report

Masterton Land Treatment of Wastewater

Prepared for Masterton District Council

By Beca Carter Hollings & Ferner Ltd (Beca)

May 2008

Revision History

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A	David Heiler and Humphrey Archer	Draft for review by T Webb, N Borrie and J Harding	23/4/08
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Document Acceptance

Action	Name	Signed	Date
Prepared by	David Heiler	D Heiler	16/5/08.
Reviewed by	Trevor Webb, Landcare Research	Trevor Webb	16/5/08
Reviewed by	Neal Borrie, Aqualinc	D.N Borrie	16/5/08
Reviewed by	John Harding, Peer Reviewer	J Harding	15/5/08
Approved by	Humphrey Archer	H Archer	16/5/08
on behalf of	Beca Carter Hollings & Ferner Ltd		

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Appendices

1 Introduction

Mr Stuart Forbes (leaseholder of the Homebush property) has proposed to the Masterton District Council that a centre pivot spray irrigation system be used to apply treated wastewater to land at Homebush, instead of the border strip irrigation system currently proposed in the consent application.

In his letter to Mayor Garry Daniel dated 29 November 2007, Mr Forbes proposed a scheme containing 10 centre pivots covering a total of 84 ha over the combined 91 ha and 107 ha sites, with the balance of land irrigated by fresh water irrigation (refer to Figure 1). He suggested that the use of centre pivot irrigation with wastewater would allow "*revenue earning ability off cropping".*

An associated submission from Hassall & Associates Pty Ltd was received by Mayor Daniel on 17 February 2008, via an email from Cr David Holmes. This submission advocates the use of centre pivot irrigation and is based on treated wastewater irrigation schemes in Australia.

The response to the centre pivot irrigation proposals is prefaced by the context of the total wastewater disposal scheme. The border strip irrigation method is then compared with the centre pivot method and the reasons are stated why the border strip method is recommended for the proposed wastewater land treatment scheme.

This response was prepared after discussion with, and with inputs by, Trevor Webb, Soil Scientist, Landcare Research and Neal Borrie, Irrigation Engineer, Aqualinc. Both advisors have extensive experience of the design and operation of effluent irrigation schemes under New Zealand conditions. John Harding, the overall scheme Peer Reviewer for Masterton District Council, also reviewed the draft report.

The cover photos are:

- Left – bubble-up valve discharging pond effluent to border strips at the Leeston WWTP (near Lincoln University, Cantebury)
- Right – typical centre pivot irrigator with low pressure sprinklers on droppers.

Figure 1 – Forbes Proposal for Ten Centre Pivots Covering 84ha (as supplied by S Forbes)

2 Summary of Proposed Wastewater Treatment and Disposal Upgrading

2.1 Key Elements of Proposed Upgrading

The main features and benefits of the proposed wastewater treatment and disposal upgrading, are summarised here for convenience (from sections 3.3 and 10.4.1 AEE, May 2007).

The upgrading comprises the following key elements:

- The construction and operation of additional maturation ponds-in-series which will significantly improve microbiological quality of the effluent.
- Construction of a land treatment disposal scheme north and west of the ponds to irrigate effluent to land whenever soil conditions allow.
- No discharge of effluent to the river at flows below median flow in the Ruamahanga River (from 1 November to 30 April) and below half median flow in the Ruamahanga River in winter (from 1 May to 31 October).
- Whenever there is a discharge to the Ruamahanga River, the ratio of river flow to effluent discharge will be a minimum of 30:1.
- New effluent discharge point in the Ruamahanga River with an outfall diffuser.

2.2 Key Improvements Resulting from Proposed Upgrading

The key improvements that will result from the proposed upgrading are as follows:

- Improved effluent quality with regard to bacteria and pathogens as a result of the installation of maturation ponds
- Maximisation of land treatment system, and minimisation of direct discharge to the river
- The new discharge location will result in improved faster mixing which, combined with the intermittent nature of the discharge, will result in full mixing well upstream of Wardells Bridge and a significant improvement in aesthetic impacts and reduction in health risk
- There will be no discharge of effluent directly to the Makoura Stream, with a subsequently significant improvement of water quality in the lower reaches of that stream.
- No discharge of treated wastewater to the Ruamahanga River when river flow is below median flow (≤12.3 m3/s) in summer (1 November – 30 April) or below half median flow (≤6.2 m3/s) in winter (1 May – 31 October).

Overall, the treatment, and disposal regime and associated upgrades:

- Will result in significant environmental improvements over the existing discharge
- Removes the direct discharge from the river at the times and flows when the river is most sensitive, most valued and most used
- Will allow the Masterton community to ensure that its wastewater can continue to be safety disposed of into the long term
- Will ensure that the discharges will have no more than minor adverse effects on the environment and will not compromise public health or aquatic ecosystems
- Will improve the quality of the water in the Ruamahanga River during the most sensitive periods in terms of ecological, social and cultural values and use
- Will not adversely effect the long term sustainability of the soils
- Will not adversely affect the quality of groundwater
- Addresses the issues raised in consultation with the community, and
- Is consistent with the objectives and policies of the relevant regional and district plans
- Is a sound and affordable long term solution for Masterton
- Involves known technology and best utilises the existing infrastructure

In order to achieve the above improvements, the discharge of effluent to land will need to be the maximum that soil conditions will allow - far greater than required for normal crop water requirements on a deficit irrigation basis – refer to Section 3 of this report.

2.3 Council Decisions

The principle of maximising discharge to land, was adopted by MDC at the 24 November 2004 meeting which accepted briefing material presented on 15 November and the Beca Issues and Options Report also dated 15 November 2004. The proposed application rates of wastewater to land were included in Council report number 167/05, by a reference to Section 4.3.2 in the Beca Summary Report – Recommended Scheme. At a Special Meeting held on 27 June 2005, Council adopted the Recommended Scheme as described in the Beca Summary Report – refer to Resolutions D and E.

