ISSUES AND OPTIONS FOR ECOLOGICAL RESTORATION OF TE ROTOKARE AND ITS MARGINS

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EXECUTIVE SUMMARY

The natural features of Te Rotokare, and ecological processes that underpin these, have been impacted by human activity over a long period of time. However, notwithstanding the early clearance and modification of vegetation which occurred within the catchment, the most substantial impacts and threats to the ecological integrity and viability of this lake ecosystem came into play relatively recently. Dramatic changes to the hydrology of the lake in the early 1970s, have increased the frequency and extent to which lake levels are drawn down, and the extent to which the lake retreats during drier periods.

Since the mid 1980s there have been a number of investigations exploring management options for the lake bed and surrounding area. These have ranged from works which would effectively drain the entire area for farming, to hydrological restoration options involving bunding and/or pumping which would retain higher water levels for longer, and enable the reinstatement of many of the wetland's natural values. At the time, none of the proposals met with unanimous support from all interested or affected parties, and none were implemented. Interested parties, then and now, include multiple landowners, and agencies with statutory interests (Hawkes Bay Regional Council, Department of Conservation, Fish and Game NZ).

Although in a degraded state, the lake retains values for a variety of wetland birds, and is likely to contribute to the local and regional sustainability of some mobile bird species. From a botanical perspective, the lake is currently of little significance, and it is unclear what values it holds to freshwater fisheries. What is certain, however, is that the lake retains significant potential for ecological enhancement.

The management regime which has prevailed for almost four decades is unsatisfactory to most parties. The regime seriously compromises ecological values, and at least two of the landowners are adversely affected, from their perspective, when lake levels approach their upper extreme. There is however, an engineering option which would reduce the impact of higher water levels on one landowner's property to the extent they're able to be reduced, and would also lessen the effects of higher water levels on a portion of the other landowner's property. Ground levels preclude meeting all of this landowner's aspirations, in that drainage of the north-eastern arm of the lake to a level that would enable the development and maintenance of a crop or pasture year round is not possible without pumping.

The recommended engineering option would retain higher lake levels for a longer period of time, which would be ecologically beneficial, but constrain the extent to which the lake advances eastwards when levels are high. Whether the proposed undertaking, and resultant hydrological regime, would be sufficient to enable the full ecological restoration potential of the wetland to be realised, would need to be determined by implementing the proposal and monitoring its effects. If outcomes were less than ideal, previously identified options for additional sources of water would be worthy of further investigation and implementation, if feasible.

Enhancement of hydrology would enable enhancement of natural features and ecological values. Restoration planting and predator control programmes could be installed, along with initiatives to improve water quality and enhance freshwater fisheries values. For these undertakings to proceed with the greatest likelihood of success, a vision and integrated set of objectives needs to be developed for Te Rotokare as a whole.

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PROJECT TEAM

Andy Garrick - Field assessment and report preparation.
Federico Mazzieri - GIS mapping and figures.

1. BACKGROUND

Te Rotokare, or Lake Rotokare as it is commonly known, has had a long history of settlement and modification. Landowners' and agencies' aspirations and activities have often conflicted with one another over the last 3-4 decades in particular, and this has accelerated the loss of the area's former ecological values. Once it used to be regularly inundated with flood waters from an adjoining catchment (the Upokohina Stream) and the Tutaekuri River itself, but the river was effectively cut off in the early 1970s by local flood control and drainage improvement initiatives. Since then it has mostly relied on precipitation and runoff from the hills immediately surrounding it to sustain it, and for extensive periods in some years has been virtually devoid of open water. The lake is multiply owned, and some owners have been happy to see the lake recede from their properties in order to accommodate other land uses, some installing drains in an attempt to give this greater permanence. Most landowners however, have lamented the loss of wildlife, landscape, and recreational values that have accompanied the lower water levels, and have strenuously campaigned over a long period of time to implement undertakings that would retain more water year round, and reduce the extent to which the lake dries out in some years.

Kris Ericksen, whose family owns a portion of the lake bed, has obtained funding from the Biodiversity Advice Fund, and commissioned Wildland Consultants to undertake an independent investigation of the issues and options for ecological restoration of the lake and its margins. This includes reviewing options for restoration of the system's hydrology, co-ordinating technical input from other parties, devising an ecological restoration strategy, and producing a report which can be used for consultation and/or to accompany applications for funding for implementation of the recommendations. Prior to the engagement of Wildlands, another landowner, Gary Williams, who owns a substantial portion of the lake bed and who has been a long running advocate for restoration of the lake's hydrology, convened a meeting attended by all but one of the most affected landowners, along with representatives of statutory agencies who have previously been involved (Hawkes Bay Regional Council, Department of Conservation, Fish and Game NZ). Conditional, if not enthusiastic support for restoration of the lake and its wetland communities was communicated by most landowners, subject to an assessment of the issues and options involved in achieving this. This report provides a comprehensive overview of the history of the lake, its past and present features, and discusses restoration issues from an ecological, and landowner's perspective. The report concludes with the presentation of a hydrological enhancement strategy, the implications of this for directly affected parties, and a discussion of ecological enhancement options for the lake.

2. METHODS

Existing information, including cadastral and topographic data, aerial photographs, previous investigations of hydrological and engineering proposals, flora and fauna observations, and relevant correspondence was collated from a variety of sources. Sources included files held by the Department of Conservation, Fish and Game NZ, and Hawkes Bay Regional Council, along with other reports and records held by these agencies. Several landowners also provided documents and/or photographs.

Most landowners were contacted by phone, and several were interviewed in person during site inspections conducted over the period 21-22 January 2010. An on site meeting was convened with key technical staff from the Department of Conservation (Hans Rook), Fish and Game NZ (John Cheyne), and Hawkes Bay Regional Council (Stephen Cave) on 21 January, and discussions were held with Troy Duncan (QEII National Trust) in relation to feedback received from affected landowners at a meeting convened in November 2009.

Field observations of existing vegetation and habitats were made during the site visits, and hydrology and landforms were visually assessed as a precursor to formulating restoration options and identifying the potential effects of these, both positive and negative. Comprehensive surveys of flora and fauna were not undertaken.

3. LOCATION AND TENURE

Lake Rotokare ('the rippling lake') is a shallow lake located on private land approximately 5 km south of Taradale and 12 kms from Napier. When water levels are high, the lake and its associated wetlands extend across ten titles. Two of these properties, which incorporate land at the eastern end of the lake, parts of which are periodically inundated, have had multiple owners over the past 40 years (three in the case of one, and four in the case of the other). Three of the properties (Williams, McCormack, and Ericksen) have been owned by the same families for 60 years or more. Property boundaries, current owners, and the relative interests each owner has in the bed of the lake if drainage was to be severely impeded and the lake close to full, can be inferred from Figure 1.

4. SITE HISTORY

Te Rotokare and the land which surrounds it has been settled for many hundreds of years, and at times has been intensively occupied. Archaeological features are present throughout the catchment, and there are several pa sites within the immediate vicinity. One of these, Oueroa Pa, is believed to have supported 7-800 people at one stage. Oueroa is probably the oldest name in the area and the most historical site (Buchanan 1957). The main access by canoe, including access to the sea, and supply of sea fish was most probably via Te Rotokare. A shell sample from Otatara Pa nearby gave a carbon dating of 1490 AD, and the age of other middens within the vicinity has been estimated at 7-800 years. The lake is likely to have been directly accessible by canoe from the Tutaekuri River during earlier years, and a major source of food in addition to being a focal point for settlement (Gary Williams, landowner, pers. comm., original source(s) unidentified). Expansive middens are present around the lake shore, and in 1994 an archaeological investigation at one site unearthed moa bones and a broken adze (Connolly 1999, original source(s) not fully referenced). Freshwater mussels have also been identified in middens. The extensive period over which the area was occupied prior to European settlement, and the intensity of use, suggests vegetation and habitats in the vicinity of the lake are likely to have undergone substantial

Figure 1

modification from an early point in time. At the time of European settlement, the area was reported to have been covered in bracken and tutu, with kahikatea present in parts (Bruce Gunn, local resident, reported in Connolly 1999).

The lake was included in the 1,330 acre Rahuirua block which was granted a title in the Native Land Court in 1867 before passing into the ownership of forebears of the Williams family who continue to own a substantial part of the lake to this day. Remaining forest, scrub and fern was converted into pasture for the grazing of cattle, and where suitable, the cultivation of crops (Connolly 1999).

The lake periodically dried out, and sometime during the period 1918-1922 it was ploughed and oats or wheat sown. A wall was constructed along the centre of the lake bed using horse and scoop in an attempt to reclaim part of the lake bed, but the entire area was flooded again the following winter (Gary Williams, unpublished paper dated 31/5/84). The current boundary fence running down the centre of the lake is positioned on top of that wall. More often the lake occupied an area of about 35 ha, and during the 1930s and 40s, and up into the 60s, was of sufficient depth to enable speed-boating[1] (Gary Williams pers. comm.).

Up until about four decades ago, the lake was periodically inundated with overflows from the Tutaekuri River which followed the course of what is now the Upokohina Stream before backflowing into the lake. This came to an end in the early 1970s when the Hawkes Bay Catchment Board (HBCB) stopbanked the Tutaekuri River from Puketapu to Redcliffe (Olsen 1984). Drainage improvement works undertaken by the Board in the Upokohina Stream in 1972-73 also significantly reduced the opportunity for flood flows to enter the lake from this catchment.

