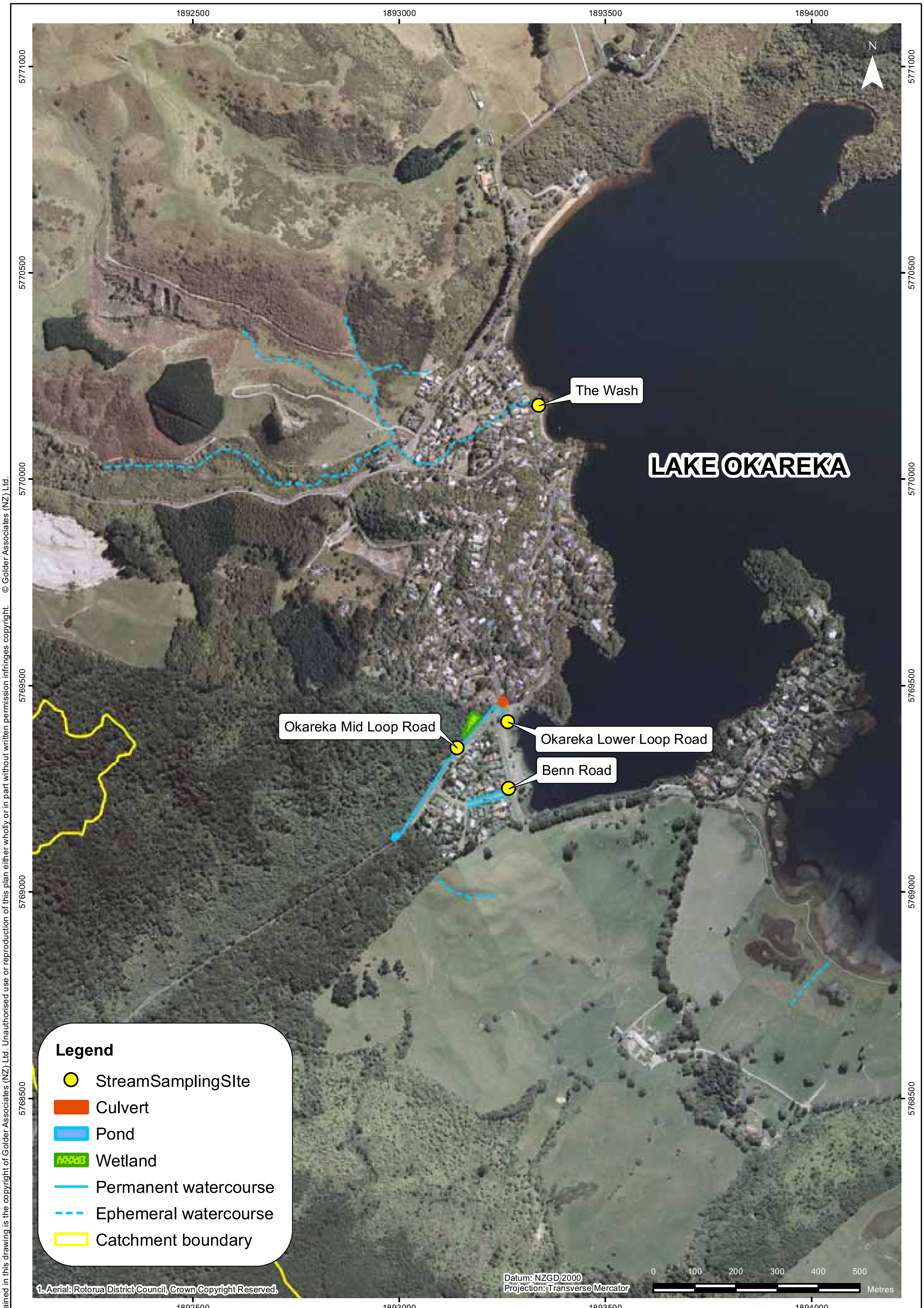
The surface waterways within the Lake Okareka Settlement are characterised by highly modified, short stream reaches holding minimal permanent surface water and choked with aquatic plants. Three stream sub-catchments were identified within the settlement area during the site visit of 9 March 2011, only two of which are permanent waterways (Figure 16).

Okareka Loop Road sub-catchment

An unnamed stream running parallel to Okareka Loop Road (hereafter Okareka Loop Road stream) was the primary drainage path for surface water within the predominantly rural sub-catchment 7. Of the three stream sub-catchments visited, Okareka Loop Road stream contained the largest volume of water at the time of sampling.

In its upper reaches the Okareka Loop Road stream is ephemeral and drains hilly, grazed pasture. The stream channel in this section is eroded and widened as a result of unrestricted grazing animal access (Figure 17a). The stream channel is unshaded and overgrown with pasture grasses and was dry during the site visit of 9 March, providing minimal habitat for aquatic species. The upper ephemeral reaches of Okareka Loop Road stream have been lost under housing developments and no longer connected to the mid-lower reaches by a surface water channel (Figure 16).

