Taheke Geothermal Development Project - Assessment of Effects on Aquatic Ecology

Prepared for Eastland Generation Limited

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Climate, Freshwater & Ocean Science

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Executive summary

Eastland Generation Limited (Eastland), in partnership with the Proprietors of Taheke 8C and Adjoining Blocks Inc. (T8C), are jointly investigating the development of a geothermal power project; the Taheke Geothermal Development Project (TGDP). An Assessment of Environmental Effects is required as part of consent applications and Eastland has contracted NIWA to assess the potential effects of construction, commissioning and operation of the proposed scheme on the hydrology and aquatic ecology of the Okere River and Onepu Stream.

The proposed system consists of a power plant that would abstract water from the Okere River as a consumptive take for operational uses. The water intake for the proposed TGDP will be situated in the headwaters of the Okere River, approximately 2 km downstream of Lake Rotoiti, and approximately 1.2 km downstream of the Okere Falls. In addition, a network of pipelines to transport both water and geothermal fluids will be required that will cross the headwaters of the Onepu Stream system at three locations. The effects of the operation of the proposed TGDP on the surrounding aquatic ecology will result from the abstraction of river water from the Okere River for operational uses, and from the construction of the network of piping and vehicle access tracks required for transporting water and geothermal fluids, which crosses the headwaters of the Onepu Stream.

Under the maximum proposed abstraction rate of 16,500 m^3/day (191 L/s), 1.55% of the mean annual 7-day low flow of the Okere River, and 2.38% of the 100-yr annual recurrence interval (ARI) low flow would be taken to operate the TGDP. At this low abstraction volume, little change to river morphology, water velocities, water levels or substrate composition will occur. The proposed maximum abstraction rate will reduce water levels by 11 mm during the 100-yr ARI low flow and this reduction is too small to cause any appreciable change in water velocities and in-river habitats for biota. Furthermore, the maximum take would only be required infrequently. At the more commonly used abstraction rates of 70 and 58 L/s (based on 5,000 m^3/day), these effects reduce to a 4 mm and 2 mm drop in water levels, respectively, during a 100-year ARI low flow event.

The main potential effects of the proposed TGDP abstraction on macrophytes would be a reduction in water levels downstream of the intake, exposing beds to desiccation. As the maximum proposed abstraction rate will have no appreciable change on water levels and water velocities within the Okere River, no changes to macrophyte habitats are anticipated. Therefore, the effects of the proposed abstraction on the habitats and hydrology for flora and fauna within the Okere River will be less than minor.

By utilising wedge-wires screens (Johnson's or equivalent) at the water intake, losses of fauna from impingement and entrainment at the TGDP intake will be minimal. The wedge-wire screens proposed for the intake will create a maximum screen approach velocity of 0.2 m/s. As a consequence, both adults and juveniles of the fish species that could be naturally present at the intake location (i.e., trout, bullies, smelt, koaro, banded kokopu, torrentfish and longfin eels) should be able to avoid impingement upon the intake screen of the TGDP using their burst swimming mode. In addition, the maximum screen approach velocity of 0.2 m/s would only occur very infrequently, with velocities dropping below
0.1 m/s under the daily maximum take of 5,000 m^3/day. Although the wedge-wire screens will eliminate virtually all fish impingement, the proposed 3 mm slot aperture could entrain both fish eggs and fish larvae.

Based on the biology, behaviour and abundance of the fish species whose larvae and eggs could be vulnerable to entrainment at the intake site, losses are likely to be negligible at a population level. Macroinvertebrates are also at risk of impingement and entrainment from the water abstraction at the proposed TGDP intake. As the intake will be positioned in the deep fast-flowing river channel clear of the stream bed, this will minimise the risk of impingement and entrainment of upstream moving invertebrates (e.g., koura), which are generally benthic and move upriver along the substrate. Effects of impingement and entrainment would, therefore, be limited to downstream drifting macroinvertebrates within the c. 2 km section of river upstream of the TGDP intake. These losses are unlikely to limit trout growth in the pool where the intake would be located, or in the river downstream. To ensure impacts on both fish and invertebrates from the TGDP intake are minimised we recommend siting the intake within the deeper, swifter waters of the main channel clear of the riverbed because most target species utilise the slower flowing marginal habitats or are benthic in swift waters.

It is proposed that the pipelines transporting geothermal fluid will be constructed with the underside of the pipe approximately 800 mm clear of the ground. Based on the small size of the Onepu Stream, 800 mm ground clearance is sufficient to prevent the pipelines from affecting the stream flow and impacting on aquatic biota. During installation of the pipeline network and any access roads required for the maintenance of this network, an increase in turbidity levels and sedimentation of the Onepu Stream is expected, which could disturb stream ecology. Appropriate measures should be taken to avoid any significant adverse effects of construction activities on stream water quality and biota caused by increased sedimentation.

Overall, the effects of construction, commissioning and operation of the TGDP on the hydrology and aquatic ecology of the Okere River and Onepu Stream are deemed to be negligible.

1 Introduction

Eastland Generation Limited (Eastland) and the Proprietors of Taheke 8C and Adjoining Blocks Inc. (T8C) are jointly investigating the development of a geothermal power project; the Taheke Geothermal Development Project (TGDP). The TGDP will be located on land owned by Taheke 8C, which is situated over the Taheke geothermal field north of Lake Rotoiti, and east of the Okere River (Figure 1-1).

In applying for consents to construct and operate the TGDP, Eastland and T8C are required to produce an Assessment of Environmental Effects (AEE), which reviews the potential and actual effects of the power plant on the receiving environment. To help inform this AEE, Eastland has contracted NIWA to reassess the potential effects of construction, commissioning and operation of the proposed scheme on the hydrology and aquatic ecology of the Okere River and Onepu Stream.

The effects of the proposed TGDP on the aquatic environment were first assessed in 2012 when Contact Energy were planned partners, but the power plant siting and design were not finalised (Baker et al. 2012). Since 2019, Eastland Generation has replaced Contact Energy as project partners and the joint parties have finalised the location and broad scale design of the TGDP. The proposed system consists of the power plant located to the east of the Taheke geothermal field that would abstract water from the Okere River for operational uses (Figure 1-1). The abstracted water would be a consumptive take and not discharged back to the Okere River. In addition, a network of pipelines to transport both water and geothermal fluids will be required, and this will cross the headwaters of the Onepu Stream system at three locations. Access roads for the maintenance of these pipelines will also be constructed.

This report assesses the ecological effects of the proposed power scheme based on:

- the intake location and design as recommended by Tan (2012)
- the layout of the east plant site and network of piping corridors, including construction parameters provided in Bannwarth et al. (2012).

As the structural components and potential impacts of the proposed development vary between the Okere River and Onepu Stream, each waterway is discussed separately. For clarity, the report has been divided into three sections:

- **hydrology**, which describes the current hydrology of the Okere River and predicted changes associated with abstraction of water for the TGDP
- **current ecological baseline**, which describes the aquatic ecology of the Okere River and Onepu Stream, and significance of the fauna, and
- **ecological effects of the TGDP on the baseline if the consents are granted**, which describes potential impacts of the power scheme on the ecology of the Okere River and Onepu Stream.

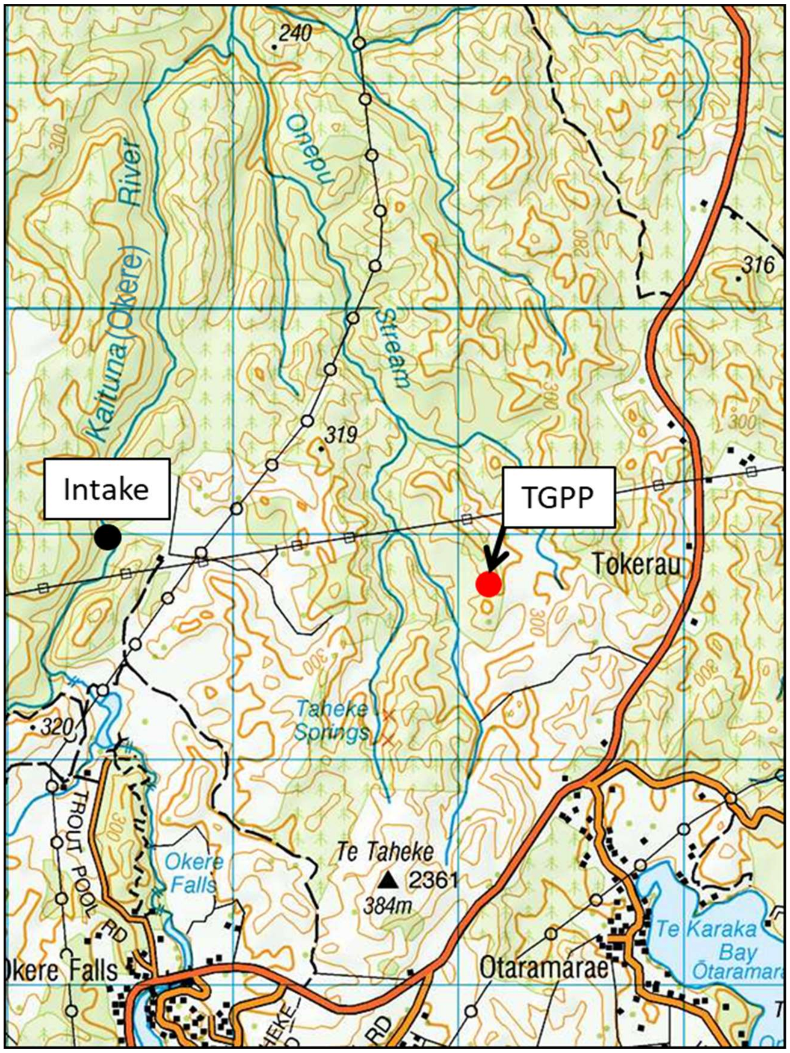

Figure 1-1: Proposed location of the Taheke Geothermal Development Project (TGDP). The indicative position of the intake is also shown.

2 Hydrology

Okere River hydrology is controlled by its source (Lake Rotoiti), which in turn is fed by substantial inflows from Lake Rotorua. The upstream lakes attenuate flood flows and sustain low flows (relative to the streams that flow into them from their upper catchments. In addition, flows in the Okere River are regulated by a management regime which aims to control water levels in Lake Rotoiti for amenity purposes, and assist in the maintenance of water quality in Lake Rotoiti and the Ohau Channel. In general, the outflow from the control gates is at least as large as the inflow from Lake Rotorua, so that the net flow is out of Lake Rotoiti. This prevents the influx of Rotorua water into Rotoiti and ensures proper functioning of the diversion wall along the western side of Rotoiti, which deflects Rotorua water flow towards the outlet of Rotoiti (i.e., the Okere River).

A new water level regime for Lake Rotoiti was consented in 2012. The regime is mostly concerned with maintenance of desirable lake levels, but there is also a flow rule (Consent 65979 rule 7.4f), which requires a 6 hourly rolling average flow of at least 7.9 m^3/s and a 7-day rolling average of at least 9.84 m^3/s. Despite these changes, it is currently thought that the effects of the new regime on Kaituna flows would be minimal, and essentially only towards the lower end of Rotoiti levels where outflows might be higher than they used to be (G. O'Rourke, BoPRC, pers. comm.). This is because of rule 7.4i that specifies that the flow below the Okere Gates should be greater than or equal to the outflow from Lake Rotorua (i.e., Qout >= Q_Rotorua_in). As a consequence, over the summer months, low river flows (13–16 m^3/s) could be a little higher than in the past but there would be no change at peak flows (G. O'Rourke, BoPRC, pers. comm.).

Because of the expected minimal effect of lake level control on flows down the Okere River we have used the long record (October 1981 to the present) in our analysis[1].

2.1 Mean flow

Figure 2-1 shows the mean flow of Okere River (at the Taheke recorder) during the spring and summer (October 1981 through March 2019) and the mean flows for each calendar year over the same period. The mean flow from October 1981 and October 2019 is 21.37 m^3/s (Figure 2-2). The median flow (that exceeded 50% of the time) is 21.69 m^3/s. The small difference between mean and median is related to the smoothing effect of the upstream lakes. The range of observed flows is relatively small, again reflecting the presence of the upstream lakes.

The seasonal pattern of flow is shown in Figure 2-3. This follows the typical North Island pattern of higher flows in winter, and lowest flows in late summer and early autumn. It is notable that the highest recorded maximum monthly mean flow is close to the mean annual flood. This sustained high flow is another feature of lake dominated catchments, where large inflows into a full lake can create very long outflow events.

