Centre for Integrated Biowaste Research

Kaikōura case study: community engagement to determine biosolids reuse

Photo courtesy The Marlborough Express

E.R. (Lisa) Langer, James Ataria, Alan Leckie, Virginia Baker, Jacqui Horswell, Richard Yao, James McDevitt, Joanna Goven, Raewyn Solomon, Louis Tremblay, Grant Northcott, Jianming Xue, Craig Ross and Brett Robinson

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AUTHORS	E.R. (Lisa) Langer, James Ataria, Alan Leckie, Virginia Baker, Jacqui Horswell, Richard Yao, James McDevitt, Joanna Goven, Raewyn Solomon, Louis Tremblay, Grant Northcott, Jianming Xue, Craig Ross and Brett Robinson
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Kaikōura case study: community engagement to determine biosolids reuse

E.R. (Lisa) Langer, James Ataria, Alan Leckie, Virginia Baker, Jacqui Horswell, Richard Yao, James McDevitt, Joanna Goven, Raewyn Solomon, Louis Tremblay, Grant Northcott, Jianming Xue, Craig Ross and Brett Robinson

Centre for Integrated Biowaste Research (CIBR)
c/- Scion
P.O. Box 29 237
Christchurch 8540

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EXECUTIVE SUMMARY

Kaikōura has approximately 1500 tonnes of sewage sludge/biosolids that have been left to weather under a resource consent granted for 10 years until 2016. With less than one third of the time remaining on the consented biosolids storage, the Kaikōura District Council was keen to engage with the local community to explore and find acceptable reuse options. The Centre for Integrated Biowaste Research (CIBR) undertook a case study in Kaikōura to investigate biosolids management options with the community.

The aim of the CIBR Ministry of Business, Innovation and Employment (MBIE) funded research was to integrate biophysical and social science and support a shared-learning process amongst stakeholders to identify the strengths and weaknesses of possible biosolids reuse strategies. This report provides an account of the process and findings.

Kaikōura District Council and community took part in the engagement process and provided well-considered input to produce a range of biosolids reuse solutions appropriate for the Kaikōura community. The methodology developed provides a framework for community engagement for biosolids reuse that can potentially provide a basis for regional land use planning, national guidelines and policy directions.

The integration of social, cultural, environmental and economic considerations as part of the engagement model gave the community a mechanism to weight (prioritise) their concerns, enabling the community and the council to make a more informed robust and transparent decision.

Overall the CIBR integrated engagement process was very successful and has enhanced the level and quality of engagement and knowledge shared between council and community on biosolids and waste management.

Similar forms of collaborative community engagement could be utilised by local government to build shared knowledge and generate robust and sustainable decision-making for other environmental health issues.

The biophysical analysis showed that the stockpiled biosolids were chemically similar to well-matured composts in nutritional values and can be classed as Grade 'Bb' with respect to pathogens and contaminants (NZWWA, 2003). The community engagement process considered the biophysical analysis alongside economic costing, environmental impact and social and cultural preferences to discuss the fate of the biosolids. The participants supported three reuse options for the stockpiled biosolids (in order of preference):

1. application to exotic forest plantations;
2. application to rehabilitate land with native plants; and
3. composting biosolids (both open air composting and vermicomposting) prior to being sold.

Although the exotic plantation application option received the most support of the individual options, there was a strong community preference for further investigation into approaches that utilise several management options to achieve the maximum economic benefit.

1.0 Introduction

The EarthCheck® benchmarked sustainable community of Kaikōura has approximately 1500 tonnes of biosolids (stabilised sewage sludge) that have been left to weather under a resource consent granted for 10 years until 2016. The Kaikōura District Council (KDC) was keen to engage with the local community to explore and find acceptable reuse options as the end of the resource consent for stockpiling draws to an end.

The Centre for Integrated Biowaste Research (CIBR) undertook the Kaikōura case study to integrate biophysical and social science in order to support a shared-learning process for end-users, Māori, and other community stakeholders to develop viable strategies for biosolids reuse (see Appendix 1 for key terms). An important objective was to improve understanding of how a reuse decision is considered and debated by tangata whenua, waste managers and other business operators, local government and the wider community. The case study has helped find alternative disposal/reuse options that satisfy social, cultural, economic and environmental criteria.

This report discusses the Kaikōura case-study process and findings with detail shown in the supporting appendices:

- Characterisation of the Kaikōura biosolids (contaminants and nutrients);
- Potentially relevant biosolids reuse options;
- The community engagement process:
    - initial community engagement – key community stakeholder hui
    - personal interviews with key community stakeholders
    - second key community stakeholder hui to develop reuse options
    - environmental life cycle assessment and economic analysis and the third key community stakeholder hui
    - fourth hui with broader community;
- Life-cycle and cost-benefit analyses; and
- Outcomes from the community hui with recommended reuse options.

2.0 Characterisation of Kaikōura biosolids and relevant biophysical research

2.1 Background to environmental and biophysical research

The case study's environmental and biophysical research was developed in response to a community need, expressed in early interviews and the first hui, to know more about the composition of the Kaikōura biosolids before making a decision on their reuse (see Section 6). Biosolids were characterised according to criteria contained in the "Guidelines for the safe application of biosolids to land in New Zealand" produced by the WaterNZ (NZWWA, 2003). These include pathogens, heavy metals and a range of nutrients (nitrogen, phosphorus and potassium). Emerging contaminants and ecotoxicity were also measured. A vermicomposting (composting with worms) trial was undertaken after the community expressed an interest in this process. Pot trials with both exotic and native tree seedlings were carried out to determine the fertiliser quality of biosolids and vermicomposted biosolids, as well as pathogen regrowth experiments.

Land application of biosolids can be considered a beneficial use when properly managed to enhance soil fertility, structure, and water-holding capacity, and plant growth, provided negative effects of contaminants are avoided. Biosolids applied to land also can provide nutrients such as nitrogen and phosphorus and condition degraded soils with organic matter.

These beneficial attributes are wasted if the material is landfilled and the Waste Minimisation Act (2008) encourages waste minimisation and a decrease in waste disposal in landfills. Phosphorus is a limited non-renewable resource that can be recycled from biosolids. However, biosolids also contain a range of contaminants such as heavy metals; organic contaminants such as pharmaceuticals and body care products; and pathogens. There are concerns regarding the fate and effects of these contaminants on both the environment and human health. Therefore, the amount and rate of addition of biosolids to land are currently controlled via guidelines and regulations that set criteria for levels of metals and pathogens, which are protective of the environment and human health (NZWWA, 2003). For the purpose of this report we have used the Grading system in the Guidelines for the safe application of biosolids to land in New Zealand (NZWWA, 2003). The grading system is made up of two parts: the first part (denoted capital 'A' or 'B') represents the stabilisation grade. The second part (denoted by lower case 'a' or 'b') represents the contaminant grade (see Table 1).

Table 1: The Grading system in the Guidelines for the safe application of biosolids to land in New Zealand (NZWWA, 2003)

Grade 'Aa'	'Aa' grade biosolids have substantially reduced pathogen contaminants, such that the product is deemed safe to be handled by the public with minimal risk.
Grade 'Bb'	Grade 'Bb' biosolids can have a lower level of treatment and may contain pathogens. Use is restricted and subject to 'best practice' management to protect the soil and waterways.

More detailed information on the New Zealand biosolids guidelines and the grading system is provided in Appendix 2.

The environmental and biophysical research information in the following sections was presented to the community at the second key community stakeholder hui to develop reuse options in March 2012 (see Section 6.1).

2.2 Economic value of biosolids as fertiliser

Biosolids are carbon-rich and contain valuable nutrients. The findings from the long-term research trial at Rabbit Island near Nelson, where biosolids have been applied to a plantation forest since 1997 (Wang et al. 2004; Wang et al. 2006) provide relevant information to guide expectations of potential reuse of Kaikōura biosolids. Biosolids application to the radiata pine plantation improved tree nutrition (e.g. foliar nitrogen concentration increased by 50%) and stem volume growth (by about 30%). Economic return increased by about 40% with biosolids application to forest plantation. The increased stem volume and greater average log diameter in the biosolids treatments is predicted to far outweigh any negative effects on log value due to the reduced wood properties. The biosolids treatments are predicted to increase the net stumpage value of logs by 30-40% at harvesting, providing a large positive impact on the forest owner's economic return. Biosolids applications did not significantly alter either soil quality or ground water quality within the trial.

2.3 Nutrients and chemicals in Kaikōura biosolids

Kaikōura biosolids are similar to well-matured compost in nutritional values. Soil chemistry test results undertaken showed that the Kaikōura biosolids have high to very high levels of plant-available macro-nutrients (nitrogen, phosphorus, sulphur, potassium, calcium and magnesium) and some micro-nutrients (boron, copper, zinc and sodium) (see Table 2 and Appendix 3). Cation exchange capacity is high, which indicates good retention of nutrients.

Table 2: Kaikōura biosolids characterisation: Chemical analyses – total elements.

	pH	%Carbon (C)	%Nitrogen (N)	Phos-phorus (P)	Sulphur (S)	Calcium (Ca)	Magnes-ium (mg)	Potassium (K)	Sodim (Na)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Mercury (Hg)
									mg/kg						
	4.1	28	2.7	4683	6972	9818	2204	4330	428	**2.8**	32	**561**	96	**878**	**2.3**
		39	5.8												
		26	2.4												
NZguidelines															
Grade A	(6-7)									1	600	100	300	300	1
Grade B	(>5.5)									10	1500	1250	300	1500	7.5
NZ Compost Stds	5-8.5	≥ 25 OM	≥ 0.6							3	600	300	250	600	2

for both soil conditioning (improving the physical quality of soils) and as an organic fertiliser, and will also improve biological activity and water holding capacity. The biosolids are acidic (pH 4.1), hence liming will be required for plants intolerant of slight to moderately acidic soils (e.g. to raise the pH to about 6 for pasture). However, the biosolids would be a suitable growing medium or soil amendment for most native shrubs and exotic plantation trees.

2.4 Composted and vermicomposted Kaikōura biosolids

A vermicomposting trial was conducted using Kaikōura and Taupō district biosolids to guide potential use of compost produced from green waste and Kaikōura biosolids (Wang et al., 2011). Taupō biosolids were included in this trial to provide a comparison, and to generate cross case study insights. A small community near Taupō was the second case study location for the CIBR research.

Vermicomposting was found to improve the nutritional value of resulting compost (e.g. 30% increase in total nitrogen and 24% increase in total phosphorus). It stabilised some heavy metals (reduced availability of arsenic, cadmium, copper, nickel and zinc) and increased soil carbon and water holding ability.

A pot trial was conducted to investigate the nutritional value of the composts. The effects of Kaikōura and Taupō district biosolids and vermicomposted biosolids on seedling growth and heavy metal uptake by native (tōtara and mānuka) and exotic (radiata pine) tree species (Xue et al., 2012). The results showed that biosolids and vermicomposted biosolids increased seedling growth of both native and exotic species on a low fertility soil which had been taken from a pine forest skid site. Vermicomposted biosolids increased seedling growth of radiata pine, tōtara and mānuka more than the non-vermicomposted Kaikōura biosolids. Application of biosolids and vermicomposted biosolids at a rate of 400 kg nitrogen per ha had little effect on the uptake of heavy metals by both native and exotic species. The accumulation of biosolids-derived heavy metals in the soil was insignificant. This study indicated that both biosolids and biosolids vermicompost have good potential as a fertiliser and/or soil amendment for rehabilitation of degraded soils.

2.5 Pathogens

Pathogens are present in raw (untreated) sewage because they are discharged in the faeces or urine of humans or animals. The New Zealand biosolids guidelines (NZWWA, 2003) require that the following pathogen standards are met for the product to be Grade 'A' for pathogens:

E.coli < 100 MPN/g
Camplyobacter < 1 /25g
Samonella < *1 /25g*
Enteric viruses < 1 PFU/4g
Helminth ova < 1 /4g

MPN = most probable number;
PFU = plaque-forming unit;

Grade 'B' products have no recommended pathogen levels in the biosolids Guidelines, but must undergo processing such as anaerobic digestion to reduce attracting vectors such as rodents and insects which may spread disease. More detail on the biosolids guidelines and the pathogens that may be found in biosolids can be found in Appendix 2.

2.5.1 Pathogens in Kaikōura biosolids

Kaikōura biosolids were tested for the presence and range of pathogens and compared to USA, New South Wales (Australia) and New Zealand biosolids guidelines (see Table 3). *Salmonella* were below the detection limit. *Escherichia coli* levels were low but due to one outlier, (2000 MPN *E. coli*/g) the biosolids are classed as Grade 'B'. It is highly likely that if more testing was carried out 95% of the samples would fall within the Grade 'A' criteria of <100 MPN/ g. The full range of pathogens specified in the biosolids Guidelines for Grade 'A' quality were not tested for as their presence was considered unlikely. It is recommended that before a decision is made on the biosolids reuse, the pathogen content is analysed.

