Water level fluctuations in Lake Rotoiti and their ecological implications

NIWA Client Report: HAM2003-156
December 2003

NIWA Project: BOP04215

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Prepared for

Environment Bay of Plenty

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Executive Summary

NIWA has been requested by Environment Bay of Plenty to prepare a short report on the likely ecological implications of changes to lake level fluctuation since the installation and operation of the Okere Gates in 1982. In this report we first assess the effects of operation of the gates on the water level regime and then comment on ecological effects that normally follow such changes.

Prior to outflow control, water level changes of 20-50 cm occurred between years in Lake Rotoiti, sometimes as part of near decadal cycles and sometimes as a steady directional change. A seasonal pattern of approximately 20 cm average range was overlaid on these long term fluctuations. These patterns have disappeared since regulation. The short term (within month) variability of 5-10 cm is, however, only slightly less than that that seen prior to regulation.

The water level range of Lake Rotoiti is now very narrow, and this will result in a narrow band of varial habitat around the edge of the lake. In sheltered areas surface reaching weed growths are likely to be persistent, whereas with seasonal fluctuations in level this would have been alleviated to some extent during spring high water. Wetlands contiguous with the lake will also have relatively stable water levels compared to the natural regime. This will tend to reduce habitat patchiness and, over time, may reduce biodiversity and facilitate lake-ward invasion by terrestrial plants.

The fact that between-year variation in level was greater than within-year variation in Lake Rotoiti prior to level control was not best suited to development of shoreline habitat. The quantitative effect on marginal habitat of the change in operation is therefore likely to be relatively small. Most impact will be seen in marginal wetlands with a water source independent of the lake. In such areas, however, wetland habitat is sustained largely by the external water source, and is affected by occasional disturbance by inundation from the lake can be an important structuring effect on the community composition. Under regulation this occasional disturbance will no longer be part of the hydrological regime and greater temporal and spatial homogeneity within the wetlands is likely to develop over time.

The deeper habitats in Lake Rotoiti, that is the zone occupied by submerged macrophytes and their associated fauna, the profundal part of the lake with no vegetation and a fauna characteristic of bare sediment, and the open water communities are unlikely to be measurably affected in by changing level regimes.

1. Introduction

NIWA has been requested by John Mackintosh of Environment Bay of Plenty to prepare a short report on the likely ecological implications of changes to lake level fluctuation since the installation and operation of the Okere Gates in 1982. In this report we first assess the effects of operation of the gates on the water level regime and then comment on ecological effects that normally follow such changes.

Water level data has been provided by Mr Glenn Ellery, and comprises mean daily water levels since 1906, as well as hourly levels for selected periods since 1970.

Water level is a fundamental variable affecting those components of aquatic ecosystems that exist close to lake margins. Organisms adapted to life in water usually perform poorly when exposed to air, and vice versa, whereas amphibious organisms are rarely competitive if subject to long exposures to either. Because of these physiological constraints, different species tend to occupy different positions along the gradient between land and water, and several aspects of water level fluctuation have been identified as important to defining these distributions (Riis and Hawes, 2002; Hawes et al., 2003). The most important aspects of level variation are; the range of water level fluctuation, which defines the overall area of the amphibious zone, the frequency of immersion/emersion, which defines the degree of desiccation and the duration of high and low water events, which determines the time available for sensitive life history stages to be completed.

In a previous study of New Zealand lakes (Riis and Hawes, 2002, Hawes et al., 2003) we found that monthly fluctuations in water level of up to 1 m were optimal for establishing and maintaining diverse amphibious turf zone communities. Narrower level ranges tended to allow a few competitively dominant species to dominate the lake margins and reduced the area occupied, while greater fluctuations allowed only the very tolerant species to survive. We also found that where inter-annual variation in water level were high relative to intra-annual variation, amphibious communities were compromised due to invasive pressures from terrestrial and aquatic communities when levels were high or low for prolonged periods. Lakes with very constant levels will tend to have a narrow, species poor fringe habitat that transitions rapidly from aquatic to terrestrial, though exceptions will occur where such lakes grade into extensive wetland areas. These broad principles will be used when assessing the water level regime of Lake Rotoiti in pre and post control periods.

