A MAURI-MODEL ANALYSIS OF REMEDIATION METHODS OF INDUSTRIAL WASTE FROM THE TASMAN PULP AND PAPER MILL IN KAWERAU, BAY OF PLENTY, NEW ZEALAND

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Abstract

Over the last four decades, the Tasman Pulp and Paper Mill dumped huge volumes of waste in a geologically active area of land next to the Tarawera River that is owned by the Ngati Tūwharetoa ki Kawerau iwi (tribe). It is of great importance to consider options to remediate the land in order to restore the mauri (capacity to sustain life) of the land, and the lifestyles and sustenance of the indigenous people. The land is contaminated with heavy metals, sulphides and nutrients, and the contaminants are leaching to the Tarawera River through groundwater and surface runoff. Various options may be employed to remediate the land. Bioremediation using plants and microbes can be used to accumulate heavy metals and break down toxins. Industrial milling may be used to pulverize and break down toxic components and reduce volume of waste. The waste can also be extracted and moved to another landfill site. Each of these options is evaluated using environmental, social, cultural and economic indicators of mauri to holistically judge the merits of the method in promoting the quality of the land. The third option – extracting and relocating the waste – promotes the mauri of the land to the greatest degree, by allowing natural features such as lakes and hot springs to re-emerge, and hence enabling the long-term reversion of the quality of land to similar to pre-dumping conditions. The other two options result in a significantly poorer degree of improvement in the mauri of the land, because they are unable to bring back the natural features that were lost. However, these two options may be more practical. Further focused research with detailed information on budget constraints, trustee priorities, availability of other landfills, etc. is recommended.

Introduction

The pulp and paper industry produced over 390 million tonnes of paper and paperboard by volume in 2010 (www.jpa.gr.jp). As one of the largest global industries, the pulp and paper industry requires a huge volume of raw material, and produces great amounts of waste. While acquiring raw materials has its own implications in terms of deforestation, soil integrity and quality, etc., another huge problem lies with the industry's treatment and disposal of waste – usually containing a wide variety of harmful components such as heavy metals, nutrients and organic toxins.

The Tasman Pulp and Paper Mill (owned by Norske Skog Tasman Limited) in the Kawerau region in the Bay of Plenty, New Zealand is only a small production facility compared to this global industry, churning out 300,000 tonnes annually (www.norskeskog.com). Yet, it has dumped more than 600,000 m^3 of solid waste in the local area owned by a Māori iwi (tribe) over the last four decades (Hikuroa et al., 2011), completely altering the physical as well as the cultural landscape.

Figure 1: The Kawerau region in the Bay of Plenty, New Zealand (www.kawerau.co.nz), marked by the large red dot. The smaller red dots mark the locations of nearby towns.

This research project investigates potential ways of dealing with the massive volume of waste to restore the integrity and *mauri* – or the life force – of the land, in order to make sure that the land is equipped to be used sustainably by the trustees. The effects of each of the methods of dealing with waste on the mauri of the land is considered from the perspective of the Māori trustees of the waste dumping site using the Mauri Model, which calculates a score for sustainability with an equal consideration for environmental, cultural, social and economic factors (Morgan, 2006). From this analysis, the effect on the landowners themselves is extrapolated, since the trustees depend heavily on the land for subsistence, community and income. This research forces thinking outside the traditional framework of strictly economic cost and benefit analyses, and has implications for work in contaminated site remediation all over the world.

Background

Norske Skog Tasman Pulp and Paper Mill

Figure 2: An aerial view of the Tasman Pulp and Paper Mill (Google Maps).

In 1954, the New Zealand government passed the Tasman Enabling Act (Hikuroa et al., 2011) to support a pulp and paper mill to be set up by the Tasman Pulp and Paper Company Ltd. (now Norske Skog Tasman Ltd.). In 1955, the Tasman Pulp and Paper

Mill started production in Kawerau, Bay of Plenty (www.norskeskog.com). It represented a huge investment, and provided hundreds of jobs in the locality. Even today, the Tasman Mill contributes over one billion dollars annually to the National GDP of New Zealand (www.e-c.co.nz).

Figure 3: The production facility of the Tasman Pulp and Paper Mill in Kawerau, Bay of Plenty (www.norskeskog.com).

