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Bay of Plenty Regional Council

Assessment of Flooding and Drainage Issues at Kopuriki

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Contents

Figures

Executive Summary

The Rangitaiki River was dammed at Aniwhenua (now called Aniwaniwa) in 1980 to form the 4.4 km long Lake Aniwaniwa. The Lake is relatively shallow and over the ensuing 37 years a delta has formed which now extends some 1.2km into what was clear water when the lake was filled. The effect of the delta is to lengthen the flow path and reduce the gradient for the Rangitaiki River to reach the lake. The change in gradient of the channel has led directly to a change in form of the river; from an incised meander to a highly braided, multi-channel delta. There has been a consequent rise in normal water levels and flood levels experienced at properties upstream of the Kopuriki Road bridge. Currently some 44 ha of land are adversely affected by impaired drainage. Flood levels are elevated over what would have existed immediately after lake filling over a reach at least as far upstream as the Horomanga confluence.

The option which provides most surety and longevity around both drainage and flood impacts is to construct and maintain a clear waterway for the Rangitaiki River out into the lake along the eastern shoreline. This action will have benefits for a number of parties by:

- Improving drainage and flood protection to land upstream of Kopuriki
- Protecting the Whakatāne District roading assets at Kopuriki
- Preventing further infill of the shallow wetlands on the south western shore of the Lake
- Maintaining the lake as open water area with useful depth for recreation
- Maintaining the live storage for hydro generation purposes

Without intervention, the delta will continue to progress down the lake and slowly but steadily increase water levels in the Kopuriki area. However it is important to recognise that any “solution’ can only mitigate the problem and in effect treat the symptoms and will require on-going maintenance intervention. The fundamental problem caused by the change in gradient and level of the river through this reach remains.

1 Introduction

1.1 Background

The Rangitaiki River was dammed at Aniwhenua (now called Aniwaniwa) in 1980 to form the 4.4 km long Lake Aniwaniwa (Figure 1). The barrage forming the lake is relatively low and the lake was quite shallow with a maximum depth of around 10 m over the original river channel and much of the lake being between 2-5 m depth. Land was acquired by the power scheme for the purposes of forming the lake and reserve areas beside it.

Immediately after the lake was formed a delta commenced to form at the upstream end and has gradually extended downstream from the (relocated) Kopuriki Road Bridge (Rabbit Bridge). The change in gradient of the channel has led directly to the change in the river form; from an incised meander to the highly braided, multi-channel delta. This was a foreseen consequence of the dam construction as the upper end of the lake was too shallow for the sediment travelling down the river to be accommodated in the “dead storage” of the dam. These matters were traversed at the original (pre RMA) planning hearings and appeal before the Planning Tribunal. The sedimentation and possible adverse effects on land immediately upstream were recognised at the Planning Tribunal hearings but apparently not given weight in comparison to the benefits of the electricity generation.

The continued accretion of the Kopuriki Delta is seen by landowners adjacent the Rangitaiki River upstream of the Kopuriki bridge as contributing to flooding and drainage issues on their properties. This has been a source of concern to them since the lake filled.

Responsibility for the lake and river lies with both the power scheme owner (currently Pioneer Energy) and the Bay of Plenty Regional Council (BOPRC). BOPRC’s main responsibility is for river control and flood management for the river upstream of Kopuriki Bridge.

Following pressure from the landowners and the wider Galatea community, works have been undertaken both immediately upstream and downstream of Kopuriki Bridge on a number of occasions since the dam was built, but principally since 2009. Largely these works have been funded by the power scheme owner (previously BOPE and Nova) and implemented by BOPRC.

However the concern remains that there is a continuing gradual increase in river water levels. This was brought to a head with the April 2017 storms which saw widespread flooding and pasture damage at a number of locations in the Galatea basin, including around Kopuriki. Accordingly BOPRC commissioned Opus Consultants to undertake a review of the river morphology and provide options for management of the effects of the power scheme upon upstream lands.

The brief for this report is to present options for management of sedimentation with advantages, disadvantages and costs. This can then be used as a basis for consultation with affected parties. Input from affected parties will determine the feasibility of options.

1.2 Key Issues

The effects of the delta formation on the upstream lands at Kopuriki fall into two distinct albeit related aspects:

1.2.1 Land Drainage

Firstly there is the loss of drainage under normal river levels. The Rangitaiki River water level at the Kopuriki Bridge is now some 300 mm higher (as an annual median, more in winter) than it was after lake filling in 1980 due to the delta. In effect the river now has to flow some 1.2 km further into what was initially lake, and this requires a water surface gradient. This is especially evident in winter when river flows are higher, this results in high groundwater levels that approach the ground surface on the low ground adjacent the river.

In all some 23 ha of land are affected with groundwater normally within 500mm of the surface and 44 ha of land have water within 1.0m of the surface. The effects of this drainage impediment are to restrict pasture growth, promote weed growth in pasture at the expense of higher producing grasses and severely curtail the ability to traffic the ground with machinery. Livestock pug the ground under wet conditions. These areas are shown on Figure 3. The drainage affected areas have been plotted from LIDAR survey, taking a point at RL 147.2m as reference. When inspected in August 2017 this point was the commencement of surface water at the north end of the Healey property.

1.2.2 Flooding

A main consequence of the delta formation is that the passage of floodwaters into the lake is impeded. This is the result of aggradation of the Rangitaiki river bed over the reach immediately upstream and downstream of the Kopuriki Bridge, but more particularly by the multiple branching of the main river stem as it enters the lake. The single channel at Kopuriki bridge splits into 2-3 main channels and some 5-6 smaller subchannels. These are shallow and prone to willow growth and encroachment which slows the flow and causes sediment to deposit. Consequently the passage of larger floods out into the lake is restricted. The effects of the restriction on peak water levels upstream of Kopuriki Bridge do vary depending on the lake level (see Section 2.2 below) and on the delta configuration. The extent of upstream influence is not well defined but would appear to extend upstream to at least as far as the Horomanga confluence at 5.2 km upstream from Rabbit Bridge (by river).

Higher flood levels result in more water spilling onto farmland more frequently with consequent silt deposition, bank erosion, damage to pastures, fencing and ponding.

1.3 Land ownership

The land around the head of the lake is in a large number of parcels, comprising various portions of lake reserve, riparian margin, road reserve and old river bed. Upstream of the original (1980) lake bed and foreshore reserves (now owned by Pioneer Energy) the land is in freehold title. The property owners are Healey, Ng and Bridgeman (true left up to Horomanga confluence) and Noe on the true right.

A brief review of the land titles was undertaken. The original lake bed is noted as for hydroelectric purposes, as is the lakeshore reserve. Generally the titles for the land upstream of the original lake have no encumbrances or covenants on the title that the land is subject to flooding or otherwise affected by the hydro lake.

1.4 Resource Consents

Two resource consents are relevant to the operation of Lake Aniwaniwa:

1.4.1 Water Right No 190

The damming of the Rangitaiki River to form Lake Aniwaniwa (then Aniwhenua) was originally authorised by Water Right 190 issued under the Water & Soil Conservation Act 1967 by the Bay of Plenty Catchment Commission and Regional Water Board dated 4th December 1975. With the passage of the RMA in 1991 this Water Right became an RMA consent with a termination date of 1 October 2026 as per the sunset provisions for existing permits under the RMA.

Consent 190 has been varied a number of times over the years and ownership transferred through the various entities that have owned the scheme. The changes have been relatively minor being mainly around details of flows through the power station etc.

The key conditions relevant to consideration of the sedimentation, flooding and drainage issues are sparse and can be summarised as:

Rights conferred:

(a) Dam the Rangitaiki River and Pokairoa Stream at the their confluence to form a lake to be known as the "Aniwhenua Lake" (Map reference N86:235829)

Condition 2 Lake Aniwhenua Water Levels

Condition 2.1 defines the term '*water level*' to be the level of the water of Lake Aniwhenua to Moturiki datum as "*measured on a gauge to be installed…as close as practicable to the entrance of the canal leading from Lake Aniwhenua to the Pahekeheke headpond*"

Condition 2.2 sets the normal operating level range of Lake Aniwhenua as 146.6m to 146.8m (Aniwhenua local datum).

Commentary: Conditions 2.1 and 2.2 define "Lake Aniwhenua" level for compliance purposes. It appears that to date the Consent holders and the Bay of Plenty Regional Council have taken the compliance point as solely the above mentioned staff gauge location and not the lake as a whole as defined by the original foreshore. Under this interpretation the water level at Kopuriki, while now exceeding the maximum lake level, is presumably deemed to be complying.

Condition 6 Sediment surveys

Condition 6 requires the consent holder to establish at least 6 cross sections of the lake and survey these at least once annually, "to determine the amount of siltation occurring". Results are to be sent to the Regional Water Board (Council).

