4. Baseline Lake Water Quality

Te Waihora/Lake Ellesmere is a unique, complex and diverse coastal lake system. The lake is impounded behind a long barrier beach (Kaitorete Spit) which extends from Birdlings Flat to Taumutu, a distance of approximately 27 kilometres. The lake currently covers an area of approximately 20,000 Ha, making it New Zealand's fourth largest lake (by area), but historically it may have covered a much larger area when water levels were high (prior to implementation of an artificial level management regime).

Te Waihora/Lake Ellesmere is considered to have formed between 6,000 and 14,000 years ago (Meredith, 2010) following sea level recovery at the end of the last ice age. Due to the mobile nature of the major river systems on this section of the Canterbury Plains, Te Waihora/Lake Ellesmere has variously formed an estuary for the Waimakariri and/or Rakaia rivers as they migrated across their respective floodplains. However, today Te Waihora/Lake Ellesmere acts as a shallow coastal lake with the Selwyn and Halswell rivers and numerous spring-fed streams the primary surface water inputs.

The Te Waihora/Lake Ellesmere catchment drains approximately 275,000 Ha and extends from the foothills of the Southern Alps across the plains between the Waimakariri and Rakaia rivers to the hills of Banks Peninsula. Due to its location at the bottom of the catchment Te Waihora/Lake Ellesmere accumulates nutrient and sediment inputs from a relatively large area.

Te Waihora/Lake Ellesmere is an internationally significant wetland for both wildlife and wildlife viewing. It supports a rich biological environment including native and introduced species of plants and animals, is a tribal taonga, and represents a major source of mahinga kai and mana. The lake is important to both local and regional communities for amenity and recreational value, and supports customary and commercial fisheries with eel, flounder and mullet the primary catch species.

4.1. Current Water Quality

At the current time water quality is monitored in Te Waihora/Lake Ellesmere by Environment Canterbury in 10 tributary streams (discussed in the previous chapter) and the four lake monitoring sites illustrated on **Figure 48** below.

4.1.1. Microbial Quality

Microbial quality affects the suitability of water for domestic and stock water supply as well as for contact recreation. As illustrated in **Figure 49**, concentrations of indicator bacteria collected from the four lake monitoring sites indicate that microbial quality is generally within limits for contact recreation.

The primary factors influencing microbial quality of the lake include faecal inputs from birdlife, grazing stock along the lake edge and inputs in tributary streams from grazing stock, domestic animals and wastewater discharges (Hayward and Ward, 2008).

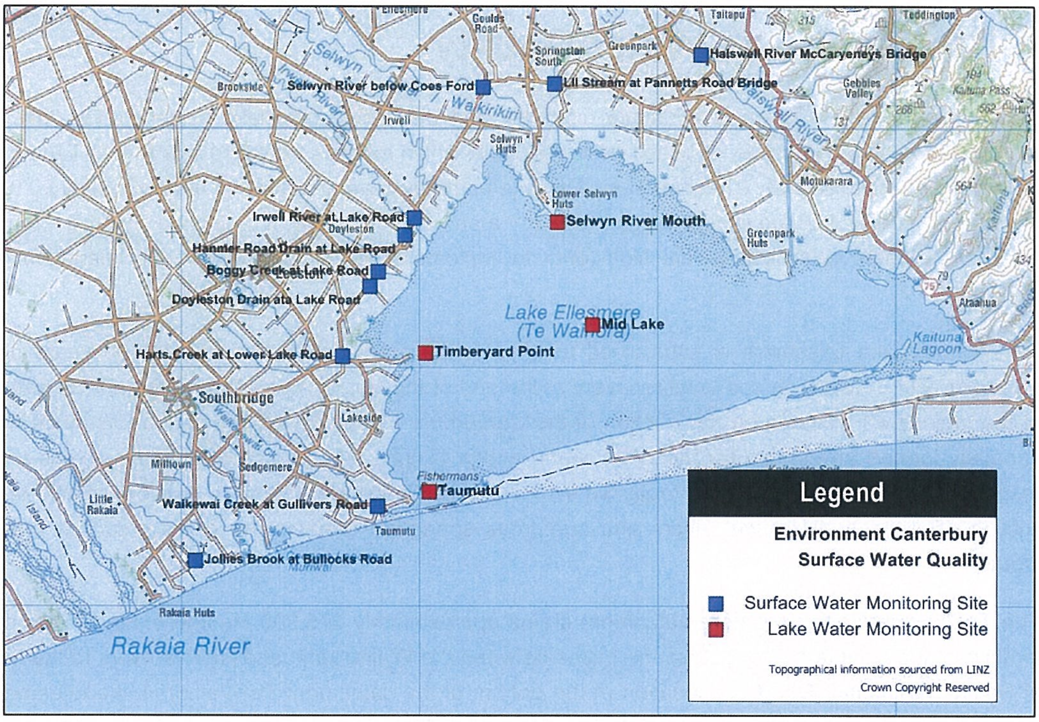

Figure 48. Location of Environment Canterbury surface water quality (blue squares) and lake water quality (red squares) monitoring sites in the Te Waihora/Lake Ellesmere catchment

