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Hydrology of Waituna Lagoon

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Contents

Abstract

In 1998, the Department of Conservation Southland Conservancy identified the need for a scientific basis for guidelines for the artificial manipulation of the water level of Waituna Lagoon, east of Invercargill. An understanding of the soil characteristics including their drainage behaviour coupled with measurements of soil-water-level changes at two sites on the margins of Waituna lagoon has enabled us to distinguish between influences of high water levels in the lagoon and rainfall influences on land wetness.

Soil wetness on farmland showed gradients with topography and distance from a stream (or lagoon margin). This indicates that changes in external water level in the lagoon (unless it is high enough to cause inundation at the lagoon margins) will only have effects within 20 m of the stream or drains that are directly coupled to the lagoon.

One of the threats to the long-term survival of the lagoon and its surrounding ecosystems is land development and intensification within the contributing catchment. Intensification from dairying, drainage of peat for further pasture development, drainage and V-blading or humping and hollowing for tree crop establishment will all continue to put increased pressures on the lagoon and its ecosystem. We recommend that a Catchment group or lagoon care group be established to act as spokesperson or advocate for the lagoon.

Keywords: Waituna lagoon, hydrology, soil water levels, catchment management

1. Introduction

The soil drainage characteristics of land surrounding Waituna Lagoon were investigated by Landcare Research for the Department of Conservation (DOC) to determine the extent and nature of the effects of various lagoon water levels on the drainage of farmland and its implication for lagoon and wetland management. This work was carried out to provide a better foundation for advocacy of lagoon management to meet wetland conservation and sustainable land drainage needs. Investigations spanned the period 1998–2001.

2. Background

In 1998, DOC Southland Conservancy identified the need for a scientific basis for guidelines for the artificial manipulation of the water level of Waituna Lagoon, east of Invercargill (Figure 1). For any guidelines to be acceptable to all parties they would need to give weight to both wetland conservation and land drainage needs for the farmland surrounding the lagoon. The research aimed to:

- determine the extent and nature of the effects of various water levels on the drainage of farmland;
- provide a record of the water level in the lagoon, the water tables in affected farmland and conservation land, and the rate of lowering of water tables after opening the lagoon;
- estimate the natural water-level regime of the lagoon.
- provide a better foundation for advocacy of lagoon management to meet wetland conservation and sustainable land drainage needs.

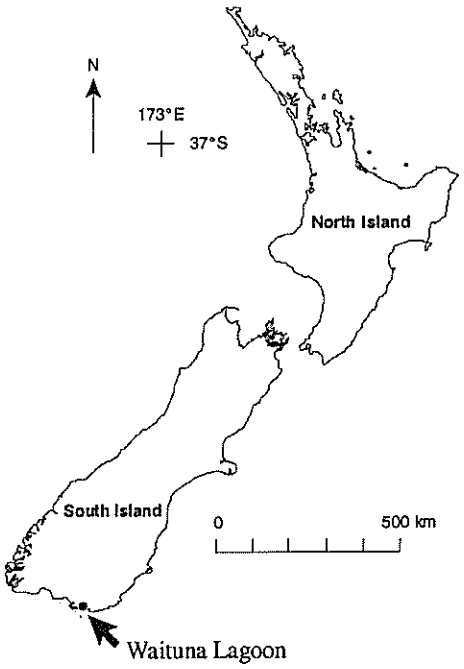

Figure 1 Location map of Waituna Lagoon.

Water level observations have been made at Waghorn's bridge for each opening since the 1970s (Figure 2). The recent water level history (as indicated in Figure 2), shows that the lagoon closed on 27 July 1997 and was opened on 20 December 1997. It then remained open for the longest period on record, some 800 days, until it finally closed on 2 May 2000. DoC advised Landcare Research that the lagoon water level was rising rapidly in late June 2000, and equipment for monitoring the period of high water levels and subsequent opening was installed in July 2000. The lagoon was opened on 14 October 2000, after passing the trigger water level value of 2.25 m as indicated on the staff gauge at Waghorn's bridge.

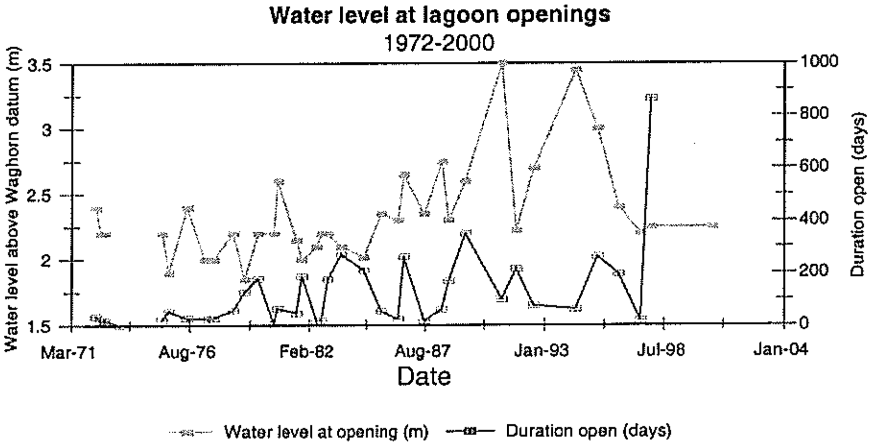

Figure 2 History of Waituna Lagoon openings

3. Objectives

The initial objectives set after discussions with DOC in 1998 were modified slightly in 1999 after it became clear that the lagoon was staying open for the longest period on record. However, the objectives of the study were to:

- Determine the extent and nature of the effects of various water levels on the drainage of farmland.
- Provide a record of the water level in the lagoon, the water tables in affected farmland and conservation land, and the rate of lowering of water tables after opening the lagoon.
- Estimate the natural water-level regime of the lagoon.
- Provide a better foundation for advocacy of lagoon management to meet wetland conservation and sustainable land drainage needs.
- Prepare a final report on water level regimes and the effects on land drainage to include:
    - discussion of the results of the soil drainage rates as water level in the Waituna Lagoon changes;
    - use of the daily model to assess the options for changing the trigger level and make a recommendation to DOC for use in advocacy;
    - discuss findings with the farmer members of the Lake Waituna Control Association;
    - assess the wider requirements for future management of the hydrology and water quality of Waituna Lagoon and its catchment to protect conservation values.

4. Methods

4.1 Site visits

Chris Phillips and Rick Jackson visited Waituna in August 1999. They met with the farmers' group (Lake Waituna Control Association) and discussed the general effects of high lagoon levels on wetness and drainage of farmland surrounding the lagoon. During these discussions two sites for monitoring of water tables in farm land were selected. The sites are on the farms of Ray Waghorn, near Little Waituna Lagoon (NZMS260 F47 758964) and Darrin Crack (E47 694965) near Moffat Creek.

Interviews with a number of stakeholder groups with interests in Waituna Lagoon were also carried out to determine background information on historical aspects of lagoon management, perspectives on current and future management, and perceived risks and threats to the lagoon. These groups included representatives from local iwi, Fish & Game, and Environment Southland.