Commentary: This is the only reference in the consent to sedimentation. There is no requirement anywhere to manage sediment accumulation.

Condition 10 Groundwater Table

Conditions 10.1 and 10.2 required the Grantee to establish groundwater monitoring bores on properties adjoining the lake and record levels quarterly. This could be changed or cancelled after 2 years.

Commentary: These bores are no longer being monitored according to BOPRC.

Condition 12 Lake Shore Reserve

Condition 12 required the setting aside of a 20m foreshore reserve around the whole lake as a public reserve.

Condition 13 Existing streams and drains

This required the Grantee to maintain drainage of specified streams and drains through the foreshore reserve.

Commentary: A plan of drains is specified but has not been viewed.

1.4.2 Consent 64684

Consent 64684 is the general consent for work in rivers held by the Rivers & Drainage Group of BOPRC. Work carried out by BOPRC in the Rangitaiki River at Kopuriki, downstream and upstream of the Rabbit Bridge, has been undertaken under this consent.

2 Lake Aniwaniwa and the Rangitaiki River

2.1 Lake Accretion Rates

Under the resource consent which the power scheme operates, the power scheme operator is required to survey the lake bed on an annual basis. This is done at 9 main cross section locations (Figure 1). These surveys have been undertaken since lake formation in 1980.

The survey data has been analysed for this study. Commencing from the 1980 lake formation survey, we have looked at changes on approximately a 5 yearly interval. A key objective is to understand how rapidly the lake is infilling and what proportion of the sediment passing under the Kopuriki bridge is passing completely through the lake and out the barrage.

The lake surveys are helpful in defining trends but do not fully establish the sediment transport dynamics.

Estimates have been made in previous reports of the sediment transport rate into the Lake. This is variously estimated between 60,000 and 100,000 m^3/annum (BOPRC File notes). In practice it is difficult to be precise about how much sediment would pass under Rabbit Bridge on an annual basis. Principally this is as the sediment transport occurs in an episodic manner driven by large floods and changes in the catchments upstream. In reality the actual quantity is of somewhat academic interest, the important factor is the nett accumulation in the lake and hence the rate at which the delta progresses down the lake. This is measurable from survey (also see Section 6.1 below on future monitoring).

The key findings of this analysis are (Appendix 1) :

- At sections 6 and 7 immediately downstream of the current end of the delta, the lake is largely infilled, with water depths now only 1-1.5m over the full width of the lake.

- At sections 6 & 7 the original river channel is now completely infilled, meaning a rise in bed level of 4-5m from the deepest point originally (1980)

- At Section 6 a slightly deeper channel (approximately 2m) remains on the east of the lake, where flow from one of the main river threads enters the lake.

- Further downstream at Sections 10 and 11, the lake bed as a whole has risen by a lesser amount, typically between 0.5 - 1.0 m.

- At Sections 10 and 11 the sedimentation in the original river channel has been more pronounced, with a rise in bed level of around 2.0m.

2.2 Lake levels

2.2.1 Operating Range

Lake Aniwaniwa is operated under a narrow operating range under normal power generation conditions. This is 200mm between RL 146.32m and 146.52m (BOPRC datum. The original operating range was quoted in a BOPE datum of Moturiki + 0.28m ie 146.6 m to 146.8m). This is the "live storage". Sediment that accumulates within this range is a disbenefit to the power scheme operator as it reduces their ability to hold back water for optimum generation times during the daily power peak. Sediment accumulating beneath RL 146.32 in the "dead storage" is less of a concern to the power scheme.

Below the normal operating range, the lake is on occasion drawn down by anything up to 2 m using the radial gates on the barrage. This can be for weed control purposes. The lake is also drawn down in flood conditions to create a strong gradient at the delta margin and so draw more sediment into the dead storage and in fact right through the lake to the outlet gates.

The standard operating procedure is to draw down the lake level when flow in the Rangitaiki River is > 90 m^3/s (a moderate fresh in the river). There is a progressive response proscribed by the operating rules with more aggressive drawdown as river flows increase.

2.2.2 Lake levels at Kopuriki road

Visual inspection confirmed by survey during August and September 2017 showed that there is a water level difference of up to 600mm across the western section of the Kopuriki Rd approach embankment (Figure 2). This difference has led to the suggestion from landowners that a culvert be put through the western embankment to assist in draining the upstream lands. This possible action is discussed further in Section 4.2.

This survey observation suggests that the water level immediately downstream of the Kopuriki west embankment is close to or in fact is, lake level. As opposed to the water level in the river at Kopuriki bridge which is manifestly higher. To better understand the relative levels we undertook an inspection of the lake from a boat in September 2017 and carried out soundings at a number of locations.

This revealed:

- The delta has not as yet reached fully across on the western shore of the lake (Figure 2). This leaves a section of the original river channel where it used to flow hard against the true left bank

- The water depth in the remnant channel is around 3-3.5m, so is not overly deep. The width between the western shore and the delta shingle banks is typically 30m, but only 20m at the narrowest point

- At the current downstream extent of the delta at some 60-100m upstream of cross section 6, the water depth is only 1.0 -1.4 m deep

- Immediately upstream of the Kopuriki bridge on the true left (west) side, the channel which leads from the main river out into the western lagoon is 15m wide and 1.5m deep.

This remnant of the lake is therefore allowing the shallow wetland area downstream of the Kopuriki west approach embankment to drain and maintain at lake level. Once the delta infills across onto the western shore the lagoon area immediately downstream of the Kopuriki road embankment will be dammed off and in time water level will rise to meet the river level at the bridge.

2.3 Rangitaiki River Levels

2.3.1 River Levels at Kopuriki (Rabbit) Bridge

There has been a level recorder at the Rabbit Bridge since 2010. This replaces a previous recorder site that was drowned when the lake was formed. The period of record is thus somewhat limiting as it doesn't include the first 30 years of the lake.

Nonetheless a useful insight into the long term trends of water level can be gained from this record. It can be assumed that in 1980 the river level at the bridge would have been lake level or very close to it. An analysis of the water level record is included as Appendix 2.

Key findings from the analysis of the water level record are shown in Table 1:

Lake Level (midpoint of range) m	Water level case	Level at Kopuriki Bridge(m)	Level at Healey Boundary (m)	Water level rise (m)
146.42	Annual median	146.67	146.78	0.36
	Median Spring	146.67	146.783	0.363
	Upper Quartile spring	146.73	146.84	0.42
	Maximum spring	147.11	147.226	0.806
	August	146.79	146.90	0.48

Table 1: Water Level analysis

Notes to Table 1: - All levels are Moturiki datum

- Level at Healey boundary taken as Kopuriki plus distance times river slope of 0.00023m/m

Table 1 shows that water levels in winter and spring conditions are typically around 0.4m higher than in 1980. When the Lake was first filled the lake finished some 200 m upstream of Rabbit bridge, ie Kopuriki Road was on a causeway in the lake bed.

An analysis of long term trends in the level at Kopuriki recorder has also been undertaken (Figures 5 & 6 in Appendix 2). The data has been presented as a 7 day moving average, to smooth out the effects of minor freshes and of the upstream power schemes at Wheao and Flaxy, and also as monthly minima to show the effect on base water levels.

The long term trend in level is affected by lake drawdown events, flood scour and other interventions. However it is apparent that in periods of relatively stable flows, such as 2012 through to 2015 there is a gradual rising trend of around 80mm/year. The correlation in the data for the 7 day moving mean is only moderate (coefficient 0.6). The correlation for the monthly minima is much stronger (0.86) and clearly shows a strong time trend. This reflects the gradual accretion in the delta area pushing up river levels.

2.3.2 Bed levels in the Rangitaiki River upstream of Rabbit Bridge

While the lake surveys are the responsibility of the electricity generator under the resource consent, the survey of the river upstream of Rabbit Bridge is undertaken by BOPRC as part of their river management role. Sections are surveyed on a 5 yearly basis. The sections are spaced at approximately 1.0 km intervals from Rabbit Bridge up to Murupara.

Examination of the bed levels shows a definite accretion of the river bed over the reach from the Rabbit bridge up to at least the Horomanga confluence.

The bed levels at the bridge itself vary quite widely (ie by up to 2 m) and are currently more reflective of flood scour events than accretion due to the delta. There was a large rise in bed level under Rabbit bridge of 3 m over the years after the dam was filled.

2.3.3 Flood levels upstream of Kopuriki

Figure 4 shows the reach of the Rangitaiki River from Kopuriki to the Horomanga River confluence. The effect of the delta on flood levels in this reach is not well defined by available measurements. In particular there is no rating applied at the Kopuriki Bridge recorder site (ie it only records water level). This is as the cross section scours in floods and it is not feasible to establish a flood flow rating. Flood flows into the lake would have to be back calculated from the power station discharge after allowing for attenuation through the lake, or estimated from upstream recording sites at Whirinaki and Murupara (as per Water Right 190).