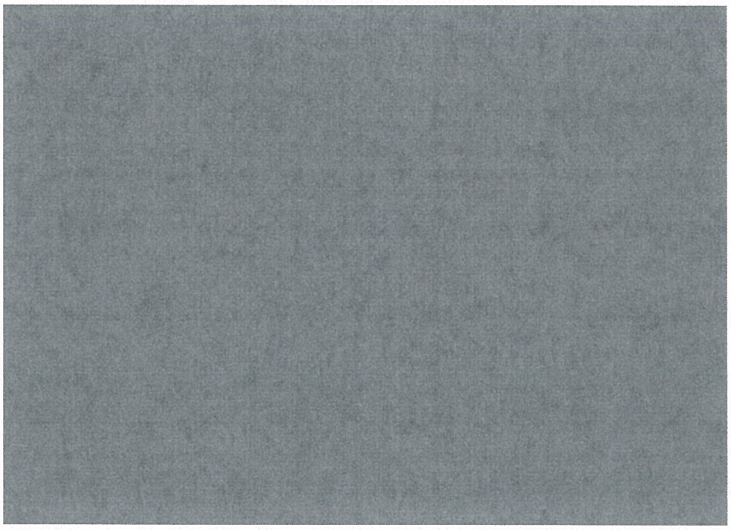

Figure 49. Faecal coliform concentrations in four sites on Te Waihora/Lake Ellesmere, 2002-2007 (reproduced from Hayward and Ward, 2008)

4.1.2. Nutrients

Figure 50 and **Figure 51** show plots of total nitrogen and total phosphorus concentrations measured in Te Waihora/Lake Ellesmere compared to other coastal lakes in the Canterbury Region (Wairewa/Lake Forsyth, Muriwai and Wainono Lagoon). The data show median total nitrogen concentrations from the four Te Waihora/Lake Ellesmere sites are higher than those observed in other coastal lakes and generally fall within the hypertrophic classification. Total phosphorus concentrations are also generally higher than other coastal lakes although Wairewa/Lake Forsyth and Wainono Lagoon also fall into the hypertrophic classification.

Estimates of nutrient inputs indicate 90% of the total phosphorus loading to Te Waihora/Lake Ellesmere is from tributary inputs, 6% from rainfall and 4% from birdlife. Approximately 98% of the total nitrogen loading is attributed to tributary inflows with only 1% derived from rainfall and direct groundwater inputs respectively (Hayward and Ward, 2008). Monitoring of the lake over the past two decades indicates little appreciable change in nutrient concentrations either in terms of phosphorus or nitrogen and total or dissolved nutrients (Hayward and Ward (2008), Meredith, (2011)).

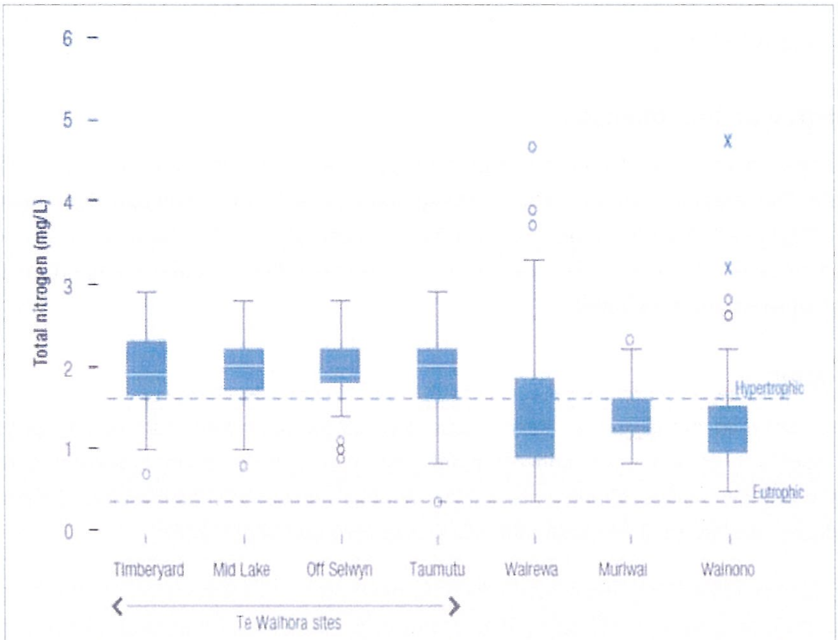

Figure 50. Total Nitrogen concentrations at four sites on Te Waihora/Lake Ellesmere compared to other Canterbury coastal lakes, 2002-2007 (reproduced from Hayward and Ward, 2007)

