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Akaroa Wastewater Options: Harbour Discharges - Risk Analysis

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REPORT

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GLOSSARY OF TERMS

Biochemical Oxygen Demand (BOD)	A measure of the amount of oxygen required to break down organic matter in water sample. The amount of oxygen required to achieve break down is proportional to the amount of biodegradable material present. BOD_5 is sometimes expressed. The suffix 5 refers to the five day incubation period adopted in the standard test procedure for determining BOD. The concentration of BOD is measure in g/m^3 or grams of oxygen per cubic meter of water.
Chemical Oxygen Demand (COD)	A measure of the amount of oxygen required to chemically oxidise the organic content in a water sample. The amount of oxygen required to achieve chemical oxidation is proportional to the amount of biodegradable material present, and tends to report a higher value of oxygen demand than BOD due to the chemical oxidation of complex and difficult to biodegrade organics.
Total Suspended Solids (TSS)	A measure of the solid material suspended in a water sample. Suspended solids in water reduce light penetration in the water column, can clog the gills of fish and invertebrates, and are often associated with toxic contaminants because organics and metals tend to bind to particles.
Total Nitrogen (TN-N)	Nitrogen is an element that is a component of protein structures in living organisms. If other physical and chemical conditions are optimal, excessive amount of nitrogen can lead to degradation of water quality by promoting excessive growth, accumulation and subsequent decay of plants, especially algae.
Ammoniacal Nitrogen (Amm-N)	Nitrogen combined with hydrogen in the form of ammonia (NH_3) or the ammonium ion (NH_4^+). High concentrations of ammonia can be toxic to aquatic life and manuals.
Dissolved Inorganic Nitrogen (DIN)	The sum of the concentrations of nitrate and ammonia. Nitrogen (in its different forms) is a major plant nutrient. In estuaries it is commonly regarded as the most important limiting nutrient (that is, the nutrient which, if its concentration is increased, is most likely to result in increasing plant growth).
Total Phosphorous (TP)	Phosphorous is an element essential to the growth and development of plants, but which, in excess, can cause unhealthy conditions that threaten aquatic animals in water bodies.
Faecal Coliform	Bacterial from colons of warm-blooded animals which are released in faecal matter.
Enterococci	Common bacterial species found in the intestines of humans and animals.
Mean Sea Level (MSL)	Average water level observed over a long period or the average level which would exist in the absence of tides.
Mean High Water Springs (MHWS)	The average spring tide high water averaged over a long period. Spring tides are semidiurnal tides of large range that occur twice a month (when the moon is new or full).
Mean Low Water Springs (MLWS)	The average spring tide low water averaged over a long period. Spring tides are semidiurnal tides of large range that occur twice a month (when the moon is new or full).
Mean High Water Neap (MHWN)	The average neap tide high water averaged over a long period. Neap Tides are semidiurnal tides of small range that occur twice a month (when the moon is in quadrature).
Mean Low Water Neap (MLWN)	The average neap tide low water averaged over a long period. Neap Tides are semidiurnal tides of small range that occur twice a month (when the moon is in quadrature).

GIS	Geographic information system (GIS) is an information system that captures, stores, analyzes, manages, and presents data that is linked to location.
Bathymetry	Sea-floor mapping, the measurement and study of the landform beneath the water surface.
Residence Time	A measure of the average amount of time that a dissolved constituent (biological or chemical) spends in a volume within a body of water (i.e., estuary or harbour). For a lagoon estuary, this is time within the whole estuary. For spatially-resolved estuaries, it is time in the particular section (head/middle/mouth) of the estuary.
Units	
g/m^3	A measure of concentration of a “chemical” of interest; grams of “chemical” per cubix metre of water.

1.0 INTRODUCTION

Christchurch City Council (CCC) owns and operates the municipal wastewater treatment plant (WWTP) that services the community of Akaroa. In July 2008, CCC obtained a Resource Consent (CRC071865) to continue to discharge treated wastewater from the current Akaroa WWTP into Akaroa Harbour. The consent requires CCC to investigate future options for managing wastewater, and includes obtaining community views through a community working party.

A preliminary technical report produced in 2008 (MWH, 2008) and considered by a working party has identified options for improved wastewater disposal, acknowledging the objection by Onuku Runanga to a wastewater treatment plant on the existing site, and the objection of the Runanga and others to the discharge of any wastewater into the harbour.

In July 2009, CCC engaged Harrison Grierson, EcoEng and Golder Associates (NZ) Limited (Golder) to undertake a "robust risk analysis with the aim of identifying any potential flaws" in options identified by the community working party, to discharge treated wastewater. These options included:

- Option 1. Harbour discharge from the current site.
- Option 2. Harbour discharge from a relocated plant. Either a new site north or south of the settlement of Akaroa (Figure 2).
- Option 3. Land irrigation from the current plant site.
- Option 4. Land irrigation from a relocated plant at a site north or south of Akaroa.

2.0 SCOPE

This assessment specifically addresses Options 1 and 2, being the harbour discharges from either the current WWTP, or a new relocated WWTP to the north or south of the Akaroa Township. In total six possible outfall locations have been considered, two for each WWTP location (current, north, and south), in each case either a near-shore outfall or a mid harbour outfall option.

The dispersion and dilution characteristics of each of the outfall options were evaluated using the CORMIX mixing zone model. The CORMIX analysis feeds into a high level ecological, human health and safety, community value, economic utility and aesthetic assessment of a possible harbour outfall(s). This assessment in turn forms the basis of a qualitative risk assessment of the various harbour outfall locations and discharge regimes.

Discharge quality standards have been recommended and compared to other relevant standards such as those currently exist within Banks Peninsular and recently issued for the Christchurch City and Waimakariri Council ocean outfalls.

The assessment includes a consideration of options for improved dispersion of treated wastewater into the harbour through outfall location and restricting discharges to the outgoing tide and/or during wet weather events.

This assessment is subject to limitation of liability outlined in Appendix A.

3.0 APPROACH

In this study, Golder has assessed the marine receiving environment and established ecological and cultural water quality requirements at the edge of the possible outfall mixing zone. Consideration of reasonable mixing, in conjunction with the CORMIX dispersion modelling results, was used to determine the required quality for the treated wastewater from a WWTP.

In assessing the possible harbour discharge options, this assessment has evaluated five broad risk factors: human health and safety, ecology, community value, economic utility, and aesthetics. The high level, qualitative assessment of these risk factors, in conjunction with the likely discharge zone of non-compliance has feed into an environmental risk assessment of the possible discharge options to the harbour.

Golder has applied the "Leopold Matrix" technique (Leopold et al. 1971) to qualitatively assess the potential environmental impacts of the various discharge options considered in this study. The advantage of a qualitative approach is that the discharge options can be ranked, and the relativity between the options considered.

The Risk Assessment has not addressed the cost, or constructability of the various options. The cost estimates and constructability will be addressed by Harrison Grierson in the final report.

4.0 HARBOUR DISCHARGE OPTIONS

4.1 Introduction

Akaroa Harbour is a tidal inlet nearly 17 km in length, with a north-south orientation. The harbour is at its narrowest (1.7 km) and deepest (25 m) at its southern facing entrance. Over most of its length, the harbour maintains a fairly constant width between 2 to 3 kms with steep cliffs and high surrounding hills. In cross-section the bed drops steeply near the shoreline but is otherwise relatively flat.

- The spring tide range is 1.9 m and the neap tide range is 1.5 m (LINZ, 2006). Heath (1976) estimated the key hydrological characteristics of the harbour as:
- Having an area at high tide of 44 km^2;
- Having tidal mud flats with a surface area exposed at low tide of 2 km^2.
- Having a harbour volume at low water spring tide (MLWS) of 5×10^8 m^3 and,
- A tidal prism [1] at spring and neap tides of 8.1×10^7 m^3 and 6.5×10^7 m^3 respectively.

A GIS (geographical information system) analysis of the Chart NZ 6234 (LINZ, 2004) and LINZ Topographical Coastal Boundary (Series 260) (Figure 1) suggests that the current tidal prism at spring tide is 8.2×10^7 m^3, as presented in Table 1 (refer to Figure 1). This correlates well with the original estimate prepared by Heath (1976).

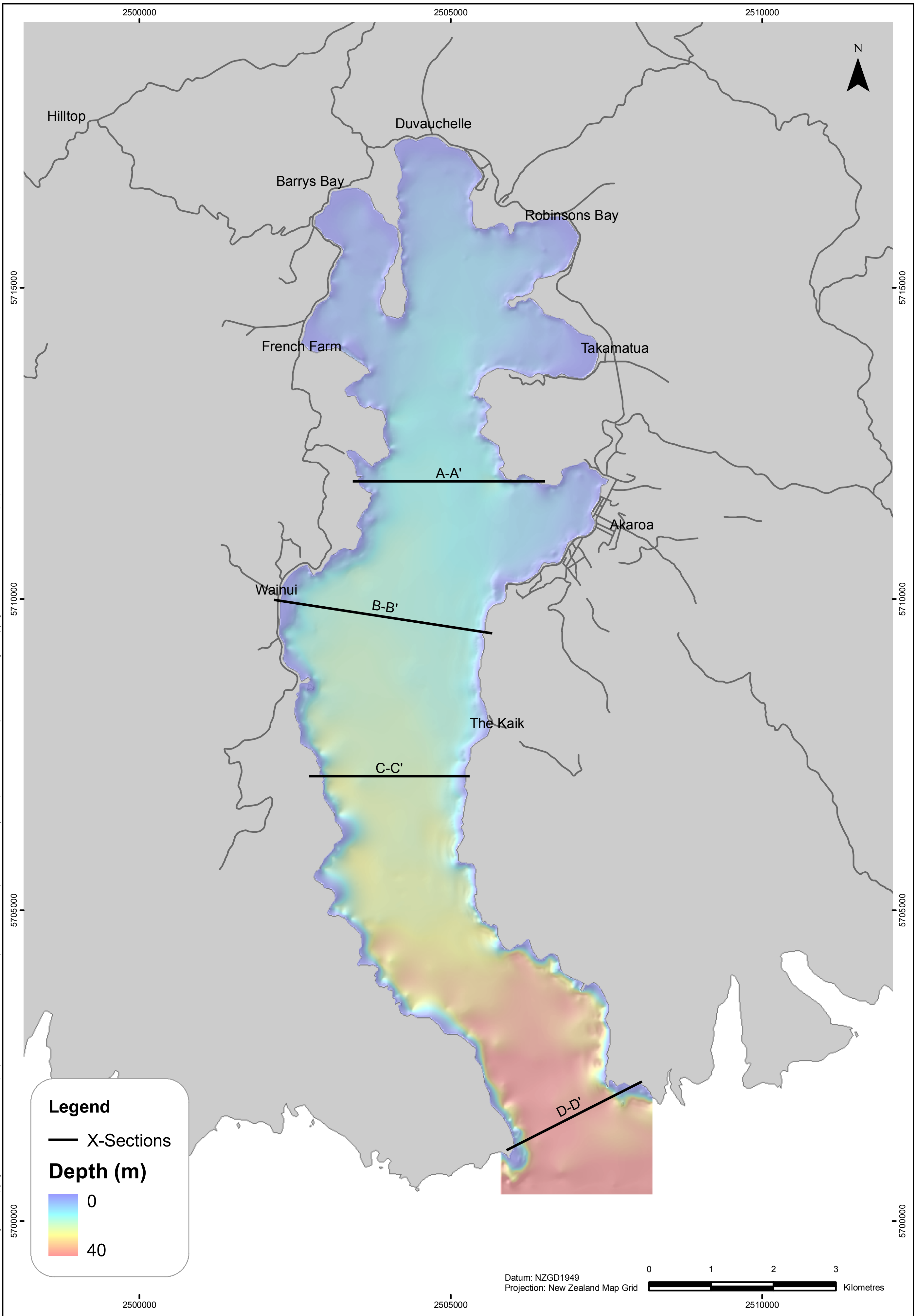
Table 1: Akaroa Harbour - estimated volume of tidal prisms.