[1] Available for the Taaheke recorder (Okere at Taaheke, site number 1114609), operated by NIWA Rotorua as part of the National Hydrometric Network funded by MBIE through NIWA core funds to 2012, after which, managed by Bay of Plenty Regional Council

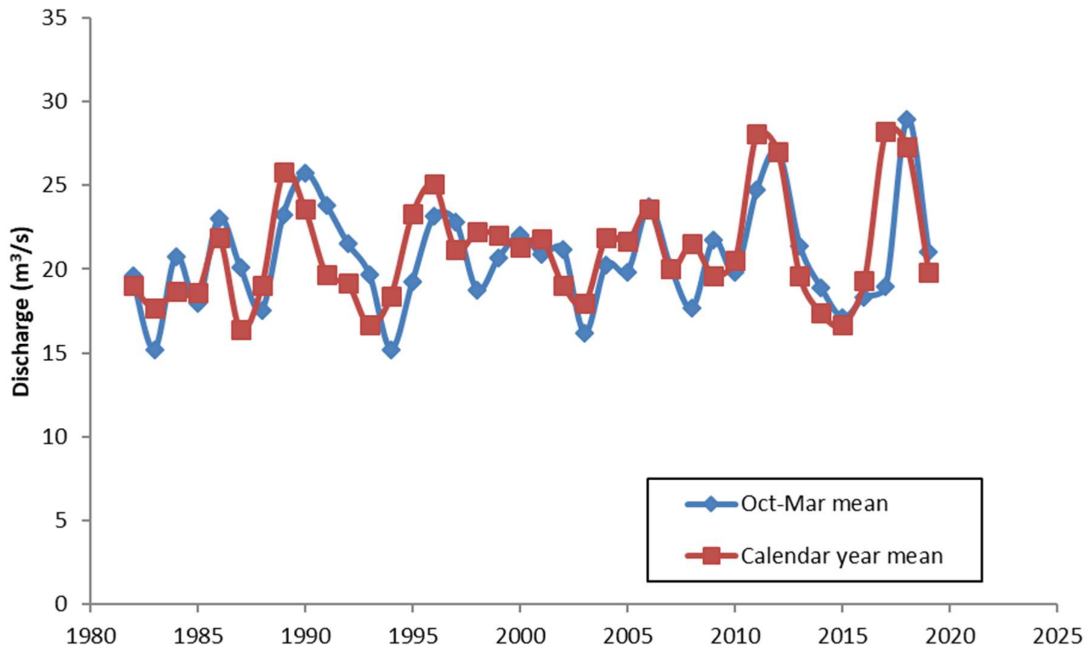

Figure 2-1: Mean flow over spring-summer (Oct 1981 – Mar 2019) and calendar years.

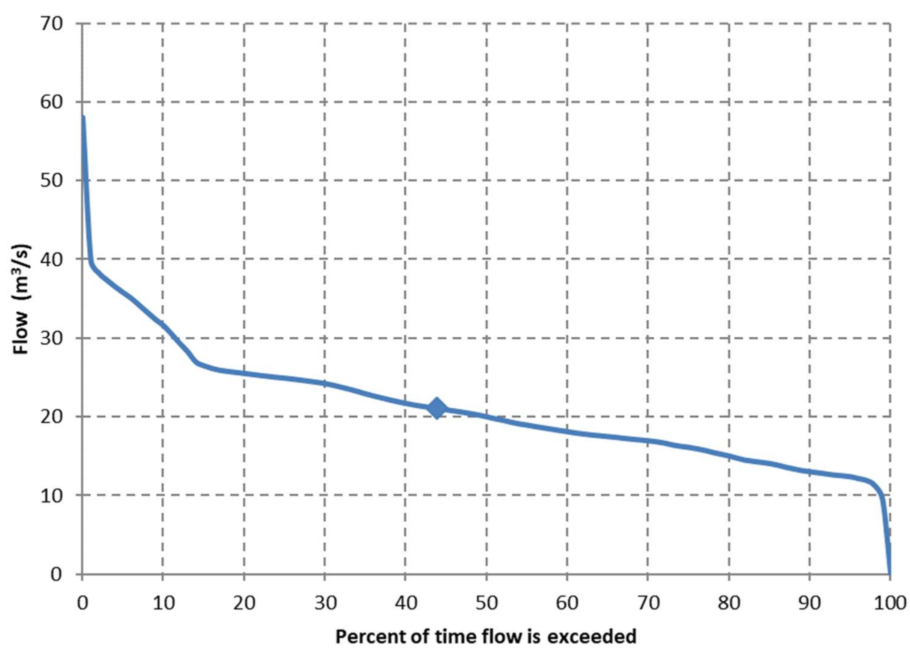

Figure 2-2: Flow duration curve for the Okere flow gauging site at Taaheke (2018-2020). The mean flow is marked with a diamond, and the median is the flow at 50% exceedance.

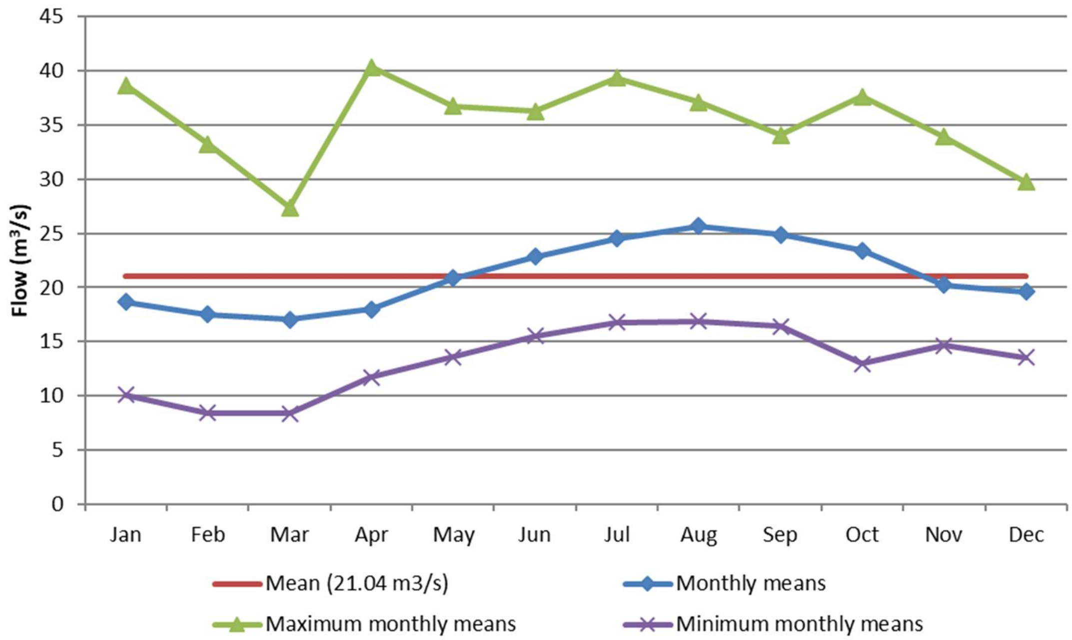

Figure 2-3: Seasonal pattern of flow on a monthly mean basis (2018-2020). The red line shows the long-term mean flow.

2.2 Flood flows

The flood return periods and flows shown in Table 2-1. The relationship between these levels and level changes at other parts of the river is complex. In general terms, we can say that in reaches that are steeper or have a wider cross section there would be a smaller height change than that at the median flow, and in reaches that are narrower or have flatter cross sections there would be a larger height change.

Table 2-1: Flood peaks, staff gauge levels and river level (RL) for common flood scenarios.

Average recurrence Interval (years)	Flood peak flow (m^3/s)	1.96 std. deviation (m^3/s)	River stage (mm staff gauge)	RL (m Moturiki Datum)	Height above median flow level (m)
2.33 (mean annual flood)	39	2.0	2492	248.372	0.556
5	44	2.9	2668	248.548	0.733
10	49	3.9	2812	248.692	0.877
20	53	5.0	2950	248.830	1.014
50	59	6.5	3128	249.008	1.193
100	63	7.7	3262	249.142	1.326

The fit of the annual flood peaks to the Gumbel distribution, commonly used for estimating flood statistics, is shown in Figure 2-4. While there is a case for fitting the alternative Generalised Extreme Value (GEV) distribution to these data, the result is a lower estimate at higher average recurrence intervals. Because of this, and the fact that the flows are managed rather than natural, we recommend adopting the more conservative Gumbel distribution rather than the GEV.

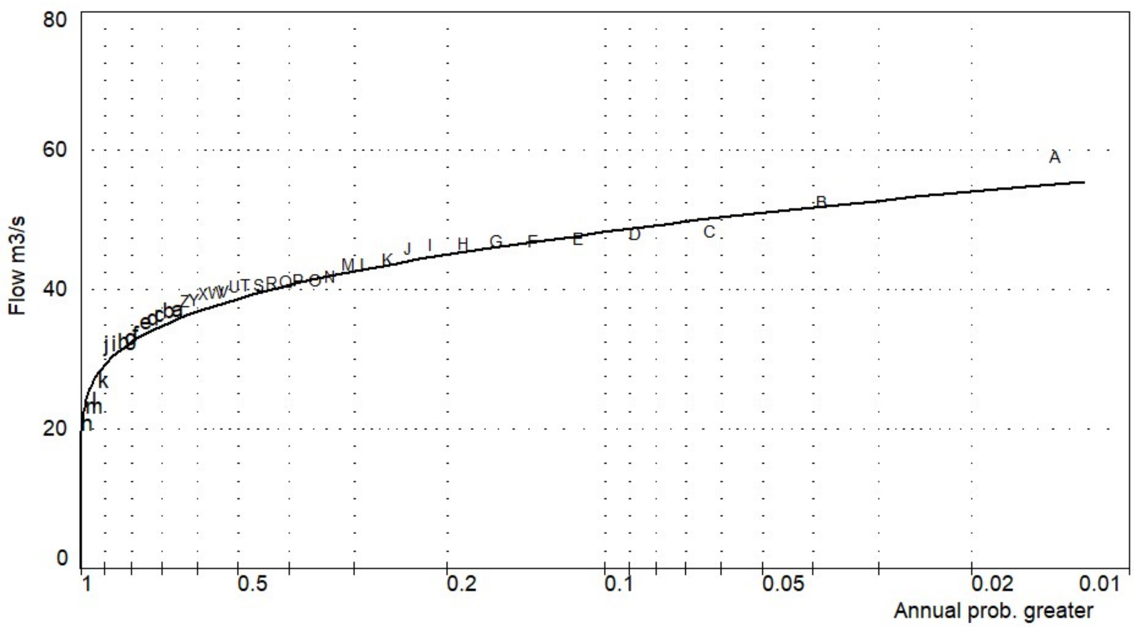

Figure 2-4: Flood frequency plot showing fit of flood annual peaks at the Taheke gauging site in the Okere River to a Gumbel distribution (black line) (1981-2020).

2.3 Minimum flows

Low flows are the part of the flow regime that might be expected to show the most influence of any management changes in discharge rates down the Okere River. However, since the new consents controlling operation of the Okere Gates (and hence discharges) have been in operation for such a short time, there is little evidence of any effect to date. Figure 2-5 shows the lowest 7-day moving mean flow for each year of record, where a year is defined from 1 October to 30 September. This is done to ensure that significant summer-autumn droughts are not broken into two parts across a year boundary and thus over sampled. There is no temporal trend in these minima, and so we present recurrence intervals in Table 2-2, and a graph of the fitted log-normal distribution with the data as Figure 2-6.

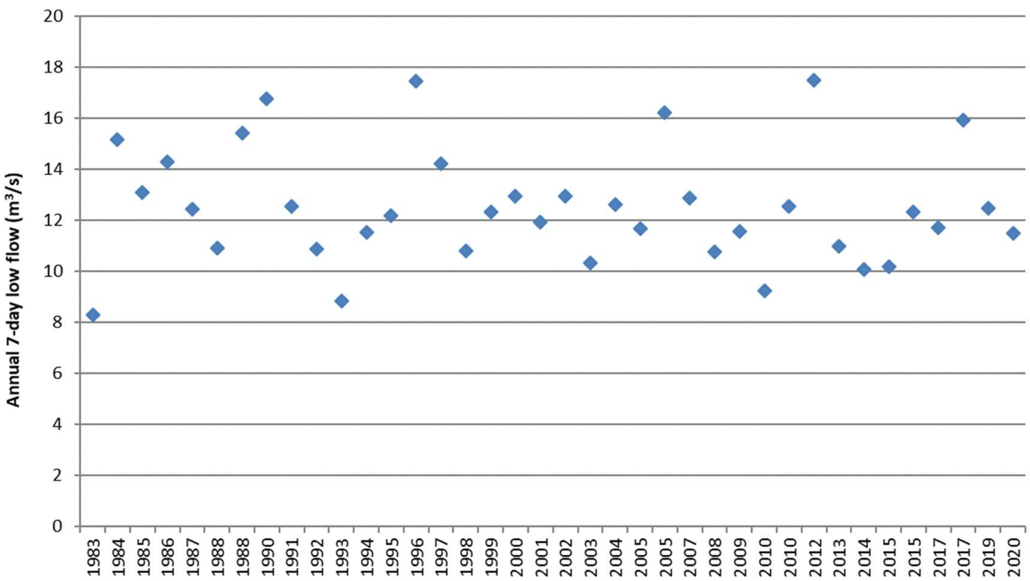

Figure 2-5: Time series of annual 7-day minima (1981-2020).

Table 2-2: 7-day low flows for common average recurrence intervals.