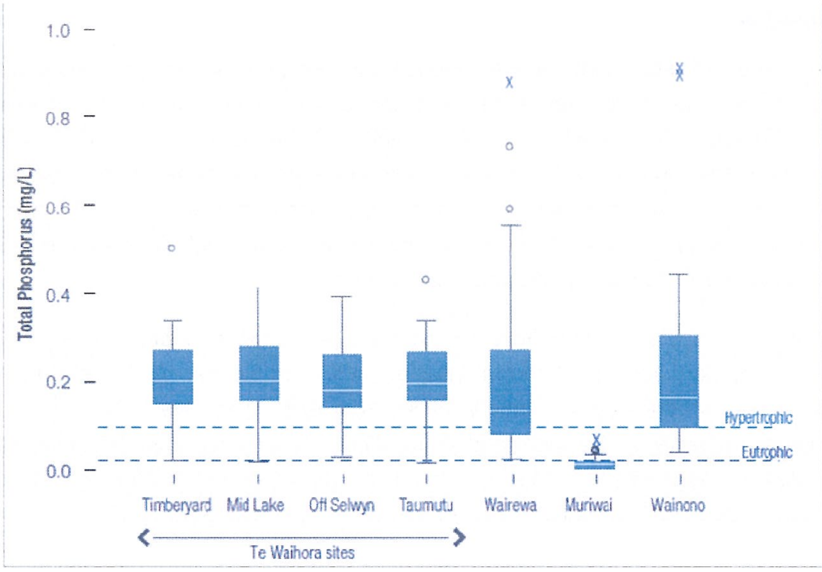

Figure 51. Total Phosphorus concentrations at four sites on Te Waihora/Lake Ellesmere compared to other Canterbury coastal lakes, 2002-2007 (reproduced from Hayward and Ward, 2007)

4.1.3. Phytoplankton biomass

Figure 52 shows a box plot of phytoplankton biomass (measured as chlorophyll a) at the four Te Waihora/Lake Ellesmere monitoring sites. These data show overall phytoplankton biomass was higher in Te Waihora/Lake Ellesmere than in other coastal lakes in Canterbury. However, annual maximum chlorophyll *a* is lower in Te Waihora/Lake Ellesmere than in Lake Forsyth/Wairewa where toxic algal blooms are more frequent.

4.1.4. Clarity

Visual water clarity, as measured by Secchi disk, as well as being important ecologically for visual feeding of insects, fish and birds and for plant and algal growth is an important contributor to recreation and amenity values. Clarity shows little variation across Te Waihora/Lake Ellesmere and is low, with a decreasing trend at all monitoring sites (Hayward and Ward, 2008).

The primary factors influencing visual clarity include phytoplankton biomass (driven by nutrients, light and temperature), suspended sediment (wind driven re-suspension of bed sediments) and sediment inputs (tributary inflows, lakeshore erosion).

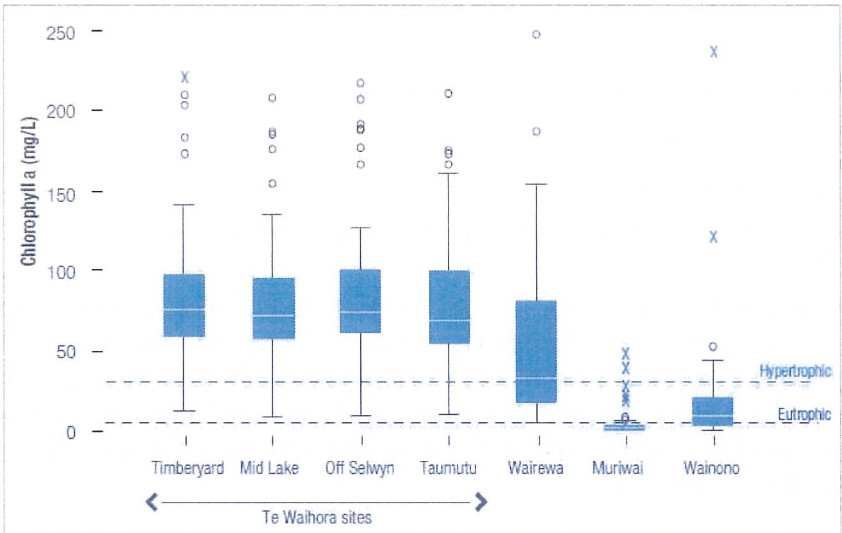

Figure 52. Chlorophyll a concentrations at four sites in Te Waihora/Lake Ellesmere compared to other coastal lakes, 2002-2007 (reproduced from Hayward and Ward, 2008)

4.1.5. Salinity

Te Waihora/Lake Ellesmere also exhibits varying salinity, characterised as brackish to mildly saline (generally <20% seawater). Salinity varies spatially and temporally across the lake and is a key factor influencing biodiversity as different communities and environments retain different tolerances to salinity levels (Meredith, 2011). The brackish nature of the lake water results from seawater inflows during lake openings and from waves overtopping the gravel barrier beach.

