THE USE OF VETIVER GRASS FOR SEWERAGE TREATMENT

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Abstract: The Esk Shire Council has recently installed a Vetiver Grass System to treat sewerage effluent at Toogoolawah in South East Queensland.

The aim of this scheme was to improve water quality before the effluent discharges to the natural wetlands. The biggest problem with the quality of the effluent is its high nutrient loading. With the recent changes to license conditions imposed by the Environmental Protection Agency, the existing treatment plant no longer complies with the license and an upgrade of the plant was required.

Instead of traditional upgrades, a new and innovative phyto-remedial technology recently developed in Queensland by the Department of Natural Resources and Mines, is being implemented at Toogoolawah. Under the Vetiver System, the effluent is being treated in two stages:

- Preliminary treatment of the pond effluent *in situ* by floating pontoons placed in the ponds, and by vetiver planting around the edges of the three sewerage ponds.
- Main treatment by vetiver wetlands, once the effluent exits the sewerage ponds it passes through a Vetiver Grass contoured wetlands. The Vetiver Grass takes up the water and in particular the grass will remove the nutrients from the water that passes through it.

As vetiver grass system is very effective in removing nutrient loads, it is expected that once the wetlands is properly established there should be no release of sewerage effluent from the treatment plant except in times of heavy rainfall.

This scheme will provide a large-scale prototype of possible sewerage treatment schemes that can be used throughout western Queensland and other locations where there is plenty of land and where the local government does not want to pay for installing and operating high cost solutions.

1.0 INTRODUCTION

1.1 The Esk Shire

The Esk Shire is situated on the north-western edge of Brisbane and covers an area of about 3,946 square kilometres. However the population of the shire is only about 14,800 people and this is scattered over most of the shire. The shire is 125 kilometres long (running north/south) and 70 kilometres wide. There are several small towns in the shire and these are difficult to service with town sewerage as they are also scattered up and down the shire.

1.2 Toogoolawah

The town of Toogoolawah is situated right in the centre of the shire. The town has a population of approximately 1,300 persons and provides the local people with a quiet rural lifestyle close to Brisbane.

2.0 THE PROJECT

2.1 Toogoolawah Sewerage Plant

The sewerage scheme for Toogoolawah was built in 1970 and the treatment plant was constructed as a primary sedimentation (Imhoff Tank) followed by three sewerage ponds. The effluent from the ponds was designed to flow down into a swamp area before it overflowed into the local creek. The plant construction was based on a very simple design but it is effective. With the recent changes to license conditions imposed by the Environmental Protection Agency (EPA) the plant no longer complies with the license and so an upgrade of the plant was required. Various options were considered such as a nutrient removal plant, a sand filter or a rock filter. These are expensive options and would require expensive ongoing operational costs. Council then considered a Vetiver Grass treatment system that would take up most of the water, as well as remove nutrients and heavy metals etc. from the sewerage effluent. The required land had already been purchased and so there was ample room for the vetiver grass planting.

2.2 License Limit

The main problem with the existing sewerage effluent was that while passing through the three ponds the nutrients were providing an environment for the production of high concentrations of algae. These in turn made the pH rise from 7.5 up 9.2 or higher, the license limit is 8.5. Also the suspended solid counts did not improve (about 85 mg/L) due mainly to the algae counts. The suspended solid license limit is 30 mg/L. The BOD reading does improve through the ponds reducing from 120 mg/L to 29 mg/L. This is close to the license limit of 20 mg/L. The high suspended solids counts are also a cause of high Faecal Coliform counts that occur once or twice a year. Reading over 6,000 organisms per 100 ml are recorded while the license limit is 1,000 organisms per 100 ml.

3.0 VETIVER SYSTEM

3.1 Introduction

Application of the Vetiver System (VS) for wastewater treatment is a new and innovative phytoremedial technology recently developed in Queensland by the Department of Natural Resources and Mines, NRM, (Truong and Hart, 2001). It is a green and environmentally friendly wastewater treatment technology as well as a natural recycling method. Its end-product has several uses including animal fodder and material for organic farming.