Recurrence Interval (years)	7-day low flow (m^3/s)	Standard error (%)
1.9 (mean annual)	12.5	6
5	10.6	7
10	9.8	8
20	9.2	9
50	8.6	11
100	8.2	12

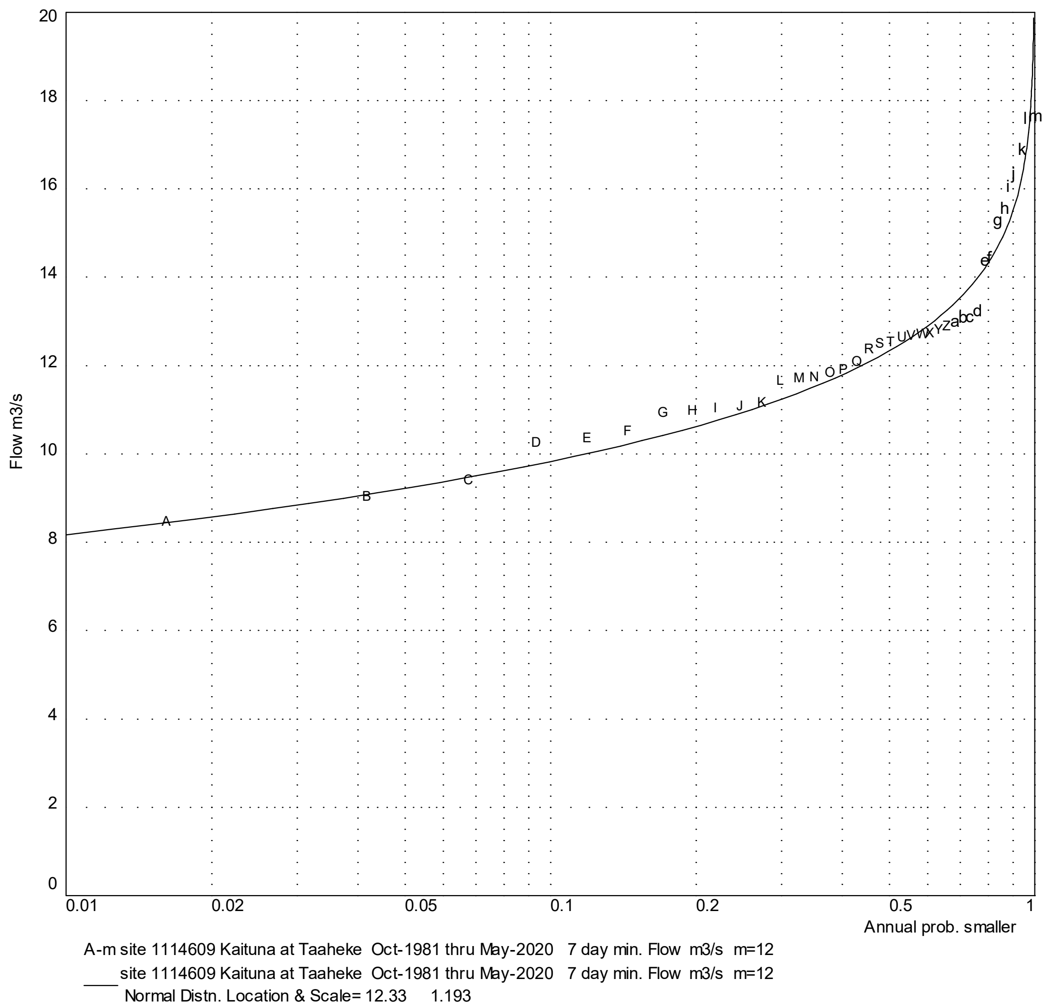

Figure 2-6: Low flow frequency plot showing fitted log-normal distribution (black line) (1981-2020).

The 7-day low flows are a reasonable fit to the log-normal distribution in spite of the managed regime and indicate a 7-day low flow of 8.2 m^3/s can be expected with an annual probability of 1 in 100. Low flows (lowest 7-day mean flow) since 2012 were all above 10 m^3/s (Figure 2-5).

2.4 Abstraction volumes in relation to river flow

Eastland and T8C propose to abstract a maximum of 16,500 m^3/day of water from the Okere River at a maximum abstraction rate of 191 L/s during plant operation. During drilling abstraction volumes will reduce to 5,000 m^3/day at a maximum abstraction rate of 70 L/s. As drilling is intermittent, the continuous demand of TGDP will be less than 5,000 m^3/day.

The equivalent flow rates for these scenarios, and the percentage of low flows in the river at Taheke, are presented in Table 2-3.

Table 2-3: Abstraction rates and their percentage of low flow values.

Abstraction rate (m^3/day)	Abstraction rate (L/s)	Percentage of mean annual 7-day low flow (12.5 m^3/s)	Percentage of 100-yr ARI low flow (7.3 m^3/s)
5,000	58	0.47	0.71
	70*	0.58	0.89
16,500	191	1.55	2.38

*maximum rate

A worst-case scenario is the maximum abstraction rate during a 100-year annual recurrence interval (ARI) low flow event. The abstraction rate is 2.38% of the river flow in these conditions. The change in water level at the Taheke recorder, using the current stage-discharge rating curve for that location, would be 11 mm. At the more commonly used abstraction rates of 70 and 58 L/s (based on 5,000 m^3/day), these effects reduce to a 4 mm and 2 mm drop in water levels, respectively, during a 100-year ARI low flow event.

3 Current ecological baselines

Potential impacts of water abstractions and discharges can occur at a range of scales within a river network depending on the location of the abstraction/discharge sites within the catchment and the magnitude and nature of the abstractions or discharges. For example, effects of abstractions on fish habitat are generally restricted to reaches below the abstraction site, whereas effects on the recruitment of diadromous native fish may extend well above it. Furthermore, effects of abstraction on the less mobile biota, such as benthic invertebrates and macrophytes, are generally more localised than those on fish. Similarly, the effects of construction activities on water quality (e.g., sedimentation) can affect not only benthic habitats at the site but may affect habitats over large distances downstream before dilution by flows from other tributaries diminishes their effect. An appreciation of such scales is required to define the location(s) over which the environmental baseline is applied.

The ecological baseline for the TGDP includes the upper reaches of the Okere River at and below the abstraction site, with the Kaituna River viewed mostly as a migratory corridor. The headwater lakes (Rotorua and Rotoiti) are also included in the assessment as a source of lacustrine fish. The baseline for the Onepu Stream includes the stream sections that would be directly affected by the pipeline construction, and downstream reaches to its confluence with the Okere River.

3.1 Okere River

The Okere River drains Lake Rotoiti and indirectly drains Lake Rotorua by way of the Ohau Channel. For approximately 27 km below the Okere Falls the river runs through a deep gorge which contains reaches where chutes and falls occur and where water velocities are high. The river drops approximately 300 m over this distance. After passage through this gorge, the gradient decreases and the river becomes broader and slower flowing. At Paengaroa, the river is named the Kaituna River and it meanders through relatively flat country until reaching the sea at Maketu.

The intake and outfall for the proposed TGDP is situated in the headwaters of the Okere River, approximately 2 km downstream of Lake Rotoiti, and approximately 1.2 km downstream of the Okere Falls (see Figure 1-1). The greatest effects of the proposed abstraction of cooling water will be on the fish, macroinvertebrates and macrophytes present in this high-altitude section of the Okere River. The following section describes the current status of aquatic fauna present in the Okere River that could potentially be affected by the TGDP water abstraction.

3.1.1 Fish

Analysis of data held in the NZ Freshwater Fish Database

Information on fish species in the Okere and Kaituna River was extracted from the New Zealand Freshwater Fish Database (NZFFD). The NZFFD is a national, site-specific database of fish presence/absence, and is the preferred repository for the majority of people undertaking freshwater fish studies in New Zealand.

A total of 18 fish species have been recorded within the Okere and Kaituna River catchment (Table 3.1). Of these species, nine are present within lakes Rotorua and Rotoiti and associated headwater tributaries (Table 3-2). In addition, catfish have recently invaded lakes Rotorua and Rotoiti but the NZFFD doesn’t currently hold records of catfish in the Okere or Kaituna Rivers.

Table 3-1: Percent occurrence of native and introduced fish species recorded in the Okere and Kaituna River catchment downstream of Lake Rotoiti. Records are taken from the New Zealand Freshwater Fish Database (NZFFD) (N=152 records). * = diadromous species. † marine wanderer.

Common name	Scientific name	Percent occurrence (%)
Native species		
Shortfin eel	*Anguilla australis**	38.8
Longfin eel	*Anguilla dieffenbachii**	37.5
Common bully	*Gobiomorphus cotidianus**	26.3
Inanga	*Galaxias maculatus**	23.7
Common smelt	*Retropinna retropinna**	17.1
Redfin bully	*Gobiomorphus huttoni**	15.8
Giant bully	*Gobiomorphus gobioides**	7.9
Banded kokopu	*Galaxias fasciatus**	7.2
Giant kokopu	*Galaxias argenteus**	4.6
Mullet	*Mugilidae*†	4.6
Torrentfish	*Cheimarrichthys fosteri**	2.6
Koaro	*Galaxias brevipinnis**	2.6
Lamprey	*Geotria australis**	2.0
Black flounder	*Rhombosolea retiaria*†	0.7
Introduced species		
Gambusia/mosquitofish	*Gambusia affinis*	16.4
Rainbow trout	*Oncorhynchus mykiss*	15.1
Brown trout	*Salmo trutta*	3.3
Goldfish	*Carassius auratus*	3.3

Table 3-2: Percent occurrence of native and introduced fish species recorded in lakes Rotoiti and Rotorua and associated headwater tributaries. Records are taken from the New Zealand Freshwater Fish Database (NZFFD) (N=373 records). * = diadromous species.

Common name	Scientific name	Percent occurrence (%)
Native species		
Koaro	*Galaxias brevipinnis**	37.8
Common bully	*Gobiomorphus cotidianus**	19.3
Common smelt	*Retropinna retropinna**	15.3
Longfin eel	*Anguilla dieffenbachii**	2.4
Shortfin eel	*Anguilla australis**	0.8

Common name	Scientific name	Percent occurrence (%)
Introduced species		
Rainbow trout	*Oncorhynchus mykiss*	20.1
Goldfish	*Carassius auratus*	5.4
Brown trout	*Salmo trutta*	2.4
Gambusia/mosquitofish	*Gambusia affinis*	1.9
Catfish	*Ameiurus nebulosus*	0.3

Within the Okere River, high water velocities and high gradient sections of the river appear to create natural migration barriers, limiting the diversity and density of diadromous fish into this section of the river (Figure 3-1). Of the 12 native diadromous species present in the Kaituna River, only seven species (banded kokopu, koaro, torrentfish, common bullies, common smelt, shortfin and longfin eels) have been recorded within the Okere River (Figure 3-1, Figure 3-2 and Figure 3-3).

Longfin and shortfin eel numbers reduce markedly with increasing distance inland, and longfin eels penetrate further into the Okere River than shortfin eels (Figure 3-1 & Figure 3-2). The presence of longfin eels upstream of the TGDP intake is extremely limited and only isolated occurrences have been recorded. As eels have not naturally established in lakes Rotorua and Rotoiti, eel occurrence in the upper Okere River could be a consequence of manual transfer of elvers into lakes Rotorua and Rotoiti rather than natural recruitment.

No banded kokopu are present in lakes Rotoiti or Rotorua (Figure 3-3), hence, banded kokopu found in the Okere River will have migrated upriver from the sea. Although banded kokopu occur downstream of the TGDP intake (Figure 3-2), it is extremely unlikely that this species would be able to migrate much further inland and hence above the TGDP intake.

Conversely, koaro are present in both headwater lakes so the koaro in the Okere River could be recruits from either the lakes or the sea. Koaro do penetrate further inland than banded kokopu so diadromous recruits could theoretically reach the TGDP intake, but again this would be in low numbers and the fish recorded in the Okere River have likely originated from the headwater lakes.

Little is known about the swimming and climbing abilities of torrentfish, but adult fish are strong swimmers and possess climbing abilities (NIWA, unpublished data). Torrentfish may penetrate further upstream than surveys have so far recorded (Figure 3-2) and occur at the TGDP intake, but high-water velocities in the Okere River would preclude effective sampling for this species.

Common bullies and common smelt are recorded throughout the Okere and Kaituna River, given these species are poor swimmers that do not possess any climbing ability (McDowall 1990), it is likely that sea-run fish are limited to the lower reaches of the Kaituna River, with the majority of fish recorded in the Okere River originating from the headwater lakes.

Lamprey larvae have only been recorded in two tributaries of the lower Kaituna River (Figure 3-1 & Figure 3-2). However, few records for lamprey exist in the NZFFD, and their distribution may be more extensive.

Lamprey habitat is very rarely targeted in fish surveys and so few are captured. Adult lamprey are often found in high gradient sections of rivers and in several river systems have been recorded reaching over 300 m in altitude. Therefore, lamprey may penetrate further into the Okere River than presently documented. However, lamprey do not penetrate as far inland, nor to as high altitudes as longfin eels, so they are expected to be restricted to habitats below the upper limit for longfin eels and hence most likely below the abstraction site.

Although rainbow and brown trout are found throughout the Okere and Kaituna River catchment (Figure 3-1 & Figure 3-3), their presence in the upper reaches of the Okere River most likely occurs as a consequence of downstream emigration from the lacustrine populations in the headwater lakes.

Downstream of Lake Rotoiti, gambusia have only been recorded in the lower reaches of the Kaituna River. Given that gambusia prefer still or slow-moving waters (McDowall 1990), limited habitat exists for this noxious species within the high gradient waters of the Okere River. Goldfish is another species found predominantly in slow moving or stagnant waters (McDowall 1990), and this species also has a very limited presence downstream of Lake Rotoiti.