Nonetheless, given the constricted nature of the river exit into the lake, as apparent from the 2016 aerial imagery (Figure 2), supported by our observations in the lake, it is reasonable to expect that the delta is causing flood levels to rise for any given flood magnitude. As the delta extends further into the lake, then less gradient is available for the river hydraulic grade line and water levels upstream must rise to compensate. Anecdotally, observations from the upstream landowners support this. They note that even when the lake is drawn down, this has only minor effect on water level in the river at their properties.

Modelling of flood flows by BOPRC (File note “Flood Water Levels for Different Flows: Existing Scheme”) shows a steeper gradient through the delta area (implying more flow resistance over this reach), a slight rise of 100mm approx. through the Rabbit Bridge constriction and then a backwater effect persisting to chainage 5000m (Horomanga confluence) at which point flood levels for flows in excess of 170 m^3/s return to the indicative “Historic Water Surface Slope”.

Specific modelling would need to be undertaken to more accurately establish the levels upstream of Rabbit Bridge for a particular flood discharge and how this would change with differing conditions in the delta. This work would need to be undertaken to establish the optimum channel width if a channel clearway option is chosen (Section 4.3).

2.4 The Delta

The delta currently extends 1.2km into the lake. Currently the Rangitaiki River flows in one defined channel for 600m downstream of the Kopuriki Bridge. There is one side flow to the west at 150m downstream where the original lake training groyne ended. Generally this is kept closed off by BOPRC to stop flow out to the west, but the river bank scoured out in April 2017 and some flow was still running down it in August.

At 600m downstream there is a major bifurcation with slightly over half the flow taking the western branch. Both channels then further branch to form several sub channels flowing into the lake. When observed in September 2017 there was strong flow from a subchannel into the western lake area (Figure 2).

The delta is formed of a fine gravel (reported as generally <10mm) with sand and silts. There is thick growth over the islands, with grass on the recent deposits by the water’s edge and then pampas and dense willow thickets on the older and higher sand banks. The vegetation would have a high roughness and resistance to flow.

Where the delta currently ends at around cross section 6 (1.2km downstream of the bridge) the lake is 240m in width and relatively shallow at around 1.5m depth with no remnant of the original river channel.

3 River Works To Date

3.1 Works in the Rangitaiki River Channel

A number of works have been undertaken over the years to attempt to influence the rate and location of the delta formation.

When the lake was formed rock protected training groynes were built both upstream and downstream on either side of Kopuriki Bridge to direct river flow (and presumably targeting sediment) out into the lake proper.

For a number of years after this only limited works were undertaken, mainly to maintain the groynes and keep the river downstream of the bridge to a single channel. However by 2000 this was somewhat of a lost cause.

A renewed effort was put into maintenance of the river channel from 2009. Actions taken over the period 2009 to present are summarised in Appendix 3.

The main action was to dredge (by land based long reach excavator) the channel from 400m upstream of the bridge down to the bifurcation. This work removed an estimated 22,000 m^3 of sediment (placed into the bunds and islands beside the river). However this work did not close off the western channel or extend the main channel down to the lake. Subsequent to this major intervention further flood damage repairs and river training works were carried out after floods in 2010 through to 2012. These works were implemented by BOPRC under consent 64684 largely using funding from BOPE.

3.2 Management of the Lake Sedimentation

Two major dredging operations were undertaken by BOPE in the late 1990's. This work was carried out by Heron Dredging using a cutter suction dredge. One operation was in the western side bay immediately upstream of the barrage (Pokairoa stream delta). A second operation was in the main body of the lake approximately between sections 7 and 9 (Figure 1). The quantity of material moved is not known but may be available in old BOPE records. Presumably it would have been in the tens of thousands of cubic metres to justify the high establishment cost of the dredge. Dredging has also been undertaken in the last 2 years immediately upstream of the barrage. This is to minimise sediment entering the headrace canal from the Pokairoa stream.

As part of the lake management, NOVA (now operating the hydro scheme on behalf of Pioneer Energy) do draw down the lake immediately in advance of floods. This is with the intent of forming a steep gradient at the delta edge and scouring sediment into the dead zone of the lake. This operation is flow dependent but could take place 1-2 times per year.

The effect of the lake drawdown on sedimentation is not clearly defined, with no available surveys immediately prior to and after a significant flood. It would be expected that lake drawdown would assist in moving finer sediments (silts and sands, and especially pumiceous material) right through the lake. It would be unlikely to have much effect on fine gravels as the velocity across the lake bed would be insufficient to move coarser sediments. This appears to be borne out by the observations from the lake cross sections in Section 2.1 above, with substantial infill taking place in the deeper parts at sections 10 & 11 close to the barrage.

4 Flood and Drainage Management Options

4.1 General

The sections below present several options for management of the flooding and drainage issues identified. Some interventions are more specifically aimed at drainage, while others address both problems.

4.2 Kopuriki Rd Embankment Culvert

When the Kopuriki road embankment overtopped and breached in the April 2017 flood this was observed to assist passage of floodwaters and reduce upstream water levels. The breach would have immediately generated a steep flood gradient down to lake level. The volume of flood water passing through the breach is not known. These observations have led to suggestions by the upstream landowners that a culvert(s) through the embankment would be useful.

There are two possible scales to this option:

a) A large waterway capable of passing a significant flood flow. Say 100-200 m^3/s. This would require multiple culverts or a flood bridge

b) A culvert sized to pass normal drainage flows

Considering these approaches:

4.2.1 Flood Bridge

To pass a significant volume of floodwater would require either multiple box culverts or a bridge span. There are however major morphological (river and delta formation related) issues with this approach.

Opening up a large waterway through the west embankment will only be effective for as long as the “Western channel” in the lake remains open (Section 2.2.2). Passing floodwaters through the Kopuriki Road embankment will draw flow and hence sediment from the main river. This sediment will immediately deposit north of the embankment and rapidly infill this area. This could in theory be mitigated by a sediment weir that held back the bedload in the main river, but this would just worsen the aggradation in the existing channel.

More problematic will be that the diversion of flow would reduce the velocity and hence sediment transport capacity in the main river channel downstream of Rabbit bridge, exacerbating the already limited sediment transport capacity through this reach.

The expected result in a relatively short timeframe (ie < 10 years) would be infilling of the western embayment and further aggradation of the delta eastern channels. Thus benefit would be short lived. This option is high cost and of doubtful longevity and is not recommended.

4.2.2 Drainage culvert

Survey indicates there is between 600 and 800 mm of water level drop across the road embankment in winter conditions. If this difference could be translated up to the low lying areas of the Healey property there would be an immediate benefit to approximately 33 ha of land. There would be no benefit to the true right side of the river (Noe property).

There is a small catchment that drains into the western lagoon. A culvert of approximate size 1500 mm would drain this area. However to be effective it would also be necessary to block off the opening between the lagoon and the main river (Figure 1, Section 2.2.2) as otherwise flow from the main river would be drawn to the culvert by the large gradient compared to the flow path out to the lake via the main channel. Not only water would be drawn into the lagoon, but also fine bedload sediment. In time this would fill the lagoon. The gap between the main river and the lagoon could be closed by a rock fill.

The longevity of this solution is short to medium term (say < 10 years) unless works are undertaken to maintain the open waterway on the west of the lake. As soon as this waterway is infilled (Section 2.2.2) then the gradient through the culvert will be lost.

For this to be anything other than a short term fix, this option would need to be in conjunction with main channel maintenance. However if the main channel is kept as a clear way as discussed below then the need for the drainage culvert is negated.

4.3 Main Channel Maintenance

Currently the river channel branches approximately 600 m downstream of the Rabbit Bridge. The smaller channels though the delta area are prone to sedimentation and vegetation growth. If a clear waterway could be maintained for a further 600m down to (currently) Section 6, then passage of flood flows would be greatly assisted. This clear waterway would need to be around 40- 50m wide.

The channel needs to be subject of specific design, based upon the flow regime and sediment gradings. If the channel is too wide velocities will not be sufficient to pass sediment through to the lake. However if the channel is too narrow it will be efficient at transporting sediment, but still create upstream backwater (flooding) and also be more prone to bank erosion. Creating this clear waterway was the intention of the 2009 works (Section 3.1) but it was not completed.

The work to form this clearway is substantial, requiring the excavation of some 20,000 m^3 of material. The river banks would need to be protected with rock in parts, or the flood flows will just erode the sides and spread the flow back into the delta. The east bank of the river would need armouring to prevent erosion to the farmland, as happened in April 2017.

With the clearway established it is expected that periodic dredging would be required at the lake end of the channel to maintain depth and encourage sediment transport out into the dead storage. The section of the lake into which the channel would feed is now relatively shallow at 1- 1.5m depth and will rapidly form a delta if not actively managed. This maintenance dredging could be carried out using a long reach excavator working off bunds beside the channel, or alternatively could be efficiently carried out using a cutter suction dredge on the water (as was done in the 1990's).