3.2 Vetiver Grass

VS is based on the use of vetiver grass (*Vetiveria zizanioides* L.), which was first recognised early in the 1990s for having a "super absorbent" characteristics suitable for the treatment of wastewater and leachate generated from landfill in Queensland (Truong and Stone, 1996). Research conducted by NRM showed that Monto vetiver grass has a fast and very high capacity for absorption of nutrients, particularly nitrogen and phosphorus in wastewater. In addition it has a very high water use rate and tolerant to elevated levels of agrochemicals and heavy metals in the effluent (Cull *et al*. 2000; Truong and Baker, 1998). As a result of these findings, presently VS has been used successfully for these purposes in Australia, China, Thailand, Vietnam and Senegal (Truong and Hart, 2001; Truong, 2000).

3.3 Early Australian Research Results

In 1995 an environmental consultant was looking for a fast growing plant for both erosion control as well as wastewater disposal at a holiday camp on the shore of a lake Somerset. Secondary treated effluent was used to irrigate lawns and garden beds around the campsite. To ensure no surface or underground leaching reaching the lake, a very deep-rooted plant with high water use capacity was required. At this initial trial eight rows of vetiver were planted on a cut slope where the soil was very poor, to both stabilise the steep slope and to absorb runoff from irrigation.

The result was excellent as the first three rows of vetiver absorbed all the runoff, which previously ran down the slope. The absorption was so complete that while the first three rows had luxuriant growth, reaching almost 2m in eight months, the next five rows down the slope were less than 1m tall showing nutrient deficiency symptoms (Fig.1). This treatment has been very effective and stable in the last six years, the only management practice required is to cut and remove the top growth two or three times a year.

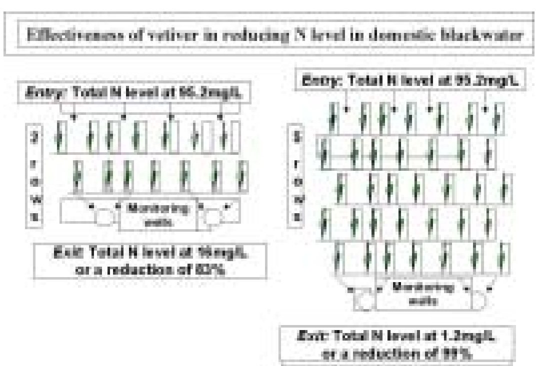
Figure 1: The first 3 rows of vetiver (R) absorbed most of the effluent at camp Somerset, Esk Shire.

In 1998 a demonstration site was set up at the Beelarong Community Farm at Morningside, Brisbane to obtain quantitative data on the effect of VS in improving its quality under field conditions and also in reducing the volume of effluent. In this NRM and EPA funded project, VS was used to treat the discharge from a septic system. Vetiver grass was selected after the failure of other plants including a variety of fast growing tropical grasses and trees, and crops such as sugar cane and banana to absorb the effluent discharge from the septic tank. After five-month growth, vetiver was more than 2m tall and a stand of about 100 vetiver plants in an area less than $50m^2$ have completely dried up the effluent discharge (Fig.2).

Groundwater monitoring (collected at 2m depth) showed that after passing through 5 rows of vetiver the levels of total N reduced by 99% (from 93 to 0.7 mg/L), total P by 85% (from 1.3 to 0.2 mg/L), and faecal coliforms by 95% (from 500 to 23 organisms/100mL), (Truong and Hart, 2001) (Fig.2). These levels are well below the following thresholds set out in ARMCANZ and ANZECC (1997):

- Total Nitrogen <10 mg/L
- Total Phosphorus <1 mg/L
- *E. coli* <100 organisms/100mL

Figure 2: Effectiveness of VS in treating domestic effluent in Morningside, Brisbane



3.4 Recent Australian Research Results

Due to these remarkable results, NRM in collaboration with a number of private companies initiated an extensive R&D to determine the effectiveness of vetiver grass under field conditions and to develop appropriate technology in treating industrial wastewater (Truong and Smeal, 2003).

Figures 3 and 4 clearly demonstrated that vetiver grass has a much higher capacity to absorb N and P than the subtropical pasture grasses commonly used for land irrigation disposal of effluent (Smeal *et al.* 2003).