	Volume (m^3)			
Cross-section	A-A	B-B	C-C	D-D
MSL	66,400,000	129,800,000	216,300,000	458,400,000
MHWS	79,200,000	149,900,000	243,200,000	497,300,000
MLWS	52,100,000	107,400,000	186,400,000	415,100,000
MHWN	76,400,000	145,400,000	237,200,000	488,600,000
MLWN	63,500,000	125,300,000	210,300,000	449,700,000
Tidal Prism				
Spring Tide	27,200,000	42,400,000	56,800,000	82,200,000
Neap Tide	12,900,000	20,100,000	26,900,000	38,900,000
Average Tide	20,000,000	31,300,000	41,900,000	60,600,000

The hydraulic residence time (HRT, a measure of the average length of time the treated wastewater remains in the Akaroa Harbour) varies from 5.6 days during spring tide to 11.8 at neap tide. The average HRT of the treated wastewater in the Akaroa Harbour is 7.6 days.

The six representative outfall options are shown in Figure 2.

[1] Tidal prism – is the change in the volume of water covering a specific area, in this case the Akaroa Harbour, between a low tide and the subsequent high tide.



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4.2 Redhouse Bay

4.2.1 Current WWTP and outfall

Currently, the Akaroa WWTP and outfall is located south of the Akaroa Township in Redhouse Bay. The current WWTP discharges treated wastewater via a single port outfall that is approximately 100 m from the shoreline in about 5.9 m of water. Redhouse Bay is relatively shallow within 50-80 m of the shoreline, and then rapidly deepens within increasing distance from the shore. Redhouse Bay is north-west facing, and the edge of the bay is defined by rocky outcrops that are visible at low tide. The northern rocky outcrop is commonly known as Green Point.

Due to the close proximity of the existing outfall to the shoreline, and the localised water current circulation present in the bay, dispersion and dilutions in the order of 50 x are predicted (Kingett Mitchell, 2005). The location of the outfall is resulting in plume impingement on the shoreline of Redhouse Bay (MWH, 2005).

Based on NZWERF (2002) guidelines, a harbour outfall exhibiting generally less than 50 fold dilution at 100 m is indicative of poor dilution. A dilution of between 50 - 250 fold at 100 m is indicative of moderated dilution, while excellent dilution occurs from an outfall exhibiting in excess of 250 fold dilution.

In the two outfall scenarios considered below, it is assumed that the WWTP is retained at the current site. Whilst the location of the WWTP does not affect the performance of the two outfall scenarios considered, economic and prudent engineering design favours locating the WWTP near the outfall (to minimise pipeline and outfall construction and installation costs) and providing sufficient elevation so that treated wastewater can gravitate to, and through, the outfall.

4.2.2 Near-shore outfall

In this discharge scenario, it is assumed that a new outfall is provided with its outlet approximately 600 m from the shoreline in 8.0 m of water (at chart datum). The outfall extends approximately 400 m past the headlands of Redhouse Bay and as a consequence is exposed to the diurnal tidal currents.

4.2.3 Mid-harbour outfall

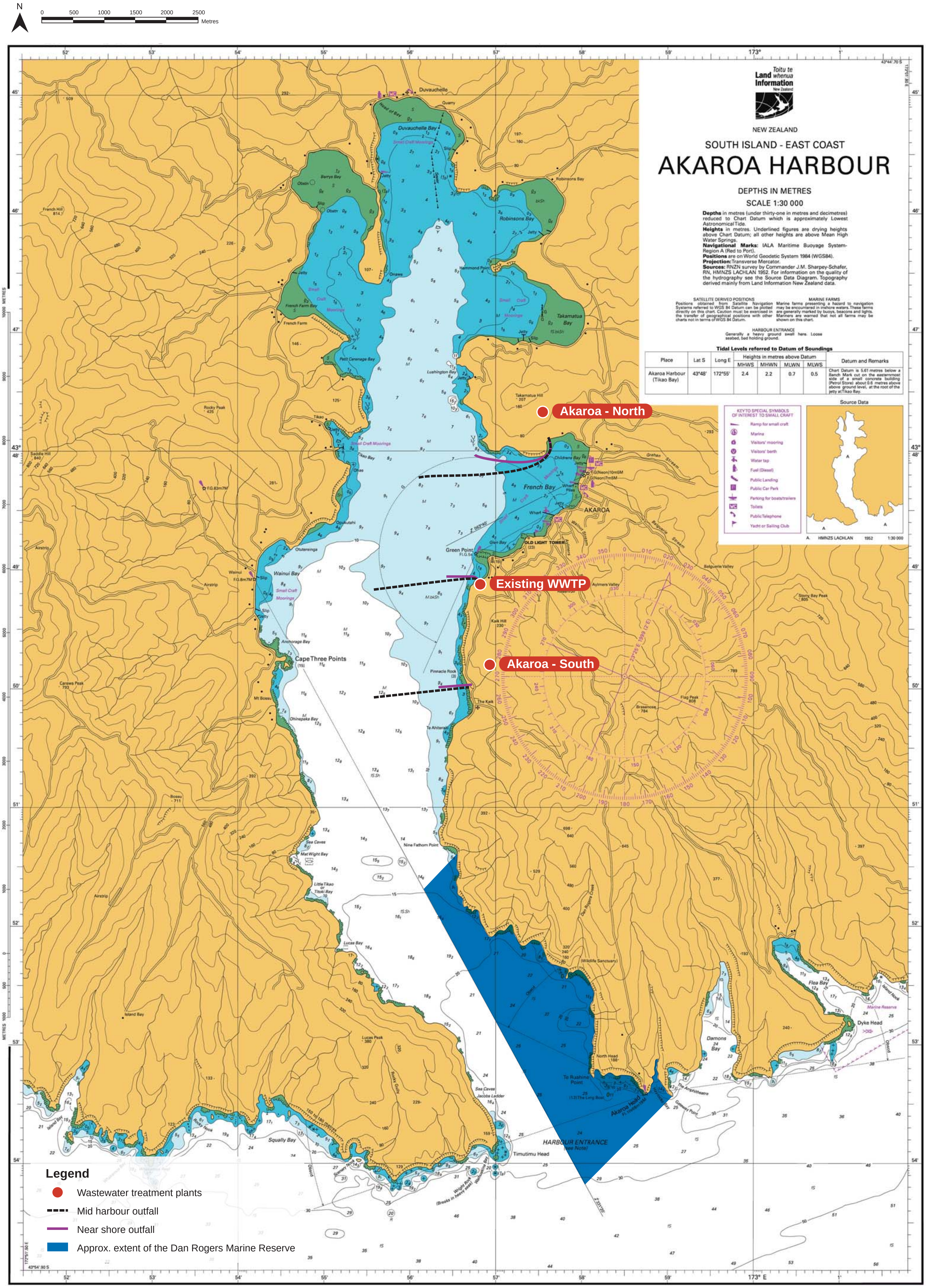
The mid-harbour outfall, considered in this study, is assumed to be located between Redhouse Bay and Wainui Bay. This possible outfall would be in approximately 9.8 m of water, and would extend approximately 1.6 km from the Redhouse Bay shoreline.

4.3 North Akaroa

4.3.1 WWTP

If a new WWTP is located to the north of Akaroa, a pipeline from the WWTP to the west shore of Childrens Bay would be required. It is anticipated that any outfall pipe would originate from the Western shore, and follow the headland into Akaroa Harbour.

In the scenarios, it is assumed that a new treatment plant is located somewhere north of the Akaroa settlement. Whilst the performance of the outfall is not dependent on the location of the WWTP, it assumed that it is not economically feasible, nor practical, to pump the treated wastewater from the current WWTP to an outfall north of French Bay (Akaroa Township).



1. MAP IMAGE: Land Information New Zealand NZMS Series. Copyright Reserved

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4.3.2 Near-shore outfall

Due to the proximity of the water skiing lanes in Childrens Bay and off French Bay (Akaroa), a 1.5 km outfall is anticipated for this option. The outfall would be approximately 200 – 300 m from the shoreline and in 8.8 m of water.

Whilst the proposed location of this near-shore outfall is indicative, the location presented in Figure 2 recognises that near the Takamatua Hill headland the water depth is approximately 2 m deeper than the adjacent sea floor.

4.3.3 Mid-harbour outfall

The mid-harbour outfall, considered in this study, is assumed to be located between French Bay and Tikao Bay. The outfall is in approximately 8.2 m of water, and in the middle of the Akaroa Harbour. Like the near shore outfall, the outfall would most likely originate from the western shore of Childrens Bay. A 2.5 km long outfall is required.

4.4 South Akaroa

4.4.1 WTP

In this scenario, the WTP would be located at a new site south of the Akaroa. Whilst the proposed location of the WWTP has yet to be confirmed, conceptually the relocated WWTP would be located to the north of the The Kaik and Onuku Marae.

4.4.2 Near-shore outfall

A near shore outfall, approximately 600 m in length would be required. In the vicinity of The Kaik, the water is relatively deep. The proposed near shore outfall, whilst only 600 m from the shoreline would reside in approximately 9.4 m of water (at Chart Datum).

