Lake Rotorua Ohau Channel Algae Harvest Project

Bay of Plenty Regional Council
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Working with our communities for a better environment
E mahi ngatahi e pai ake ai te taiao

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Cover Photo: Algae Harvesting – Ōhau Channel

Acknowledgements

Bay of Plenty Regional Council and Aquaflow Bionomic Corporation Limited would like to thank the following groups and organisations for their assistance with this project:

The Trustees of the Waiatuhi Block who encouraged the project to proceed after listening to the Bay of Plenty Regional Council proposal which supported a local strategic initiative regarding algae harvesting. In particular we would like to recognise Fred Whata and Tai Eru from the Waiatuhi Trust for their ongoing support during the harvesting trial.

Willie Newton the current lessee for the Waiatuhi block whose land and roadway needed to be excavated, (and at times submerged) during the deployment of the harvester in order to facilitate its continuous operational needs.

New Zealand Trade and Enterprise (NZTE) whose management and project financial support ensured that the project was able to be implemented, in conjunction with shared funding from the Bay of Plenty Regional Council and Aquaflow stakeholders.

Executive summary

This project was aimed at addressing the potential for algae harvesting within some of Bay of Plenty Regional Council's eutrophic lakes.

Aquaflow have developed a technology for algae harvesting and this trial is the first opportunity to test this technology on wild algae within a lake environment with the objective of improving water quality by removing algae and its associated nutrients.

This project focuses primarily on harvesting of algae and the removal of nitrogen from the lake.

The Ōhau Channel was identified as an ideal location to test this equipment. This is because of a consistent flow of water from Lake Rotorua where water and algae can be taken and delivered to the harvesting system.

The aim of the project was threefold:

- To undertake a "proof of concept" trial to test the capacity for wild algae harvest in a water quality improvement project;

- To test the technology for algae harvesting within some of Environment Bay of Plenty's eutrophic lakes; and

- To fulfil one of the key recommendations from the Proposed Rotorua and Rotoiti Action Plan to investigate the role of biomass harvesting within the Lakes Protection and Restoration Programme.

The project was undertaken for a period of three months commencing April 2010. A suitable site was located on land adjacent to the Ōhau Channel for an intake structure and the associated pumping and harvesting equipment. The take and discharge of water was minimal at 25 cubic metres per hour from the Ōhau Channel flowing at 17 cubic metres per second. Water was returned to the Ōhau Channel in a somewhat cleaner state with algae removed.

Examination of the specific poly-electrolyte used identified no eco toxicological risks. A well mixed representative grab sample of the harvested algal slurry was taken from 1 m^3 containers approximately every two days and analysed for:

- Total solids (g/m^3)

- TN (g/m^3)

A C3 submersible fluorescence/temperature logger was deployed upstream of the inflow to the harvester in the Ōhau Channel. The logger was programmed to give five minute readings for relative chlorophyll-a concentrations, relative phycocyanin concentrations, turbidity and temperature.

Influent grab samples were taken from Ōhau Channel upstream of the intake to the harvester weekly. Effluent grab samples were also taken weekly from a sample tap in the exit line before effluent was discharged into the Ōhau Channel oxbow, downstream of the intake.

Results

Algal laden water was drawn from the Ōhau Channel at approximately 25 m^3/hour from 29 April to 29 July 2010, a period of 92 days. Over this period approximately 94,000 litres of concentrated algal laden slurry had been drawn off the harvesting plant.

The weight of solids extracted from harvested effluent over the trial period was approximately 1,000 kilograms in 92 days.

Based on the difference between the suspended solids (SS) load in the influent and the effluent, the harvester removed on average around 30% of the SS load from the influent.

Removal of organic material showed that over 90% of chlorophyll-a has been removed from the influent. Phosphorous concentrations were lower in the effluent than the influent with on average 59% TP removal achieved, indicating that most of the phosphorous is associated with the suspended solids material.

The resultant 1,000 kilograms of algal concentrate harvested from the Ōhau Channel over the trial period indicates that the harvesting of wild algae from a water body can be successfully achieved by the Aquaflow harvest method.

Over the three month trial period the harvester managed to extract approximately 14.0 kilograms of nitrogen. An estimated 60% nitrogen has been recovered which is on average approximately the same percentage of phosphorus recovered, based on the difference in phosphorous concentrations in the influent and effluent.

To meet half of the nitrogen target for Lake Rotorua of 175 tonnes per annum would require approximately 131,000 m^3 of water to be processed per day. This presents a significant challenge as the test equipment was only capable of 0.02% of the flow. Smaller abstraction rates targeted at algae hot spots may have long term benefits for lake health by helping to break the cycle of algal bloom, algal deposition and sediment nutrient release, by using the Aquaflow system. Identifying these hot spots could be difficult as algae tend to move rapidly in response to wind conditions.

The Aquaflow Harvester is proficient at removal of algae from a water body with fluctuating algal concentrations and species. Any analysis must also consider the costs of deployment (capital and operational) and potential cost recovery from the recovered algae or algae derived product. There is also an aesthetic improvement of the water quality with the removal of toxin producing algae from the water body to facilitate increased recreational use, particularly swimming.

Contents

Tables and Figures

Part 1: Introduction

The Rotorua Lakes Protection Restoration Programme is a joint programme between Bay of Plenty Regional Council, Te Arawa Lakes Trust and Rotorua District Council. It is aimed at protecting and restoring water quality within the 12 lakes in the Rotorua district. The main issue with these lakes is the poor water quality of some of the lakes and the potential for continued decline of water quality of all of the lakes. A number of the lakes are eutrophic and the main issue with these eutrophic lakes is the presence of algae generated by excess nutrients in the water column.

The Rotorua Lake Protection Restoration Programme includes development of action plans for each of the lakes. Within the action plans specific methods and interventions are recommended to the partners to guide protection and restoration actions. Generally these include things such as sewage reticulation of communities around each of the lakes and addressing of inputs of nutrients from point and diffuse sources within each lake catchment. Rotorua District Council manages all the sewage reticulation projects while Bay of Plenty Regional Council manages the other interventions.

Within the Proposed Lakes Rotorua and Rotoiti Action Plan, one of the key recommendations is to undertake exploratory work into biomass harvesting from Lake Rotorua. There are two potential options here:

- Weed harvesting
- Algae harvesting

Bay of Plenty Regional Council is undertaking weed harvesting work on two lakes within the programme. It has a harvesting regime on Lake Rotoehu which harvested 3,000 tonnes and 2,700 tonnes of weed in 2009 and 2010 respectively. A small harvesting programme is also being undertaken on Lake Rotoiti where weed in Okawa Bay was harvested in 2009 and 2010. Harvesting of weed is aimed at firstly reducing nutrient concentrations within the water column. This occurs by removing weed from the catchment which removes the associated nutrient content of the weed. A secondary objective is for aesthetic reasons to avoid non-attached weeds being blown up on shore and causing other problems with weed strandings around lakeside properties.

This project is aimed at addressing the potential for algae harvesting within some of our eutrophic lakes.

The project is a joint project between Bay of Plenty Regional Council, New Zealand Trade and Enterprise and Aquaflow Biodynamic Corporation Limited (Aquaflow). Aquaflow have developed a technology for algae harvesting and this is being tested on sewage treatment ponds in the Marlborough region of New Zealand. This trial is the first opportunity to test this technology on wild algae within the environment with the objective of improving water quality by removing algae and its associated nutrients. There are also a number of potential end uses for harvested algae. These include the production of bio-fuels, animal feeds, composting medium, feedstock for anaerobic digestion producing methane and other products such as activated carbon used in various filtration and absorption technologies. This project focuses primarily on the harvesting of algae and secondly on using the algae as a microbial input in a commercial composting operation.

Figure 1 Algae Harvesting – Ōhau Channel.

The Ōhau Channel has been identified as an ideal location to test this equipment (Figure 1). This is because there is a consistent flow of water from Lake Rotorua, where water and algae can be taken and delivered to the harvesting system. At some times in the year algae concentrations within Lake Rotorua outflow and consequently Ōhau Channel are high. This has caused considerable concern to residents and users of the Ōkere Arm of Lake Rotoiti and Kaituna River users downstream. Since the construction of the Ōhau Diversion Wall all water from Lake Rotorua is diverted directly into the Ōkere Arm and when algae concentration is high in Lake Rotorua this has caused some concern regarding down stream water quality. Appendix 1 identifies the key metrics for the Aquaflow System site pad necessary for this deployment.

In summary the aim of this project is threefold:

1 To undertake a “proof of concept” trial to test the capacity for wild algae harvest in a water quality improvement project;

2 To test the technology for algae harvesting within some of our eutrophic lakes; and

3 To fulfil one of the key recommendations from the Proposed Rotorua and Rotoiti Action Plan to investigate the role of biomass harvesting within the Lakes Protection and Restoration Programme.

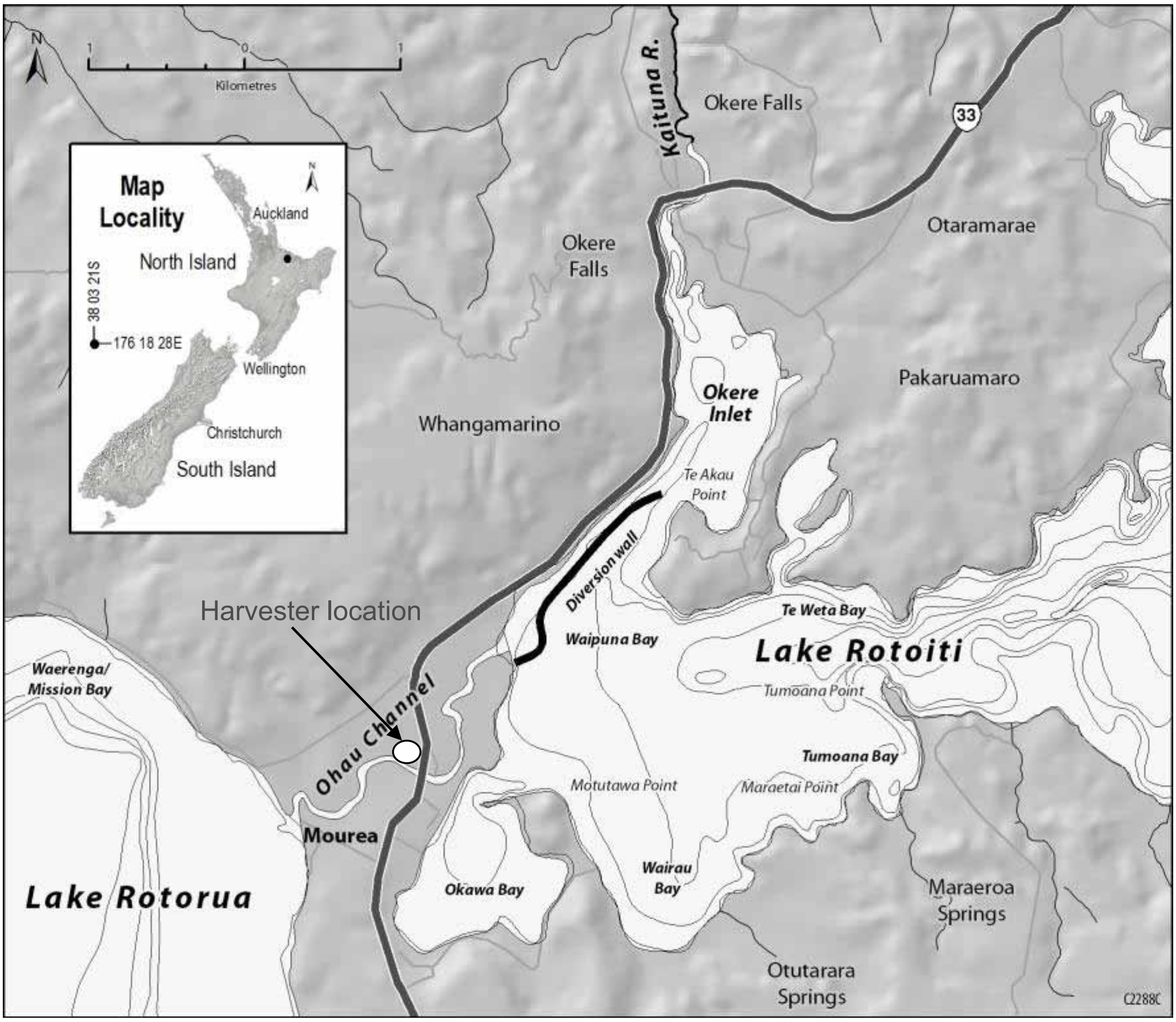

Figure 2 Map of Ōhau Channel.

Lake Rotorua and Lake Rotoiti are joined by the Ōhau Channel. The harvester operated with algae laden input water from the Ōhau Channel (Figure 2).

Part 2: A case for algae harvesting

As already mentioned, the Proposed Rotorua and Rotoiti Action Plan specifies a direction to undertake exploratory work into biomass harvesting. This matter came from discussion between working party members as the Action Plan was being developed and was the subject of a technical report by Professor Warwick Silvester of the University of Waikato.