Table 3: Pathogen in Kaikōura biosolids presented alongside USA, New South Wales (Australia) and New Zealand biosolids guidelines.

Microorganisms	U.S.A		New South Wales*	New Zealand*	Kaikōura biosolids
	Class A	**Class A**	**Class B**	**Grade A**	
E. coli	N/A	N/A	N/A	<100 MPN/ g	680 MPN/g
Faecal coliforms	<1000 MPN/ g	<1000 MPN/ g	<2000000 MPN/ g	N/A	Not analysed
Salmonellae	<3 MPN/ 4 g	Not detected / 50 g		<1/ 25 g	Not detected / 25 g
Enteric viruses	<1 PFU/ 4 g	<1 PFU/ 4 g		<1 PFU/ 4 g	Not analysed
Helminth ova	<1/ 4 g	<1/ 4 g		<1/ 4 g	Not analysed

PFU = plaque-forming unit;
MPN = most probable number;
* New Zealand and New South Wales Grade/Class 'B' sludges have no limits for microorganisms.

2.6 Organic contaminants

Organic and heavy metal contaminants are present in urban wastewaters at relatively low concentrations, but are concentrated in biosolids during wastewater treatment processes. Contaminants accumulate in the sewage sludge as they tend to concentrate in the solid fractions. More information on organic contaminants can be found in Appendix 2.

2.6.1 Organic contaminants in Kaikōura biosolids

International and New Zealand data on organic wastewater contaminants (OWCs) in biosolids and their fate and effects is insufficient to develop a suitable risk assessment under New Zealand conditions. However, there is little evidence to limit land application of biosolids for the purpose of rehabilitating degraded soils. The added benefits of nutrient input to facilitate vegetation and reestablishment of viable functioning topsoil can outweigh the potential risks arising from the presence of OWCs in the Kaikōura biosolids.

To date we have analysed a wide range of commonly prescribed pharmaceutical residues in Kaikōura biosolids representing 11 classes of medicinal drugs. Twenty seven out of a total of 65 individual pharmaceuticals were measured in Kaikōura biosolids. The pharmaceuticals measured in stockpiled Kaikōura biosolids were present at very low concentrations and were much lower than those reported in fresh biosolids from other countries, and from freshly produced biosolids. The relatively low concentration of pharmaceutical residues within the Kaikōura biosolids is likely to have resulted from continued degradation during the extended period of storage and stabilisation. It is expected that the concentration of other OWCs within the stockpiled Kaikōura biosolids will have continued to decline during storage and stabilisation.

Our research to date indicates that the aged biosolids have no acute toxicity in earthworm standard tests. Earthworms are model organisms used internationally in ecotoxicity testing (Kinney et al., 2012). The fact that the stockpiled biosolids contain large numbers of earthworms strongly indicates that the material has negligible toxicity.

2.7 Further characterisations of organic wastewater contaminants

Multiple products and medications that contain numerous chemicals are used by the community daily, but there is limited information available of their concentration or effects to develop proper environmental risk assessment.

2.7.1 Organic wastewater contaminants in Kaikōura biosolids

The ecotoxicology component of the CIBR has been assessing the risk associated with contaminants that can persist through the various treatment technologies and accumulate in the biosolids. Those contaminants could lead to potential detrimental effects if applied to the soil or could leach into the environment. Some contaminants that have been found principally from domestic sources in the Kaikōura biosolids derive from pharmaceuticals for human use and provide a good indication of the implications of domestic wastewater disposals (summarised in Table 4 with more detail in Appendix 4). The research results showed that the Kaikōura biosolids and some of the micro-contaminants did not lead to short-term toxicity to soil organisms in standard tests using earthworms and springtails as models. However, the long-term implications of those contaminants in soil ecosystems are unknown. Therefore, the research is continuing to better characterise the risk of the micro-contaminants present in biosolids.

Table 4: Pharmaceuticals found in the stockpiled Kaikōura biosolids.

Pharmaceutical type	Name
Analgesic	Naproxen, Acetaminophen
Lipid regulators and statins	Fenofibrate
Psychiatric drugs	Carbamazepine
Antibiotics	Sulfamethoxazole, Ciprofloxacin
Beta blockers	Metoprolol, Propanolol

Initial research has focussed on three micro-contaminants: triclosan (commonly used antimicrobial agent); bisphenol-A (industrial plasticiser); and carbamazepine (psychiatric drug). The approach used for this research component involves the toxicity characterisation of the chemicals, both individually and in combinations with the others. The earthworm assay is being used as well as other types of tests such as the *in vitro* worm coelomocyte toxicity assay that evaluates the effects of the chemicals on the immune system. This ongoing research will generate more information to develop a more in-depth risk assessment of the most prevalent micro-contaminants found in the Kaikōura and other New Zealand biosolids.

Overall, the research has concluded that a range of micro-contaminants are found in the Kaikōura biosolids. However, they do not cause short-term acute toxicity (based on CIBR ecotoxicity studies). Long-term implications are unknown. The research is continuing to characterise the effects of the contaminants, both individually and in combinations, and to better assess their potential long-term implications on exposed ecosystems.

International research has found that the environmental risk is low where these compounds are found at small levels in both biosolids and wastewater, providing best practice guidelines are followed.

2.8 Heavy Metals

High amounts of trace elements such as heavy metals (zinc, copper etc.) can become contaminants and impact environmental health. Sources of heavy metals can be industrial (e.g. particularly in large towns/cities) and domestic (e.g. hot water cylinders and personal care products). Scientific research will enable a better understanding of how heavy metals behave in the environment.

2.8.1 Heavy metals in Kaikōura biosolids

There are no known industries which release heavy metals into the Kaikōura waste stream and hence any heavy metal contamination is likely to have come from domestic sources. Slightly elevated concentrations of cadmium and mercury, along with elevated copper and zinc concentrations (see Table 2, Section 2.3) place the Kaikōura biosolids as Grade ‘b’. Tests were not carried out on the bioavailability of these contaminant heavy metals (owing to the limited funding), hence their potential uptake and concentration in plants and fate in the environment is unknown. However, previous research within the CIBR programme suggests that this risk is low. The other potential contaminant heavy metals tested for were within Grade ‘a’ specifications in the biosolids guidelines (NZWWA, 2003).

2.9 Biosolids reuse options

2.9.1 Overview

Kaikōura biosolids, rich in nutrients, but low in pH, currently meet Grade ‘Bb’ of the New Zealand guidelines. If the best practices outlined in the guidelines are followed (e.g. land management practices), then Grade ‘Bb’ biosolids are not hazardous to human health or the environment. Kaikōura biosolids are not likely to be suitable for amending soils for food production or for agricultural uses owing to the ‘Bb’ grading and pathogen and contaminant content. The characteristics of the biosolids suggest potential as supplemental fertilisers or soil amendments. For example, they could be used as a soil conditioner to improve the fertility of poor quality soils in plantation forestry or local native tree rehabilitation projects, but not within five metres of waterways (NZWWA, 2003). Considerably wider buffer zones have been specified in some resource consents (e.g. 10 m from forest edges for forest margins, 50 m for open water courses, 100 m for occupied houses, 250 m for residential areas, 50 m in any direction and 250 m up gradient in the direction of groundwater movement plus/minus 30 degrees for drinking water bores to avoid contamination of water bodies; Jenkins, 1998). However, further stabilisation, for example co-composting with green waste with or without the addition of worms (vermicomposting) has the potential to improve the quality of the biosolids to Grade ‘Aa’, allowing them to be used for home or public park lawns.

2.9.2 Open air compost

Composting biosolids with green waste is a viable, beneficial option for biosolids management and has been practiced in the US over 20 years. Open air composting could raise the biosolids Grade to ‘Aa’. It is a proven method for pathogen reduction and results in a product that is easy to handle, store and use (United States Environmental Protection Agency, 2002). However, composting of biosolids may lead to considerable nitrogen loss, and the generation of carbon dioxide (CO_2) and other greenhouse gases if not managed properly. This is not known to occur when biosolids are vermicomposted.

2.9.3 Vermicomposted biosolids
As vermicomposting was found to raise the Grade to 'Aa', improve the nutritional value of resulting compost, stabilise some heavy metals (reduced availability of arsenic, cadmium, copper, nickel and zinc) and increase soil carbon and water holding ability, it will provide a useful compost for local use. However, costs of production and willingness to pay for the compost need to be considered (see the cost benefit analysis, Section 5.0).

2.9.4 Farm application
Some 25% of New Zealand farms are deficient in one or more trace elements. The addition of biosolids to soil is a potential solution. Fodder crops produced on biosolids-amended soil improve animal nutrition (Anderson et al., 2012), particularly with regard to the micronutrients, copper and zinc. Best practice guidelines are required to ensure contaminants and pathogens are not passed into humans and animals. In addition, the application of biosolids to farm land within the food chain was not favoured by stakeholders engaged in the community hui (see Appendices 7 and 9).

Degraded and low-fertility soils can be rebuilt with a 2:1 biosolids:biochar (charcoal) mixture. Using biochar in the mixture mitigates the nitrate leaching risk that would otherwise occur (Knowles et al., 2011). Such rebuilt soils can be used to produce superior-quality crops (Gartler et al., 2013). Nevertheless the use of biochar with biosolids for land application was not considered to be a feasible option at this stage owing to the lack of adequate biochar resources locally.

2.9.5 Exotic forest application
Long-term research carried out at Rabbit Island near Nelson suggests that the application of Kaikōura biosolids to exotic plantation forests will improve tree nutrition, stem volume growth and economic returns. Soil and ground water quality would unlikely to be impacted if best management practices are used.

2.9.6 Rehabilitation of degraded sites with native species
Areas that have been disturbed or degraded in some way (e.g. erosion, development or mining) also will have suffered loss of chemical, biological and physical fertility. A key factor influencing this decline in fertility is a decrease in soil organic matter caused by the loss of topsoil. In situations where topsoil has been lost or has become degraded, organic amendments (soil conditioners) such as biosolids can be used to supply sufficient organic matter and nutrients to initiate successful soil rehabilitation. In turn, plants should benefit from the increased fertility. However, soil contamination from biosolids-derived heavy metals could create potential risks if biosolids are applied to rehabilitate low quality degraded sites.

3.0 Initial community engagement process

3.1 Initial community engagement hui, October 2009

In October 2009, the first Biowastes programme hui was held at the Takahanga marae in Kaikōura. Participants included approximately 20 key stakeholders who have a direct interest in, or were likely to be affected by, the management of Kaikōura biosolids. They included representatives of tāngata whenua, Te Korowai o Marokura (a community environmental action group), business operators, local government, commercial and recreational fishing and other environmental groups. The selection of participants for the initial hui was itself a process of one-on-one discussions with members of the Kaikōura community: firstly, to find community members with an interest in the reuse of their biosolids and secondly, to recruit participants for the hui. This hui then led to the identification of key stakeholders and subsequent face-to-face interviews with them.

The hui had three key aims:
1. Introductions and learning about the rūnanga and its marae.
2. Presentations from 'heads of the community' and finished with information about the biosolids issue in Kaikōura. This provided an opportunity for the CIBR team to learn about the community and to introduce itself to community representatives with a view to grounding the future research firmly in the community.
3. Discussion of programme milestones, programme-community linkages, case study site integration, and communication strategies. Field trips at the conclusion of the hui provided information about a range of sustainability initiatives in the Kaikōura community. All participants of the hui followed marae protocols, and this created an atmosphere of goodwill between the community and the CIBR team.

Community knowledge helped shape the research of biophysical science team. Interest in vermicomposting biosolids was expressed in the initial community engagement in Kaikōura. This led to the establishment of vermicomposting trials with the stockpiled Kaikōura biosolids and, as a comparison, fresh biosolids from Taupō District Council (see Section 2.4). In addition, a key stakeholder present at this initial hui suggested that the biophysical work not just focus on exotic pine trees, but also consider native species. As a result the pot trials, which tested the characteristics of the vermicompost for rehabilitation/remediation of degraded and unproductive land, included mānuka and tōtara seedling growth tests alongside radiata pine (radiata pine was still included to allow comparisons with previous research results). This in turn has led to interesting new research which has revealed negative effects of chemical fertilisers (but not vermicomposts) on the colonisation percentage of endomycorrhizal fungi in mānuka and tōtara roots.

3.2 Personal interviews, April-May 2010

Face-to-face interviews were conducted with 22 key community stakeholders to explore what they value about their environment, what they thought should be done with existing biosolids, and what concerns they had about the possible impact of biosolids reuse.