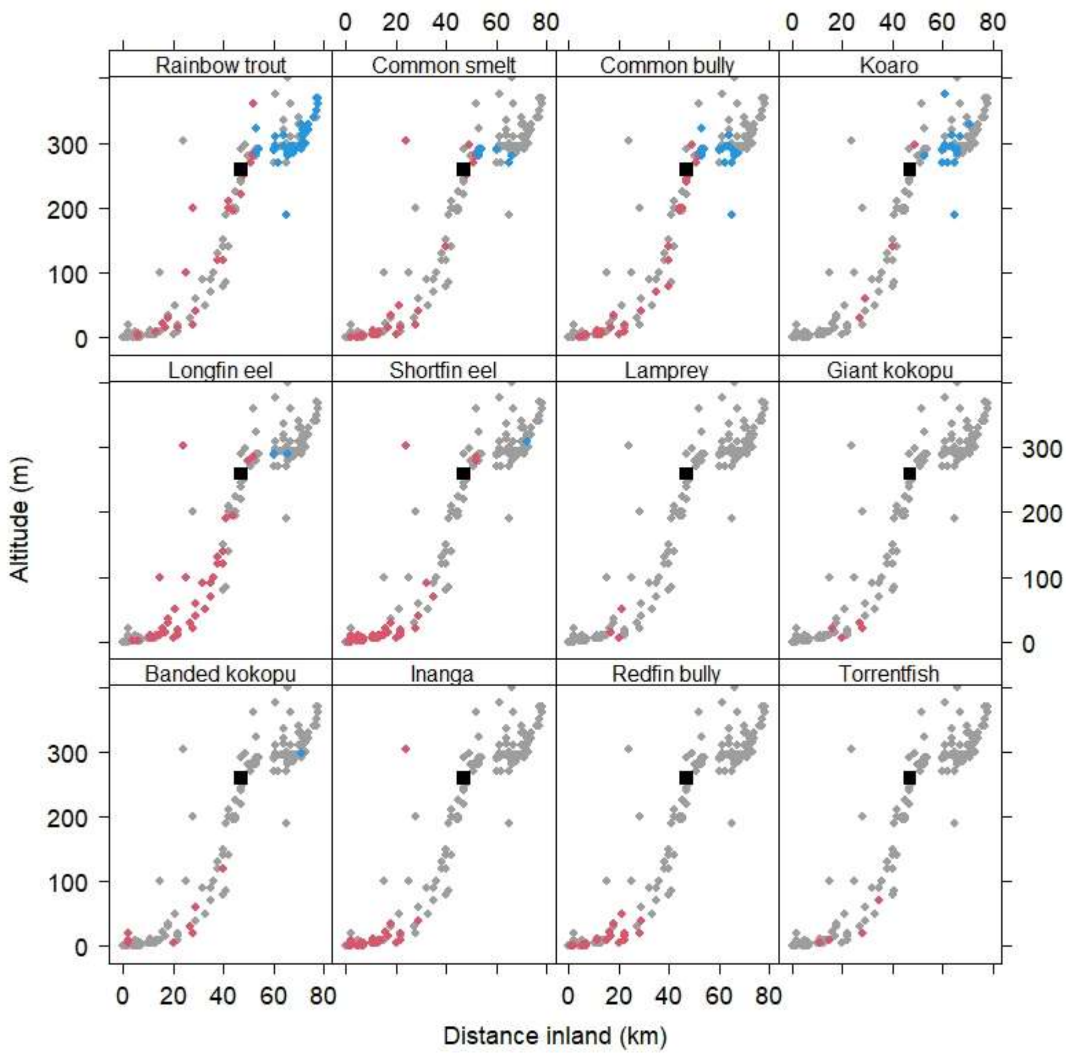

Figure 3-1: Distribution of freshwater fish in the Okere and Kaituna catchment. The location of all NZFFD records are shown as grey circles, sites connected to the river below Lake Rotoiti are shown in red, and sites within lakes Rotoiti and Rotorua and associated headwater tributaries are displayed as blue circles. The Lake Rotoiti outlet gates are located 49 km inland and at 290 m altitude. The proposed location of the Taheke Geothermal Development Project (TGDP) water intake is indicated by the black square.

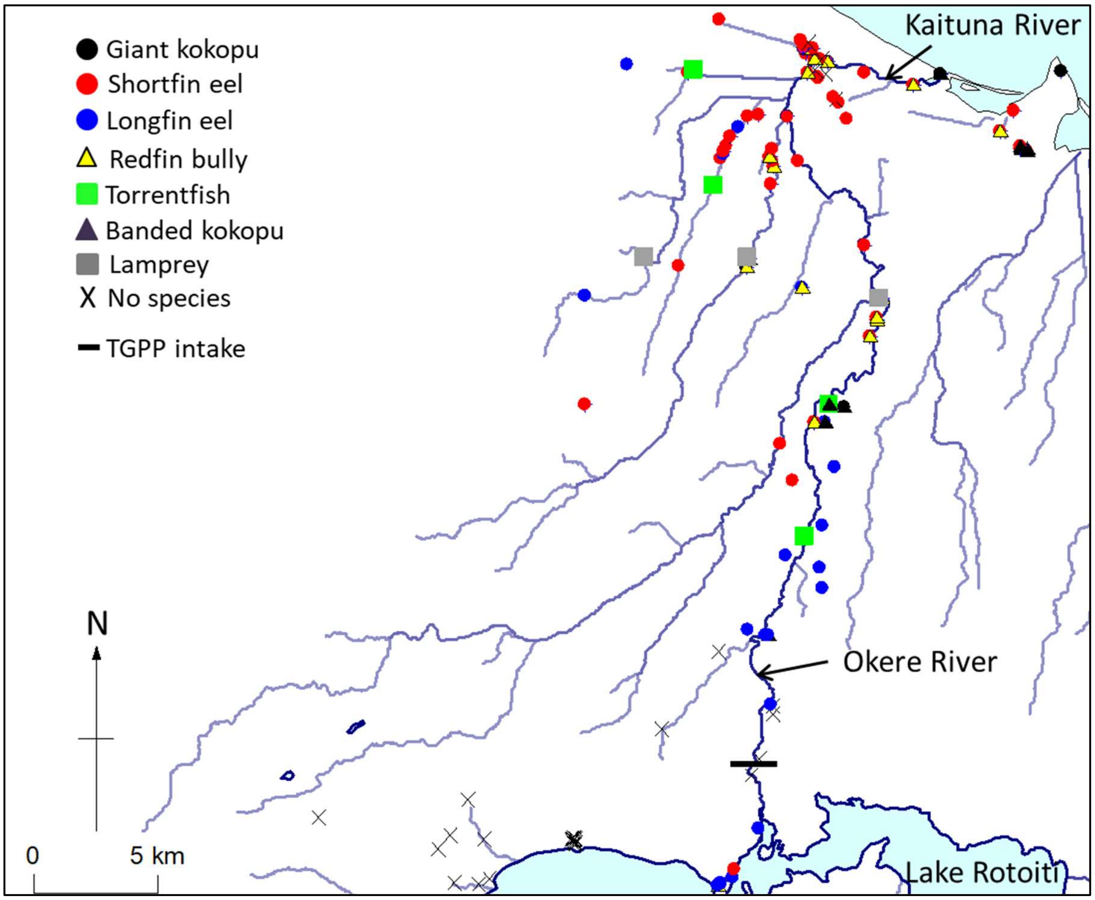

Figure 3-2: Distribution of diadromous fish species in the Okere and Kaituna River catchment. Records from the New Zealand Freshwater Fish Database (NZFFD). The proposed location of the Taheke Geothermal Development Project (TGDP) water intake is indicated by the solid black line. Note: for clarity only stream orders greater than 3 are depicted.

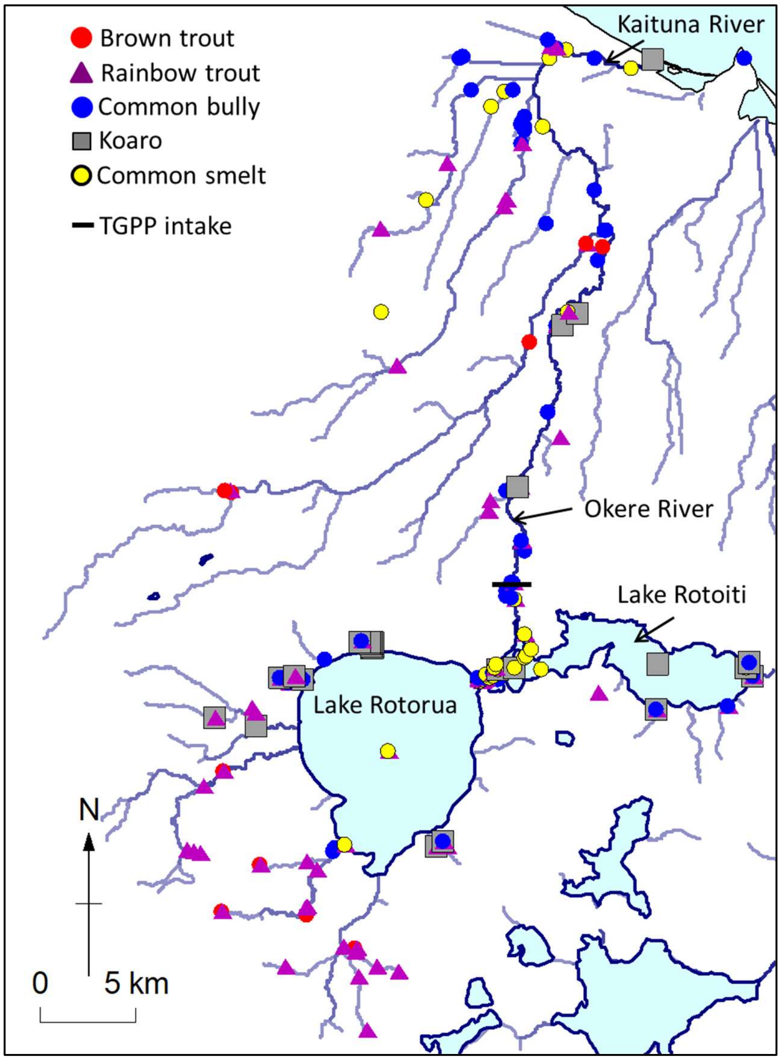

Figure 3-3: Distribution of native and exotic fish species in the Okere and Kaituna River catchment that have formed lacustrine populations within lakes Rotorua and Rotoiti and associated headwater tributaries. Records from the New Zealand Freshwater Fish Database (NZFFD). The proposed location of the Taheke Geothermal Development Project (TGDP) water intake is indicated by the solid black line. Note: for clarity only stream orders greater than 3 are depicted.

Site visits

Site visits were undertaken on 15th November 2012 and 11th September 2020. During the 2012 visit, backpack electric fishing was used to sample fish in the Okere River at the proposed intake location. The deep, high velocity waters in the main river channel (Figure 3-4 & Figure 4-2) made sampling difficult. Therefore, only spot electric fishing was undertaken in the wadeable margins of the backwater along the true right river margin (Figure 3-4). Common bullies were the only fish species seen and captured (Figure 3-5). Within the backwater fished, bullies were relatively common (3-5 fish/10m^2) with most fish between 30 and 60 mm in length. The bullies captured did not have open lateral line canal pores on the top of their heads, which indicates they have originated from a lacustrine population (McDowall 2000). This notion is supported by the distributional records presented in Figure 3-1 & Figure 3-3. In 2020, no fishing was undertaken.

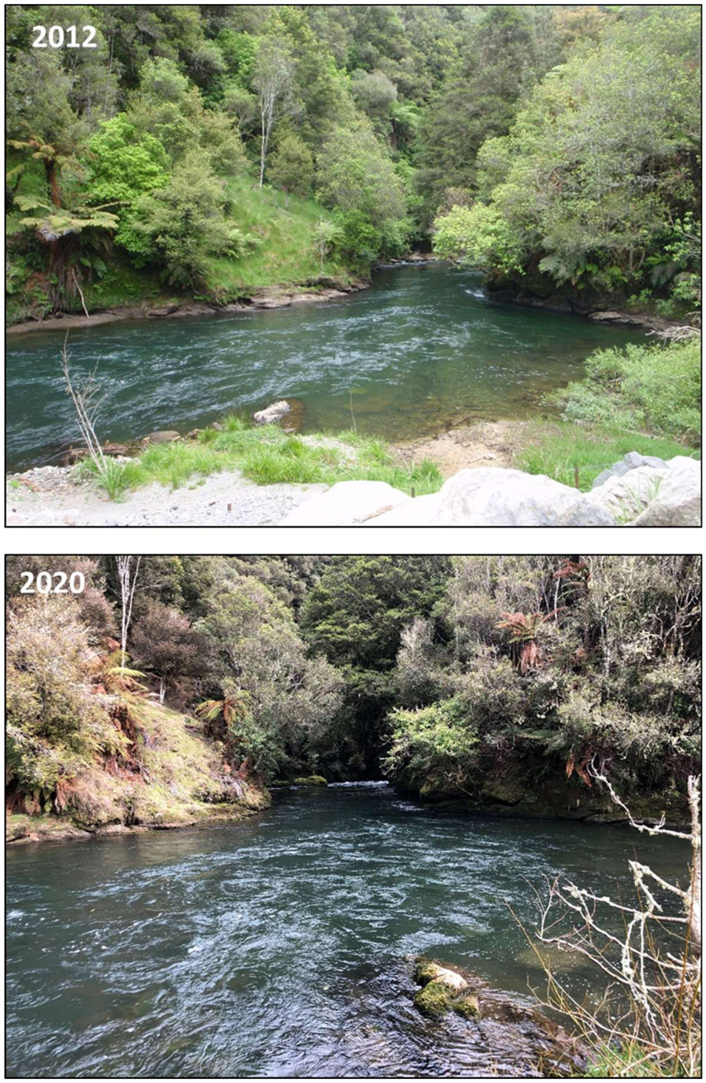

Figure 3-4: The Okere River immediately downstream of the proposed water intake for the Taheke Geothermal Development Project (TGDP). River flows from left to middle/right of the picture. Backwater on the right of the top picture was electric fished during the 2012 site visit.

Figure 3-5: Common bullies captured in the backwater downstream of the proposed water intake for the Taheke Geothermal Development Project (TGDP) in 2012.