The cost to establish a cutter suction dredge is substantial (Heron Construction have provided an estimate of $60,000 for mobilisation and demobilisation of their dredge the "Matuku"). The advantage is that working from the Lake, the full width of the channel can be cleared. Sediment can be pumped up to 500m (longer with boost pumps). Whether this is cost effective compared with working with long reach excavators would depend upon the volume of material to be shifted. The dredge has the advantage that excavated material does not need to be double handled. Long reach excavators have a low establishment cost but a lesser productivity. The cutter suction dredge would be more suitable for a periodic major scale cleanout, say every 5-10 years.

The benefits of maintaining a clear outflow channel right through to the lake are principally to flood flow passage. It will also assist in reducing water levels in the Healey and Noe properties especially in winter conditions. The exact amount of drainage improvement that would result is difficult to estimate precisely but could be expected to be in the range of 200-300mm in winter/spring high flow conditions. What maintaining a clear waterway into the lake will do is prevent the gradual rise in upstream water level which otherwise will occur.

4.3.1 Channel Establishment

The works to establish the clear channel from the bifurcation down to the Lake at Section 6 involve:

- Closing off the western channel with 90m of bund and rock protection.
- Willow removal on the true left bank for some 550m, willows to be laid on the ground and an access road formed with gravel from the river excavation (as was done in 2009)
- Rock protection to the banks at some locations
- Excavation of the channel

Survey of the channel and a specific design is required to accurately cost this work, but based upon the 2009 channel works it is expected to cost in the order of $100-150,000. This is inclusive of engineering and survey costs and does include a small allowance of $5,000 for resource consents. This assumes works are able to be undertaken under BOPRC Consent 64684. If the works are controversial with third parties and consents are opposed then costs would be considerably greater.

4.3.2 Channel Maintenance

The ongoing effort that will be required to maintain the clear channel will depend in part upon frequency of flood events and the effectiveness of lake drawdown in shifting sediment through the lake. Principally the dredging would need to be concentrated over the downstream end of the channel as it enters the lake.

An approximate estimate would be that an area of 1 ha would need dredging (being 350m length of channel by 30m width). Dredge depth would be in the range of 1.5 - 2.0 m giving a dredge volume of 15,750 to 21,000 m^3. In comparison around 22,000 m^3 was reported to have been cleared from the river channel in 2009.

Assuming the cutter suction dredge is used, then the dredge cost at $7.50/$m^3$ plus mobilisation/demobilisation would be in the range of $178,000 - $217,000. This assumes the dredge spoil can be disposed of within 500m by building up the already dry land on the delta. If this cannot be done and the dredge spoil has to be removed completely from the area then costs would rise very substantially.

It is hard to be definitive over the frequency at which this operation would need to be carried out. A reasonable estimate would be on a 5-10 yearly cycle. In addition some flood damage repairs to river banks and rock work would be expected on occasions in the intervening years. Therefore on an annualised basis the maintenance budget would be in the order of $20,000 - $50,000 pa.

4.4 Pumped Land Drainage

It would in theory be possible to improve the drainage on the lowest parts of the Healey and Noe properties by low stopbanks and pumped drainage. However this is a high capital and operating cost option. It does not address the causes of the problems or provide long term surety against future accretion and rising river levels.

4.5 Retreat from lowest paddocks, possibly with farm amalgamation

In total some 44 ha of the Healey and Noe properties are currently adversely affected by the elevated water tables.

If the cost of improving and maintaining the drainage exceeds the productive value of the land then a better long term solution may be retiring the low land from farming. The funding and mechanism for this would need be worked out between the affected landowners and the power scheme operator. We would make the observation that loss of the lower lying land may leave the affected farms as a whole an uneconomic unit unless other (higher) land could be added.

Without works to maintain a clear channel into the lake then the backwater from floods will continue to rise and extend further up the river.

4.6 Extraction of Gravel Upstream

The sediment that is forming the delta is being transported through the upper river systems of the Rangitaiki, Whirinaki and Horomanga and other smaller tributaries coming off the Galatea foothills. The Horomanga River in particular has a broad gravel floodplain and transports large quantities of gravel. Gravel is removed for forestry roading purposes at several locations, principally around the Troutbeck Road bridge. Removal of gravel from the rivers upstream of Kopuriki would be of some assistance in slowing the accretion in the delta and decreasing the frequency and scale of maintenance activity, but is not in itself a solution.

4.7 Wider Benefits

Achieving a viable long term solution to the accretion at Kopuriki brings benefits to more than just the immediately adjoining and upstream landowners. A number of other stakeholders have an interest and would benefit. These include:

4.7.1 The Roading Network

Whakatāne District Council advise that Kopuriki Road is a strategically important link for the Galatea plain. In particular the bridge is rated for HPMV loads (High Productivity Motor Vehicle). This links the Galatea area to milk processing sites at Reporoa and Edgecumbe via the off highway. The current Galatea Road is not suitable for these vehicles due to limitations on the bridge at the head of Lake Matahina.

Further accretion at Kopuriki will increase the frequency of flooding of the Kopuriki Road and use of the overflow weir (Section 5 below).

4.7.2 The Hydro Electric Scheme

Further loss of volume from the live storage of Lake Aniwaniwa does affect the ability of the power scheme operator to take advantage of peak generation periods. The quantum of this loss is not known, but is understood to be not a major concern to the current owner (Pioneer Energy, perscomm Peter Mulvihill).

4.7.3 Loss of wetlands

Currently there are extensive areas of shallow water and wetlands on the west of the lake below the Kopuriki Road embankment (Section 2.2.2, Figure 2). Continuing infill and loss as wetlands of these areas from the delta can be expected if no intervention is made to the delta channels.

4.7.4 Loss of lake area and depth

Lake Aniwaniwa is a Regional asset for various water recreation activities including boating and fishing. Continuing infill and shallowing of the lake is steadily diminishing the value of the Lake as a recreational asset. Shallower water promotes macrophyte weed growth and development of islands.

5 Long Term Predictions

Currently the delta extends 1.2 km into the lake, leaving a further 3.2 km until it reaches the barrage. While it has taken 37 years for the delta to build to this extent, it would be misleading to pro rata the development of the delta and predict a further 135 years for the delta to reach the barrage. In reality it is likely to be considerably longer. The current regime of lake drawdown is moving finer sediment through the lake and this will become more effective as the delta gets closer to the barrage (a steeper gradient will result). Interventions around maintaining the clear waterway and periodic judicious dredging would assist in transporting sediment through to the barrage.

Without intervention, the delta will continue to form, the lake will infill and eventually reach the barrage. At that time the river will form a new stable gradient. The gradient would be a function of the river flow regime, frequency of flooding, sediment supply, sediment grading, vegetation and land use on the old lake etc. Given that complete infilling of the lake is many years away it is speculative to attempt to say exactly what the gradient of the re-established river would be. However we can say it will be greater than zero and less than the natural gradient of the Rangitaiki River as existed prior to the dam.

The natural river gradient as existed prior to the dam was approximately 0.0013 m/m (reference is Figure 19 of the water right hearing). The current gradient taken from the mid-range lake level (146.42 Moturiki) to the mean spring water level at Kopuriki (146.68m Moturiki) is around 0.00023 m/m. If it was assumed that the re-established channel stabilised at a gradient similar to the existing (ie 0.00023 m/m) then the typical winter/spring water elevation at Rabbit Bridge would be around RL 147.4 m Moturiki, ie 700mm higher than today. The effect of this on the low lying land upstream of Rabbit Bridge would be substantial, extending the area of drainage impeded land upstream of the currently affected 44 ha (Figure 3). This would be a “best case” figure and depending on how the channel through to the dam was allowed to develop and be maintained it could be considerably higher (ie +1-2m).

River levels in floods would be higher also. The extent of the resulting backwater effect would need to be established by modelling but would be expected to extend well upstream of the Horomanga confluence.

6 Future Monitoring

The monitoring of lake and river water and bed levels undertaken to date has been of some assistance in defining trends and establishing the level of effects on upstream property, but unfortunately has not been found to be definitive. In particular we observe:

6.1 Lake Bathymetry and Delta Extent

The annual lake surveys are taken on sections between 200-400m m apart. These establish the trends at these locations but make an overall volume calculation difficult and imprecise. Also from the data available to us, not all years have been surveyed and in some years not all sections are on the file. With modern technology it would be relatively easy to capture the whole lakebed with sonar linked to GPS. This could be done on a 3 yearly basis and would then give a surface which can be easily processed to accurately assess overall changes in bathymetry. The annual frequency is not required. A specific pick up of the vegetation margin at the edge of the delta should be captured. This is easily done with a drone. It would also be very helpful to complete a bathymetric survey immediately after a flood drawdown event.