Few of the key stakeholders had extensive knowledge about biosolids. Almost all felt that acceptable reuse depended on the composition of biosolids. This provided further impetus for the CIBR research team to determine the characteristics of the biosolids. Land application was the popular choice for managing the current stockpiled biosolids, with varied views of what would be the most appropriate means of achieving this. However, a number of concerns were raised including the cost of the solution, not wanting to transport the 'problem' elsewhere, and 'unknowns' around microbes, metals, chemicals, pharmaceutical and body-care product issues. These concerns helped to shape the biophysical and economic research components of this study. Details of the Kaikōura community views are summarised in Appendix 5.

The framework of this component of social and cultural research, which was based on kanohi ki te kanohi (face-to-face) exchange of information, provided a method of identifying community priorities, values and concerns, particularly with regard to the unknown potential of contaminants. This framework also enabled a feed-back loop where the social and cultural research guided subsequent work in the biophysical science (e.g. risk of contaminants that are of most concern to the community) and where findings from the resulting biophysical work are fed back to the community to help it manage uncertainty around environmental impacts of biosolids reuse. As with the initial hui (October 2009), the personal interviews drove a refinement of biophysical science (see Section 2.0).

3.3 Second community engagement hui, February 2011

A second community engagement hui was held at the Takahanga marae in February 2011 with about 15 key stakeholders. The aims were to discuss with stakeholders the results of the social, cultural and biophysical research undertaken to date and to provide community views on reuse options for the stockpiled biosolids.

Results from the characterisation of the Kaikōura biosolids were presented to the participants by the CIBR scientists, showing that the nutrients present are comparable to composts and were Graded 'Bb' with respect to the biosolids Guidelines (see Appendix 2).

After the presentation of the science results, a facilitated workshop session was held to enable the participating key stakeholders to discuss all known feasible options for their biosolids. A total of 19 options were presented to the participants; these included further biosolids stabilisation (six options); land application (five options); rehabilitation of land (four options); resource recovery (four options) (see Appendix 6). Participants were asked to discuss the social and cultural positives and negatives; environmental positives and negatives; economics and feasibility of each of the options (see summarised views in Appendix 7). Each community participant was given four numbered dots to vote individually on their preferred options showing their recommended priority for future management of the stockpiled biosolids. The voting used a weighted methodology: first choice received a weight of four votes, second choice three votes etc.

Of the potential biosolids reuse or management options the following were ranked highly by key stakeholders present at the hui (see Figure 1):

- Further stabilisation – composting (including vermicomposting with worms);
- Land application
    - Farm application outside food chain;
    - Exotic forest application; and
    - Rehabilitation of disturbed sites with native plant species.

Interest was also expressed in the use of biochar (charcoal that is added to soil) mixed with biosolids to reduce leaching of biosolids derived nitrogen and heavy metals from the soil. Resource recovery (e.g. production of biosolids pellets, landfill and transporting out of the area) were not supported by many participants (Figure 1).

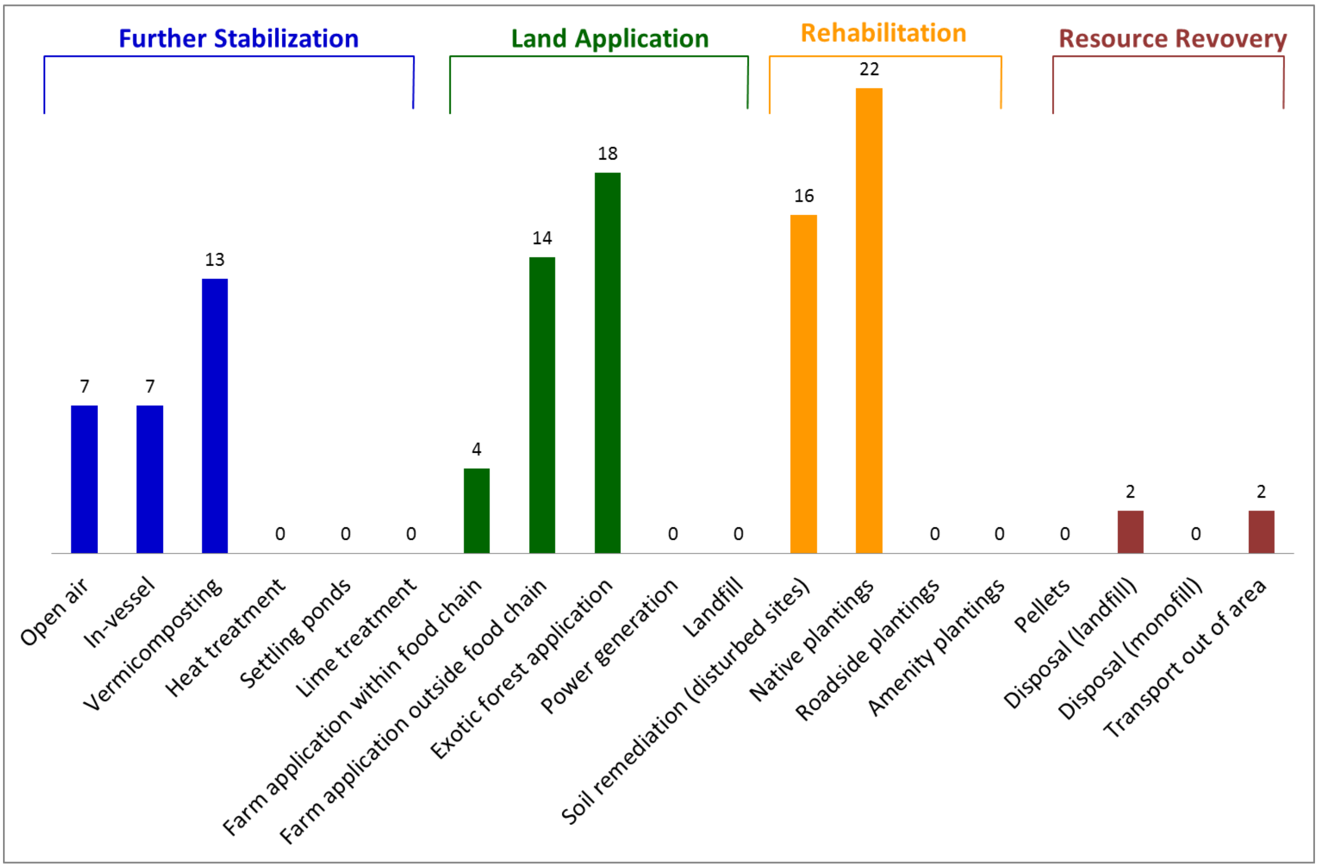

Figure 1: Ranking of biosolids reuse options from second community engagement hui, February 2011.

3.4 Third community engagement hui, December 2011

The third hui focused on providing community input into an environmental life cycle assessment and an economic analysis of reuse options undertaken by the CIBR team. The hui, at the Takahanga marae in December 2011, involved about 18 district council, tangata whenua and community group representatives. The aim was to elicit community priorities regarding environmental impacts and community 'willingness to pay' for vermicomposted biosolids.

The CIBR scientists explained environmental impacts that are quantified in a Life Cycle Assessment (LCA) study and then determined priorities through weighted voting. The votes were numbered one to ten to represent most to least important. Each stakeholder was allocated ten votes to represent how important the different environmental impacts regarding the biosolids reuse options were to them. Stakeholders were also encouraged to record the reasons for their vote. Details of the environmental impacts and the scores can be found in Figure 2.

The priorities placed on the environmental impact categories were relatively consistent (see Figure 2). A key output was that the community participants ranked water use, land use and water quality as the most important impacts and global warming as the least important. The stakeholders recorded despondency about environmental issues such as global warming and ozone depletion because these issues require a concerted and consistent international effort that has so far been absent. Consequently, they felt the most pertinent issues for the Kaikōura community were the ones they could do something constructive about. Therefore water use, land use, and water quality metrics scored as the most important. Given that the main industries in Kaikōura involve farming or marine tourism, this is understandable. However, climate and water are inextricably linked, and perhaps this approach did not make that explicitly clear.

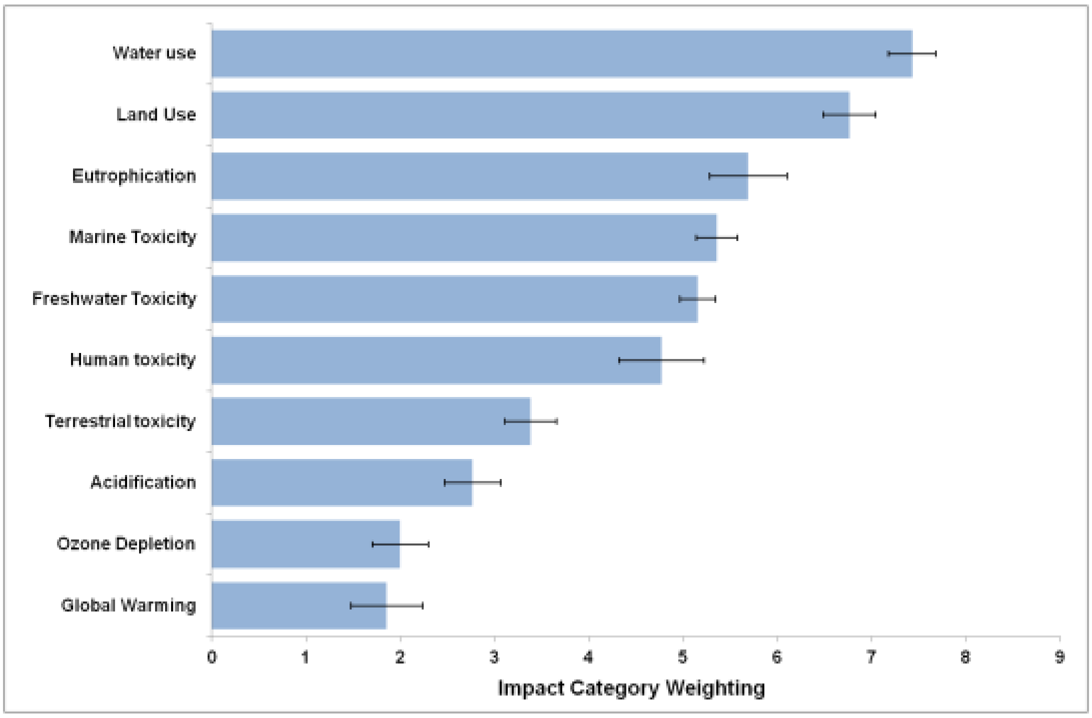

Figure 2: The environmental impact category weightings developed from voting. 10 = most important, 1 = least important (error bars are the standard error of the mean).

To provide input to the cost and benefit analysis for the open-air composting and vermicomposting reuse options, a questionnaire was presented to key community stakeholders who participated in this community engagement hui (see Section 5.0).

4.0 Life Cycle Assessment

Following the input received from the key community stakeholders at the third community engagement hui, December 2011 hui (see Section 3.4) a LCA was undertaken. The goal was to assess the potential environmental impacts for the selected biosolids reuse options. The functional unit was set as the treatment of one tonne of biosolids. The scope of the assessment extended from the initial stage to the end of life for all the reuse options and the associated operations. More information on the methodology behind LCA analysis is in Appendix 8.

The results of this study suggest that the direct land application options have a relatively benign environmental impact compared to the options that involve significant infrastructure or reprocessing. As depicted in Figure 3, all the reuse options were found to have a lower environmental score than landfilling the biosolids. This is likely to be symptomatic of the chemical composition of Kaikōura's biosolids and the total amount of biosolids to be processed considering the infrastructure necessary for the reuse options that involve reprocessing.