Significance of fish species in the Okere River

The data on fish occurrence from the Fish Database indicates that the species present at and in the vicinity of the abstraction site will mostly be downstream migrants from the lakes. The only upstream migrants capable of reaching this site are longfin eels, koaro, and perhaps banded kokopu and torrentfish. With the exception of lacustrine koaro, the other three species were scarce at sample sites in the upper Okere River and, therefore, they appear to be at the upper limit of their distributional range.

Species that can be expected to be present both at and immediately below the abstraction site include rainbow and brown trout, common smelt, and common bullies. In general, the water is too fast-flowing (Figure 3-4) to support a large population of smelt, but trout and bullies are present. Other species that may be found include downstream emigrants such as koaro, goldfish and gambusia, but suitable habitat for goldfish and gambusia is very limited.

Although longfin eels are regarded as being At Risk - Declining under the Department of Conservation's Threat Classification System (Dunn et al. 2018), their occurrence at the abstraction site is expected to be an isolated and rare consequence of stocking the headwater lakes, rather than a natural occurrence related to upstream migration of elvers. Nevertheless, the presence of large female longfins in the upper reaches of the Okere River is significant and is expected to represent a lack of eel harvesting pressure because of the difficult access. Such longfins (Figure 3-6) are an important breeding stock and need to be protected. There are no other species likely to be present at the abstraction site that are threatened or at risk.

The status of the Okere and Kaituna River trout fishery was determined as part of a nationwide telephone survey of New Zealand resident anglers conducted in 1994/5, 2001/2 (Unwin and Image 2003), 2007/08 (Unwin 2009) and 2014/15 (Unwin 2016). These surveys show that up until 2014/15, the Okere and Kaituna River (specific reaches were not identified) was the fourth most popular large river fishery in the region after the Rangitaiki, Tarawera and Whakatane Rivers (Table 3-3). In 2014/15, the Whakatane River had dropped in angler usage to below the Kaituna River for the first time. None of these Bay of Plenty rivers support trout fisheries of national significance (Teirney et al. 1982) and the Okere and Kaituna fishery is less valued than fisheries in the Tarawera and Rangitaiki Rivers that are of regional significance (Table 3-3). Overall, Lake Rotoiti and Rotorua are two of the most popular trout fishing lakes in the Eastern Region with limited fishing in the Okere/Kaituna River.

The upper Okere River was the third most visited river in the Rotorua area after the Ohau Channel and Ngongotaha Stream, but was not as highly valued as either of these latter streams for fisheries (Richardson et al. 1987; Table 3-3). Angling within the upper Okere River only occurs down to the trout pool (end of the road), and therefore is confined to the reach above the proposed TGDP intake. Hence the trout present at the abstraction site, and which may be affected by the abstraction, do not contribute to a significant fishery.

Table 3-3: Estimated angler usage (angler-days) of selected rivers and lakes in the Eastern Fish and Game region for the 1994/5, 2001/2, 2007/8 and 2014/15 angling seasons. Note: usage is for the mainstem river itself and not associated tributaries within the catchment. From Unwin (2009, 2016).

Water	1994/95 usage	2001/02 usage	2007/08 usage	2014/15 usage
Tarawera River	5,010	4,070	1,320	1,370
Rangitaiki River	5,680	9,540	5,030	2,580
Whakatane River	2,230	1,450	1,590	180
Kaituna River	2,460	1,560	410	300
Lake Rotoiti	43,370	40,540	48,070	40,150
Lake Rotorua	40,190	27,510	32,000	17,800
Ngongotaha Stream	8,800	11,240	11,240	7,450
Ohau Channel	4,720	2,180	6,290	1,060

Figure 3-6: Longfin eel (1150 mm) captured by NIWA in the Okere River, weighing approximately 5 kg. NB: many longfin eels captured are double this weight.

3.1.2 Macroinvertebrates

Relatively few studies have been undertaken of the macroinvertebrate fauna of the Okere River. Most investigations have concentrated on assessing the impacts of the AFFCO Freezing Works or other human activities on aquatic health in the lower Kaituna River (Bioresearches 1982; Bioresearches 1991; Bioresearches 1993; Bioresearches 1998; Bioresearches 1999). In 2004, NIWA carried out field surveys of macroinvertebrates at a limited number of sites within the Okere River (mostly on tributaries). These NIWA surveys provided the basis for an initial assessment of the biodiversity of the Kaituna River.

From all existing information, a total of 108 taxa were recorded from up to 7 different habitat types in the Okere River. The fauna was dominated by caddisflies (Trichoptera) and true flies (Diptera), contributing 55% of the biodiversity, with mayflies (Ephemeroptera), stoneflies (Plecoptera), beetles (Coleoptera), Crustacea and snails/mussels (Mollusca) also contributing significantly to overall biodiversity (a further 26%) (Figure 3-7). Pollution sensitive EPT taxa (Ephemeroptera, Plecoptera and Trichoptera) comprised 50% of the total fauna.

Of the crustaceans present within the Okere River, koura (*Paranephrops planifrons*) is widely distributed throughout the catchment and has been recorded in the vicinity of the TGDP intake (Figure 3-8).

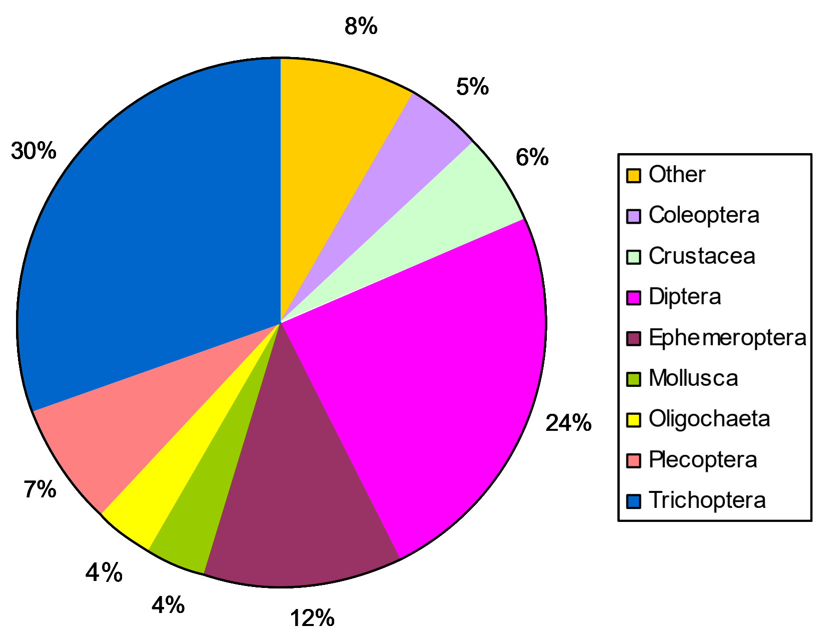

Figure 3-7: Relative occurrence of different macroinvertebrate groups in the Okere River.

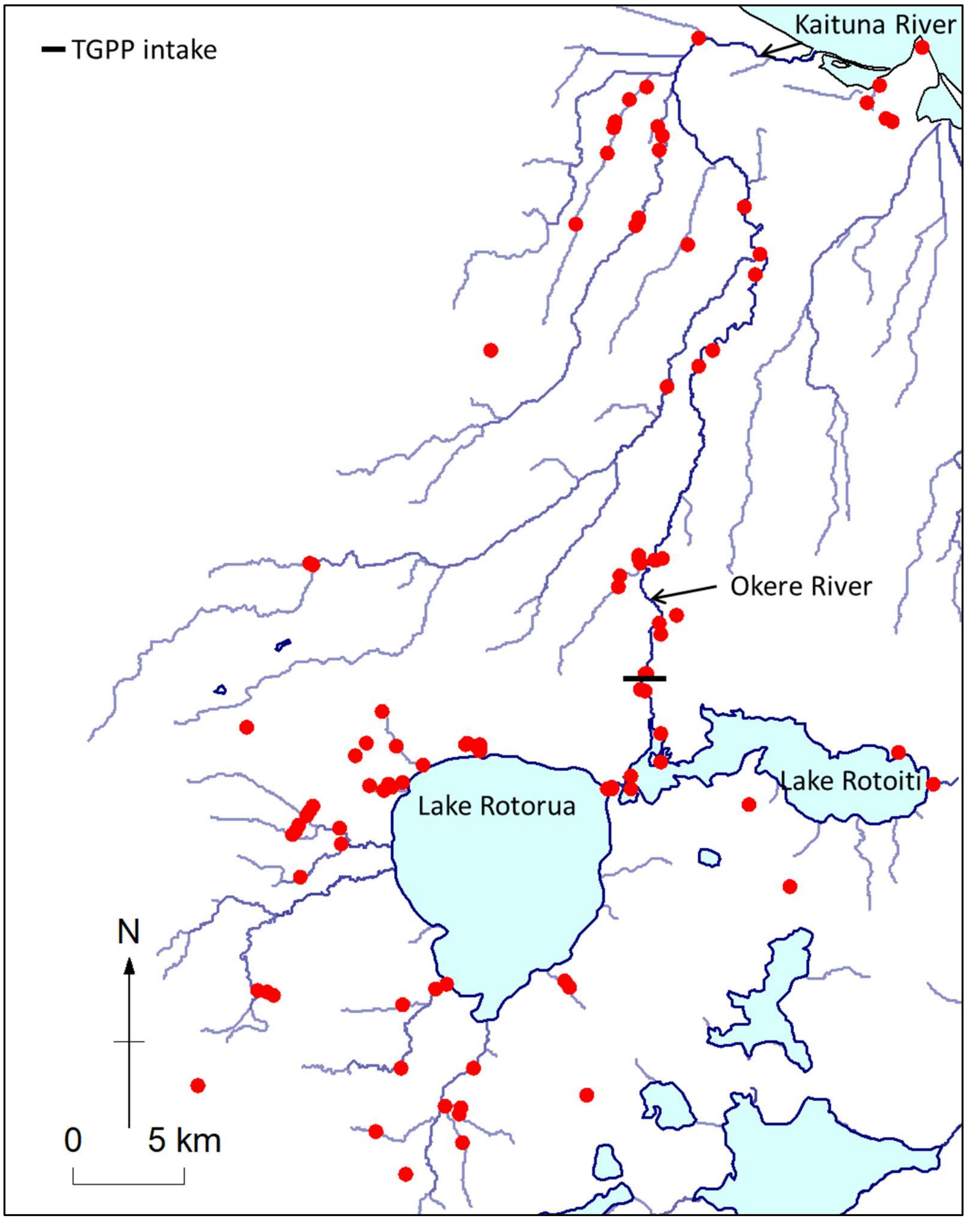

Figure 3-8: Distribution of koura in the Okere and Kaituna River catchment. Records from the New Zealand Freshwater Fish Database (NZFFD). The proposed location of the Taheke Geothermal Development Project (TGDP) water intake is indicated by the solid black line. Note: for clarity only stream orders greater than 3 are depicted.

Significance of macroinvertebrate species in the Okere River

A regional assessment of the relative significance of the Okere River macroinvertebrate communities was undertaken by comparing communities with the lower Kaituna River, Tarawera River (lake-fed) and Mangorewa River (gorge) (NIWA, unpublished data).

When the upper Okere and lower Kaituna River macroinvertebrate assemblages were compared, the results collectively suggest that the Okere and Kaituna River sections support taxonomically different macroinvertebrate faunas, and that there is variation within each river section. The Okere River communities consisted of over double the number of EPT taxa than the Kaituna River. This increase was due to the dominance of Trichoptera (caddisflies), as a similar diversity of Ephemeroptera (mayflies) and Plecoptera (stoneflies) was found between the two river sections. A higher diversity of Diptera (true flies) and Coleoptera (beetles) was also found in the Okere River compared to the Kaituna River, whilst the Kaituna River contained a higher diversity of Crustacea. This highlights the differences in habitats between the Okere and Kaituna River, and suggests that at least some taxa are specific to particular river sections or habitats.

When the Okere and Kaituna River was compared to the Tarawera and Mangorewa Rivers, it was found that the macroinvertebrate assemblage was taxonomically different from either the Tarawera or Mangorewa River (NIWA, unpublished data). As the taxonomic composition of a river will reflect, in part, the availability of habitats, this difference may reflect differences in habitats between the three river systems. However, there was no significant difference in the taxonomic distinctness measures of the Tarawera and Mangorewa Rivers.

While no species of conservation interest were recorded from the Okere River, the NIWA study suggested that the assemblages of macroinvertebrates supported by the Okere and Kaituna River differ from those of both the Mangorewa and Tarawera Rivers.

3.1.3 Macrophytes

The main macrophyte species present in the Okere and Kaituna River are lagarosiphon (*Lagarosiphon major*), elodea (*Elodea canadensis*), nitella (*Nitella* sp.), egeria (*Egeria densa*) and hornwort (*Ceratophyllum demersum*). Lagarosiphon, egeria, elodea and hornwort are all introduced species and are regarded as pests (de Lange et al, 2004; Johnson and Brooke, 1989); only nitella is native. Because of the difficulty in accessing and surveying the Okere River, existing information on macrophytes within the river is limited. Field surveys in selected locations of the Okere River carried out by NIWA in 2004 found that the combination of high velocity and unsuitable substrate excludes macrophytes from virtually all of the upper river. Chambers et al. (1991) demonstrated that macrophyte biomass decreased with increasing water velocities, with macrophytes mostly absent at flows above 1 m s^{-1}.

Hard rock surfaces above and just below the water surface, and in seeps, supported bryophyte (moss and liverwort) communities. In areas of lesser flow, where sunlight penetrates (mostly south facing banks), isolated clumps of macrophytes occurred (e.g. *egeria*) along with associated epiphytes. In well-lit backwaters, where rooting conditions permit, more extensive macrophyte beds can be expected.