The upper extent of the permanent stream appeared to be a large pool southwest of the intersection of Okareka Loop Road and Benn Road (Figure 17). Above the Okareka Loop Road culvert, the stream is channelised, wide (mean width 2.93 m) and moderately deep (ranging from 0.05 to 0.45 m). Stream substrate comprised pumice-type fine grained silt/sand with abundant large woody debris and some fine organic detritus. The mid-upper reaches of the stream are poorly shaded and support high aquatic plant and algae biomass that choke the channel and restrict stream flow in places (Figure 17b). Aquatic macrophyte species include duckweed (*Lemna minor*) and watercress (*Nasturtium officinale*). Above the Okareka Loop Road culvert the stream opens into a wetland containing raupo (*Typha orientalis*), *Carex* spp., kiokio (*Blechnum novaeseelandiae*) and karamu (*Coprosma robusta*). The stream drains a semi-urban land use with roads and urban housing on the true left streambank and native vegetation (replanted and remnant) on the true right streambank. The mid-catchment section of Okareka Loop Road stream provides poor aquatic habitat for fish and invertebrates.



Golder Associates

TITLE SAMPLED WATERCOURSES IN LAKE OKAREKA CATCHMENT

JUNE 2011

PROJECT 1078207446

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Below the Okareka Loop Road culvert is a short stream section that flows to Lake Okareka. The stream is narrow (1.8 m wide) and shallow (0.02 to 0.1 m deep) with a small gravel and silt/sand substrate. No woody debris was observed within the sampling reach, and aquatic plants including duckweed, water pepper (*Persicaria hydropiper*) and water cress, provided limited instream habitat for invertebrates (Figure 17a).

Riparian vegetation comprises native shrubs including karamu and five finger (*Pseudopanax arboreus*) on the true right bank and grasses/low stature shrubs including giant umbrella sedge (*Cyperus ustulatus* f. *ustulatus*) and fiddle dock (*Rumex pulcher*) on the true left bank providing 5 to 10% shade throughout the stream length. Macrophyte cover comprises approximately 25%. No evidence of streambank erosion was observed, but channel scour was observed below the road culvert.

a) Upper pasture reaches of Okareka Loop Road stream

b) Permanent stream channel of Okareka Loop Road stream

Figure 17: Stream habitat conditions in the a) upper and b) mid-reaches of the Okareka Loop Road stream running parallel to Okareka Loop Road.

Benn Road sub-catchment

Two minor stream channels were identified running parallel to Benn Road above Acacia Road. The short channel reach and large volume of water observed at the time of sampling confirms that there are naturally occurring springs in this area.

Both streams were highly artificial, straightened, reinforced drains with low ecological value (Figure 18b). Macrophyte cover comprised approximately 50% and riparian vegetation provided approximately 20% channel shade. Both stream channels are piped below Acacia Road and drain into Lake Okareka.

a) Lower reach of Okareka Loop Road stream

b) Instream habitat within the Benn Road stream

Figure 18: Instream habitat conditions observed in the a) lower section of Okareka Loop Road stream and b) Benn Road stream.

The Wash sub-catchment

The Wash is located on the northern side of the settlement and drains a predominantly rural sub-catchment (Figure 2). The catchment land use is mainly pasture with mixed exotic (gorse and pine) and remnant native bush vegetation in the upper reaches. Both the left and right tributaries of The Wash were identified as swampy, ephemeral drains with little aquatic habitat value (Figure 19a). The Wash becomes a highly modified open drain below the Millar Road culvert until it reaches Lake Okareka east of Steep Street. The Wash sub-catchment contained no surface water at the time of sampling and as such, provided no aquatic habitat. Instream modifications observed within the lower reaches of The Wash included reinforced streambanks (wooden boxing and gabion baskets), artificial stream substrates, numerous stormwater outlet pipes and check dams within the channel (Figure 19b). Vegetation cover was generally poor, and was restricted to patchy native plantings including flax (*Phormium tenax*) and akeake (*Dodonaea viscosa*) and large exotic trees providing minimal shade (5 to 20%).

a) Upper pasture reach of The Wash catchment

b) Lower reaches of The Wash catchment

Figure 19: Instream habitat conditions observed in the a) upper reach and b) lower reach of The Wash sub-catchment.

6.10.2 Stream health assessment

6.10.2.1 Invertebrate communities

Urbanisation changes the physical, hydrological and chemical conditions of streams resulting in changes to the biological communities therein (Suren & Elliott 2004). Aquatic invertebrate communities change in predictable ways with increasing land use pressure and are key indicators of stream health. In particular, the abundance and number of taxa sensitive to poor water and habitat quality declines with a corresponding increase in tolerant taxa. Typical tolerant taxa observed in urban waterways include snails, orthoclad and chironomid midges, oligochaete worms and blackfly larvae (Suren & Elliott, 2004).

Invertebrate samples were collected and processed using standard Protocols C2 and P1 (Stark et al., 2001). Lack of surface water throughout the Lake Okareka catchment precluded aquatic invertebrate sampling at multiple sites. Two sites were sampled within the Okareka Loop Road stream sub-catchment (Figure 2).