Effectively the report by Professor Silvester stated that algae harvesting was unlikely to be an effective intervention for reducing nutrient concentrations within the Rotorua Lakes Programme. This is primarily due to the significant quantities of water that would need to be pumped to remove any appreciable quantity of nitrogen or phosphorus.

Although due regard has been taken to Professor Silvester's comments, Aquaflow has developed a method of algae harvesting which has proven capable of removing quantities of algae from sewage treatment ponds. It is envisaged that a low cost, short term trial such as this will assist in demonstrating the feasibility of any algae harvesting to the local community and will allow for the practical and economic assessment of scaling this process up within the Rotorua Lakes environment.

Appendix 2 identifies the Project Budget developed for a three month trial period of $195,401. NZTE contributed 50% and Aquaflow/Bay of Plenty Regional Council contributed 50%. The project would not have been possible without NZTE's financial and corporate personnel assistance.

Part 3: Trial algae harvest project background information

The following is the basic technical details of the short term project.

The project was undertaken for a period of three months commencing in April 2010. A suitable site was located on land adjacent to the Ōhau Channel for an intake structure and the associated pumping and harvesting equipment. The land used belongs to the Waiatuhi Trust and was offered for the period of the trial by the Trustees. The land is currently leased to Willie Newton who agreed to the use of the land for the trial.

Appendix 3 details the resource consent that was obtained that covered the Resource Management Act (RMA) matters with respect to taking water from the Ōhau Channel and discharging it back to the channel. The consent was granted for a three year term although was never envisaged the trial would continue beyond the three to six month initial period. A longer term was obtained because algae concentrations within the Rotorua Lakes are seasonally dependent and we were uncertain as to whether peak algae concentrations would occur during the autumn of 2010 when the initial trial set up was programmed.

Appendix 4 details the project plan and necessary activities from the first project meeting in November 2009 until the project concluded in July 2010.

The trial equipment consists of an intake structure (Figure 3) feeding to a pump then to the harvesting equipment (Appendix 1). The outlet from the harvesting equipment comprises two streams. First stream is concentrated algae slurry which was stored for trial analysis and disposal elsewhere. The second stream is the treated water or effluent stream which was discharged back into the Ōhau Channel close to but downstream of the intake structure. The harvesting equipment is capable of processing 35 cubic metres per hour of treated water. For the trial period the flow was set to 25 cubic metres per hour. The Ōhau Channel has an average flow of about 17 cubic metres per second. Consequently the volume of water take had no impression on Ōhau Channel water flows.

Figure 3 Orange safety flagged water intake on the Ōhau channel.

The harvesting equipment comprises a treatment tank where treated water dosed with polyelectrolyte enters at one end. Dissolved air is pumped into the bottom of the tank from a compressor which lifts the flocculated algae to the tank surface. The floating algae flocculent is removed by a surface skimmer to a sump at the tank end and the treated water is returned to the receiving water.

The harvesting equipment was located 300 m north of the Ōkere Falls bridge on State Highway 22, which crosses the Ōhau channel. The discharge was into an Oxbow section of the Ōhau channel (Figure 4).

Water intake and discharge structures were similar to normal irrigation intake structures and have a relatively small footprint extending one to two metres out into the Ōhau Channel. The water intake was orange flagged for water course user's visibility.

Figure 4 Water output into the Oxbow, Ōhau channel backwater.

Part 4: Environmental considerations of the project

The project had a number of objectives as outlined in section 1, with the overall main objective being: "to test the capacity for wild algae harvest in a water quality improvement project". Consequently, ensuring that the project did not have unacceptable environmental outcomes was paramount. There were a number of minor potential effects of the trial that were addressed:

1. The take and discharge of water was minimal at 25 cubic metres per hour from the Ōhau channel flowing at 17 cubic metres per second. Water was returned to the Ōhau Channel in a somewhat cleaner state with algae removed.

2. The discharge of residual polyelectrolyte has some potential for effect on the stream. Poly-electrolytes are a water treatment chemical commonly used for the treatment of potable drinking water. Examination of the Material Safety Data Sheet for the specific poly-electrolyte used identified no eco-toxicological risks. Dose rates were kept to acceptable industry levels for treating seasonal algae concentrations, in order to reduce unnecessary flocculent carry over (Appendix 5).

3. The intake screen and discharge structure were designed with minimal extension into the channel to avoid any impact to channel flow or channel users. The intake on the Ōhau channel had orange flag identification for boat users to avoid.

4. The trial was located in a rural area, away from any residential properties to minimise any possible generator or pumping noise risk.

Part 5: Community engagement

Bay of Plenty Regional Council believes consultation on its lake restoration projects is an important part of engagement with the community around the whole programme. For this small scale trial project, with a very minor environmental impact, limited consultation was beneficial. Bay of Plenty Regional Council undertook consultation with a number of groups prior to commissioning the trial.

Groups or people consulted included:

1 The Trustees representing the land owners and the lessee of the Waiatuhi Block.

2 The local Ratepayers Group.

3 The Lakes Water Quality Society.

4 Department of Conservation.

5 Eastern Region Fish and Game Council.

6 Specific local Māori elders and representatives of Ngati Pikiao.

It is appreciated that the Trustees of the Waiatuhi Block, Mr Fred Whata and Mr Tai Eru were extremely helpful and positive in providing the land for the trial (Figure 5). All other groups consulted supported the project including the land lessee. The project also initiated a significant number of enquiries about its application from the Rotorua Community and initiated wider discussion on the lakes programme.

Figure 5 NZTE, Bay of Plenty Regional Council and Waiatuhi Trustees members all view the algae harvest during the official opening of the project.

Part 6: International engagement

On 2 June 2010, two senior management staff from Melbourne Water visited the harvesting site to review the algae harvesting process. The visit was part of an investigation into the use of algae biomass with anaerobic digestion to develop bio-gas for power generation by Melbourne Water using Aquaflow's harvesting technology. Presentations were given by Melbourne Water and Bay of Plenty Regional Council with questions regarding harvesting site requirements, leading to a worthwhile transfer of water remediation and energy ideas between the three parties. Following the visit to the Aquaflow harvesting location at Ōhau Channel other Bay of Plenty Regional Council water remediation project sites were visited. The value of these project interactions cannot be underestimated when there is an openness to share ideas and discuss technical options between willing parties. Discussions between Melbourne Water and Aquaflow continue, regarding possible project development in Australia.

Part 7: Methods

Methods and analyses used to provide the results data for the algal harvest trial are outlined below (Figure 6 and Table 1).

7.1 Monitoring

7.1.1 Harvest volumes

A well mixed representative grab sample of the harvested algal slurry was taken from 1 m^3 containers approximately every two days and analysed for:

- Total solids (g/m^3)
- TN (g/m^3)

The time for the discharge (hours) into the output was noted from the generator hour meter each time the harvester tote was emptied and logged against the volume of recovered algae for reporting. A representative sample from the 1 m^3 containers was also weighed in a 20 litre bucket to estimate harvested mass.

7.1.2 Influent monitoring

A C3 submersible fluorescence/temperature logger was deployed upstream of the inflow to harvester in the Ōhau Channel. The logger was programmed to give five minute readings for relative chlorophyll-a concentrations, relative phycocyanin concentrations, turbidity and temperature.

Influent grab sample were taken from Ōhau channel upstream of the intake to the harvester weekly.

Grab samples were analysed for:

- Chlorophyll-a (mg/m^3);
- pH (field measurement);
- Dissolved oxygen;
- TN, TP (g/m^3);
- Suspended solids (g/m^3);
- Volatile suspended solids (g/m^3);
- Turbidity (NTU); and
- Algal cell count and species identification.

7.1.3 Effluent monitoring

Effluent grab samples were taken weekly from a sample tap in the exit line before effluent was discharged into the Ōhau Channel oxbow, downstream of the intake.

Samples were analysed for:

- Chlorophyll-a (mg/m^3);
- pH (field measurement);
- TN, TP (g/m^3);
- Suspended solids (g/m^3); and
- Volatile suspended solids (g/m^3).

Figure 6 Paul Scholes, Geoff Ewert and Andy Bruere, staff from Bay of Plenty Regional Council, discuss the algae pH sampling process.

7.1.4 Ōhau Channel oxbow discharge monitoring

Four grab samples were taken from the middle of the oxbow. One before the discharge from the harvester started and three during the three month operation. Analyses were as for the influent monitoring.

Nutrient and solids analyses were completed by Hills Laboratory.

Table 1 Test methods and detection limits for analyses.

Test Method	Description	Default Detection Limit
Volatile Suspended Solids	Filtration (GF/C, 1.2 µm). Ashing 550°C, 30 min. Gravimetric. APHA 2540 E 21st ed. 2005.	3 g/m^3
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D 21st ed. 2005.	3 g/m^3
Total Solids (TS)	Gravimetric. APHA 2540 B 21st ed. 2005.	10 g/m^3
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N.	0.05 g/m^3
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO3- I (Proposed) 21st ed. 2005.	0.002 g/m^3
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-Norg C. (modified) 4500 NH3 F (modified) 21st ed. 2005.	0.10 g/m^3
Chlorophyll-a	1.0 um filtered. acetone pigment extraction, Spectrofluorometric measurement.	0.01 mg/m^3
Turbidity	APHA Method 2130-BNephelometry, Hach 2100A meter. Non-ratio turbidity	0.01 NTU

Part 8: Results

8.1 Harvest quantities

Algal laden water (Figure 7) was drawn from the Ōhau Channel at approximately 25 m^3/day from 29 April to 29 July 2010, a period of 92 days. Over this period approximately 94,000 litres of algal laden water had been drawn off the harvesting plant (Figure 8). Intake problems did occur due to weed blockages, but relocation of the intake overcame this problem in the first month of the trial.

The weight of solids extracted from harvested effluent over the trial period was approximately 1,000 kilograms in 92 days. Average and median total solids and total nitrogen concentrations are listed in Table 2.

Figure 7 IBC container with algae for composting on trailer.

There appears to be three periods of solids harvested which are likely to relate to the concentration of algae in the channel. Average and median values for solids and nitrogen over these two periods are listed in Table 2. Comparison of these three phases shows the quantity of solids extracted by the harvester was much greater during the latter phase with the percentage solids extracted around an order of magnitude better than the first phase. Figure 9 shows that the greatest mass of solids harvested occurred during a bloom in late June and this also holds true for total nitrogen harvested.

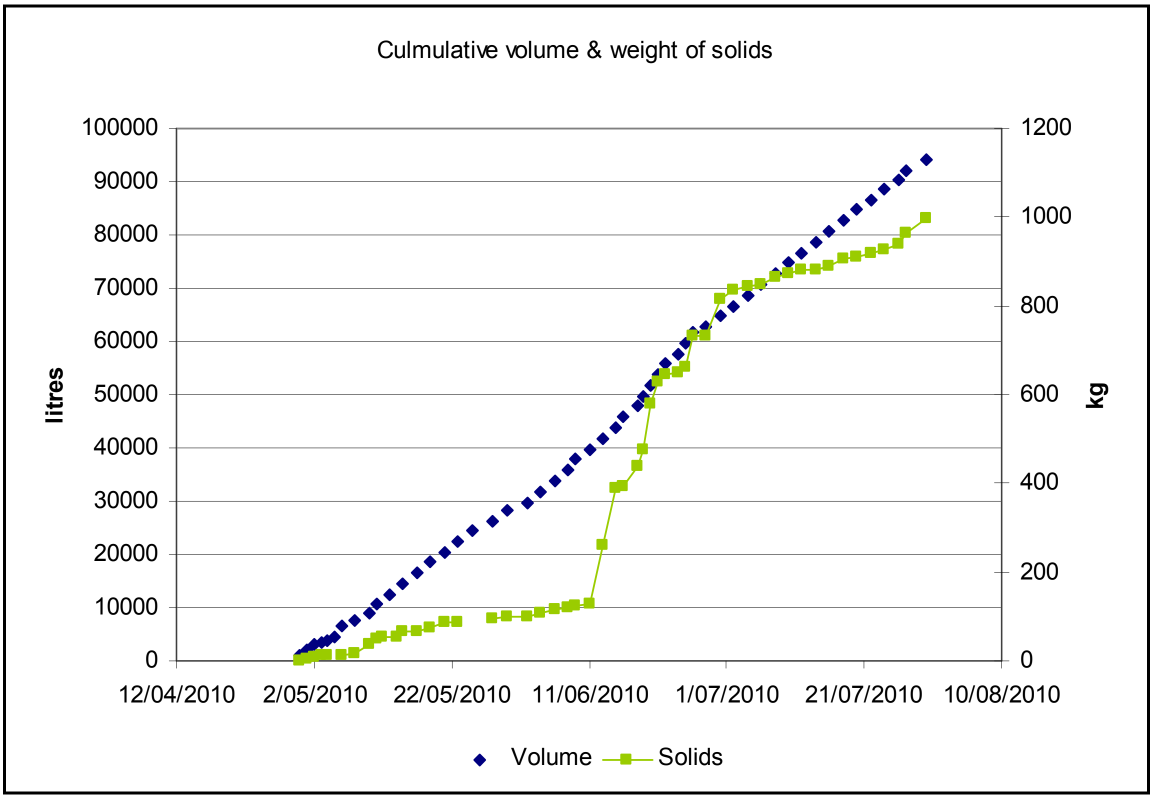

Figure 8 Cumulative harvest volume and cumulative total solids harvested.