The Tasman Act granted many generous provisions to the company, setting out privileges of discharging waste to the Tarawera River, securing privately owned land, etc. The following is an excerpt from the Act:

> "9. Entry on private land---Where it is necessary for the purposes of carrying out any of the powers conferred on the company by this Act to enter on any land, other than Crown land, occupied by another person, reasonable notice shall, if practicable, be given by the company to the owner and the occupier of the land."

Equipped with this power, the company acquired some land very close to its production regime to use as an economical waste-dumping site. In 1971, it started dumping solid waste on the land around what was then Lake Rotoitipaku, leased from the Ngati Tūwharetoa ki Kawerau iwi against their wishes. The lease expires in 2013 (Hikuroa et al., 2011).

The Dumping Site: Te Kete Poutama

The land leased to the Tasman Mill for dumping waste – known as Te Kete Poutama to the Ngati Tūwharetoa ki Kawerau iwi – used to be a place of enormous significance to the trustees. Besides serving as a major source of subsistence through plants, fish and animals, the indigenous people had ancestral spiritual connection to the land (Hikuroa et al., 2011), and their lifestyles were intricately interconnected with the land through generations of cultural and social traditions.

The site itself consists of highly faulted, pumiceous rock that is very permeable. The water column is high and the Tarawera River runs very close (100m at the closest point) to the site. Finally, the region is geothermally active (GRML, 2004), as a result of the Pacific plate subducting under the Indo-Australian plate in the broader region of the Taupo Volcanic Zone. Owing to the combination of all these factors, the site has been called "one of the worst locations one could contrive for a waste disposal site" (Tull, 2008).

Yet, the Tasman Mill has dumped over 600,000 m^3 of solid waste in the area since 1971, resulting in the complete blockage of Lake Rotoitipaku (see Figure 4) and various hot springs that used to be active in the area. Currently, over 20 meters of solid waste covers the land, leaching contaminants into the groundwater, river and underlying sediment (SKM, 2007).

Figure 4: The waste disposal site of the Tasman Pulp and Paper Mill in the land leased from the Ngati Tūwharetoa ki Kawerau tribe, showing Lake Rotoitipaku filled in with solid waste.

The Mauri Model

This research evaluates viable options of industrial waste treatment, using their effects on the mauri of the land as a proxy for measuring sustainability. The following excerpt from Hikoroa et al. (2011) explains the concept of mauri:

> "Mauri – the physical life principle (Marsden 2003, Peet, 2006); the spark of life, the active component that indicates a person is alive (Mead, 2003), the binding force between the physical and the spiritual (Durie, 1998); the capacity for air, water or soil to support life (Marsden, 2003) is a universal concept in Māori thinking. Mauri is found in water, land, forests as well as mist, wind, soil and rocks, and is the force that interpenetrates all things to bind and knit them together (Marsden & Henare, 2002)."

The Mauri Model evaluates the mauri of a system, incorporating a consideration of the environmental, cultural, social, and economic factors (Morgan, 2006). Under these factors, there are many indicators that may contribute to the overall status of the factor. For example, under environmental factors, there may be components of biodiversity, leaching of contaminants, shocks to the food chain, etc. Each of these indicators can be rated on an integer scale from +2 to -2, where the high end of the scale represents full mauri and the low end represents completely degraded mauri. Figure 5 gives a graphical representation of the model. By rating indicators of each of the four factors using this scale, a score can be calculated for the overall mauri of the land. Because the model uses such a coarse rating system, it forces objective thinking. According to previous analysis in consultation with the land trustees, the change in mauri from pre-dumping levels to current times in Te Kete Poutama has been a 92.5% decrease from +2 to -1.7 (Hikuroa et al., 2011).

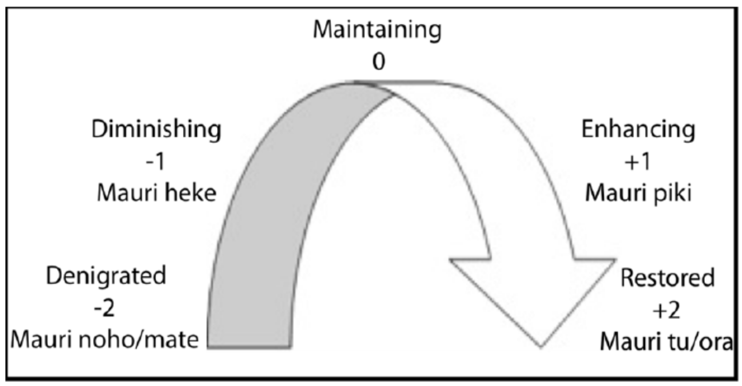

Figure 5: The “Mauri-o-Meter”, a scale using which indicators are scored on the Mauri Model.