2. Water level regime at Lake Rotoiti

Prior to 1970 the water level in Lake Rotoiti was under natural control. The level was high during years of high natural inflows, and low during years of relative drought. This situation was changed in the early 1970's with the installation of some degree of control on the outflow from Lake Rotorua (the major source of water for Lake Rotoiti) and further in 1982 with completion of the control gates on the outflow of Rotoiti at Okere Falls.

Comparison of the mean daily lake levels for the twenty years pre and post control indicate that there has been a substantial change in regime (Figure 1). The conspicuous feature of these plots is the great reduction in variability over month/year/decade timescales in recent years. Short term variability (the "noise" on the plots), on a vertical scale of 10 cm, remains.

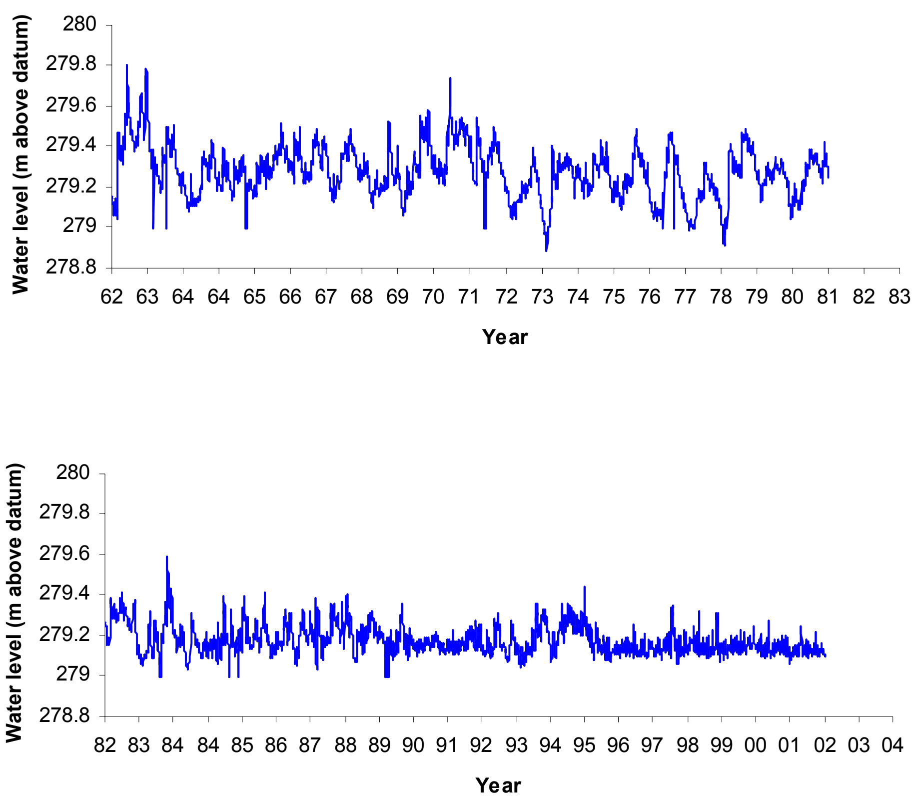

Figure 1: Mean daily water level of Lake Rotoiti in the 20 years before and after level regulation.

Long term patterns of monthly median level and variance about this level show this control effect more clearly, and indicate how management has largely succeeded in attaining the target level of 279.15 ± 0.075 m (figure 2). Figures 2 and 3 also indicate how the uncontrolled level of Lake Rotoiti varied over short and long time scales. Long term changes are particularly evident in figure 3. There was a period of near-decadal cycles in the early part of the 20th Century, followed by gradually accumulating water level from 1945 to 1965 and sustained high levels in the 60's and early 70's. The current level has stabilised just below the average pre-1950 median level (279.17 m), but this is towards the low end of the range seen in the decade prior to regulation.