2.4 Storage in Ponds

The storage capacity of the upgraded pond system is an important aspect of the operation of the treatment and discharge regime, as –

- The land cannot take all of the daily wastewater volume in summer and the excess wastewater must be stored in the ponds until it can be irrigated to land or, when in-river conditions are met, discharged to the river; and
- Land application can be interrupted by wet weather, and therefore the wastewater would need to be stored in the ponds until it can be applied to land or discharged to the river (again, only when in-river conditions are met).

Due to these factors, as well as variable influent rates, the discharge to land and river regime will therefore result in variable water levels within the ponds. The proposed discharge regime requires a storage volume above minimum pond operating level upto 275,000 m^3, until application to land and/or discharge to the river is possible.

2.5 Full Time Discharge to Land

As outlined in AEE Section 10.4.1, an irrigation area of 340 ha would be needed to handle average winter flows. Major wet weather flow events could not be applied to the 340 ha and discharge to river would be required. For all wastewater to be discharged to land, an area in excess of 800 ha would be needed.

2.6 Proposed Land Treatment Area

The two properties purchased by MDC at Homebush have a gross total area of 91 ha + 107 ha = 198 ha. When ponds and unusable areas are subtracted, the existing pasture area that can be utilised for land treatment of pond effluent is approximately 127 ha. It is proposed to use 75 ha of existing pasture initially with potential to use a further 52 ha, if required in the future. The future 52 ha area is on the western side of the 107ha property which has poorly drained soils with high water table, and application only in summer is likely to be feasible (refer to Fig 2).

Following investigations in 2008, it is now proposed to develop pasture in the area of the existing ponds when these have been drained, desludged and re-graded using fill from the existing pond banks. Topsoil from the new ponds area will be spread over this area. A further 22 ha of pasture will be developed in the existing pond area. Thus the proposed total area of wastewater treatment by application to pasture, initially will be 75 ha + 22 ha = 97 ha.

Because the 97 ha is well short of the 340 ha and 800 ha needed for winter or full time disposal to land (as in section 2.4 above), there will be discharges to the river according to the discharge rules outlined in section 2.2. In order to minimise the discharge to river and to keep within the 275,000 m^3 storage provided, relatively high volumes will need to be disposed to land.

2.7 Cut and Carry Pasture

A key aspect of the proposed wastewater land treatment scheme is that nutrients (especially nitrogen and phosphorus) will be removed from the Homebush property in the form of a “cut and carry” method such as baleage. If the pasture was not removed from the property and was grazed by stock, the nutrients would be recycled and would be leached from the soil into groundwater and enter the Ruamahanga River causing undesirable growths of periphyton during low flow periods. A further reason for having no stock on the property, is avoidance of pugging which restricts the soils infiltration capacity. Refer also to section 3.3 for discussion of pasture harvesting.

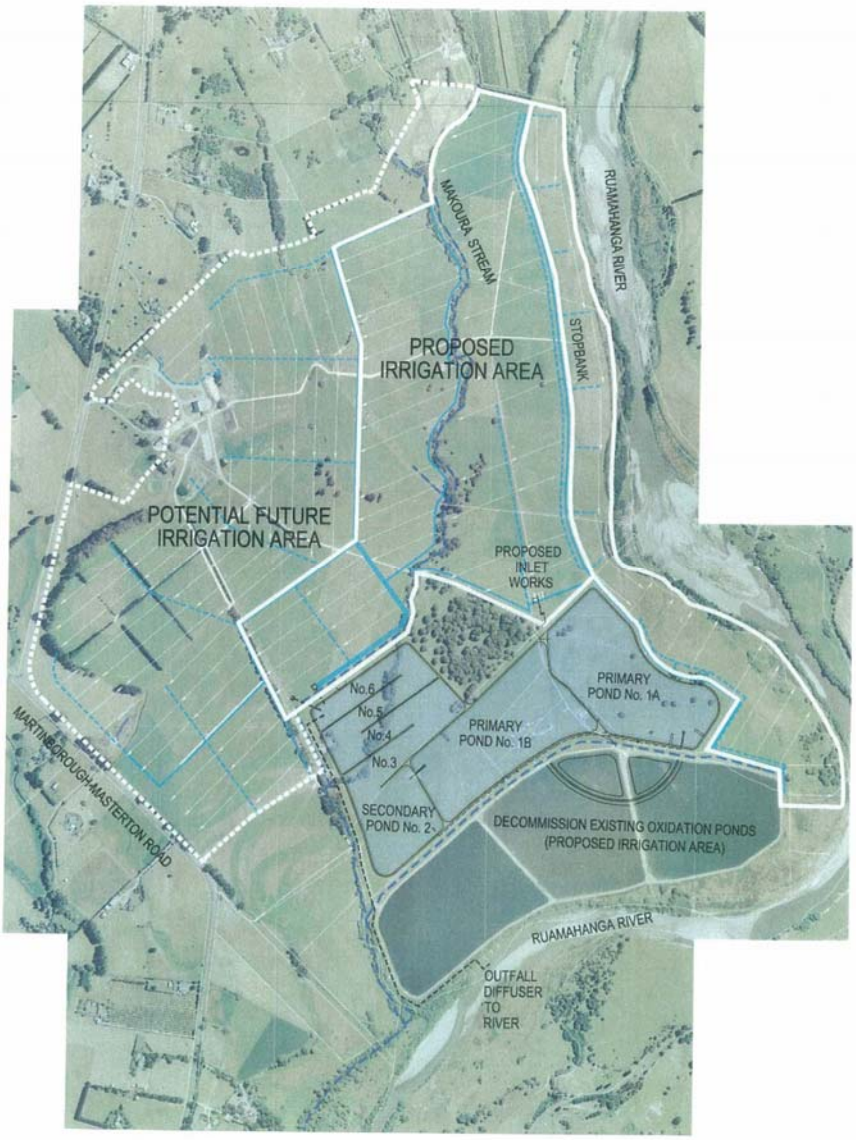

Figure 2 – Land Treatment Areas Proposed for 2008 AEE

3 Analysis of Forbes and Hassall Proposals

3.1 Overview

It appears that the Forbes and Hassall proposals are based on the objectives of maximising returns from crops. This section discusses the differences between:

- Normal farming use of irrigation to satisfy soil moisture deficits and to maximise crop returns, and
- Land treatment of wastewater which applies the maximum possible quantities that soil conditions will allow, thereby minimising the residual volume which has to be stored, or be discharged to the river.