During this visit soil water levels were measured at three sites in the wetland on the DOC reserve on the southern side of the lagoon.

Measurement localities and transects on each farm were chosen following input from the two farmers. Soils were hand augered and described. A survey of each site was carried out with a Sokisha total station theodolite to determine relative levels and ground surface elevations.

Equipment for monitoring water levels in the soil on the farm sites was installed during the second visit on 19–21 July 2000, as the water level in the lagoon was high. The instruments would monitor water levels and their response to opening of the lagoon when that next occurred.

The sites were visited again in December 2000 to retrieve the instruments and download the data collected over the months preceding and following the lagoon opening on 14 October 2000.

4.2 Instruments

4.2.1 Soil water tensiometers

Tensiometers were inserted into the soil into slightly undersized holes made with a soil auger. Readings were taken with a Lok portable pressure transducer with 1 mbar resolution. Readings were repeated over several hours after installation to ensure equilibrium had been reached. Lok mbar values were converted to matric potentials and to total potentials with the local-site ground surface as the datum.

Measurements were made at the Waghorn site in August 1999 along the transect at 20-m intervals and at 0.3-m depth to assess the spatial pattern. In addition, profiles were done at the 60-m, 120-m, 160-m, and 200-m points on the transect at 0.1-m, 0.2-m, 0.6-m, and 0.9-m depths to assess the soil water gradients at various localities on the transect.

These measurements were repeated in July 2000 at the 60-, 120- and 200-m points on the transect.

4.2.2 Water level: capacitance probes

Water levels in the soil at both sites and in Moffat Creek were measured with capacitance probes (Trutrac 1.3 and 2.3 m). Probes were installed at some points on the transects to give time series data for a period when the water level in the lagoon was rising after it had closed in May 2000 up to the time it reached the trigger level. Monitoring continued for a few months following the opening. Data were collected for the period 20 July to 20 December 2000.

Capacitance probes were suspended in rigid plastic tubes inserted into the soil on the transect lines at the Crack and Waghorn sites. The tubes were slotted both above and below ground level to allow water to reach the instrument. They were sited to cope with water levels up to about 2.8 m above the level of the bridge datum.

4.3 Waghorn site

A 280-m transect was chosen in August 1999 on land gently sloping down to swamp on the margin of Little Waituna (Table 1, Figures 3&4), soil profiles were described and soil water levels measured with tensiometers. The upper site inside the paddock comprised a soil profile – 0–25 cm Ap plough layer, dark brown silt loam, friable; 25–30 cm many mottles / concretions, wet, dark brown silt loam; at 28 cm a hard pan or quartz pebbles. Water was present at about 15 cm depth.

On 20 July we revisited the site, pegged out the same transect line, and installed tensiometers to compare the current water status with that in August 1999. We also installed capacitance probes (1 m long) to monitor water levels in or above the soil at the 60-, 120-, 200-m sites along the transect. We also selected a site in jointed wire rush (*Leptocarpus similis*) at the edge of the water (at F47 764964) in a drainage channel connected to Little Waituna Lagoon and installed a 2-m-long capacitance probe. The capacitance probes were set to record water levels at hourly intervals.

The transect line and all instrument sites were surveyed with fence posts used as reference points (Table 1). As weather conditions were calm and the lagoon surface was still, the water level at the water edge was assumed to be the same as that at the Waituna Lagoon monitoring site at the bridge on Waghorn's Road (F47 772957).

Table 1. Survey marks at Waghorn site – labels refer to Figures 3 & 4

Ray Waghorn's site	**Label**
From Instrument Station	
Fence Post (top 1.250 m)	A
Fence Post	B
Drain at the end of Lagoon (W.L. WAI-005)	C
Drain at the end of Lagoon(G.S)	D
250 m marker	E
Black Hole (drain opening)	F
200 m (C.P WAI-009)	200
150-m (maker)	150
120 m (C.P WAI-002)	120
100-m (marker)	100
60 m (C.P WAI-001)	60
50-m (marker)	50
0-m (marker)	0
Fence Post	G

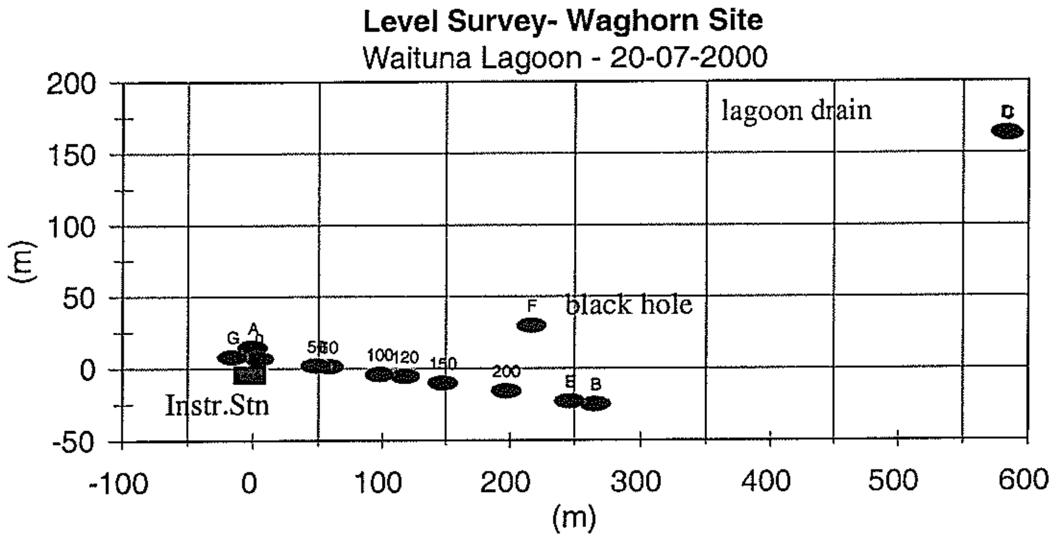

Figure 3. Plan view of instrument locations at Waghorn site.