In conjunction with the Upokohina Stream works, the current outflow channel from the lake was formed, and two other works were undertaken at the eastern end of the lake. The first of these comprised the installation of a 'cross-drainage' system extending more or less from one side of the valley to the other at the head of the lake[2]. The purpose of this was to discharge runoff from either side of the valley into the outflow channel now draining to the Upokohina Stream. The other initiative involved the diversion of a substantial drain that had previously discharged runoff into the lake from the south-eastern sub-catchment[2] of the Rotokare basin. Flow from this was directed into the southern 'cross drain' and thence into the Rotokare outlet drain (Gary Williams pers. comm.).

Just prior to these works being undertaken (August 1973), a meeting was held between landowners and the HBCB, and it was agreed that the material excavated to form the 'cross drains' would be used to construct a stopbank along the western side of the drains which would enable higher water levels to be retained in the lake during the summer months. A culvert was to be placed through the stopbank to discharge excess water from the lake, and the understanding communicated to landowners was that the maximum lake level would be higher than it currently was. The stopbank was

[1] There have also been many other years and decades during which comparable water depths were experienced and speed-boating/water skiing would have been an option if desired (cf. Appendix 3).

[2] The locations of the two cross drains and the south-eastern sub-catchment (sub-catchment 2) are shown in Figure 5.

never constructed, and the culvert was installed at a lower level than landowners considered necessary to retain the higher levels sought (refer EFG Ericksen, landowner, correspondence dated 9/9/73 and 8/11/74, and Gary Williams, unpublished paper dated 31/5/84). From 1973, and for the next 27 years or so, files held by agencies indicate ongoing submissions and correspondence from some of the landowners, the periodic involvement of the NZ Wildlife Service and Hawkes Bay Acclimatisation Society, and later Fish and Game NZ, in addition to the HBCB prior to its disestablishment in 1991, and its successor the Hawkes Bay Regional Council. Key undertakings, investigations and proposals since 1973 and the events outlined above, and the present, are summarised below.

In 1977, HBCB advised the stopbank referred to above, was not formed because it doubted the lake level would get that high. The Board noted that a management plan for all lakes might be prepared as a long term solution for resolving issues, but recommended more immediately, that another meeting of landowners could be convened to consider targeted control of raupo (which had proliferated with the lower water levels and was adding to the natural aging of the lake), construction of the stopbank if water levels warranted it, and construction of contour drains to direct water into the lake from the hills on each side of the lake at its northern end (PK Simons, HBCB, correspondence dated 2/9/77). A meeting was held in 1978 and the practicalities of isolating some owners' properties from the wider lake and draining these while enhancing levels in the remainder of the lake were discussed. HBCB undertook to take core samples to estimate ground level subsidence in areas that might be drained, and to investigate means of enhancing lake levels and quantity of water required to maintain higher levels (Bill Spooner, HB Acclimatisation Society, meeting notes dated 27/4/78). Extensive areas of raupo in the southern half of the lake and at its eastern end were aerially treated with herbicide in 1977 and 1978.

In early to mid 1983, the HBCB realigned the outlet channel to enable better utilisation of the flat land east of the lake on behalf of the then owner of what is now William Tait's property. At the same time a small contour drain was formed "around the extreme north-west[1] margin of the lake" (refer P.K. Simons correspondence dated 28/7/83).

In July 1983, HBCB proposed that a low (metre high) dam wall be constructed across the north-eastern arm of the lake, the intention being to enable horticultural development within 2/3 of the arm while retaining approximately 3 ha of it as marsh, along with the remainder of the lake (refer PK Simons correspondence dated 28/7/83, and Hans Rook, NZ Wildlife Service, correspondence dated 27/7/83). Provision was made to direct 'extra catchment' into the lake and to control the lake at a level of RL 23.0 m. This plan was rejected by the NZ Wildlife Service on the basis of the major loss of wetlands nationally, the need to protect those that remained, the loss of shallow wetland habitat this proposal would entail, and the support most landowners had indicated at an onsite meeting in April 1983 for fully restoring and maintaining the lake as opposed to partially developing it (D.J. Pike, NZ Wildlife Service, correspondence dated 15/8/83).

[1] This should actually have read "north-east margin" (Gary Williams pers. comm.).

In September 1984 a report was produced by the HBCB which reviewed options for the future management of Te Rotokare. These included (i) maintaining the lake bed in a dry condition by installing feeder drains and a pumping station to collect and discharge catchment runoff to the outlet drain, (ii) taking no action, and (iii) artificially refilling the lake by pumping water into it from the Tutaekuri-Waimate Stream. The latter could be aimed at either a full restoration, or a partial restoration where *c.*8 ha of swampy margin in the north-eastern corner of the lake could be drained by installing tile drainage and a small stopbank (refer Olsen 1984).

In November 1984, Gary Williams commissioned an investigation by Rikan Engineering of the feasibility of refilling and maintaining the lake. A water budget taking typical rainfall, catchment area and evaporation rates into account indicated a minimum input of 4l/s would be required to maintain the lake during drought conditions such as that in 1981/82. Two options to supply water were considered, one being to pump water into the lake from the Tutaekuri-Waimate Stream, the other being to siphon and gravity feed water into it from a spring located 1500 m to the south-west. The latter was concluded to be a significantly cheaper option over the lifetime of the project (refer Richard Karn, Rikan Engineering, correspondence dated 20/11/84).

In July 1985, and again in October 1985, concern was expressed that a former owner of the land now owned by William Tait, was undertaking unauthorised works in the outlet drain, initially to prevent inflow of floodwaters from the Upokohina, and on the later occasion, to improve drainage out of the lake. That owner had applied for a water right to erect a stopbank on lake bed on the boundary of his title in 1983 shortly after he had purchased it. The application was objected to by the NZ Wildlife Service, the HB Acclimatisation Society, and neighbouring landowners, and doesn't appear to have been processed further. Following the July 1985 incident, HBCB advised that the relative levels of the lake bed, the outfall channel, and the Upokohina Stream meant that any further development of the drainage outfall from the lake bed was not possible without the aid of pumping (P. Koutsos, correspondence dated 25/7/85).

In May 1986 the NZ Wildlife Service lodged applications with the HBCB and Regional Water Board to take and divert water from a spring on Gary William's property and discharge it into the lake in accordance with Rikan Engineering's concept of a siphoned/gravity fed water supply as earlier described. The applications also provided for the construction of a 0.5 m high dam across the eastern end of the lake (including the north-eastern arm), the purpose of which was to maintain water levels within the lake at a maximum level of RL 23.4 m from 1 March to 1 November in any year. Outside that period, a minimum water level of RL 23 m would be maintained, by pumping if necessary. The Department of Conservation however, which was established in 1987 and took over the statutory roles and responsibilities of the former Wildlife Service, withdrew the applications in December 1988 due it appears, to the highly polarised positions of several of the landowners.

In 1994, a former owner of the land now owned by the Gregory-Hunts applied to the Hastings District Council to have his 16.2 ha, and a further 146 ha incorporating the northern arm and eastern end of the lake, and hills to the north of this, rezoned to enable a proposed subdivision of 73 rural-residential lots. This application was subsequently withdrawn, and another lodged in 1995 for a subdivision of the applicant's property only. This too was put on hold by the applicant, apparently in response to opposition voiced by various parties at a prehearing meeting (Gary King, Fish and Game NZ, file note dated 10/3/95).

Consent was granted however, to a subdivision application in 1996 which enabled the creation and development of 19 lots ranging in size from 1.5 to 2.5 ha on the hills immediately to the north-east of the lake. Two of these properties each have a wet gully system connected to the north-eastern arm of the lake.

In December 2000, the Hawkes Bay Regional Council (HBRC) undertook water level and drain invert surveys at the northern and eastern ends of the lake in response to a neighbour's concerns that drains within the north-eastern arm of the lake and at the outlet were being deepened. The concern was that deepening of these drains would lead to a lowering of lake levels via seepage of ground water into the drains, and this water would be conveyed out of the lake catchment via the outlet drain which discharges to the Upokohina. The HBRC advised that (i) the water level in the recently deepened drain was lower than that in the lake, (ii) the outlet drain below the deepened section had a bed level 380 mm higher than the water level in the deepened drain, and (iii) the water level in the deepened drain was lower than the water level in the Upokohina Stream by approximately 300 mm. HBRC concluded that it did not intend altering the design levels in the outlet drain to the Upokohina, so the only way in which water levels (meaning current or lower levels) in the deepened drains could be lowered (other than by evaporation) would be by pumping. HBRC also noted its ground water scientist dismissed the likelihood of significant seepage from the lake to the drain based on the nature of the soils, the hydraulic gradients involved, and the distance to the lake (Jan Lilburn, HBRC, correspondence dated 8/12/00).

5. ECOLOGICAL CONTEXT

Te Rotokare lies within the Heretaunga Ecological District. This district is composed mainly of low hills of gentle to moderate topography surrounding the Ruataniwha and Heretaunga Plains (Lee 1994). Several large rivers cross the plains transporting material derived from the rapidly eroding ranges to the west, and it is this material that has contributed to the formation of the plains. The former vegetation cover of the district was vastly different to that which now covers the land. Once virtually all of the Hawkes Bay lowlands supported a cover of forest and shrublands, and extensive areas of low lying swampy ground were found towards the coast (Lee 1994). Freshwater wetlands bordered by flax, cabbage, manuka and kahikatea would once have been common, but very little of this now remains. The few remaining wetlands within the district comprise a number of swamps (the most substantial of these being the Pekapeka Swamp), ponds and seepages, several shallow lakes (the largest and most significant today being Runanga, Oingo, Poukawa, and Hatuma), and the three large estuaries located close to Napier.