3.2 Differences between Fresh Water and Treated Wastewater Irrigation

Forbes proposal is to irrigate land with pond treated effluent to maximise crop yields. This would imply that the irrigation requirement would be met by applying pond treated effluent in volumes similar to that required for normal fresh water irrigation. Applying excess treated effluent would likely result in reduced yields of the higher value crops. On this basis, the volume of treated effluent that can be applied to the 84 ha proposed by Forbes, is the estimated moisture deficit plus a 20% margin for application inefficiencies. The moisture deficit has been estimated by HortResearch using its SPASMO model.

Table 1 compares the proportion of wastewater inflow that can be applied to 84ha of land planted in pasture and irrigated by centre pivot on a moisture deficit basis, with the proportion of wastewater inflow that can be applied to land under the proposed 75 ha border strip scheme, as documented in the AEE in Table 24. Note that the 75 ha of existing pasture has changed only in location, not in extent, since the 2007 AEE was prepared. The potential pasture area that could be developed in the area of the existing ponds, would be common to both the Forbes and 2007 AEE schemes, and is not included in this comparative assessment.

The seasonal irrigation requirements for maize (alternative crop to pasture) are less than those of pasture and so the utilisation of treated effluent for land application when land is used for other cropping, would be less than those presented in Table 1.

Table 1

Comparison of the Proportion of Wastewater Inflow Applied to Land

Month	Forbes Proposal (84ha centre pivot, irrigated to meet soil moisture requirement)		AEE Scheme Table 24 (75ha border strip)
	Average Rainfall Year	Low Rainfall Year	Average Rainfall Year
January	15%	30%	46%
February	12%	25%	45%
March	4%	8%	43%
April	0%	0%	38%
May	0%	0%	20%
June	0%	0%	15%
July	0%	0%	12%
August	0%	0%	13%
September	0%	0%	16%
October	2%	5%	15%
November	6%	13%	35%
December	10%	20%	37%
Total per year	**4%**	**8%**	**26%**

Table 1 shows how the irrigation requirement (deficit) only occurs over a 6 month season from October to March inclusive. During the winter months, there is no deficit (i.e. rainfall meets crop needs) and so crop yields will be maximised by not applying treated effluent to land. This means that under the Forbes proposal, the application of treated effluent to land will not occur between April and September inclusive. The proposed scheme in the AEE is focused on wastewater treatment, so the application of pond effluent to land continues over winter, at reduced rates where needed, due to higher soil moisture.

The marked differences between the treated wastewater applications are also illustrated in Table 2. Note that rainfall depths are not included in Table 2.

Table 2

Comparison of Annual Treated Wastewater Applications

	Forbes Proposal (84ha centre pivot, irrigated to meet soil moisture requirement)		AEE Scheme (75ha border strip)
	Average Rainfall Year	Low Rainfall Year	Average Rainfall Year
Total wastewater depth per year, mm	243	504	1,760
Wastewater Volume per year, m^3	204,000	423,000	1,320,000

3.3 Pasture vs Other Crops

Mr Forbes mentions the production of high yield crops on the Homebush site, without defining the type of crops he is proposing. Maize has been grown on the property as supplementary feed for dairy cows.

Permanent pasture (rye grass, clover mix) has been proposed for the AEE scheme as it provides the best year round performance in terms of nutrient removal (grows year round), can cope with wet conditions and doesn't require regular cultivation. Other seasonable crops that may provide high yields from a single crop, are not as effective as pasture for assimilating the applied nutrients and at being tolerant of wet soil conditions.

The maintenance of stable topsoil structure is critical to achieving the high infiltration capacity required for wastewater application. Under well-managed irrigated pasture, stable topsoil structure increases over time. Under cultivation of soils for cropping, stable topsoil aggregates are broken down to form seed beds. It takes two to three years to re-establish stable topsoil aggregation. Also with cash cropping, crops are harvested when much of the soil surface is exposed and therefore subject to compaction and creation of ruts under harvesting vehicles.

In addition, establishment of annual crops would require lengthy periods of restricted wastewater application during the germination and young growth periods when frequent watering would cause damage to the crops. Similarly water application would need to be restricted near crop harvest periods. Reduced effluent application to the crop areas would require excessive application to remaining land areas, or increased discharges to the river.

While “direct drilling with no tillage” would reduce the impact on topsoil structure as discussed above, the longer withholding periods for seed germination, would reduce the amount of treated wastewater that could be applied.

Cash cropping (other than pasture) poses considerable risks to sustainable wastewater treatment, requires a much greater degree of storage of wastewater and lowers the capacity (less mm per year) of the land to accept wastewater. Land based wastewater treatment systems require careful management to maintain healthy soil and biological conditions. It is therefore essential that priority be given to managing the land for wastewater treatment. It will be a recipe for failure, if decisions are made for attaining income from crop production, rather than maximising the system's capacity to assimilate wastewater.

It should be noted that baleage, or another similar "cut and carry" pasture harvesting method, will provide useful returns to MDC. At Taupo, treated wastewater is irrigated over 136 ha. The pasture is harvested four to five times per year and sold as baleage to farmers (8-10,000 bales/year). Based on the Taupo example, the Masterton wastewater-irrigated area is likely to have a gross return of about $300,000 per year. This does not include returns from the balance of the MDC property not irrigated by wastewater. It would be feasible to grow higher value crops on the 52 ha to the west of the 107 ha property.

3.4 Extent of Treated Wastewater Irrigation Development

The Forbes proposal of 10 centre pivots with 84 ha of swept area for treated wastewater irrigation, occupies most of the MDC owned land (both the 91 and 107 ha sites) refer to Fig 1. In comparison, the 2007 AEE scheme has 75 ha in border strip irrigation, with potential to expand to about 127 ha, if the 107 ha site is fully developed for effluent irrigation in the future, refer to Fig 2.