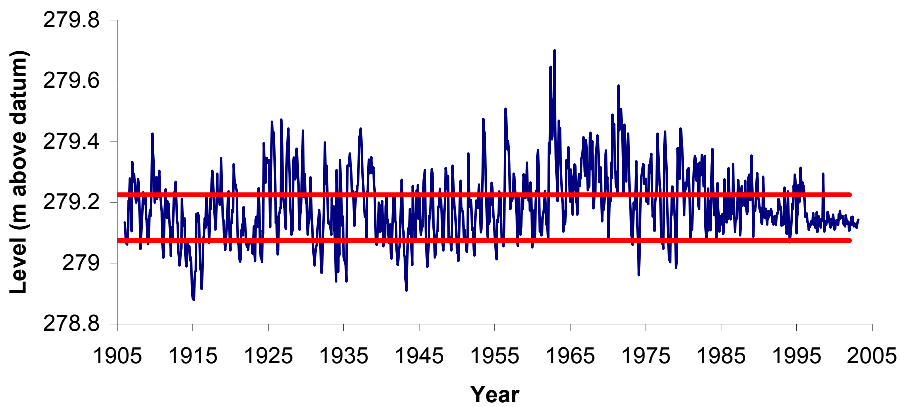

Figure 2: The long term history of monthly median water level at Lake Rotoiti. The red lines indicate the current target level range.

As discussed above, variance of water level, both range and timescale, is critical to marginal aquatic ecosystems. Figure 4 summarises the short (within month) and medium term (within year) variability of water level. The statistic used to make these comparisons are an inter-decile range, that is the range between the upper and lower 10% of recorded levels. Decile values are useful indicators of ecologically important fluctuations as they avoid short-duration peaks and troughs in levels, which organisms can tolerate and therefore have less ecological impact than longer duration fluctuations. Inter-decile ranges show how within year variance (15-50 cm) used to exceed within-month variance (5-15 cm). Under the control regime, within-month variance has declined only slightly, while within year variance has declined to 5-10 cm and is now equal to within-month variance.

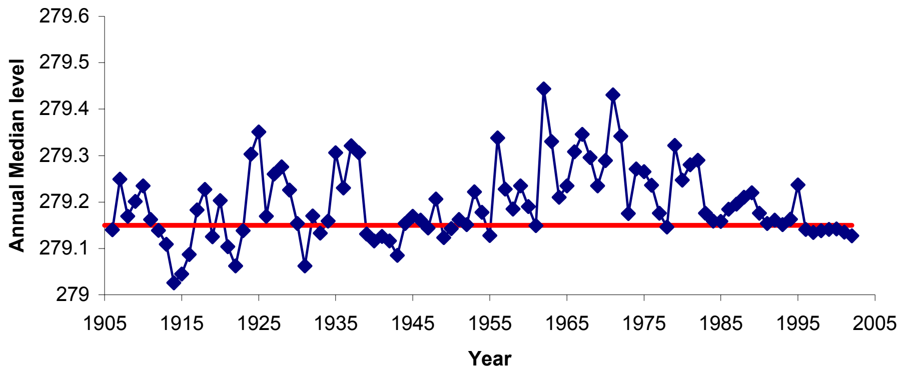

Figure 3: Annual median water levels in Lake Rotoiti. The red line indicates centre of the current target level range.

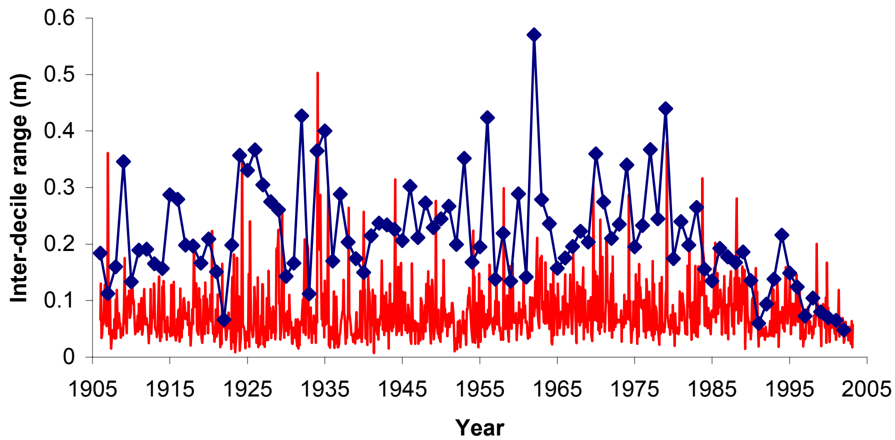

Figure 4: Inter-decile range of water levels by year (blue) and by month (red).