A Protected Natural Areas Programme survey was undertaken within the Heretaunga Ecological District in 1993/94. All wetlands surveyed were described as having been greatly modified by human activity. In most cases native vegetation had been reduced to a narrow fringe dominated by raupo, *Carex* and *Juncus* species, and grazed pasture was generally growing right to water's edge, with stock able to access the wetland itself. Only one very small wetland had a significant area of native woody vegetation associated with it (Lee 1994).

Four bioclimatic zones occur with the ecological district. Te Rotokare is located within the 'lowland arid zone' which is characterised by extreme growing season deficits (Fromont and Walls 1988).

Five other lakes (Runanga, Oingo, Hurimoana, Kautuku, and Potaka), and riverine habitats associated with the Ngaruroro and Tutaekuri Rivers are located within the close proximity (<10 kms) of Te Rotokare. Although all are in a degraded or highly modified state, these waterbodies are collectively important because they contribute to local and regional habitat networks for a variety of waterfowl and other mobile wetland bird species. Figure 2 shows the geographic disposition of Te Rotokare to these waterbodies, and Figure 3 provides a three dimensional overview of landforms and landcover within the wider area.

6. RESOURCE DESCRIPTIONS

6.1 Landform and hydrology

Te Rotokare lies within a basin surrounded by hills on three sides, the highest of which rises to just on 100 m above the lowest point in the basin. Eastwards of the lake, the land rises almost imperceptibly for a distance of approximately 5-600 m (distance dependent on the level of the lake prevailing at the time). At this point Breckenridge Road traverses the landscape in a more or less south-east to north-west direction from one set of foothills to the other, and coupled with drains within the vicinity, effectively forms a hydrological barrier across what was at one time a sub-catchment of the lake and the route through which the lake once received water from the Upokohina catchment and the Tutaekuri River when these were in flood. Figure 4 shows ground elevations east of the lake.

Figure 5 shows the three present day 'sub-catchments' contained within the area to the west of Breckenridge Road, and the direction of key drainage paths. Due to manipulation of natural drainage patterns, only Sub-Catchment 1 is truly a catchment of the lake today in the sense that it discharges directly into the lake under all conditions. Sub-Catchment 1 comprises an area of approximately 135 ha. Sub-Catchment 2 occupies an area of *c.*26 ha and discharges into the outlet drain and thence to the Upokohina drainage system if levels in the lower catchment enable water to flow in this direction. Overland runoff from the extensive 'flats' and northern foothills immediately bordering these in 'Sub-Catchment' 3, also ultimately heads in this direction after flowing westwards to be intercepted by the cross drains, or north-south directly into the outlet drain. The fate of runoff north of Breckenridge Lane was not investigated during this exercise, but it is reasonable to surmise that it is probably discharged to the Upokohina Stream via another culvert under the Breckenridge Road. 'Sub-Catchment' 3 occupies an area of *c.*42 ha.

None of the drains within the area described above flow permanently, and the bed of some are completely dry at times. Rainfall and runoff from Sub-Catchment 1, are almost certainly all that sustains the lake during drier periods, and most summers, as there are no known springs within the Rotokare basin itself, or any indication that a spring(s) might be present[1] (athough Gary Williams (pers. comm.) advises that at its southern end, there is a very wet area developing above lake level which may not simply be a result of poor drainage). When lake level rises to approximately RL 23.0 m, and after a period of prolonged rainfall, parts of Sub-Catchments 2 and 3 may also contribute water to the lake if water levels in the outlet and lower Upokohina are high enough to preclude drainage in that direction. As outlined in Sections 1 and 4, periodic back flows from the Tutaekuri, and to a lesser extent, the Upokohina, were effectively curtailed in the early 1970s. Occasionally however, as occurred in July 1985, high water levels in the Upokohina can redirect water back up the outlet drain for a short period of time.

Just as precipitation and runoff, albeit from a truncated and very localised catchment relative to that which was formerly present, represent the principal, if not only source of water for the wetland, evaporation/evapo-transpiration[2] is the key if not only means by which water is lost when lake levels are at or below approximately RL 22.75 m. This is because the bed level of the upper end of the outlet drain is (or was) approximately RL 22.75 m while that in the Upokohina Stream is (or was) in the order of RL 22.6 m (interpreted from diagram drafted by Norm Olsen, HBCB, 4/7/85).

When water levels are higher than approximately RL 22.75 m, and there is a hydraulic gradient between the lake and the drainage system below the outlet with no intervening obstructions, the lake drains in this direction in addition to losing water to evaporation. When lake levels are very high due to heavy and prolonged rainfall events, drainage may be impeded and less efficient due to hydraulic barriers present in the lower outlet drain and Upokohina system, and insufficient capacity in the drains.

The nature of the soils in this environment suggests loss of water via ground seepage is unlikely to be an issue (c.f. comments made by Jan Lilburn, HBRC, in correspondence dated 8/12/00). The fine sediments and organic material which have accumulated in the upper layers of the bed of the lake over time provide an effective barrier to the downward migration of water.

Lake levels, and hence water depth and the extent of the lake can be highly variable during the course of the year (see Plates 6 & 7), and are heavily influenced by rainfall. Low levels can persist well into winter if the preceding summer has been a dry one, but heavy rainfall events can rapidly top it up again (Brendan McCormack, landowner, pers. comm.). Empirical observations of lake levels over time are not

1 HBRC bore records, and discussions with well drilling operators confirm that an artesian bore with positive head has not been located within the area (John Cheyne, Fish and Game NZ, pers. comm.)

2 Transpirational water loss through vegetation is unlikely to be significant as the lake in its present state is largely an open water body.

Figure 2

Figure 3

Figure 4

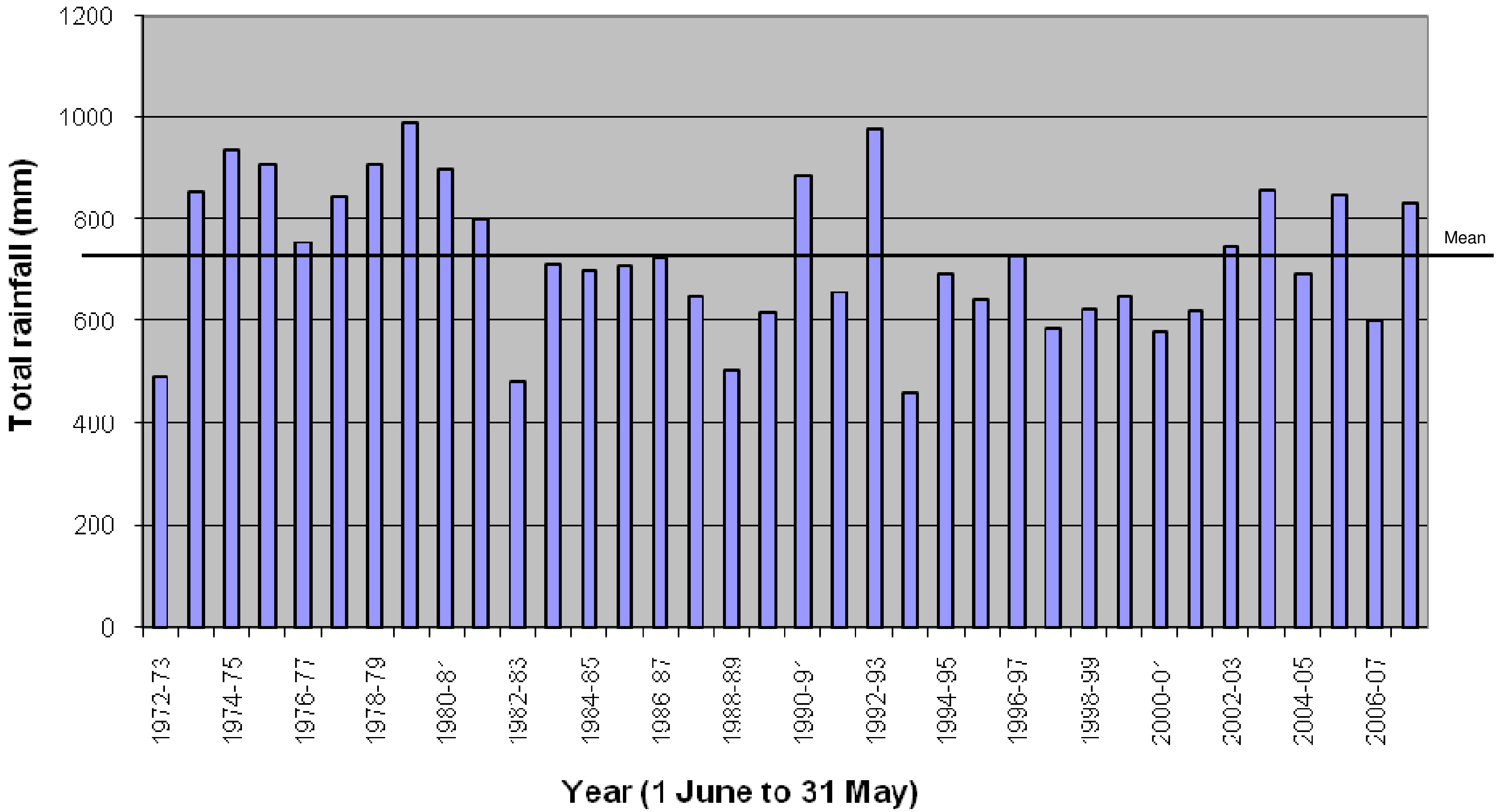
Figure 5

available, but rainfall records are, and these have been measured in parts of the region for many years. Figure 6 presents annual rainfall data recorded at Ngatarawa[1] just south of Fernhill for the period 1972-2008. In addition to highlighting years that were particularly dry or wet, these records indicate that some decades have been wetter or drier than others. The 1980s were considerably drier than the 1970s, while the 1990s were drier again and for a more protracted period, total annual rainfall being well below a 36 year average for six out of the 10 years. The last decade, while experiencing some significant rainfall events in some years, have also been relatively dry over the decade as a whole, though dry years have been more regularly interspersed with wet years. Only time will reveal whether annual rainfall is trending downwards, but 127 years of rainfall data recorded in Napier itself between 1872 and 2008, suggests this pattern is nothing unusual over a broader time frame (see Appendix 3).