Significance of macrophyte species in the Okere River

None of the macrophyte species present in the Okere and Kaituna River is considered rare or of national or regional conservation significance. However, macrophyte beds in general are an important part of the freshwater ecosystem as they provide in-stream cover for fish and habitat for invertebrates (leaf surfaces for grazing and refugia), which in turn provide food for birds. Macrophytes also reduce local current velocities, which stabilises the banks and promotes sedimentation.

3.2 Onepu Stream

The Onepu stream enters the Okere River approximately 2.5 km below the abstraction site. An unnamed tributary enters the Okere River approximately 0.5 km below its confluence with the Onepu Stream, and the Hururu Stream enters the Okere River approximately 2.5 km below this. The mean estimated flows (from the REC) of the Onepu Stream, the unnamed tributary below this and the Hururu Stream are 0.13 m^3/s, 0.21 m^3/s and 1.19 m^3/s respectively. The flow of the Onepu stream into the Okere River is, therefore, well diluted by flows in the Okere River, as well as from the streams entering the Okere River immediately below it.

There are no NZFFD records for fish species in the upper reaches of the Onepu Stream, nor have there been any previous surveys of aquatic biota undertaken. During the site visit undertaken on the 15th November 2012, four sites in Onepu Stream where pipes are proposed to cross or run adjacent to the stream (Sites 1 – 4) were assessed to determine the potential impacts of the piping network on the fish and invertebrate communities present (Figure 3-9). During the site visit on 11th September 2020, only Sites 2 – 4 were assessed as Eastland had confirmed the proposed location for the TGDP and pipework will no longer cross the Onepu Stream at Site 1.

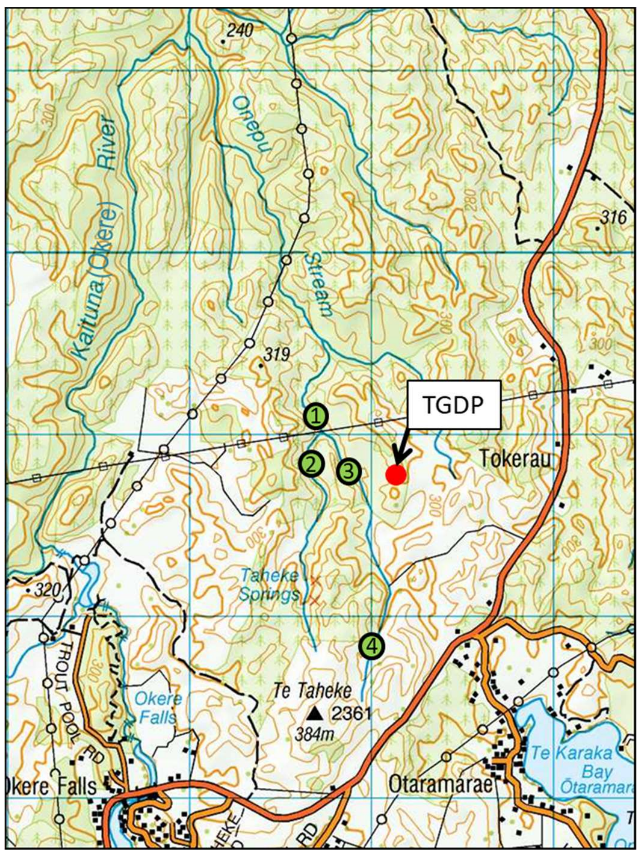

Figure 3-9: Location of the four sites surveyed in Onepu Stream. The proposed location of the Taheke Geothermal Development Project (TGDP) is also shown.

The headwaters of the Onepu Stream are strongly influenced by the Taheke geothermal field. Sites 1 and 2 had high water temperatures (35 & 26-32°C, respectively) and low pH (1.95 & 2.1, respectively) (Table 3-4). This renders the stream unable to support fish life and limits the aquatic biota capable of living in these upper reaches of the stream. In addition, few fish species would be expected in the headwaters of Onepu Stream, because the stream gradient is similar to that of the Okere River, and high water velocities will most likely create natural migration barriers, restricting upstream penetration to fish with strong climbing abilities such as eels, banded kokopu and koaro. However, no diadromous fish species would be able to penetrate up to, or past Site 1 because the geothermal water prevents fish from surviving here.

At both Site 1 and Site 2, the stream was small and heavily sedimented (Figure 3-10 & Figure 3-11). Based on the surrounding land use, which was predominantly forestry, a high level of sedimentation would be expected during flood flows and especially during logging. The only macroinvertebrate species found were blood worms (chironomids), which were common at both sites (Figure 3-11). Their presence was not surprising as bloodworms are often associated with geothermal waters up to 34°C and with a pH down to 1.8 (Winterbourn et al. 2006). A higher diversity of macroinvertebrate fauna is likely to be present at Sites 1 and 2, as three genera of Hydrophilidae beetles and at least two genera of Ephydridae (shore flies) are known to be associated with geothermal waters and these genera occur within the Rotorua region (Winterbourn et al. 2006). However, to comprehensively record all macroinvertebrate fauna present, a detailed investigation with laboratory analyses would be required, which was outside the agreed scope of this report.

Table 3-4: Physical conditions of the four sites surveyed in Onepu Stream. See Figure 4-5 for location of sites. Note: Site 1 was only visited during 2012, Site 3 was ephemeral and dry during both site visits and pH was not measured during the 2020 visit.

Water quality	Site 1		Site 2		Site 3		Site 4	
	2012	2020	2012	2020	2012	2020	2012	2020
Temperature (°C)	35.2	N/A	26.1	31.9	-	-	15.2	9.9
Dissolved Oxygen (%)	83.0	N/A	81.2	92.2	-	-	98.5	70.5
pH	1.95	-	2.1	-	-	-	6.39	-

Figure 3-10: Site 1 in Onepu Stream in 2012.

Figure 3-11: Site 2 in Onepu Stream, locally known as Hot Water Stream. Inset depicts a bloodworm from the stream.

Figure 3-12: Site 3, an ephemeral section of Onepu Stream, dry at the time of inspection in both 2012 and 2020.

Site 3 is ephemeral and was dry during both site visits (Figure 3-12). When flowing, this section of the Onepu Stream is unlikely to support fish species as Site 1 creates a migration barrier to diadromous species. Of the non-diadromous species present within the Okere and Kaituna catchment (Table 3-1 & Table 3-2), all species would require manual introduction as they would not be able to access these headwaters naturally. However, the habitat is not suitable for trout species and goldfish and gambusia are both undesirable species to have within the stream.

Site 4 of the Onepu Stream contained a wetland, which quickly became ephemeral and dry within 100 m downstream (Figure 3-13). Based on the physical conditions, the wetland was the only site deemed capable of supporting fish life (Table 3-4). However, as a geothermal migration barrier (Site 1) and ephemeral stream sections (Site 3) prevent diadromous fish from reaching the wetland, the aquatic biota present at Site 4 will be limited to macroinvertebrates.

It appeared that the majority, if not all of the stream between Sites 3 and 4 was ephemeral and, therefore, could potentially restrict the biodiversity of macroinvertebrate populations capable of colonising this section of the Onepu Stream during intermittent flows. The perched culvert at the downstream end of the wetland will create a barrier to upstream movement of some macroinvertebrate larvae (Figure 3-13b). However, invertebrate community colonisation will be driven by physical habitat, and the habitat differences between the lentic and lotic environments (wetland vs ephemeral stream) will result in different invertebrate communities upstream and downstream of the perched culvert. Therefore, the perched culvert is unlikely to be of ecological significance to macroinvertebrate migrations.

Figure 3-13: Site 4 in Onepu Stream in 2012. A, upper wetland; B, perched culvert at the base of the wetland; C, ephemeral stream below the wetland. Water pipes currently run adjacent to the stream and through the wetland.

4 Effects of the TGDP on aquatic ecology

The effects of the operation of the proposed TGDP on the surrounding aquatic ecology will result from the abstraction of river water from the Okere River for operational uses, and from the construction of the network of piping and vehicle access tracks required for transporting water and geothermal fluids, which crosses the headwaters of the Onepu Stream. Each of these effects is detailed separately in the following sections.

4.1 Okere River – effects of water abstraction

The abstraction of cooling water for the operation of power plants can result in several impacts to the riverine environment. Firstly, large, continuous abstractions can alter river morphology, substrate composition, and alter or reduce habitats for river biota. If large enough, they can also reduce the dilution of heat, contaminants and nutrients downriver of the abstraction site. Secondly, impingement of fish and invertebrates upon the intake screens can occur, along with the entrainment of small invertebrates, fish larvae and eggs through the screens and into the water system.

4.1.1 Abstraction volumes

Eastland and T8C propose to abstract a maximum of 16,500 m^3/day of water from the Okere River. Proposed abstraction rates for both drilling and plant operation are as follows:

- 5,000 m^3/day at a maximum abstraction rate of 70 l/s during drilling.
- 16,500 m^3/day at a maximum abstraction rate of 191 l/s during plant operation.

4.1.2 Effects of abstraction volume on habitats

Large, continuous abstractions can alter river morphology, substrate composition, and change in-stream habitats for aquatic fauna. Under the maximum proposed abstraction rate of 16,500 m^3/day (191 L/s), 1.55% of the mean annual 7-day low flow of the Okere River, and 2.38% of the 100-yr ARI low flow would be taken to operate the TGDP (Table 2-3). The maximum volume of water abstracted (16,500 m^3/day) will reduce water levels by 11 mm during the 100-yr ARI low flow. This reduction is too small to cause any appreciable change in water velocities and will have negligible change to river morphology and substrate composition.

In addition, the maximum take would only be required infrequently. The anticipated continuous abstraction rate is likely to be less than 5,000 m^3/day (maximum rate of 70 L/s). Based on a conservative estimate of continuous demand at 70 and 58 L/s (based on a maximum take of 5,000 m^3/day), these effects reduce to a 4 mm and 2 mm drop in water levels, respectively, during a 100-year ARI low flow event (Table 2-3). Thus, at the proposed continuous abstraction rates, no changes to in-stream habitats for fish, macroinvertebrates or macrophytes would be detectable.

Overall, both the continuous and maximum abstraction volumes are minor in relation to the low flows in the Okere River. Therefore, the effects of the proposed abstraction on the habitats for flora and fauna within the Okere River will be negligible.

4.1.3 Effects of abstraction volume on commercial/recreational river users

The high gradient fast-flowing water of the Okere River has resulted in the river becoming popular for commercial rafting and recreational kayaking since 1992 (Charles 1999). Since then it has become one of the most used whitewater runs in the country, and is an incredibly valuable resource (Charles

1999). The majority of kayaking and rafting occurs upstream of the proposed TGDP intake with two lower class runs; Okere Falls (class 3-4) and Awesome Gorge (class 3+). The Okere Falls run starts at the control gates downstream of Lake Rotoiti, and finishes just above Trout Pool Falls. Awesome Gorge starts just below Trout Pool Falls and finishes at the proposed TGDP intake. Therefore, the proposed water abstraction will not affect the flow and character of the Okere Falls or Awesome Gorge whitewater runs. As the intake structure will be positioned in the deep river channel, close to the substrate, the structure itself should not hinder kayakers and rafters exiting the Okere River at the intake location. Furthermore, the shallow beach most conducive to exiting the river is below the proposed intake location and will still be accessible for kayakers and rafters.

A further whitewater run, Gnarly Gorge, occurs downstream of the proposed TGDP intake. Gnarly Gorge is a treacherous class 5 run, with only experienced kayakers paddling this water, no commercial rafting occurs in this section of the Okere River (Charles 1999). Based on the proposed maximum abstraction rate, and the anticipated continuous abstraction rate reducing water levels by 11 mm and 4 mm, respectively, during the 100-yr ARI low flow, the proposed TGDP abstraction is too small to cause any appreciable change in water velocities and character of the Gnarly Gorge run. Therefore, the proposed TGDP water abstraction will have less than minor effects on commercial rafters and recreational kayakers.

4.1.4 Intake screening

Tan (2012) recommended a Johnson wedge-wire screen (or equivalent product) be utilised at the water intake of the TGDP (Figure 4-1). Wedge-wire screens are widely used throughout New Zealand including the Tauhara intake in the Waikato River near Taupo. The screen is cylindrically shaped and is situated with one of the pointed ends facing into the river flow. The screen is made of wedge-wire with a V-shape profile that allows effective back-flushing to clean the screen (Figure 4-1).

Cylindrical wedge-wire screens can be effective at reducing entrainment of river biota at water intakes providing the screen slot size can physically block passage of the smallest life stage to be protected. Impingement is reduced by a low slot velocity which enables fish to swim away from the screen, and an adequate ambient cross-flow is required to carry organisms and debris around and away from the screens. Tan (2012) has recommended that the screen apertures be 3 mm, with the screen sized to produce a maximum water velocity of 0.2 m/s under the maximum abstraction rate of 16,500 m^3/day (191 L/s).

Presently, New Zealand does not have a national standard or guidance document for intake screening. However, the proposed wedge-wire screen design at the TGDP meets the criteria outlined in the 2007 guidelines produced by the Fish Screen Working Party for protecting aquatic biota from impingement and entrainment impacts (Jamieson et al. 2007).