4.4.3 Mid-harbour outfall

The mid-harbour outfall from proposed Southern WTP site, would be located 1.5 km west of Te Ahiteraiti (south of The Kaik). The outfall would be approximately 12.8 m of water, and in the middle of the Akaroa Harbour. Like the near shore outfall, the outfall would most likely originate from north of the The Kaik and Onuku Marae. A 1.9 km outfall would be required.

5.0 HARBOUR RISK FACTORS

5.1 Introduction

The following broad risk factors were considered in the risk assessment. These factors are consistent with the approach recommend by NZWERF (2002):

- Human health and safety.
- Ecology.
- Community value.
- Economic utility.
- Aesthetics.

Many of the risk factors are similar for all the outfall options assessed and as such the consideration of the risk factors has focused on those that vary between outfall options.

5.2 Human Health and Safety

The risk to human health and safety is particularly relevant to the proposed outfall options. Since many of the options have the potential to impinge on areas with contact recreational values. The concern is associated with the potential contact with pathogens in the treated wastewater and/or the physical hazards that may be caused by poor water clarity and /or slime build-up on substrates.

Limited specific information on contact recreation in Akaroa Harbour was identified, however the following observations are made:

- The majority of swimming and bathing is expected to occur from the shore and therefore closest to near-shore outfalls.
- Water ski access lanes are located in Childrens Bay and at the Glen.
- Childrens Bay is likely to be popular for contact recreation as it is close to Akaroa Township and has a beach.
- The Akaroa Recreation Ground boat ramp is located in Childrens Bay.
- Childrens Bay is classified as a Class Coastal CR (contact recreation) Water Quality Area (ECan 2005).
- Swimming and bathing occurs in other areas of Akaroa Harbour from private and commercial vessels (e.g., swimming with the dolphins).
- French Bay and Glen Bay are Mooring Areas (ECan 2005).

5.3 Ecology

The following is a summary of key species, communities and ecosystems that may be adversely affected by the discharge of wastewater.

Of particular relevance are aquatic sediments and the sensitivity of benthic communities, as they are a good indicator of wastewater impacts. NIWA (2004) noted the following in relation to aquatic sediments in Akaroa Harbour:

- Sediment characteristics were quite similar throughout the harbour (north of Lucas Bay).
- Mud generally comprised the majority of sediment.
- Sediment organic content was generally low to moderate.
- Total nitrogen in sediment decreased towards to harbour mouth.
- Metal content of sediment showed little pattern.

NIWA (2004) noted the following in relation to benthic communities in Akaroa Harbour:

- Species occurrences were similar throughout the harbour (north of Lucas Bay).
- Mean faunal densities increased steadily seaward.
- Several common benthic species tended to be less abundant inshore.
- The distribution of fauna or community pattern was most strongly correlated with the combination of three factors: water depth (most), sediment organic content and zinc content.
- Total faunal diversity in Akaroa Harbour was similar to that reported for other locations around Banks Peninsula.
- Benthos densities in Akaroa Harbour varied widely but were largely consistent with benthos densities elsewhere around Banks Peninsula.
- Lyttelton Harbour and Akaroa Harbour share many common species.
- Faunistically, inner harbour stations were very similar to each other, but dissimilar to the outer harbour stations.

Particular areas of high sediment or benthic community quality were not identified within Akaroa Harbour.

In relation to hard bottom benthos, (NIWA 2004) noted that:

- Patterns of intertidal biota distributions appear largely controlled by exposure to wave action.
- The intertidal biota in Akaroa Harbour comprised species that are widely distributed around Banks Peninsula and elsewhere along the east coast of the South Island.

Limited specific information on plankton ecology of Akaroa Harbour was identified (NIWA 2003) however ECan (2005) notes the following:

- Based on dissolved inorganic nitrogen (DIN) concentrations there is a slightly greater likelihood of enhanced phytoplankton growth at the heads of the harbour.
- The seasonal pattern in dissolved nutrient concentrations reflects the uptake of these nutrients by the phytoplankton in the spring and the release of nutrients back into the water column in mid-late autumn.

Ten species of phytoplankton formed blooms (cell concentrations >10,000/L) in Akaroa Harbour on one or more occasions between mid 1999 and November 2002 (NIWA, 2003). As nutrients were not monitored over this period the relationship between nutrient concentrations and phytoplankton has not been investigated (ECan 2005).

Treated wastewater is currently discharged into Akaroa Harbour at Wainui and Duvauchelle in addition to the existing Akaroa WWTP discharge. Stormwater in the region is generally enters small streams which flow into the harbour or directly into the sea via stormwater outlets. Stormwater flow can result in inputs of contaminants including sediment, nutrients, metals and pathogens. In wet weather, fertiliser and animal wastes run off from the surrounding hillside into streams which then flow into the harbour contributing to the nutrient load to the harbour water. Marine farming (in particular salmon farming) activities are located along the western side of the harbour near the mouth and are another potential source of nutrients in the harbour (ECan 2005).

Fish species observed in the area include wrasse, butterfish, red and blue cod, blue moki, triplefin, leatherjacket, carpet shark and whitebait (AHMPS, 1996). Many other oceanic and both feeding fish may enter the harbour on occasions.

A marine discharge via an outfall has the potential to affect fish spawning areas, increase sedimentation, and fish flesh tainting.

There is no evidence of any commercial flatfish species have significant spawning grounds in the vicinity of the possible outfall locations. The fish resources in the area of the possible outfall locations have not been quantified and the possible effects of an outfall on the fish resource are difficult to predict without better baseline information of the fish resource and species present.

Based on the performance of the existing outfall, possible sedimentation effects are less than minor and not differentiable from regions elsewhere in the harbour. Fish flesh tainting can affect the palatability of aquatic food. An analysis of the potential for fish flesh tainting for the Christchurch outfall concluded that the low concentration of compounds known to cause fish flesh tainting in the mean dilution factor of the treated wastewater in the near field, demonstrated that the concentrations of these compounds fell below those known to cause tainting (NIWA, 2004).

It is possible that the increased nutrient supply in a harbour discharge could be beneficial for plankton and this ultimately as food for fish, but this effect, if it occurred, would likely manifest itself with the harbour rather than in the vicinity of the outfall.

Hectors dolphins are common in Akaroa Harbour, entering most harbours and embayments and are found in the inner harbour during summer (DoC website). Hectors Dolphin densities are reported as being quite variable in Canterbury coastal waters, but high densities have been reported in Akaroa Harbour (NIWA 2003). The entire harbour is a Marine Mammal Sanctuary for Hectors Dolphins (DoC website).

Hectors dolphins feed mostly on school-fish around 10 – 35 cm in length, most likely found within the harbour (PBAL, 2001). Research indicates that the predominant prey species of Hectors dolphin includes red cod, stargazer, ahuru and Sole species, mid-water sprat, yellow-eyed mullet, hake, squid and small barracouta

A search of literature did not elicit any evidence indicating that the current discharge of treated wastewater into the Akaroa Harbour is adversely affecting the health of Hectors Dolphins. In a recent presentation to the Working Party, Dr Liz Slooten (University of Otago) indicated that information on the concentration of bioaccumulating, non-biodegrading and carcinogenic compounds; and certain bacteria in the treated wastewater and sediments may assist in determining the risk of adverse impacts on Hectors Dolphins from the discharge of treated wastewater. However there appears to be no documented evidence that current discharge of treated is a primary cause of historical decline in Hectors Dolphin numbers.

Although not proximate to any of the outfall options considered, it is noted that the Dan Rogers Marine Reserve is proposed for the eastern side of the harbour entrance.

5.4 Community Value

Community value has been taken to include cultural or social risk factors. The key consideration for Akaroa Harbour is understood to relate to shellfish gathering. Limited specific information on shellfish gathering in Akaroa Harbour was identified however the following is noted:

- The majority of harbour is classified as a Class Coastal SG [shellfish gathering] Water Quality Area (ECan 2005).
- Green-lipped mussels (*Perna canaliculis*) are reported to form a dense covering over rock surfaces and dominate the sublittoral fringe on rocky shores (NIWA 2003).
- The area to the south of the The Kaik, around Te Ahiteraiti, is highly regarded by the Onuku Runanga for its kai moana and is proximate to the Onuku Marae.
- Onuku Runanga do not currently collect kai moana from Redhouse Bay (or Takapuneke) due to the current discharge of treated wastewater into the bay.
- The entire harbour is a Taiapure (Taiapure are local fisheries in coastal waters which recognise the special significance of the area to local iwi or hapu, either as a source of seafood, or for spiritual or cultural reasons. Taiapure give Maori greater say in the management of their traditionally important areas. A major difference between mataitai and taiapure is that taiapure allow commercial fishing (DoC website)).

Mäori are deeply, offended and disturbed by the discharge of human wastes, particularly to natural waters (sea or rivers) and also under certain circumstances to land. Historically, in Mäori settlements, “kuparu” (human wastes) were disposed of to land and kaumatua decided how many years needed to pass before Papatuanuku had transformed the wastes into non-human form. Onuku Runanga has expressed cultural concerns regarding the disposal of wastewater to the harbour, however as members of the Akaroa community they want the best practical treatment and disposal option.

5.5 Economic Utility

The key current economic uses of the harbour that may be adversely affected by the discharge of treated wastewater are expected to be commercial fishing, marine farms and tourism. Limited specific information on economic uses of Akaroa Harbour was identified however the following observations are made:

- Marine Farms are located on the western (opposite) side of the harbour from the outfall locations assessed.
- The Akaroa Harbour ecology directly supports a range of tourism activities such as dolphin watching, swimming with dolphins, kayaking and general sightseeing tours. Tourism activities that use the marine environment of Akaroa Harbour include:
  - Wildlife cruises and tours.
  - Kayak hire and tours.
  - Fishing charters.
  - Swimming with Hectors Dolphins.
  - Water skiing.
  - Yacht tours, charters and boat hire.
  - Jet-boat tours.

Specific details of the location and intensity of these tourism activities is not known. Wildlife cruses and tours are expected to predominantly occur south of the Akaroa township except in adverse weather (http://www.akaroadolphins.co.nz/itinerary.html).

In 2008 international and domestic travellers made a total of 12.27 million visits to Canterbury (Ministry of Tourism, 2009). The Ministry of Tourism (2009) forecasts predict a 7.5 % increase in tourism in Canterbury by 2015. Assuming that the region or country of origin of visitors/tourist to Akaroa is similar to the Canterbury, then approximately 75 % of the tourists will be domestic tourists, 69 % of which are from Canterbury, 7 % from Otago, and 6 % from the Auckland region. The remaining 25 % of the tourist are forecast to be international visitors; in order of rank, 39 % of the remaining 25 % are from Australia, 14 % from the United Kingdom, 8 % from United States, 4.6 % from Germany, and 4.5 % from Japan.