Nature and Movement of Waste

In Māori indigenous views, the presence of anthropogenic contaminants represents an intrinsic negative impact on the mauri of land. The concentration of the contaminants is not as important; it is the difference between presence and absence that is most crucial (Hikuroa et al., 2011). Yet, the concentrations of contaminants – that is, whether they are within regulated guidelines – are important with regards to health and public safety considerations.

Waste Components

The concentrations of nutrients, total Sulphides, Hydrogen Sulphide, and selected heavy metals (Mercury, Manganese, Boron, Arsenic) in groundwater at the dumping site were reported in 2007 by Sinclair Knight Merz – contracted by Norske Skog – to be higher than the Australia and New Zealand Environmental Conservation Council (ANZECC) guideline values for safe fresh water (SKM, 2007). The concentration of dioxins was lower than the Ministry of Environment guideline, but higher than background levels (SKM, 2007).

The water from the Tarawera River showed concentrations of nutrients, Boron and Arsenic above ANZECC levels both upstream and downstream of the site. In the sediment, only the Mercury levels were above ANZECC guidelines (SKM, 2007).

Migration of Contaminants

The groundwater was found to be flowing towards the Tarawera River at 11.8 m/day, carrying contaminants into the river. However, the actual rate of contaminant migration is many times lower due to natural dispersion and retardation effects (SKM, 2007). The groundwater discharge into the river was 1170 m^3/day – about 1340 times lower than the discharge of the Tarawera River.

Hence, there is a high dilution factor, and there is insignificant difference in river water quality between the upstream and downstream sites monitored (SKM, 2007). Figure 6, below, shows the difference in groundwater flow directions and patterns from pre-dumping (bottom panel) to current levels.