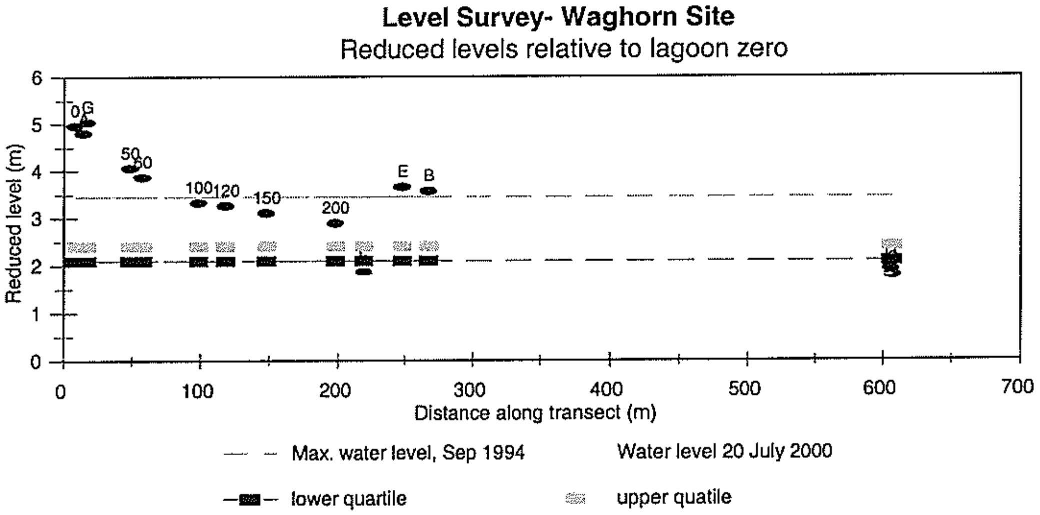

Figure 4 Waghorn site elevation plan.

4.4 Crack site

A 68-m transect was chosen in August 1999 on almost flat ground beside Moffat Creek, which flows into Waituna Lagoon (Table 2; Figures 5&6). Soil profiles were described and soil water levels measured with tensiometers.

On 19 and 21 July we revisited the site, pegged out the same transect line, installed tensiometers to compare the current water status with that in August 1999, and installed capacitance probes to monitor water levels at four points on the traverse. These capacitance probes were 1 m long, but as the water level at the site closest to Moffat Creek was 0.9 m below the ground surface an additional capacitance probe 2 m long was installed at this site. Note that the 0-m location on the transect referred to in Figures 5 & 6 and in discussions about water levels later in this report is not taken from the Moffat Creek location but is located some 10 m away from the creek.

We also selected a site within Moffat Creek itself, and installed a 2-m-long capacitance probe to measure fluctuations in the water level of the creek.

The transect line and all instrument sites were surveyed with fence posts as reference points. As weather conditions were calm, the lagoon surface was still, and there was little water movement in Moffat Creek, the water level in Moffat Creek was assumed to be the same as that at the Waituna Lagoon monitoring site at the bridge on Waghorn's Road (F47 772957).

Table 2. Survey marks at Crack site – labels refer to Figures 5 & 6

Darren Crack's Site	Label
From Instrument Station	
On Top of the fence post (1.085 m high)	A
Corner fence post (G.S)	B
Fence post (G.S)	C
Site-4 (WAI-007)	4
Site-3 (WAI-003)	3
Site-2 (WAI-008)	2
Site-1 (WAI-010 & WAI-004)	1
Site-0 at the stream (G.S)	.
Site-0 at the stream (Water level WAI-006)	.

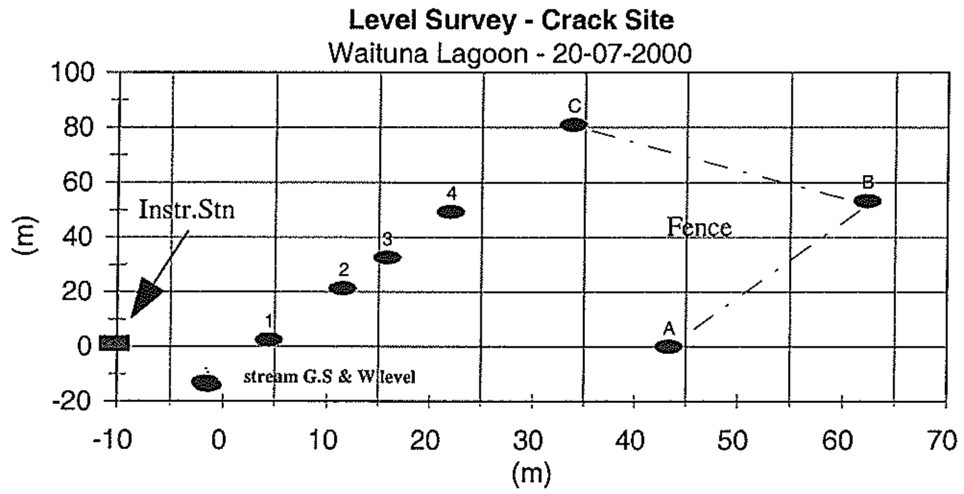

Figure 5. Survey plan Crack site showing instrument sites.

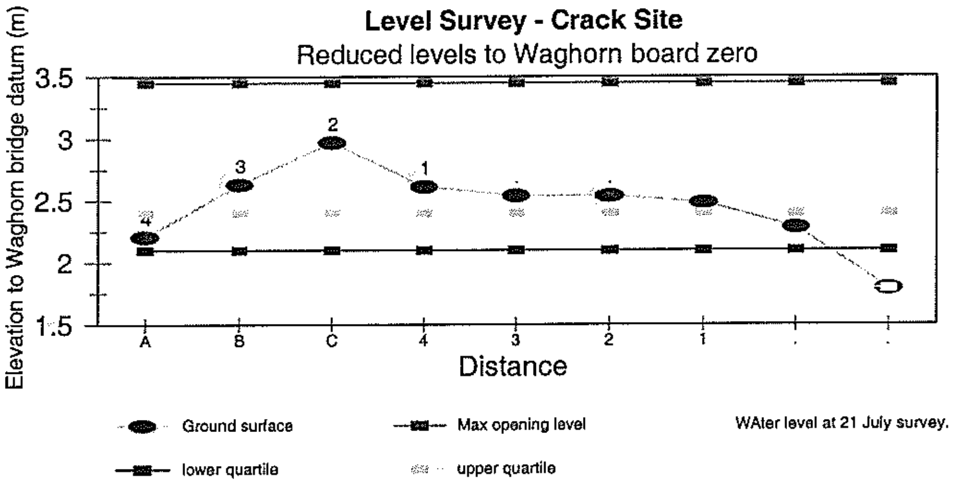

Figure 6. Reduced levels at Crack site.

4.5 Datasets

Two sets of data were obtained. The first during the initial site selection and characterisation in August 1999, and the second after the lagoon closed until 2 months after the opening on 14 October 2000.

4.6 Rainfall and water budget

A recording raingauge was installed on 21 July near Darrin Crack's house on Moffat Road (E47 701973) and data are collected at 30-min intervals.

A daily water balance model, based on concepts in Horrell's (1992) thesis study of Lake Ellesmere was used to analyse the water level changes in the lagoon and at the land transects. The model calculates the land component from the daily rainfall data and evaporation for Invercargill from New Zealand Meteorological Service (1986).

Drainage from the land component provides input to the lagoon, and estimates of the change of water level are derived from the input from land and rainfall and losses by evaporation and leakage. Details in appendices.

5. Results

In the various sections that follow, a common datum was used to provide a comparison with the water level data from the various sites. This was taken as the zero level on the staff gauge on Waghorn's bridge.