6.2 Upstream flood levels

The trend in flood levels upstream is not well understood. The river bed surveys (5 yearly) give some indication of trends but do not directly relate to water levels in flood conditions. We would recommend installing 3-4 high stage flood recorders (basically a painted post in a pipe) at strategic locations (such as the corner on Bridgeman's property opposite the Horomanga). These would be levelled in and can then be easily read after a flood event. This information is useful in two regards:

- Allowing a direct comparison of levels for similar sized flood flows using the measured outflows at Aniwaniwa. This will track flood backwater effects with time.

- The level and corresponding flow records could then be used in conjunction with the 5 yearly river surveys to accurately calibrate a river model. A river model is required to optimise the width of the clearway channel into the lake.

6.3 Groundwater levels.

Currently there is no monitoring of groundwater level in the Healey property close to the lake. This leaves the assessment of drainage impediment and trends in the drainage condition subjective. It would be helpful for all parties to have a monitored bore that can be used to track the groundwater level at a point some 400m upstream from the property boundary (Figure 3).

7 Conclusions

On the basis of this review the following conclusions are reached:

1. The most reliable option for providing long term drainage and flood relief to the land adjacent the Rangitaiki River and upstream of the Kopuriki Bridge is to establish and maintain a clear channel to the lake

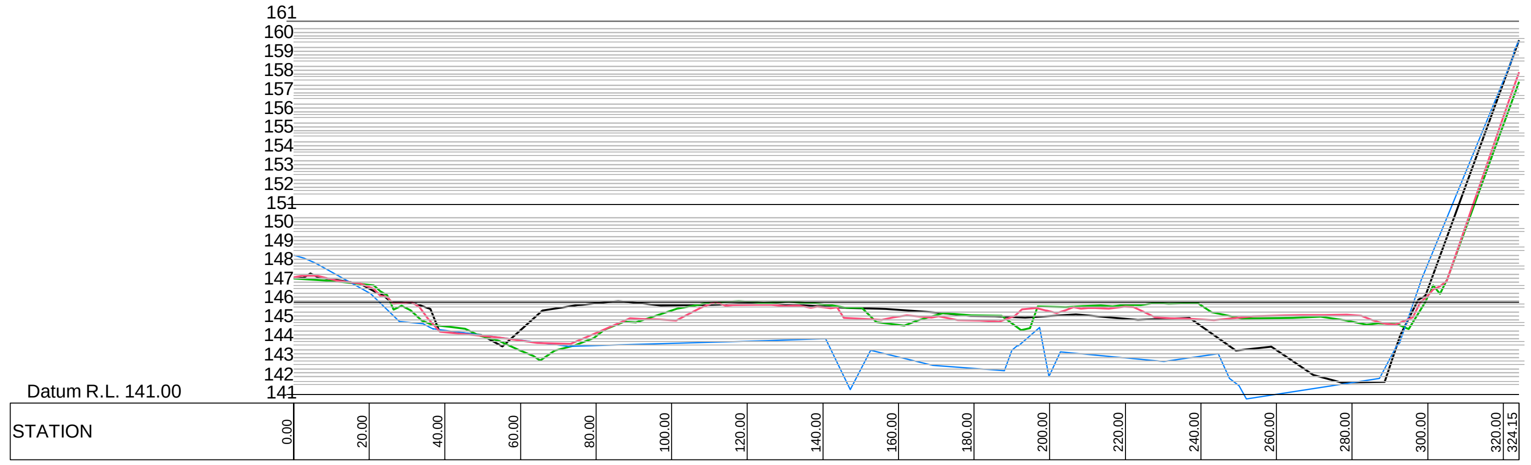
2. Survey and specific design including hydraulic modelling for the clear channel is required to better define the optimum channel width and hence costs.

3. The cost effectiveness of this approach needs to be determined following consultation with the various parties, being Pioneer Energy, the landowners, BOPRC and third parties with an interest in the river and lake being Iwi and Fish & Game.

4. A focussed programme of survey and water level monitoring needs to be put in place to ensure quality data is collected that will define trends and provide a sound basis for planning the management of the lake and river.

It is important to recognise that any “solution’ can only mitigate the problem and in effect treat the symptoms and will require ongoing maintenance intervention. The fundamental problem caused by the change in gradient and level of the river through this reach remains.

Appendix 1 – Lake Cross Sections



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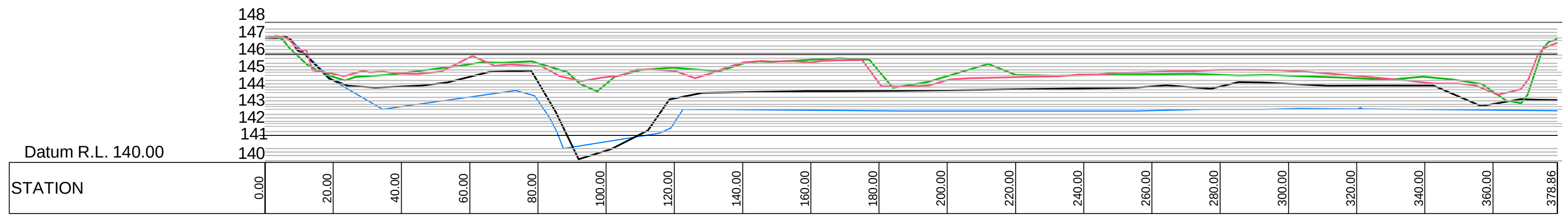

LONGSECTION - SECTION 7

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LEGEND

- 1981
- 2002
- 2012
- 2016

Revision	Amendment	Approved	Revision Date

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Project	LAKE ANIWANIWA CROSS SECTIONS
Sheet	SECTION 6 & 7
Approved	F SHILTON
Approved Date	14/11/2017
Drawn	G ROSE-INNES
Scales	AS SHOWN
Project No.	234346.00
Sheet. No.	C01
Revision	A

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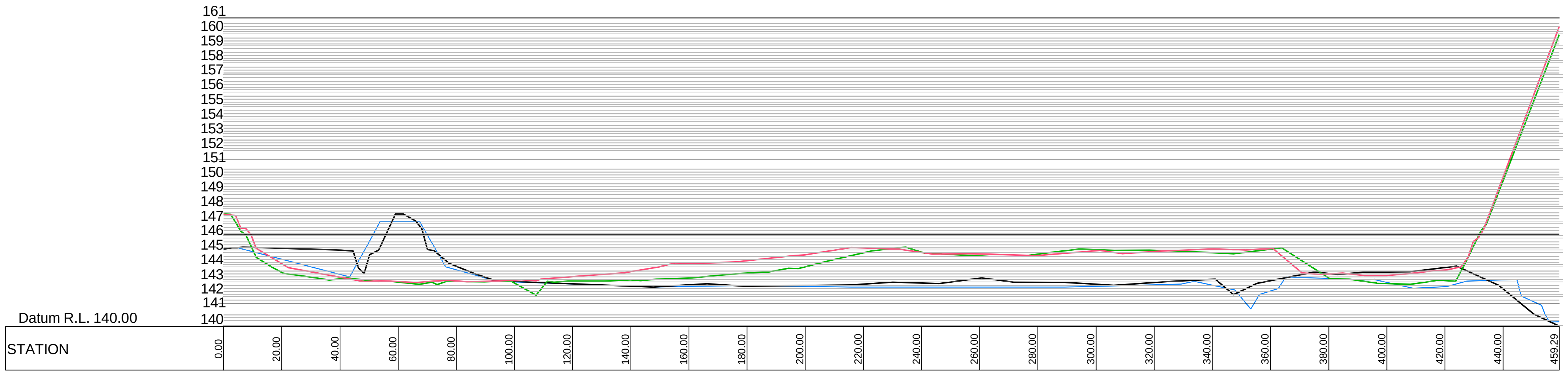

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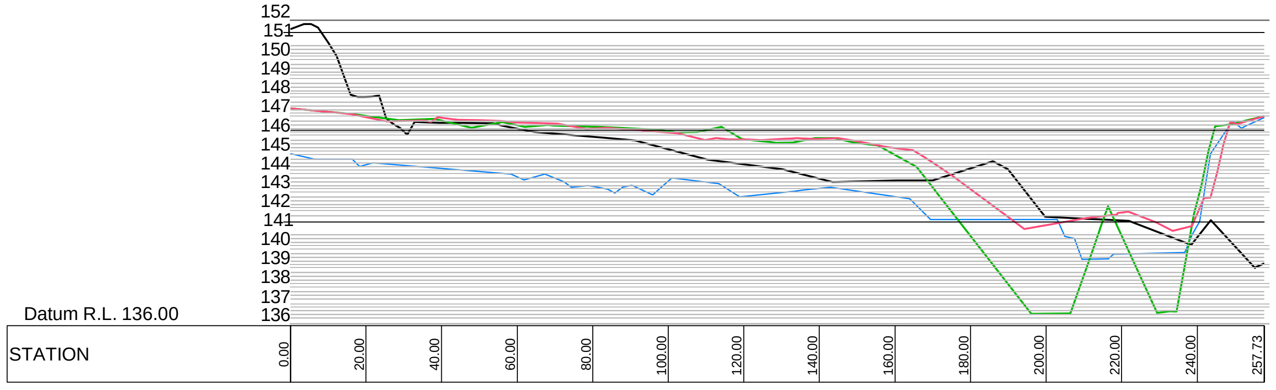