Volumes of nitrogen show a similar change in extractable weight over the trial (Figure 10). Approximately 14.4 kilograms of nitrogen have been removed by the harvester. This equates to approximately 0.16 kilograms of total nitrogen per day.

Table 2 Harvested total solids and total nitrogen total, average and median values.

		TN (g/m^3)	TS (g/m^3)	Solids extracted (kg)	TN extracted (kg)	% Solids	TN:TS%
Day 1-92	Average	157.2	10076	19.3	0.31	0.55	3.40
	Median	106.5	3550	6.6	0.21	0.21	2.72
	Total			1003.4	14.4		
Day 1-44	Average	134.2	3691	6.6	0.24	0.21	3.64
	Median	106.5	2300	3.5	0.17	0.12	4.63
Day 45-64	Average	226.2	22746	45.2	0.45	1.15	0.99
	Median	184.5	15700	31.4	0.37	0.79	1.18
Day 65-92	Average	85.1	5984	11.6	0.2	0.3	1.5
	Median	56	3900	7.8	0.11	0.20	1.46

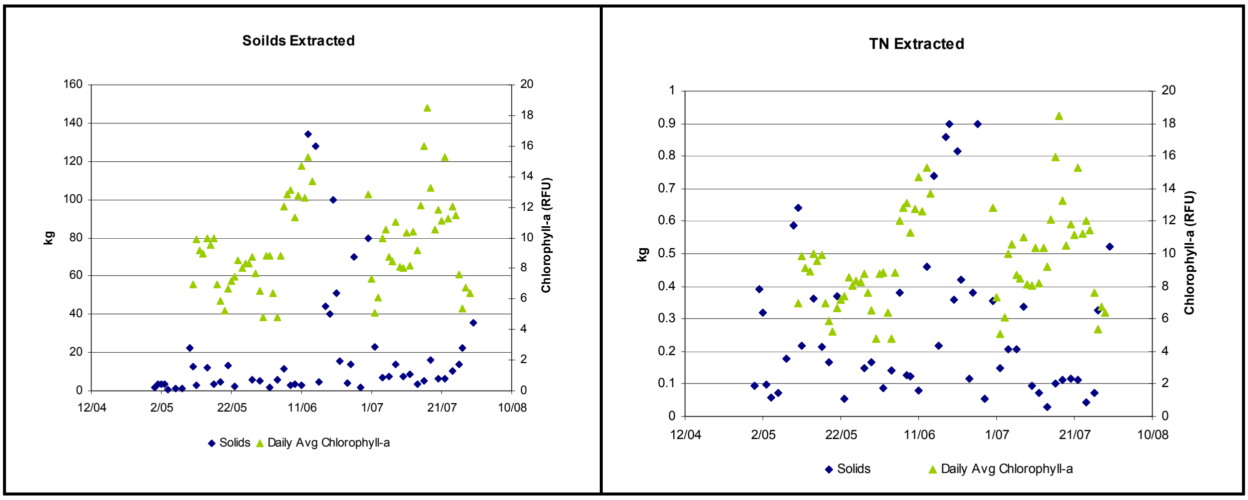

Figure 9 Weight of solids and TN extracted by harvester and Ōhau Channel chlorophyll-a daily average concentrations (by fluorescence).

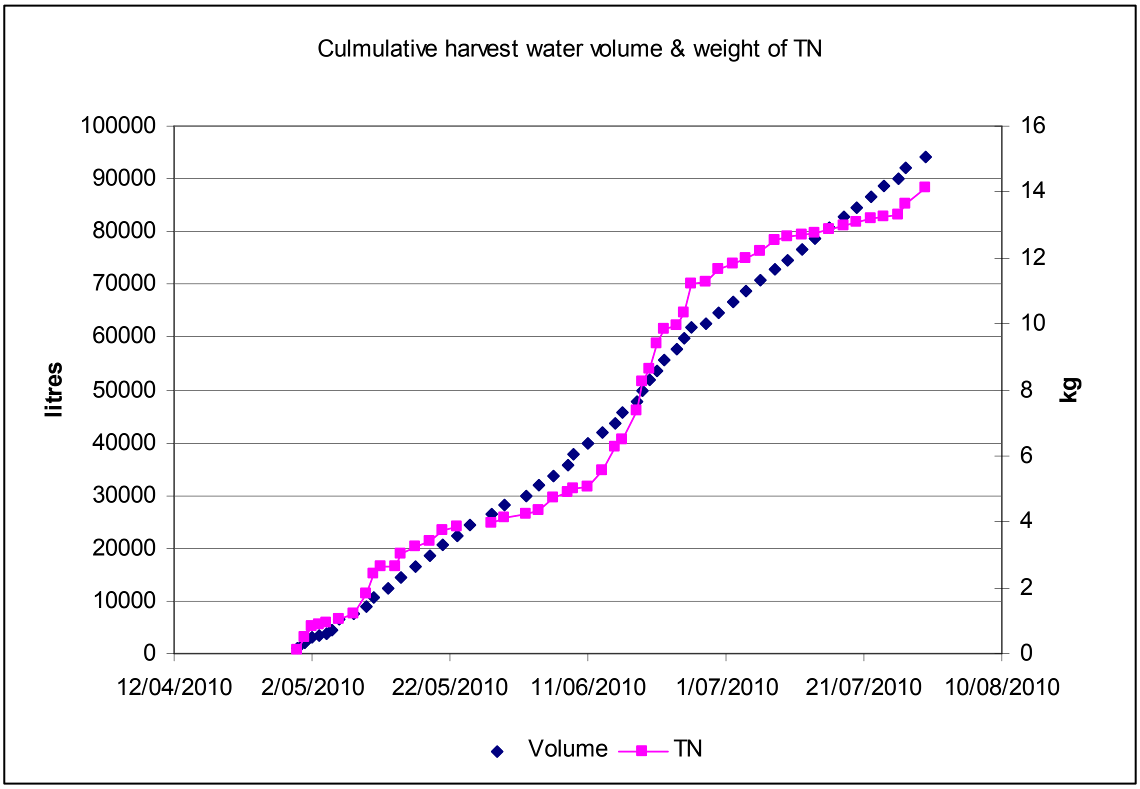

Figure 10 Cumulative harvest volume and cumulative total nitrogen harvested.

8.2 Ōhau Channel (influent) and effluent monitoring

Continuous fluorescence sensor monitoring in the Ōhau Channel indicates periods of increased algal volume in mid-May, the beginning of June and also mid-July (Figure 11). Diurnal variation of chlorophyll-a concentrations became more pronounced in July, probably due to a decrease in temperature (Figure 12) and a more consistent diurnal change.

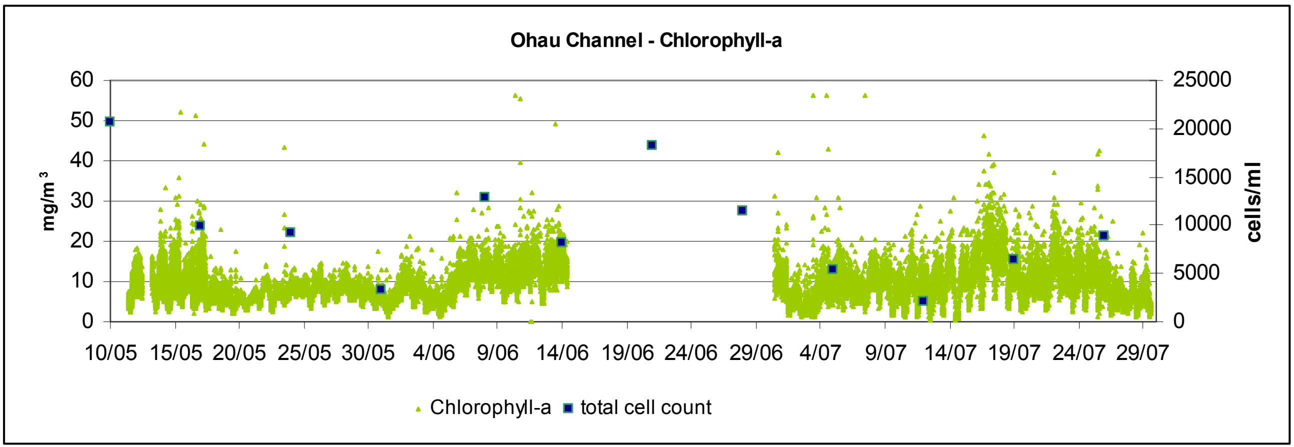

Figure 11 *Ohau Channel Chlorophyll-a concentrations by fluorescence and total algal cell counts.*

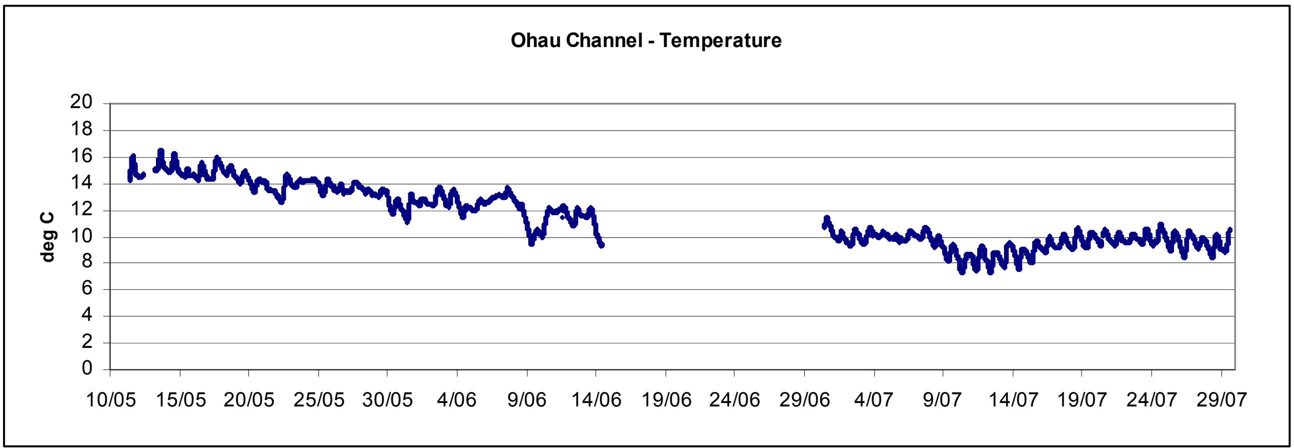

Figure 12 *Ōhau channel temperatures adjacent to harvester intake.*

The fluorescence sensor also measures phycocyanin fluorescence, a measure of the blue pigmentation found most often in blue-green algae (cyanobacteria). A smoothed daily average concentration (relative fluorescence units (RFU)) of phycocyanin is shown in Figure 13, along with cyanobacteria estimated biovolumes (mm^3/l), taken on a weekly basis. Both sets of data indicate that the cyanobacteria biomass decreased from mid-June with much of the biomass swinging from cyanobacteria domination to diatom assemblages (Figure 14). After mid-June *Aulacoseira spp*. and *Fragilaria spp*. become dominant. It is already noted above, that around this time a rise in chlorophyll-a concentrations occurred and an increase in the recovery of total solids harvested occurred.