5.1 Soil water, soil properties and drainage

5.1.1 Southern end of lagoon on DOC wetland

Soil investigations on the wetland south of the lagoon indicated >1 m of peat/soil profile under the scrubby mānuka/*Empodisma*. The upper 20 cm of the profile was fibrous peat which became more humified with depth. Water was present at about 20 cm below the surface. Given that the site was a mound about 2 m above the surrounding area and it had about a 10 degree side slope, we infer that there is a permeability limitation to controlling the site wetness.

Tensiometer measurements in August 1999 (Figure 7) in soils under native vegetation west of Waituna Lagoon showed a high water table and very low hydraulic gradient, caused by slowly permeable subsoils. This means that the water regime in these soils is controlled by the local balance of rainfall and evaporation and is little affected by lagoon water levels.

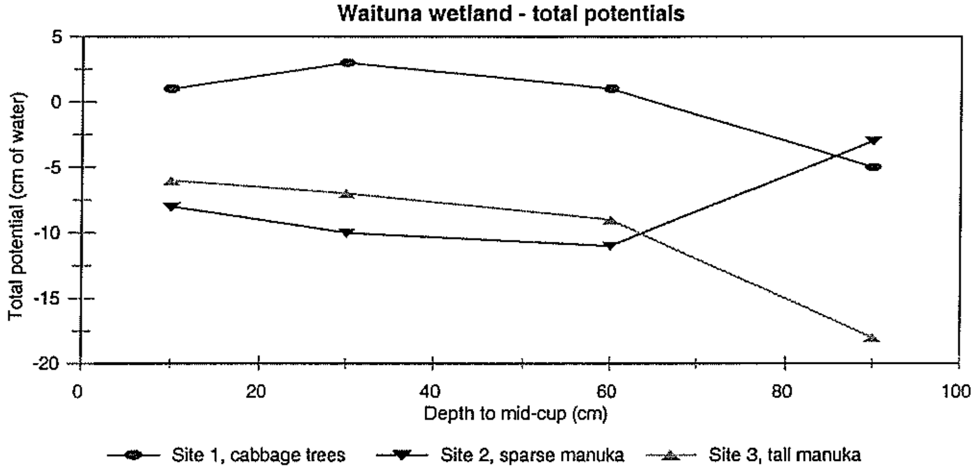

Figure 7. Total potentials for the wetland area on south side of Waituna Lagoon, August 1999.

5.1.2 Waghorn site

Total potentials varied little with depth (Figure 8), indicating no vertical hydraulic gradient in the soil; this is characteristic of a profile drained to equilibrium with a water table. The total potential then provides a measure of the depth from ground surface to the water table on the site. The tensiometer results also show a clear pattern of increasing (less negative) total potentials from top to bottom of the slope, i.e., the water table was closer to the ground surface at the lower sites.

Topography was the main influence on soil drainage on the transect on the Waghorn site, with very wet conditions on lower sites while the lagoon water level was low.

The data in July 2000 (black ovals in Figure 9) showed lower values at all three points on the slope than in August 1999, i.e. at each site the water table was lower by 0.2 to 0.4 m (Figure 9).

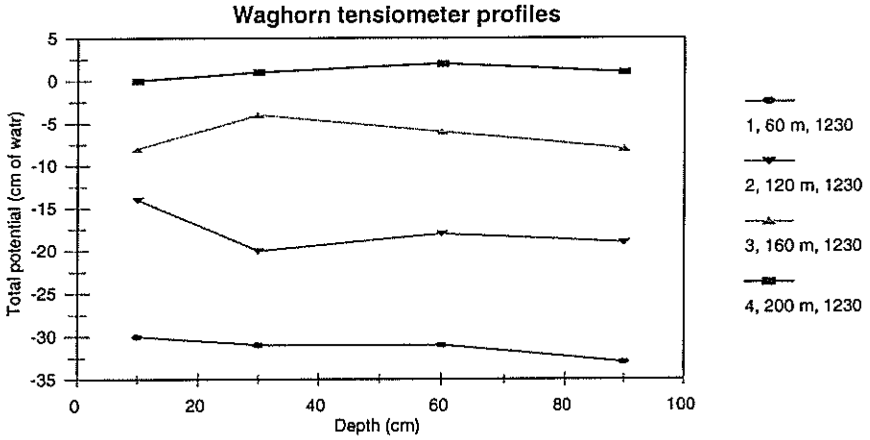

Figure 8. Total soil water potential variation with depth for each point on the Waghorn transect.

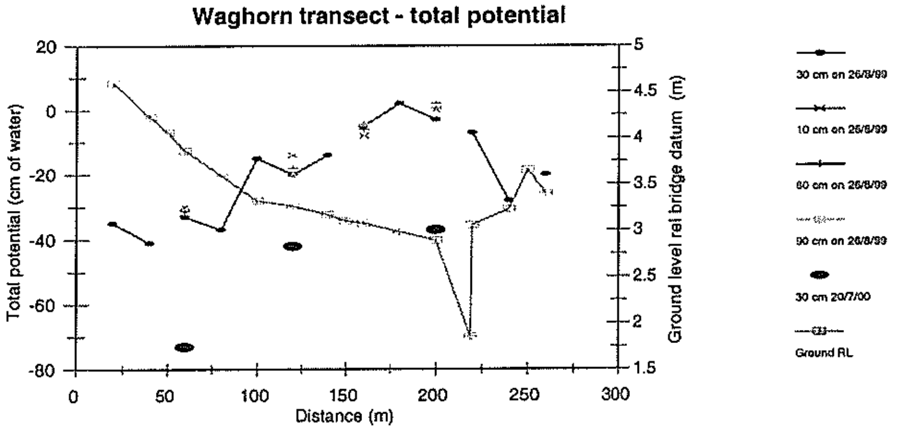

Figure 9 Total soil water potential at Waghorn transect.

5.1.3 Crack site

The tensiometer data showed that the water table levels in the soil were the same as in August 1999 except at the site closest to Moffat Creek where the water table was 0.2 m above the August 1999 level (Figure 10). Tests of the piezometer method for measuring hydraulic conductivity of the soil, which is required for modelling of water table movement, were made at two locations at this site.

Distance from a stream on the level transect on the Crack site was a major influence on the water table and hydraulic gradient within 20 m of the drain but had little effect further away (Figure 11).

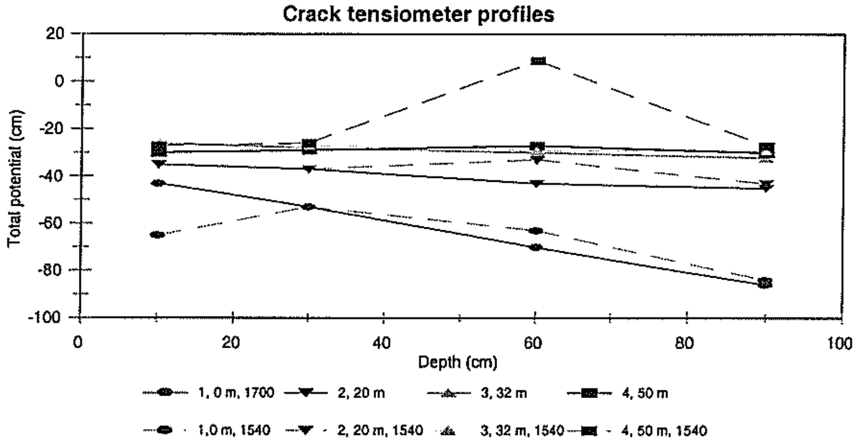

Figure 10. Total soil water potential variation with depth for each point on the Crack transect.