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LEGEND

- 1981
- 2002
- 2012
- 2016

Revision	Amendment	Approved	Revision Date

Bay of Plenty REGIONAL COUNCIL

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Project	LAKE ANIWANIWA CROSS SECTIONS
Sheet	SECTION 8 & 9
Approved	F SHILTON
Approved Date	14/11/2017
Drawn	G ROSE-INNES
Scales	AS SHOWN
Project No.	234346.00
Sheet. No.	C02
Revision	A

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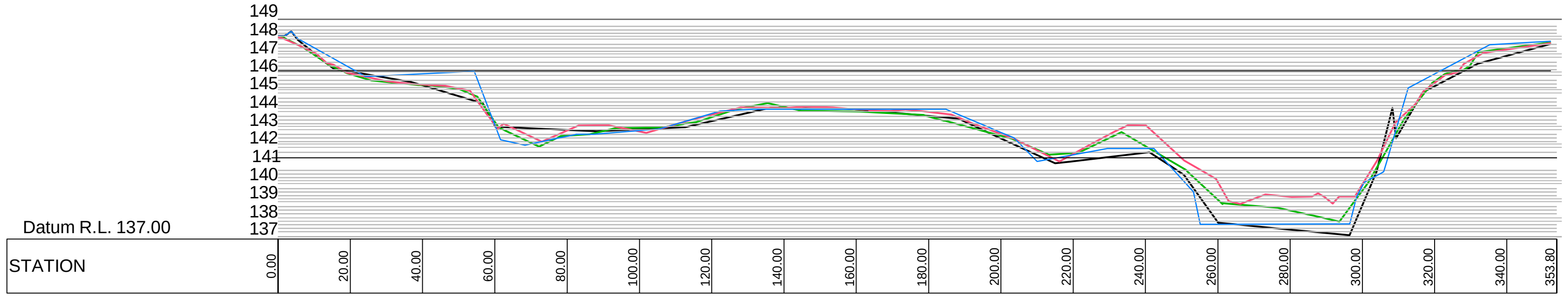

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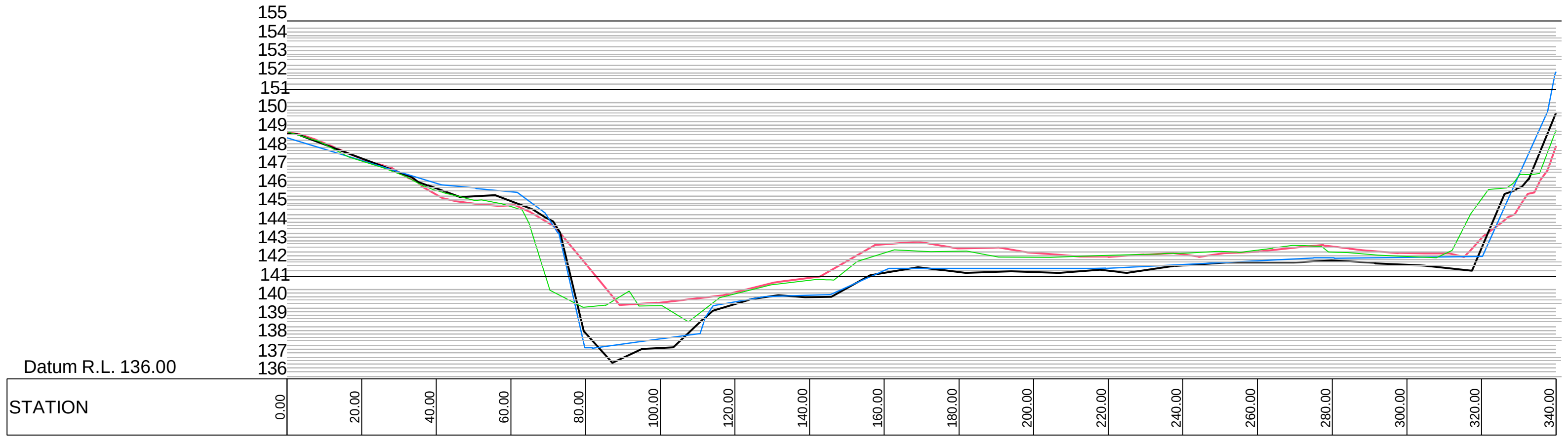

LONGSECTION - SECTION 11

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LEGEND

1981
2002
2012
2016

Revision	Amendment	Approved	Revision Date

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Project	
LAKE ANIWANIWA CROSS SECTIONS	
Sheet	
SECTION 10 & 11	

Approved	Approved Date
F SHILTON	14/11/2017

Drawn	Scales	Project No.	Sheet. No.	Revision
G ROSE-INNES	AS SHOWN	234346.00	C03	A

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Appendix 2 – Kopuriki Water Level Recorder Analysis

Memorandum

To	Peter Askey
Copy	
From	Lizzie Fox
Office	Wellington Office
Date	20/11/2017
File	2-34346.00/200WK
Subject	Rangitaiki River at Rabbit Bridge Water Level Analysis

As part of the Kopuriki flooding project in the Bay of Plenty, water level analysis is required of the Rangitaiki River. This will provide supplementary information on how the Rangitaiki River has changed over time and how this influences flooding adjacent to the river.

There are two active recording sites directly on the Rangitaiki River; Rangitaiki at Rabbit Bridge and Rangitaiki at Te Teko. The former site is a water level only site, monitored by Bay of Plenty Regional Council (BOPRC) and installed in April 2010. It is located on Rabbit Bridge where Kopuriki Rd crosses the Rangitaiki above the Aniwhenua Lake, which was damned in 1980/1981. The latter Rangitaiki site is run by a combination of BOPRC and NIWA and is located in the town of Te Teko, approximately 34km south of the present day Rabbit Bridge site.

A third Rangitaiki River flow monitoring site, named Rangitaiki at Kopuriki, existed from 1966 to 1980. This was closed due to the damming of the Rangitaiki resulting in the formation of Lake Aniwhenua as part of the Rangitaiki River hydro scheme. This site was operated by NIWA and was located approximately 3.4km downstream of the present day Rabbit Bridge site.

Analysis was therefore carried out using the Rangitaiki River at Rabbit Bridge site, though the short record (~ 7 years) impacts the applicability of the results for long term analysis.

Figure 1 shows the Rangitaiki River at Rabbit Bridge water level record from April 2010 until June 2017. Water Level is measured in mm at the site, and has been converted to the Moturiki datum for analysis.

The relationship of the Rabbit Bridge site to the Moturiki datum is + 145.989 i.e. if the water level recorder measured 0, then this is equal to 145.989m to Moturiki

Figure 2 compares the measured water level at Rabbit Bridge with a surveyed water level taken at the site on 31st October 2002. It also has data points filed in 1980 to represent the original operating range of the downstream Lake Aniwhenua; a minimum water level height of 146.320m and 146.520m (Moturiki datum). Figure 3 shows the same data but with the lake level thresholds as lines to show how the recent data compares with the original operating range.

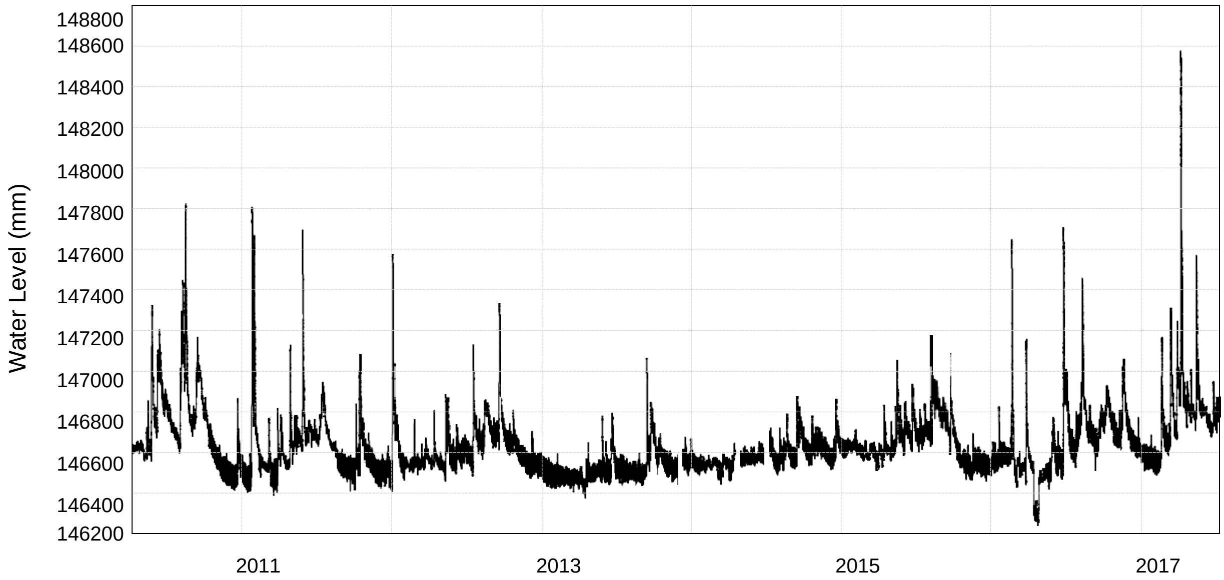

Figure 1: *Rangitaiki River at Rabiit Brige Water Level record to Moturiki datum (+145.989m added to site RL). Data provided by BOPRC from April 2010 to June 2017*