Aside from month to month and year to year variation, lake levels, and the extent of the lake, have varied quite considerably over a much greater period of time, and to a much greater degree. Gemma Connolly, a former student at Massey University, extracted a core sample from the western third of the lake bed in 1998 (Connolly 1999). Assessment of the sediments at this point, which were sampled to a depth of 5 m below the present day lake bed level, indicate both the depth of the lake and its circumference, i.e. its footprint, have fluctuated over a time scale of hundreds of years. The bottom three metres of the core suggest relatively little change in the lake for a prolonged period other than at one point where there appears to be a transition from lake mud to more organic sediment suggesting the lake may have been drier for a period. Higher up the core, organic sediments interspersed with clay dominant sequences suggest similar but relatively more frequent events. This is indicative of fluctuating lake levels and is corroborated by pollen analyses. Connolly was unable to assign absolute chronologies to events, but concluded that prior to Maori deforestation and vegetation clearance within the catchment, a significant increase in raupo pollen suggests the lake may have been much shallower for a period prior to again becoming a deeper waterbody as evidenced by a reduction in the raupo pollen count which followed. She speculated that the Tutaekuri River may have changed course and no longer been as closely connected to the site as it once might have been, and that this led to a lowering in water tables prior to a levee being formed at the eastern end of the lake which led to it being impounded once more. Later again, but prior to European influence becoming apparent in the pollen profiles, there is again evidence of a drying out phase and a natural 'terrestrialisation' process occurring. About the time European influence becomes evident in the form of pine pollen, it appears the area again became wetter, possibly as a result of precipitation no longer being intercepted by forest or other indigenous plant communities within the catchment which by now had largely been cleared. The uppermost core sample suggests a further increase in raupo, but a decrease in other emergent wetland species.

[1] Although it would have been useful to utilise rainfall records collected at Omarunui, this data only spans a 17 year period from 1991-2008, whereas Ngatarawa records are available for a 36 period from 1972-2008. While the Omarunui observations might be a little more closely aligned to actual rainfall at Te Rotokare, the Ngatarawa data nevertheless provides an insight into trends and year to year variation.

Figure 6: Annual Rainfall Ngatarawa 1972-2008



While the precise timing, duration, causes, and extent of these alternate deeper lake/shallower lake phases cannot be established from Connolly's work, it is clear that a substantive waterbody has been present for many hundreds of years though its depth and the surface area it occupies has waxed and waned. In the 1990s, a 10 m × 1 m deep channel was excavated in the head of the lake, and at about 700 mm depth, a readily discernible layer (*c.*30 mm thick) of sediment containing pumice was evident. Immediately below this was an approximately 40 mm thick layer of well preserved raupo leaves lying parallel to one another as though they had been flattened from one direction. It was speculated that this represented the last Taupo eruption which occurred *c.*1,800 years ago and evidence that the presence of a wetland at this site predates that event (Gary Williams pers. comm.).

Surface features provide some indication as to how extensive the lake may previously have been, and suggest it may once have occupied the entire valley floor between where it currently lies, and Breckenridge Road or beyond. Theodolite surveys indicate that the height of the embankment upon which Breckenridge Road sits, equates to that of a former lake edge evident above the present day lake margin in the mid and upper valley (Gary Williams pers. comm.). The former lake edge is marked by a very conspicuous berm (Plate 8), the size of which suggests the former lake is likely to have been present for a considerable period of time. Analysis of HBRC's recent LiDAR data suggests this former lake might have occupied an area of 70 ha or more.

Olsen (1984) noted that the lake about that time occupied a surface area of approximately 18-20 ha, with an additional swampy area at the north-eastern end of about 12-14 ha. He noted however, that prior to that, the lake had been up to 35 ha in extent, and 1.4 m deep. Analysis of HBRC's LiDAR generated contours confirms these dimensions. Figure 7 indicates the location of the shoreline, and depth range of the lake, at three prescribed water levels. When water levels drop to RL 22.5 m, the main body of the lake occupies an area of 15.9 ha, maximum water depth is *c.*0.5 m, and surface water within the north-eastern arm of the lake is reduced to *c.*3 ha (although it is not far below ground level within much of the area). When lake level sits at RL 23.0 m, the lake covers an area of 34.0 ha, and depth ranges from 0-1 m. If water levels rise to (or are able to attain) RL 23.5 m, the natural footprint of the lake, if unconstrained, would extend over 41 ha, with water depth varying from 0-1.5 m. This could only occur if the outlet and Upokohina drainage system were seriously overloaded or otherwise incapacitated (which did not occur during 2010 despite significant rainfall events during the winter).

Lake water quality has not been investigated, but is likely to be very poor and highly enriched with nitrogen and phosphorus. Faecal coliform loadings are also likely to be high as a consequence of surrounding land use and the ready access that stock, and cattle in particular, have to parts of the waterbody.

6.2 Vegetation

Very little naturally occurring indigenous vegetation is present within the Rotokare catchment. Introduced pasture grasses and associated species extend to water's edge around virtually the entire margin of the lake. In 2008, William Tait fenced off and excluded stock from *c.*700 m of his lake margin along the northern shoreline of the main water body[1], but elsewhere, stock if present, have unimpeded access to the lake edge and into the lake itself. Some landowners utilise the available grazing opportunities more so than others, but the entire margin reflects the effects of grazing of cattle in particular. Riparian plant communities mostly comprise short species only. Rushes (including *Juncus acuminatus, J. effusus* and possibly *J. edgariae*[2]) occur at scattered intervals along the shoreline, along with a variety of grasses and herbaceous species such as Mercer grass (*Paspalum distichum*), creeping bent (*Agrostis stolonifera*), broad-leaved plantain (*Plantago major*), and a suite of others. Very few sedges are present other than occasional clumps of grazed kapungawha (lake clubrush; *Schoenoplectus tabernaemontani*[2]). Carexes appear to be absent altogether, and there are no tall emergents or naturally occurring flaxes, cabbage trees or woody vegetation within this zone. Raupo (*Typha orientalis*[2]) occupies extensive areas of the lake bed along the central axis of the main water body, but doesn't presently extend to the lake margin proper due to the generally lower water levels that now prevail, and cattle grazing (although photographs and Acclimatisation file notes indicate it has in recent decades).

Much of the substrate within the shallower and more ephemeral north-eastern arm of the lake is vegetated. Species composition is likely to vary in some years according to how wet or dry the area is, and for how long conditions persist. During the field inspection in January 2010, extensive meadows of Mercer grass were present in parts, with occasional clumps of kapungawha emerging through this. Scattered tall rushes were evident in wet pasture where conditions were a little drier, and a smaller rush, *Juncus acuminatus*, was widespread along the margins. A submerged aquatic species, red pondweed (manihi; *Potamogeton cheesemanii*[2]), was observed in areas where water is likely to persist for longer, and extensive rafts of two small, free floating plants, Pacific azolla (retoreto; *Azolla filiculioides*[2]) and duckweed (karearea; *Lemna minor*[2]) were present in open water areas. Hornwort (*Ceratophyllum demersum*). which is a highly invasive introduced oxygen weed, was not detected in this or any other part of the lake during the survey, but three small clumps of this species were recently (October 2010) observed in the outlet drain *c.*150-200 m below the lake by John Cheyne (pers. comm.). These plants may have been introduced to the drain from machinery brought in during recent drain maintenance operations.

William Tait has planted (May 2008) a variety of native plants within the area he has retired. These have included flax (harakeke; *Phormium tenax*), cabbage tree (ti kouka; *Cordyline australis*), akeake (*Dodonaea viscosa*), manuka (*Leptospermum scoparium*), and kohuhu (*Pittosporum tenuifolium*). William has also planted a number of introduced tree species within the vicinity of the lake since he purchased the property in 2000. These include elm, liquidamber, and turkey oak (William Tait pers. comm.). Very few mature trees are present along the northern margin of the lake, and the same applies along much of its southern shoreline. At the south-western end, but set back some distance, is a low density pine plantation, a feijoa orchard, a grove of redwoods established in 1918, a grove of eucalypts, and scattered other large specimen trees. At the eastern end of the lake, rows of large weeping willows and

1 HBRC can provide assistance to do this via its Regional Landcare Scheme which offers up to 50% subsidy on costs.
2 Indigenous species.

Figure 7

what appear to be willow cultivars, have been established along the margins of drains, and individual specimens are present at various points along the lake margin, particularly in the north-east arm. Occasional large poplars are also present in parts. A shelterbelt of casuarina trees occurs along the southern margin of the Rotokare outlet drain, and redwoods are present in what is now the Meate property. Aerial photographs indicate the casuarinas, redwoods, and most of the willows, were not established until after the mid 1980s. These trees were planted during a prolonged dry period (refer Figure 6) in which lake levels were particularly low, and as a consequence of the return of water levels more in line with what they were prior to the 1980s, some trees, the redwoods in particular, have been adversely affected, and have been for some years now (Brendan McCormack pers. comm.).