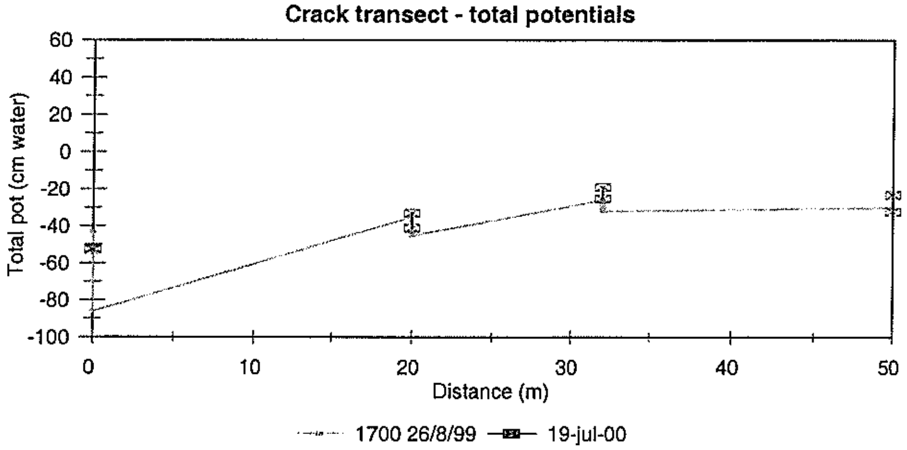

Figure 11. Total soil water potential at Crack transect. Note the much closer correspondence in total water potential between the two sampling dates compared with the Waghorn site.

5.2 Water levels in the lagoon

The lagoon was opened when the water level reached a level of 2.2 to 2.5 m on average about once a year since 1970, and then remained open for periods ranging from 2 weeks to 1 year until it was closed by action of the sea. It was last opened in December 1997 and remained open until the beginning of May 2000, giving the longest recorded period with the lagoon open (Figure 2). While the lagoon was open, the water level was 0.5 to 1.3 m with a tidal range up to 0.5 m. The water level reached 2.1 m at the end of June 2000, but then fell to 1.8 m as rainfall was low (5 mm from 1 to 21 July).

EnviroSouth installed a water level recorder in Waituna Lagoon in December 1999 and this provided some data. However, problems with the recorder and its lack of operation during the critical times of lagoon opening mean we have an incomplete record and cannot use any of the data provided.

The two capacitance probes in open water, Moffat Creek at the Crack site (dark blue trace in Figure 12) and the drain linked to Little Waituna at the Waghorn site (light blue trace in Figure 12), show similar behaviour, indicating that they are connected to the lagoon. Although the Waghorn lagoon probe failed on 18 August 2000, we can use the Moffat stream data at both Crack and Waghorn sites to compare values obtained from the capacitance probes and for use in the water balance modelling.

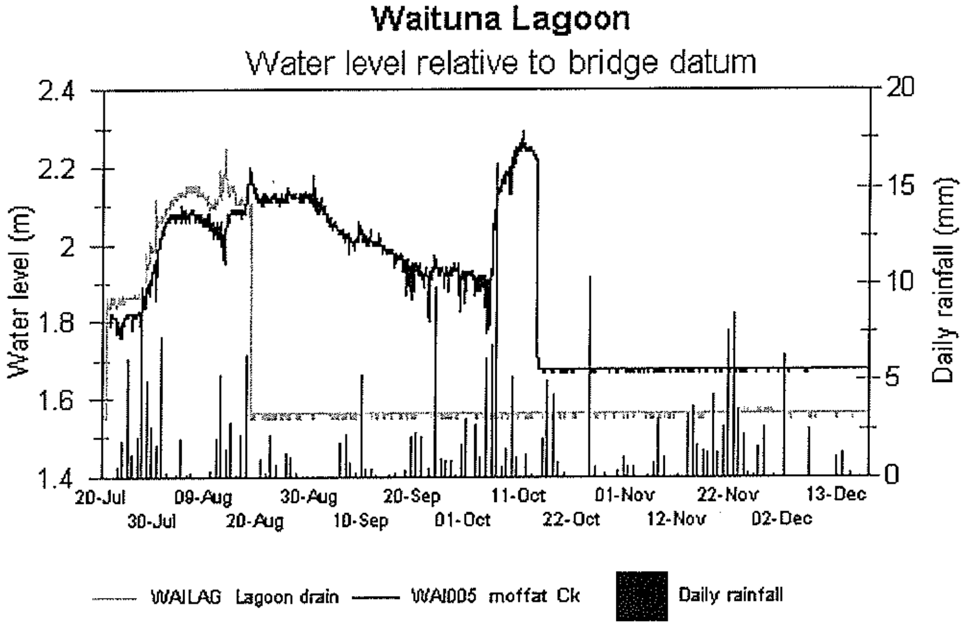

Figure 12. Water levels in the lagoon inferred from drain on Little Waituna and in Moffat Creek.

5.3 Water levels in the soil

Water level data can be presented with reference to a datum that is specific to each instrument site, usually the ground surface. Or, they can be presented with reference to a datum that is shared by all instruments. In the present study we have taken the latter option, using the zero of the staff gauge on the Waghorn Rd bridge as the datum. This allows the water level at each site to be related directly to the behaviour of the lagoon.

5.3.1 Waghorn site

At this site, a number of the instruments malfunctioned or were disturbed. Several sites were reported as disturbed in mid-August 2000 by Wynston Cooper (DOC) and were rehung in their tubes. During the final visit in 20 December 2000 disturbance of some probes was also noted. As a consequence the data are not as reliable as they could have been, although parts of the data sets have been useful. Horizontal lines in Figure (13) represent ground surface level at each instrument sites. The water level is shown in the same colour.

At the 60-m location on the transect the capacitance probe shows strong responses to rainfall until the end of September 2000 and then ceases to respond (blue trace in Figure 13). Blockage of the bottom of the instrument is suspected and data after 28 September 2000 have been discarded. The water level response to rainfall is rapid with water level reaching close to the ground surface several times such as in late July and late August. This is interpreted as slow soil water movement in response to rainfall giving rise to a perched water table that indicates that this high-elevation site is unconnected to the lagoon water level. Initial data in July 2000 indicate that the water table was about 0.8 m below ground surface at the 60 m site, which agrees with the tensiometer measurement at that time (0.7 m).