Tan (2012) proposed locating the intake within a location where sufficient flow to ensure fresh flowing water is abstracted as opposed to stagnant waters (Figure 4-2). The intake will also be located at a depth sufficient to prevent air entrainment that can reduce abstraction flow through the screen during low river flows. From an ecological perspective, placement of the intake can further reduce the susceptibility of biota to impingement and entrainment. As discussed in the following sections (4.1.5 and 4.1.6), siting the intake within the deeper, swifter waters of the main channel will reduce the risk of impingement and entrainment to biota because most target species utilise the slower flowing marginal habitats.

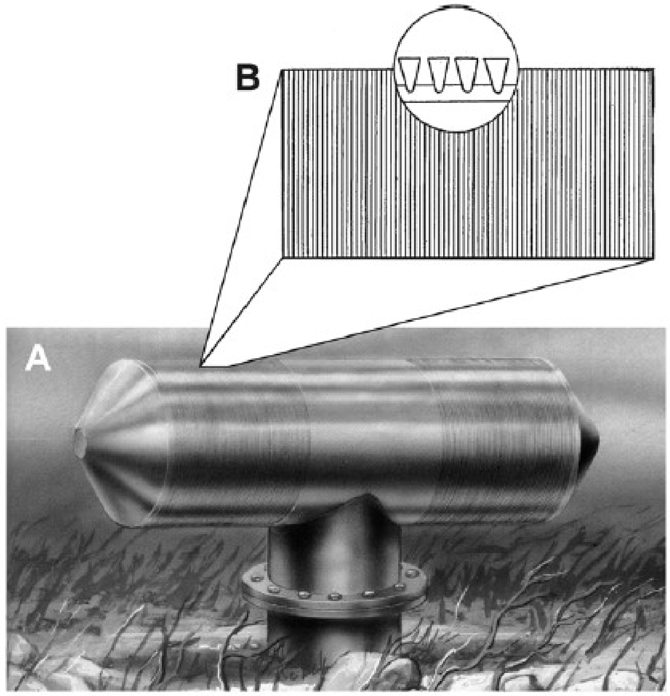

Figure 4-1: A, Cylindrical wedge-wire screen (Johnson Screens™). B, Close up of the wedge shaped wires welded to a cylindrical frame to form a slotted screening element. Reproduced from EPRI (2013).

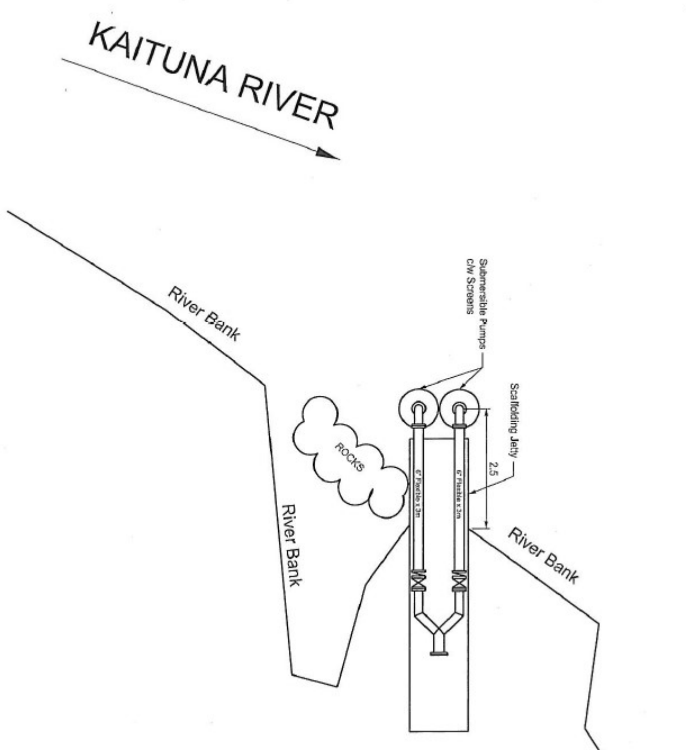

Figure 4-2: Indicative location of the intake screen within the Okere River.

4.1.5 Effects of the intake screen on fish impingement

Wedge-wire screens have been shown to be effective in preventing impingement of a variety of fish species at different types of water intakes (mainly irrigation, municipal water supply, and cooling water intakes) without any major maintenance problems (EPRI 2013). Evidence that the proposed screening system for the TGDP intake will avoid fish impingement comes from power plants in the USA where wedge-wire screens are installed. The Eddystone Generating Station on the Delaware River, Pennsylvania have retrofitted wide mesh wedge-wire screens on the cooling water intakes of Units 1 and 2 (c. 28,000 L/s combined) because over 3 million fish were reportedly impinging over a 20 month period (USEPA 2001). The screens have virtually eliminated fish impingement. Field tests of wedge-wire screens were also carried out in the intake canal of Oyster Creek Nuclear Generating Station in New Jersey. Screens with slot apertures of 1, 2, and 3 mm were tested. The screens were designed to generate an average through slot velocity of 0.15 m/s. Monitoring of the screens in-situ revealed that impingement was negligible for organisms near the screens (EPRI 2007). Larval fish (20–25 mm TL), such as silversides, were seen swimming in the immediate vicinity of the screen in ambient currents of 15–20 cm/s without any signs of difficulty (EPRI 2007).

With respect to the TGDP water intake, it is proposed that with screen apertures of 3 mm, under the maximum abstraction rate of 16,500 m^3/day (191 L/s) water velocities approaching the screen would be a maximum of 0.2 m/s. Of the species potentially present at the intake location only trout and common bullies are resident and relatively common. Their continued presence at this site will depend on downstream recruitment from the lakes and is not dependent on upstream movement past the intake site. Other species that may occur at the intake location from time to time are longfin eels, smelt, koaro, torrentfish, banded kokopu, goldfish and gambusia. Of these species habitat at the intake location is most suited to koaro, torrentfish and longfin eels. Based on swimming abilities, all species will be able to avoid impingement upon the intake screen of the TGDP using their burst swimming mode (Figure 4-3, Franklin et al. 2018).

As common bullies and rainbow trout are the species most likely to occur in the highest abundance at the intake location, impingement effects, if they were to occur, would be greatest on these species. The maximum screen approach velocity will be well within the burst and sustained swimming abilities of these species and the intake location will also be sited within the deeper, swifter waters of the main channel. This will reduce the risk of impingement to common bullies and juvenile trout because the habitat for both these species occurs in slower-flowing marginal waters.

A further factor that will reduce the risk of impingement is that the maximum screen approach velocity of 0.2 m/s would only occur infrequently. The anticipated continuous abstraction rate is likely to be below 5,000 m^3/day (70 L/s). At these lower abstraction rates, screen approach velocities would drop below 0.1 m/s, which would be fully protective of impingement for all fish species.

Given the paucity of fish species present at the proposed intake location and the swimming abilities of those species, impingement effects from the water intake for the TGDP would be less than minor and the wedge-wire screens are deemed the appropriate screening device for protecting juvenile and adult life stages of fish species in the Okere River.

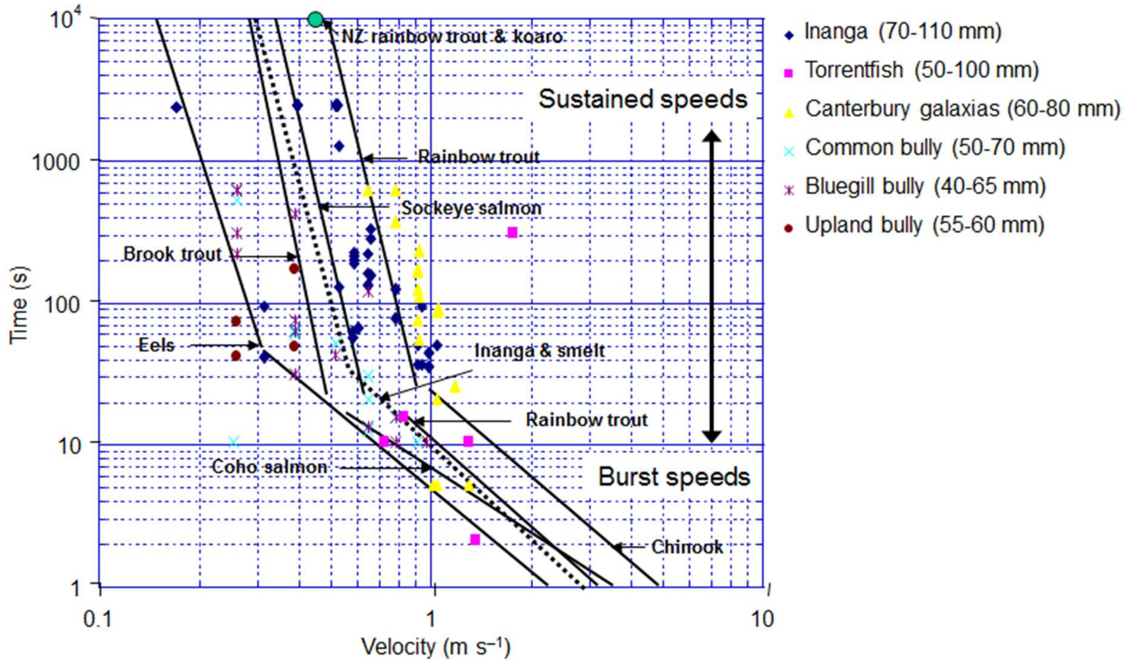

Figure 4-3: Swimming speeds of New Zealand fish compared to swimming speeds calculated for North American fish species. Lengths of fish are detailed in the key alongside the figure (redrawn from Boubée et al. 1999).

4.1.6 Effects of the intake screen on fish entrainment

Although wedge-wire screens can virtually eliminate fish impingement, entrainment of fish eggs and larvae can still occur, especially at larger slot apertures. The 3 mm slot aperture proposed for the intake screen of the TGDP is wide enough to entrain both fish eggs and some fish larvae. Based on international literature, entrainment of eggs and larvae would be markedly reduced using wedge-wire screens as opposed to conventional mesh screens which tend to have apertures of 5 mm or larger. Compared with conventional screens, it has been estimated that the Logan Generating Station in New Jersey has 90% less entrainment of larvae and eggs with 1 mm wedge-wire screens (USEPA 2001). More recently, EPRI (2006) undertook a field study to evaluate the effectiveness of cylindrical wedge-wire screens for protecting the early life stages (eggs and larvae) of fish at cooling water intakes. The study was carried out in Chesapeake Bay and involved comparing the densities of fish entrained within a 'control' intake (fitted with a mesh of 9.5 mm) and two intakes with test screens in place. Sampling was conducted with two different test screens (0.5 and 1.0 mm slot widths) operating at two different intake (or through-slot) velocities (0.15 and 0.30 m/s). Screen sizes were standardised to permit the same intake/through slot velocity to be achieved at each intake when sampling at similar flow rates. In comparison to the control intake, both test screens significantly reduced the entrainment of fish eggs and larvae but the reduction was greater with the smallest slot width (0.5 mm). Through slot velocity also affected entrainment rates. For all species of larvae, the 0.5 mm screen reduced entrainment by 72 and 58%, respectively, at slot velocities of 0.15 and 0.30 m/s.

At the proposed TGDP intake in the upper Okere River, the predicted level of entrainment for eggs and larvae of the fish species that could be present are as follows:

Longfin eels: As eels spawn at sea, no eggs or larvae will be present within the Okere River. The 3 mm apertures of the intake screen would protect juvenile eels (elvers) from entrainment as elvers will be larger than 100 mm if they reach the proposed intake location. Very few, if any, elvers are expected to reach the site because of downstream barriers to their migration.

Rainbow and brown trout: Spawning habitat for rainbow trout is generally in small relatively shallow tributary streams of rivers and it is unlikely to occur in the mainstem pools of the upper Okere River. Brown trout are known to utilise larger streams for spawning in rivers but suitable spawning habitat is unlikely to be present in the upper Okere River. Both species bury their eggs in gravel so that they are not dislodged by stream flow. Hence it is extremely unlikely for trout eggs to be present at the proposed intake location of the TGDP and subject to impingement or entrainment. Trout fry would be the smallest life stage expected to occur here and they would be at little risk of entrainment because their habitat is the shallow margins of rivers, not the deeper, faster-flowing waters where the intake screen will be located.

Banded kokopu and koaro: larvae of banded kokopu and koaro could potentially be washed downstream from tributary spawning streams or the headwater lakes (koaro only). However, banded kokopu have not been recorded upstream of the proposed TGDP intake location and it is extremely unlikely that they have the migratory ability to penetrate this far into the Okere River. Therefore, entrainment of larvae is extremely unlikely and will be negligible at a population level. Koaro predominantly occur as isolated lake-locked populations in the spring-fed inlet streams of lakes Rotorua and Rotoiti. As with banded kokopu, it is extremely unlikely that diadromous koaro will occur at or upstream of the TGDP intake. Consequently entrainment of juvenile, upstream migrants would be negligible. Although larvae of lacustrine koaro could be washed downstream from Lake Rotoiti and entrain in the proposed TGDP intake, this loss would be negligible at a population level and would not have any measurable effect on downstream stocks of diadromous koaro.

Common bullies and common smelt: Larvae of common bullies and common smelt at the intake site will be emigrants from lakes Rotorua and Rotoiti. Although common bullies would be able to spawn within some areas of the upper Okere River, it is probable that a large proportion of the larvae present at the proposed TGDP intake site will have originated from lacustrine populations within the headwater lakes. For example, Rowe et al. (2006) found that densities of larval fish drifting down the Okere River (the outlet for Lake Rotoiti) were an order of magnitude higher than in the Ohau Channel (the outlet for Lake Rotorua). In this regard, any impingement or entrainment of the larvae of smelt and common bullies present in the upper Okere River will not affect lacustrine populations in the lakes, or diadromous stocks further downriver. The position of the proposed TGDP intake, deeper in the main river channel, will further limit entrainment of larval bullies because icthyoplankton studies in the Waikato River have shown that bully larvae are most concentrated at the river margins (Meredith et al. 1989, 1992).