The north-eastern arm tributary located within the Bloxham and Cleverton properties is more densely vegetated close to the lake margin than is the case elsewhere on the lake. This site was not visited in January 2010, but from a distance clearly supports weeping willow. Crack willow may be present in low densities in the side gullies associated with the arm, but grey willow appears to be absent from the system (John Cheyne pers. comm.). This needs to be confirmed, as grey willow in particular, is highly invasive in this environment and could rapidly compromise habitat values elsewhere within the system.

Gemma Connolly's palynological studies at Te Rotokare in 1998 (Connolly 1999) identified pollen from a wide diversity of indigenous plant species, but because some of these could have been inwashed from the Tutaekuri, or blown in on the wind from further afield, its not possible to precisely describe the composition of the former vegetation. However, nearby lakes Runanga and Oingo, although highly modified also, provide an insight into the plant communities that would have formerly been present. Native species present on margins include cabbage tree and flax, raupo, and three carex species (*C.secta, C. geminata,* and *C. lambertiana*). Three other sedges are also present in shallow water areas (*Bolboschoenus fluviatilis, Eleocharis acuta,* and kapungawha). Submerged or floating aquatic species include *Potamogeton pectinatus, P. cheesemanii, Lemna minor, Azolla filiculioides, Wolffia australiana,* and *Myriophylllum triphyllum.* Two rare plants have been recorded, swamp nettle (*Urtica linearifolia*) which is classified as "declining" by de Lange et al (2008), and a floating liverwort (*Ricciocarpus natans*), which is an uncommon species that Walls (2005a) indicated was known from only two locations within Hawkes Bay (Runanga and Horseshoe Lake). Walls (2005a, 2005b) noted that in the past, and beyond the immediate margins, these lakes would have naturally been surrounded by dense forest dominated by totara, ngaio, kowhai, and kanuka on the hills, and by tall kahikatea on the rich wet soils near the shore. Very wet peaty flats may have contained shrub communities that included manuka.

6.3 Birds

Appendix 1 lists bird species recorded at Te Rotokare and their national conservation status. No comprehensive bird counts appear to have been undertaken on the lake in the last 30 years, but four one off counts of all wetland birds present were carried out by the Ornithological Society of New Zealand during the period 1963 to 1979 (see Appendix 1). Black swan numbers have been recorded at least once a year for 22 of the past 35 years, the last 15 as part of a regional aerial trend count programme conducted by Fish and Game NZ. Fish and Game NZ has also trapped, banded and released mallard ducks at Te Rotokare in all but one year since 2000.

Twenty-five wetland bird species have been recorded at the lake since the mid 1950s. If more comprehensive or more frequent observations had been undertaken over this period, this number would undoubtedly be higher. Bird counts were not undertaken during the survey in January 2010, but species observed at the time, coupled with an evaluation of habitats available, suggests that 22 or 23 of the species recorded are likely to continue to utilize the lake today, though to a lesser extent for quite a number of these as habitat values have probably diminished considerably over the past few decades. Stopbanking of the Tutaekuri, and drainage works in the Upokohina Stream, Rotokare outlet and south-eastern catchment of the lake, have resulted in lower mean lake levels over time, and the persistence of lower levels for longer periods. Subsequent to the implementation of these works in the early 1970s, the numbers of black teal (NZ scaup) typically present dropped rapidly, and for a period black swan became more prolific as feeding depths became more suitable for this species (Gary Williams pers. comm.).

Of the 25 species recorded, 23 are native. Four of these are accorded today, a "nationally threatened" status as per Miskelly *et al.* (2008) and four others are listed as "at risk". It is unclear what role Te Rotokare currently plays in terms of sustaining these species locally, but for most it is probable that habitat opportunities are quite limited, and seasonal. From a habitat perspective, the most significant of these nationally threatened species is the Australasian bittern, and the NZ dabchick. The Hawkes Bay region as a whole probably supports no more than 30-40 bittern (John Cheyne and Hans Rook pers. comms.) which heightens the significance of any area habituated or periodically frequented by bittern. One of the other more interesting records for the lake is the 1954 observation of a pair of marsh crake with at least one juvenile. Although a cryptic species very rarely seen or heard, it is most unlikely to be a feature of the lake today (although it is still present elsewhere in the region, as evidenced by several quite recent observations (John Cheyne, pers. comm.)).

The most conspicuous and numerous of the wetland birds that use the lake are undoubtedly waterfowl, and of these black swan[1], and mallard[1]. Others present in lesser numbers and/or less often are paradise shelduck[1], Australasian shoveler[1], grey duck[1], grey teal, NZ scaup, and Canada goose. Pukeko[1] are also likely to be locally common. Over the past decade, about 300 mallards on average have been banded at the lake in January of each year, and up to eight grey ducks (Matthew McDougall, Fish and Game NZ, pers. comm.). Not all of these birds are likely to have been 'resident' at the time, instead many will have been drawn there to feed on the grain laid out prior to trapping. Black swan numbers can be quite variable during and between years, but have exceeded 100 on occasions.

6.4 Fish and invertebrates

Fish species present in the lake have not been surveyed, but Te Rotokare was renowned as an eeling lake during its early years of occupation (Pat Parson, local

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[1] These species are classified as game birds under the Wildlife Act 1953 and are able to be harvested, subject to conditions, during the game season each year.

historian, Daily Telegraph article 26 April 1994). Olsen (1984) reported that eight tonnes of eels had been commercially harvested there in 1972, and Gary Williams (pers. comm.) advised that approximately two tonnes were taken in 2007, and again in 2010. Although hydrological connectivity with the Tutaekuri River and other catchments is very limited, and consequently opportunities for fish passage impaired, several species known to be present at other sites within the vicinity could potentially be present within the lake or access it on occasions. These include the indigenous common bully (*Gobiomorphus cotidianus*), and the exotic mosquito fish (*Gambusia affinis*). Shortfin eel, longfin eel, common bully, and goldfish (*Carassius auratus*) are known from Lake Runanga (Walls 2005a). Appendix 2 lists fish species recorded in other catchments nearby.

Aquatic invertebrates have not been sampled, but live freshwater mussels (kakahi; *Hydridella* sp.) are very likely to still be present, as seagulls have been seen plucking live specimens from fissures in the lake bed when it has been exposed (Gary Williams pers. comm.). Koura (*Parenephrops planifrons*) too, may also be present.

7. ECOLOGICAL/BIODIVERSITY VALUES

In its current state, Te Rotokare has moderate to low ecological values overall. Although a comprehensive botanical survey has not been undertaken there, the highly modified nature of the lake and its margins, its long history of being in this state, and the ongoing disturbances to which it is subject from surrounding land uses, suggests it is unlikely to support features of particular significance from a botanical perspective. Threatened plant species are unlikely to be present based on what is known of other wetlands within the region, and neither the bed nor the margins of the lake support representative plant communities. Currently, Te Rotokare can be categorised as being of low botanical value.

The lake is however, of greater value from a fauna perspective, and wetland birds in particular. During the 1970s, the former NZ Wildlife Service identified the lake as having high, and regionally significant wildlife values. While this is probably an overstatement today, the lake nevertheless continues to be seasonally important to a variety of waterfowl and wading birds, and continues to be utilised from time to time it would appear, by Australasian bittern (possibly several individuals (John Cheyne pers. comm.)) and NZ dabchick. It is a relatively large water body in a local and regional sense, and in addition to its intrinsic values, is likely to play an important role within the local complex of wetlands of which it is part, by providing complementary habitat opportunities for mobile wetland bird species. The lake is probably of lesser value to fisheries as a consequence of water quality and fish passage issues than it was prior to the 1970s, but this has not been investigated.

What is particularly worthy of note, is that the lake and its margins retain significant potential for enhancement of habitat values for flora and fauna, and ecological values more generally (see Section 9).

8. RESTORATION ISSUES

8.1 Ecological

- The prevailing hydrological regime is constraining potential biodiversity values by impacting on habitats, and opportunities for plants and birds in particular. The water storage capacity of the present system, coupled with its water supply, is insufficient to regularly sustain water depths, during the late summer/autumn/early winter period, at levels which enable a significant year round presence of indigenous plant and animal communities and/or other valued features, e.g. introduced game birds. Loss or diversion of a significant proportion of the lake's former catchment, and installation of the outlet drain in the early 1970s, is largely responsible for this situation. While summer drawdown of water levels is often a desirable feature in shallow water wetlands because it can greatly enhance the productivity of many plant and animal communities, the elevation of almost 50% of the eastern end of the lake bed (which includes the north-eastern arm) is such that since the work in the 1970s much of this area dries out altogether, often for an extended period. This degree of drawdown is too great and occurs too frequently.

- Natural character has been adversely affected by hydrological modification, historical indigenous vegetation clearance, ongoing effects (both direct and indirect) of adjoining land use, and the overriding dominance of exotic vegetation along the margins of the lake. Representative indigenous plant communities are of very limited extent, or are missing altogether from the system, particularly along the margins of the lake. Much of the shoreline of the lake is grazed to water's edge, and natural recruitment and successional processes which might otherwise lead (ultimately) to the re-establishment of former indigenous communities are effectively held in check by grazing and trampling. A low diversity and virtual absence of emergent plant species in the littoral zone[1], and an absence of the more structurally significant and cover producing species which characteristically occupy the riparian zone[2] in systems such as this, has implications for fauna in addition to botanical values per se. In addition to open water, many wetland birds require complementary marginal cover in which to seek refuge, roost, breed or moult. Some species, such as spotless and marsh crake, forage there as well, and occupy these vegetated habitats almost exclusively. While the 'islands' of raupo present in the western half of the lake go some way towards meeting some species' needs, it is shallow water areas in which sedges such as carex, and a variety of other interspersed plants are present, which typically provide the greatest opportunities and hold the highest values.