At the 120-m location on the transect, the capacitance probe is less responsive to rainfall than the probe at 60 m, though the trace is similar (green trace in Figure 13). Early in September 2000 the probe shows a very slow response and an indication of some equipment malfunction.

The initial data in July 2000 indicated that the water table was about 0.6 m below ground at the 120-m site (difference between the horizontal green line and the green trace), which agrees less well with the tensiometer measurement at that time (0.4 m). The gradual rise indicates a max. water level at about 0.3 m below local ground, similar to tensiometer readings taken in August 1999.

At the 200-m location on the transect, data was good until mid-August 2000 (red trace on Figure 13). Then two abrupt steps suggest disturbance (the higher water level after the first step would indicate the instrument dropped into water, probably to the bottom of the casing and it was lifted again at the second step to sit higher in the water, i.e. step changes here are position relative to water level, not movement of water level) where it picked up a plug of soil. The gradual rise brings water up to ground surface (broad flat trace approaching the horizontal red line around mid-October in Figure 13), which is where the tensiometers put it in August 1999.

5.3.2 Crack site

Note that the 0-m mark on the transect is not taken from the Moffat Creek location but is located some 10 m away from the creek.

The period before lagoon opening shows the gradual responses of the water level in sites in open water such as at Moffat at the Crack site. Also one of the sites close to a drain at Cracks shows a similar response (WAI004 0-m). Sites further from the drain show rapid responses to rainfall. Maximum water levels are close to ground surface at the 20- (black), 32- (purple) and 50-m (green) sites, but not at 0-m (light brown/orange) (Figure 14). The data indicate a combination of direct rainfall and lagoon water level influences, with the latter most important at those sites close to the stream.

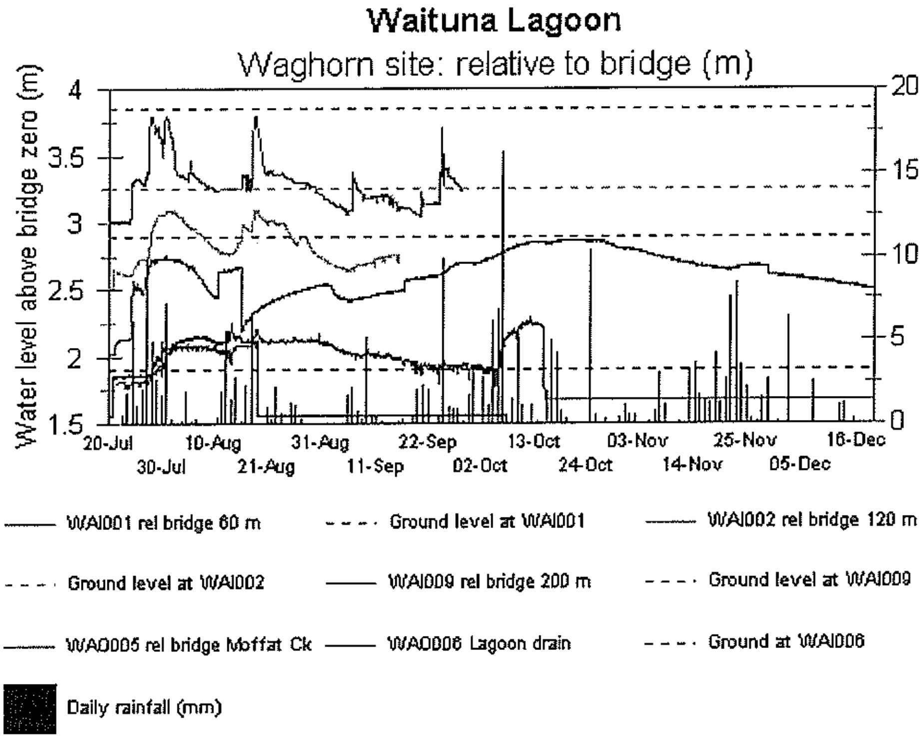

Figure 13. Water levels at Waghorn site. Note that some instruments malfunctioned and record has been truncated. Instrument trace and its respective ground level have the same colour.

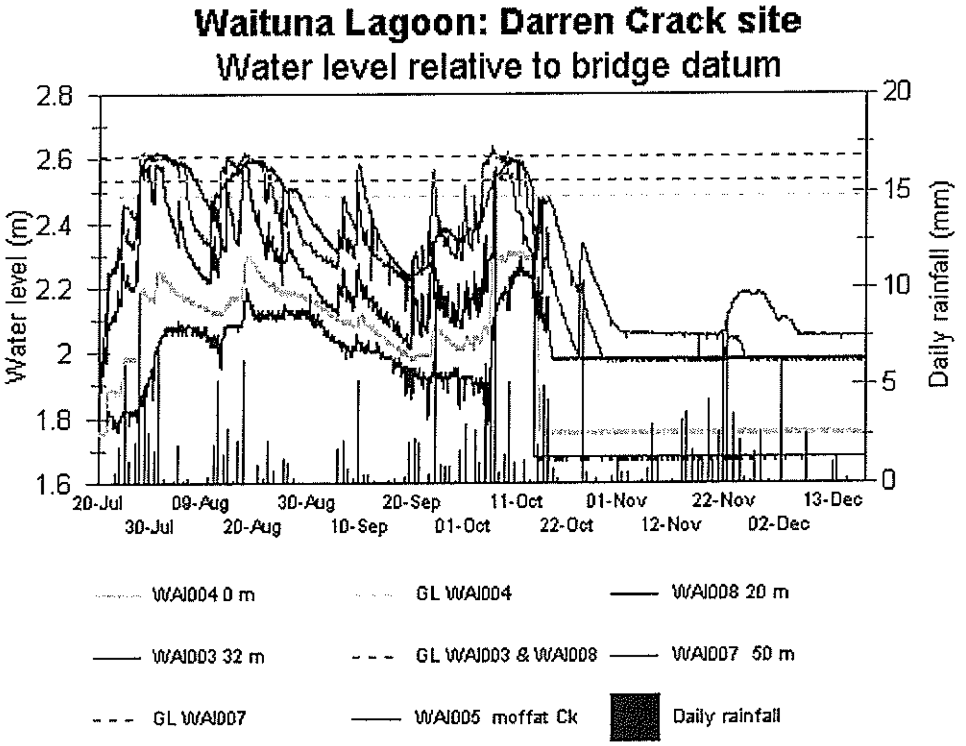

Figure 14. Water levels at Crack site – whole record. Instrument trace and its respective ground level have the same colour except WAI003 and WAI008, which have the same ground level (horizontal purple line).

Figure 15 shows the spread of drainage responses more clearly than Figure 13, particularly around the time of the lagoon opening. The closest site to Moffat Creek (WAI004 – orange trace) shows a similar response to that of the probe in Moffat creek itself (blue trace). As one moves away from the stream the traces respond more slowly to the lagoon water levels and more to rainfall. This can be clearly seen in the period immediately after the lagoon opening in October—the traces close to the stream drop suddenly and stay flat while those sites that are further away from the stream (WAI003 at 32m and WAI007 at 50m) show rapid responses to rainfall.