3.5 Proposal by Hassall & Associates

Hassall & Associates are based in Dubbo, New South Wales and provides Environmental Services. It has experience of effluent irrigation schemes in Australia and with the Fonterra effluent irrigation systems at Clandeboye (South Canterbury) and Edendale (Southland).

The Hassall proposal is based on the typical approach used for rural Australian towns where there is low summer rainfall and unrestricted land area available for both storage and irrigation. Treated effluent is stored over winter and all effluent is applied to land over summer for enhanced pasture or crop growth under semi-arid conditions. The Hassall proposal has some common elements with the Forbes proposal, but the winter storage proposed by Hassall requires separate evaluation.

For the Masterton case, Hassall assumed an average wastewater flow of 4,000 cubic metres /day which is typical for an Australian rural town of 18,000 population and with restricted water supply. A winter storage volume of 560,000 cubic metres was calculated by Hassall based on 140 days storage. This storage volume is additional to the volume of ponds required for treatment.

However because of infiltration and higher water usage in Masterton, the actual design wastewater flow is an annual average of 16,050 cubic metres/day. Due to the greater flows in winter, the design average flow over winter is 18,000 cubic metres/day. Thus the required winter storage would need to have a volume of 2,520,000 cubic metres for 140 days storage (as assumed by Hassall above). If a water depth of 3 metres is assumed (the typical average depth achievable on sloping land), the area of this storage would be about 95 hectares (allowing for area occupied by banks). The 35 hectares occupied by the proposed new ponds, would be additional to the 95 ha of storage. Thus about 130 ha would be occupied by ponds, with only 35 ha available for irrigation. This small area would not handle the required summer application. These comparisons are summarised in Table 3.

Thus the Hassall proposal is not practicable for Masterton. In comparison, the proposed scheme in the AEE has been tailored to the actual wastewater flows, river flows and restricted area of land available at Masterton.

Hassall also advocate the use of centre pivot irrigation and that is understandable under semi-arid conditions and ample land availability, because centre pivot irrigators apply water efficiently during summer, thus maximising the benefit of the wastewater in these water-short areas. However, in the Masterton situation, very high treated wastewater applications will be needed, which are not practicable with centre pivot irrigation.

Table 3

Comparison of Hassall Proposal with Actual Masterton Requirements

	Hassall Proposal	Actual Masterton Requirements based on Hassall Concept
Wastewater flow, m^3/d	4,000	16,050
Winter storage volume required, m^3	560,000	2,520,000
Area of storage if 3m deep, ha	23	95
Total area of ponds and storage, ha	58	130
Land available for irrigation, ha	107	35

4 Selection of Irrigation Method

4.1 Overview

A number of irrigation methods were investigated during the preliminary design phase of this project. These included border strip (flood irrigation) and spray systems – including the use of both travelling spray irrigators (such as the pivot systems proposed by Mr Forbes and Hassall Pty Ltd) and solid set (fixed grid) spray systems. The choice of irrigation systems was explained in the AEE and in 'Response to Further Information Request by the Greater Wellington Regional Council', dated 25 September and 12 October 2007 (question 7) – refer to Appendix A.

Also included in Appendix B, are commentaries by Ian McIndoe of Lincoln Environmental (now Aqualinc), regarding selection of irrigation systems for dairy farms. These commentaries provide background to the selection of irrigation method.

The main reasons for selection of the border strip method for this land treatment scheme over spray irrigation systems, are explained in the following sections.

4.2 Re-grading the Land to Uniform Slopes without Hollows

In order to minimise discharges to the Ruamahanga River, and for there to be no discharge when river flows are below the median value, relatively large volumes of treated effluent will have to be applied to the land, as shown in Tables 1 and 2. Border strip has the ability to apply the large volumes required.

The topography of the Homebush site has reasonably consistent gradients that are suited to the establishment of border strip irrigation. This method of irrigation will involve the land being divided into "strips" and uniformly graded. Treated effluent will be applied at the top end of each strip and the water will move down the slope as sheet flow, infiltrating into the soil at the rate allowed by the infiltration characteristics of the local soils.

The regrading will eliminate hollows, which is particularly important for the irrigation of pond effluent, because under ponding conditions, algae accumulate in hollows sealing the soil surface and exacerbating the ponding.

4.3 Application Rate Limitations

The application rate for spray irrigation systems is generally limited by the lowest permeability soils within the irrigation area. Under the high application rates required in this effluent scheme, spray irrigation systems would apply high loading to hollows, or to areas with slow infiltration rates. These areas are unlikely to be able to infiltrate high applications and would be likely to pond.

This does not apply to border strip irrigation where, due to the uniformly sloping strips and application method, the infiltration rate is self correcting over areas of variable soil down the length of each strip. Border strip irrigation therefore maximises the opportunity for more permeable soils to infiltrate greater amounts of water.

Centre pivot irrigators do have some ability to change application depths in different sectors to suit variable soil conditions. However, the adjustments would be coarse in comparison with the border strip method and ongoing attention by the operators would be required to optimise the application depths.

4.4 Application Frequency

Centre pivot spray systems would need to operate almost continuously to apply the required volume of treated wastewater to the land area available. This means that there would be about one day for the soil to drain and re-aerate between applications of treated wastewater. Under this system, the soils would be perpetually moist to wet and soils would be prone to develop anoxic conditions with resultant smell and retardation of plant growth.

In comparison, treated wastewater will be applied to border strips at a much higher rate but only every 7 to 10 days, allowing a longer period for the soil to re-aerate and for organic material to breakdown and be assimilated.

Also it should be noted that centre pivot systems typically have an installed delivery capacity of about 0.6 litres/sec/ha. Thus the Forbes proposal covering 84 ha, would have a delivery capacity of about 60 litres/sec. The proposed border strip system will have two x 300 litre/sec delivery mains – one on either side of the Makoura Stream. With an installed total capacity of 600 litre/sec, the unit capacity will be 8.0 litre/sec/ha.