- Water quality is severely impaired, and impacted not only from runoff of fertiliser and stock effluent, but is worsened through stock having unimpeded access to much of the lake margin, and the bed of the lake itself. This situation is

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1 Littoral zone here is defined as the shallow (0-30cm deep), inundated margin of the lake generally within close proximity (≤30 m) of the shoreline.

2 The riparian zone is the transitional area between open water and dryland which typically supports a characteristic suite of plant species, each of which is adapted to growing in soils of a particular 'wetness'.

exacerbated during dry periods in particular, when water depths are shallow, and extensive areas of the lake bed are exposed and accessed by cattle.

- Fish passage has not been investigated, but barriers to upstream passage may, in some years, be an issue in the outlet drain at critical times (e.g. in summer/autumn for elvers when water levels are low or non-existent), and there may be other impediments lower down the catchment between the Tutaekuri and the Upokohina, and the confluence of the latter with the outlet drain.

- Environmental plant pests such as grey willow and crack willow (*Salix cinerea* and *S. fragilis*), hornwort (*Ceratophyllum demersum*), and a suite of other invasive species which are capable of dramatically modifying wetland systems, do not currently appear to be an issue at Te Rotokare, but could readily become one if not kept in check or prevented from establishing there. The few clumps of hornwort recently observed in the outlet drain should be eradicated immediately.

- Introduced mammalian predators such as feral cats, Norway rats and mustelids may periodically be an issue, or could become one. Domestic cats and uncontrolled dogs can also generate considerable disturbance to wildlife in an environment such as this.

8.2 Landowners

- The prevailing hydrological and management regime for the lake appears to be unsatisfactory to most, if not all landowners. As indicated in Section 1, some wish to see the lake raised and managed at levels comparable to those which prevailed prior to the early 1970s; some have advised they wish to see indigenous wetland plant communities and habitat for wildlife enhanced; and some have noted they would like to see riparian planting extended all the way around the lake, and plant and animal pest/predator control undertaken. One landowner has signalled they don't want the lake anywhere near their property, and one would prefer to have levels reduced across part of his property if it was practicable to do so. The position or aspirations of three minor owners at the north-eastern end of the lake have not been determined.

- As can be inferred from Figure 7, higher water levels have relatively little impact on the footprint and extent of the western arm of the lake, and accordingly, relatively little impact on the owners of these properties, particularly when levels exceed 23.0 m. At the eastern end of the lake however, levels greater than 23.0 m have more substantial consequences for two of the landowners, particularly if water levels significantly exceed this height. This is because portions of these properties straddle the lake bed. If water levels reach 23.5 m, the north-western corner of the Gregory-Hunt property could, if drainage systems were incapacitated, have surface water lying over an area of up to 0.9 ha, or have water just below ground level. High levels impact on the ability of the landowners to sustain productive pasture and graze horses within this part of their property in accordance with present land use.

- Most affected however, or potentially affected by higher water levels, is William Tait. If levels approaching 23.5 m were to be attained due to severely impeded drainage, up to 1.9 ha of pastoral land which is put into crop most years for autumn/winter grazing would be inundated, or have water close to ground level. A much lesser area is typically affected each year, but this nevertheless impacts on management options for this part of the property. Water levels in the range of 22.5-23.0 m also affect Mr Tait's ability to utilise this end of the property as and when he needs to, by effectively isolating it from the western end of his farm. When levels are in this range, which can, and in the past has been, year round, the north-eastern arm of the lake is inundated. Mr Tait has constructed a small section of elevated causeway extending eastwards from the western side of the arm as a first step towards more permanently linking the two parts of his property, but considerably more has still to be done to bridge the gap. When Mr Tait purchased the property in 2000 after a prolonged period of dry years (see Figure 6) and low lake levels, it was his desire to develop much of the north-eastern arm of the lake into pasture as had been the objective of the preceding landowner. After a series of attempts to do so, it has become apparent this is not a practicable or cost effective undertaking (William Tait pers. comm.). Even if the north-eastern arm of the lake was hydrologically isolated from the remainder of the lake, ground elevations within a significant portion of this area are lower than the bed of the upper outlet drain (<22.75 m), and lower than the bed of the Upokohina into which it discharges (<22.6 m). Outside of drought years, pumping would be the only way to effectively drain this area, and the costs of doing so, even if resource consent could be obtained, are likely to preclude this from being an economic option.

- Maintaining the integrity of fences located in the bed of the lake is an ongoing issue, and when lake levels are particularly low, opportunities are greater for stock to cross property boundaries than on dryland.

9. ECOLOGICAL RESTORATION OPTIONS

9.1 Overview

A key objective of this exercise is to facilitate an agreement between landowners with regard to the future of Te Rotokare, and the management undertakings required to realize whatever that vision might be. Once a vision and a set of underlying goals or principles have been agreed to, a prescriptive implementation plan(s) can be prepared.

Four management options are presented along with the implications of each. While the primary focus has been on identifying means of enhancing ecological values, an important principle has been to take all landowners' issues into consideration, and devise an approach that resolves non ecological concerns also, to the extent it is possible to do so.

Ecological *enhancement* rather than ecological *restoration* is the key concept, simply because it is not possible to re-create the hydrological regime that formerly prevailed, nor is it possible to remove all of the exotic elements now firmly entrenched within the system. There is little doubt however, that the present day ecological values of the lake could be significantly improved.

9.2 Option 1: Maintain status quo

One option is to maintain the status quo, which effectively is to do nothing. The consequences of this, would be to retain all of the issues itemised in Section 8, and the ongoing frustration of the most affected and interested landowners. Water quality would continue to decline, and invasive pest plants such as grey willow could rapidly become an issue if allowed to establish and spread unchecked. Raupo too, although periodically controlled in the past, would ultimately spread to all ungrazed parts of the lake, and impact on the features and values of the wetland if not selectively managed. Widespread proliferation of raupo would be beneficial for some wildlife species, but detrimental to others, and would significantly transform the system.

From an ecological perspective there is nothing positive to be gained from persisting with this approach.

9.3 Option 2: Enhance hydrology in main body of lake only

The underlying objective of this initiative, is to implement a cost effective and practical means of buffering the frequency and extent to which water levels vary within the main body of the lake, while preserving opportunities for the landowners of the north-eastern arm of the lake to drain, develop, or manage this portion of the lake bed as they see fit. There are four key elements associated with this proposal:

1. Construction of a *c.*0.7-1.0 m high bund around the eastern end of the lake more or less as shown in Figure 8. This bund would be keyed into the lake bed, and would have an adjustable sill or weir incorporated into it to enable manipulation and fine tuning of water levels. The facility would initially be set to retain a water level of RL 23.5 m. The bund could be vegetated with shallow rooted vegetation such as rushes and sedges to give it a more natural looking appearance.

2. Redirection of the southern contour drain so rather than discharging runoff from Sub-Catchment 2 into the southern cross drain, it discharges directly into the lake, more or less as indicated. Whether it is possible to reconfigure any other drains in Sub-Catchment 2 (or 3) so that these, too, direct runoff into the lake could also be investigated.

3. Installation of a staff gauge into the lake and instigation of a monitoring programme to (i) identify an optimum maximum water level, and (ii) determine whether Items 1 and 2 are sufficient to ameliorate the current situation, or whether an additional source of water is required to offset seasonal water losses and enhance biodiversity and wetland habitat values.

4. Investigation and implementation of a supplementary water supply(ies) if required (e.g. by siphoning or pumping water from the spring in the Paherumanihi Stream to the south-west, and/or periodically diverting stormwater flows in the Upokohina back up the outlet drain).

The implications of implementing these measures would be as follows:

9.3.1 Positive effects

- The bund, coupled with rediversion into the lake of as much runoff from Sub-Catchment 2 as is possible, would enable higher water levels to persist for longer within the main body of the lake, and reduce the extent to which water levels would otherwise be drawn down seasonally. The persistence of higher water levels into spring and summer might also reduce the duration of extreme low level events.

- Buffering the extent to which water levels vary most years would provide greater year round opportunity for mobile wetland birds, and this would be reflected in higher numbers of some of the species utilising the lake over the course of the year. Species diversity however, would be unlikely to change substantially.

- Water temperatures in the main body of the lake during summer months might be moderated by the deeper water conditions, and this could be beneficial to fishery values, and invertebrates such as koura and kakahi.

- Higher water levels maintained for longer periods would reduce the risk of invasion of some environmental and invasive weed species into the main body of the lake, and inhibit the spread of some exotic pest plants already present within the system. Raupo spread might also be slowed.

- Installation of a supplementary water supply would provide greater certainty that all of the above would be realised.

9.3.2 Shortcomings

- Enhancement of hydrology within the main body of the lake alone, while a positive step, would fall well short of enabling the ecological potential of Te Rotokare to be fully realised. Despite drying out altogether in some years, the north-eastern arm of the lake supports an extensive area of shallow swamp meadow habitat which contributes significantly to the productivity of the overall Te Rotokare system, and wetland birds in particular, and this could be further enhanced if Options 3 and 4 were to be implemented.

- Year round habitat values for many of the bird species which currently utilise the lake would continue to be limited to certain activities, and certain times of the year, and opportunities for others, lacking altogether. Representative indigenous plant communities would continue to be a feature missing from the area, and vegetation would remain dominated by introduced plant species characteristic of a highly modified rural landscape.

- This option, on its own, would do little towards addressing water quality issues.