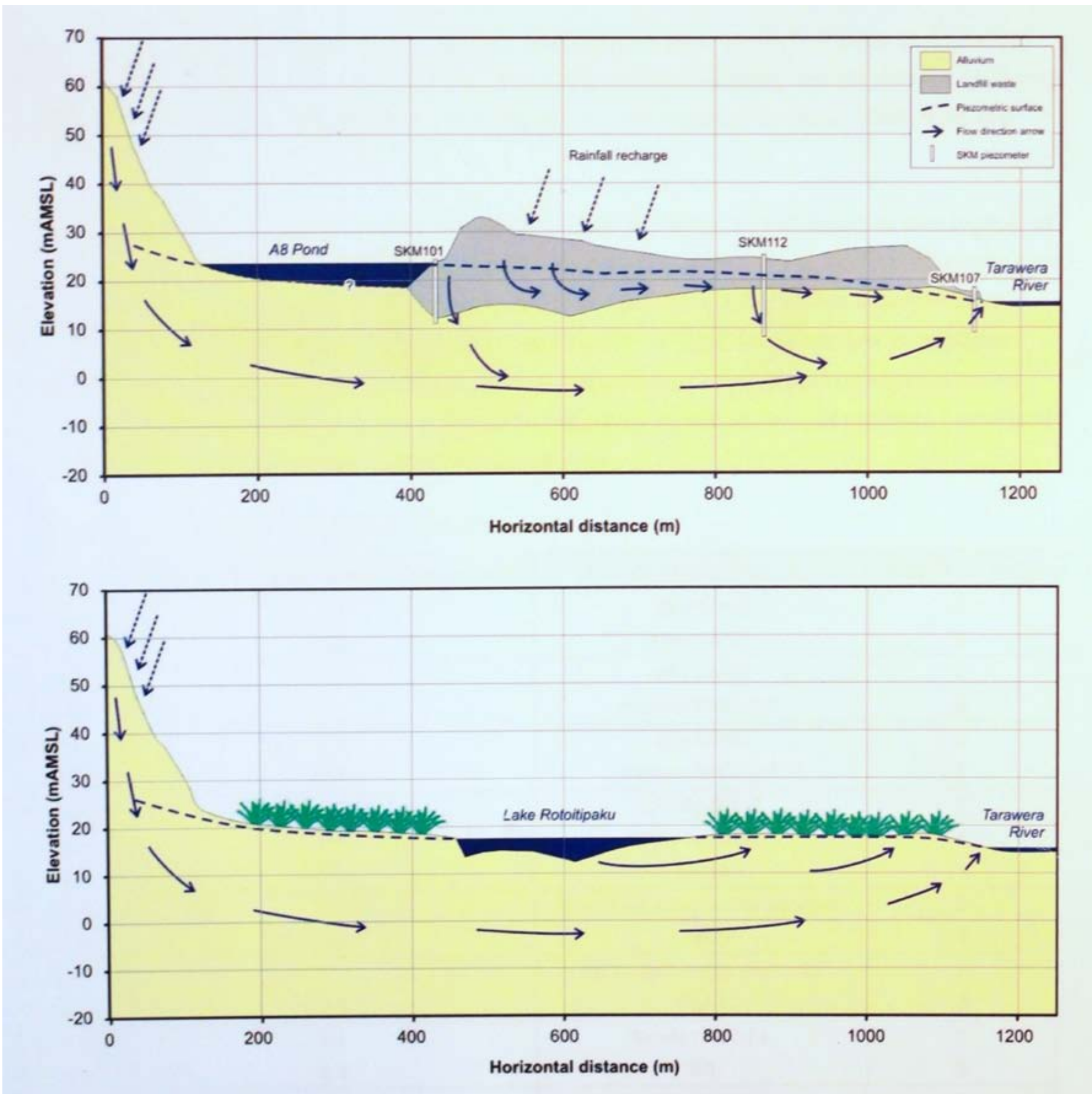

Figure 6: Groundwater flow patterns around Lake Rotoitipaku at pre-dumping (bottom panel) and post-infilling levels. (SKM 2007)

The surface water runoff contained higher heavy metal concentrations than groundwater, suggesting that surface runoff was a key pathway for contaminant migration (SKM, 2007).

Remediation Options

Bioremediation

Bioremediation is a biological process by which environmental pollutants are eliminated or converted to less toxic (or even useful) substances (Brigmon, 2002). The biological agents may be microbial or plant populations in soil or aquatic systems (Brigmon, 2002). Bioremediation is generally an in-situ treatment, allowing the soil to be modified without being removed. While this allows for much cheaper costs, it also operates on a long timescale to bring about significant changes in contaminant concentrations (Philp et al., 2005).

Various types of bioremediation may be applicable to our site of interest. Phytoextraction and hyperaccumulation of heavy metals – that is, uptake of heavy metals by plants and absorption into plant tissue – has shown great promise, allowing for accumulation of metals several orders of magnitude greater than normal levels (McCutcheon & Schnoor, 2003). Intrinsic bioremediation can aid in containment of toxins by slowing down or preventing migration (depending on relative speeds of containment and spread) of contaminants to reach points of contact with human or wildlife populations (Brigmon, 2002), in this case, mainly the Tarawera River. Phytoremediation and mycoremediation (processes using fungal and microbial agents) often work hand in hand because the plant rhizosphere (spatial reach of roots) supports higher diversity of microbial and fungal life (Brigmon, 2002), and both can be used in the site.

Milling

The Fruitgrowers' Chemical Company had a long history of production and pollution in Mapua near Nelson over most of the twentieth century. The polluted site was heavily contaminated with DDT, dioxins, and pesticides. In the last couple of decades, the Ministry for the Environment undertook a large operation to restore the land. The world's first Mechano-Chemical Dehalogenation (MCD) plant was constructed, to pulverize the waste and break down toxic components by grinding them with high velocity steel balls, thereby also reducing the waste in volume. Though not without its challenges, the project was generally considered a success, with lower release of toxic gases than other methods such as high temperature incineration (Ministry, 2011).

The Mapua case study calls for the investigation of the merits of a similar approach for the Kawerau site. Milling can break up organic toxins, and potentially oxidize heavy metals through ex-situ aeration (Ministry, 2011). And since the Mapua site remediation was the first of its kind, lessons learned from this past project can be implemented in designing a new large-scale undertaking.

This process would undoubtedly be costly, but would treat the waste faster and more efficiently than bioremediation techniques. It would also reduce the volume of waste, and may therefore allow the restoration of some natural features of Te Kete Poutama, such as a part of the lake, or some buried hot springs.