The marked difference in hydraulic capacities reflects the difference in application frequency and is the main reason for the difference in cost between the proposed wastewater land treatment scheme and standard farm irrigation systems. Due to weight and structural limitations, it would not be practicable to increase the hydraulic capacity of centre pivots much above the standard designs.

4.5 Centre Pivot Wheel Rutting

Even with standard irrigation application rates in normal farm situations with the centre pivot irrigators, ruts can be formed by the wheels that support the rotating watermain and sprinkler boom structure. If centre pivots were used for effluent application at Homebush, wheel rutting is expected to be severe, given the very high application rates.

The normal method to minimise rutting, is to mound the wheel tracks so that less water infiltrates into the soil at the tracks, together with the addition of gravel or lime chip to stabilise the soil. However, the circular mounding at frequent intervals would create ponding on the sloping ground and result in application rates having to be reduced.

4.6 Effects of Spray Drift

Experience of consenting land based effluent treatment systems has been that spray irrigation systems require more disinfection than border strip systems due to the perceived effects of spray drift. For Masterton, the estimated cost of a UV disinfection system to treat pond effluent to a level appropriate for spray application, would be $1.7 million with an annual operating cost of approximately $200,000 per year. The operating cost includes electricity consumption (at rapidly escalating cost) which would detract from the scheme's sustainability.

It has been suggested that spray drift can be minimised when centre pivots are used, because the low pressure sprinklers can be set close to the ground. This would be possible for pasture, but if tall crops such as maize are grown, sprinklers would need to be set well above the ground.

Regardless of the sprinkler height, the substantial rotating boom structure of centre pivots would be a visible reminder to neighbours of the wastewater application and could attract concerns regarding perceived effects of aerosols in the spray drift – refer to cover photo of a centre pivot irrigator.

4.7 Comparison of Costs – Border Strip vs Centre Pivot

Due to the hydraulic capacity limitation outlined in Section 4.4, centre pivot irrigators could not apply the quantities to land required for this wastewater land treatment system. Pricing for standard centre pivot irrigators, used for typical deficit irrigation, is therefore not applicable to this proposed wastewater land treatment scheme.

The Beca report "Masterton Wastewater Treatment Plant Upgrade Preliminary Design Report" (2007) contains a breakdown of the estimated costs of the land treatment system. Most of the cost is associated with the large diameter piping and automated valves that will be needed to distribute the 300 litres/sec flow around the property. This delivery main cost would be common to any irrigation method used to apply pond effluent to pasture with the desired interval period of 7 to 10 days, which is needed for drainage and re-aeration of the soils.

5 Potential Use of Treated Wastewater on Private Farms

Once the proposed treated wastewater scheme on the MDC owned property has been consented and is in operation, it would be possible to consider requests from farms in the vicinity to use treated wastewater for irrigation.

There are stringent disinfection requirements if the wastewater is to be applied to dairy farms, as outlined in Appendix C. These disinfection requirements would be very expensive and direct use of treated wastewater on dairy farms is unlikely to be economic in this locality.

The proposed new ponds will produce a well treated effluent which could gain resource consents for application to non-dairy farms. However there could be residual concerns regarding health risk to humans and stock, plus algae in the effluent could cause clogging of some soils.

These concerns would be mitigated if groundwater was extracted from the MDC owned land and supplied to private properties. A row of wells along the river frontage at existing Ponds 2 and 3, would intercept most of the groundwater flow from the proposed irrigation area. Passage of pond treated wastewater through topsoil and filtration by underlying sandy gravels, would produce a high quality water resource and would greatly reduce disease transmission risk. There would be no algae in the extracted groundwater.

The groundwater extraction concept is recommended to MDC as a more sustainable and safer way of meeting the objectives of increasing the production of crops in the vicinity and enhancing economic returns to nearby farmers if they choose to take the groundwater. In effect, the treated wastewater would be irrigated twice – firstly on the MDC owned Homebush land, and then as extracted groundwater on other farms in the vicinity.

Based on the wastewater applied to the MDC owned land at Homebush, the area of private farms that could be irrigated by extracted groundwater, on a soil moisture deficit basis in an average year, could be in the order of 300 ha – subject to later investigations of groundwater yield.

It is emphasised that the potential extraction and use of groundwater from MDC land on private property, will not be part of the 2008 consent applications by MDC. The concept is “flagged” here for future consideration. At some future date, MDC would need to apply for consents to extract the groundwater, and each farm owner would need to apply for and hold the resource consents to irrigate the “groundwater of wastewater origin”. Appropriate agreements would be required between MDC and the farm owners.

6 Conclusions

- The principal objective of the irrigation system is to maximise the sustainable treatment of wastewater by passage through land, not to maximise revenue earning ability from cropping.
- It can be seen from the results presented in Tables 1 and 2, that a much greater proportion of treated effluent (at least three times as much during the summer months and seven times as much on an annual basis) will be applied to land by the border strip scheme proposed in the AEE, than by the Forbes centre pivot proposal.
- The Forbes centre pivot spray irrigation and cropping proposal, is not supported because it would greatly diminish the scheme's ability to reduce effluent and therefore nutrient discharges to the Ruamahanga River. That would be contrary to the stated MDC objective of maximising discharge to land.
- Border strip application is recommended as the best method of achieving the land treatment objectives of this wastewater treatment scheme, because relatively large volumes of treated wastewater can be applied to land.
- Standard centre pivot irrigators for an 84 ha operation would handle about 60 litres/sec. The border strip scheme is designed for twin 300 litres/sec delivery mains – 600 litres/sec total. The cost of the proposed land treatment scheme reflects the much greater delivery capacity. Standard on-farm irrigator costs, cannot be compared to the much higher capacity land treatment proposal.
- For irrigation of pond effluent containing algae, the land should be re-graded to eliminate hollows where algae would accumulate and blind the surface – applies to spray systems as well as border strip
- If a spray irrigation system was to be used to apply pond effluent, it is possible that the Hearing Panel could impose a requirement to install UV lamp disinfection to mitigate concerns regarding health effects due to aerosols in spray drift. This would have an additional capital cost of $1.7 million and additional annual costs of $0.2 million.
- Permanent pasture, rather than other cropping, is strongly recommended because pasture will allow the formation of stable topsoil aggregation and high infiltration capacity required for the high wastewater application rates. Also permanent pasture is more effective at assimilating the applied nutrients and being able to accept wastewater on a year round basis.
- Baleage, or other similar "cut and carry" pasture harvesting method, will provide useful returns to MDC. Based on the Taupo wastewater irrigation example, the Masterton wastewater-irrigated area is likely to have a gross return of about $300,000 per year. This does not include returns from crops grown on the western portion of the property, which initially will not be irrigated with wastewater.
- The Hassall proposal was based on incorrectly assumed wastewater flows and would be not practicable for the "higher than normal flows" and restricted land area available at Masterton. The Hassall concept is suited to rural towns in Australia, which have unrestricted land area available for winter storage and irrigation in summer under semi-arid conditions.
- Extraction of groundwater from the MDC land and supply to private farms in the vicinity (if there is a demand) is recommended as a more sustainable and safer way of increasing crop production rather than supplying treated wastewater directly. This concept is "flagged" at this stage for future consideration and will not be part of the consent applications by MDC in 2008.