Under the current operating regime, the lake is periodically opened to the sea to facilitate drainage (to prevent inundation of surrounding farmland) and enhance fisheries values (provide for migration and recruitment of eels, flounder, trout and other aquatic species). In general, the salinity of the lake seems to decline as the number and duration of openings decrease, although this is not strictly always the case (Meredith, 2011).

4.1.6. Trophic State

Overall, water quality in Te Waihora/Lake Ellesmere is characterised in terms of high nutrient and suspended sediment concentrations, with consequent high phytoplankton (suspended algae) biomass and low clarity. The scale used to assess lake condition in New Zealand is called the trophic level Index (TLI). The TLI is an indicator of lake water quality compiled from annual values of total nitrogen, total phosphorus, algal biomass (as measured by concentrations of chlorophyll a) and water clarity (measured as secchi disc depth). A TLI score is calculated for each of these parameters and summarised into a single overall TLI score for the lake. The overall score is categorised into seven trophic states indicating progressively more nutrient enrichment, more algal productivity and reduced water clarity. These are:

- ultra-microtrophic TLI score <1 (pristine)

- microtrophic TLI score = 1-2
- oligotrophic TLI score = 2-3
- mesotrophic TLI score = 3-4 (moderately productive)
- eutrophic TLI score = 4-5
- supertrophic TLI score = 5-6
- hypertrophic TLI score >6 (extremely degraded, algae blooms common).

Figure 53 shows a plot of the TLI index for Te Waihora/Lake Ellesmere calculated from in-lake measurements since January 2000. The figure shows the calculated TLI remained relatively stable over this period ranging between 6 and 7.0 (i.e. hypertrophic), except for brief periods in 2002 and 2011 when values below 6 (i.e. supertrophic) were measured. The mean annual TLI at the Mid Lake monitoring site is approximately 6.8, which is the most nutrient enriched water quality for any lake in New Zealand (Gibbs and Norton, 2012)

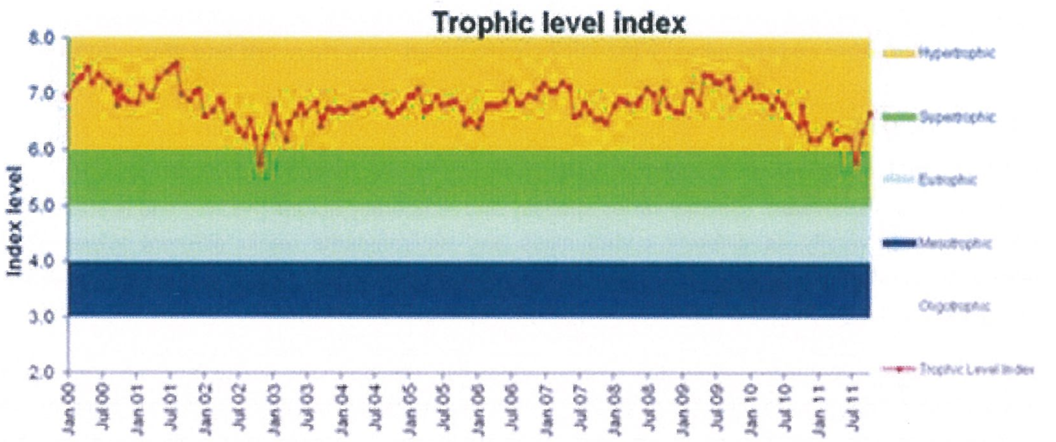

Figure 53. **Plot of moving annual mean trophic level index (TLI) based on in-lake measurements since January 2000 (reproduced from Norton *et.al*, 2012)**

Figure 54 shows a schematic illustration of the current tropic state of Te Waihora/Lake Ellesmere compared to the estimated pre-European state and the water quality target established in the Natural Resources Regional Plan (NRRP- Table WQL6).