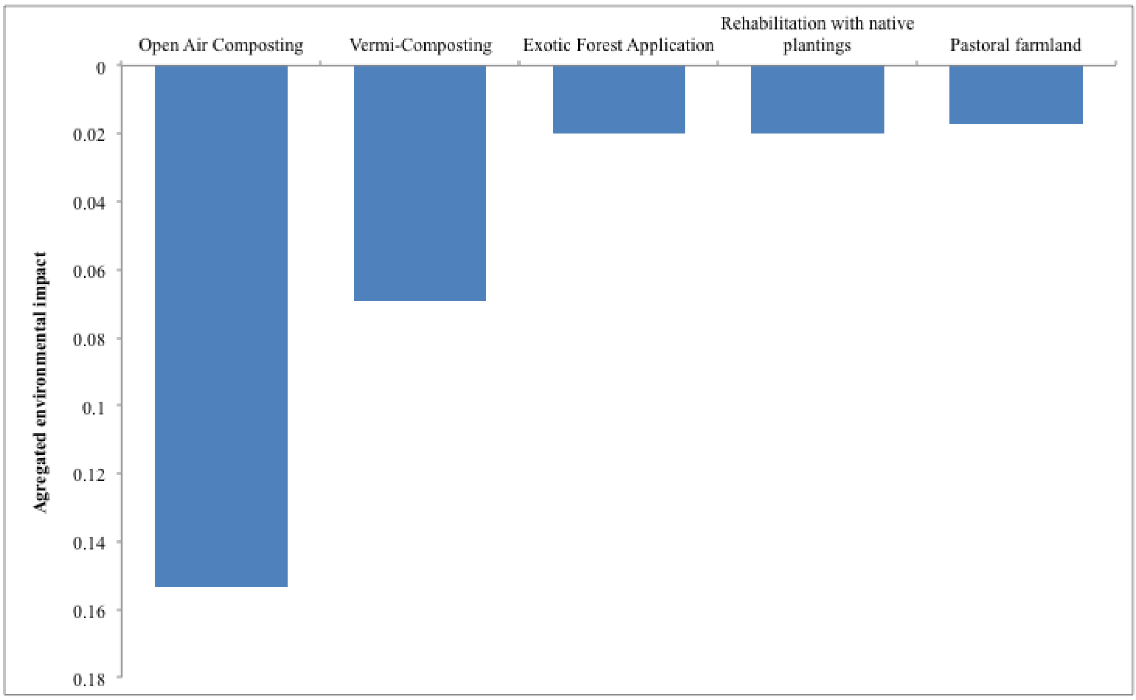

Figure 3: The aggregated environmental impact index for each of the reuse options presented relative to landfilling the waste.

5.0 Cost Benefit Analysis

A cost benefit analysis (CBA) was carried out to assess the relative net cost of each of the five preferred reuse options.

To provide input to the cost and benefit analysis for the open-air composting and vermicomposting reuse options, a questionnaire was presented to key community stakeholders who participated in the third community engagement hui (see Section 3.4). The questionnaire subsequently was supplied at a Te Rūnanga o Kaikōura monthly hui for additional responses and was completed by a total of 23 individuals from different stakeholder groups. One finding of the questionnaire was a measure of personal and community's 'willingness to use' and 'willingness to pay' for vermicomposted biosolids compared to the existing open-air composting of biosolids with green waste.

The questionnaire provided a scale of uses from most restrictive to least restrictive and participants were asked to indicate how far along the scale they would rank themselves as well as indicating their willingness to apply vermicomposted and open-air composted biosolids to their gardens. Four options were given, from most restrictive ("I would not even touch it") to least restrictive ("I would use it on my vegetable garden"), with two intermediate options (would not or would use on trees with edible fruit), and the respondents were asked to choose one option. For open-air composted biosolids, the highest proportion of respondents (41%) indicated that they would use it on trees with edible fruit; 23% would NOT use on trees with edible fruit, 18% would not even touch it, and another 18% would use it on their vegetable garden. For vermicomposted biosolids, 40% were willing to use it on their vegetable gardens, 30% would use on trees with edible fruit, 20% would NOT use on trees with edible fruit and 10% would not even touch it. This result might indicate that there is a potential niche market for biosolids compost in the community. However, the sample of respondents might be too small to provide a sufficient assessment of the market potential of biosolids compost in the community. A more comprehensive market study would need to be conducted if the community elected to explore this option further.

The questionnaire also provided an indication of the average ‘willingness to pay’ for a trailer load of biosolids compost (see Table 5), which was estimated as weighing 70 - 80 kg. Respondents were made aware of additional processing which occurs in vermicomposting which potentially could provide a higher quality end product than open-air composting. This is probably a reason why respondents indicated a greater average ‘personal willingness to pay’ ($21 per trailer load) for vermicompost rather than open-air compost ($17 per trailer load). In addition, they anticipated that the community would be prepared to pay a marginally higher amount (‘willingness of community to pay’) than indications of their ‘personal willingness to pay’. However, these values represented only about half of the current price ($40 per trailer load) of the regular compost produced from green waste without biosolids currently being sold by Innovative Waste Kaikōura (IWK) to the community.

Table 5: Personal and community willingness to pay for (WTP) biosolids vermicompost compared to current green waste composting (open air compost).

Biosolids compost	**Personal willingness to pay**		**Willingness of community to pay**	
	Mean WTP	(min-max)	Mean WTP	(min-max)
Open air compost	$17	$0 - 30	$19	$5 - 30
Vermicompost	$21	$0 - 30	$23	$5 - 40

Assumptions had to be made for each reuse option[1]. This included the assumption that the two composting options would be undertaken using IWK facilities. The status quo of leaving the biosolids permanently stockpiled at the wastewater treatment plant (business as usual) was not considered to be an option. Each option was apportioned into individual tasks to approximate the required amount of labour, machinery time, raw materials and transport to complete the task. For instance, for the open air composting option, cost items included health and safety costs, transport of biosolids and shredding of green waste. Benefits included the potential sale of the compost product and avoided payment of the waste disposal levy.

Based on a conversation with the IWK manager and calculations, it would take more than three years to process the stockpile of biosolids into vermicomposting. The open air composting option would take two years longer (than vermicomposting) as it requires additional processes. As the composting options would take several years to complete, the time value of money was accounted for using a discount rate of 8%. The exotic forest application option could be accomplished in the shortest time (about 12 weeks) and therefore discounting was not necessary. The anticipated cost of the open air compost and vermicomposting were about $60,000 and $75,000 respectively.

As there were no large areas of farm land outside the food chain available in the district it was not considered to be a practical option. However, if some farm land was taken out of food production it was estimated to take more than 2 years to complete and cost about $70,000.

The option of exotic forest application mainly involved the costs of transport and spreading of biosolids and did not involve materials and processing tasks. The benefit was principally the avoided payment of the waste disposal levy. There could be other benefits such as the potential increase in wood yield and improvement in soil fertility, but these may vary with the type of soil,

[1] Further refinement on the cost estimates of the options has been carried out since the March 2012 hui. Please see section 8.0 of this report.

rainfall, topography and temperature. No such data were available for forests in the district (e.g. Clarence forest) so they were not taken into account. Given that the nearby Clarence forest plantation is more than 390 hectares in area, the CBA calculations suggested that it is feasible to apply the stockpiled biosolids following the recommended New Zealand agronomic application guideline (maximum of 200 kg of nitrogen per hectare per year; NZWWA, 2003). The results indicated that application to exotic pine forest plantation at Clarence was the least expensive option (approximately $50,000).

Native plantings in small patches are scattered across the district. It would be expensive (about $85,000) and time consuming (more than 3 years) to spread the full quantity of the stockpiled biosolids to those sites. New planting was not included in the costing. However, reusing a smaller quantity of the biosolids in that way would be feasible.

Both the LCA and CBA were carried out under the assumption that only one option can be adopted, and that the Kaikōura community is obliged to manage their biosolids waste in isolation of other communities. Rural communities across New Zealand are faced with similar challenges and a collaborative approach to biosolids management may reveal new opportunities, options and insights. For example, options that rely on significant infrastructure may become more feasible in communities where larger economies of scale operate or infrastructures can be shared by communities in close proximity. Similarly, it may be more feasible to consider costings for a mix of preferred options.

6.0 Final community engagement process

6.1 Fourth community engagement hui, March 2012

A fourth hui was held at the Takahanga marae in March 2012 to bring together about 25 key stakeholders and members of the broader community to review the scientific and economic data, and determine the most suitable options for the reuse of the 1500 tonnes of stockpiled biosolids.

The options discussed at this community hui had been selected at the second community engagement hui (see Section 3.3), following the evaluation of a comprehensive range of options. They were grouped as follows:

a) No further treatment of the biosolids and
- application to exotic forest;
- application to farmland outside the food chain;
- application to rehabilitate land to grow native plants.

b) Further treatment of the biosolids and
- open-air composting and sold to the public;
- vermicomposting and sold to the public.

Extensive time and energy were put into recruiting key stakeholders with follow-up telephone calls to ensure their attendance.

At this hui, the CIBR team presented the results of research on the characteristics of the biosolids (i.e. beneficial nutrients and contaminants), LCA and the economic costs and benefits of the reuse options. (See Sections 4.0 and 5.0 for details.) This enabled full discussion of the preferred options for the communities' biosolids with the results of this research to hand.

Six researchers from the CIBR presented the key aspects of the biophysical, economics, social and cultural research to the Kaikōura community using a technique of very short presentations and key messages (five minutes each). This was followed by five minutes for questions. A board was provided for additional questions which participants wanted addressed, and a commitment was made to get the relevant scientist to answer the questions at points throughout the hui. Summary information on the five preferred options selected by key stakeholders at the hui in February 2011 was presented (Table 6). Information on biochar was provided, but use of biochar applied to land together with biosolids was not presented as an option for discussion as it was not considered a feasible option at this stage owing to the lack of adequate biochar resources available locally.

Table 6: Key characteristics of previously selected biosolids reuse options, developed by research team and presented to participants at the March 2012 hui.

	Preferred reuse options	**Key characteristics**
Further stabilisation	Open air composting	Expand IWK composting facility Biosolids mixed with community's green waste Grade 'Aa'# – safe to be handled by public with minimal risk Sold for private use Long term project (5 years+).
	Vermicomposting	Expand IWK composting facility Biosolids mixed with community's green waste Grade 'Aa' – safe to be handled by public with minimal risk Sold for private use Long term project (5 years+).
Land application	Farm application outside food chain (E.g. horse pasture; animals for fibre production; golf course or airfield)	Some pathogens and contaminants present Grade 'Bb' – site management required (e.g., grazing restricted for 6 months) Requires a lot of land (800 ha) Long-term project (5 years+) to complete (if land available).
	Exotic forest application	Large land required (400ha) Potentially Clarence (370ha) and Conway forests (20 ha flat land and roadsides) available Some pathogens and contaminants Grade 'Bb' – site management required (e.g., no public access for 6 months) Require hiring of spreader Short time to complete (months).
	Rehabilitation with native plantings	Landfill, alongside walkways, coastal areas & amenity plantings 1998 Kaikōura Coastal Management Strategy but limited finance Some pathogens and contaminants present Grade 'Bb' – site management required (e.g., > 5m from waterways) Large area required (400 ha) Cost of seedlings and planting additional costs Long-term project (10 years+ to complete).

Biosolids grades are determined the Guidelines for the Safe Application of Biosolids to Land in New Zealand (NZWWA, 2003) and briefly described in Appendix 2.

After presentation of the research results, a facilitated workshop session was held to enable key stakeholders to discuss the five options for their biosolids. A station for each option was set up and manned by a technical expert and a note taker. This facilitated an open forum between the community and the CIBR researchers. All views and opinions of the participants were recorded for each option. Participants were asked to comment if they *supported* or *did not support* each option. (A summary of views expressed is presented in Appendix 9).

This was considered to be the most important component of the hui from both the participants' perspective and that of the social and cultural researchers. It represented a key moment in integrated research, and perhaps the pinnacle of CIBR Kaikōura case-study as the research information, research experts and community came together to discuss the options in detail and record the views and opinions of the participants with respect to each option.

Community participants voted on their preferred option(s). Each participant was given five votes that were weighted according to their preference order. Participants were asked to vote according to their order of preference of each option. Their first choice was equal to five points, the second choice to four points, etc.

7.0 Community recommendations for biosolids reuse

The land application of the stockpiled biosolids to exotic forestry and for rehabilitation with native seedlings were the two most popular reuse options (see Figure 4) following voting described in Section 6.1. In total, the options which did not further process the biosolids received about 60% of the support, compared to the composting options; open air and vermicomposting combined had 36% support.

The community participants supported:

- biosolids application to exotic forest plantations (84 weighted votes; 31%);
- application to rehabilitate land to grow native plants (65 weighted votes; 24%); and
- composting (both open-air composting (42 weighted votes; 15%) and vermicomposting (57 weighted votes; 21%) prior to being sold to the public.