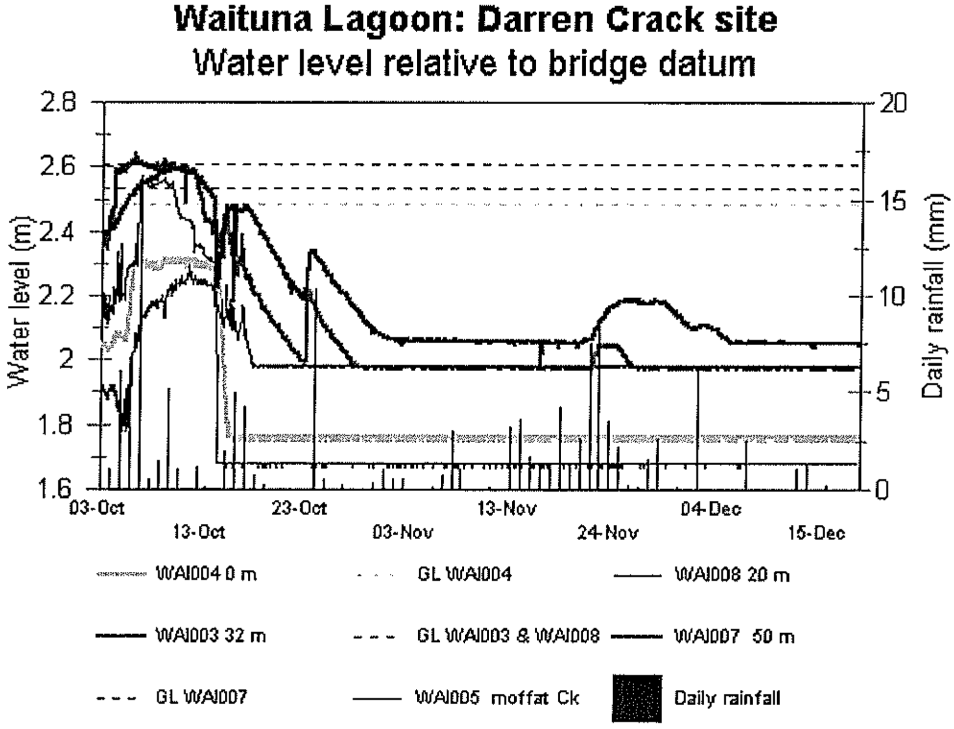

Figure 15. Water levels at Crack site – part record around opening on 14 October 2000 until instruments removed in December 2000. Instrument trace and its respective ground level have the same colour except WAI003 and WAI008, which have the same ground level (horizontal purple line).

5.4 Rainfall and water budget

Model calculations based on daily rainfall (Figure 16) provide estimates of the date on which the water level reaches the trigger level for artificial opening according to the present consent. The model requires the recorded date of closure by sea action, as unlike the Ellesmere situation (Canterbury Regional Council 1996), we have no basis for modelling coastal behaviour. Given the date of closure, the date of the next opening is predicted within a week or two, largely because sufficient water inflow is generated by the first large rainfall after soils have become saturated. With this type of inflow regime the choice of trigger level usually has a minor effect on the date at which the trigger is reached as the rate of rise is rapid. The model also predicts that if the sea action closed the lagoon quickly, there would be a need for many more artificial openings.

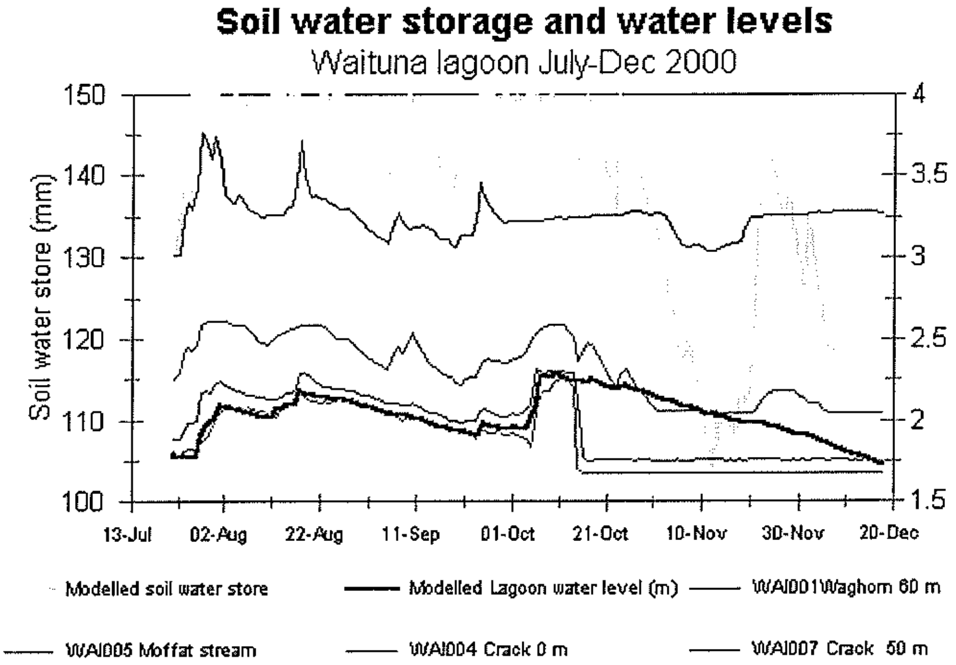

Figure 16. Daily water balance model for Waituna Lagoon July–December 2000. Modelled lagoon water level is in blue and modelled soil water store is in bright green.

6. Discussion

The soil measurement transects show the contrast in relief at the Waghorn and Crack sites (Figures 4 & 6). When the elevations are compared with the data on water levels of the lagoon at all openings since 1970, it is clear that both sites are above the interquartile range of lagoon openings. The highest water level at opening (3.45 m) flooded the entire Crack site and half of the transect at the Waghorn site.

In general, lagoon water levels are not well coupled to the drainage of farmland. When the farmland is wet it is due to rainfall causing local water tables to rise to the ground surface rather than responding to high water levels in the lagoon. This is best seen in the early part of the trace at the 60-m point at the Waghorn site (Figure 13), which shows the detailed changes that we see in the modelled soil water. The inference from this information is that the water levels here reflect the balance of rainfall and evaporation, and not the lagoon water level.

The water level records from the Crack site indicate that those probes closest to Moffat Creek record similar traces to the creek water levels, which in turn follow the lagoon water levels. As one moves further away from the stream, such as at WAI007 50 m from the stream (Figure 15) the probe shows some of the details of the soil water store-rainfall response and the level falls much more slowly than in those probes close to the stream. The inference here is that like the high-elevation probe site at Waghorns (WAG 60 m) the dominant influence on soil wetness is the balance of rainfall and evaporation.