Removal and Off-Site Disposal

This option requires the extraction of all the solid waste, and re-depositing it in a suitable landfill. This remediation option has a significant number of advantages as well as associated challenges.

The advantages include a near-complete removal of toxins and contaminants, allowing the trustees to start anew. Removal of waste would also allow for the maximum possible restoration of buried and lost features, including the lake, hot springs, and geothermal pools.

The challenges include finding a suitable landfill site, bearing costs of waste transport and possible treatment of the waste before it can be dumped into another landfill.

Methods: Mauri-Model Analysis

The impact on mauri was assessed using the same scale from the Hikuroa et al. (2011) paper. The scale was adapted to give equal consideration to the four factors – environmental, cultural, social, and economic. In the Hikuroa paper, the environmental factor had nine indicators, cultural had ten, while social and economic each had seven. For consistency across factors, the natural contaminants indicator was deleted from the environmental factor because it always obtained the same score under all scenarios due to no variation of natural contaminants. The indigenous biodiversity of the lake and the hot springs was collapsed into a single indicator, because they received the same scores across most scenarios. Under cultural, the three indicators on healing, corresponding to geothermal mud, drinking water from pools, and baths in pools, were collapsed into a single indicator (they all received the same scores). The two indicators on flora collection – for medicinal or other purposes – were collapsed into one indicator, resulting in seven indicators for the cultural factor.

The seven indicators from each factor were rated on the Mauri-o-Meter (Figure 5) for each of the three waste treatment scenarios roughly 15-20 years in the future. For the sake of consistency, it is assumed that the milling and off-site disposal techniques will have completed the waste remediation in that time frame. However, for the more time-consuming operation of bioremediation, it is only assumed that the process will have been well under way and continuing to have an impact on the land at the time that the future mauri is projected for.

Each indicator was assigned a score based on how well the land may be expected to perform under the three waste treatment options. It was assumed that all the indicators are mutually exclusive, so that the effect on the land from just that one aspect (as given by the indicator) could be determined and incorporated in the results.

In order to aid in the understanding of the analysis process used, several key, representative indicators (or unusual ones) were selected across all factors, and the rationale for the scores that they received under the Mauri-Model Analysis are explained in Table 1. The meanings of all the indicators are explained in Appendix A at the end of this report.

Table 1: The rationale for scores assigned to key indicators across the four factors (environmental, cultural, social, economic) in the Mauri Model for each of the three remediation scenarios (bioremediation, milling and off-site disposal).

	Future - 12 to 15 years				Rationale for Scores
	Indicator	**Bio-remed-iation**	**Mill-ing**	**Off-site disposal**	
Environmental	Anthropogenic contaminants	0.0	1.0	2.0	Bioremediation is a slow process, and reduces concentration of existing contaminants, thereby maintaining the mauri at 0. Milling is fast and breaks down some contaminants, so improves the mauri. Off-site disposal is the only process that fully removes contaminants, and therefore restores mauri to pre-dumping levels.
	Waste in-filled lake	-2.0	-1.0	1.0	Under bioremediation, there is no opportunity for the lake to be recovered. Milling may allow the lake to be partially recovered due to reduction in volume of waste and local transportation of waste. Off-site disposal will allow complete removal of waste, and the entire lake may be recovered, but may not be in pre-dumping health.
	Indigenuous biodiversity on land	0.0	-1.0	0.0	Bioremediation will allow for a more natural environment and may allow some indigenuous biodiversity to recover. Just following an industrial milling plant, it is more difficult for indigenous biodiversity to recover. Following waste removal, indigenous biodiversity may recover.
Cultural	Mahinga Kai	0.0	1.0	1.0	The land vegetated for phytoremediation will allow for some food to be grown (e.g. grazing livestock). Milling and off-site disposal will allow for more food to be obtained, from the restored lake as well as grazing animals.
	Healing from geothermal pools, mud	-2.0	-2.0	-1.0	The features do not exist for bioremediation, and are contaminated even if partially restored through milling - and hence have no healing properties. For off-site disposal, features may regain some healing properties.
	Rongoa and flora collection	-1.0	-1.0	-1.0	Flower populations may recover somewhat as a result of the natural bioremediation, as well as the improvement of land brought about by milling or off-site disposal. So, all get the same score.
Social	Fishing camps	-2.0	-2.0	1.0	Either no lake, or contaminated lake unsuitable for fishing for bioremediation or milling. For off-site disposal, fishing may be resumed.
	Loss of respect	1.0	1.0	-1.0	Bioremediation is a natural process and improves respect. Milling lets trustees take ownership of their land and also improves respect. Off-site disposal involves moving soil and land, and is considered disrespectful, and so receives a low score.
Economic	Cost of restoration	-1.0	-2.0	-2.0	Bioremediation incurs some costs, but both milling and off-site disposal incurs large costs.
	Loss of discretion	1.0	1.0	2.0	All options allow the trustees to improve their decision-making capacity for their land, but the off-site disposal allows the trustees to start anew and regain full control.
	Legal costs	0.0	-1.0	-2.0	Bioremediation does not incur any additional costs, so maintains the mauri at 0. Milling may involve legal costs from setting up a production plant, consenting process, etc. Off-site dispoal involves negotiating another landfill site, treatment of waste, etc. and receives the lowest score.