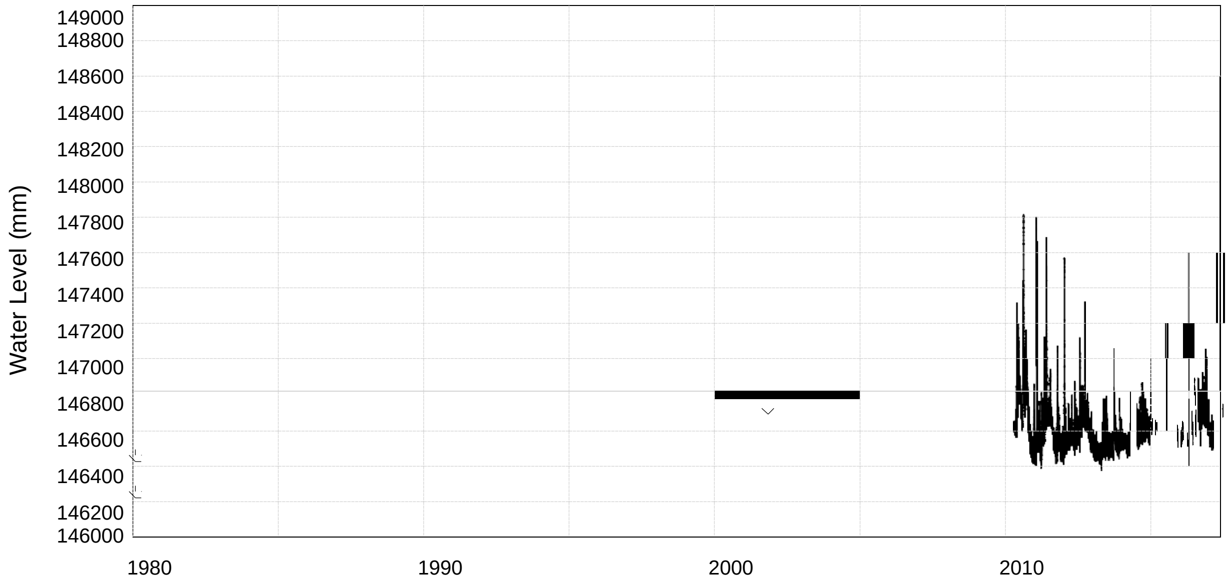

Figure 2: *Extended Water Level record at Rangitaiki River at Rabbit Bridge using obtained water level survey points*

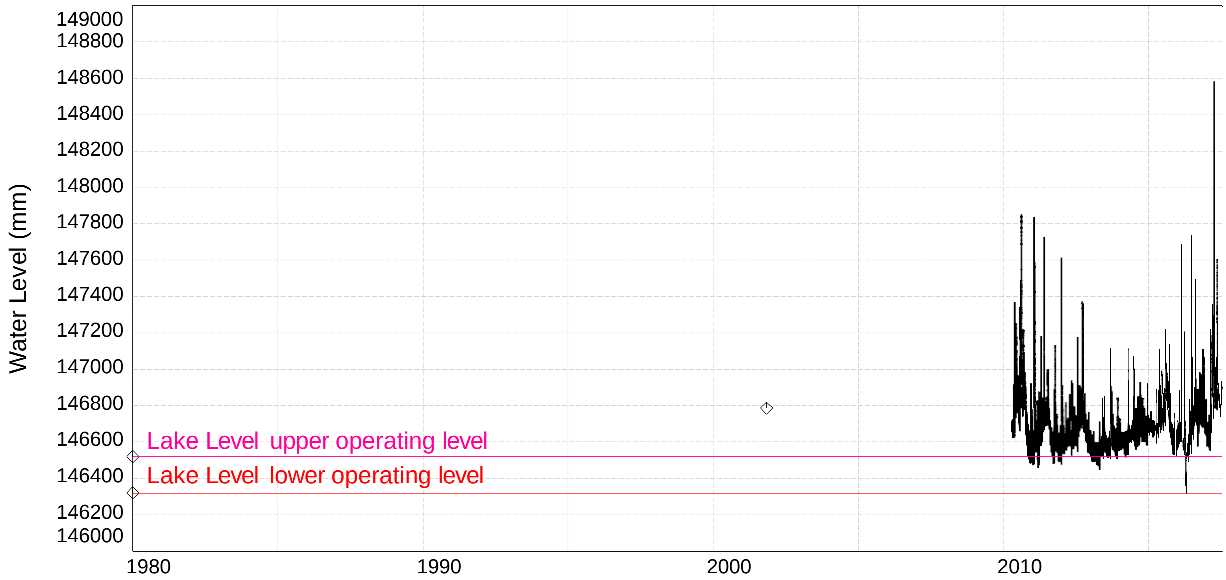

Figure 3: Extended Water Level record at Rangitaiki River at Rabbit Bridge using obtained water level survey points with the original lake operating range displayed as threshold lines to demonstrate how the water level has changed from 1980 to present.

Of particular interest to the Kopuriki flooding project are water level heights over time. Table 1 displays the annual statistics for the site for each year (i.e. from 2010 to 2017). Note that years 2010 and 2017 are incomplete years.

Table 1: Annual statistics on Water Level (m) for Rangitaiki River at Rabbit Bridge (2010-2017)

Year	Minimum	Median	Mean	Maximum	Lower Quartile	Upper Quartile
*2010	146.484	146.755	146.796	147.854	146.656	146.888
2011	146.460	146.642	146.684	147.837	146.586	146.743
2012	146.527	146.659	146.691	147.613	146.615	146.734
2013	146.448	146.586	146.600	147.114	146.555	146.623
2014	146.516	146.651	146.666	147.116	146.620	146.696
2015	146.527	146.698	146.720	147.220	146.651	146.768
2016	146.317	146.700	146.722	147.738	146.619	146.798
*2017	146.557	146.833	146.846	148.583	146.691	146.899
All	146.317	146.668	146.704	148.583	146.608	146.762

The time of year that is prone to flooding in the Kopuriki area is in mid to late spring; Table 2 compares the annual statistics for the site for the month of October and November based on the available water level record at Rabbit Bridge. During spring months the mean water level is 146.684m relative to Moturiki datum.

Table 2: Annual statistics on Water Level (m) for Rangitaiki River at Rabbit Bridge for the 'spring' months of October and November (2010-2017)

Year	Minimum	Median	Mean	Maximum	Lower Quartile	Upper Quartile
*2010	146.506	146.642	146.665	146.931	146.588	146.727
2011	146.486	146.622	146.65	147.132	146.578	146.691
2012	146.557	146.679	146.679	146.869	146.638	146.714
2013	146.511	146.624	146.626	146.805	146.593	146.655
2014	146.6	146.69	146.692	146.84	146.666	146.717
2015	146.529	146.629	146.639	146.786	146.601	146.667
2016	146.655	146.823	146.836	147.113	146.77	146.885
All	146.486	146.667	146.684	147.132	146.614	146.73

The water levels for August are also considered a time where flooding may be an issue; as winter comes to an end and temperatures begin to increase into the spring months. The annual statistics for the months of August are displayed in Table 3. The mean water level is 146.792m relative to Moturiki datum; this is greater than the spring mean water level, and higher than the overall year mean water level measured at this site; of 146.704m relative to Moturiki.