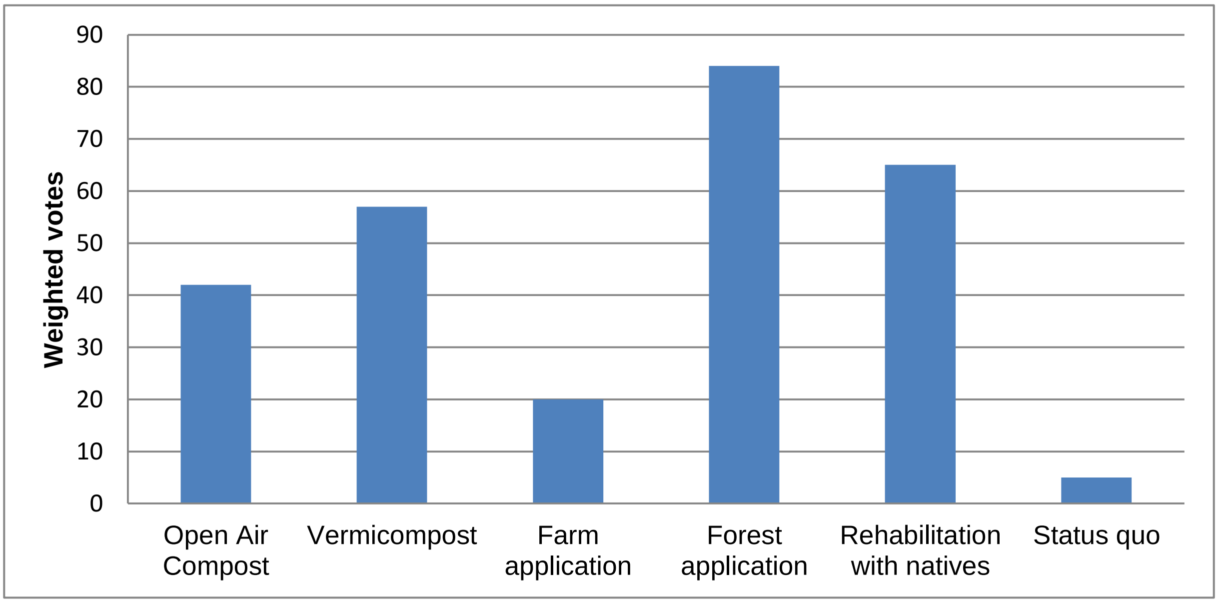

Figure 4: Weighted votes for the five preferred biosolids reuse options and the status quo.

Less community support was given to farm application outside the food chain (20 weighted votes; 7%). One attendee voted for the status quo (2%) which entailed leaving the biosolids in the current stockpile site with a latter option of combining it with wood waste.

Although exotic plantation application was the individual option receiving the most support, the community favoured a multi-solution approach with biosolids reused in more than one option.

Kaikōura District Council took part in the entire case study from its inception to the fourth hui and received the community recommendations for preferred reuse. The biophysical research provided the characterisation information on the Kaikōura biosolids, carried out specific research on these biosolids and drew on the wealth of New Zealand and international research findings. The community provided well-considered and described input in the reuse option evaluation process.

At the time of the hui and in a series of telephone interviews with participants the CIBR research team received very positive feedback and comments about the process which was designed and tailored specifically for this community (see Appendix 10). The process was praised for providing relevant information in an understandable and usable form, being inclusive of the community, enabling people to be heard, and facilitating fair and informed decision-making.

The full community engagement process was very successful in bringing members of the community together with researchers to discuss, understand and debate biosolids reuse, concluding with the community determining their preferred options.

8.0 Further Cost Benefit Analysis

Following the final community engagement hui a more refined cost benefit analysis was conducted to consider the costs and time required for the reuse of the biosolids in greater detail. Assumptions were made of estimated costs and all options were off-set by the cost of the Ministry for the Environment waste levy ($10/tonne) avoided by not landfilling the biosolids ($11,000). It was assumed that a permanent resource consent would not be granted to maintain the stockpiled biosolids indefinitely at the wastewater treatment site (see Appendix 11).

The refined numbers come out roughly the same as those presented at the hui, with the same order. The forest option favoured at the March 2012 hui was slightly less expensive than was presented, and vermicomposting slightly more.

The cost and time for application of the two composting and forest options remained largely unchanged (see Table 7). As no large areas of farm land outside the food chain were available in the district this option was not explored further. Similarly the cost of application of biosolids to native plantings was not considered in further detail because native plantings only occur in small patches and these are scattered across the district. It was considered to be uneconomic and time consuming to spread the full quantity of the stockpiled biosolids to those sites and new plantings would add substantial costs.

Following a more detailed analysis of the exotic forest application it was estimated only to take approximately 4 weeks to apply and cost approximately $46,400 (see Table 7). This was established on the basis of 20 days' work for 2 full-time workers, 17 half-days' work for 2 part-time workers and personal protection (see Appendix 11). In addition, the cost of the resource consent application was estimated to be $15,000.

Table 7: Summary costings for the five preferred biosolids reuse options for the Kaikōura biosolids.

Option	Time period	Net Cost
1. Open air composting (IWK)	5 years	$59,100
2. Vermicomposting (IWK)	3 years	$78,100
3. Farm (non-food) application	No non-food farm land in the district	
4. Exotic forest direct application (Clarence forest)	4 weeks	$46,400
5. Application on native plantings	Very long time	Very high cost
6. Business as usual (not an option)		

9.0 Key lessons

- The Kaikōura case-study has illustrated that there is community interest in the management of biosolids.
- Community engagement at an early stage in a potentially controversial topic can be mutually beneficial for both the local authority and the community.
- The integration of social, cultural, environmental and economic considerations as part of the engagement model gave the community a mechanism to weight (prioritise) their concerns, enabling the community and the council to make a more informed, robust and transparent decision.
- Quantitative approaches using techniques such as Life Cycle Assessment help clarify issues.
- The biosolids Guidelines require upgrading, for example they do not factor in community engagement. The experience from the Kaikōura case study offers future guidelines a framework for community engagement.
- Regional management options that involve adjacent rural and urban communities may be more efficient because of an economy of scale.
- The planned process developed by the research team to facilitate active involvement of key stakeholders in the Kaikōura community in decision-making around the disposal or reuse of their biosolids was a successful model to guide the development of ‘fit for purpose’ community engagement guidelines.

10.0 Recommendations

- Kaikōura District Council gives transparent consideration of the options preferred by the community for future reuse of the stockpiled biosolids, relative to constraints of the Council plan and budget.
- The CIBR team continues to work with the Council and community to help facilitate the next steps in the process.
- The CIBR develops a best practice or ‘fit for purpose’ framework using the Kaikōura collaborative process to guide other councils and communities to consider the options and adopt sustainable reuse solutions for biosolids reuse. The CIBR encourages other local governments and communities to adopt similar forms of collaborative community engagement to generate robust and sustainable decision-making for other environmental health issues.
- CIBR biophysical research continues to provide knowledge of nutritional benefits and environmental impacts of contaminants for the land application of biosolids.

Acknowledgments

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On behalf of the CIBR, we would like to thank our Māori research partners, Te Rūnunga o Kaikōura for their superb hosting and manaakitanga for these hui, and for their support, engagement and invaluable contribution to the research.

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Appendix 1. Key Terms

Biowastes

In New Zealand about 2.5 million tonnes of solid waste are sent to landfills each year (http://www.mfe.govt.nz/environmental-reporting/report-cards/waste-composition/2011/). Biowastes (organic biodegradable component of municipal, commercial and industrial waste including food, garden and household wastes) make up about 28% of the total wastes going to landfill in New Zealand (Ministry for the Environment, 2009).

One of the major components of any community's organic waste is biosolids (treated or stabilised sewage sludge). Biosolids are carbon-rich and contain valuable nutrients. However, biosolids can contain a range of micro-contaminants such as heavy metals, pathogens, pharmaceuticals and personal care products. While these characteristics present challenges, the waste material also offers opportunities for reuse. Small communities face the extra challenges of producing low volumes of a variety of different organic wastes and finding a low-cost and low-tech waste solution that matches the community's aspirations for the reuse that can be easily managed within the community.

Biosolids

About 77,000 tonnes (dry weight) of biosolids are produced each year in New Zealand (New Zealand Waste Water Association, NZWWA, 2003) from approximately 250 public wastewater treatment plants.

At least 60% of the biosolids end up in landfill or monofill (a type of landfill where only one product is disposed of), largely because of the perceived and real uncertainties about the risks of alternative disposal methods (WaterNZ survey 2012, unpublished data). Only around 20% is reapplied to land.

Centre for Integrated Biowaste Research

The Centre for Integrated Biowaste Research has been developed to better understand the environmental risks and benefits that can arise from applying biowastes (particularly biosolids) to land, with the aim of facilitating more sustainable reuse options such as land application. The CIBR research programme brings together a multi-disciplinary team of scientists and researchers from ESR, Scion, Cawthron Institute, Landcare Research, Northcott Research Associates, Lincoln University, Kukupa Research, Te Rūnanga o Kaikōura and Whenua.biz. CIBR specialists have expertise in environmental microbiology and toxicology, forest ecology, soil science, molecular biology, social sciences, economics, soil chemistry, biochemistry and Māori issues-based research.

The CIBR can help communities consider the options for biowastes reuse, enabling them to decide on the best solution for their situation. The Kaikōura community was chosen for a case study approach following positive discussions with Te Rūnanga o Kaikōura and the Kaikōura District Council in 2009.

Appendix 2. Chemical and microbiological contaminants in biosolids

A 2.1 The Guidelines for the safe application of biosolids to land in New Zealand (the Guidelines

The guidelines contain information and recommendations to assist producers, dischargers and regulators (regional councils) to manage the discharge of treated domestic sewage to land in New Zealand. However, these Guidelines have no legal status and the application of biosolids to land is regulated by the Resource Management Act (1991) and the Health Act (1956). A resource consented application carries with it a requirement to prepare an assessment of environmental effects (AEE) and, in some cases, provides an opportunity for full public scrutiny of the proposal by a public notification process. The AEE must be prepared in accordance with the Fourth Schedule of the RMA. Sometimes a specific public health risk assessment may be required.

A 2.2 Biosolids Guidelines grading system

The New Zealand biosolids guidelines propose a grading system based on microbiological and chemical contaminants. The grading system is made up of two parts: the first part (denoted capital 'A' or 'B') represents the stabilisation grade. The second part (denoted by lower case 'a' or 'b') represents the contaminant grade. 'A' grade biosolids have substantially reduced pathogen contaminants, such that the product is deemed safe to be handled by the public with minimal risk. Grade 'B' biosolids can have a lower level of treatment and may contain pathogens. Heavy-metal and specified organic compounds concentration limits for Grade 'a' and 'b' biosolids are specified in the Guidelines (NZWWA, 2003). However, the range of chemical contaminants considered in the Guidelines is quite narrow and does not include a number of contaminants of concern, such as those deriving from pharmaceuticals and personal care products.

A 2.3 Pathogens

Pathogens, including bacteria, viruses, parasites and fungi, are too small to see with the naked eye and are a concern as they can cause disease. If a person has an infection (e.g. food poisoning) the number of pathogens that they excrete can be extremely high, and can continue for many weeks, so they remain carriers. Consequently, pathogens in the waste stream cannot be controlled at source like other contaminants (e.g. heavy metals).

The range of pathogens that may be found in waste streams include bacteria, viruses, parasites (helminths/protozoa) and fungi. The most important pathogens in terms of human health risk assessments are those spread by the faecal-oral route and include organisms such as *Campylobacter* species, *Salmonella* species and enteric viruses.

Many regulations suggest a dual-barrier approach to ensure public safety. Firstly, the sludge is stabilised (in the case of Kaikōura this has involved stockpiling the sludge for 6 years), which considerably reduces, but does not eliminate the pathogen load. Therefore there is still the potential for contamination of food crops and surface and ground waters by run-off of pathogens from land-applied biosolids. The second part of the dual-barrier is the application of constraints such as exclusion periods for public access to a site, or withholding periods before land can be used (e.g. for grazing) or a crop harvested.

Grade 'A' biosolids are effectively 'pathogen free' and microbiological criteria specified in the guidelines are based on detection limits for a particular pathogen. Grade 'A' biosolids products have unrestricted use in land treatment systems (if the product also has reduced chemical contaminants), and are considered to be of sufficiently high quality that they can be safely handled by the public and applied to land without risk of significant adverse effects.

It is not practicable to monitor biosolids for the presence of the wide variety of potential pathogens. A more reasonable approach is to monitor indicator organisms and representatives of known pathogenic species to represent the larger set of pathogens (e.g. *Salmonella* species, enteric viruses and helminth ova). Indicator organisms such as total and faecal coliforms and *E. coli* are often used in predicting both the density and reduction of pathogenic bacterium and viruses. The advantages of using indicator organisms also include ease of counting. However, it has been widely demonstrated that coliform bacteria do not adequately reflect the occurrence and survival of pathogens in treated sewage and wastewater. Thus it is important to monitor a suite of organisms including a subset of pathogens such as those specified in the guidelines (NZWWA, 2003).