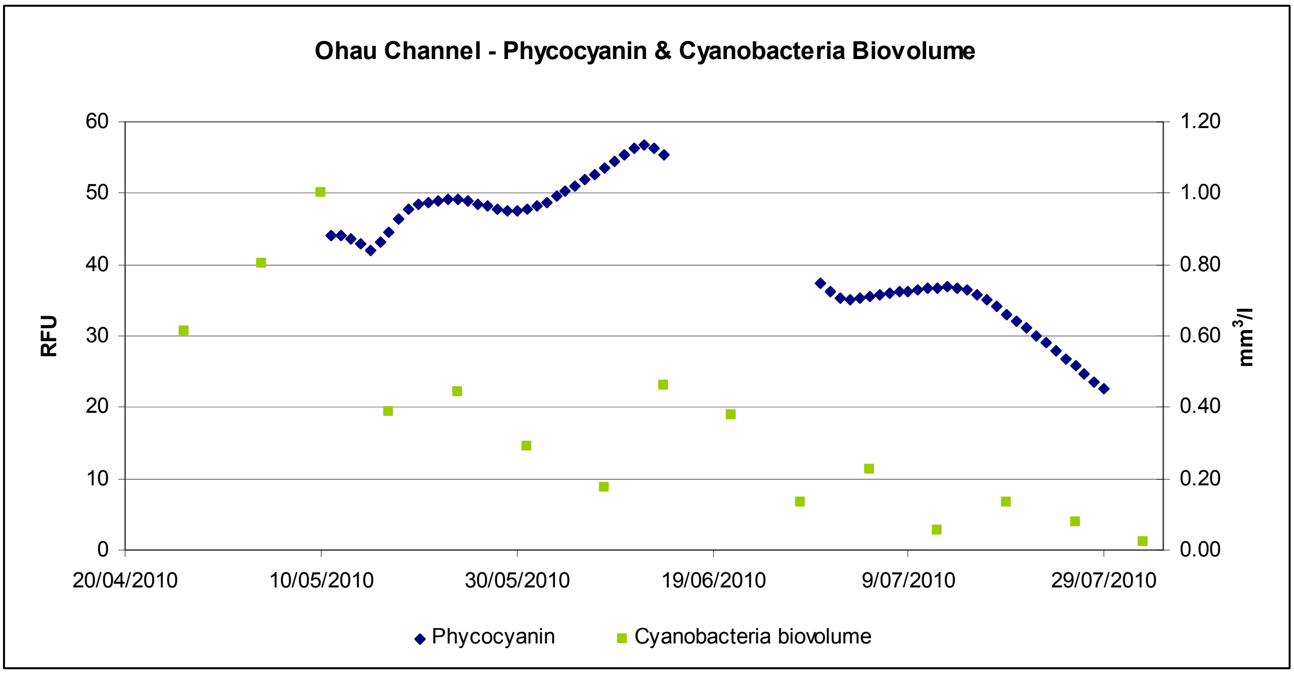

Figure 13 *Ōhau Channel Phycocyanin concentrations (lowess[1] smoothed) by fluorescence and cyanobacteria estimated biovolumes.*

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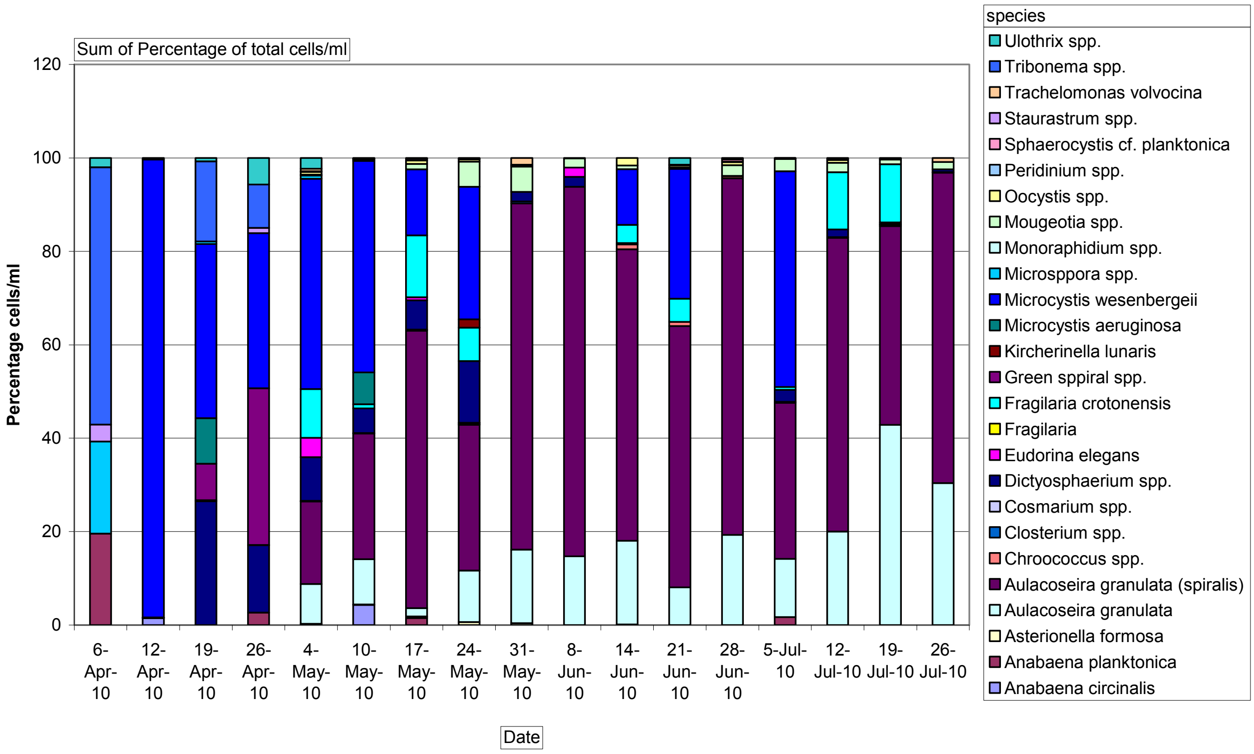

Figure 14 *Algae species distribution over the trial based on percentage cell count.*

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[1] Lowess = locally weighted scatterplot smoothing (30% span).

Suspended solids (SS) concentrations measures the level of solids in the channel at any one time and analysis of volatile suspended solids (VSS) gives a relative measure of how much of these solids are composed of organic material. SS levels in the channel over May to mid-July were on average 10.4 g/m^3 with SS levels in the effluent discharged to the Ōhau Channel at 5.9 g/m^3. Based on the difference between the SS load in the influent and the effluent, the harvester is removing on average around 43% of the SS load from the influent (Figure 15). However, TP and chlorophyll-a reduction are much higher and it is possible that the SS analysis has been compromised by the flocculent used in the harvester.

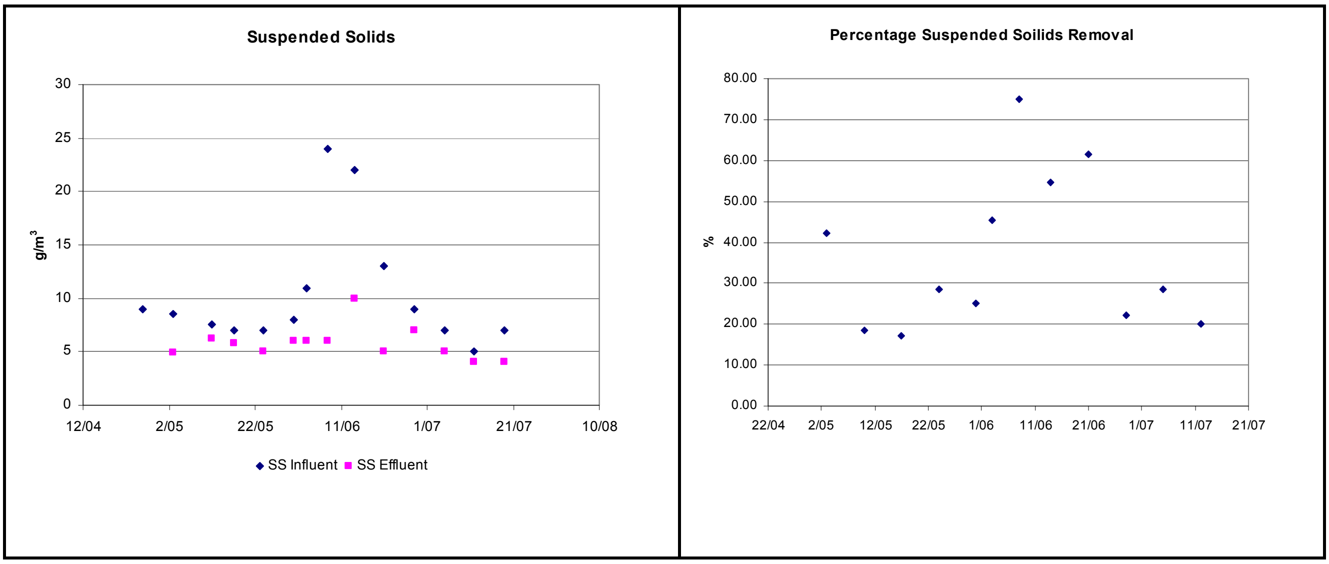


Figure 15 Suspended solids concentrations in influent and effluent; and percent solids removed from influent by the harvester.

Analysis of volatile suspended solids (VSS) indicates that on average around 55% of the SS load is organic material (Figure 17). The inorganic load in the Ōhau Channel shows an increase in mid-June (Figure 17) relative to the VSS. However, there is an increase in harvested solids at this time.

Removal of organic material by the harvester (Figure 16) based on the difference in chlorophyll-a concentrations from the Ōhau Channel intake and the effluent pumped back to the channel generally showed that over 90% of chlorophyll-a has been removed from the influent. Figure 17 shows the results of intensive sampling on 3 June, where chlorophyll-a levels increase during the day but remain stable at low concentrations in the effluent, a pattern repeated throughout the trial.

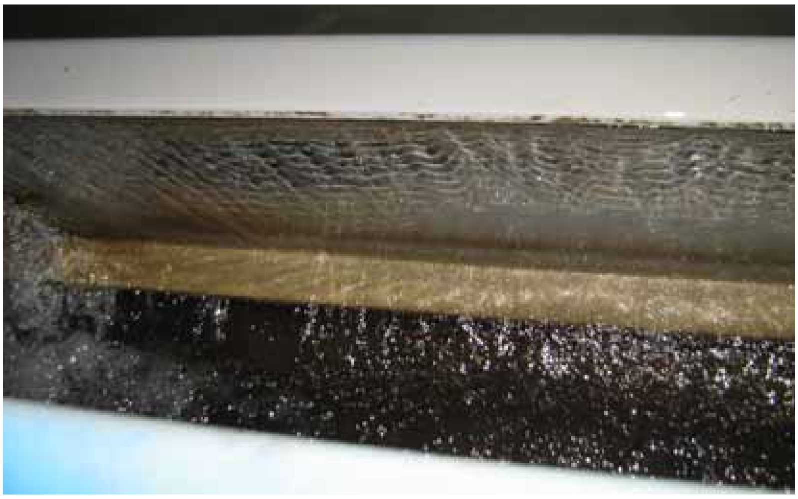


Figure 16 Cleaned output water following algae harvesting.

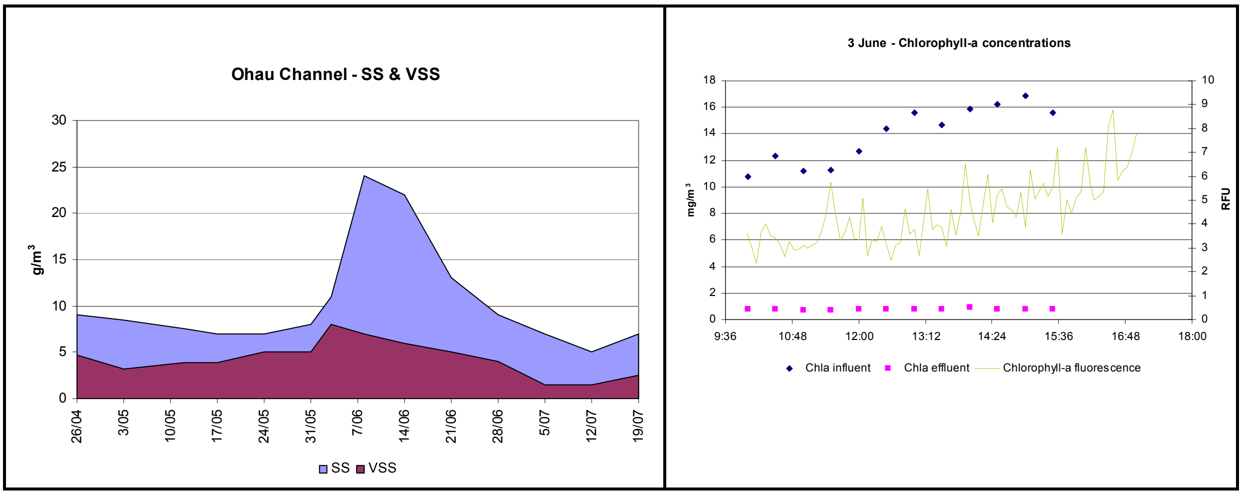


Figure 17 SS and VSS concentrations in the Ōhau Channel; and chlorophyll-a concentrations in influent and effluent; and relative fluorescence of the influent.

Total nitrogen concentrations measured in the Ōhau Channel above the intake (influent) and the effluent stream discharged to the Ōhau Channel oxbow are displayed in Figure 18. Effluent TN concentrations are generally higher than influent concentrations particularly at the beginning of the trial when solids recovery was lower.

In contrast, phosphorous concentrations were lower in the effluent than the influent (Figure 18) with on average 59% TP removal achieved. This percentage is higher than the percentage of SS removal although both variables showing a similar pattern change over the trial, potentially indicating that most of the phosphorous is associated with the suspended solids material.