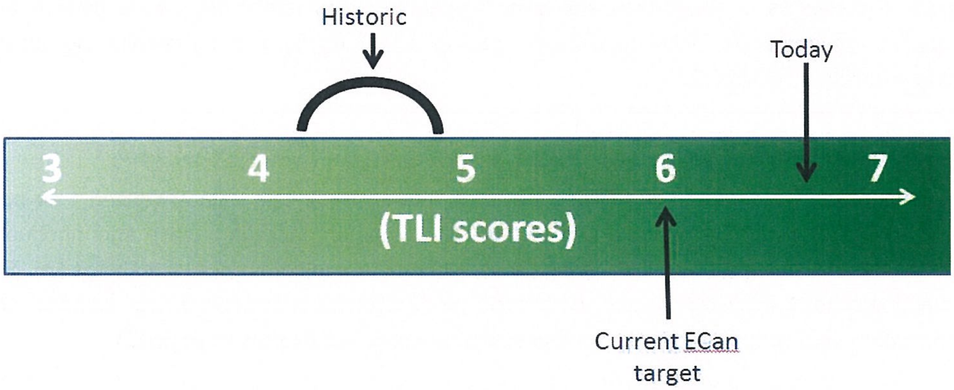

Figure 54. Illustration of TLI scale showing the relative position of the current state versus estimated (pre-European) and water quality target established in the NRRP

Key factors influencing water quality in the Te Waihora/Lake Ellesmere identified by Gibbs and Norton (2012) include:

- External loads of nitrogen (N), phosphorus (P) and organic carbon (C) from the intensification of agriculture in the catchment;
- High suspended sediment loads in tributary streams;
- The suspension of lake bed sediments in the lake due to a combination of wave action and its shallow depth; and
- Internal loads of N and P recycled from lake sediments to the water column;
- Organic carbon is a major energy source for microbial processes affecting N and P recycling in the lake.

In a lake such as Te Waihora/Lake Ellesmere, only a portion of the external N and P loads are exported from the lake via direct outflow with the remainder forming part of the internal nutrient loads, being lost to the atmosphere (e.g. via denitrification) or becoming buried in lake sediments. As a consequence, the lake is a sink for nutrients and sediments from sources within its catchment and this sink of nutrients may be reactivated through processes such as wind re-suspension of bottom sediments (Gibbs and Norton, 2012).

However, as noted by Hayward and Ward (2008), despite its highly enriched state Te Waihora/Lake Ellesmere does not exhibit many of the regular and widespread negative or detrimental features of a highly enriched lake, such as:

- frequent conspicuous algal blooms and scums
- seasonal or regular deoxygenation of waters
- frequent episodes of fish kills and poisoning of wildlife

Furthermore, it continues to support an abundant indigenous, commercial and sports fishery, and diverse and abundant wildlife including wetland, wading and dabbling species despite the current state of water quality (Meredith, 2011).

4.2. Biophysical state

As previously noted, Te Waihora/Lake Ellesmere is an internationally significant wetland[10] for both wildlife and wildlife viewing. It supports a rich biological environment including native and introduced species of plants and animals, is a tribal Taonga, and represents a major source of mahinga kai. The lake is important to Manawhenua and both local and regional communities for amenity and recreational value, and supports commercial and customary fisheries (Norton *et.al*, 2012).

Key customary and commercial fisheries species are eel (Tuna), flounder (Patiki) and yelloweye mullet (Aua). These fisheries are substantial but variable due primarily to variable exploitation and recruitment. For the customary fishery, although the lake is still used by whanau members for food gathering, the state of the lake is not considered as providing resources that are fit for use, principally through not providing for safe gathering of uncontaminated and palatable food. The commercial fishery supplies both domestic and international markets. Recreational fisheries species include inanga (whitebait) and brown trout, although the latter fishery has declined in recent years (Norton *et.al*, 2012).

Flipping is a term used to describe dramatic changes in shallow lakes between alternative 'stable' states. The most common shift is between clear ('blue water') lakes dominated by the primary production of a wide margin of aquatic macrophytes (rooted plants); and turbid ('brown' or 'green' water) lakes largely without macrophytes and dominated by phytoplankton (either green algae or blue-green (cyanobacteria) algae). One such major change in the physical environment of Te Waihora/Lake Ellesmere is the absence of macrophyte growth which has largely been absent since the Wahine storm in 1968. This event was a critical element in altering the lake state from one of relatively clear water with fringing (Ruppia) macrophyte beds to one of a macrophyte free lake with consistently high turbidity from both suspended sediments and phytoplankton. This change also altered the foodweb of the lake from one based around primary (plant) and secondary (animal) production in the macrophyte beds to one based upon production by and harvesting of the suspended phytoplankton production throughout the lake. However, previous macrophyte decline and increasing turbidity/poor clarity may have indicated Te Waihora/Lake Ellesmere was entering a different state, and the Wahine storm was a final 'nudge' required to complete the 'flip' (Meredith, 2011).