The number of invertebrate taxa recorded from the two sampling sites ranged from 9 to 11 taxa at the lower and mid-catchment sites respectively (Table 6). Mollusc (snail) and dipteran (true-fly) taxa were the most abundant taxa at both sites, with fewer oligochaete worms, *Xanthocnemis* damselflies, hemipterans (water bugs) and coleopterans (water beetles) recorded. No sensitive mayfly, stonefly or caddisfly taxa were recorded. Invertebrate community composition at the mid- and lower Okareka Loop Road stream sites reflected the highly modified nature of the catchment and the poor instream and riparian habitats observed.

Table 6: Invertebrate taxa recorded at sampling sites.

	Species	Mid-Okareka Loop Road Stream	Lower Okareka Loop Road Stream
Mollucsa	*Physella*	VA	A
	Potamopyrgus	VVA	A
	Pseudosuccinea	A	C
Diptera	Orthocladinae spp.	VA	VA
	Tanypodinae	C	-
	Austrosimulium	R	C
	Nothodixa		R
	Sciomyzidae	R	-
Coleoptera	Dytiscidae	-	R
	Hydrophillidae	C	-
Hemiptera	*Anisops*	A	R
Oligochaeta		R	C
Odonata	*Xanthocnemis*	A	

Notes: R = 1-4 individuals. C = 5-19 individuals. A = 20-99 individuals. VA= 100-499 individuals. VVA = 500+ individuals.

6.10.2.2 Fish fauna

No fish were recorded from the fish survey site located in the mid-reach of the Okareka Loop Road stream. New Zealand freshwater fish database (NZFFD) records from the surrounding area indicate a low diversity fish community comprising four native and one introduced fish species (Table 7). Fish records from the surrounding catchment include galaxiids (banded kokopu and koaro), common bully, smelt, and introduced rainbow trout. Records of koura (freshwater crayfish) in Lake Okareka are significant as koura are nationally threatened (gradual decline) and are sensitive to habitat quality declines.

Table 7: New Zealand Freshwater Fish Database (NZFFD) records for Lake Okareka and tributaries. Accessed 21 February 2011.

Common Name	Species	Native	NZFFD Records	
			Lake Okareka Tributary	Lake Okareka
Banded kokopu	*Galaxias fasciatus*	Y	✓	
Common bully	*Gobiomorphus cotidianus*	Y	✓	✓
Koaro	*Galaxias brevipinnis*	Y	✓	✓
Rainbow trout	*Oncorhynchus mykiss*	N	✓	✓
Smelt	*Retropinna retropinna*	Y		✓
Koura	*Paranephrops planifrons*	Y		✓

A potential barrier to upstream fish passage was identified within Benn Road stream that comprised of heavily silted culverts that could potentially restrict fish movement (Figure 20). Barriers to upstream fish passage are of only minor concern in the sub-catchments surrounding Lake Okareka because the streams are typically very short with moderate-poor habitat and are unlikely to support diverse fish communities.

Figure 20: Potential artificial barrier (culvert) to fish passage observed within Benn Road Stream.

6.10.3 Identification of degraded receiving environments

The upper reaches of the Okareka Loop Road stream on the boundary of the settlement area contains high periphyton and aquatic plant biomass, slow flow, high sedimentation and generally poor aquatic habitat. Periphyton observed at the time of sampling comprised long filamentous green algae and gelatinous green mat algae that proliferated on macrophyte surfaces (Figure 21a). Excessive algae growth is indicative of nutrient enrichment and the high algal cover observed within the stream is likely a reflection of the surrounding rural catchment. High algae and macrophyte cover reduces instream aesthetic and benthic biodiversity values. High sedimentation in Okareka Loop Road stream resulted in poor streambed stability, smothering of benthic substrates and loss of habitat for invertebrate species (Figure 21b).

a) Excessive algae growth on aquatic macrophytes observed in the Okareka Loop Road stream

b) Silt deposition observed in the upper Okareka Loop Road stream

Figure 21: Degraded receiving environments observed within Okareka Loop Road stream including a) excessive algae growth and b) silt deposition.

6.10.4 Summary

Lack of surface water throughout the Lake Okareka catchment precluded aquatic invertebrate sampling at multiple sites. Of the two sites sampled within the Okareka Loop Road stream sub-catchment invertebrate community composition reflected the highly modified nature of the catchment and the poor instream and riparian habitats observed. No fish were found.

The upper reaches of the Okareka Loop Road stream on the boundary of the settlement area reflect the surrounding rural catchment with high algae and macrophyte cover and stream bank sedimentation reducing instream aesthetic and benthic biodiversity values.

7.0 PREDICTED LAND USE DEVELOPMENT AND GROWTH IN IMPERVIOUS COVER

7.1 Existing Development

The RDC District Plan, under Rule A17.1, states sections greater than 2,500 m^2 are permitted a maximum site coverage (imperviousness) of 400 m^2 (approximately one fifth).

Sites less than 2,500 m^2 are permitted site coverage (imperviousness) of 250 m^2 or 16% of the site whichever is the greater.

The exact proportion of existing impervious surface area of the settlement area of Lake Okareka has not been calculated. However, using indications of allowable impervious cover in the RDC District Plan rules (discussed above) and recent aerial photography it is estimated to be 40%.