A risk of a harbour discharge, in the context of tourist economic utility, is that a harbour discharge is out of context to the standard approach of disposing of treated wastewater in the tourist’s country of origin. Table 2 demonstrates that in New Zealand 1% (by volume) of all the treated wastewater enters a harbour, but 65 % of all treated wastewater is discharged to a marine environment; this is consistent with Australia in which 72 % of all treated wastewater is discharged to a marine environment.

Table 2: Wastewater disposal method by volume.

Disposal Method	New Zealand (NZWERF, 2002)	Australia (CSIRO, 2002)
Freshwater	24 %	17.5 %
Lake	0.4 %	
Estuarine	20 %	72 %
Harbour	1 %	
Shoreline	1 %	
Off-shore outfall	43 %	
Land	11 %	9.5 %
Reuse	-	1 %

The analysis, outlined above indicates that discharging treated wastewater to a marine environment is consistent with management and disposal of treated wastewater of the home country of the majority of the tourists to Akaroa. Since the disposal of treated wastewater aligns with the home country approach, it is anticipated that the continued disposal of treated wastewater to a marine environment will not result in a change in the risk to tourism related economic utility.

5.6 Aesthetics

Aesthetic risk factors overlap to a degree with matters addressed under community value and economic utility such as proximity to reserves and recreational areas, and tourist activity.

Treated wastewater that is of similar colour and clarity to the receiving water is expected to pose a lower risk of potential adverse impact on aesthetics.

The risk of adverse impacts on visual clarity is reduced due to the naturally turbid waters within Akaroa Harbour.

5.7 Summary of Risk Factors

Based on the information summarised above, the risk factors relevant to the discharge of treated wastewater into Akaroa Harbour for each of the outfall locations assessed have been ranked and summarised in Table 3. The risk has been ranked from one to six, with one being an outfall with the highest risk and six being an outfall with the lowest risk.

Table 3: Summary of harbour discharge ranked risk factors.

Outfall location	Human health & safety	Ecology	Community value	Economic utility	Aesthetics	Comments
Akaroa North – near-shore	1	1=	1	2	1	High recreational activity, close proximity to Akaroa
Akaroa North – mid-harbour	4	2=	4	4	2	
Current WWTP – near-shore	3	1=	3	5	3=	
Current WWTP – mid-harbour	5	2=	5	3	5	
Akaroa South – near-shore	2	1=	2	6	3=	High cultural value, close proximity to Marae.
Akaroa South – mid-harbour	6	2=	6	1	6	

Whilst Table 3, provides a summary of the harbour discharge risk factors and the relative rank, the detailed risk assessment, in Section 9.0, systematically measures the magnitude and importance of environmental factors that are subsets of the risk factors considered above.

6.0 AKAROA HARBOUR MARINE ENVIRONMENT

6.1 Introduction

Bolton-Ritchie (2007), in an internal Environment Canterbury (ECan) memo regarding the current Akaroa Wastewater Treatment Plant (WWTP) discharge, identified that ANZECC (2000) numeric guidelines were not directly transferable for use in Akaroa Harbour. We concur with that view. In that memo Bolton-Ritchie adopted the approach of examining a relatively large data set of water quality that was available from within Akaroa Harbour (Bolton-Ritchie 2005). Bolton-Ritchie (2007) also recognised that there may be differences between the inner and outer parts of the harbour. The former influenced by catchment runoff and the latter influenced more by oceanic inputs from outside the harbour. The water quality near the entrance is also known to be affected at times by the discharge from the Rakaia River some 25 km to the south (Heuff et al. 2005).

Bolton-Ritchie (2007) followed ANZECC (2000) approach, and applied 80th percentile of concentration values of available information, to identify a threshold value which could be utilised as a benchmark for water quality in Akaroa Harbour. The 80th percentile value is referred to by ANZECC (2000) as a "low risk trigger value". This essentially means that if the waters are not already impacted, a value up to that concentration is not likely to pose any 'risk' in the receiving water. This does not imply that any concentration over the low risk trigger will have adverse effects. Bolton identified the following values as low risk triggers (based on the existing water quality data) for inner Akaroa Harbour:

- Nitrate and nitrite nitrogen (NNN) 0.023 g/m^3
- Total nitrogen (TN) 0.021 g/m^3
- Dissolved reactive phosphorus (DRP) 0.017 g/m^3
- Total phosphorus (TP) 0.039 g/m^3

Bolton-Ritchie (2007) did not identify the 80th percentile for ammonia nitrogen (NH_3N) of 0.024 g/m$^{3.}$ as a trigger value. However, Bolton-Ritchie did identify the ANZECC (2000) 95% trigger value for toxicity in marine waters of 0.910 g/m^3 as being protective of coastal biota if not exceeded. Table 4 provides a summary of relevant water quality guidance values applicable to the effects of any discharge to Akaroa Harbour.

6.2 Receiving Environment

The following may have an influence on the wastewater treatment standards that will be required:

- The entire harbour is a Taiapure (Taiapure are local fisheries in coastal waters which recognise the special significance of the area to local iwi or hapu, either as a source of seafood, or for spiritual or cultural reasons. Taiapure give Maori greater say in the management of their traditionally important areas. A major difference between mataitai and taiapure is that taiapure allow commercial fishing. – DoC website). The Dan Rogers Marine Reserve is proposed for the eastern side of the harbour entrance.
- The majority of the harbour is Classed Coastal SG [shellfish gathering] Water Quality Area (ECan 2005a).
- The near shore area of Children's Bay is Classed Coastal CR [contact recreation] Water Quality Area (ECan 2005a).
- The entire harbour is a Marine Mammal Sanctuary (Hectors Dolphins) and dolphins are found in the inner harbour during summer (DoC website).
- Marine farms are located along the western shore of Akaroa Harbour between Wainui and Timutimu Head.

Table 4: Summary of receiving environment water quality guidance values applicable to Akaroa Harbour.

	Bolton-Ritchie (2007) 80th %ile	ECan (2005a) [1]	ANZECC (2000) [2]	USEPA (2006), USEPA (1989) [3]	MfE (2003)
Temp (°C)		25 (±3)			
Nutrients					
TN	0.21		0.12		
NOx	0.023		0.005		
TP	0.039		0.025		
DRP	0.017		0.01		
Oxygen					
DO (% sat.)		>80	90-110		
BOD_5 sol.		2			
Toxicants					
Ammonia	0.910		0.910	14 (pH 7.0) – 1.4 (pH 8.0) [4]	
Copper (mg/m^3)		5	1.3	3.1	
Lead (mg/m^3)		5 (sol.)	4.4	8.1	
zinc (mg/m^3)		50 (sol.)	15	81	
Bacteria					
Enterococci		35/100 mL (median), 277/100 mL (single sample)	35/100 mL (primary), 230/100 mL (secondary)		140/100mL
Faecal coliforms		14/100 mL (median), 43/100 mL (90%ile)	150/100 mL (primary), 1,000/100 mL (secondary)		14/100 mL (median), 43/100 mL (90%ile)

Note: All units are in g/m³ unless otherwise stated. [1] Class Coastal SG and CK waters. [2] South-east Australia marine water for nutrients and oxygen; 95% level of protection for marine ecosystems for toxicants; and recreational water quality guidelines for bacteria. [3] Chronic value for toxicants. [4] Based on a water temperature of 15°C and salinity of 10 ppt.

These should, or may need to be, taken into account in any final selection assessment (e.g., triple bottom line).

We would note at this point that if the discharge plume from any proposed discharge location is identified as impinging upon the footprint of any marine farms within Akaroa Harbour, it is recommended that a Quantitative Microbiological Risk Assessment be considered to confirm the levels of risk involved.

6.3 Receiving Environment Quality

In assessing the implications of any discharge, a number of factors need to be considered. These include:

- Assessing the effects within the immediate mixing zone to ensure that there are no acute effects arising from the discharge.
- Sedimentation effects arising from the discharge in situations where the solids concentration is elevated.
- Toxicity effects arising from chronic exposure to the wastewater discharge (generally for wastewater these effects are predominantly due to un-ionised ammonia).
- Chronic effects arising from elevated concentrations of oxygen demanding substances in the discharge.
- The effects of nutrients in the discharge, including on shoreline ecology and on plankton in the harbour.
- Public health effects, including contact recreation and shellfish gathering.

For the purposes of this initial assessment, the following guidance values (Table 5) were utilised to establish to determine the likely wastewater treatment/discharge quality required fro the outfall in question.

Table 5: Diluted treated wastewater targets at edge of mixing zone.

BOD_5	TN	Ammonia-N	NOx	TP	DRP	Cu	Pb	Zn	Enterococci	Faecal coliforms
2	0.21	1.4	0.023	0.039	0.017	1.3	4.4	15	140 cfu/100 mL	14 cfu/100 mL

Note: All units are in g/m^3 unless otherwise stated.

In this initial assessment, the information obtained from modelling the discharge options has been compared to the following:

- The numeric nutrient values identified by Bolton-Ritchie (2007).
- The ANZECC (2000) trigger values for metals.
- The ECan BOD_5 guidance value.
- The MfE (2004) microbiological guidelines for contact recreation and shellfish waters.

7.0 DISPERSION STUDY

7.1 Introduction

CORMIX is a USEPA supported mixing zone model and decision support system that is often used to assess the impact on the mixing zone environment from continuous point source discharges into water bodies (Doneker & Jirka,1996). CORMIX is an internationally and nationally recommend analysis tool in key guidance documents (Jirka (1992), USEPA (1991a, 1991b, 1998, and 1999), and ANZECC (2000)), and as a consequence is regarded as a primary tool to evaluate plume profiles and dispersion characteristics of treated wastewater discharges into river and marine environments.

7.2 Methodology

The dilution and dispersion modelling was conducted using CORMIX (v5.0.2.0). This assessment provides a summary of the likely minimum dilution expected from each of the six outfalls evaluated in this study. The evaluations are based on an extreme rate of discharge from the WWTP, and tidal conditions. These predicted rates of dilution form the basis of the risk assessment and the determination of the likely performance requirements of possible upgrades to the current WWTP or design of a new WWTP.

The CORMIX outfall predictions summarised in this report are based on schematised approximations of the harbour bathymetry (measure of the harbour depth) at the point of discharge, and approximations of the harbour currents based on tidal prism evaluations.