Results

The scores assigned to all the indicators across the four factors for the three future waste treatment scenarios, along with the prior assessment of pre-dumping and present day mauri scores, are summarized in Table 2.

The overall score was 2.0 in pre-dumping levels, and -1.8 in the present day. The present day is considered the baseline, meaning that at pre-dumping conditions, the mauri score was 92.5 percent greater. The scores improve to -0.8, -0.7 and 0.6 for the three treatment options bioremediation, milling and off-site disposal respectively. This represents a 25 percent improvement in the mauri score under bioremediation, a 27.5 percent improvement for milling, and a 60 percent improvement for off-site disposal.

Discussion

The removal and off-site disposal of waste affects the mauri of the land most positively, resulting in a 60 percent increase from current levels. In comparison, the other two methods result in an increase of mauri by 25 percent and 27.5 percent. The major reason for this is that the removal of waste is likely to bring back most, if not all the natural features that used to exist in the area, such as the lake and hot springs. If all the waste is excavated, there will be a depression in the land in place of Lake Rotoitipaku, which will eventually re-form the lake from rainwater and drainage patterns. However, the same does not hold true for the bioremediation and milling options.

Table 2: Projected Mauri Model scores for each of the three treatment options: bioremediation, milling, and off-site disposal, along with prior assessment scores of pre-dumping and present levels.

Factor	Indicator	Pre-dumping	Current	Future - 15 to 20 years		
				Bio-remediation	Milling	Off-site disposal
Environmental	Anthropogenic contaminants	2.0	-2.0	0.0	1.0	2.0
	Waste dumped on land	2.0	-2.0	1.0	1.0	2.0
	Waste in-filled lake	2.0	-2.0	-2.0	-1.0	1.0
	Waste in-filled hot springs	2.0	-2.0	-2.0	-1.0	1.0
	Toxins in waste	2.0	-2.0	0.0	1.0	2.0
	Indigenuous biodiversity on land	2.0	-2.0	0.0	-1.0	0.0
	Indigenuous biodiversity in lake & hot springs	2.0	-2.0	-2.0	-2.0	-1.0
Average rating for Environmental Indicators:		**2.0**	**-2.0**	**-0.7**	**-0.3**	**1.0**
Cultural	Mahinga Kai	2.0	-2.0	0.0	1.0	1.0
	Waahi tapu (sacred areas)	2.0	-1.0	0.0	0.0	1.0
	Healing from geothermal pools, mud	2.0	-2.0	-2.0	-2.0	-1.0
	Rongoā and flora collection	2.0	-2.0	-1.0	-1.0	-1.0
	Kokowai	2.0	-2.0	-2.0	-2.0	-1.0
	Te Wai u o Tūwharetoa	2.0	-2.0	-2.0	-2.0	1.0
	Kaitiaki displaced	2.0	-2.0	-2.0	-2.0	1.0
Average rating for Cultural Indicators:		**2.0**	**-1.9**	**-1.3**	**-1.1**	**0.1**
Social	Swimming	2.0	-2.0	-2.0	-2.0	1.0
	Hygiene	2.0	-2.0	-2.0	-2.0	1.0
	Fishing camps	2.0	-2.0	-2.0	-2.0	1.0
	Hunting - pigs and deer	2.0	-2.0	1.0	-1.0	1.0
	Singe pigs, plucking ducks	2.0	-2.0	-2.0	-2.0	1.0
	Loss of respect	2.0	-1.0	1.0	1.0	-1.0
	Flooding neighbouring land	2.0	-2.0	-2.0	0.0	1.0
Average rating for Social Indicators:		**2.0**	**-1.9**	**-1.1**	**-1.1**	**0.7**
Economic	Cost of restoration	2.0	-2.0	-1.0	-2.0	-2.0
	Food costs	2.0	-1.0	-1.0	-1.0	0.0
	Loss of discretion	2.0	-1.0	1.0	1.0	2.0
	De-value Te Kete Poutama	2.0	-1.0	1.0	1.0	2.0
	De-value adjacent land	2.0	-1.0	1.0	1.0	2.0
	Legal costs	2.0	-2.0	0.0	-1.0	-2.0
	Loss of potential earnings	2.0	-1.0	0.0	0.0	2.0
Average rating for Economic Indicators:		**2.0**	**-1.3**	**0.1**	**-0.1**	**0.6**
Average rating for all four factors combined:		**2.0**	**-1.8**	**-0.8**	**-0.7**	**0.6**
Percentage difference from current (baseline) levels:		**+95%**	**Base-line**	**+25%**	**+27.5 %**	**+60%**