Figure 3: Vetiver has a much higher capacity to uptake N than other crops and tree

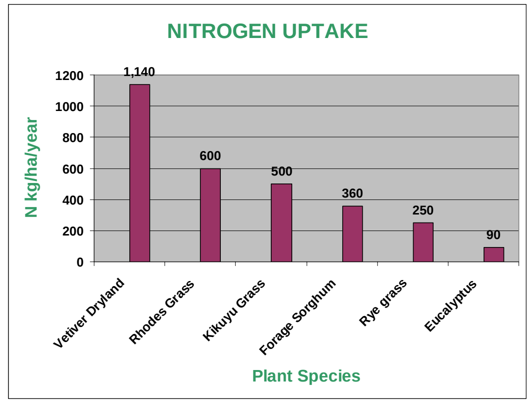
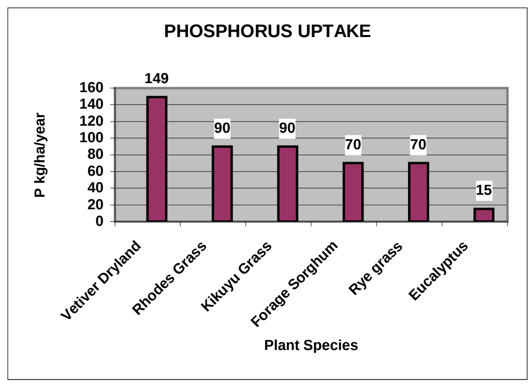


Figure 4: Vetiver has a much higher capacity to uptake P than other crops and tree



Hart *et al.* (2003) also demonstrated that under hydroponics conditions, vetiver grass was even more effective in removing nutrient loads in sewage effluent (Table 1).

3.5 Overseas Research Results

Extensive R&D on wastewater treatment has also been conducted in several countries, particularly China and Thailand. In China vetiver grass is being used to treat polluted river water in central China. The removal percentage of total P was 93.7% after 2 weeks and more than 99% after 3 weeks. The removal percentage of total N was 58% after 2 weeks, and 71% after 4 weeks. Phosphorous is usually considered to be a key element in water eutrophication (Anon 1997; Zheng *et al*, 1997).

Thai researchers carried out a 'constructed wetland' experiment to purify domestic wastewater. It was found that in the first system with five-day standing and two-day dry period, a total volume of wastewater passed through the system was 33.1m^3/day. The second system with overflow wastewater with one-day standing water in the wetland, the total treated amount of wastewater was 59.99 m^3/day. (Truong 2003).

Mongkon Ta-oun *et al*. (2003) studied the effect of wetland depth (5, 10, and 15 cm) and flow length (3, 6, and 9m) on the growth of two vetiver varieties and their effectiveness in treating wastewater. Their results show that BOD values at water levels of 5 and 10 cm. were lower than those of 15 cm for all varieties and DO varied from 3-7 mg/L depending on the length of time. When comparing different distances of flow, the results show that the BOD decreased when the distance increased. DO increased when the time increased but at a smaller value when measured with deeper water levels from 5, 10 and 15 centimetres.

Table 1: Vetiver has very high N and P under hydroponics conditions

Plant species	Nitrogen (kg/ha/year)	Phosphorus (kg/ha/year)
Vetiver hydroponic	13,688	1,026
Vetiver pot trials	2,040	153
Vetiver field trial	1,142	149
Rhodes grass	600	90
Kikuyu	500	90
Green Panic	430	70
Forage sorghum	360	70
Bermuda grass	280	30-35
Eucalypts trees	90	15
Rye grass	200-280	60-80
Wheat (6)	23-208	3-27

4.0 CALIBRATION OF VETIVER GRASS FOR THE MEDLI MODEL

MEDLI (Model for Effluent Disposal by Land Irrigation) is a computer model developed by DPI and NRM. QEPA has adopted MEDLI for the management of Queensland industrial wastewater including sewerage effluent.

To date the application of MEDLI in tropical and subtropical Australia has been restricted to a number of tropical and subtropical crops and pasture grasses, which have been specially calibrated for MEDLI use. Due to its extraordinary capacity for nutrient uptake, particularly N and P and its enormous potential for effluent irrigation schemes, vetiver grass has recently been calibrated for MEDLI application (Vieritz *et al.* 2003).

MEDLI model simulation, using the new data set has shown that VS is much more efficient in treating wastewater than other grasses currently used for this purpose in Queensland. For example, at an abattoir near Brisbane, MEDLI model predicted that to sustainably dispose of 2ML of effluent (155mg/L of N and 15mg/L of P) per day, the abattoir would need 178ha of land if Kikuyu grass was used, but only 87.6ha would be needed when vetiver grass was used. This land area could be further reduced if the effluent was treated with VS first before irrigation.