7.3 Preliminary Results

In selecting the scenarios in this study, many factors have been considered that could affect the resulting dispersion and dilution. The key aim of modelling is to identify an envelope of scenarios that cover most, if not all, of the environmental conditions that may be encountered. This approach leads to an evaluation in which the actual discharge would usually result in a better rate of dispersion and dilution than that predicted in the modelling study.

The model scenarios considered in this study encompass the following range of environmental and discharge conditions:

- *Rate of Discharge of Treated Wastewater* is less than 1,795 m^3/day (being flows less than the predicted maximum daily flow or maximum wet weather flow in 2041).
- *Tidal Current* is less than that experienced during a spring tide.
- *Water Level* is greater than that expected during Mean Low Water level during a Spring Tide (MLWS).

The discharge of the treated wastewater from the diffuser exhibits a generic shape and profile shown in Figure 3.

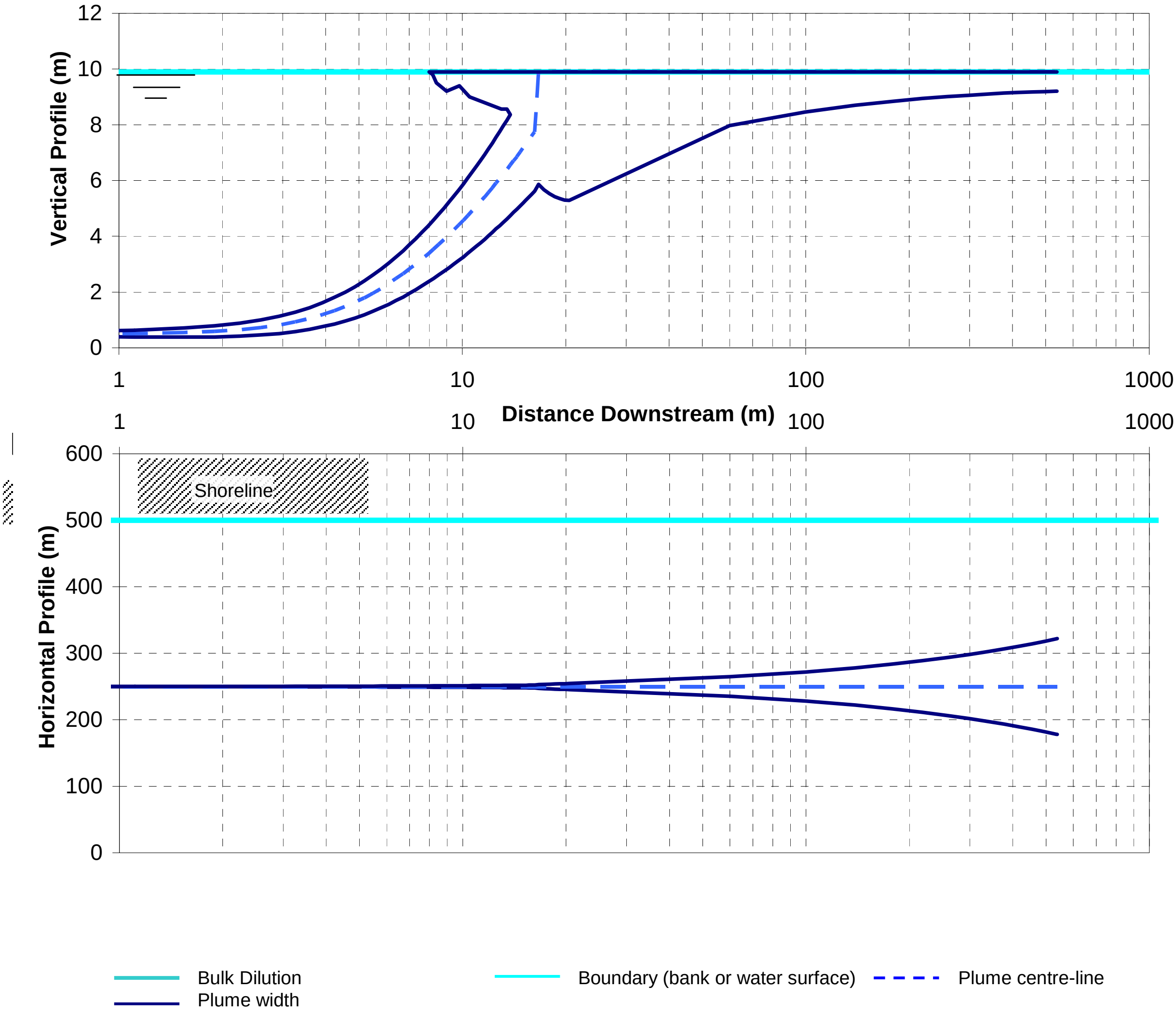


Figure 3: Generic profile of the discharge from a single port outfall in Akaroa Harbour.

The discharge is hydrodynamically "stable", that is, momentum of the discharge is weak compared to the relative effect of the discharge buoyancy. The discharge is effectively fresh water that is lighter than the saline harbour water, and as a consequence the treated wastewater tends to rise to the surface.

The discharge of treated wastewater from the outfall progressively passes through several phases. The following provides a qualitative description of the discharge plume(s) during those phases:

1) The discharge is initially dominated by the momentum of the discharging jet from the diffuser. The jet is weakly deflected by the ambient harbour current in the proximity of the discharge.

2) After some distance the buoyancy of wastewater dominates, and the rate of plume rise is more rapid. The plume is still deflected by the ambient current.

3) As the rising plume impinges on the water surface, the plume spreads more or less radially along the water surface. In particular, the flow spreads some distance upstream against the ambient flow, and laterally across the ambient flow.

4) The discharge plume continues to spread laterally across the water surface. At this stage the plume is conveyed by the surface harbour current. The plume thickness may decrease during this phase. The mixing rate is now comparatively small compared to the earlier phases. Near shore outfalls may experience possible plume-boundary interaction with the shoreline.

5) After some distance the background turbulence in the harbour dominates the mixing mechanism. The plume continues to mix in the harbour and ultimately is flushed out of the harbour.

As outlined earlier a body of treated wastewater spends on average 7.6 days in the Akaroa Harbour before it is flushed out of the harbour. To put this into some context, in summer when the flows into the WWTP are the greatest (summer average daily flow in 2041 is expected to be 1,625 m^3/day), approximately 0.0027 % of water in the harbour would have passed through the Akaroa WWTP, or in other words 99.973% of the water is “fresh” sea water.

7.4 Mixing Zones

Each of the discharge options considered was modelled using CORMIX. Outfall modelling needs to consider typical (long-term) and worst case (short-term) discharge flows.

The critical design case differs depending upon what aspect of receiving environment quality is being managed and/or protected. In some cases the critical case may be minimum dilution which occurs when the WWTP is discharging the peak hourly flow (i.e., the peak flow over an hour during a storm event). In others it may be the average daily or peak daily flow.

Table 6 provides discharge dilution information during peak daily flows which encompasses average daily flow (so is relatively conservative in terms of daily flow using average or 90%ile discharge quality concentrations).

Table 6: **Modelled minimum dilution at edge of mixing zones at outfall options.**

WWTP Location	Outfall Location	Reasonable mixing zone (m)	Minimum dilution
Akaroa North	Near Shore	100	215
	Mid-Harbour	250	275
Existing	Near Shore	100	251
	Mid-Harbour	250	340
Akaroa South	Near Shore	100	526
	Mid-Harbour	250	871

Based on the modelled site-specific dilution and the receiving environment goals set out in Table 5, Table 7 provides an indication of the limiting treated wastewater discharge concentrations. An example of the back-calculation technique is presented below:

Example of back-calculation:

BOD from the Akaroa North – Near Shore Outfall:

Minimum dilution at extent of reasonable mixing zone (100 m): 215 x (Source: Table 6)

Diluted treated wastewater target at edge of reasonable mixing zone – BOD: <2 g/m^3 (Source: Table 5)

$$2\ g/m^3 \times 215 = 430\ g/m^3$$

Cells of Table 7 shaded green are those parameters and locations where the current WTP discharge concentration is below the numeric back-calculated values (monitoring data on the current concentration of NOx, TP and enterococci in the wastewater was not available).

Table 7: Back-calculated numeric values of treated wastewater quality to meet receiving water goals.

WWTP Location	Outfall Location	BOD_5	TN	Ammonia -N	NOx	TP	DRP	Enterococci (cfu/100 mL)	Faecal coliforms (cfu/100 mL)
Akaroa North	Near Shore	430	45	300	4.9	8.4	3.6	16,000	3,000
	Mid-Harbour	550	60	385	6.3	10.7	4.7	19,500	3,900
Current	Near Shore	500	50	350	5.8	9.8	4.3	18,900	3,500
	Mid-Harbour	680	70	475	7.8	13.0	5.8	24,600	4,800
Akaroa South	Near Shore	1,050	110	740	12.0	21.0	8.9	35,500	7,400
	Mid-Harbour	1,740	180	1,220	20.0	34.0	15.0	59,400	12,200

Note: All units are in g/m³ unless otherwise stated.

Based on the back calculated values, the current WWTP treated wastewater quality is not likely to meet receiving water numerical guidelines beyond a zone of immediate mixing. These are:

- Dissolved inorganic nitrogen (DIN[2]) at the existing and Akaroa North near shore outfalls.
- DRP at sites Akaroa North near shore and existing site mid-harbour outfalls.
- TP at same sites as DRP assuming DRP is 50% of TP.
- Total phosphorous.

As a consequence, an improvement in WWTP performance and reduction in concentration in concentration of DIN and phosphorous will be required to continue to discharge into the Akaroa Harbour.

In the following sections each of the key receiving environment issues noted above is discussed in relation to setting discharge quality limits.

Effects within the immediate mixing zone to ensure that there are no acute effects arising from the discharge.

Based on current Akaroa WWTP treated wastewater quality, immediate dilution does not result in any acutely toxic effects within the current immediate mixing zone. The USEPA (1989) saltwater acute criteria for ammonia are pH, salinity and temperature dependent. At 15°C and 10 ppt, the acute criteria are 92 g/m³ at pH 7 and 9.4 g/m³ at pH 8.0. Based on these values and the concentration of ammoniacal-nitrogen in the treated wastewater (8.9 g/m³), either a relatively small amount of dilution or none at all is required to avoid acutely toxic effects of ammonia. No specific issues have been identified that give rise to any concern about likely adverse effects within the mixing zone. Ammonia toxicity is typically the limiting parameter in some discharge situations if the discharge nitrogen is predominantly in reduced form.

Sedimentation effects arising from the discharge (in situations where solids quality is elevated).