Table 3: Annual statistics on Water Level (m) for Rangitaiki River at Rabbit Bridge for August months only (2010-2017)

Year	Minimum	Median	Mean	Maximum	Lower Quartile	Upper Quartile
*2010	146.662	147.016	147.074	147.854	146.849	147.267
2011	146.552	146.667	146.656	146.762	146.616	146.696
2012	146.630	146.782	146.787	146.915	146.730	146.853
2013	146.510	146.579	146.577	146.668	146.560	146.594
2014	146.550	146.674	146.677	146.850	146.650	146.700
2015	146.659	146.882	146.883	147.220	146.824	146.944
2016	146.708	146.840	146.885	147.496	146.783	146.910
All	146.510	146.745	146.792	147.854	146.656	146.874

To 'smooth' the data to give less weight to the peaks and low water levels of the Rangitaiki, a 7 day moving mean was derived from the dataset. This is displayed in Figure 4. Annual statistics were derived for the smoothed data and are displayed in Table 4.

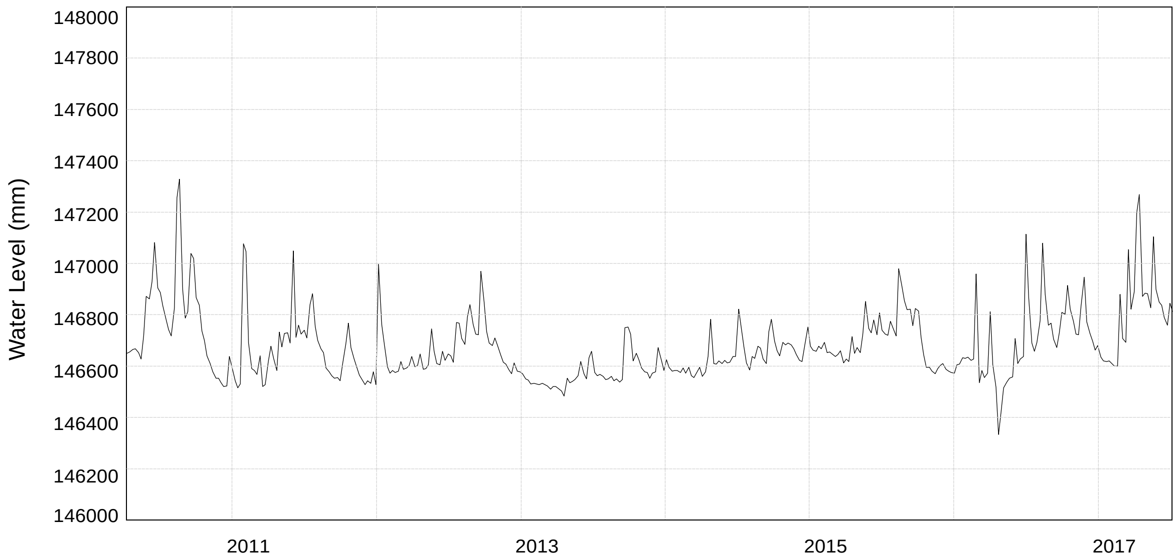

Figure 4: Rangitaiki River at Rabbit Bridge 7 day moving mean water level (2010-2017).

Table 4: Annual statistics for 7 day moving mean Rangitaiki River at Rabbit Bridge (2010-2017).

Year	Minimum	Median	Mean	Maximum	Lower Quartile	Upper Quartile
*2010	146.545	146.760	146.798	147.344	146.658	146.903
2011	146.538	146.651	146.686	147.347	146.585	146.751
2012	146.589	146.655	146.689	147.068	146.619	146.739
2013	146.502	146.583	146.599	146.818	146.563	146.617
2014	146.568	146.652	146.666	146.868	146.621	146.702
2015	146.578	146.697	146.720	146.999	146.651	146.773
2016	146.355	146.706	146.722	147.143	146.633	146.801
All	146.622	146.850	146.845	147.536	146.713	146.902

From the smoothed, seasonal 'spring' and for all months of the year datasets, the brief analysis suggests that overall, from 2010 to the present, there has been a general increase in the mean water level measured at this site. This is further implied by the current water levels exceeding the original operating range of the downstream Lake Aniwhenua, implying the river is generally aggrading. Large flood events reduce the water level at the site as the channel is momentarily scoured and eroded, but continual sediment supply is slowly infilling the river channel, increasing the water level measured at this site.

This is supported by the trend analysis of the 7-day moving mean data displayed in Figure 5. From 2013 to 2015, there appears to be a relatively steady increase in minimum water level at the site, as evident by the positive trend line analysis. It is important to note that though the 7-day moving average has been used here to reduce bias from the peak flows, they are still included in deriving the trend line, creating positive bias.

To reduce further bias peak flows have on determining the overall trend of water level at the site, the minimum monthly water levels for each month between the stable period of 2013 to 2015 were analysed (Figure 6). This also shows that there is an increasing water level pattern observed at the site, with less bias from large peak flows during the relatively stable period.

It is important to note that only assessing the water level of a site to determine the flood risk has inherent uncertainty; it is assumed that the increase or decrease in water level is a direct result of the channel bed degrading or aggrading, and is representative of the reach. No assessment could be carried out to determine if the change is site specific i.e. scour or deposition restricted to the water level site at Rabbit Bridge. It is recommended to incorporate this data with cross sectional surveys along the Rangitikai to verify the assumptions made here of an aggrading river channel.

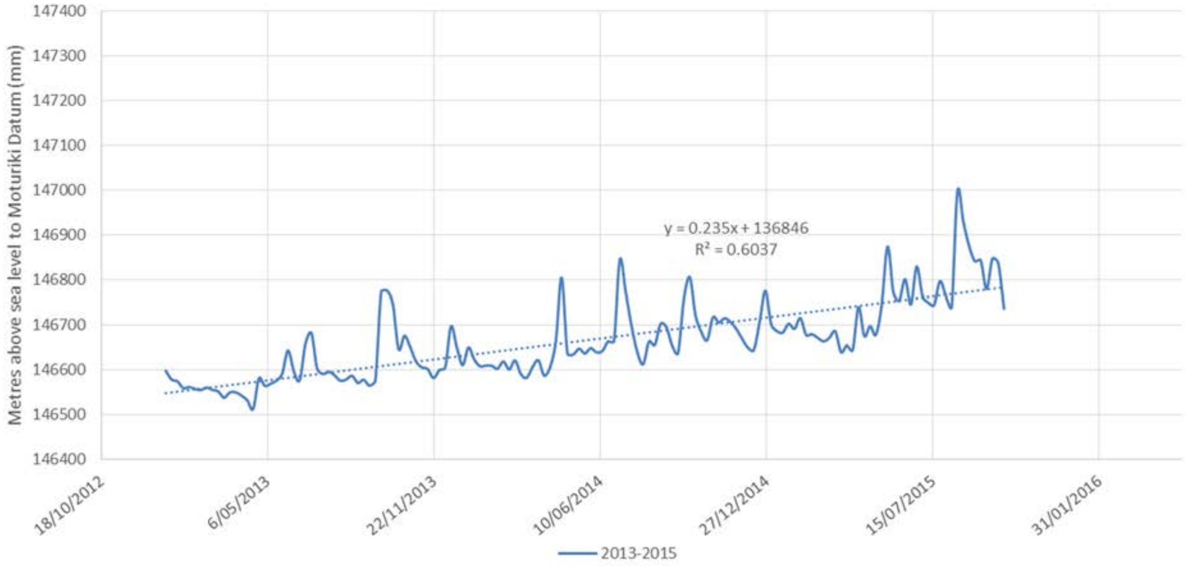

Figure 5: *Mean water level trend analysis for 7-day moving mean water level data at Rabbit Bridge*

Figure 6: *Minimum monthly water level trend analysis at Rabbit Bridge (2013-2015)*

Appendix 3 – Works undertaken at Kopuriki

Memorandum

To	File
Copy	Simon Stokes
From	Peter Askey
Office	Whakatane Office
Date	24 August 2017
File	2-34346.00
Subject	Channel Works at Kopuriki

From perusal of the BOPRC box files (Volumes 1-3) I have identified the following occasions when BOPRC has carried out work in the Rangitaiki channel and delta area. Generally this appears to have funded by BOPE:

Date	Work carried out	Cost	Excavation quantity	By
1994	Extend training banks into lake			BOPE
Nov 2007	Willow clearing at Rabbit Bridge	$14,500	Not stated	BOPRC
March – April 2009	Pilot cut and channel excavation, 400m u/s to 800 m d/s of bridge	$77k ($60k BOPE $17k BOPRC	22,000m3	BOPRC
December 2009	New causeway d/s, minor erosion repairs, shut off LH channel	$14,844 (continuation of March works)	Not stated	BOPRC
February 2010	Causeway d/s of bridge	$16,371		BOPRC funded by BOPE
March-April 2010	Works u/s of bridge, willow clearance and rock armour	On going funding by BOPE		BOPRC
Sept 2010	Post flood repairs of causeway d/s of bridge	Not stated		BOPRC
Aug-Sept 2011	Remove islands, clear willows, bank protection	Not stated		BOPRC funded by BOPE
February 2016	Intention to remove gravel at head of lake March/April 2016	Not stated		Not clear if work completed

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