In summary, prior to outflow control, water level changes of 20-50 cm range occurred between years in Lake Rotoiti, sometimes as part of near decadal cycles and sometimes as a steady directional change, and a seasonal pattern of approximately 20 cm average range was overlaid on these long term fluctuations. These patterns have disappeared since regulation. The short term (within month) variability of 5-10 cm is, however, only slightly less than that that seen without regulation.

4. Ecological consequences of water level regulation

The type and vertical zonation of vegetation around the edge of a lake is dependent on the type of substrate, exposure to waves and water level range. Vegetation zones are useful indicators of ecological health not only from a plant biodiversity perspective but also because the invertebrate and algal populations that they support form the basis of littoral zone food webs.

On sandy shores exposed to strong wave action no vegetation develops in shallow water, but as wave size diminishes a typical “turf” community develops that is resistant to moderate wave action and tolerant of episodic emersion (Chapman et al 1971). Typically, fully submerged vegetation develops below this community, the upper limit of which is set by wave action. At yet more sheltered sites, emergent vegetation can develop if shoreline management permits. In parts of Lake Rotoiti lakeside wetlands occur, which are hydraulically linked to the lake, and these are also affected by lake levels.

In general, reduced water level range will result in reductions in the range of the various marginal zones. Under the controlled regime, tall growing submerged macrophytes (*Ceratophyllum demersum* currently dominates at the west end of the lake) stabilise at high cover at a depth set by wave action. In sheltered areas this will be very close to or at the lake surface. The vertical extent of any turf zone will be narrower with a less variable lake level, but this community will not be excluded from the exposed shores of the lake.

Wetland zonation will also have been affected under a more stable level regime. Patchiness and zonation in wetlands is in large part set by the gradient of the inundation regime allowing species with different flood tolerance to dominate at different locations. Flood tolerance has a temporal aspect as well as a depth one, in that the competitive edge of different plants varies with the duration of immersion/emersion. To a point fluctuating levels create greater habitat diversity, hence vegetation diversity, than stable ones. A very stable level regime is likely to result in a narrower and less diverse band of lake margin wetland than an unstable one, with corresponding impacts on the invertebrates, fish and birds that exploit the zone.

Wetlands around the lake with a source of water other than the lake are likely to be affected through the reduction of inundation associated with occasional prolonged high levels. In such wetlands, waterlogging is maintained by the balance between landward and lakeward water supply. Under constant conditions a stable gradient of species will result. Disturbance through inundation is a key factor creating variability in such systems. Under controlled lake levels we will expect great temporal constancy within these systems, which is likely to reduce overall diversity. Reduced habitat extent and diversity may also impact on the birds and fish which exploit marginal vegetation or that part of the shore which is episodically flooded and dry, either for breeding or feeding habitat.

Depth zones below the immediate effects of level fluctuations; that is the submerged macrophytes and the profundal communities are unlikely to be affected by the change to water level regime. These habitats are only affected by fluctuating water levels insofar as they alter the amount of light received, or the effective exposure to wave action. These variables will be changed only slightly in these deeper habitats, and the magnitude of the effects of level are likely to be much smaller than variability due to changing water clarity or by climatic variation. What will have changed is the conditions for the upper margins of the submerged vascular plant community. Acclimate to the more stable level regime is likely to involve a more homogenous and greatr biomass close to the surface, and a higher covering of epiphytic algae and slimes.

The open water foodweb is little affected by water level fluctuation, being primarily dependent on planktonic organisms. Planktonic organisms respond most to changes in nutrient supply or mixing regime. It seems very unlikely the constant level will have affected either of these variables, hence links between stable level regime and blooms of algae are probably coincidental.

Quantifying the effect of level management on lake marginal habitat is beyond the scope of this short report. This requires an understanding of shoreline slope and wave exposure that exceeds the information currently available. However, the water level range of Lake Rotoiti was historically less than one metre and much of the range was inter-annual and seasonal rather than short term. There is likely therefore to be only a small direct impact of the reduction of seasonal and inter-annual water level range on the littoral fringe habitat. Ecological effects are likely to be restricted to a relatively small depth range, perhaps a 30 cm ring above and below the current mean level. The areal extent of this ring will be dependent on shoreline slope.

5. References

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