The Lagoon water balance model predicts that if the lagoon had not been opened on 14 October 2000 it would have gradually fallen from its high of 2.27 m. This is not meant to suggest that the opening was not justified, it merely is the result of the model. However, if 30 mm of rainfall is added after that on 4–6 October, which actually produced the high water level, the model predicted a maximum increase to 2.5 m, i.e. one more wet day would have produced a lot of flooding.

Another way of looking at this is that runoff from wetlands is a high proportion of rainfall once the soil is saturated. With a catchment area for Waituna Lagoon that is approximately 10 times that of the lagoon area itself, we could expect 1 mm of runoff to give a 10-mm rise in lagoon water level. Allowing for evaporation losses the rainfall of 5–9 October 2000 is estimated to produce about 25 mm of runoff giving a rise in lagoon water level of 0.25 m, which was similar to that observed. The water balance model predicts as above, however, that if left unopened, the lagoon water level would have fallen slowly from its max of 2.25 m. If a further 20 mm of rain had fallen before the lagoon was opened, a water level rise of about 0.2 m would have occurred, to 2.45 m. This rise would have affected the farmland immediately adjacent to Moffat Creek and Little Waituna. It would not, however, have affected land further away from the creek or lagoon margins. If those soils were close to saturation, then they would have responded to that rainfall by bringing the soil water table up to the surface and possibly created local flooding. However, the link between the high lagoon level and the 'flooded land' would have been one of perception rather than a reality.

7. Conclusions

An understanding of the soil characteristics including their drainage behaviour coupled with measurements of soil water level changes at two sites on the margins of Waituna lagoon has enabled us to distinguish between influences of high water levels in the lagoon and rainfall influences on land wetness.

Soils under native vegetation on the wetland at the southern end of Waituna Lagoon were very wet in August 1999 because of the local rainfall/evaporation regime. Lagoon water level probably has little influence on this regime.

Soil wetness on farmland showed gradients with topography and distance from a stream (or lagoon margin). This indicates that changes in external water level in the lagoon (unless it is high enough to cause inundation at the lagoon margins) will only have effects within 20 m of the stream or drains that are directly coupled to the lagoon.

During the visit to Waituna Lagoon in December 2000 it became apparent that one of the threats to the long-term survival of the lagoon and its surrounding ecosystems is the land development and intensification within the contributing catchment. At that time, one of the authors raised the issue with DoC of poor water quality in the lagoon in terms of high organic loads and water clarity. Intensification from dairying, with its increase in the use of fertiliser inputs and possible effluent incursions, drainage of peat for further pasture development, drainage and V-blading or humping an hollowing for tree crop establishment will all continue to put increased pressures on the lagoon and its ecosystem.

The other major threat to the lagoon and its wetland plant communities is the spread of weed and nuisance plants. Some evidence of these, e.g. gorse, exists around the lagoon margins, particularly when the lagoon levels are low. If such plants managed to get a hold then they could create a significant management problem.

8. Recommendations

In terms of water management of the lagoon, a series of high-quality water level recorders should be employed at Waghorn's bridge and at least one other stream site entering the lagoon. Environment Southland would be the obvious agency to service such instruments. If a raingauge was also installed near the lagoon, it would be possible to use a version of the simple water balance model as used in this report to assist in decision making about whether to open the lagoon as the water levels approach the trigger level.

As indicated in the discussion, we believe that the major threat to the lagoon ecosystem is not the drainage and management of farmland immediately around the margins of the lagoon but more importantly what goes on in the rest of the catchment. We would recommend that a Catchment group or lagoon care group be established to act as spokesperson or advocate for the lagoon. We would see that this group would advocate through education and increasing land holder awareness of the interaction between activities in the catchment and the future of Waituna Lagoon and its surrounding wetlands and plant communities.

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11. Appendices

11.1 The Waituna Lagoon model

This model combines two components:

I. a soil water balance model, which uses rainfall and evaporation data to predict the soil water storage and the amount of water draining into streams (the land component); and

II. a lagoon water balance, which uses the input from streams, rainfall into and evaporation from the lagoon, and leakage estimates, to predict changes in the lagoon water level.

The approach is based on Horell (1992). The catchment area is taken a 200 km2 (Johnson & Partridge 1998), and the lagoon area as 18.5 km2 (Kirk & Lauder, 1994). The rainfall at the Crack farm is assumed to apply to the entire catchment as the isohyets in Riddell (1984) indicate little variation.

The land component

This part of the model uses the soil water balance equation:

$$Q = P - E + \Delta S \qquad (1)$$

The soil water is calculated with a daily time step, in millimetre depth units, where:

P is the daily rainfall (mm), from the gauge at the Crack farm;
Q is the runoff, as an equivalent water depth (mm) over the catchment area;
E is evaporation, using the data from Invercargill Airport in NZ Meteorological Service (1986);
ΔS is the change in soil water storage (mm).

The runoff , Q, is the total input to streams as quickflow (QF) and baseflow (BF). Only the QF portion contributes to the flood inflows that occur when soil water storage exceeds field capacity. Wetland catchments are highly responsive to rainfall when the soils are wet. For the Larry River catchment in Westland the QF is about 60% of total Q (Jackson 1987).

The lagoon component

The water balance of the lagoon is given by:

$$\Delta V = QF + BF + P - E - L \qquad (2)$$

The lagoon water balance is calculated with a daily time step, in cubic metres of water, where:

ΔV is the change in volume of water in the lagoon (m^3)'
P is the daily rainfall falling onto the lagoon surface (m^3),
E is evaporation from the lagoon surface (m^3),
L is the leakage loss from the lagoon (m^3).

QF and BF are the quickflow and baseflow components of the soil water balance, now calculated as m^3 from the catchment area.

The change of water level is calculated by dividing ΔV by the lagoon area. QF is calculated as 0.6 times Q from equation (1) and multiplied by the catchment area. It is not possible to calculate daily BF and L independently. Nothing is known about the time-distribution of BF, but we can estimate an average daily BF from the soil water balance; this gave a figure of 0.4 mm/day from the catchment area, or 0.11 m depth in the lagoon from 27 August to 23 September. We can also estimate L + BF from the fall of water level, 0.2 m, during the period from 27 August to 23 September, when there were no rainfall events large enough to generate QF; this gave an average L + BF of 140 000 m^3/day (net outflow). In practice, the model was run with this estimate of average L + BF as there was no need to calculate BF and L separately. However, the independent estimate of BF does indicate that leakage may be about 220 000 m^3/day.

Leakage was estimated in the following way. Between 27/8/00 and 27/9/00 there was a continual fall of lagoon water level by a total of 0.2 m over 30 days. Evaporation in this period was estimated to be 1.3 mm/day = 40 mm or 0.04 m. That leaves 0.16 m fall attributed to leakage losses, i.e. 0.2−0.04 = 0.16 m. With a lagoon area of 1850 ha or 18.5×10^6 m^2, leakage is 2.9×10^6 m^3 or approx 10^5 m^3/day.

The model was run for the 160 days for which we had data. It was initialised with the soil water store 20 mm below field capacity based on descriptions of the preceding weather.