Figure 8

- Installation of the bund as prescribed, would not on its own meaningfully reduce the duration and extent to which paddocks at the eastern end of the lake are flooded, or have water close to ground level. Additional bunding to isolate the north-eastern arm from the eastern paddocks, and/or substantial pumping of water out of the arm, would be required to provide relief to the Tait property, and quite possibly the Gregory-Hunt property also, and enable these landowners to manage their land in the manner they might wish to.

9.4 Option 3: Enhance hydrology in main body of lake and north-eastern arm

The underlying objective of this option (Wildlands' recommended option) is to implement a cost effective and practical means of buffering the frequency and extent to which water levels vary, and reinstate much of the lake's former (pre 1970s) footprint while minimising impacts on landowners' interests to the east of this. There are five key elements associated with this proposal:

1. Construction of a *c.*0.7-1.0 m high bund across the eastern end of the lake more or less as shown in Figure 9. This bund would be keyed into the lake bed, and would have an adjustable sill or weir incorporated into it to enable manipulation and fine tuning of water levels. The facility would initially be set to retain a water level of RL 23.5 m. In addition to building a slight curve into the structure, the bund could be vegetated with shallow rooted vegetation such as rushes and sedges to give it a more natural looking appearance.

2. Redirection of the southern contour drain so rather than discharging runoff from Sub-Catchment 2 into the southern cross drain, it discharges directly into the lake, more or less as indicated. Whether it is possible to reconfigure any other drains in Sub-Catchment 2 (or 3) so that these, too, direct runoff into the lake could also be investigated.

3. Installation of a staff gauge into the lake and instigation of a monitoring programme to (i) identify an optimum maximum water level, and (ii) determine whether Items 1 and 2 are sufficient to ameliorate the current situation, or whether an additional source of water is required to offset seasonal water losses and enhance biodiversity and wetland habitat values.

4. Investigation and implementation of a supplementary water supply(ies) if required (e.g. by siphoning or pumping water from the spring in the Paherumanihi Stream to the south-west, and/or periodically diverting stormwater flows in the Upokohina back up the outlet drain).

5. Construction of a culverted causeway across the north-eastern arm of the lake as indicated in Figure 9, to provide all weather access to and from the eastern and western ends of the Tait property. While this would not directly contribute to the enhancement of hydrology, construction of this structure could facilitate retention of the north-eastern arm as a fully functioning and integral component of the lake ecosystem. A variation on this theme would be to construct an all weather access around the perimeter of the arm.

The implications of implementing these measures would be as follows:

9.4.1 Positive effects

- The bund, coupled with rediversion into the lake of as much runoff from Sub-Catchment 2 as is possible, would enable higher water levels to persist for longer, and reduce the extent to which water levels would otherwise be drawn down seasonally. The persistence of higher water levels into spring and summer might also reduce the duration of extreme low level events.

- Buffering the extent to which water levels vary most years would provide greater year round opportunity for mobile wetland birds, and this would be reflected in higher numbers of some of the species utilising the lake over the course of the year. Species diversity however, would be unlikely to change substantially.

- The persistence of higher water levels in the north-eastern arm of the lake would lead to shifts in the composition of some plant communities, and changes in the relative abundance of some species. Desirable indigenous sedges such as kapungawha could become a little more prolific than is currently the case, and the relative dominance of Mercer grass, an introduced species which can form extensive meadows to the detriment of other species, could be considerably reduced.

- Water temperatures during summer months might be moderated by the deeper water conditions, and this could be beneficial to fishery values, and invertebrates such as koura and kakahi.

- Higher water levels maintained for longer periods would reduce the risk of invasion of some environmental and invasive weed species, and inhibit the spread of some exotic pest plants already present in the system. Raupo spread might also be slowed.

- Installation of a supplementary water supply would provide greater certainty that all of the above would be realised.

- Installation of the bund as prescribed would reduce the duration and extent to which the paddocks at the eastern end of the lake were flooded, or had water close to ground level. This would provide some measure of relief to the Tait and Gregory-Hunt properties and their management of these areas.

- Construction of an all weather culverted causeway running east-west across the north-eastern arm (or a raised embankment around its margin) would provide year round connectivity to either end of the Tait property for vehicular access and the movement of stock.

Figure 9

9.4.2 Shortcomings

- Enhancement of hydrology alone, while a very positive step, would fall short of enabling the ecological potential of Te Rotokare to be fully realised. Year round habitat values for many of the bird species which currently utilise the lake would continue to be limited to certain activities, and certain times of the year, and opportunities for others, lacking altogether. Representative indigenous plant communities would continue to be a feature missing from the area, and vegetation would remain dominated by introduced plant species characteristic of a highly modified rural landscape.

- This option, on its own, would do little towards addressing water quality issues.

9.5 Option 4: Implement other measures to enhance biodiversity values

The initiatives associated with this option would confer greatest benefits if the previous option has been implemented, and a more natural, and less dynamic and extreme hydrological regime for a water body of this size was in place. Additional undertakings could include the following:

9.5.1 Exclude stock and plant margins

- Fencing the entire periphery of the lake and excluding stock from it, would enable the establishment of riparian and emergent vegetation along the shallow margins of the lake. In addition to enhancing landscape values, an increase in marginal cover, subject to species planted, could significantly enhance habitat values for many of the wetland birds which currently utilise the lake in low to moderate numbers, or on a seasonal basis only, and provide opportunities for species that once would have been present but no longer are, including some terrestrial birds.

- Excluding stock from the lake and its margins, particularly if coupled with other on farm initiatives, would also lead to a significant improvement in water quality and aquatic values over time.

- If the periphery of the lake was fenced, there would be no further requirement for boundary fences extending across the lake bed. In addition to improving landscape values, this would reduce ongoing issues and costs of maintaining stock proof fences in an environment that for much of the year is inundated or partially inundated.

9.5.2 Restoration planting

- Exclusion of stock, and planting the margins of the lake as described above, could, with little extra effort or cost, be taken one step further if a complementary objective was to restore many of the species, communities and habitats that were formerly a feature of Te Rotokare and its margins. Due to the many introduced plants now present, and irreversible modifications that have been made to hydrological and ecological processes, it is not possible to faithfully re-create all elements of the landscape precisely as they were prior to the dramatic changes brought about by human settlement, but key and characteristic features of this environment could be. In addition to restoring habitat opportunities for many wildlife species, and enhancing the appearance of the lake and its surrounds as in 9.5.1 above, restoration planting using species that formerly occurred in this area would significantly increase the naturalness of the site, its botanical values, and its ecological importance more generally.

- As well as restoring plant communities representative of the site, threatened plant species could also be re-introduced to the area.

9.5.3 Weed control

- Pest plants are not a significant issue currently. In some years Mercer grass may dominate open water plant communities within the north-eastern arm, but if the recommended hydrological regime is implemented (Option 3), the frequency of this occurring should be lessened.

- Removal of grazing from the lake margins, greater use of the wetland and its margins by both wetland and terrestrial bird species, and the possibility of well intentioned, but uninformed introductions of invasive plants into the area by adjoining landowners, is likely to elevate the risk of colonisation and/or spread of pest plants within the area as a whole. This is not an issue if regular surveillance for troublesome plants and follow up control is undertaken, but could become one if this doesn't occur. The low density hornwort populations recently observed in the outlet drain should be eradicated immediately.

9.5.4 Enhance fish passage

- As previously indicated, fish passage was not investigated, and it may or may not be an issue. If significant barriers to fish passage are present between the lake and the Tutaekuri River however, removing these impediments may be an additional means of enhancing the biodiversity and ecological values of Te Rotokare. An objective evaluation of the implications of doing this would need to be undertaken first.

9.5.5 Predator control

- Revegetation of the margins of Te Rotokare, enhancement of habitat values for wildlife, and increased usage of the area for breeding will provide greater opportunities for introduced mammalian predators (rats, hedgehogs, mustelids, and feral cats). Possums, which can be a predator also, might become a feature within the area too. All of these animals could be readily controlled at Te Rotokare using a combination of traps and poison. While many wetland birds are relatively unaffected by these predators, others can be impacted in environments such as these where the depth of the riparian cover that might be created, and the ratio of this cover to open water area, is likely to be relatively small on both counts. Predator control would be another useful undertaking to enhance habitat values within this system.

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Kris Ericksen initiated the project and obtained the funding for this investigation. John Cheyne (formerly Department of Conservation and more recently Fish and Game NZ), and Hans Rook (Department of Conservation) provided access to correspondence and other documents held on departmental files, and participated in an on-site visit and discussion of technical considerations. John also reviewed an earlier draft of this report as did Kris Ericksen. Gary Williams (landowner) provided a very useful historical perspective, access to other sources of information, and ongoing comment. Two other landowners, William Tait and Brendan McCormack, also provided feedback and/or comment and information. Stephen Cave from Hawkes Bay Regional Council organised lidar contour data, and facilitated access to other information held by Regional Council including historical rainfall records, and comment from Norm Olsen (formerly Hawkes Bay Catchment Board, now Hawkes Bay Regional Council). Steve also participated in the on-site visit to review issues and options. Professor John Flenley of Massey University copied and forwarded Gemma Connolly's palynological thesis.