Grade ‘B’ products have no recommended pathogen levels in the biosolids guidelines, but must undergo processing such as anaerobic digestion to reduce attracting vectors. Vectors (e.g. rodents and insects) are attracted to putrescible organic matter (such as raw sewage sludge) and are able to spread disease by carrying and transferring pathogens. Further processing can reduce vector attraction or remove such putrescible organic matter. Owing to the higher levels of pathogens potentially present in Grade ‘B’ biosolids, adequate time (6-12 months) must be allowed for the biosolids to remain in, or on, the land for natural die-off to further reduce the pathogens before use of the land for cropping or public access is allowed. These recommended controls enable environmental factors, such as temperature and ultra violet light (UV) exposure, to enhance the decay of microorganisms, thereby reducing any potential public health risks from exposure to pathogens potentially present in biosolids. It is considered useful to analyse the pathogen content of Grade ‘B’ biosolids before land application particularly if the application site is near to an urban area, or if there is public resistance to land application of wastes. It is also recommended that for Grade ‘B’ biosolids, monitoring is carried out on the land where biosolids have been applied at the end of the restraint period (after 6-12 months, e.g. public access constraint after application of biosolids to forest land) in order to ensure that there has been no cumulative increase in microorganisms from the biosolids application. Control samples (i.e. from an adjacent site that has not had any biosolids applied to it) should be taken before application and at the end of the restraint period to determine ‘background’ *E. coli* numbers as these may fluctuate naturally (with season). High background levels also could indicate presence of feral animals or birds. If numbers of *E. coli* are found to be 100 fold higher than background counts, decisions about further restricted access or landuse should be made on a case-by-case basis after consultation with the local Medical Officer of Health (Health Act, 1956). For example, if access is required to fell trees, forest workers could be exposed to elevated levels of pathogens in dust particles. *E. coli* analysis is neither arduous nor expensive, and may provide useful information on pathogen die-off in receiving soils and potentially minimise public health concerns.

A 2.4 Organic contaminants

Traditionally, the organic chemicals in sewage sludge of most concern to regulators worldwide have been those classified as Persistent Organic Pollutants (POPs). At the time the New Zealand biosolids guidelines were being drafted, POPs were the principal organic contaminants of concern to New Zealand regulators. At the same time, the European Union and United States Environmental Protection Agency included POPs as contaminants for biosolids destined for application to land. This led to a range of POPs and concentration limits being incorporated into the guidelines. The chlorinated POPs specified within the guidelines include organochlorine pesticides, polychlorinated biphenyls (PCBs) and polychlorinated dibenzodioxins/furans (PCDD/PCDFs).

A number of subsequent studies demonstrated that the concentration of these POPs continues to decline in the New Zealand environment and in New Zealand biosolids. This was confirmed in the 2005 MfE sponsored Roadblocks study (Ministry for the Environment, 2005) which found no detectable levels of persistent organochlorine pesticides (DDT, lindane, dieldrin, aldrin etc.) in New Zealand biosolids. While the Roadblocks study did not specifically analyse PCBs or PCDDs/PCDFs in New Zealand biosolids, other studies of these POPs within New Zealand clearly demonstrate their concentrations continue to decline. Today they represent ever decreasing background concentrations that present little or no risk to the environment. It is debatable whether the POPs currently included within the biosolids guidelines are appropriate, or if they should be replaced with more relevant chemicals, particularly high production-volume chemicals that are widely used on a day to day basis.

Over the last decade a wide range of organic chemical residues, collectively termed organic wastewater contaminants (OWCs), have been identified in biosolids. OWCs include emerging contaminants such as PPCPs, endocrine disrupting chemicals (EDCs), surfactants and their metabolites, fragrances, plasticisers and pesticides. PPCPs are used in almost all consumer products including medicines, fragrances, skin and hair care products, cosmetics, insect repellents, and industrial and domestic cleaning products.

There is limited local data on the concentration of OWCs and the CIBR research programme is addressing this issue by analysing a wide range of OWCs in New Zealand biosolids, including the material stockpiled at Kaikōura.

At this time there is an absence of risk assessment data for OWCs in biosolids, soils, and biosolids-amended soils. However, risk assessments of these contaminants in aquatic ecosystems demonstrate they pose a very low risk to human, wildlife and environmental health. In the soil, most organic contaminants are likely to be degraded through a range of microbial and biological processes over time. Data available from international biosolids field trials demonstrate the majority of OWCs do not accumulate in biosolids amended soil, the levels measured do not pose a risk to the environment, humans and wildlife, and have no measureable impact on soil fertility and function.

In summary there is currently no evidence to suggest OWCs applied to land in New Zealand under the recommended guidelines present a risk to the environment, wildlife, or human health. Research in this area is continuing.

A 2.4.1 Ecotoxicology studies of organic contaminants found in biosolids

Ecotoxicology studies the effects of natural and synthetic chemicals (stressors) in the biosphere on exposed biota. The ecotoxicology component of the CIBR assesses the risk associated with contaminants that can persist through the various treatment technologies and accumulate in the biosolids. Those contaminants could lead to potential detrimental effects if applied to the soil or could leach into the environment. To date, the CIBR research on New Zealand biosolids has demonstrated that they contain a range of micro-contaminants. The contaminants identified are varied and originate from various industrial and domestic sources, including pharmaceuticals, personal care products and industrial chemicals. These chemicals are found at low concentrations and are often referred to as micro-contaminants, but form very complex mixtures of chemicals once they accumulate in biosolids. To assess the toxicity of the biosolids, trials were established using standard earthworm tests. Earthworms are excellent indicators of toxicity as they live in close contact with the contaminants and the tests used are well-established and recognised worldwide. The tests provide information on the short-term toxicity of the biosolids as well as the sub-lethal longer-term effects of the contaminants on the reproductive fitness or the ability of the earthworms to produce neonates. This is a key parameter as a reduced capacity to reproduce and maintain healthy populations can have devastating consequences for an ecosystem.

Appendix 3: Chemical analyses for Kaikōura biosolids

Hill Laboratories
BETTER TESTING **BETTER RESULTS**

R J Hill Laboratories Limited
1 Clyde Street
Private Bag 3205
Hamilton 3240, New Zealand

Tel +64 7 858 2000
Fax +64 7 858 2001
Email mail@hill-labs.co.nz
Web www.hill-labs.co.nz

ANALYSIS REPORT — **Page 1 of 3**

Client:	NZ Forest Research Institute	**Lab No:**	864826
Address:	Sala Street	**Date Registered:**	03-Feb-2011
	Private Bag 3020	**Date Reported:**	08-Feb-2011
	ROTORUA 3046	**Quote No:**	
		Order No:	
		Client Reference:	X09692
		Add. Client Ref:	Kaikoura Biosoil
Phone:	07 343 5899	**Submitted By:**	Scion

Sample Name: X09692 Kaikoura Biosoil — **Lab Number:** 864826.1
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range	Low	Medium	High
pH	pH Units	5.3	5.8 - 6.3			
Olsen Phosphorus	mg/L	128	20 - 30			
Potassium	me/100g	1.90	0.50 - 0.80			
Calcium	me/100g	31.9	6.0 - 12.0			
Magnesium	me/100g	5.00	1.00 - 3.00			
Sodium	me/100g	0.69	0.20 - 0.50			
CEC	me/100g	56	12 - 25			
Total Base Saturation	%	71	50 - 85			
Volume Weight	g/mL	0.39	0.60 - 1.00			
Sulphate Sulphur	mg/kg	1,089	7 - 15			
Aluminium ($CaCl_2$ Extractable)*	mg/kg	0.3	0.0 - 3.0			
Boron	mg/kg	3.2	1.0 - 2.0			
Dry Matter*	%	37.5				
Moisture*	%	62.5				
Base Saturation %		K 3.4	Ca 57	Mg 8.9	Na 1.2	
MAF Units		K 15	Ca 16	Mg 44	Na 12	

The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the

Appendix 4. Pharmaceutical residues in biosolids (ppb)

Therapeutic Class	Compound	Kaikōura
Analgesics & NSAIDS	Phenazone	N.D
	Propiphenazone	N.D
	Ketoprofen	N.D
	Naproxen	47
	Ibuprofen	N.D.
	Indomethacin	N.D.
	Mefenamic Acid	6
	Acetaminophen	76
	Diclofenac	8
	Phenylbutazone	N.D.
	Codeine	N.D.
Lipid Regulators and Statins	Bezafibrate	8
	Fenofibrate	67
	clofibric acid	N.D.
	Gemfibrozil	1
	Atorvastatin	17
	Mevastatin	N.D.
	Pravastatin	N.D.
Beta Blockers	Atenolol	N.D.
	Sotalol	7
	Metoprolol	42
	Timolol	N.D.
	Nadolol	1
	Pindolol	N.D.
	Propanolol	114
	Betaxolol	N.D.
	Carazolol	N.D.

Therapeutic Class	Compound	Kaikōura
Antihypertensives	Nifuroxazide-hyp	36
	Enalapril-hyp	N.D.
	Lisinopril-hyp	N.D.
Anti-depressants	Carbamazepine	105
	Lorazepam	N.D.
	Diazepam	N.D.
	Fluoxetine (SSRI)	N.D.
	Paroxetine (SSRI)	N.D.
Macrolide Antibiotics	Clarithromycin	4
	Roxythromycin	BLD
	Erthromycin	BLD
	Josamycin	BLD
	Tylosin	BLD
	Azithromycin	BLD
Other Antibiotics	Sulfamethazine	3
	Trimethoprim	5
	Chloramphenicol	N.D.
	Metronidazole	N.D.
	Sulfadiazine	9
	Sulfamethoxazole	15
	Norfloxacin	BLD
	Ciprofloxacin	29
	Danofloxacin	N.D.
	Flumequine	N.D.
Bronchodilators	Clenbuterol-bronch	N.D.
	Salbutamol-bronch	0

Therapeutic Class	Compound	Kaikōura
Barbiturates	Phenobarbital	N.D.
	Butalbital	N.D.
	Pentobarbital	10
	Nifuroxazide-hyp	36
	Enalapril-hyp	N.D.
	Lisinopril-hyp	N.D.
Diuretic	Hydrochlorothiazide-di	4
	Furosemide-diur	8
Antacids	Glibenclamide	
	Ranitidine	23
	Cimetidine	10
	Famotidine	2

Appendix 5. Summary of findings from personal interviews with Kaikōura key community stakeholders

Four themes were explored during the interviews and generated the following responses:
What do Kaikōura residents value about their environment?

- Interviewees gave a very clear picture of aspects about the town that were important to them, with special emphasis on the quality of the environment and an important sense of being part of the community.

What do they think should be done about the biosolids?

- There was strong enthusiasm for managing biosolids reuse in the town, according to the recycling principles that prevail;
- For many, the biosolids were not perceived as ‘treated’ and there were many concerns about the composition of the biosolids and the presence of residual contaminants that might be harmful to both the environment and human health;
- Information from scientific analysis was seen as an essential requirement to direct the eventual selection of biosolids reuse option(s);
- There was some interest in use of the biosolids for fuel, power or to treat damaged land, but this also raised questions about inherent cost and volume requirements and possible air pollution; and
- There was unanimous interest in the possibility of land application, but with mixed views on whether or not biosolids should be used on productive or non-productive land. More particularly there was interest in whether it should or should not be used on farm land within the food chain.

What are their concerns about the possible impact of biosolids disposal?

- Many were concerned about leachate from the biosolids affecting underlying soils, aquifers and waterways;
- There was concern about readiness of the wider community to accept land application; and
- There was concern about adverse long-term implications of any initiatives or aspects that might not be foreseeable now.

Measures such as learning from overseas initiatives, gaining financial support, managing the location points of dispersal, education and communication, and conducting a pilot within the town were offered as possible solutions to these concerns.

What role do they feel that the community should play in the decision-making process?

- Further stakeholder groups were suggested, including those representing medical professionals, farmers, tourist accommodation, business organisations, Kaikōura dairy factory, and schools or students;
- There were mixed views on how the public should be consulted. These ranged from an open forum for the community as a whole, to a smaller working group comprising stakeholder representatives;
- Two tiers of information needs were identified, ranging from ‘short and simple’ to ‘detailed and comprehensive’; and
- Many felt that the decision-making was, ultimately, the responsibility of the council.

Insight into community views on contaminants

Although the questions were not focussed specifically on their views on contaminants, through the course of the interviews this issue was frequently raised by interviewees, thus allowing an insight to be obtained on the Kaikōura community’s views on contaminants.

Many interviewees considered that the biosolids are currently a product with the potential to contaminate.

> *"The stuff they've got piled up there now - how bad is it? I would imagine it's not great stuff by a long stretch - what would you need to do to bring it back?"*

> *"I'm quite open to recycling and using it as no waste is bad waste. If we could get out the bad stuff that would be good but then I suppose it's got to go somewhere then doesn't it?"*

Typically the types of issues mentioned were unknown concentrations of heavy metals, chemicals, toxic products, acids, pharmaceuticals, nitrates, hormones, or elements that are hazardous to the environment or humans. There was also concern about by-products from humans that might cause disease, such as viral matter or "bad" bacteria. The high through rate of tourists (about 1 million tourists annually) potentially carrying contaminants was noted, as was the longevity of any undesirable microbial or viral DNA which has the capacity to resist treatment and lie dormant for many years.