The relative stability of this latter state is illustrated by the relatively constant nutrient, phytoplankton, and clarity data over the past 20 or more years (as described in the previous section) and the apparent inability of macrophyte beds to naturally re-establish and persist. The lack of recovery of the macrophyte beds (and the consequent absence of clear inshore waters) since the 1968 Wahine storm is generally attributed to the high turbidity associated with suspended sediment and phytoplankton proliferation as the external nutrient loads have increased (Gibbs and Norton, 2012). Lower lake

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[10] Lake Ellesmere/Te Waihora also meets the criteria of an internationally significant wetland under the 1971 Ramsar agreement on wetlands, although the process for formal recognition has not been completed (DoC)

levels and resulting desiccation of the exposed lake bed when the lake is opened to the sea may also contribute to the non-recovery of the macrophyte beds (Jellyman *et al.*, 2009).

Due to the combination of land development and associated nutrient and sediment inputs, drainage, and lake level management as well as natural climatic variability, the biophysical state of Te Waihora/Lake Ellesmere at the current time is markedly different from that occurring historically. **Table 10** provides a summary of the current biophysical state of Te Waihora/Lake Ellesmere compared to pre-European conditions.

Table 10. Comparison of current biophysical state of Te Waihora/Lake Ellesmere with estimated pre-European conditions (reproduced from Norton *et.al*, 2012)

	Today	Pre-European
Lake openings & freshwater versus brackish state	There are regular artificial openings to the sea allow periodic saltwater inflow (i.e. a brackish state). Excavators and bulldozers are used to artificially open the gravel beach barrier to allow outflow until the lake reaches a level where outflow ceases and seawater inflow may occur on an incoming tide. Lake closure occurs when sea-deposited gravel closes the opening. Since 1970, the lake has been opened in spring in 34% of years and in autumn in 47% of years.	In pre-European times the lake would have spent long periods (years) in a closed freshwater phase with infrequent saltwater inflow. Openings only occurred when natural lake level or river flows breached the beach gravel barrier.
Lake level	Water level is managed by opening the lake to reduce periods at high levels (i.e. above around 1.0 m above msl) that would otherwise cause flooding of wetland margins and land currently drained for farming. There is no ability to control the minimum lake level as closure relies on sea conditions depositing gravel that closes the opening. Historically the lake level has been at <0.55 m for 23 days/year; <0.6 m for 36 days/year; and <0.7 m for 61 days/year (annual averages)	In pre-European times, higher average water level meant a larger lake area with greater water volume. Lake level was probably in the order of 2.0 to 2.6 m above msl.

	Today	Pre-European
Macrophyte beds	Macrophyte beds are virtually absent. Macrophyte beds were periodically abundant in the 1900-1960s but have not returned in significant cover following the Wahine storm (1968). Some small areas of natural re-establishment have occurred on occasions (1986, 2011) but these have not persisted.	Historically there have been extensive macrophyte beds, mostly confined to lake margins and embayments.
Water clarity and colour	Throughout the lake, water is turbid with very low clarity (~10 cm Secchi depth), and brown/green in colour due to wind/wave suspended bed sediment and algae (phytoplankton). There are no clear water areas because there are no macrophyte beds.	In mid-lake areas the water would have been murky, low to moderate clarity, light brown in colour due to suspended sediment, but less green than today due to less nutrients and phytoplankton. In the lake margins water clarity would have been high amongst the macrophyte beds.
Trophic state	The lake is currently highly enriched with nutrients (N and P). The annual average TLI is 6.8 mid-lake (hypertrophic), but varies considerably between about 5.9 and 7.5. Despite the enrichment it is thought there is no regular severe oxygen depletion (Hayward and Ward, 2008).	In pre-European times the lake nutrient load would have been moderate (i.e. Trophic Level Index (TLI) would have been 4 to 5 in mid-lake areas (Meso to Eutrophic).
Cyanobacteria and/or other toxic algae	Historically there have not been regular blooms of scum-forming toxic cyanobacteria, despite the relatively high risk associated with hypertrophic state (Hayward and Ward, 2008) There have been occasional increases in cyanobacteria concentrations that led to temporary health warnings such as those placed on the lake during the 2011/12 year.	There were probably no or few toxic blooms in pre-European times.
Fringing wetlands	Modest areas of fringing wetlands still exist and these are highly valued. Fringing wetlands are restricted in area due to regular lake level control to	In pre-European times, extensive fringing wetlands would have existed as a result of larger areas flooded at a higher water level for