5.0 AUSTRALIAN PROJECTS

Currently Veticon Consulting is using VS to treat several wastewater projects in New South Wales: Lithgow City Council, Lake Macquarie City Council, Armidale City Council, Tweed Shire Council (Percy and Truong, 2003) and Grafton City Council (Hart *et al*. 2003), and in Queensland: Redland shire Council (Truong and Stone, 1996), Esk Shire Council (Ash and Truong, 2003), Murilla Shire Council.

Teys Bros. Pty Ltd Abattoir in Beenleigh and Gelita Australia Pty Ltd in Beaudesert have engaged Veticon Consulting to develop a VS suitable to treat large volume of highly concentrated wastewater discharge from these factories (Smeal *et al*. 2003).

At Teys Bros. Abattoir, vetiver planting has reduced N level from 130mg/L to 17.5 and 10.6mg/L after 20 and 50m downslope respectively (Table 2).

Table 2:

Effectiveness of vetiver planting on quality of effluent seepage

Analytes	Nutrient levels		
	Inlet	Mean levels in monitoring bores	
		20m down slope from inlet	50m down slope from inlet
pH	8.0	6.5	6.3
EC (uS/cm)	2200	1900	1600
Total Kjel. N (mg/L)	130	11.0	10.0
Total N (mg/L)	130	17.5	10.6
Total P (mg/L)	32	3.4	1.9

At Gelita Australia in Beaudesert, large scale planting of vetiver is in progress to treat the entire gelatine factory wastewater out put of 1.3Ml/day (Fig.5).

Fig.5: Vetiver grass grazing trial at Gelita wastewater disposal area

6.0 TREATMENT PROCESS CHOSEN FOR TOOGOOLAWAH

6.1 MEDLI Model Simulation

For the Toogoolawah sewage treatment plant, the MEDLI model simulation predicted that less than 3ha of land is needed to treat the entire effluent output to comply with EPA licensing conditions. The primary treated effluent previously being discharged from the Toogoolawah had the following characteristics:

- Daily output 0.3 ML
- Nitrogen concentration at 13 mg/L
- Phosphorus level of 5.5 mg/L

However if the effluent is pre-treated in the ponds to reduce N and P concentrations by approximately 10% before releasing into the vetiver plots, the land area needed would be less than 1.5ha

6.2 Treatment Program

A two-phase treatment program was adopted:

- Phase 1: Preliminary treatment in the ponds.
- Phase 2: Main treatment by vetiver wetlands.

6.2.1 Phase 1: Preliminary treatment of effluent in the ponds

Floating pontoons have been used successfully to treat piggery effluent ponds in Vietnam (Fig.6), and also recently at the Teys Bros. abattoir in Queensland, where both N and P levels in the pond leachate were sufficiently reduced to eliminate the blue-green algae infestation. The effluent in the three ponds at Toogoolawah is first treated hydroponically by the vetiver pontoons, which are able to reduce N and particularly P loading of the effluent before releasing it to the wetlands. Preliminary trial indicated that vetiver grass can be established and grew vigorously on pontoons in Toogoolawah ponds (Fig.7).

Fig.6: Vetiver pontoons treating a piggery effluent pond in Vietnam

The 21 floating pontoons were designed so vetiver plants sitting on the pontoons and the roots suspending in the effluent. The size of each pontoon is 2.4m x 2.4m with about 300 individual plants placed on each pontoon. The number of pontoons required will depend on the level of nutrient load. The number of pontoons can be increased later to ensure an effective treatment process was achieved. Maintenance program will include replacement of dead plants, regular harvest to encourage new growth and the export of absorbed nutrients.

In addition, vetiver is being planted at the high water level around the ponds to further reduce the nutrient loading and also to stabilise the pond banks.

Fig.7: Excellent growth (1.5m) after 5 months in an effluent pond at Toogoolawah

6.2.2 Phase 2: Main treatment Vetiver Grass Wetlands

After being treated hydroponically in the 3-pond system, effluent is released by intermittent irrigation to the main vetiver grass wetlands areas.