There were a significant number of indicators that dealt with the presence of these features, and the interaction of the landowners with these features (for example – healing properties, swimming in lake, etc.). For these indicators, the removal and off-site disposal option received greater score because of the re-establishment of these natural features. However, for in-situ bioremediation, there is no opportunity for the restoration of these features. For milling, there may be more of an opportunity, but since the wastes, albeit reduced in volume, have to be dumped again in the same land, it is unlikely that many natural features can be restored.

However, even though the third option affects the mauri most positively, it poses a number of difficult challenges for the landowners. Finding a landfill site where the waste can be transported may be prohibitively costly. The landowners may also not want to dispose the land somewhere else, because of their ancestral ties to the land and soil.

The two other options, milling and bioremediation, produce a similar score in the mauri model. Bioremediation performs better for economic indicators, while milling performs better for cultural and environmental indicators. Either of these can be viable waste remediation options if off-site disposal proves impossible. The Mauri Model assigns the same weight to all indicators, and hence, the trustees may have to prioritize which indicators they value most in order to decide whether bioremediation or milling may be a suitable course to pursue.

To aid the trustees in reaching a decision, targeted research is necessary with specific goals and constraints in mind. The trustees may decide on specific environmental or cultural goals, or determine a budget constraint. These parameters will direct what information is required to make decisions. For example, a list of potential landfill sites in the region that the waste can be transferred to, and their respective distances from Te Kete Poutama cam inform legal and budgetary considerations of off-site disposal. Such goals, constraints and key information will allow focusing on the details of which processes may be suitable.

This research had a number of limitations. The impacts to mauri were crudely projected without consultation from experts on each remediation technique, or from the trustees. So there is concern about the accuracy of the predictions. This concern is exacerbated by the uncertainty that accompanies all future projections. There are differences among the timescales at which each of the three processes operates, so there is a question of consistency as well. However, since the scale is so coarse, there should not be too much of a discrepancy in the overall holistic evaluation reached through the analysis.

There are other treatment options possible that were not considered in this paper. High temperature incineration and cap and contain methods are potential approaches that have been successfully applied in other parts of the world. They may provide insights or address certain components of remediation better than the methods discussed (for example, high temperature incineration may reduce the overall volume of the waste the most).

Conclusion

The pulp and paper industry produces a huge volume of waste. While this report finds that the largest gain of mauri is associated with waste removal and off-site disposal, it also gleans insights on improving environmental standards by treating the waste through bioremediation and milling. On a global scale, merely transporting wastes from one landfill to another will not do. With these huge volumes of waste, some form of detoxification is necessary. Bioremediation and milling are both emerging as promising techniques that may provide us with an answer to how we can treat this industrial waste, rather than running out of space to put them. However, for the trustees of Te Kete Poutama, the best course of action seems to be in transporting the waste to a proper landfill, thus resulting in the restoration of natural features lost from the land and with that, an opportunity to re-establish and reinforce the ancestral ties to the land.