Currently Akaroa treated wastewater quality is sufficiently high enough (median TSS of 18 g/m³) that sedimentation effects are unlikely at any outfall option. The discharge of wastewater has been occurring from the current WWTP and outfall since the 1960s. Sediments around the current Akaroa WWTP outfall do

[2] Dissolved inorganic nitrogen (DIN) is a measure of the dissolved nitrite + nitrate + ammonia in solution.

not show evidence of anaerobic conditions in sediments arising from accumulation of excessive organic matter, and there is no indication that organic matter has accumulated around the outfall (Golder Kingett Mitchell 2007).

Chronic effects arising from the discharge, including toxicity arising from ammonia and contaminants.

Chronic toxicity arising from ammoniacal-nitrogen is not likely as only minimal dilution is required to reduce receiving water concentrations to below ANZECC (2000) trigger values or USEPA (1989) criteria. At the identified worst case dilution (215 times), the discharge could contain in excess of 100 g/m^3 ammoniacal-nitrogen and not result in chronic effects due to toxicity. Given the median concentration (8.9 g/m^3) is currently much lower than this chronic toxicity from ammonia is not expected to be of particular concern. Ammonia contributes to dissolved inorganic nitrogen loading and this is discussed further below.

Chronic effects arising from the discharge relating to elevated concentrations of oxygen demanding substances.

The current Akaroa WWTP discharge water quality is sufficiently low (median BOD_5 of 10 g/m^3) that oxygen demand from residual oxygen demanding substances is very low and unlikely to result in measureable changes. BOD in wastewater discharges can directly reduce dissolved oxygen concentrations in receiving waters and consequently aquatic life. In most circumstances reduction in dissolved oxygen is not expected to be of particular concern for wastewater discharges to marine environments (NZWERF 2002).

The effects of nutrients in the discharge, including effects on shoreline ecology and on plankton in the harbour.

In relation to nutrients (nitrogen and phosphorous), the following need to be considered prior to any final decision being made regarding any limits being imposed on either nitrogen or phosphorous in the discharge:

- Bolton-Ritchie (2007) identified a guidance value for dissolved oxidised nitrogen to presumably aid in prevention of excess plankton growths in Akaroa Harbour. Any consideration of the potential effects of nitrogen needs to include dissolved inorganic nitrogen, which will include ammoniacal-nitrogen. Following a similar approach in ANZECC (2000), Bolton-Ritchie (2007) identified that the 80^{th} percentile concentrations of both NNN and NH_3N in the inner harbour were ~0.024 g/m^3 (giving a combined concentration of 0.048 g/m^3) may result in excess plankton growths in the harbour. However it should be noted that the ANZECC (2000) and Bolton-Ritchie (2007) have identified likely trigger values for further site-specific studies, rather than thresholds.
- Based on DIN concentrations there is a slightly greater likelihood of enhanced phytoplankton growth at the Akaroa Harbour Heads than at other sites (ECan 2005b).
- The circulation and the residence time of water within the harbour and in the vicinity of proposed outfalls.
- The overall proportion of the nitrogen and phosphorous load that the Akaroa WWTP contributes to Akaroa Harbour. It is understood that ECan are currently investigating nutrient loads being contributed to Akaroa Harbour from sources including waterways.
- The shoreline contact of diluted wastewater plumes and any contribution to growth of attached algae. Although some growth is evident adjacent to the current discharge point, the occurrence of shoreline growth at locations remote from the discharge is not fully known.
- The likely loss of bioavailable nutrients into biological material.

Public health effects, including contact recreation and shellfish gathering.

The bacterial indicators measured in harbour waters are used to indicate the possible presence of pathogens. The key pathogenic indicator of choice is Rotovirus, especially where human wastewater is involved. Although the modelling provides dilution information that can be used to assess bacterial dilution (and also hypothetical viral dilution based on estimates in wastewater), a number of factors need to be considered, in conjunction with statistical data on their occurrence. These include; viral numbers, treatment efficiency, dispersal and dilution at locations where contact recreation and shellfish gathering occur, information about contact recreation, uptake of viral particles by seafood and ingestion of water and seafood.

For a preliminary consideration of the potential effects on contact recreation activity and seafood consumption, comparison has been made with guidance from MfE (2003). It should be noted, however, that the MfE (2003) guidelines were not intended for use in locations that are (or will be) directly impacted by treated wastewater.

Current Akaroa discharge quality is sufficiently high enough (median faecal coliforms 270 cfu/100 mL) that the risk of exceeding the median shellfish gathering guideline (14 /100mL) at the edge of the preliminary mixing zones is low. As noted above, enterococci numbers in the current wastewater discharge were not available. Provided enterococci numbers are similar to faecal coliform numbers, the risk of exceeding the recreational guideline (140 /100mL) at the edge of the preliminary mixing zones is similarly low.

Depending on the possible location of a harbour discharge, it may be necessary to consider a Quantitative Microbial Risk Assessment (QMRA) to assess the potential human health and safety risks. A QMRA focuses on assessing the pathogen concentrations of a discharge and infer associated health effects from known dose-response relationships (MfE 2003). Quantitative health risk assessment procedures (like QMRA) are now becoming an essential part of an AEE (Assessment of Environmental Effects) when recent resource consents for treated wastewater discharges (e.g., Mangere, Christchurch, Dunedin, Tauranga, Waimakariri District) undertaking an qualitative health risk assessment.

A QMRA should be considered if there is a clear risk to human health and safety, which in turn is dependent on the location of the outfall. The likely health receptors are likely to be, but not limited to, the marine farming activities in the harbour, contact/water recreational activities (swimming, water skiing, and boating) and/or tourism activities. It is expected that the outcome of any QMRA would be outfall location dependant; near shore outfalls are likely to present a greater human health and safety risk, whilst the southern mid channel outfall may pose a risk to the salmon farm. Further consideration is required to determine if a QMRA is appropriate for any or all of the possible harbour discharges.

The effects of contaminants in the discharge on Hectors Dolphins.

As noted earlier, a search of literature did not elicit any evidence indicating that the current discharge of treated wastewater into the Akaroa Harbour is adversely affecting the health of Hectors Dolphins. In a recent presentation to the Working Party, Dr Liz Slooten (University of Otago) indicated that information on the concentration of bioaccumulating, non-biodegrading and carcinogenic compounds, and certain bacteria in the treated wastewater and sediments may assist in determining the risk of adverse impacts on Hectors Dolphins from the discharge of treated wastewater.

Persistent organic pollutants (POPs) are currently not routinely monitored in the Akaroa WWTP treated wastewater, which is consistent with other wastewaters in New Zealand (NZWERF 2002). Screening tests for POPs are recommended where the risk analysis process has identified potential sources (e.g., industry) (NZWERF 2002). Whilst we are aware of issues with POPs, bioaccumulating, non-biodegrading and carcinogenic and “novel” compounds in wastewater, we note that these issues are inherent to all WWTP discharges into marine environments.

The specific risk of adverse effects of the discharge of treated wastewater on Hectors Dolphins (either directly or indirectly (via the food chain)) is unlikely to be better quantified without significant additional research. As outlined earlier, a literature research has not identified the current harbour a discharge (either Akaroa, Wainui or Duvauchelles WWTP) has been linked to the primary cause of Dolphin deaths.

7.5 Options for Improved Dispersion

7.5.1 Outfall location

The location of an outfall (being either near-shore or mid-harbour) has a direct effect on the probability and hence the risk of unacceptable algal growths on the shoreline and the potential bacterial (or viral) contamination of shellfish or recreational waters impacting users of those resources.

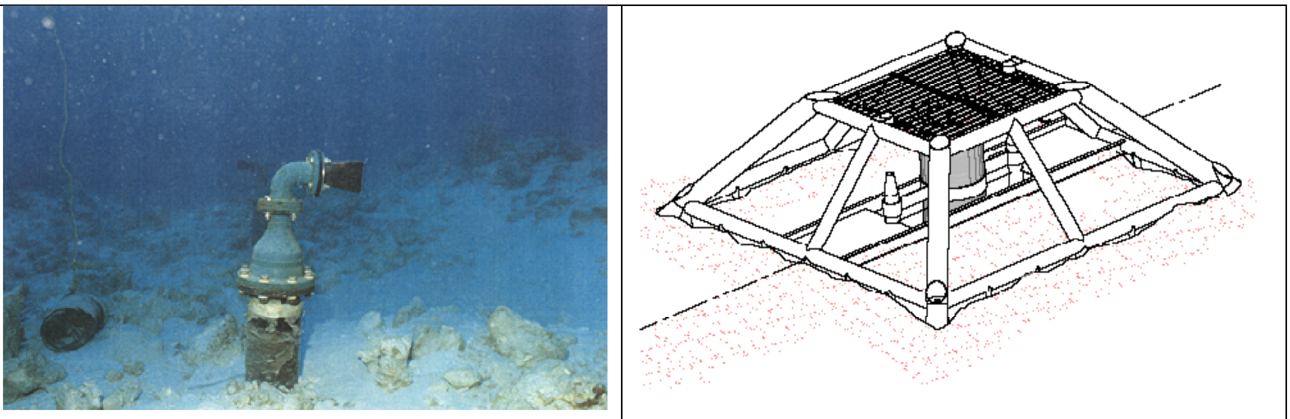
In general, the mid-harbour outfalls are in deep water some distance from the shoreline, and are hence less likely to contribute to algal growths, contamination of shellfish or to routinely come in contact with shore-based recreational users of the Akaroa Harbour.

7.5.2 Diffusers

Due to the relatively low discharge rate, a single riser harbour outfall comprising a single port, similar to that presented in Figure 4 (a) appears suitable. A duckbill valve is proposed on the outfall port. Duckbill valve is the name given to a rubber flap valve (manufactured by Red Valve Co, USA) that allows water to flow out of the valve, but does not allow water to flow back through it. These valves offer two benefits. Firstly, they prevent the seawater from flowing back into the outfall pipe that could carry sand and/or shellfish spat. The accumulation of sand or shellfish growths could reduce the hydraulic capacity of the outfall. Secondly, the valve increases the discharge velocity, which in turn increases the rate of near field mixing.

The diffuser outlet would need to be elevated, to prevent the diffuser section being buried by sand as the harbour floor topography changes over time. For the purposes of this study, it has been assumed that the diffuser invert level is 500 mm off the harbour bottom.

A frame structure (or similar) would be required over the diffuser riser, to prevent fishing nets and anchors entangling the outlet port, causing damage to the diffuser, outfall pipe and/or the fishing nets. It is envisaged that a tubular structure, similar to that presented in Figure 4 (b), has the potential to reduce entanglement and hook nets, whilst minimising the potential for the structure to interfere with the mixing and dispersion of the treated wastewater plume.