For the wetlands, Vetiver grass was planted in rows on approximate contour lines to spread the flood-irrigated effluent, trapping sediment, slowing down flow velocity during storms and increasing infiltration. The interval between main rows is at about 12 metres. In between the main rows of vetiver grass there was also planted extra rows to increase the amount of grass in the wetlands. This meant the final spacing between rows was 3 metres.

Following full establishment, the gaps between plants were closed and the rows began to act to slow down the flow of the effluent and trap the sediment and extract the nutrients.

Two separate areas have been planted and each area is fed with effluent from the treatment ponds by its own pipeline. This means that both areas can be operated at the same time, or one of them can be taken off line and dried out so that maintenance work can be undertaken on the grass in that area.

Vetiver planting density*:*

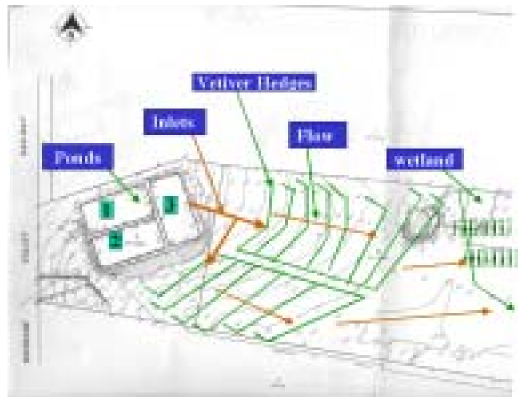
- Planting density of contour rows was approximately 10plants/linear metre.
- Inter-row spaces were planted in rows of approximate 8plants/linear metre.

Average planting density is 3 plants/m^2

6.3 Monitoring Program

In conjunction with the treatment program, monitoring of both surface and sub-surface flows is also being carried out to ensure adequate treatment and to provide data for the site management such as quantity and frequency of irrigation schedule during summer and winter; and wet and dry periods. Groundwater monitoring wells have been installed at strategic points and are being sampled when they are available. Surface water monitoring is undertaken at the inlet to the plant, at the outlet of the Imhoff tank and lagoons, at the outlet of the Vetiver Grass wetlands and finally at the discharge into the local creek. Four monitoring wells have been installed to monitor the quality of groundwater. These are located on the downstream side of the treatment area. The sampling at the outlet of the vetiver grass wetlands monitors the exit levels of N and P.

Figure 8: A general outline of the treatment area.



7.0 IMPLEMENTATION

The wetlands were constructed over a six-month period. The work consisted of the following stages:

7.1 Site Clearing

The site chosen for the wetlands is on a 16.5 ha block of land to the east of the Toogoolawah Sewerage Treatment Plant. About 8 ha of the site are being used for the wetlands. The site was firstly cleared of all trees and bushes. Care was taken to remove all large root systems.

7.2 Ground Preparation

The site was broken up into two areas with a road down the middle. An access road was constructed around the northern side. About 60% of the areas to be planted were prepared. Firstly the ground was sprayed with Roundup herbicide to kill the existing vegetation. The ground was then rotary hoed and then sprayed again to eliminate all potential weeds.

7.3 Survey

Using a laser level contour rows were pegged out across the slope for each area. These rows were about 12 metres apart with a fall of 200 mm between each row. Trenches were then dug along each row.

7.4 Grass Planting

Two types of fertilizer were placed in each row. This included DAP and Muriate of Potash at a rate of 300kg per hectare for both. The grass was delivered in clumps with about fifty plants in each clump. The grass was planted along the rows about 100 mm between each plant. Watering of the plants started immediately after each day of planting. In some cases channels were dug to each row to ensure that water got to every plant.

Within each bay further single or double rows were planted about 3 metres apart. The main aim of watering was not to flood the plants for too long. The best results were obtained when the grass was given a good watering and then was given time to dry out. Planting started in early February 2003 and was substantially completed by the end of May. In total about 25,000 Vetiver Grass plants have been placed in the wetlands so far.

7.5 Pipeline Construction

To feed the sewerage effluent to the wetlands a new outlet chamber and pipeline from the sewerage ponds were constructed. This is a gravity feed system and the 150mm pipeline can deliver about 15 L/sec or about 5 times the average dry weather flows to either area or to both areas at the same time. Valves have been installed to direct water to either or both areas.