Torrentfish: very little is known about the spawning biology of torrentfish. Male and female torrentfish are spatially distributed within rivers, with female fish penetrating further inland compared to males. This suggests a spawning migration is likely, but the direction of movement is unknown (McDowall 2000). Given the majority of torrentfish are expected to occur downstream of the proposed TGDP intake, it is likely that any entrainment of larvae will represent a minor proportion of the total river population.

In summary, although entrainment of some fish eggs and larvae could potentially occur at the proposed intake location of the TGDP, based on the biology, behaviour and abundance of the fish species likely to be present in the upper Okere River, entrainment effects are likely to be less than minor.

4.1.7 Effects of the intake screen on macroinvertebrates

Some macroinvertebrates are also at risk of impingement and entrainment from water abstraction at the proposed TGDP intake. If the intake is positioned in the deep fast-flowing river channel clear of the stream bed (Figure 4-2), it is anticipated that only downstream drifting invertebrates would be at risk of impingement and entrainment. This is because upstream moving invertebrates including koura are generally benthic and move upstream along the substrate.

Downstream drift is a well-documented dispersal mechanism for macroinvertebrates (Townsend and Hildrew 1976). Based on genetic studies, within stream dispersal of invertebrate larvae was limited, and ranged from 0.11 to 2.5 km (Schultheis et al. 2002). Therefore, effects of impingement and entrainment would be localised to macroinvertebrate populations that occur within the c. 2 km section of river upstream of the TGDP intake.

By utilising wedge-wires screens losses of macroinvertebrate fauna from impingement and entrainment is expected to be minimal. For example, a cyclindrical wedge-wire screen with 2 mm apertures was tested in-situ for subsequent installation at the intake of a seawater desalination plant in Santa Cruz (Tenera Environmental 2010). At a maximum through slot velocity of 0.10 m/s the screen was successful in completely eliminating impingement of shrimps and crabs. Video footage showed that all amphipods and shrimps that encountered the screen were able to free themselves after contact (Figure 4-4). Field tests of wedge-wire screens with slot apertures of 1, 2, and 3 mm were carried out in the intake canal of Oyster Creek Nuclear Generating Station in New Jersey (EPRI 2007). With an average through slot velocity of 0.15 m/s, some invertebrates were found impinged on the screen, however, many crabs, amphipods, and isopods were seen moving freely along the screen face.

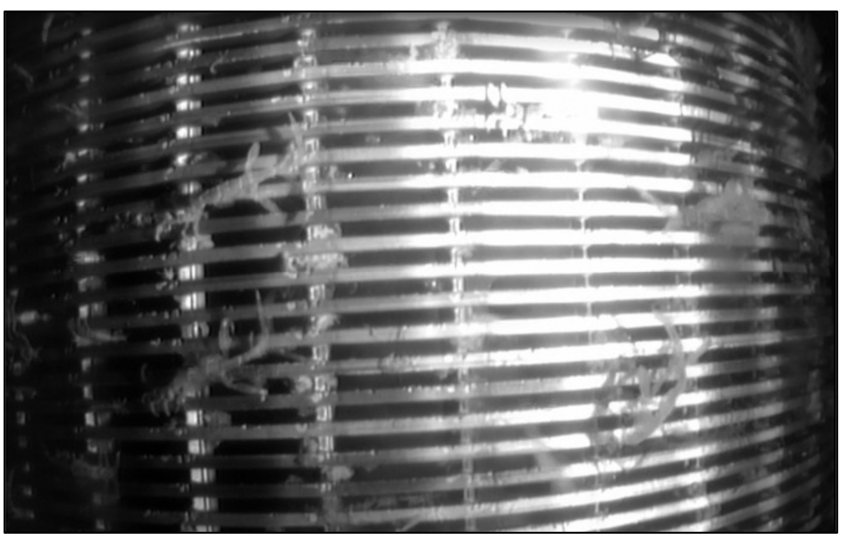

Figure 4-4: Amphipods in contact with a wedge-wire screen with a maximum through-slot water velocity of 0.1 m/s. All amphipods observed were capable of swimming away freely. Photo taken from Tenera Environmental (2010).

Although the maximum screen approach velocity at the TGDP intake is proposed to be 0.2 m/s, this would only occur very infrequently. The anticipated continuous abstraction rate is likely to be less than 5,000 m^3/day (70 L/s). At these lower abstraction rates, screen approach velocities would drop below 0.1 m/s, which will be protective of impingement for virtually all macroinvertebrate species. Although some entrainment of smaller macroinvertebrates will occur, these losses will be localised to drifting taxa present upstream of the proposed TGDP intake, and will have no measurable effect on macroinvertebrate populations in the river. Hence effects of invertebrate impingement and entrainment on trout feeding are expected to be negligible. As such, the effects of the proposed water abstraction for the TGDP on both invertebrate densities and trout feeding in the Okere River at and below the intake site will be less than minor.

4.1.8 Effects of the intake screen on macrophytes

Because of the high flow velocity and large substrates found in the Okere River, any macrophyte beds will be restricted to shallow marginal habitats and backwaters or pools. The main effects of the proposed TGDP abstraction on macrophytes would be by reducing water levels downstream of the intake and exposing beds to desiccation. As discussed above, the effects of the maximum proposed abstraction of 16,500 m^3/day (191 L/s) will have no appreciable change on water levels and water velocities within the Okere River that would influence macrophyte growth and establishment. Therefore the maximum proposed abstraction rate will have less than minor effects on macrophytes within the Okere River.

4.2 Onepu Stream – effect of pipeline construction

4.2.1 Proposed piping network

The proposed TGDP will utilise a network of pipelines to transport both water and geothermal fluids. In addition to supplying the power plant, it is proposed that water will also be piped to the drilling water reservoirs and well pads, and to separator stations. Geothermal fluids will also be piped from production wellheads to the generating plants and then on to reinjection (Figure 4-5). The proposed siting of the piping corridor will cross the headwaters of the Onepu Stream at three locations (Figure 4-5). As such, the construction and presence of the pipes, and any further vehicle tracks required for their maintenance, could impact upon the aquatic biota within the Onepu Stream.

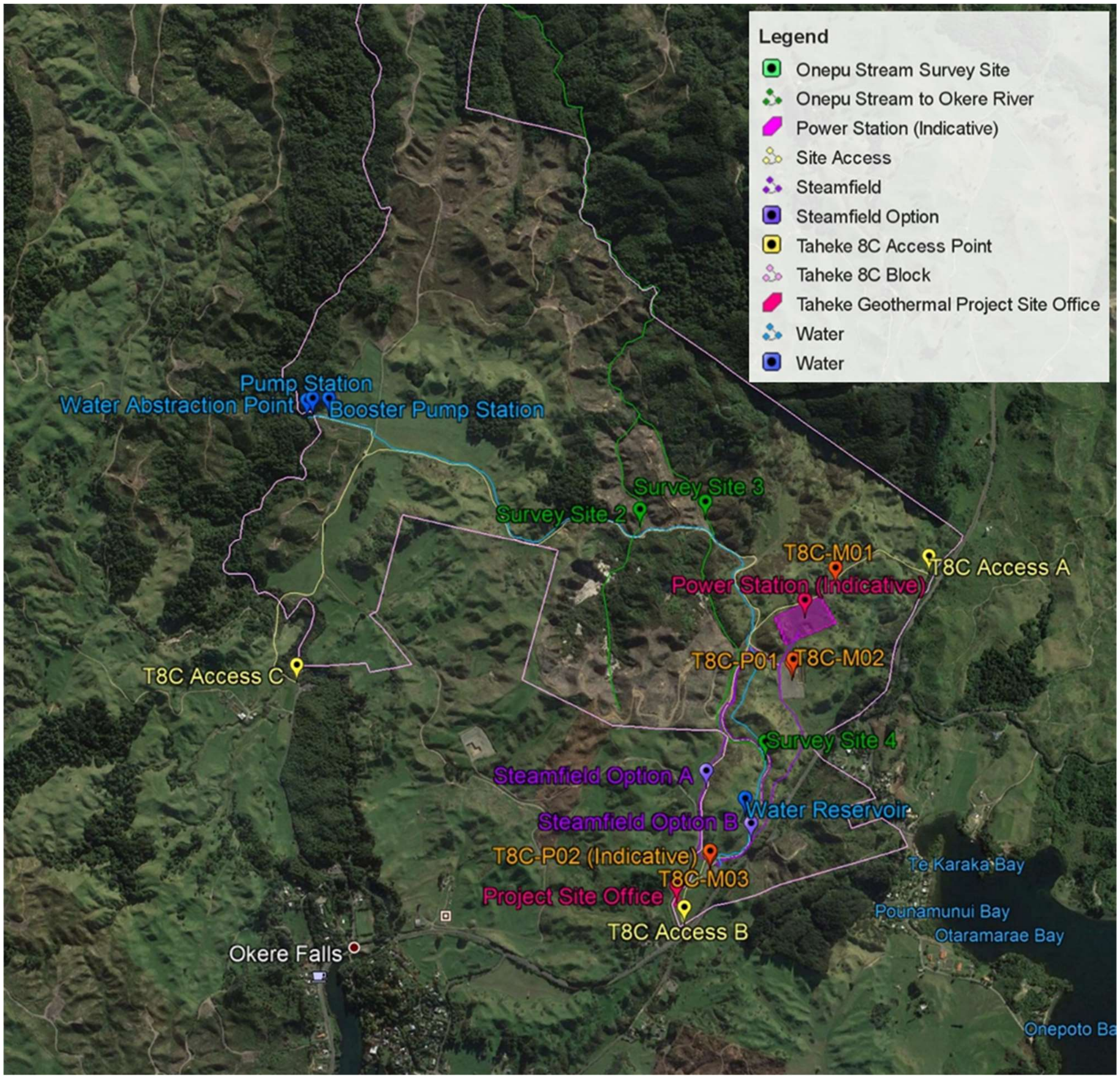

Figure 4-5: Proposed site layout for the Taheke Geothermal Power Plant (TGDP) showing the three locations (Sites 2–4) the piping network that will cross the headwaters of the Onepu Stream, and the four sites surveyed.

4.2.2 Effects of pipeline construction

Pipelines transporting geothermal fluid are constructed with the underside of the pipe approximately 800 mm clear of the ground (Bannwarth et al. 2012). This is to provide space to fit drain valves. Based on the small size of the Onepu Stream, 800 mm ground clearance is sufficient to prevent the pipelines from affecting the stream flow and impacting on aquatic biota. Where the pipelines cross the Onepu Stream, the supports for the pipelines should be placed outside of the stream channel so the stream flow remains uninterrupted.

During installation of the pipeline network and any associated access roads (over and above the current vehicle tracks) there will be some disturbance to the stream beds, siltation of substrate and increases in turbidity downstream. Because these streams are geothermally influenced and occur within a heavily modified (mainly forested) catchment, they do not support valued species, communities or environments. Hence, the effects of increased siltation and turbidity in the stream sites affected by construction activities will not reduce any threatened species, communities, environments or fisheries.

Any effects at or downstream of the construction activities can be minimised by the use of appropriate measures to avoid significant adverse effects on stream water quality and biota. These include always ensuring that works do not contaminate water quality downstream, and that sedimentation into the stream is minimised though ‘best-practice’ silt-trapping methods incorporated into a sediment management plan.

If the works are carried out as described above there will be negligible effects of the pipeline network on the water quality and stream biota within Onepu Stream.

5 Conclusions

The construction, commissioning and operation of the proposed TGDP has potential impacts on the hydrology and aquatic ecology of the Okere River, which arise from the abstraction of river water for operational uses. In addition, the network of piping required for transporting water and geothermal fluids, crosses the headwaters of the Onepu Stream at three locations and could therefore potentially impact upon the aquatic ecology of the stream.

5.1 Okere River

Large, continuous abstractions can alter river morphology, substrate composition, and change in-stream habitats for aquatic fauna. Furthermore, at the abstraction site impingement of fish and invertebrates upon the intake screens can occur, along with the entrainment of small fish larvae and eggs through the screens and into the water system.

The effects of the maximum infrequent abstraction rates proposed on the hydrology of the Okere River would be small, representing 2.38% of the 100-yr ARI low flow, which is equivalent to an 11 mm drop in river level at the Taheke flow recorder. At the more commonly used abstraction rates of 70 and 58 L/s (based on 5,000 m^3/day), these effects reduce to a 4 mm and 2 mm drop in water levels, respectively, during a 100-year ARI low flow event.

The proposed wedge-wire intake screens are considered best practice at cooling water intakes for reducing impingement and entrainment impacts on aquatic biota. Although New Zealand does not have a national guidance document for intake screening, the proposed wedge-wire screen design at the TGDP meets the criteria outlined in the 2007 guidelines produced by the Fish Screen Working Party for protecting aquatic biota from impingement and entrainment impacts. From an ecological perspective, placement of the intake can further reduce the susceptibility of biota to impingement and entrainment. We recommend siting the intake within the deeper, swifter waters of the main channel to reduce the risks to river biota because most target species utilise the slower flowing marginal habitats.

Overall, the ecological effects on fish, macroinvertebrates and macrophytes as a result of water abstraction from the Okere River, are deemed less than minor.

5.2 Onepu Stream

The piping network which transects the Onepu Stream headwaters will be set 800 mm above the stream and is, therefore, unlikely to impact the ecology of the stream.

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