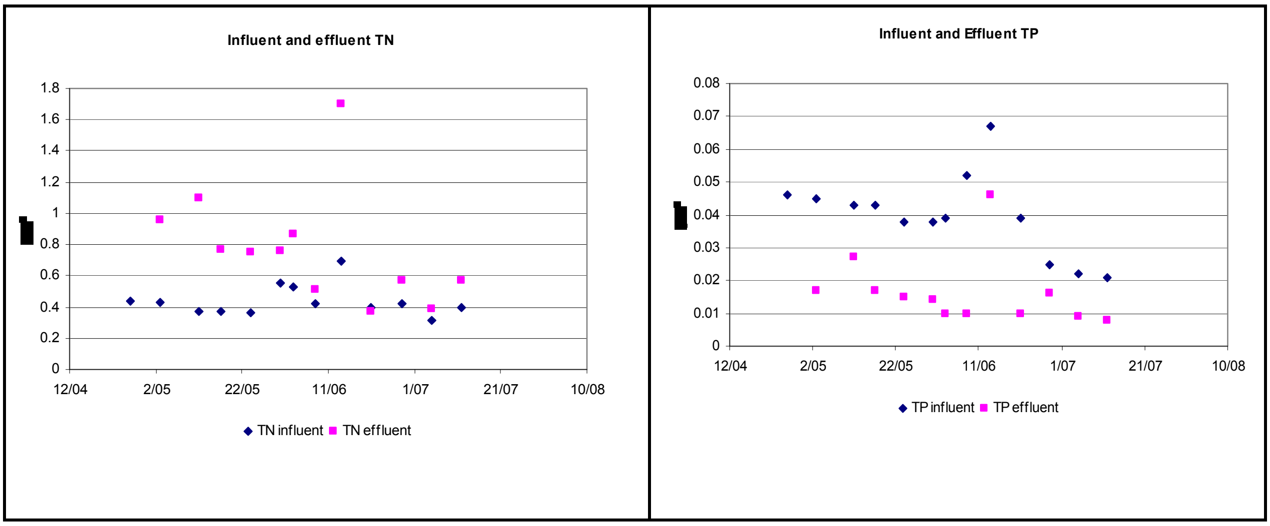


Figure 18   TN and TP influent and effluent concentrations.

Part 9: Discussion

9.1 Harvest quantities

Algal laden water (Figure 19) was drawn from the Ōhau Channel at approximately 25 m^3/day from 29 April to 29 July 2010, a period of 92 days. Over this period approximately 94,000 litres of algal laden water had been drawn off the harvesting plant (Figure 8). Intake problems did occur due to weed blockages, but relocation of the intake overcame this problem in the first month of the trial.

The weight of solids extracted from harvested effluent over the trial period was approximately 1,000 kilograms in 92 days. Average and median total solids and total nitrogen concentrations are listed in Table 2.

Diverting over 55,000 m^3 of water from the Ōhau channel over three months through an algal harvester resulted in harvesting less than 0.2% of the diverted water, and capturing around 60% of the algal biomass. The resultant 1,000 kilograms of algal concentrate harvested from the Ōhau Channel over the trial period indicates that the harvesting of wild algae from a water body can be successfully achieved by the Aquaflow harvest method.

The quantity of solids removed from the influent by the harvester was variable based on data from weekly grab samples taken from the Ōhau Channel and the harvester effluent. It is difficult to attribute changes in quantity of solids harvested to any one factor. Increasing concentration of algae in the Ōhau Channel does appear to have led to an increase in weight of solids harvested. Other factors such as an increase in the Ōhau Channel's discharge, changes in solids generation from wind and wave action, change in species of algae and in the performance of the harvester are also likely to be factors impacting the harvest.

Stormy weather and periods of high rainfall led to increased discharge volumes in the Ōhau Channel. The same intense weather events also cause increased fetch on Lake Rotorua, with the resulting waves stirring up sediment on the shallow delta area leading to the Ōhau Channel. Re-suspension of material during these wind generated activities is likely to be the main reason for the differences in inorganic and organic suspended solids.

Figure 19 Algae sample from the harvest tank.

Species change is also likely to have played a part in the final harvested volumes. Blue-green algae (cyanobacteria) first dominated the algal species make-up. Diatoms become more abundant a month into the trial, although blue-green algae did again have periods of dominance. Differences in cell size, shape and biological make-up of individual species are also likely to impact harvest volumes as the reaction of the various algae differs through the harvesting process (Figure 20).

Performance of the harvester is dependant on influent feed, dosing of flocculent and mechanical efficiencies of the harvester. Initially the inflow pipe had some blockage issues and was relocated in the first week of the trial, but otherwise relatively few issues inhibited the performance of the harvester. Issues with the harvester are discussed in section 10.

Over the three month trial period the harvester managed to extract approximately 14.0 kilograms of nitrogen. Based on the average nitrogen concentration in the influent and using an estimated 55,000 m^3 of influent abstracted over the trial period, relates to a potential 24.1 kilograms of nitrogen available for harvesting. Hence, an estimated 60% nitrogen has been recovered which is on average approximately the same percentage of phosphorus recovered, based on the difference in phosphorous concentrations in the influent and effluent.

Figure 20 Algae paste from the harvester.

The difference between TN concentrations in the influent and effluent shows that the flocculent used in the harvesting process added nitrogen to the effluent being discharged back to the Ōhau Channel. It is likely that the flocculent is in a concentrated ammonium form. If the objective of harvesting is to remove nitrogen from the waterbody then this type of flocculent would be unsuitable for use in a harvester.

No correlation between chlorophyll-a grab samples from the Ōhau Channel and the intermittent fluorescence monitoring of chlorophyll-a, based on matching time stamps for the fluorescence sensor data with the time of grab samples, was found. However, while individual samples did not show any correlation, the average trend of both data sets is generally in agreement. Reduction of chlorophyll-a concentrations in the effluent compared to the influent was over 90 percent, higher than suspended solids, nitrogen or phosphorous removal by harvesting. Transformation of chlorophyll-a during the harvesting process is a possible explanation, particularly as chlorophyll-a concentrations in the effluent were at a consistent level (with one exception).

Monitoring adjacent to the effluent discharge back to the Ōhau Channel detected little difference in water quality downstream of the discharge compared to that measured near the intake.

There seems little doubt that the Aquaflow Harvester is proficient at removal of algae from a waterbody with fluctuating algal concentrations and species. Detailed economic and environmental analysis of the benefits of improved water quality gains from deployment of such a system would be required to robustly assess long term use on the Rotorua Lakes.

Harvesting algae from eutrophic Rotorua lakes using the technology trialled in this project would involve abstracting much larger quantities of lake water to meet nutrient targets for the lakes. For example, to meet half of the nitrogen target for Lake Rotorua of 175 tonne per annum would require approximately 131,000 m^3 of water to be processed per day. Abstraction rates targeted at algae hot spots may have long term benefits for lake health by helping to break the cycle of algal bloom, algal deposition and sediment nutrient release. Locating hot spots, however, would be difficult as they tend to move with the wind and not be in one predictable location.

9.2 Algae harvesting cost comparison: Opex + Capex

Any analysis must also consider the costs of deployment (capital and operational) and potential cost recovery from the recovered algae or algae derived product. The derived value from this harvested algae is found in Appendix 6.

Table 3 CAPEX/OPEX comparison of Blenheim and Rotorua harvest sites.

ITEM COST COMPARISON $/kg (dry algae)		
ITEM	**BLENHEIM**	**ROTORUA**
Flocculent	0.98	2.20
Electricity/Fuel	0.42	7.73
Labour	0.09	0.09
OPEX TOTAL	**1.49**	**10.02**
CAPEX 20 yr amortised	**1.15**	**1.15**
TOTAL COSTS	**2.64**	**11.17**

Discussion

The higher cost for the equivalent dry algae harvest at Rotorua is a function of three components: algae density, flocculent usage and site generator use.

The harvester can process up to 35 m^3/hour water flow subject to site conditions. The harvester at Rotorua was set at 25 m^3/hour to enable ease of balancing the input and output pump volumes with unmanned harvesting. In the Blenheim situation the algae concentration was approximately 140 mg/m^3 of water, whereas the Rotorua algae concentration was approximately 10 mg/m^3 of water harvested. This increases the cost per kg (dry algae) when the algae concentration is lower, since the pumping costs are relative to the water volume processed, not the algae concentration. See Table 3 for the comparative values.

The flocculent dosing pump was set at an operating speed to harvest an algae concentration level of 20-25 mg/m^3, which our project scoping indicated. This dose rate was implemented to ensure that we harvested all the available algae in the influent water during the trial. The actual algae concentration levels were 50% lower than our initial scoping indicated, so more flocculent was used than the optimal amount necessary. This resulted in flocculent being discharged into the effluent water.

Because of the short duration of the trial and the remote site, we were unable to get electrical power supplied to the site economically. The use of a generator system ensured that we had a maximum power supply of 30 KWhr for the system to operate at full capacity. The pumps were balanced at 25 m^3/hr and this ensured an adequate generator power capacity was available for the complete system to operate, largely unattended. Again, the low concentration of the algae translates to a higher energy cost per kilogram in Rotorua compared to Blenheim, but the energy per unit of water treated would be similar at both sites.

Part 10: Improvements and issues

The following section outlines some of the issues which arose in undertaking the operation and recommends how these can be overcome with improvements for any future application.

10.1 Operational

Operationally the harvester performed well during the trial period managed by an operator that had two days operational training on site during commissioning. Initial training was by Aquaflow's Technical Manager and the operations were supported with standard operating procedure (SOP) manuals. As a remote deployment, the operator required a high level of support during the initial start-up period and local technical support with some electrical issues. Following this initial phase the support levels reduced significantly as he developed confidence in the equipment operation. With a future deployment an additional two days operator training at an existing harvesting operation would enable the operator to confidently manage the harvester to optimal use from its initial start-up.

An intelligent circuit loop operating from a TSS monitor on the incoming water supply to control the flocculent pump dosing levels when wide variations of algae concentration occur during the season would be a harvesting system improvement. This will avoid the situation of over or under flocculating the influent water to harvest the algae compared with using a set point dosing rate, as was done during the Rotorua trial.

A river influent water supply has a variety of weed, grasses and fine material in suspension beside the micro algae. These additional materials entered the intake line and caused some pumping flow meter inconsistencies and blockage to the priming pump. A secondary intake sleeve filter was attached and a deflection screen upstream of the intake pipe remediated the problem. Cleaning of the intake sleeve filter becomes an operator activity as part of the daily SOP schedule.

It was necessary to have the services container door ajar during the project to allow heat dissipation caused by the diesel generator. A larger ventilator in the roof of the container, and/or larger circulating fans, are required to dissipate the heat in the services container.

The discharge pump in the algae harvest bin failed to operate correctly with a less viscous algae paste separating and floating on the water. This was caused either by sensor failure or foreign objects blocking the mono pump operation. A screened intake or small trash pump with increased sensitivity probes will overcome this algae discharge issue.

As an environmental precaution when operating near a lake or river, a high water level alert probe to stop both the harvester pumps would ensure that no spills could occur into a surrounding sensitive aquatic zone from the harvested water containing a flocculent. The system would go into a shut down mode if this spill situation was imminent. In a sensitive aquatic zone a 0.5 m high bund surrounding the containers platform area would additionally be recommended to contain any water or diesel spills during operation subject to local water authority or council safety recommendations.

10.2 Capturing and harvesting floating algae

The Aquaflow unit successfully harvested a concentration of 10 g of algae per m^3 of free flowing outlet water from Lake Rotorua, i.e. 10 ppm, which is a very dilute level of micro algae. In waste water applications the unit has successfully harvested up to 280 g of algae per m^3 of water, i.e. 280 ppm. – *Blenheim District Council*

A high degree of variability is incorporated into the unit: variable input/output water flows, algae harvesting speed, air flotation supply and flocculent dosing rates. With the fixed intake pipe below water level any surface algae blooms are not harvested with the current mechanical configuration. Floating algal bloom harvesting could however be achieved in two ways:

1. A remote intake pipe boom is floated onto the water to harvest the near shoreline blooms, with the harvester remaining on land site. A cutting device or a masticating head would harvest the bloom into the water intake pipe leading to the harvester.

2. The harvester is incorporated into a floating barge with an open front water feed capacity for both suspended and bloom algae conditions. A remote intake pipe boom could also be deployed where operating depth of the barge becomes an issue. Nurse barges associated with the main harvesting barge would then take the algae material away for processing onshore.

10.3 Harvest metrics

The following harvest metrics were developed from the Total Opex costs. The Opex does not contain any labour component which was an in kind contribution from Bay of Plenty Regional Council under the terms of the NZTE contract.

Table 4 Harvest metrics results; outcome of quantities and costs.

HARVEST RESULTS	QUANTITY	UNITS	$ HARVESTED COST
Water Volume harvested	55,200	m^3	0.15/m^3
Algae Paste harvested (3%)	94	m^3	90.40/m^3
Algae Solids: (1% of paste)	940	kg	9.04/kg
Nitrogen @ 1.46% solids	13.7	kg	620.18/ kg

Table 5 OPEX materials, usage and cost for three month harvesting trial.

OPERATING COSTS	USEAGE	PRICE/UNIT	TOTAL COST
Flocculent	152.1 kg	12.37/kg	1,881.47
Diesel Fuel	5,606 litres	1.18/litre	6,615.08
TOTAL OPEX			**8,496.55**

10.4 The community and future applications

As the algae is separated from the water there are two primary value propositions that can be developed.

- What is the value of the cleaned water/m^3
- What is the value of the harvested algae/kg

10.4.1 Water: Proposal one

If we assume all the harvesting costs are associated with the water remediation process, this equates to 15 cents per m^3. What price are residents prepared to pay for cleaned water?

The report by Nimmo – Bell June 2004 for Bay of Plenty Regional Council: "The Rotorua Lakes, Evaluation of Less Tangible Values".

a) Page 17: The Value and Importance of Lakes

The following attributes were ranked by Rotorua resident responses:

1	Fresh air;	2	Un-spoilt environment;
3	Aesthetics;	4	Healthy Trout fishery;
5	Recreational activities; and	6	Traditional food supply.