Appendix A

Extracts Regarding Irrigation from "Response to Further Information Request" 25 September and 12 October 2007

RESPONSE

There are several facets to our response to this question.

First, we consider that it is not appropriate to use 95th percentile values for effluent quality given the buffering effects of additional pond storage, soil adsorption capacity and the smoothing effect of groundwater travelling from the irrigated area to the receiving waters. Concentrations of contaminants from the soil profile in the irrigation model which were time varying, were averaged over the 8-year time series in the groundwater model.

Second, with respect to looking at "pulses" travelling through the aquifer, to predict this phenomenon requires a transient contaminant transport model. This modelling was attempted and, despite liaising with the software writers, was found not to be feasible with the current modelling software.

The current groundwater modelling is, in fact, conservative because it does not allow for adsorption or transformation of nitrogen or phosphorus in the aquifer, nor adsorption of bacteria in the aquifer (only die-off), both of which will occur. However, in order to consider an upper bound case, the irrigation and groundwater models were re-run using the upper limit area of 80 ha and the highest expected irrigation rates as shown in Table 1 below[1].

Table 1: Soil Types and Proposed Average Seasonal Irrigation Rates

Soil Type	Area (ha)	Summer (mm/day)	Winter (mm/day)
Free draining	63	15	5
Clay rich	17	10	5
Total area	80		

The modelling is currently being completed, the conclusions from which will be forwarded to you once completed.

Third, with respect to the pond leakage, the groundwater model did not include pond leakage effects as this would not be practical, considering the complexity of the varying leakage rates that are likely to be occurring over the pond area.

We consider that pond leakage is only relevant when evaluating the effects on the receiving environment. The irrigation modelling gives the increment from the irrigation over and above what is currently occurring from the pond leakage (which has been measured in the river). The outputs from the irrigation model will be simply added to the measured river concentrations to give the predicted effects of pond leakage and irrigation. Attempting to model the pond leakage will not provide a better answer than this.

7. Information Requested

Why is border-strip irrigation the preferred disposal method? What alternative methods were considered?

Reason:

Border-strip irrigation can commonly result in over-application of water and nutrient leaching. Section 10 of the AEE does not discuss alternative methods of disposal (e.g., spray or drip irrigation). A number of submitters have raised concerns about the method of irrigation chosen.

1 80ha was determined to be the upper limit of the irrigated area and accordingly likely to have the worst case effects on the groundwater (the actual area would be confirmed with the detailed design).

RESPONSE

The choice of border strip instead of spray irrigation was made after consideration of a range of factors as outlined below.

While spray irrigation has advantages in some situations, border strip irrigation was the preferred method for this effluent irrigation scheme.

When spray irrigation of effluent is proposed, usually there are many submissions which raise concerns about spray drift and aerosols causing effects on neighbours' health (in this regard, some submissions on the Masterton consents have mentioned the effects of "spray drift" even though spray irrigation is not proposed). Typically, to mitigate such concerns, applicants for spray irrigation schemes typically propose additional mitigation measures such as; UV lamp disinfection, larger separation distances and/or to stop spraying when the wind direction could carry aerosols onto residential properties, roads or recreational areas. If the applicant does not offer such mitigation measures, on the basis of other decisions elsewhere in New Zealand, the consent authority would be likely to impose such conditions. It should be noted that a UV system for pond effluent would have an additional capital cost of $1.7 million and operating costs for power and lamp replacement of $200,000 per year.

While technical justifications can demonstrate that the risk to public health might be minor, the perceived effect of effluent sprays (which are very visible) has been recognised elsewhere as a valid effect. The public is familiar with how far the spray will travel from a lawn sprinkler or a farm irrigator, under strong winds, and members of the public do not accept the difference in potential effects between low vs. medium vs. high pressure sprays.

Submission 30 refers to "the lay of the land with humps, hollows and changing gradients" and also to "areas of heavy soil in hollows". With a spray irrigation scheme, it is not usual practice to re-grade the site to uniform slopes, because the costs for spray irrigators and distribution pipework are already significant. For cleanwater irrigation, the consequences of runoff to hollows and ponding are minor, and, if needed, the application rate can be readily reduced (as has been required for the spray irrigation system operated by the previous landowner). However, for effluent irrigation, runoff to hollows and ponding would lead to odour emission, as the ponded effluent decayed. This effect would be exacerbated by a more rapid build-up of algae solids in the hollows, which would increase the ponding volume and duration. For a border strip system, algae solids are well distributed down the length of the strips and do not clog the topsoil due to the alternating wetting and drying cycles and biological activity in the topsoil.

Accordingly, for these reasons, and where the topography is suitable (as is the case at Masterton), it is preferable where effluent irrigation is proposed to grade the land to uniform slopes so that ponding does not occur. The re-grading also allows runoff to be collected and directed to enhanced infiltration areas within the wipe-off drains, with surplus first-flush volumes pumped to the ponds. Such a management system would not be possible for a spray application scheme where the land is not re-graded.