7.6 Floating Pontoons and Ponds

As already described, 21 floating pontoons have been placed on the ponds to improve their water quality. Advanced plants were first established in pots before they are placed onto the pontoons. About 300 potted plants are placed onto each pontoon. To remove the nutrients further vetiver grass was planted around the edge of the lagoons. About 6,000 plants have been used in the pontoons and the same amount was planted around the lagoons.

7.7 Maintenance of Weeds

Herbicides have not been used since the initial clearing of the site the weed growth has also been vigorous. To overcome this a ride on mower has been used to keep the weeds down between the rows of vetiver grass and a Wiper Snipper was used to cut the weeds up close to the rows of grass.

7.8 Nursery

Because there was not enough staff to undertake the planting quickly a small shaded nursery was constructed on site to keep the plants alive during planting and to produce potted plants for the floating pontoons. Whenever the operator of the sewerage treatment plant turns on the effluent reticulation for washing the sides of the Imhoff tank the plants in the nursery are watered automatically. This nursery has proven to be very worthwhile and has been a great help in enabling the project to succeed.

8.0 RESULTS OF THE SCHEME SO FAR

8.1 Vetiver Grass Pontoons

Results of a preliminary trial conducted on site with the first 3 pontoons, show that vetiver established and flourished (up to 1.5m in 3 months) under hydroponic conditions of all three ponds. These pontoons have been removed and the grass harvested to produce about 5 new tillers of grass from each original tiller placed on the pontoons. The pontoons have now become the source of Vetiver grass for the project. Vigorous growth has been seen in the vetiver grass plants that were placed onto the 21 new pontoons (Fig.9) and 2 months later (Fig.10).

8.2 Growth on the Pond edges

Planting vetiver just above the pond supply level is the second part of the plan to pre-treat the effluent in the ponds. At this position the extensive vetiver roots has full access to the high nutrient load of the pond effluent (Fig.11 &12).

Fig.9: New pontoons in March 2003

Fig.10: Two months later.

For the wetlands, the growth of the vetiver grass has been varied for the first three months. Where the grass was able to dry out between watering the growth was good. In places where the water lay around the grass the growth was poor. Growth was much reduced during winter and frost only burnt some of leaf tips of young plants.

Fig.11: Vigorous growth 8 months after planting

Fig.12: In wet weather effluent level often submerged part of the plant

Fig.13: Wetland, one month after planting

8.3 Ten months Growth in the Wetlands

Good growth resumed in spring and continued to grow vigorously in early summer. On the Open Day in early February 2004, most plants were at least 1.5m tall (Fig 14).

Fig.14: Ten month old vetiver in the wetland

8.4 Irrigation Schedule

At this early stage, best vetiver growth is obtained when the wetland is irrigated on a 4-day cycle, one wet day and three dry days. When the plants are fully mature and more vetiver grass is planted in the bay, it is expected that a 2-day cycle will be possible.

8.5 Water Quality

Even at this early stage, there is already evidence that the quality of the effluent is improving in respect to nutrient loads. The total Phosphorous level for the plant influent varies between 10 – 20 mg/L and the effluent results have dropped to between 1– 3 mg/L. Similarly the total N influent results are 30–80 mg/L and the effluent results are now 4–6 mg/L. Further details are given in Table 3.

Table 3. Effluent quality levels before and after vetiver treatment

Tests	Plant Influent	Previous Results 2002/03	New Results (Effluent) 2004
PH (6.5 to 8.5)	7.3 to 8.0	9.0 to 10.0	7.6 to 9.2
Dissolved Oxygen (2.0 minimum)	0 to 2 mg/l	12.5 to 20 mg/l	8.1 to 9.2 mg/l
5 Day BOD (20 - 40 mg/l max)	130 to 300 mg/l	29 to 70 mg/l	7 to 11 mg/l
Suspended Solids (30 - 60 mg/l max)	200 to 500 mg/l	45 to 140 mg/l	11 to 16 mg/l
Total Nitrogen (6.0 mg/l max) *	30 to 80 mg/l	13 to 20 mg/l	4.1 to 5.7 mg/l
Total Phosphorous (3.0 mg/l max) *	10 to 20 mg/l	4.6 to 8.8 mg/l	1.4 to 3.3 mg/l

* Licence requirements. (N and P levels are possible future requirements)

It is expected it will take a further 12 months of growth before the wetland grass is properly established. However the results so far already show that the Vetiver Grass wetlands can improve the effluent quality to the same quality as a high tech BNR sewerage treatment plant.