Clearly 2, 3, 4, 5 and 6 are influenced by water quality (i.e. 5 of 6).

b) Page 21: Effect of Algal Blooms

Does the presence of algal blooms affect your use of the lakes?

Rotorua resident responses:

69% - Yes 20% - No 11% - Unsure

Clearly over two thirds of the population regard algal blooms as a problem.

c) Page 30-31: Willingness to Pay

For Rotorua households, 25.6% of them had a willingness to pay $91.24 year to improve lake water quality. Based on 22,254 households, this is $2.03 million/year.

Based on the willingness of 22,254 Rotorua households to pay, how much water would be remediated/year with this money?

Opex = 15 cents m^3

Funding: $2.03 million/0.15 = 13.5 x 10^6 m^3 (Water volume able to be remediated).

Lake Rotorua = 888.8 x 10^6 m^3 (Total lake volume).

Summary: Proposal one

In one year 13.5 m^3/888.8 m^3 = 1.5% of the lakes water is remediated.

On this basis it would take 66 years to remediate the lakes total water volume, assuming 2010 value of currency for costs if it is funded by the residents only. Clearly this is impractical for the whole lake at this time.

Water: Proposal two

Based on the willingness of 22,254 Rotorua households to pay, how much water could be made safe to swim in and develop a safe swimming area?

Many tourist destinations in the world have fenced water swimming areas to protect swimmers from shark attack or jelly fish infestations. A membrane fenced section of Rotorua Lake bordered by the beach closest to the CBD could be continuously remediated from algae blooms with an enclosure and the Aquaflow algae harvesting process (Figure 21).

Figure 21 Membrane fencing could protect 2.5 ha of safe swimming area with algae harvesting for Lake Rotorua.

This would promote swimming and recreational use of the lake near the city centre where tourism activities occur. It is understood that up to 5,000 visitors per night visit Rotorua, but they are unable to swim in the lake.

Funding $2.03 million:

$1.5M	= Membrane fence 2.5 ha of lake by the beach.
$0.53M/0.15	= 3.5 x 10^6 m^3 of cleaned water/year.
	= 2.5 ha water area continuously cleaned every five days.

Summary: Proposal two

With the stated Bay of Plenty Regional Council objective to reduce nutrient concentrations within the water column, a proof of concept enclosed swimming area has environmental, recreational and aesthetic benefit as a possible next step for this algae harvest process development. The algae could continue to be used as a nutrient and microbe input for a composting operation that is sited outside of Rotorua or alternative uses investigated.

The value to the community of this swimming development would need to be measured in additional tourism dollars and increasing resident satisfaction that an algae remediation programme was being implemented for the long term benefit of the Rotorua Lake. Besides the increased water quality what is the value of the harvested algae biomass?

There are several different uses for the algae biomass that could be considered, besides the algae water (compost tea) for compost use that was implemented. These include feedstock for: bio-fuel production, soil fertilizer, livestock feedstuffs, bio-char for carbon sequestration or bio-char for water filtration medium.

A process where the value of the algae meets or exceeds the operating cost of the harvesting process would pay for the enclosed remediated water for the swimming area.

Figure 22 Harvested algae provide essential nutrients and microorganisms for the Gibbons Hornwort composting business at Paengaroa.

A price for the harvested algae material would need to be $135/m^3 to provide a business proposition for a harvesting company. Since the costs are known for the composting operation this is used to determine an economic outcome.

Composting analysis:

Raw material: $8.66/500 kg DM (cow/goat dry pad scraping)

Algae water: $135/1,000 kg (3% dry matter)

Composting needs the water in the algae for the processing, then evaporates.

Ratio: 2x Algae water (1,000 kg): 1x Raw material (500 kg)

Total Dry Weight = 30 kg algae + 500 kg raw material = 530 kg

Cost of production: $143.66 530 kg = $0.27/kg

Retail price for compost = $7.75/20kg = $0.38/kg

This gives a 30% margin: manufacturer to retail outlet pricing where the retail cost can be as high as $7.70 kg.

The economics of using the algae water for producing compost material are positive with the costs presented. Transportation of the raw materials to site influences the economic outcome, so a production facility at/near the source of the algae is desirable (Figure 22).

Part 11: Conclusions

1) Three aims for the project were identified as:

   A) *To undertake a "proof of concept" trial to test the capacity for wild algae harvest in a water quality improvement project.*

   The ability to harvest wild algae was confirmed by the harvester successfully operating at only 8 grams algae/m^3 of water concentration, a low suspended algae concentration figure for lake water conditions. Using the chlorophyll as the chemical indicator for algae presence, the 90% chlorophyll-a removal rate (Figure 17) for the influent water during this trial would indicate a very successful proof of concept trial for lake water projects. Eight grams/m^3 is only 6% of the usual concentrations found in waste water applications where the harvester has demonstrated 80% efficient algae removal operation.

   The harvester could be used in more eutrophic lakes where the concentration of algae could be as high as 240 g/m^3 of water processed and confidently expect efficient harvesting.

   B) *To test the technology for algae harvesting within some of Bay of Plenty Regional Council's eutrophic lakes.*

   The technology around the use of a specific poly-electrolyte material to facilitate flocculation of the algae without any adverse ecotoxicological risks was confirmed. The period of testing was not a continuously high eutrophic period for the Ōhau Channel, however there were periods of orange alert (medium alert level) during the period and the harvester converted 90% of the algae into a biomass product. At times, the effluent water contained trace levels of the poly – electrolyte, but this did not cause any harmful effects to fish or wildlife. A different form of flocculent that does not contain concentrated ammonium could be used for harvester use, where nitrogen removal is the primary requirement in a commercial algae harvesting application. A standard commercially available flocculent was used for this trial.

   The methodology of harvesting from a fixed point along the Ōhau Channel suited a proof of concept trial. This enabled key parameters to be measured regularly with the C3 submersible fluorescence/temperature logger and confidently recorded without any site variability issues. Site influent and effluent water samples were able to be taken physically from the harvest site which confirmed the effectiveness of the algal harvest.

   C) *To fulfil one of the key recommendations from the Proposed Rotorua and Rotoiti Action Plan to investigate the role of biomass harvesting within the Lakes Protection and Restoration Programme.*

   The harvester processed 0.2% of the Ōhau Channel flow from the Waiatuhi block site location with a satisfactory outcome. Several harvesters could be located on this land, however the outcome would still only be a relatively small percentage of the total water harvested and biomass removed. The concept of a harvester(s) being located onto a barge(s) to harvest biomass on a continuous and sustainable basis is a practical scale up situation with this technology. Larger size units could be permanently deployed in areas known for their bloom activity, however their operation may only be seasonal. The necessary nutrients for continuous biomass growth are continuously being fed into the water column from all sources and scientific evidence would appear to support subterranean nutrient presence for 40 plus years in Lake Rotorua if all nutrient leaching into the lake was able to be stopped today.

The limitation to the harvesting of the biomass resource is that there is no currently accepted value proposition around the resources of 1) algae biomass or 2) remediated lake water. The volume of algae harvested at 8 g/m^3 means that it takes 125 m^3 of water to provide 1 kg of dry biomass. In order to make the harvesting operation financially feasible there must be a value associated with the cleaned water environmentally or the algae must be used/processed into a high value product.

It is predicted that lakes like Rotorua under the auspices of the Protection and Restoration Program, will enable sustainable algal harvesting to be regarded as a management tool, to maintain the health and heritage of these lakes water quality for the future generations.

2) Algae, including blue green algae/Cynobacteria was successfully harvested by Aquaflow's harvest process from the Ōhau Channel, ranging from very low levels 0.03 to 4.02 mm^3/litre of biovolume or 5 to 25 g/m^3 dry weight algae. See Table 4 for harvest metric results.

The trial flow rate was :	25 m^3/hour
The total volume of water passing through the harvester in 92 days was:	55,200 m^3
The total volume of algae slurry collected was :	94 m^3
The total mass of dry weight equivalent algae material in the slurry was:	940 kg
The total mass of nitrogen removed was:	13.7 kg

The returned water was significantly cleaner with the turbidity reducing from an average inlet level of 7.6 NTU to 4.5 NTU at the outlet and chlorophyll-a (green colour) reducing by 40%.

No negative environmental or eco-toxicity issues were identified with the process.

The algae slurry collected was beneficially used in producing compost, where it enhanced the rate and degree of composting as well as providing nitrogen, phosphorous and other secondary nutrients at 16 to 30% increased levels.

The operating costs during the trial were established as 15 cents/m^3 of water treated. See Table 5 for a breakdown of OPEX costs. If the combined Opex and Capex costs were allocated to the following outputs their individual treatment cost would be:

$90.4 m^3 Harvested Algae – wet weight

$9.04 kg Harvested Algae Solids – dry weight

$620 kg Nitrogen removed

The Total Operating Cost breakdown (as below):

19.6%	Consumables
69.2%	Energy
0.9%	Labour
10.3%	Capital
100%	TOTAL

It needs to be noted that power was supplied by diesel generator, suitable for remote sites, but the operating cost in a region supplied by grid electricity would be considerably less. The operating cost at a location on the Ōhau Channel utilising the natural gravity flow of the water would result in a significantly reduced power consumption. Treating the Ōhau Channel would also have positive benefits for Lake Rotoiti and the Kaituna River.

There was positive community support for the project in relation to the aesthetic values of seeing a cleaner lake and making use of a problem material (the algae). A Nimmo Bell survey showed community support for the less tangible values associated with the lake. The community was prepared to pay towards a cleaner lake.

Rotorua Community:	$716,801	(22,254 houses @ $32.21 each/year)
Tourism levy:	$3,640,000	($2/head @ 5,000 visitors/night)
N removal charge	$13,760	(Clean lakes program – central government)
Compost	$3,700,000	(if $135 m^3 algae slurry price)
TOTAL:	$8,070,561	

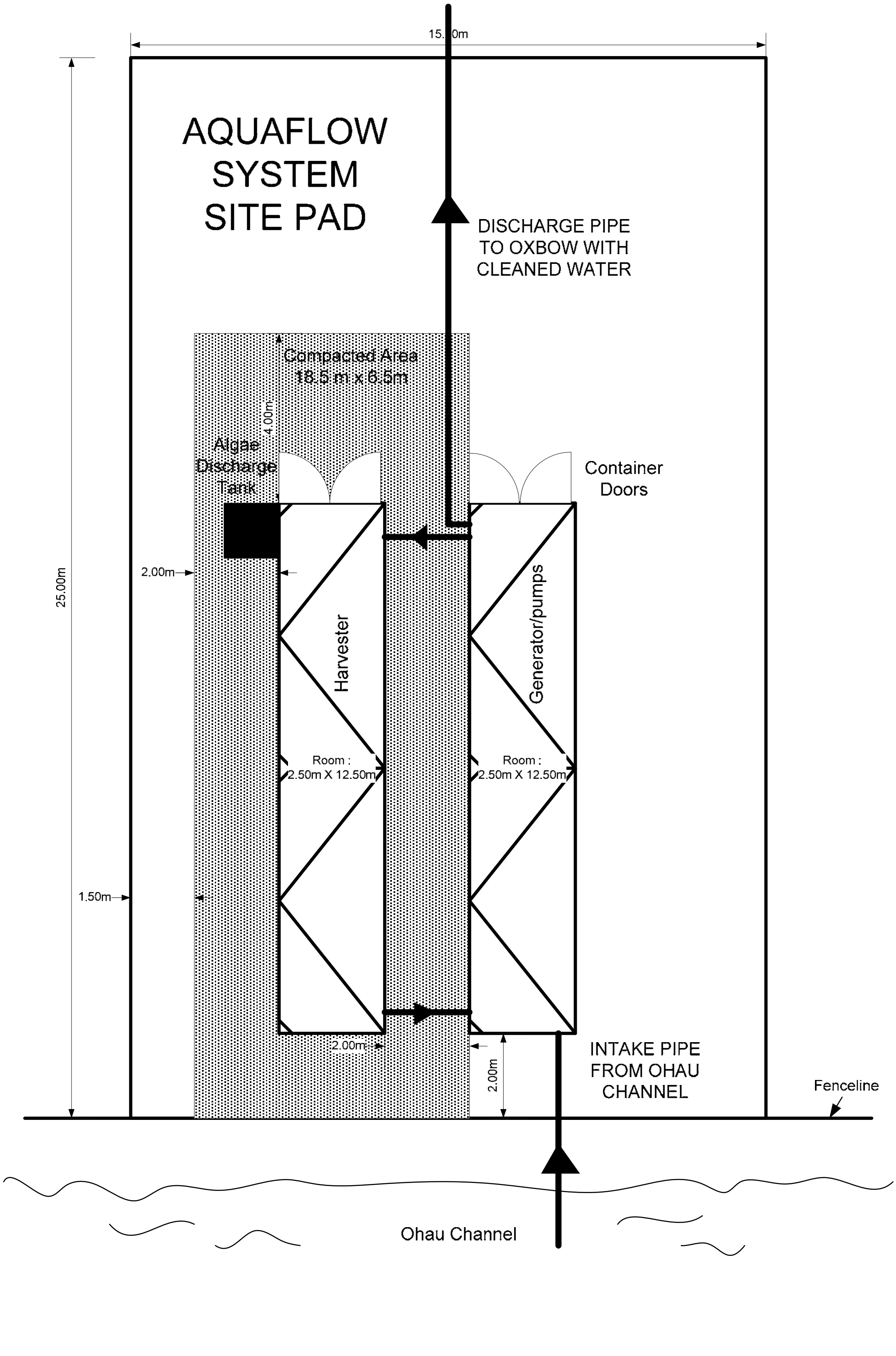
Up to 53.8 million m^3 of water could be processed per year if this income could be generated.