(a) (b)

Figure 4: Example of (a) duckbill diffuser and (b) frame structure over an outfall (Source (a) Tideflex (2009), (b) URS (2004)).

7.5.3 Outgoing tide only discharge

Discharging on the outgoing tide will require the WTP to storage at least the 75 % of the maximum daily discharge of treated wastewater. It is assumed that the discharge will occur during the first three hours of the outgoing tide, with two discharges per day. Consequently, a storage tank providing at least 1,220 m^3 (Peak summer ADWF 1,625 m^3/day x 0.75 day) of active storage would need to be provided. This is equivalent to a tank 6 m in height and 16 m in diameter.

Whilst the storage tank will be capable of storing many of the wet weather inflows into the plant, it is neither practical nor feasible to retain all the wet weather discharges. During extreme wet events excess wastewater will be discharged to the harbour, possibly during periods of the incoming tide. Fortunately during periods of extreme wet weather events the harbour is highly loaded with silt and sediments from the streams that feed into the harbour, and the harbour is not actively used by residents or visitors. Consequently, the environmental and societal risk of the wet weather discharge is reduced.

A comparative assessment of the options of continuously discharging treated wastewater to the harbour and discharging on the outgoing tide identified the following attributes:

- The mass of nutrient or contaminant load into the harbour is identical.
- The effective residence times of the nutrients/contaminants in the harbour are near identical.
- Discharging on the outgoing tide reduces the risk of exposure to the treated wastewater, as the discharge is on average only 6 hours per day.
- The discharge on the outgoing tide limits the possibility of plume attachment to the harbour bottom or shoreline to areas down current of the respective outfall(s).
- To overcome the increase in rate of discharge of an outgoing tidal option, a multiport diffuser would be required. Consequently, the size of the reasonable mixing zone would need to increase, to reflect the spacing between the diffusers. This would be expected to increase reasonable mixing zone by 40-50m.
- A multiport diffuser would incur a marginal increase in cost to construct and install.

As outlined earlier, the hydraulic residence time in the harbour is around 7.6 days. Discharging on the outgoing tide is unlikely to result in a noticeable change in the retention of nutrients and possible contaminants in the harbour.

The advantage of this discharge option is that the extent and direction of the possible discharge plume can be restricted to a zone in the direction of the outgoing current from the respective outfall.

The earlier dispersion and dilution studies are directly applicable to this discharge option, with the exception that the zone of reasonable mixing will be slightly larger to reflect the size of a multiport diffuser.

7.5.4 Hybrid land irrigation/harbour discharge

In the hybrid option, land irrigation will predominantly occur during summer. However during winter, or during prolonged periods of wet weather, the land irrigation blocks may be unable to assimilate additional treated wastewater. The surplus treated wastewater will be discharged to the harbour.

The hydraulic buffering provided by the land irrigation storage tank(s) is likely to result in a discharge to the harbour less than the CORMIX assessed discharge of 1,795 m^3/day (being the maximum daily inflow into the WTP in 2041). The earlier CORMIX dispersion studies are therefore directly applicable to this discharge option.

Since the hybrid treatment plant will be designed to provide treated wastewater suitable to be discharged to land, it is likely that the treated wastewater quality will be of a higher standard (i.e., lower concentration of nutrients and possible contaminants).

The primary advantage of this discharge option is that frequency of discharge is restricted to periods in which the recreation values in the Akaroa Harbour are low, due to inclement weather.

8.0 REQUIRED WASTEWATER QUALITY

Treated wastewater quality standards have been proposed based predominantly on the preliminary risk assessment (Table 8). The current Akaroa WWTP discharge permit (CRC071865) does not specify nutrient discharge standards. The standard proposed from DIN is less than the nitrate-nitrogen concentrations identified in the preliminary modelling work and appears to be achievable by the current Akaroa WWTP. The effects of bioavailable nutrients, specifically DIN, appears to be parameter that should dictate the design and operation of the WWTP for a marine discharge. Until the completion of further assessment, the proposed discharge standard is based on the assessment of nitrate nitrogen.

Table 8: Comparison of median final effluent quality proposed for Akaroa WWTP with Lyttelton Harbour's proposed discharge standards (Harbour Outfall).

Parameters	Akaroa WWTP - Current Consent Conditions	Proposed Treated Wastewater Quality for Akaroa WWTP for Harbour Discharge	
		Treated Wastewater Quality Required to Meet Environmental Objectives	Likely Consent Conditions (Median)
BOD_5 (g/m^3)	< 30	< 500	< 30
TSS (g/m^3)	< 30	-	< 30
TN-N (g/m^3)	-	< 40	< 30
Amm-N (g/m^3)	-	< 350	-
DIN (NO_3^--N) (g/m^3)	-	< 8	< 6
TP-P (g/m^3)	-	< 10	< 8
DRP-P (g/m^3)	-	< 5	< 4
Faecal Coliform (cfu/100mL)	< 1,000	< 3,000	< 1,000
Enterococci (cfu/100mL)	-	< 19,000	< 1,000

Notes: "Limits at Minimum Dilution" refer to the estimated median pollutant limits to comply with guideline values based on minimum dilution in the harbour. It has been assumed that DRP is 50% of TP

Other factors have guided the recommended treated wastewater quality standards for some contaminants, particularly:

- TSS and BOD_5 are not key contaminants of concern in relation to the marine discharge. The discharge standards are not based on the outcomes of a risk assessment, rather they are optional standards that could be proposed to satisfy public/regulatory perception – that the proposed WWTPs will (1) operate satisfactory, and (2) provide consistency with similar current wastewater discharge permits.
- The faecal coliform (indicator for effects on shellfish gathering) standard is proposed for consistency with similar current wastewater discharge permits (including that for the Akaroa WWTP) and is not strictly based on the outcomes of the risk assessment. The indicator and standard will be less relevant if the discharge and mixing zone are sufficiently separated from areas used for shellfish gathering (i.e., This standard may not be applicable for a mid-harbour discharge).
- The enterococci (indicator for effects on recreational use of marine waters) standard is not strictly based the outcomes of the risk assessment but recognises that ideally the contact recreation criteria should be comfortably satisfied at the surface, immediately above the outfall.

The bacterial indicators measured in harbour waters are used to indicate the possible presence of pathogens. The key pathogenic indicator of choice is Rotovirus especially where human wastewater is involved. Although the modelling provides dilution information that can be used to assess bacterial dilution (and also hypothetical viral dilution based on estimates in wastewater), a number of factors need to be considered (in conjunction with statistical data on their occurrence). These include; viral numbers, treatment efficiency, dispersal and dilution at locations where contact recreation and shellfish gathering occur, information about contact recreation, uptake of viral particles by seafood and ingestion of water and seafood.

Table 9: Comparison of median final effluent quality proposed for Akaroa WTP with treated wastewater quality standards in Canterbury marine wastewater discharge permits.

WWTP	Consent no.	BOD_5	TSS	Faecal coliforms (/100 mL)	Enterococci (/100 mL)	DIN	Amm-N	TN	DRP
Akaroa (Proposed)	-	30	30	1,000	1,000	<6	-	30	4
Akaroa (Current)	CRC071865	30 [1]	30 [1]	1,000	-		-	-	-
Christchurch	CRC012011.2	10 [2]	30	2,000 – summer, 10,000 - winter (std) 20,000 [3]	-		40 45 - maximum	40	8
Duvauchelle	CRC991835	30	30	1,000	-		-	-	-
Governors Bay	CRC981106	30	30	1,000	-		-	-	-
Diamond Harbour	CRC031546	30	30	1,000	-		-	-	-
Lyttelton	CRC940690A	30	30	1,000	-		-	-	-
Wainui	CRC032102.1	50	50	1,000	-		-	-	-
WDC ocean outfall	CRC041162.2	25 [2]	200	1,000 – summer, 9,000 - winter (std) 5,000 [3] – summer, 20,000 [3] – winter (higher)	500 (std) 1,500 [3] (higher)		27	-	-
CCC ocean outfall	CRC051724	20 [2]	50	1,000 (std), 5,000 [3] (higher)	1500 (2 consecutive samples)		40	-	-

Notes: All values are g/m³ unless otherwise stated. All limits are medians unless otherwise specified. Resource consents require different methods for calculating medians. “Summer” is November to February inclusive, “Winter” is

March to October inclusive. [1] Values are triggers rather than limits. [2] Limit is for filtered BOD_5. [3] No more than two samples from eight consecutive samples may exceed this value.

Having noted that, for a preliminary look at the potential effects on contact recreation activity and seafood consumption, comparison has been made with guidance from MfE (2003). It should be noted however that the use of the MfE (2003) guidelines were not intended for use in locations that are (will be) directly impacted by treated wastewater. Detailed site specific assessment of the pathogen concentrations and indicator bacteria (Faecal Coliform and Enterococci) in the treated wastewater is required; however this assessment is outside the scope this study.

The proposed treated wastewater quality standards are similar to those specified on other marine wastewater discharge permits in Canterbury.

Some of the resource consents identified in Table 8 also have conditions that specify receiving environment contaminant concentration limits and discharge mass load limits however these have not been reported.

9.0 RISK ASSESSMENT

The risk assessment approach adopted in this study is based on “The Leopold Matrix” method (Leopold et al., 1971). The technique is applicable to qualitative environmental impact assessments, and is used to identify the potential impact of a project or discharge in this case on the environment. The method consists of a matrix with columns representing the various activities of the project, and rows representing the various environmental factors to be considered. The intersections are filled in to indicate the magnitude (from -10 to +10) and the importance (from 1 to 10) of the impact of each activity on each environmental factor.

Measurements of magnitude and importance tend to be related, but do not necessarily directly correlate. Magnitude can be measured fairly explicitly, in terms of how much area is affected by the development and how badly, but importance is a more subjective measurement. While a proposed development may have a large impact in terms of magnitude, the effects it causes may not actually significantly effect the environment as a whole.

In this Risk Assessment, only the environmental factors have been considered, specifically the physical and chemical characteristics like water and deposition, biological conditions and associated effects on flora and fauna in the marine environment. Societal factors like land use, recreation, aesthetics and cultural aspects have been considered. The costs of the various options have not been considered in this report, Harrison Grierson will address this aspect of the project in the final report to be presented to the working party.

The detailed assessment matrix is reproduced in Appendix B, a summary of which is presented below in Table 10.