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RECORDED BIRD COUNTS AT TE ROTOKARE

Scientific Name	Common Name	Conservation Status (Miskelly *et al.* 2008)	May 1954	Spring 1963	June 1967	Sept 1969	July 1978	April 1979	Feb 1990	1996-2010[1]
Indigenous										
Anas gracilis	tete; grey teal							19		✓
Anas rhynchotis	kuruwhengi; Australasian shoveler			12		30		50		✓
Anas superciliosa superciliosa	parera; grey duck	Threatened-Nationally Critical		✓		1		3		✓
Ardea novaehollandiae	white-faced heron			3		2		4		✓
Aythya novaeseelandiae	papango; New Zealand scaup				9	47	4	10		0-35
Botaurus poiciloptilus	matuku; Australasian bittern	Threatened-Nationally Endangered		6	1	3	1	2		1
Charadrius bicinctus	tuturiwhatu; banded dotterel	Threatened-Nationally Vulnerable		3						
Charadrius melanops	black-fronted dotterel			5				5		✓
Circus approximans	kahu; Australasian harrier			2		4				✓
Cygnus atratus	black swan			19	2	0	>100	46	36	0-106
Egretta alba modesta[2]	kotuku, white heron						1			✓
Himantopus himantopus leucocephalus	poaka; pied stilt	At Risk-Declining			3	4		12	22	✓
Hirundo tahitica neoxena	welcome swallow				10	16		10		✓
Larus dominicanus dominicanus	karoro; black-backed gull					4	✓			✓
Phalacrocorax carbo novaehollandiae	kawau; black shag	At Risk-Naturally Uncommon		20	2	✓		7		✓

1 Recorded as present on one or more occasions during this period.
2 Recorded as a 'white egret', but other accounts of the time suggest this was most likely to have been a white heron.

Scientific Name	Common Name	Conservation Status (Miskelly *et al*. 2008)	May 1954	Spring 1963	June 1967	Sept 1969	July 1978	April 1979	Feb 1990	1996-2010[1]
Phalacrocorax melanoleucos brevirostris	kawaupaka; little shag	At Risk-Naturally Uncommon		30		4			101[1]	✓
Phalacrocorax sulcirostris	little black shag	At Risk-Naturally Uncommon		1				6		
Poliocephalus rufopectus	weweia; New Zealand dabchick	Threatened-Nationally Vulnerable		4		7		2		✓
Porphyrio porphyrio melanotus	pukeko			4	40	✓	12	40	50	✓
Porzana pusilla affinis	koitareke; marsh crake	At Risk-Relict	3							
Tadorna variegata	putangitangi; pari; paradise shelduck			9	9	45	0	14	0	6-23
Todiramphus sanctus	kotare; sacred kingfisher					✓				✓
Vanellus miles	spur-winged plover									✓
Introduced										
Anas platyrhynchos	mallard			✓		70	*c*.300	*c*.100	*c*.250	✓
Branta canadensis	Canada goose									✓

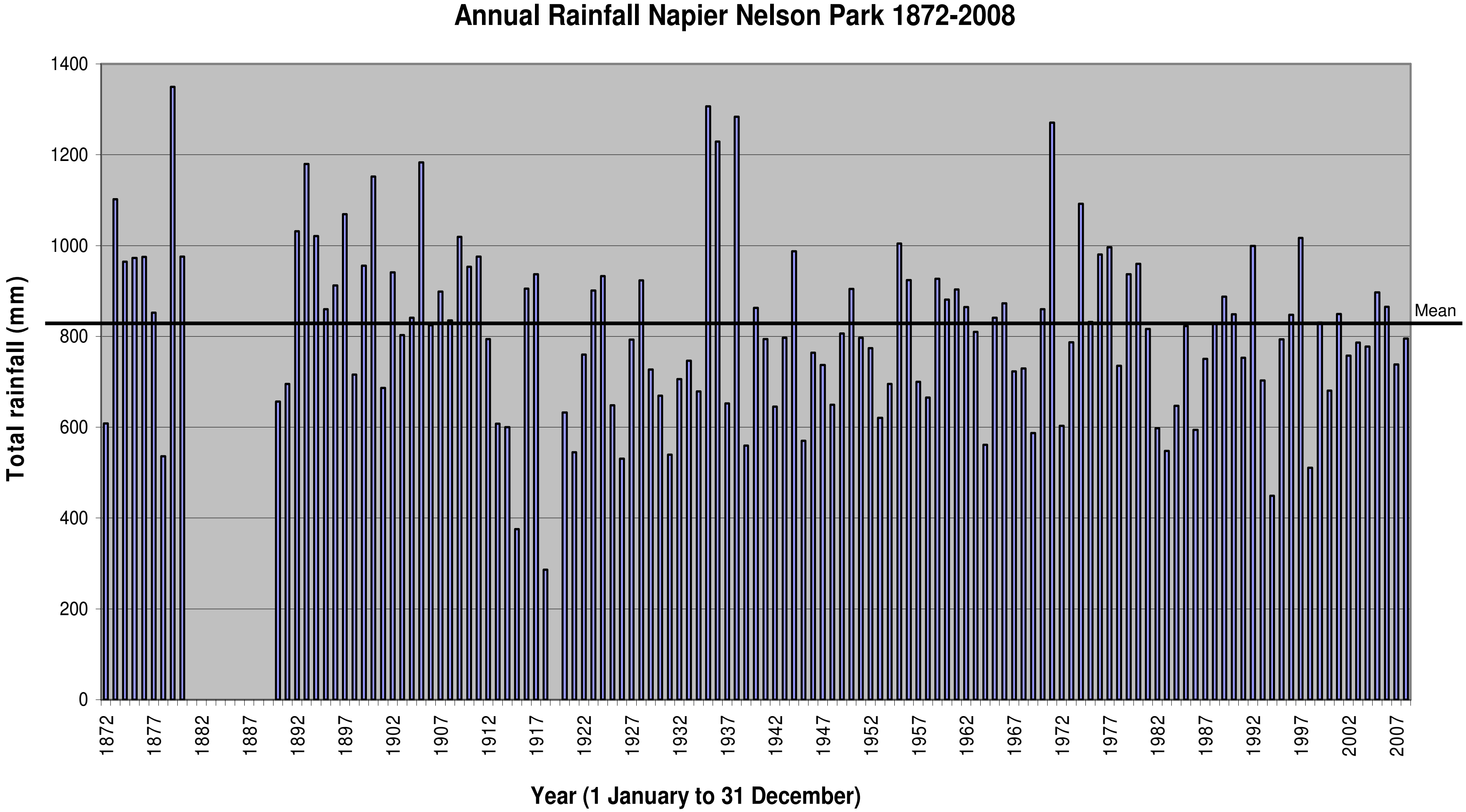
1 Species not confirmed.

FRESHWATER FISH RECORDS WITHIN THE VICINITY OF TE ROTOKARE

(Source: NZFFD May 2010 and John Cheyne pers.comm. (JC) as indicated)

Scientific Name	Common Name	Conservation Status (Allibone *et al.* 2010)	Tutaekuri-Waimate 1986-2006	Tutaekuri 1994-2006	Ngaruroro 1986-2006
Indigenous					
Anguilla dieffenbachii	long-finned eel	At Risk-Declining	✓	✓ (JC)	✓ (JC)
Anguilla australis	short-finned eel		✓	✓ (JC)	✓ (JC)
Cheimarrichthys fosteri	torrentfish	At Risk-Declining		✓	✓
Galaxias brevipinnis	koaro	At Risk-Declining		✓	✓
Galaxias divergens	dwarf galaxias	At Risk-Declining			✓
Galaxias maculatus	inanga		✓	✓	✓
Geotria australis	lamprey	At Risk-Declining			✓
Gobiomorphus basalus	Crans bully				✓
Gobiomorphus cotidianus	common bully		✓		
Gobiomorphus gobioides	giant bully		✓		
Gobiomorphus huttoni	redfin bully	At Risk-Declining		✓	✓
Retropinna retropinna	common smelt		✓		
Introduced					
Gambusia affinis	mosquitofish		✓		
Oncorhynchus mykiss	rainbow trout		✓	✓ (JC)	✓ (JC)
Salmo trutta	brown trout			✓ (JC)	✓

ANNUAL RAINFALL RECORDED AT NAPIER NELSON PARK 1872-2008


Annual Rainfall Napier Nelson Park 1872-2008
Total rainfall (mm)
Year (1 January to 31 December)
Mean
0
200
400
600
800
1000
1200
1400
1872
1877
1882
1887
1892
1897
1902
1907
1912
1917
1922
1927
1932
1937
1942
1947
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
2007

SITE PHOTOGRAPHS

Plate 1: Main body of Te Rotokare as viewed from north-western end (21 January 2010).

Plate 2: Upper (western) end of main water body (21 January 2010).

Plate 3: Lower (eastern) end of main water body (21 January 2010).

Plate 4: Upper (northern) end of north-east arm of lake (21 January 2010).

Plate 5: Mid and lower section of north-eastern arm of lake,
looking south-eastwards (21 January 2010).

Plate 6: Te Rotokare viewed from southern side of lake looking across to north-eastern arm when water levels are high (September 2009). Photo supplied by Gary Williams.

Plate 7: Eastern end of Te Rotokare viewed from southern side, looking into north-eastern arm when water levels are very low. Photo taken in 2007 by Gary Williams.

Plate 8: Gary Williams demonstrating the location of a former lake edge, relative to the present day margin (as viewed 21 January 2010).

Plate 9: Outlet drain of Te Rotokare just below its junction with the southern cross drain (left mid photo) and the northern cross drain (entering from right mid photo). Note water level very close to surrounding ground level at this point. Photographed 21 January 2010.

Plate 10: Te Rotokare outlet drain viewed from *c.*200 m below the lake which lies behind the trees in the distance. This photograph was taken on the same occasion as Plate 9. Note the depth of the drain and lack of water within it at this point which illustrates the extent to which ground level rise eastwards of the lake.