This represents 6% of the lake water harvested annually and in 16.5 years of continuous operation, Lake Rotorua will have had one complete cycle of algae harvesting and over 200 tonnes of nitrogen removed from the lake system.

A proposal to fence off and clean 2.5 ha of lake front for swimming/water sports near central Rotorua would be feasible at a cost of $2.03 M. This would include $1.5 M for a membrane fence and $0.53 M as operating cost for 3.5 x $10^6 m^3$ of cleaned water per year. This would equate to 2.5 ha water area being continuously cleaned every five days to provide a safe clean swimming environment. This would further enhance Rotorua as an environmentally scenic city for local and international visitors to enjoy, thus creating additional revenue for the region.

Appendices

Appendix 1 – Site drawing



Appendix 2 – Aquaflow project budget

AQUAFLOW PROJECT BUDGET

	NZTE Budget	BOPRC in Kind	ABC in Kind	TOTAL $ BUDGET
CONSENTS / FEES	0	7,000	0	7,000
SITE PREPARATION	0	3,000	0	3,000
TRANSPORTATION	16,800	0	0	16,800
PUMPS/FILTERS/TANKS	1,500	0	0	1,500
LABOUR	7,700	9,000	8,800	25,500
TRAVEL	4,000	0	0	4,000
FLOCCULANT	5,000	0	0	5,000
FUEL	14,385	3,596	0	17,981
ROADING	3,500	3,500	0	7,000
HARVESTER	27,000	0	27,000	54,000
SERVICES CONTAINER	16,560	0	16,560	33,120
MONITORING / ANALYTICAL COSTS	0	12,500	0	12,500
ALGAE DISPOSAL	0	0	0	0
REPORTS	0	4,000	4,000	8,000
TOTAL:	**96,445**	**42,596**	**56,360**	**195,401**
$ INPUTS NZTE : CLIENT (50:50)	**49.36**	**21.80**	**28.84**	**Condition met for contract**

Appendix 3 – Resource consent

Consent Number: **66044**

Bay of Plenty Regional Council

Resource Consent

Pursuant to the Resource Management Act 1991, the **Bay of Plenty Regional Council**, by a decision dated 5 March 2010, **Hereby Grants** to:

BAY OF PLENTY REGIONAL COUNCIL

A Resource Consent

(a) under section 13(1)(a) of the Resource Management Act 1991 and Rule 71 of the Bay of Plenty Regional Water and Land Plan to carry out a discretionary activity being to **Place and Use a structure In, On, Under or Over the Bed of the Ohau Channel**; and

(b) under section 13(1)(b) of the Resource Management Act 1991 and Rule 71 of the Bay of Plenty Regional Water and Land Plan to carry out a discretionary activity being to **Disturb the Bed of the Ohau Channel**; and

(c) under section 14(3)(a) of the Resource Management Act 1991 and Rule 43 of the Bay of Plenty Regional Water and Land Plan to carry out a discretionary activity being to **Take, Use, Divert or Dam Water from the Ohau Channel**; and

(d) under section 15(1)(a) of the Resource Management Act 1991 and Rule 37 of the Bay of Plenty Regional Water and Land Plan to carry out a discretionary activity being to **Discharge Water to the Ohau Channel;**

subject to the following conditions:

1 Purpose

For the purpose of taking water from the Ohau Channel and discharging treated water from an algae harvesting facility back into the Ohau Channel in Rotorua.

2 Points of Water Take and Discharge

2.1 The water take point shall be located in the Ohau Channel, in accordance with BOPRC Plan Number RC 66044-1 submitted with the application for this resource consent.

2.2 The point of discharge of the effluent from the algae harvesting plant shall be in the Ohau Channel in accordance with BOPRC Plan No 66044-1 submitted with the application for this resource consent.

3 Quantity and Rate for Water Take and Discharge

3.1 The rate of water take from the Ohau Channel shall not exceed 10 litres per second.

3.2 The daily maximum water take shall not exceed 864 cubic metres.

3.3 The discharge from the algae harvesting facility to the Ohau Channel shall not exceed 864 cubic metres per day.

4 Map Reference

NZMS 260 U15:0240 - 4563 at or about the site of the water take; and

NZMS 260 U15:0241 - 4569 at or about the site of the water discharge.

5 Legal Description

Pt Waiatuhi, ML 9508 (Rotorua District).

6 Notification of In-stream Works

6.1 No less than five working days prior to the overall start of works under this consent, the consent holder shall request (in writing) a site meeting between the principal site contractor and the Chief Executive of the Regional Council or delegate. Notification at this time shall include details of who is to be responsible for site management and compliance with permit conditions (see Advice Note 4).

6.2 The consent holder shall notify (in writing) the Chief Executive of the Bay of Plenty Regional Council or delegate within five working days of the completion of works under this permit (see Advice Note 4).

6.3 Conditions 6.1 and 6.2 also apply to in-stream works required to remove the intake and discharge structures before the expiry of this permit.

7 General Operation at the Site

7.1 No fuel storage or machinery refuelling shall occur where fuel could enter a water body in the event of a spillage.

7.2 All chemical storage at the site shall be designed and managed to prevent the discharge of contaminants to land, water or air.

8 Works

8.1 All stream works shall be undertaken from above water level where practicable. Machinery shall be kept out of the channel unless impracticable.

8.2 The stream works shall be carried out in a manner that minimises discoloration of the Ohau Channel.

8.3 No vegetation, soil, slash and other debris shall be deposited in the Ohau Channel, or left in a position where the material could enter water.

8.4 The permit holder shall ensure that all construction equipment, machinery, plant, and any debris is removed from any of the work site (channel and treatment plant) on completion of works.

8.5 Every precaution shall be taken during the works to ensure that the channel banks are not damaged and that their erosion resistance is not compromised by the construction activity.

8.6 Any scour of the bank channel resulting from works under this consent, shall be effectively stabilised as soon as practicable.

8.7 The permit holder shall ensure that no concrete or cement based-substances enter surface water.

9 Structure

9.1 All works under this permit shall be constructed in accordance with the information (plans and documentation) submitted with the application for this consent.

9.2 One month before the expiry of this permit, the intake and discharge structure shall be removed from the channel and the channel shall be reinstated.

10 Treated Effluent Discharge Quality and Rate

10.1 There shall be no objectionable or offensive odour or dust nuisance, as determined by a Regional Council enforcement officer, at or beyond the boundary of the site.

10.2 The permit holder shall monitor the pH of the influent and the final effluent before the discharge to the Ohau Channel.

10.3 There shall be no increase of nitrogen-nitrate content in the stream resulting from the discharge of the algae harvesting system. The results of monitoring of Nitrogen-Nitrate shall be made available to the Regional Council Pollution Prevention Officer upon request.

10.4 The consent holder shall ensure that, after reasonable mixing (State Highway 33 Bridge), the discharge from the Algae Harvesting Plant shall not result in any of the following:

- The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials;
- Any conspicuous change (20%) in the colour or visual clarity;
- Any emission of objectionable odour;
- Any significant adverse effects on aquatic life;
- The natural temperature of the water shall not be changed by more than 3^{o} C; and
- Aquatic organisms shall not be rendered unsuitable for human consumption by the presence of contaminants.

11 Treated Effluent Monitoring

11.1 The water quality parameters under condition 10.2 shall be analysed regularly using one representative sample of the influent as well as a sample from the outlet effluent of the algae harvesting system, both samples taken simultaneously. The samples shall be taken at least twice per day while the harvesting system is in operation for the duration of this permit.

11.2 The results from water quality monitoring undertaken in accordance with conditions 11.1 shall be made available to the Chief Executive of the Regional Council or delegate upon request.

11.3 The permit holder shall at all times operate, maintain, supervise, monitor, and control all processes on site so that discharges authorised by this permit are maintained in compliance with the permit conditions.

12 Stream Monitoring

12.1 The permit holder shall on at least three occasions prior to the expiry of the permit invite representatives of DoC, Fish and Game and Tangata whenua to meet and inspect the facility and its downstream effects and shall keep records of these meetings and participant concerns (if any).

13 Erosion and Sediment Control

13.1 The permit holder shall install appropriate sediment and erosion controls to effectively avoid or minimise erosion and sediment discharge to the stream during the construction and plant operation associated with this permit.

13.2 All erosion and sediment controls shall be installed prior to the commencement of any work at the site.

13.3 The permit holder shall divert uncontaminated catchment stormwater runoff away from any operational areas such as, but not limited to, chemical storage, chemical preparation or treatment plants.

13.4 Unless otherwise specified in this permit, the permit holder shall ensure that all erosion and sediment controls comply with specifications set out in Environment Bay of Plenty Guideline No. 2001/03 – "Erosion and Sediment Control Guidelines for Land Disturbing Activities" or its successor.

14 Maintenance

14.1 The intake and discharge structure shall be operated and maintained in good working order at all times, to the satisfaction of the Chief Executive of the Regional Council or delegate.

14.2 The permit holder shall take full responsibility for constructing and maintaining this structure in a manner that does not compromise the health and safety of humans, their livestock or damage any property.

14.3 The use of the intake and discharge structure shall not cause scouring in the Ohau Channel or its margins. If scouring is present, the permit holder shall take immediate action to stop any further scouring from occurring. Scouring resulting from the exercise of this permit shall be effectively stabilised.

14.4 The intake and discharge structure shall be inspected on a monthly basis or immediately after a significant rain event. The permit holder shall keep a record of such inspection and make it available to a Regional Council enforcement officer upon request.

15 Monitoring Results

15.1 The permit holder shall provide, annually, a comprehensive report comprising but not limited to the following items:

(a) the treatment plants monitoring results;

(b) records of stakeholder meetings and identified concerns (refer condition 12.1);

(c) discuss the effects (positive and negative) of the discharge on the Ohau Channel;

(d) proposed methods to avoid or mitigate adverse effects on the Ohau Channel of the activities authorised under this consent;

(e) Any other information relevant to this consent.

16 Chemical Analysis

16.1 All physico-chemical analyses and samples preservation shall be carried out as set out in the latest edition of “Standard Methods for the Examination of Water and Wastewater” — APHA — AWWA — WPCF or using such other method as may be approved by the Chief Executive of the Regional Council or delegate.

17 Notification of Operation Change

The permit holder shall notify the Regional Council of any changes to the operation (as set out in the application for this resource consent) that may come about from unforeseen circumstances during the exercise of this resource consent and that may increase discharges of contaminants to water or cause discharges to land or atmosphere.

18 Term of Permit

This permit shall expire on 30 March 2013.

19 Resource Management Charges

The consent holder shall pay the Bay of Plenty Regional Council such administrative charges as are fixed from time to time by the Regional Council in accordance with section 36 of the Resource Management Act 1991.

20 **The Permit** hereby authorised is granted under the Resource Management Act 1991 and does not constitute an authority under any other Act, Regulation or Bylaw.