> *"A concern is around biological problems and the longevity of viral matter because we have so many tourists through here - it is quite possible that they are carrying something and are unaware of it."*

Concern was also raised about the nature of growth from plants or grass grown with biosolids and whether or not contaminants follow through to the plant or grazing into the food chain.

When discussing land application options about half the interviewees voiced concern was about the contamination of underlying soils, waterways and, eventually, the sea from contaminated water leaching out of the biosolids, or from rain water washing through it.

> *"You wouldn't want to get it flowing into streams if it has the same impact as say the excrement from dairy."*

Potential negative impacts of initiatives
About a third of the interviewees were concerned that, whatever initiative was selected for biosolids reuse, it should not have adverse consequences either 'further down the line', or at a later date. Examples where similar initiatives had unexpected adverse consequences were given, such as: contamination and lengthy deterioration times of products once advocated for disposal at landfills; contamination of waterways from farm effluent; making the product too costly to appeal to the target market; costly waste collection facilities encouraging illegal dumping; and facilitating undesirable practices (such as mining) by offering a final appealing solution.

> *"We should become more innovative in the way that we do things so we don't have to come up with solutions to clean up a bit of land because we have done so and so to it - we should be trying not to ever damage in the first place."*

> *"In today's world we see things that have been put on the ground 10 or 20 years ago and now they're suffering from diseases they've got from it."*

> *"Let's learn from those lessons. Don't just look at the short-term fixes. Let's see if all this study and research can say we can now come up with a process for this solid that's going to sustain us forever."*

There was also a cautious note about tracing back a serious disease (i.e. Bovine Spongiform Encephalopathy - BSE) to a practice once considered acceptable and safe.
Further details can be found in Langer et al. (2012).

Appendix 6. Kaikōura biosolids processing options

Further stabilisation – biosolids from Kaikōura's settling ponds		
Method	**Potential**	**Comments**
Open Air Composting	Yes	Could become grade 'Aa' from grade 'Bb'
In-Vessel Composting	Possible	Could become grade 'Aa' from grade 'Bb' but expensive
Vermicomposting	Yes	Could become grade 'Aa' from grade 'Bb'
Incineration	No	Potential for energy production BUT high cost – probably not suitable for small communities
Vitrification	No	High cost
Heat Treatment	Maybe	Could become grade a for pathogens, but still grade 'B' for contaminants unless diluted; BUT high cost probably not suitable for small communities
Settling Ponds	Possible	Present Kaikōura biosolids dredged from settling ponds
Lime Stabilisation	Possible	Possible BUT no real advantage as Kaikōura biosolids already stabilised due to long-term storage; Could become 'a' for pathogens
Reed Beds	No	Only applicable for liquid effluent

Resource Recovery		
Method	**Potential**	**Comments**
Gas Extraction Methane	No	Currently not feasible for a small community – maybe in 20 yrs??
Gas Extraction Hydrogen	No	Currently not feasible for a small community – maybe in 20 yrs??
Pyrolysis	No	Currently not feasible for a small community – maybe in 20 yrs??
Thermal oxidation	No	Technology still being developed and currently not feasible for a small community – maybe in 20 yrs??
Pellets – Heat drying	Possible	Currently not feasible for a small community – maybe in 20 yrs??– However, New Plymouth use this technology and recover some costs by selling as fertiliser
Final Treatment		

Land Application/Beneficial Reuse – Fertiliser & soil conditioner		
Method	**Potential**	**Comments**
Farm application within food chain	Yes	Utilise nutrients, but grade 'Bb' needs resource consent and site controls
Farm application outside food chain	Yes	Utilise nutrients, but grade 'Bb' - needs resource consent and site controls
Exotic forest Application	Yes	As above but out of food chain
Power generation – Biofuels	Possible	Would require large areas dedicated for biofuel crop planting
Landfill Cap	Yes	Add biosolids as a cap to landfill to grow vegetation on the landfill in some cases

Rehabilitation Fertiliser & soil conditioner		
Method	**Potential**	**Comments**
Soil remediation on disturbed sites	Yes	Application to low grade soils to improve fertility – grade 'Bb' so controlled land application; Generally native plantings
Native plantings	Yes	Except close to waterways
Roadside plantings	Possible	In strategic locations
Amenity plantings	Possible	Parks and reserves, golf clubs etc.
Disposal		
Method	**Potential**	**Comments**
Landfill	Possible	Does not utilise nutrients, Waste Minimisation Levy, transport costs etc.
Monofill	Possible	A single use landfill that does not utilise nutrients, Waste Minimisation Levy, transport costs etc.
Other		
Method	**Potential**	**Comments**
Transport out of district	Possible	High costs, would need to find somebody else who wants it

Appendix 7. Kaikōura second community engagement hui, February 2011

Facilitated workshop session: comments from the community

1. **Further Stabilisation (e.g. composting)**

Environmental positive
- Take biosolids to Grade 'Aa' for any use.

Environmental negative
- Nil.

Social Cultural positive
- Take to Grade 'Aa' – perception;
- Plus end use costs/recovery – could you sell it; and

Social Cultural negative
- Nil

Economics
- Relatively low cost for the potential benefit;
- IWK already compost – might be low or no cost to community
  - so cheaper than forest application and could recover cost;
- Scale of economic cost and rarity;
  - When P becomes rare will biosolids become more popular?
  - Economic value is scarcity driven; and
- Use worms to compost biosolids + green matter
  - Bulk up, sell worms and capture market.

Feasibility/Other
- Will levels of metals change over time with improved system?

Questions or further issues
- Other emerging contaminants;
- Resource consent easier for Grade 'Aa' compared to 'Bb'
  - Are there greater costs for different options? and
- Emphasis on heavy metals and not on oestrogens – why??

2. **Resource Recovery (e.g. landfill)**

Environmental positive
- Minimum cost to environment; and
- Transport out
  - Only if being used in environmentally responsible and beneficial way**.**

Environmental negative
- Insufficient space in landfill
  - Goes against community goals
  - Loss of potential [nutrients] in biosolids; and
- Transport out – do other districts want our biosolids?

Social Cultural positive
- Nil.

Social Cultural negative
- Cultural impact negative on Papatuanuku;
- Inconsistent with Green Globe status; and
- Irresponsible.

Economics

- Pellets, landfill, transport out of Kaikōura - Big $$$$$ - worth looking at.

Feasibility/Other

- Landfill impacts – need to look at 50 years – future questions.

Questions or further issues

- Potential of mobile units to deal with small communities - future options; and
- Landfill impacts – need to look at 50 years – future questions.

3. **Land Application**

Environmental positive

- Farm outside food chain;
    - As long as designated land does not go into food production later
    - Time bomb effects of unknown contaminants;
- Exotic forest
    - Time bomb effects of unknown contaminants; and
- Landfill cap – already out sourced [by IWK].

Environmental negative

- As analytical detection capabilities increase
    - Time bomb effect;
- Future proofing for future use
    - Emerging contaminants will compromise future use; and
- Is there enough planting [area] to make forestry feasible option?
    - Buffer zones – make areas of application "no go" areas.

Social Cultural positive

- Go up the pipe
    - Education of community and visitors to product usage;
- Take responsibility for our behaviour;
- Only one application possible – to the forest;
- Kaitiakitanga – responsibility of iwi as stewards and caretakers for
    - Land, waterways [rivers, sea]; and
    - All people.

Social Cultural negative

- Future unknown risks;
- Land application has an effect on the land of:
    - Manawhenua values, Wairua, mana, mauri ora, hau ora;
- Land application into food chain has risks for:
    - Us, our children, our children's children
    - Requires more information over time before considerations given;
- Mauri ora – impact on human health;
- Mauri – everything else pertaining to environment;
- Hau ora, the benefits of Mauri ora; and
- Land application for food and fodder
    - A 10+ year mindset to go before people will adopt this.

Economics

- Not enough biosolids for power generation or growing biofuels.

Feasibility/Other

- Quantity is not huge;
- Don't need to focus on getting rid of it quickly
    - Further stabilisation [e.g. composting];
- Could have a double application, but must have constraints; and
- Mixing with biochar for farm application.

Questions or further issues

- Nil

4. **Rehabilitation**

Environmental positive

- Many sites not accessible;
- Trees for travellers as a remediation project?
- Use biosolids as pot plant mix;
- KDC beautification;
- Get Grade 'Aa' and reduce environmental impact;
- Increase environment in Clarence reserve as soils are degraded; and
- Consistent with Green Globe.

Environmental negative

- Does a dilution of 50:50 [biosolids & green] mean a 50% drop in [heavy metals]? and
- How much input to get [heavy metals] below Guidelines?

Social Cultural positive

- Employment & amenity – eco-sourced trees, increase biodiversity & vistas, feel good;
- Unemployment reduces in area;
- Use of biosolids consistent with Green Globe;
- Positive effects on kaitiakitanga
    - Positive Māori re-connection with environment
    - Positive assertion of manawhenua;
- Wai ora very important to keep away from surface water; and
- Healthy environment = healthy people
    - Mauri ora and Hau ora.

Social Cultural negative

- How much has to go into making Grade 'Aa' with respect to community?

Economics

- Marketing plan to sell plants;
- Partnership between IWK and private companies;
- Big expense for IWK;
- Create an income stream to pay for it;
- Is this an expensive "once only" set up?
- Short term economic gain
    - Economic needs to be long-term to generate wealth & sustainable environment; and
- Economic health = environmental health + integrity linked to human health.

Feasibility/Other

- Yes – used in other areas – why not here?
- Dual usage – biosolids + compost at IWK;
- Greatest potential and greatest environmental benefit [safe]; and
- Use as soil conditioner – not concerned about Cu and Zn
    - Put controls in place to reduce leaching potential.

Questions or further issues

- Funding avenues to cover costs of research [SIFT].

Appendix 8. Life Cycle Assessment

Life Cycle Assessment (LCA) calculations were conducted in accordance with ISO14044:2006. Data for the calculations was obtained from published literature and standardised LCA databases. The calculated environmental scores were integrated with the weighting determined at the third community engagement hui, December 2011 hui (section 3.4) using Equation Y (see below) to produce a single figure that described the overall environmental impact.

$$Index_{RU} = \sum \left(\frac{RU_n * W_n}{L_n * W_n} \right)$$

Equation Y: The equation used to calculate the overall score for the reuse options. Where: RU = the normalised impact of the reuse option, L = the normalised impact of landfilling option, W = weighting factor, and n = environmental impact.

The data was combined to a single figure using the equation and the overall scores revealed an interesting trend.

Further details can be found in McDevitt et al. (2012; 2013).

Appendix 9. Kaikōura fourth community engagement hui, March 2012

Facilitated workshop session comments from the community

1. **Vermicomposting - sold for private use**

Support the reuse option
Positive results in these areas:
1. A small community with low industry would have fewer chemical contaminants;
2. Assist in water retention in an area with poor soil water holding capacity; and
3. Future options
    a. Dry and pelletised and sold over time
    b. More frequent desludging of the ponds – more cost effective
    c. Vermicompost immediately after desludging next time
    d. Vermicompost with green waste at IWK – no need for a separate facility.

Positive results for the vermicomposting option saw a small community with limited industrial input into the wastewater supply would produce a low contaminant sludge. As the locality had poor native soils with low water holding capacity and a pea gravel an application of vermicomposted biowastes would improve the soils.

Future options using dry and/or pelletised vermicomposted biowaste may allow for the biowastes to be stored and sold as required.

Storage ponds may need to be de-sludged more frequently as this could prove more cost effective as the wet sludge could be incorporated with fresh green waste at IWK.

Vermicomposting the sludge at IWK would not require a separate facility to be engineered and built.

Do not support the reuse option
Negative results in these areas:
1. It's a small market
    a. May not sell well in Kaikōura – negative public perception/opinion
    b. It's expensive and not practical
    c. Locals would buy cheaper open air compost
2. Application to dairy farms not practical.

As Kaikōura is a small market for the sale of vermicomposted biowastes and a negative public perception may prevail the waste may not be able to be sold. There may be a range of prices of both vermicomposted and open air composted biowaste and the cheaper version may be favoured by the local buyers. Some sites for the application of vermicomposted biowastes may not be suitable such as farmland.

2. **Farm application – outside food chain**

Support the reuse option
Positive result in these areas:
1. An application option for any surplus biosolids after forest and rehabilitation application.

An application of aged biowastes to farmland after it has been used in both forest and rehabilitation may be able to be used.

Do not support the reuse option
Negative results in these areas:

1. Not practical in Kaikōura
    a. Contaminants may enter food chain
    b. Ethically wrong
    c. Land issues – extra pressure on land
    d. Fencing and other practicalities
    e. Bugger the economics.