The environmental risk assessment identified that if treated wastewater is required to be discharged to the Akaroa Harbour, then a mid harbour outfall near the existing WWTP site offers the least adverse environmental, societal and cultural impact. Closely followed by a mid harbour outfall from the proposed Akaroa South and North sites. There is noticeable grouping based on outfall locality. The near shore outfalls have a Leopold Matrix weighting in the -20’s while the mid-harbour outfall are in the -10’s. This suggests that a noticeable reduction in the potential adverse effects of the discharge to the harbour can be reduced by providing a mid-harbour outfall.

Table 10: Ranked preference of possible Akaroa Harbour discharges (Leopold Matrix).

Location of Harbour Discharge		Rank		
		Location	**Regime**	**Weighting**
Existing Site (Redhouse Bay)	Near shore outfall	4		-17.8
	Mid harbour outfall	1		-10.6
Akaroa North	Near shore outfall	6		-24.5
	Mid harbour outfall	3		-13.5
Akaroa South	Near shore outfall	5		-21.4
	Mid harbour outfall	2		-11.5
Discharge Regime				
Conventional Discharge	Near shore outfall		6	-21.7
	Mid harbour outfall		3	-11.9
Outgoing Tidal Discharge	Near shore outfall		5	-20.2
	Mid harbour outfall		1	-11.2
Hybrid Discharge	Near shore outfall		4	-18.9
	Mid harbour outfall		2	-11.4

Note : Ranking 1 = preferable, 6 least preferred.

Applying the Leopold Matrix to assess the environmental benefit of discharging on (1) an outgoing tide, or (2) the hybrid land irrigation/harbour discharge (Table 10) identified the following:

- Mid-harbour discharges are less environmentally detrimental compared to near shore outfalls.
- The discharge on the outgoing tide is slightly better than the hybrid discharge, which in turn is slight better than a continuous discharge from an outfall in the Akaroa Harbour.

Table 10 results indicate that a mid-harbour outfall, offshore from the Redhouse Bay and discharging during an outgoing tide would cause the least environmental, societal and cultural effects. However the benefit of a outgoing tidal discharge is barely distinguishable from a conventional (continuous discharge) or the hybrid discharge option.

10.0 CONCLUSIONS AND RECOMMENDATIONS

On the basis of an environmental risk assessment, this report has ranked the preferable harbour discharge options on the basis of human health and safety, ecological, community value, economic utility and aesthetic risk factors. The “Leopold Matrix” technique was applied to qualitatively assess (and ranked) the environmental impact of the possible outfall options. This assessment identified the following:

- Mid-harbour discharges are less environmentally detrimental compared to near shore outfalls.
- The discharge on the outgoing tide is slightly better than the hybrid discharge, which in turn is slightly better than a continuous discharge from an outfall in the Akaroa Harbour. However, it appears that the additional benefit is unlikely to warrant the additional costs.
- A mid-harbour outfall, offshore from Redhouse Bay and discharging during an outgoing tide would cause the least environmental, societal, and cultural effects. However the benefit of an outgoing tide is barely distinguishable from a continuous discharge or the hybrid option considered in this study.

This assessment has not considered the cost to construct nor operate the various harbour discharge options. It is recommended that the final selection of a preferred discharge option, consider both the environmental risk assessment, outlined in this report, in conjunction with an economical consideration of the cost of the various option(s) to the rating base.

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APPENDIX A

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APPENDIX B

Leopold Matrix

APPENDIX B
Leopold Matrix

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LEOPOLD MATRIX
ASSESSMENT OF AKAROA WWTP DISCHARGE INTO THE AKAROA HARBOUR

				Discharge to the Akaroa Harbour						**Discharge Regime**					
				Existing Site (Redhouse Bay)		Akarao North		Akarao South		Continuous Discharge		Outgoing Tidal Discharge		Hybrid Discharge	
				Near shore outfall	Mid harbour outfall	Near shore outfall	Mid harbour outfall	Near shore outfall	Mid harbour outfall	Near shore outfall	Mid harbour outfall	Near shore outfall	Mid harbour outfall	Near shore outfall	Mid harbour outfall
Environmental Condiitons	PHYSICAL AND CHEMICAL CHARACTERISTICS	*Water*	Coastal Zone	-7 / 5	-5 / 5	-10 / 5	-7 / 5	-8 / 5	-6 / 5	-8 / 5	-6 / 5	-6 / 5	-4 / 5	-7 / 5	-6 / 5
			Quality	-7 / 5	-6 / 5	-8 / 5	-7 / 5	-7 / 5	-6 / 5	-7 / 5	-6 / 5	-7 / 5	-6 / 5	-6 / 5	-5 / 5
		Processes	Deposition	-2 / 1	-2 / 1	-2 / 1	-2 / 1	-2 / 1	-2 / 1	-2 / 1	-2 / 1	-2 / 1	-2 / 1	-2 / 1	-2 / 1
	BIOLOGICAL CONDITIONS	*Flora*	Aquatic plants	-4 / 4	-1 / 4	-5 / 4	-1 / 4	-5 / 4	-1 / 4	-6 / 4	-2 / 4	-5 / 4	-1 / 4	-5 / 4	-1 / 4
			Endangered species	-2 / 8	-2 / 8	-2 / 8	-2 / 8	-2 / 8	-2 / 8	-3 / 8	-3 / 8	-2 / 8	-2 / 8	-2 / 8	-2 / 8
		Fauna	Fish & shellfish	-9 / 8	-5 / 8	-9 / 8	-6 / 8	-9 / 8	-4 / 8	-9 / 8	-4 / 8	-9 / 8	-5 / 8	-9 / 8	-5 / 8
			Benthic organisms	-7 / 7	-5 / 7	-7 / 7	-5 / 7	-7 / 7	-5 / 7	-7 / 7	-5 / 7	-7 / 7	-5 / 7	-7 / 7	-5 / 7
			Endangered species	-5 / 8	-6 / 8	-5 / 8	-6 / 8	-6 / 8	-7 / 8	-6 / 8	-7 / 8	-5 / 8	-6 / 8	-5 / 8	-6 / 8
	SOCIAL FACTORS	*Land use*	Fisheries	-7 / 4	-2 / 4	-9 / 4	-3 / 4	-8 / 4	-1 / 4	-8 / 4	-1 / 4	-7 / 4	-2 / 4	-7 / 4	-2 / 4
		Recreation	Fishing	-6 / 6	-1 / 6	-9 / 6	-2 / 6	-9 / 6	-1 / 6	-9 / 6	-1 / 6	-8 / 6	-2 / 6	-8 / 6	-2 / 6
			Boating	-4 / 7	-3 / 7	-8 / 7	-5 / 7	-6 / 7	-4 / 7	-6 / 7	-4 / 7	-7 / 7	-4 / 7	-7 / 7	-4 / 7
			Swimming	-4 / 8	-2 / 8	-9 / 8	-4 / 8	-7 / 8	-3 / 8	-7 / 8	-3 / 8	-7 / 8	-3 / 8	-2 / 8	-1 / 8
		Aesthetics & Human Interest	Wilderness qualities	-3 / 5	-2 / 5	-4 / 5	-3 / 5	-3 / 5	-2 / 5	-3 / 5	-2 / 5	-3 / 5	-2 / 5	-2 / 5	-1 / 5
			Unique physical features	-3 / 6	-2 / 6	-3 / 6	-2 / 6	-3 / 6	-2 / 6	-3 / 6	-2 / 6	-3 / 6	-2 / 6	-3 / 6	-2 / 6
			Rare & unique species or ecosystems	-3 / 2	-3 / 2	-3 / 2	-3 / 2	-3 / 2	-3 / 2	-3 / 2	-3 / 2	-3 / 2	-3 / 2	-3 / 2	-3 / 2
			Historical or archaeological sites	-9 / 5	-5 / 5	-6 / 5	-3 / 5	-6 / 5	-3 / 5	-6 / 5	-3 / 5	-6 / 5	-3 / 5	-6 / 5	-6 / 5
		Cultural Status	Health and safety	-5 / 10	-2 / 10	-8 / 10	-3 / 10	-7 / 10	-3 / 10	-7 / 10	-3 / 10	-6 / 10	-2 / 10	-2 / 10	-1 / 10
			Employment	2 / 1	3 / 1	2 / 1	3 / 1	2 / 1	3 / 1	2 / 1	3 / 1	2 / 1	3 / 1	2 / 1	3 / 1
			Population density	-1 / 1	-1 / 1	-4 / 1	-2 / 1	-3 / 1	-2 / 1	-3 / 1	-2 / 1	-3 / 1	-2 / 1	-3 / 1	-2 / 1
	CULTURAL		Iwi	-8 / 8	-7 / 8	-7 / 8	-6 / 8	-7 / 8	-6 / 8	-7 / 8	-6 / 8	-5 / 8	-4 / 8	-5 / 8	-5 / 8
			Local community	-2 / 8	-1 / 8	-8 / 8	-5 / 8	-3 / 8	-2 / 8	-3 / 8	-2 / 8	-3 / 8	-2 / 8	-2 / 8	-1 / 8
			Total	-17.8	-10.6	-24.5	-13.5	-21.4	-11.5	-21.7	-11.9	-20.2	-11.2	-18.9	-11.4
			Rank	4	1	6	3	5	2	6	3	5	1	4	2

Evaluation Method — Magnitude / Importance

-10 to 10: A measure of the mangitude of the interaction.
1 to 10 : The real importance of the phenomenon for the given project.

Rank $\sum \left\{ \text{Magnitude} / \text{Importance} \right\}$

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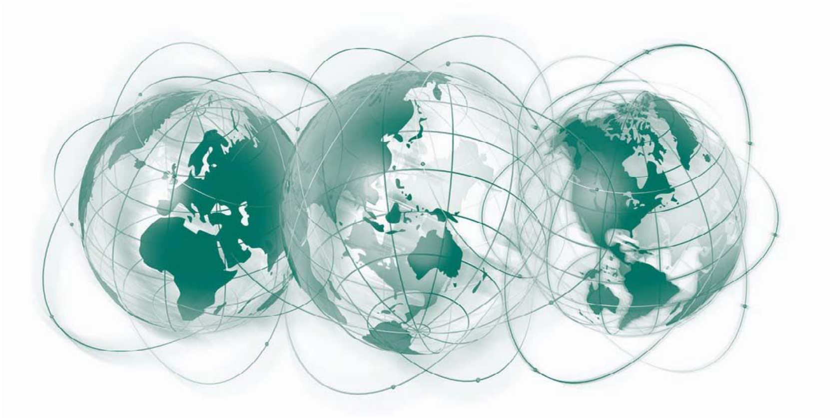

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