Advice Notes:

1. *The permit does not authorise discharges on any property not owned by the permit holder. The permit holder must be the legal owner of the land which the works authorised under this consent are being undertaken on or have approval from the relevant landowner.*

2. *The permit holder is advised that non-compliance with permit conditions may result in enforcement action against the permit holder and/or their contractors.*

3. *The permit holder is responsible for ensuring that all contractors carrying out works under this permit are made aware of the relevant permit conditions, plans and associated documents.*

4. *Unless otherwise specified, Reporting and notification shall be directed (in writing) to the Manager Pollution Prevention, Environment Bay of Plenty, PO Box 364, Whakatane (or fax 0800 368 329 or notify@envbop.govt.nz) including the permit number 66044.*

5. *This permit does not cover the requirement for chemical storage under the HSNO Regulation or building permit required by the District Authority.*

6. *For more information on the effects of cement in waterways and reasonable prevention measures refer to the following document available on the Auckland Regional Council website (www.arc.govt.nz), "Pollution Fact Sheet – Construction Activities".*

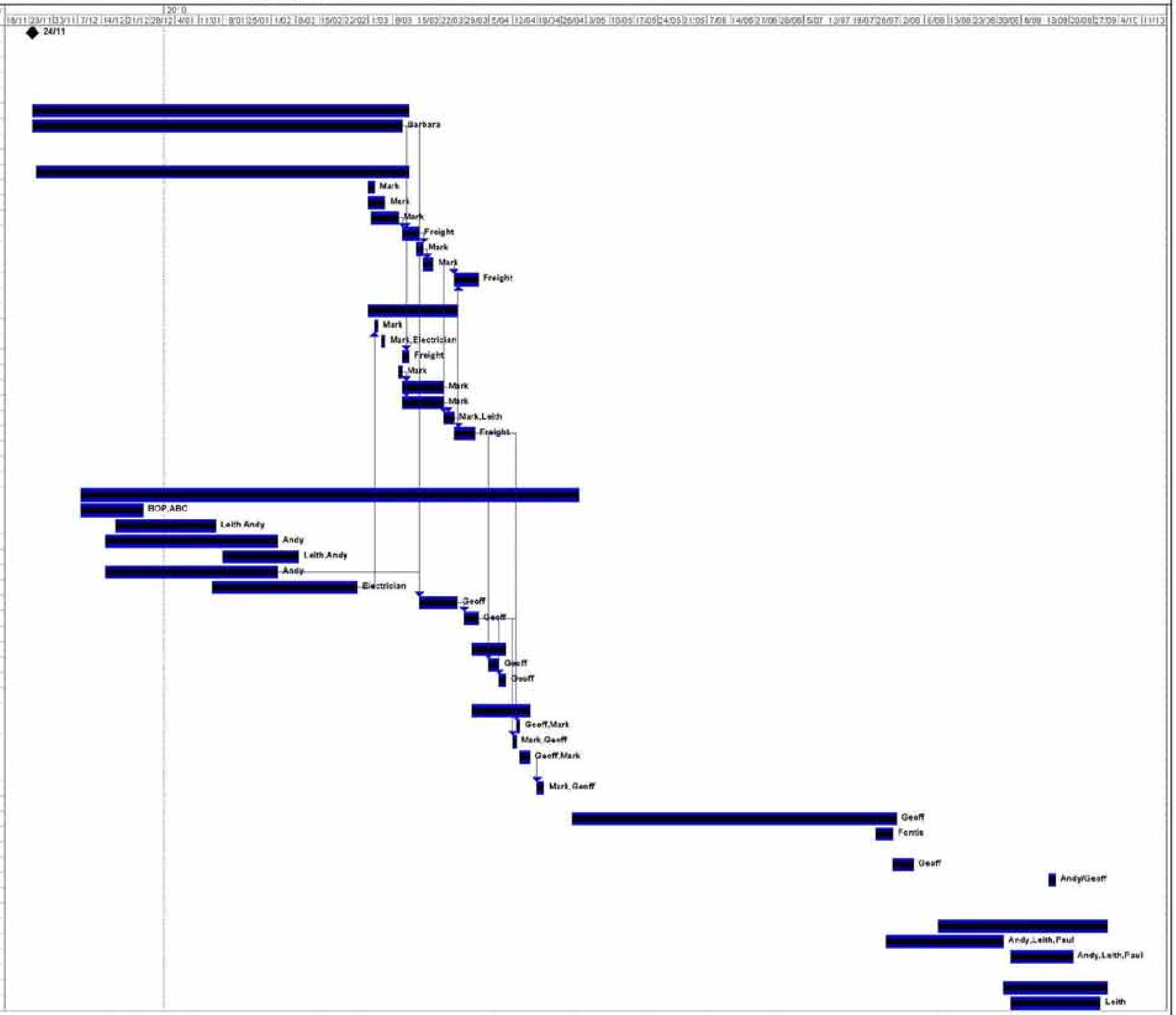
DATED at Whakatane this 5th day of March 2010
For and on behalf of
The Bay of Plenty Regional Council

W E Bayfield
Chief Executive

Appendix 4 – Project plan

Project EBOP 1

ID	Indicators	Task Name	Duration	Start	Finish	Predecessors
1			0 days	Tue 24/11/09	Tue 24/11/09	
2						
3						
4						
5						
6	✓	**NZTE PROJECT APPROVAL**	78 days	Tue 24/11/09	Fri 12/03/10	
7	✓	Project funding contract development	77 days	Tue 24/11/09	Wed 10/03/10	
8						
9						
10	✓	**HARVESTER PREPARATION**	70 days	Wed 25/11/09	Fri 12/03/10	
11	✓	OPTION DAF Install or use existing harvester	2 days	Mon 1/03/10	Tue 2/03/10	
12	✓	Decommission: V Belt, pumping pipes, floc pump, water etc	5 days	Mon 1/03/10	Fri 5/03/10	
13	✓	Decommission Water Supply / Discharge	6 days	Tue 2/03/10	Tue 9/03/10	
14	✓	Transport Blenheim to Nelson	3 days	Thu 11/03/10	Mon 15/03/10	13,7
15	✓	Water blast clean and maintenance	2 days	Mon 15/03/10	Tue 16/03/10	14
16	✓	Install disc discharge filters	3 days	Wed 17/03/10	Fri 19/03/10	15
17	✓	Transport Nelson to Rotorua	5 days	Fri 26/03/10	Thu 1/04/10	16,28
18						
19	✓	**GENERATOR AND PUMP CONTAINER : Preparation**	20 days	Mon 1/03/10	Fri 26/03/10	
20	✓	Clear out and move non essential materials	1 day	Wed 3/03/10	Wed 3/03/10	37
21	✓	Decommission electrics and pipes	1 day	Fri 5/03/10	Fri 5/03/10	
22	✓	Transport to Nelson – generator	2 days	Thu 11/03/10	Fri 12/03/10	7
23	✓	Water blast and clean	1 day	Wed 10/03/10	Wed 10/03/10	
24	✓	Installation of pipe, electrical, generator, tanks, pumps	8 days	Thu 11/03/10	Mon 22/03/10	23
25	✓	Installation of floc system	8 days	Thu 11/03/10	Mon 22/03/10	23
26	✓	Test harvester / Generator system	3 days	Tue 23/03/10	Thu 25/03/10	24,25,10
27	✓	Transport Nelson to Rotorua	4 days	Fri 26/03/10	Wed 31/03/10	26
28						
29						
30						
31	✓	**CONSENTS & SITE PREPARATION : Rotorua**	134 days	Tue 8/12/09	Fri 30/04/10	
32	✓	Visit and investigate harvesting options	14 days	Tue 8/12/09	Fri 25/12/09	
33	✓	Site location confirmed EBOP/Aquaflow	21 days	Fri 18/12/09	Fri 15/01/10	
34	✓	Resource Consents process and local discussions	36 days	Tue 15/12/09	Tue 2/02/10	
35	✓	Develop site and implementation plan EBOP/Aquaflow	16 days	Mon 18/01/10	Mon 8/02/10	
36	✓	Resource Consents process	36 days	Tue 15/12/09	Tue 2/02/10	
37	✓	Decide 240 volt Power Supply / Generator alternative	30 days	Fri 15/01/10	Thu 25/02/10	
38	✓	Level Site and install crushed metal base	8 days	Tue 16/03/10	Fri 26/03/10	36,7
39	✓	Harvester and Generator/Pump containers delivered to site	4 days	Mon 29/03/10	Thu 1/04/10	38
40						
41	✓	**HARVESTER**	8 days	Wed 31/03/10	Fri 9/04/10	
42	✓	Establish pump intake to Ohau / discharge to Oxbow	3 days	Mon 5/04/10	Wed 7/04/10	39,27
43	✓	Algae removal / disposal tank system installed	2 days	Thu 8/04/10	Fri 9/04/10	39
44						
45	✓	**GENERATOR / PUMP**	13 days	Wed 31/03/10	Fri 16/04/10	
46	✓	Connect floc pump line and floc mixing tank	1 day	Tue 13/04/10	Tue 13/04/10	39,27
47	✓	Connect electrics: pumps, harvester	1 day	Mon 12/04/10	Mon 12/04/10	39
48	✓	Operator safety training and SOP manual instruction	3 days	Wed 14/04/10	Fri 16/04/10	
49						
50	✓	**COMMISSIONING: START UP**	2 days	Mon 19/04/10	Tue 20/04/10	48
51						
52	✓	**OPERATIONAL**	67 days	Thu 29/04/10	Sat 31/07/10	
53	✓	Floc trial	5 days	Mon 26/07/10	Fri 30/07/10	
54						
55	✓	**DE COMMISSIONING**	4 days	Sat 31/07/10	Thu 5/08/10	
56	✓	Transport to holding site	3 days	Tue 14/09/10	Wed 15/09/10	
57						
58						
59	✓	**REPORTS**	35 days	Fri 13/08/10	Thu 30/09/10	
60	✓	Draft	24 days	Thu 29/07/10	Tue 31/08/10	
61	✓	Final	12 days	Fri 3/09/10	Mon 20/09/10	
62						
63	✓	**FINANCIAL**	22 days	Wed 1/09/10	Thu 30/09/10	
64	✓	Final accounts to NZTE (project funds finish 3rd Sept)	18 days	Fri 3/09/10	Tue 28/09/10	



Project: PROJECT BOP
Date: Fri 3/12/10

Task	Split	Progress	Milestone ◆	Summary	Project Summary	External Tasks	External Milestone ◆	Deadline ⇩

PROJECT HARVEST EBOP

Appendix 5 – Dilution and flocculant dose rate calculations

1. Flocculent Dose Rate:

Dose solution: 5 kg Floc in 1000L water = 5g/L

Pump dose water into water for treatment @ 50 L/hour,

Max rate of take 35 m^3/hr

Nett Floc dose rate: 5 g/Lx 50 L/hr = 250 g/hr,

Floc conc: 250g into 35 m^3(/hr) = 250/35 = 7.14 g/m^3 (ppm).

2. Receiving Water Flocculent Dilution Rate:

Receiving water dose (assuming worst case: no removal in harvest operation):

35 m^3/hour into 17 m^3/s= 0.0097 m^3/s into 17 m^3/s

= 0.058%

Receiving water conc = 7.14 ppm x 0.058%

= 0.004 ppm

Appendix 6 – Algae end use

The harvested algae (3% solid, 97% water) was collected into two x 1,000 litre IBC plastic tanks on site. A start up composting operation located at Paengaroa, 65 km from the harvesting site, utilised the harvested algae. Two thousand litres of the algae was transferred by small tanker towed by a utility truck every second day from the harvesting to the composting site. The algae material was then sprayed onto composted windrows to provide an essential source of nitrogen with water (composting tea) to enable the composting process to occur. The "compost tea" is applied at a rate of 3 litres/m^3 every two days to the composting rows. This use continues for a period of six weeks in the 9-12 week composting process.

A comparison trial of the compost nutrients using (1) composting tea compared to (2) plain water was completed at the Paengaroa site during May 2010. Primary raw material inputs and management activities for both processes were the same apart from the water based material inputs.

Lab test results from Hill Laboratories indicate the following nutrient differences in the final compost material between the composting tea process and water only liquid applications (Table A6.0).

Table A6.0 Comparative chemical analysis for component differences.

COMPONENT	UNIT	COMPOST + ALGAE WATER	COMPOST + WATER	DIFFERENCE%
Organic Matter	%	44.0	45.1	(2)
Total Carbon	%	25.5	26.1	(2)
Total Nitrogen	%	1.47	1.24	18
C/N Ratio		17.4	21	3.6
Dry Matter	%	36.4	32.9	10
Total Phosphorous	mg/kg	6,280	5,070	24
Total Sulphur	mg/kg	2,990	2,580	16
Total Potassium	mg/kg	12,470	10,470	19
Total Calcium	mg/kg	13,270	10,830	22
Total Magnesium	mg/kg	4,750	3,640	30
Total Sodium	mg/kg	3,980	3,370	18

The laboratory results show significantly increased levels of primary and secondary nutrients available in the compost treated with Algae Water (compost tea) compared to compost treated with water only.

Primary Nutrient Levels: Nitrogen +18% Phosphorous +24% Potassium +19%

Secondary Nutrient Levels: Calcium + 22% Magnesium +30% Sulphur +16%

The capability of compost to form organic matter is a function of the core constituents of animal bedding, manure and urine with water and any available nutrients within an environment that encourages microbial activity. The algae water provides available nutrients for the microbes to make this process happen quickly.

The algal compost material maintained a wetter profile during the earlier stage of the composting process, whereby humidity was not a limiting condition for the microbe activity to occur. Algae are known to retain water as their cell structure slowly breaks down. The outcome of the compost treated with the algae water was a sweeter smelling and a drier compost material when the composting process was completed by week nine. This shows in the higher dry matter content result comparison of 36% cf 33%.

Figure 23 Algae water being applied to a week three compost development wind row.

No comparative growth application studies were possible with this trial; however this would be a worthwhile study to develop some empirical comparative study values around the use of the different compost products in end use trials. This would determine the optimal amount of algal biomass to use in the algae paste (compost tea).

Organic material is composed of two components; residues and humus. Residues include dead parts of plants and animal excreta in all stages of rapid decomposition by microbes. Humus is the dark coloured soil organic matter with a slow decomposition rate compared to residues.

Humus has a high cation exchange capacity (CEC) which is defined as “the capacity of a soil to absorb or hold cations and to exchange species of these ions in reversible chemical reactions”. A high CEC soil has the ability to hold and retain minerals within the root zone to allow plant growth to occur over time. This ability reduces the incidence of minerals leaching out of the root zone and into the ground water where they potentially become a pollutant.

Compost has the ability to form humus quickly when incorporated into the soil. Since humus has a high CEC capability it holds minerals and allows microbes to operate in the soil structure. Algae water in this environment is contributing much more than just NPK as a comparative fertiliser for plant growth. Algae water is contributing nutrients, moisture and microbes into the soil to support the development of humus, which is regarded as the “health and wealth” of soil.