Farm application of aged biowastes in Kaikōura was not deemed practical for the following reasons. Contaminants may leach into the groundwater, it is ethically [and culturally] wrong to land apply biowastes to land near the food chain; fencing and other practicalities may deem it uneconomical.

3. **Exotic Forest Application**

Support the reuse option
Positive results in these areas:

1. Low cost, low risk and fast – gets rid of the problem
    a. Logical cheap and fast – low leaching
    b. Keeps the rates down
    c. Low wage area so a low cost option is best
    d. Economic benefits
2. It is on land the public do not use – fewer issues
    a. There are two forests to apply
3. There are guidelines to cover Forest Application
    a. The research looks good – lower chance of leaching and the CBA looks positive
4. Can provide jobs in the area – land stays in forestry to support local industry
5. Environmental footprint is low.

This low cost, low risk, fast and low environmental footprint method will enable the stockpile of waste to be removed before the resource consent expires. A low cost option in a low waged community will release pressure from the necessity to increase district council rates therefore provide an economic benefit. The district council leases approximately 400ha of exotic forest until 2029 where aged biowastes can be land applied under the New Zealand Guidelines for the Application of Biosolids to Forests (NZWWA, 2003). Employment can be provided in the area around the land application and also around the expected increases in tree volume over the rotation.

Do not support the reuse options
Negative results in these areas:

1. Find the best economic return then decide which option – not just choose forestry
2. If results are “bad” and you deforest you have lost this resource
3. Forestry removes water from soil – leaves it acidic.

Opting for land application of aged biowastes to forestry may not be the best option and this should be tested, although both the CBA and the LCA have been applied. If forestry turns out to be the incorrect option and the rotation needs to be shortened, then a valuable resource to the district has been lost.

4. **Open air composting**

Support the reuse options
Positive results in these areas:

1. KDC should pilot trial this to obtain results – composting lowers perception of risk

2. Economically and commercially feasible – sell locally
3. Could utilise other carbon sources – green waste, wood waste, sawdust – dredge more frequently to supply demand for AOC
4. Could be made into different products – e.g. potting mix
5. We have a responsibility to take care of our waste – that can involve a cost.

Open air composting may provide the perception of a lower risk and scientific trials to test this hypothesis can be tested. It is thought to be both economically and commercially feasible to sell locally as “normal” compost is sought after in the area. Carbon bulking sources [green waste, wood waste, sawdust] appear at different times during the year and the ponds could be dredged to link in with these high productions to enable open air composting.

Do not support the reuse options
Negative results in these areas:

1. Environmental footprint quite high
    a. Some of the green material can contain hormones that are residual chemicals
    b. Are we sure we know what chemicals are on the green waste now ?
    c. Would need public and end-user education.
2. Future considerations
    a. Is the system viable
    b. Will it all be sold or just dumped in landfill
    c. What is the quality control?
    d. Does it need to stand & settle
    e. Lack of control on where it’s used – it could go anywhere.

The environmental footprint of open air composting is high and the green bulking agents can contain contaminants such as hormone based herbicides that persist in the compost. An education of the end-users of open air compost may need to be completed to ensure the correct land application method is used.

Future considerations around this method in regard to viability, quality control and long term storage are important. If the product does sell where will it be used and also if the product does not sell will it be dumped in the landfill?

5. **Rehabilitation with natives**

Support the reuse options
Positive results in these areas:

1. There are a number of areas where it could be added to natives rehab
    a. Ecan know of the opportunity
    b. Good for Earth Check
    c. Labour is available – local community groups
    d. Fertiliser boost – plants grow faster and keep weeds down
    e. Part of the overall solution
2. Vegetation cover is an attraction of the area
    a. Make the area more beautiful – positive for tourism
    b. Replace pines with natives along coast
    c. Supply fertiliser to green spaces
    d. Give indigenous perspective to New Zealand.

There are a number of possible sites where aged biowastes can be added to native plantings and this has a number of positive attributes: It is good for the EarthCheck® status of the locality, labour is available, a fertiliser addition will enable the plants to grow faster suppressing the weeds. This extra vegetative cover will make the area more appealing to tourists and could replace some old coastal pines to the south of the town.

Do not support the reuse options

Negative results in these areas:

1. Can't have near tourist places, waterways, steep land, public land,
    a. Pathogen and contaminant metal issues
    b. Nitrogen could leach,
    c. Spreads noxious weeds in native planting areas
2. Economics
    a. May have to add water if plantings are in dry areas – expensive
    b. Weed control
    c. Ongoing maintenance
    d. Poor return on 'willingness to pay'
    e. Public access for 6 months
    f. Manual spreading is expensive.

Aged biowastes should not be applied to areas where the tourism industry could be negatively impacted, close to waterways, or on steep or public land. Excess growth from the fertiliser effect may spread noxious weeds in the area where native plantings occur. There may be an economic cost associated with adding aged biowastes to native plantings; water may need to be applied to the native trees; manual application, weed control and ongoing maintenance will need to be timetabled; and public access is restricted for the first six months.

Appendix 10. Kaikōura fourth community engagement hui 2011: Evaluation by participants

Feedback following the fourth community engagement hui held in March 2012 was extremely positive.

The presentation of research results by the Biowaste research team and the resulting information flow was highly praised by participants at the conclusion of the hui.

> *Mark Solomon, Chair of Ngai Tahu said it was one of the best scientific meetings or hui explaining scientific data he had attended.*
>
> *Prof Evan Gallagher of Washington State University, a toxicologist who observed the hui, commented on how creating a space for open dialogue with communities achieved a strong information flow and the result was acceptable to all. He said it would never happen in the US!*
>
> *John Hales, Suffolk, UK, who lives part of the year in Kaikōura said it was the best presentation he has ever been to – his son, Peter who also attended is a biogas consultant and wastewater engineer in the UK researching alternative sewage, waste and biogas technologies was very impressed with our methodology and results.*

Telephone interviews were conducted with eight participants and one person was interviewed face to face; again the feedback was overwhelmingly positive. The hui process was highly commended, and it was seen as being inclusive of the Kaikōura community. Participants thought that their involvement in the hui was valuable for the community and that the hui was a really useful way of gauging what people think.

According to community participants

> *"[It was] the best forum I have participated in with scientists because I understood everything you put on the table."*
>
> *"The structure of the day was really well thought out and the scientists weren't too sciency."*
>
> *"Certainly council and other organisations could take a leaf out of your book as far as consultation goes."*

The 5-minute research presentations outlining the characteristics of their biosolids and the environmental, social, cultural and economic impacts of the biosolids reuse options most favoured by key stakeholders were particularly appreciated:

> *"I enjoyed all the presentations because I understood every word."*
>
> *"[They were] done very well from the scientist point of view to explain it in layman's terms."*
>
> *"There was enough information and any more than that may have started to confuse people."*
>
> *"Because you left all your scientific terminology out and explained everything it was a simple hui to follow."*

The use of voting on the biosolids reuse options was supported by community participants:

> *"Voting was the fairest way to do it – it gives the community ownership."*

“Voting is a pretty democratic way of doing things.”

When asked how they would you rate the marae experience responses included:

“Māori have more concern about the environment than most people so that’s a comfortable home.”

“Māori have always been open to comment or criticism or whatever. That is what a marae is for...”

Also when asked whether the hui changed the way they thought about waste and the environment responses included:

“This is a good starting point to get people doing more than they are already doing.”

“It definitely has changed the way I think about waste and the environment.”

Most importantly a number of people interviewed stated that *“the views of people were definitely taken into account”*.

Appendix 11. Cost Benefit Analysis assumptions, costs, benefits and overall net costs

Option 1 - Open air composting with biosolids (5 years to complete)

Assumptions

• Volume of biosolids for composting (1,115 tonnes)	1500 cubic metres (m^3)
• Volume of green materials for composting	1500 m^3
• Total volume of compost	3000 m^3
• Weight of compost in tonnes	1950 tonnes
○ Density of compost = 0.65	
• Total number of batches in 5 yrs	40
• Time to produce one batch	6 weeks (average)
• Weight of a trailer load of compost	80 kg
• No more selling of regular composts	Provides revenue of about $6,400/yr
• Calculated the Net Present Value	Standard 8% discount rate
• Open air composting operation production	Approx. 1200 trailer loads/yr

- However, we have set a maximum of 465 trailer loads that can be sold/yr
  - Given that in 2011 only 425 trailer loads were sold.
- The rest of the compost will be picked up for free by a hypothetical forest company.

Summary of costs

- OSH for 2 workers
- Materials, collection, transport, labour and marketing costs
- Equipment hire, maintenance and operating costs.
- Avoided benefit in selling compost from the existing operation - $5,400/year for five years

Summary of benefits

- Sale of biosolids composts (465 trailer loads/yr × $19/trailer load)
- Avoided cost on waste levy ($2,230/yr for 5 yrs)

Net Cost of open air composting (assuming the existing composting operation does not continue) **$59,077.39**

Option 2 – Vermicomposting with biosolids (3 years to complete)

Assumptions

- Volume of biosolids for composting (1,115 tonnes) — 1500 m^3
- Volume of green materials — 1500 m^3
- Initial investment cost will for establishing the new facility in IWK — $17,580
- Existing composting operation will continue as usual
    - Insufficient worm numbers will limit large scale vermicomposting operation
- Calculated the Net Present Value — Standard 8% discount rate
- Vermicomposting operation - produce 1500+ trailer loads of vermicompost/yr.
- However, we have set a maximum of 900 trailer loads that can be sold/yr.
- The rest of the compost will be picked up for free by a hypothetical forest company.

Summary of costs

- Initial investment (Construct vermicomposting facility in IWK)
- OSH for 2 workers
- Materials, collection, transport, labour and marketing costs
- Vermicomposting and other operations
- Equipment hire, maintenance and operating costs

Summary of benefits

- Sale of vermicomposts (900 trailer loads/yr × $23/trailer load)
- Avoided cost on waste levy/yr ($11,150/yr for 3 yrs)
- Sale of worms (3,250 kg × $10/kg)
- Sale of worm juice (15,000 L × $1/L)

Net Cost of vermicomposting (assuming that the existing composting operation would continue) $78,097.88

Option 4 - Exotic forest application (approximately 4 weeks to complete)

Assumptions

- 1 cubic metre of biosolids weight — 0.65 tonne
- Total amount of biosolids — 1114 tonnes
- Nitrogen content — 3.6% (3.6 g/100 g)
- Nitrogen application rate to forest — 400 kg of N/hectare (ha)
- Tonnes of biosolids applied per ha — 11.111 tonnes biosolids/ha
    - 400kgN / 0.036 kg N per tonne of biosolids
- Area required = (1,114.4 tonnes / 11.111 tonnes/ha) — Approx. 100.3 ha
- Distance from stockpile in Kaikōura to Clarence forests — 41.1 km
- Spreader capacity — 5.575 tonnes/load
- Cost of diesel/L — $1.53/litre
- No. of spreader trips required = 1114.4 tonnes / 5.575 tonnes/load — 200 spreader trips
- Number of spreader trips/day (assuming no stoppages for breakdown etc.) — 12 trips/day
- Amount of diesel for spreading/day — 93 L/day of spreading
- Transferring biosolids via tractor (approx. 6 km/10 km trip × 2 km/L × 12 loads/day) — 36 litres/day of tractor transporting
- Fuel cost for tractor - spreading + transferring * L/day × No. of days × cost/L — $3348

Summary of costs
Spreader hire

- Spreader hire for 4 weeks ($1,780/week) — $7,120
- Transport spreader Chch to Kaikōura and back — $1,560
- Cost of diesel for spreader (93+36 L/day × 17 days × $1.53/L of diesel) — $3,348

Hiring of 2 trucks

- Hiring of 2 trucks (20 m^3 truck + tail lift) @ $144/day × 28 days × 2 trucks — $8,064
- Transport cost of 2 trucks from Chch to Kaikōura and back ($0.49/km × 370 km × 2 trucks) — $363
- Cost of diesel (198.31 L × 17 days × $1.53/L) — $5,158
- Depreciation costs of 2 trucks (5 trips/day × 82.1 km/trip × 17 days × 49 cents/km) — $6,839

Labour costs

- Maintenance charge to working state = 6 hours × $35/hr — $210
- 20 days × 8 hours/week × 2 full-time workers × $18/hour — $5,760
- 17 days × 4 hours/week × 2 part-time workers × $18/hour — $2,448

- Hepatitis C shot (Twinrix) ($210/person × 4 persons) $840
- Personal protection equipment ($200/person × 4 persons) $800
- Approximate cost of resource consent application $15,000

Total costs $57,509

Summary of benefits

- Avoided cost of waste levy (1114 tonnes of biosolids × $10/tonne) $11,140

Net Cost of exotic forest application **$46,359**