A key advantage of border strip irrigation is that effluent can move down the strips and percolate into the soil at the localised rate, as dictated by topsoil moisture demand and underlying drainage characteristics; this process is inherently self-correcting. Hence, it is not possible to apply more effluent than the soil's hydraulic capacity to accept, as is possible with other spray systems. Thus, hydraulic loading rates can be maximised in keeping with the key objective for this scheme which seeks to divert effluent away from the river, particularly at low river flows. Effects on groundwater in terms of nutrient breakthrough will be monitored and application rates can be adjusted for specific areas on the basis of operating experience.

Border strip systems have been criticised because of the difficulties in automating the distribution system and measuring the flows in open head race channels. In addition, gates to individual border strips can often leak creating permanently wet areas with anaerobic soils. To avoid these problems, a piped distribution system will be installed with bubble-up valves to individual strips which are leak-tight when shut, and actuated valves to groups of strips which will allow the system to be largely automated, with overview inspections by an operator.

Effluent application to land systems elsewhere in New Zealand have been designed to the site specific constraints of topography and soil infiltration rates. Spray systems have been used for steeper slopes (Rotorua, Levin, Whangamata and Whitianga) or where the soils are very free draining (Taupo on pumice soils). Border strips have been used successfully for up to 40 years, for alluvial plain locations similar to Masterton: at Templeton, Burnham, Waimate and Leeston (refer to the Leeston poster attached as Appendix C, which was displayed at the NZWWA Conference in 2006, and to the article in the *Local Government* magazine, attached as Appendix D).

A very large system has operated at Werribee (southwest of Melbourne) for over 100 years (refer to the paper in Appendix E, and the aerial photographs in Appendix F). This system handles a flow from 1.6 million people using some 4,200 ha of the 11,000 ha total area, and uses the flood irrigation method with check borders (similar to border strip). Effluent percolates slowly through the permeable soil and is collected by a network of deep open drains. The typical soil profile is a red-brown silty clay loam, with 35 % clay, 45 % silt and 20% sand. Thus, in comparison, the Werribee soil profile is less permeable than at Masterton where the underlying gravel strata and proximity to the river allows for adequate sub-drainage.

Buried drip-lines would mitigate the health concerns, but application rates would be restricted and the topsoil uptake of moisture and nutrients would be reduced.

In addition, the long-term performance of drip-lines handling pond effluent is uncertain. Clogging of the sub-surface soils close to the emitters would occur with higher application rates. Removal of algae prior to drip-lines would be prohibitively expensive. It is justified to install driplines in the perimeter buffer planted areas, because the "visible effluent" effect is avoided. Also, it would not be a major cost if the driplines had to be replaced at a future date, if clogging of the subsoil occurred.

Thus, in summary, the border strip method has similar costs to the spray and buried drip-line options but has the key advantage for the Masterton site of the surface undulations being removed during the re-grading of the site. It will also avoid the common community concerns associated with spray irrigation. The border-strip irrigation method for oxidation pond effluent disposal has the longest successful operational history, both in New Zealand and Australia, even in soils with less favourable filtration characteristics than those at the Homebush site.

8. Information Requested

Please explain the level of earthworks required to establish the border-strip irrigation system, and how any earthworks may affect any changes in soil properties and characteristics.

Reason:

The feasibility of border-strip irrigation has been questioned by a number of submitters.

RESPONSE

Typically, the earthworks for the formation of border strips involve grading the near-surface soils to provide a shallow fall of between 1 in 300 to 1 in 500 gradient. Border strips would be a minimum width of 12m and up to 50 m and be separated with a low (300mm) bund. Some modification of the land surface is therefore necessary.

To achieve effective treatment of the effluent by filtration through the topsoil and subsoils, the earthmoving will be managed more intensively than is the case for typical on-farm situations, so that local areas with extremes in permeability will be modified to be close to the average values for the site. This will be achieved by the following measures:

a) Topsoil will be stripped and temporarily stored in longitudinal piles to allow the sub-base to be graded to the required fall. Uniform depths of topsoil will be placed on the re-graded sub-base, the local depth being dependent on the available topsoil in the locality. Since the topsoil provides a significant portion of the water holding capacity, border strips will have a more uniform water absorption rate compared to a spray system on "natural" alluvial ground that would have variable topsoil depths.

b) Where gravels protrude to the surface, these will be removed and reused for the construction of pond bunding. This source of gravel will be lower cost than alternative sources and the extracted gravel volume from the irrigated area will be maximised. The gravel areas will be backfilled with silty sand as a sub-base and compacted to match the density of the surrounding soils so as not to provide a preferential flow path and the topsoil will be reinstated.

c) Localised areas of known existing ponding will be investigated during construction and the drainage improved with sand-filled slit drains if needed (most likely to be required where there are soils with significant depths of underlying silty clay).

d) The earthworks will be carried out in the summer season to avoid excessive compaction of the soils. Full-time construction monitoring of the earthworks will be implemented for good quality control.

e) Construction equipment will be fitted with laser-guided features for precise level control.

f) By handling the topsoil separately, there will be minimal changes to the near surface soil characteristics, thus allowing pasture to be re-established quickly. The proposed changes to subsoils will be to improve the filtration characteristics.

9. Information Requested

Please explain how at least 97% of DRP will be removed/retained in the soil (p.138 of AEE) if site investigations revealed very low phosphorus retention rates (8-19% on p.93 of AEE).

Reason:

These statements appear contradictory – low phosphorus retention would suggest a high probability of leaching to groundwater.

RESPONSE

Modelling was carried out to assess the environmental fate of the surface-applied phosphorus. The results were reported in the HortResearch (2007) report which forms part of the AEE. The total phosphorus content of treated effluent from the oxidation ponds is expected to be, on average, 3.2 mg L-1. Most of this content will be in the form of dissolved reactive phosphorus (DRP) which adsorbs partially to the soil's clay and mineral particles, and is also easily taken up by plants.