	Today	Pre-European
	avoid flooding neighbouring land.	longer and greater water level range.
Biodiversity	Reduced species richness compared to pre-European state but current biodiversity is nonetheless highly valued (i.e. wetland plants, invertebrates, fish and the highest recorded bird diversity of any location in NZ. Noteworthy absent (but present post European arrival) are macrophyte beds and freshwater mussel (kakahi).	In pre-European times the lake probably had significantly greater species richness, particularly fringing wetlands, macrophyte beds and associated invertebrate and fish communities, and marine birds and mammals.
Fisheries	Key customary and commercial fisheries species are eel (tuna), flounder (patiki) and yelloweye mullet (aua). These fisheries are substantial but variable due primarily to variable exploitation and recruitment. Recreational fisheries species include inanga (whitebait) and brown trout, although the latter fishery has declined in recent years.	In pre-European times the same fish populations were present (excluding trout) plus freshwater mussels (kakahi). Cultural fisheries existed (Māori)
Microbial quality	Indicator microorganism concentrations usually (but not always) within criteria for 'Good' contact recreation grade.	Higher microbial quality (fewer microorganisms), although still some faecal contamination from birds and marine mammals.

4.3. Future Baseline Water Quality

As noted in **Section 2.4.2**, recent work undertaken for the Environment Canterbury, Selwyn Waihora zone limit setting process involved modelling of the potential environmental, economic and social effects associated with a range of future land use scenarios. Of the future land use options considered Scenario 1, comprising continuation of 2011 land use with no additional water allocation or irrigation, essentially provides an assessment of future baseline water quality in the absence of CPW scheme development.

Modelling of various land use scenarios (Norton, et al., 2012) indicate that even if there is no further land use intensification in the catchment (Scenario 1) it is expected that a 35% increase will occur in the current load of total nitrogen (TN) entering the lake over the next 10 to 20 years as a result of the effects of current land use. This is because of the time lag for nutrients lost from up-catchment land to travel through soil and groundwater system to lowland streams and ultimately the lake. The projected future increase in TN inputs to the lake from current land use is calculated to result in an average TLI

score of 7.2 mid lake and an associated increase in the frequency of nuisance algal blooms and toxic cyanobacteria blooms. This deterioration in water quality is to some extent unavoidable because this increased nutrient loading is already entrained in the catchment groundwater system.

Table 11 provides a summary of anticipated effects on the biophysical state of Te Waihora/Lake Ellesmere under Scenario 1 analysed for the Selwyn Waihora limit setting process. The data indicate several key indicators including TLI, cyanobacteria, colour and fisheries values are likely to decline as the effects of current land use (particularly in terms of N) move through the groundwater system to the lake.

Table 11. Projected effects on the baseline biophysical state of Te Waihora/Lake Ellesmere calculated for Scenario 1 utilised for the Selwyn Waihora limit setting process (from Norton *et al.*, 2012)

Indicator	Projected Future State (under current land use)
Lake openings and salinity	An increased frequency of openings to the sea is predicted due to the new Water Conservation Order (WCO) lake opening rules and a small increase in lake inflows (Appendix A). ▪ 63% of years open in spring (~double historic frequency). ▪ 62% of years open in autumn (~ 30% increase on historic). This is a significant benefit for fish migration (autumn openings) and recruitment (spring openings) for indigenous species (e.g. eels, flounder, mullet, and whitebait). Increased saltwater intrusion supports salt marsh vegetation and influences vegetation patterns
Lake Level	Negligible change is expected to long-term average lake water levels. However modelling results suggest that increased frequency of spring openings (due to compliance with the WCO lake opening rules) may increase the chance that an opening occurs prior to a drought period and thus increases the risk of extended periods of low lake level in summer. Low lake level during summer droughts will worsen water quality, ecological health, recreation and visual amenity values. The average annual number of days the lake is at <0.55 m would increase by around 30% (i.e. from 23 days to 30 days)
Trophic State	The lake TN load will increase by 35% compared to current load. This reflects the nutrient 'load to come' from current land use and will lead to an average TLI score of 7.2 (i.e. still hypertrophic)
Cyanobacteria and/or other toxic algae	A small increase in risk of toxic algal blooms is expected (see Figure 3-4). This is due primarily to increased nutrient loads, and frequency of spring openings and lower summer lake levels leading to greater saline intrusion events during summer. This means a small increase in the frequency that temporary recreation restriction warnings would be placed on the lake. It also means potentially increased incidences of dog, stock and wildlife poisoning.
Water colour	The effect of increased nutrients (i.e. 35% TN increase) and phytoplankton on water colour and clarity will be subtle but negative. Due to the fact that colour and