9. COST COMPARISON

The final budget for this project was as follows:

Final Cost Estimate

Clearing / site works	$12,000
Diversion Channels / Pipelines	$8,000
Lagoon outlet	$3,000
Vetiver grass plants 40 000 @ $0.70	$28,000
Planting of Vetiver grass	$19,000
Monitoring wells	$5,000
Herbicides and fertilisers	$500
Land	$65,000
Pontoons 20 at $1,200	$24,000
Consultancy Reports	$7,000
Supervision	$10,500
Nursery	$18,000
Total	**$200,000**

Other options considered were:

- Rock Filter estimate cost $250,000
- Sand Filter (alum dosing) $450,000
- BNR Plant Upgrade $1,500,000

10. CONCLUSION

The Vetiver Grass wetland has already shown itself to be a suitable alternative to more expensive solutions to upgrade existing sewerage treatment plants. A high technology solution is not necessarily the best available option.

11. REFERENCES

Anon. 1997. A consideration and preliminary test of using vetiver for water ultrophication control in Taihu Lake in China. Proc. Environmental group, Institute of Soil Science, Academia Sinica, Nanjing. Proc. International Vetiver Workshop, Fuzhou, China October 1997.

Ash R. and Truong, P. (2003). The Use of Vetiver Grass Wetland for Sewerage Treatment in Australia. Third International Vetiver Conference, Guangzhou, China, October 2003

ARMCANZ 1997. (Agriculture and Resource Management Council of Australia and New Zealand) and ANZECC (Australian and New Zealand Environment and Conservation Council) Australian Guidelines for Sewerage Systems Effluent Management – National Water Quality Management Strategy, Canberra, Australia.

Cull R.H, Hunter H, Hunter M and Truong P. 2 000. Application of Vetiver Grass Technology in off-site pollution control. II. Tolerance of vetiver grass towards high levels of herbicides under wetland conditions. Proc. Second Intern. Vetiver Conf. Thailand.

Hart B, Cody R and Truong P. 2003. Efficacy of Vetiver Grass in the Hydroponic Treatment of Post Septic Tank Effluent. Third International Conference on Vetiver, Guangzhou, China.

Mongkon T., Patcharee T., Santibhab P. and Suttipong P. (2003). Vetiver Grass Research: Primary Management of Wastewater from Community Proc. Third International Conference

Percy I, and Truong, P. 2003. Landfill Leachate Disposal with Irrigated Vetiver Grass. Proc. Third International Conference on Vetiver, Guangzhou, China.

Smeal C, Hackett M and Truong P. 2003. Vetiver System for Industrial Wastewater Treatment in Queensland, Australia. Third International Conference on Vetiver, Guangzhou, China.

Truong P. 2000. The Global Impact of Vetiver Grass Technology on the Environment. Proc. Second International Conference on Vetiver. Thailand.

Truong P. (2003). Clean Water Shortage, an Imminent Global Crisis. How Vetiver System can Reduce its Impact. Third International Conference on Vetiver, Guangzhou, China.

Truong P, and Stone R.1996. Vetiver grass for landfill rehabilitation: Erosion and leachate control. Report to DNR and Redland Shire Council, Queensland, Australia.

Truong P, and Baker D. 1998. Vetiver Grass System for Environmental Protection. Technical Bulletin N0. 1998/1. Pacific Rim Vetiver Network. Office of the Royal Development Projects Board, Bangkok, Thailand.

Truong P, and Hart B, 2001. Vetiver System for Wastewater Treatment. Technical Bulletin no. 2001/21. Pacific Rim Vetiver Network. Office of the Royal Development Projects Board, Bangkok, Thailand.

Truong, P. and Smeal (2003). Research, Development and Implementation of Vetiver System for Wastewater Treatment: GELITA Australia. Technical Bulletin No. 2003/3. Pacific Rim Vetiver Network. Office of the Royal Development Projects Board, Bangkok, Thailand.

Vieritz A, Truong P, Gardner T and Smeal C. 2003. Modelling Monto vetiver growth and nutrient uptake for effluent irrigation schemes. Proc. Third International Conference on Vetiver, Guangzhou, China.

Zheng C, Tu C, and Chen H. 1997. Preliminary study on purification of eutrophic water with vetiver. Proc. International Vetiver Workshop, Fuzhou, China October.