The proposed irrigation scheme would add between 28 and 63 kg P ha-1 each year to the pasture sites. Some 20-35 kg ha-1 of this would be assimilated by pasture that is subsequently harvested and removed from the site under the cut-and-carry operation. Irrigation of treated effluent adds more phosphorus to the soil than can be utilized by the pasture, so there is opportunity for leaching to occur. However, the remaining DRP is largely retained, or filtered, by the soil profile. The degree of renovation will depend on the interaction between soil processes and water movement.

For the purpose of modelling, P partitioning in the soil was described using a Langmuir adsorption-isotherm that relates the equilibrium solution concentration [C, mg L-1] to the amount of P adsorbed onto the soil matrix [q, mg kg-1]. Figure 1 below presents isotherm data from the Bw horizon (clay loam at 50 cm) where the P retention is 19%. The maximum sorption capacity of these clay rich layers is typically between 410-615 mg kg-1.

Following 28 years of historic application of phosphorous to the existing pasture, a large fraction (~60-80%) of the applied P still resides in the top 1.0 m of the soil profile (Figure 2). While the soil

Appendix B

Extracts from "Things You Should Know About Irrigation System Selection" by Ian McIndoe, Lincoln Environmental, June 2001

These comments on irrigation systems, were made in a presentation to dairy farmers in Canterbury – only the systems relevant to Masterton wastewater have been included.

Border-strip irrigation

Border-strip irrigation was the traditional method used on the majority of community irrigation schemes in New Zealand. Today, the number of new systems being installed is very low, partly because inadequate water supplies are available and partly because the cost of construction on uneven soils is costly.

Although the method is often considered to be an inefficient method of irrigation from a water-use perspective, with good design on suitable soils it can be as efficient as spray irrigation systems. The use of laser levelling has improved the efficiency of the newer systems and has been used with considerable success. Its low labour requirement, long life and simplicity make border-strip an attractive method of irrigation where pasture is grown and where an adequate gravity-fed water supply is available.

On the right farms, border-strip can be a low-medium cost method of irrigation.

Fixed centre-pivot

As with lateral move irrigators, the greater emphasis being placed on irrigation uniformity and the need to apply variable applications has increased the popularity of centre-pivots, particularly on dairy farms. Fixed centre-pivots also have one other major attraction and that is a very low labour requirement. Most of the operational time is spent on routine maintenance, as operation is very simple.

Generally, centre-pivots have very high application uniformity and the ability to apply a wide range of depths. Application rates are very low at the centre of the pivot, and increase with distance from the centre. On very long systems, sprinkler flow rates and therefore application rates at the ends can be very high because of the large area watered by the end span. This can create problems with ponding and surface redistribution, which can be minimised by applying small depths of water more often. The control systems of centre-pivots allow enormous flexibility such as changing application depths over the full circle or in different sectors simply by programming in requirements.

A wide range of sprinkler types can be fitted to them ranging from LEPA systems, low pressure spray jets through to large impact sprinklers. However, the preferred choice of sprinkler is now Rotators or similar low pressure plastic sprinklers, which have excellent uniformity and reliability with an acceptable application rate.

Because sprinklers tend to be quite closely spaced, these systems are not greatly affected by wind.

Farm shape must suit these machines to obtain good overall coverage. Square or circular areas with no obstacles are best. They can be used on flat or rolling country at slopes that most other irrigation systems cannot operate on, but they are not suitable for small irregular areas. Although corners are not watered, sector operated end-guns or controllable corner towers can be used to cover most of the corners. Generally, they are fed directly from the centre, so damage to crops is limited to wheel tracks every 50 metres or so. Drive systems are usually independent, with underground electric cable or diesel motors being most common.

On larger systems, the cost per hectare irrigated is low, making them extremely cost-effective. On small systems however, fixed centre-pivots can be costly.

Appendix C

Fonterra Policy Updated in 2007

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HUMAN EFFLUENT TO PASTURE

In 2000, the New Zealand Dairy Industry, under the New Zealand Dairy Board developed and adopted the Dairy Industry Environment and Animal Welfare Policies. One of these policies banned the spreading of human waste to pasture that was to be grazed by, or harvested for feeding to dairy animals. This position was reached after a review of our markets via feedback from our marketers around the world. At that time there was one municipal area that was spreading treated waste to pasture, with that pasture being harvested and used by a small number of dairy suppliers. This was permitted to continue while the industry investigated further the issue of acceptable levels of treatment.

There has been a growing demand from a wide range of regional authorities to utilise land application as part of their treatment process with land supporting dairy farming systems being identified. Fonterra carried out a worldwide review of treatment technology and market perceptions/requirements to identify a level of treatment that satisfied the food safety and market perception issues surrounding animals grazing pasture that has had treated human effluent applied.

We have been able to identify through, Dr Jim Barnett a level of treatment after which it is acceptable to spread the treated waste to pasture for grazing by dairy animals that supply milk to Fonterra, or pasture that is to be harvested for feeding to these animals.

Treatment equivalent to the Title 22 of the California Health Law has been adopted.

The standard of acceptable treatment is summarised as:

- Sewage or sewage derived material can only be applied to pasture destined for consumption by dairy cattle if it has been secondary treated and disinfected.
- Secondary treatment requires a process producing an oxidised effluent (i.e. the organic matter in the sewage has been stabilised and contains dissolved oxygen).
- The degree of disinfection required is based on the residual total coliform bacteria in the water. The median concentration of total coliform bacteria must not exceed a most probable number (MPN) of 23 per 100mL (based on a 7 day period) and the maximum number in any one sample over a 30-day period must not exceed an MPN of 240 per 100 mL.
- A management plan must be developed for where sewage is applied to a dairy farm.

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This level of treatment will allow us to collect milk produced from pasture on which the treated effluent has been spread.

We continue to accept:

1. Sub surface placement of effluent not treated to the above standard.
2. Incorporation of effluent not treated to the above level, into soil, the growing of crops for harvest then sowing pasture for grazing.

Our suppliers have been updated on our position.

If you have any questions relating to our new policy please feel free to contact me on 07 850 9866

Yours sincerely,

Charlotte Rutherford

Environment Programme Manager

Fonterra Milk Supply