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Appendix A: Definition of Indicators

Factor	Indicator	Definition
Environ-mental	Anthropogenic contaminants	The presence of any concentration of anthropogenic contaminants has a significant negative impact upon mauri.
	Waste dumped on land	Land is no longer accessible – covered in waste.
	Waste in-filled lake	The lake has been completely filled in.
	Waste in-filled hot springs	The waste has covered the hot springs completely.
	Toxins in waste	The dumping of the waste significantly altered Te Kete Poutama and negatively impacted the mauri. In addition, the presence of contaminants in the waste has a further impact on the mauri.
	Indigenuous biodiversity on land	Native biodiversity has been almost completely destroyed.
	Indigenuous biodiversity in lake & hot springs	Native biodiversity in lake and hot springs has been almost completely destroyed. However, it is unclear if thermophilic bacteria are still present.

Cultural	Mahinga Kai	Te Kete Poutama was considered the food basket of Ngāti Tūwharetoa ki Kawerau who also derived considerable mana from the abundance of tuna. Other kai from Te Kete Poutama include koura and kakahi and food-bearing trees.
	Waahi tapu (sacred areas)	The waste has buried Moturoa, a small low-lying island that used to lie within Rotoitipaku. The island bore many food-bearing trees and was also used for wānanga.
	Healing from geothermal pools, mud	The geothermal pools were revered for their curative and healing properties, and small amounts of the waters were consumed as a tonic. The mud was used for healing bruises, as a poultice and also for treating hakihaki.
	Rongoā and flora collection	Plants were collected for medicinal and other purposes e.g. toetoe, raupō, harakeke, paopao.
	Kokowai	Kokowai was collected from geothermal muds/clays.
	Te Wai u o Tūwharetoa	Severed connection Te Wai U o Tūwharetoa had to Rotoitipaku and Tarawera River. Te Wai U o Tūwharetoa is the spring from which the waters flow that were used to soothe the infant Manaia, who later became Tūwharetoa, the eponymous ancestor of Ngāti Tūwharetoa. The severed connection between Te Wai U o Tūwharetoa, Rotoitipaku and the Tarawera River is not only a physical action, but it also has spiritual ramifications.
	Kaitiaki displaced	The water borne kaitiaki – the taniwha – in the Rotoitipaku has been displaced and lost its connection with kaitiaki in adjacent and nearby waterways.
Social	Swimming	Rotoitipaku and the hot springs were popular swimming/soaking spots. In particular local accounts refer to a unique phenomenon – 'the bubble', a plume of turbulent water that flowed intermittently in Rotoitipaku. The objective was to 'ride' the bubble. The geothermal waters warmed Rotoitipaku and afforded swimming all year round.
	Hygiene	Specific pools were designated for bathing that have been lost.
	Fishing camps	At various times of the year families would set up temporary housing around Rotoitipaku to fish.
	Hunting - pigs and deer	Both a social activity and also a means of procuring meat for the table.
	Singe pigs, plucking ducks	These activities were undertaken in the hot springs.
	Loss of respect	The trustees feel they have lost some respect as their land has been taken against their will and then contaminated.
	Flooding neighbouring land	The waste has blocked the natural flow of Te Wai U o Tūwharetoa and created a new body of water on neighbouring land. It is called Te Whariki Toetoe.

Economic	Cost of restoration	Whilst ultimately the bearer of the cost of restoration has yet to be elucidated, various restoration options will have different impacts upon mauri.
	Food costs	This refers to the additional cost to families who originally would have sourced significant amounts of their food from Te Kete Poutama and who now have to buy food.
	Loss of discretion	This indicator refers to potential losses the trustees may have incurred by not being able to make decisions about their land e.g. building a spa based around the hot springs. It also includes the potential preclusion from undertaking certain activities in the future due to the presence of contaminants.
	De-value Te Kete Poutama	This refers to the impact the dumping of contaminant bearing waste to the dollar value of the land.
	De-value adjacent land	The presence of contaminant bearing waste in Te Kete Poutama may de-value neighbouring land.
	Legal costs	If court proceedings take place – either the trustees challenging Norske Skog or if the trustees are taken to court in the future for polluting waterways or de-valuing neighbouring land. For the future, this may include legal costs of acquiring a new landfill site for disposal, or consent process of setting up an industrial milling operation.
	Loss of potential earnings	This refers to the potential loss of earnings resulting from possible marketable products derived from unknown geothermal extremeophiles.