and clarity	clarity will continually change depending on weather conditions (and thus sediment re-suspension), it is likely the effects of Scenario 1 would not be noticed by a casual observer. It is possible that changes could be noticed, over a long period of time, by regular close observers and/or scientific measurement. Predicted changes are as follows: ▪ Clarity: Negligible change in clarity is expected because this is dominated by fine suspended sediment and sediment loads are not expected to change significantly provided good land management practices are employed throughout the catchment. ▪ Colour: Increased nutrient loads are expected to contribute to greater phytoplankton abundance and therefore increased green contribution to the brown/green water colour. During windy conditions brown sediment will dominate colour which will be similar to present. During calm periods (usually only hours to small numbers of days) the greener colour will be more noticeable.
Macrophyte beds	Macrophyte beds will remain absent.
Fringing Wetlands	Negligible change is expected as a result of increased nutrient loads under Scenario 1.
Biodiversity	Predicting effects on biodiversity is challenging and carries a high degree of uncertainty. It is estimated that increased nutrient loads will cause negligible change to current species diversity, for the following reasons: ▪ The current species present are able to inhabit the very enriched (i.e. hypertrophic) current conditions; ▪ Threshold change (i.e. 'flipping') has already occurred, i.e. Te Waihora/Ellesmere is now in an enriched phytoplankton-dominated state rather than a macrophyte-dominated state, and further threshold shift is not anticipated; ▪ Severe dissolved oxygen depletion is unlikely; and ▪ Mid-lake Nitrate-N concentrations are predicted to remain almost always below toxicity guidelines of 1.7 mg/L (one breach in 10 years) and 1.0 mg/L (2 breaches in 10 years - these being the chronic guideline criteria for 95% and 99% species protection respectively (Hickey and Martin 2009).
Fisheries	Despite increased nutrient loads (i.e. 35% TN increase), populations of the indigenous fish species, eel, flounder, mullet and inanga, may not be adversely affected in the lake under Scenario 1 for two reasons. First, these species are tolerant of the current enriched state in the lake and currently form productive populations provided there is opportunity for successful recruitment from the sea. Second, increased lake opening frequency in spring and autumn (compared to current) should favour successful recruitment from the sea to the lake and

	migration from lake to sea, respectively. Successful recruitment is thought to be a key factor, along with harvest control, influencing fishery productivity (Jellyman and Smith, 2008). However, there is more to a quality fishery (both customary and commercial) than just population size of the fish. Increasing nutrient enrichment under Scenario 1 is likely to have a significant detrimental effect on the quality of customary fisheries. Increasing enrichment also puts the commercial fishery at greater risk of volatility due to greater risk of tainting and toxicity from algae blooms, and reduced market perceptions of a quality product. For the trout fishery the negative effects are i) increased Nitrate-N concentrations in the tributaries and tributary mouths, and therefore risk of toxicity stress to both adult fish and spawning success, ii) reduced potential for future water clarity improvements, and iii) reduced angler amenity value. There is also a potential benefit; it is possible that increased lake opening frequency may increase numbers of sea-run trout, which are favoured by some anglers for their quality.
Microbial Quality	Negligible change is expected based on the assumption that good land management practices are employed, stock are excluded from waterways, and point source discharges are tightly managed. In general, losses of microorganisms from land, mostly associated with particulate material, are more easily controlled than nitrate.

4.4. Summary

Historically, Te Waihora/Lake Ellesmere had a much higher water quality than the current time with less nutrient and suspended sediment inputs from the catchment and clearer waters within the macrophyte beds as well as between them and the shore line. The abundance and bed cover of macrophyte weed beds periodically decreased and recovered in the first half of the 20th century. However, following a major storm (the Wahine storm) in 1968, the macrophyte beds have not recovered and as a result the clear inshore waters are no longer present.

Current water quality in Te Waihora/Lake Ellesmere is characterised in terms of high nutrient and suspended sediment concentrations, with consequent high phytoplankton (suspended algae) biomass and low clarity. Monitoring of key water quality parameters indicate water quality in the lake has remained relatively stable over the last 20 years with the overall water quality state consistently classified as hypertrophic (average annual Trophic Level Index (TLI) ~6.8).

Modelling of potential future land use scenarios for the Selwyn Waihora limit setting process indicates that the overall total nitrogen (TN) loading to the lake is likely to increase by around 30 percent under current land use. This increase reflects the time taken for nutrient loadings already entrained in the groundwater system to reach the lake. Such increases in TN are likely to result in an overall decline in the trophic state of the lake with consequent adverse effects on several key indicators including TLI, cyanobacteria, colour and fisheries values.

However, as noted by Meredith (2011), while there is a widespread perception that the lake ecology is significantly impacted by its current (and potential future) trophic state (i.e. particularly its turbid, discoloured appearance), Te Waihora/Lake Ellesmere remains a lake in a stable but highly productive state with abundant life and viable fisheries and wildlife populations.