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Draft Report

Far North District Council Sludge Study - Stage 2 and 3 Report - Final

Prepared for Far North District Council

Prepared by CH2M Beca Ltd

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Revision History

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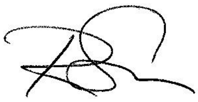
A	Azaria Rahardjo, Gokul Bharambe	Draft Report – Stage 2 and 3	08/12/2017
B	Azaria Rahardjo, Gokul Bharambe	Final Report – Stage 2 and 3	31/01/2018

Document Acceptance

Action	Name	Signed	Date
Prepared by	Azaria Rahardjo / Gokul Bharambe / Kate Simmonds		31/01/2018
Reviewed by	Rachael Shaw		31/01/2018
Approved by	Rachael Shaw		31/01/2018
on behalf of	CH2M Beca Ltd		

Executive Summary

A sludge strategy has been developed for Far North District Council (FNDC's) Wastewater Treatment Plants (WWTPs), with the ultimate objective being to develop a cohesive and cost-effective sludge management strategy, and to inform FNDC's long term plan. The sludge strategy was developed over three (3) distinct stages:

- An initial long list which was reduced via high level screening of the options, bearing in mind the overall project objectives and key FNDC constraints
- A technology selection Multi Criteria Analysis (MCA) workshop using only non-cost selection criteria to select the most appropriate technology options for costing and strategy development
- A Quadruple Bottom Line (QBL) analysis which incorporates both cost and non-cost selection criteria, to select the most appropriate strategy option for implementation.

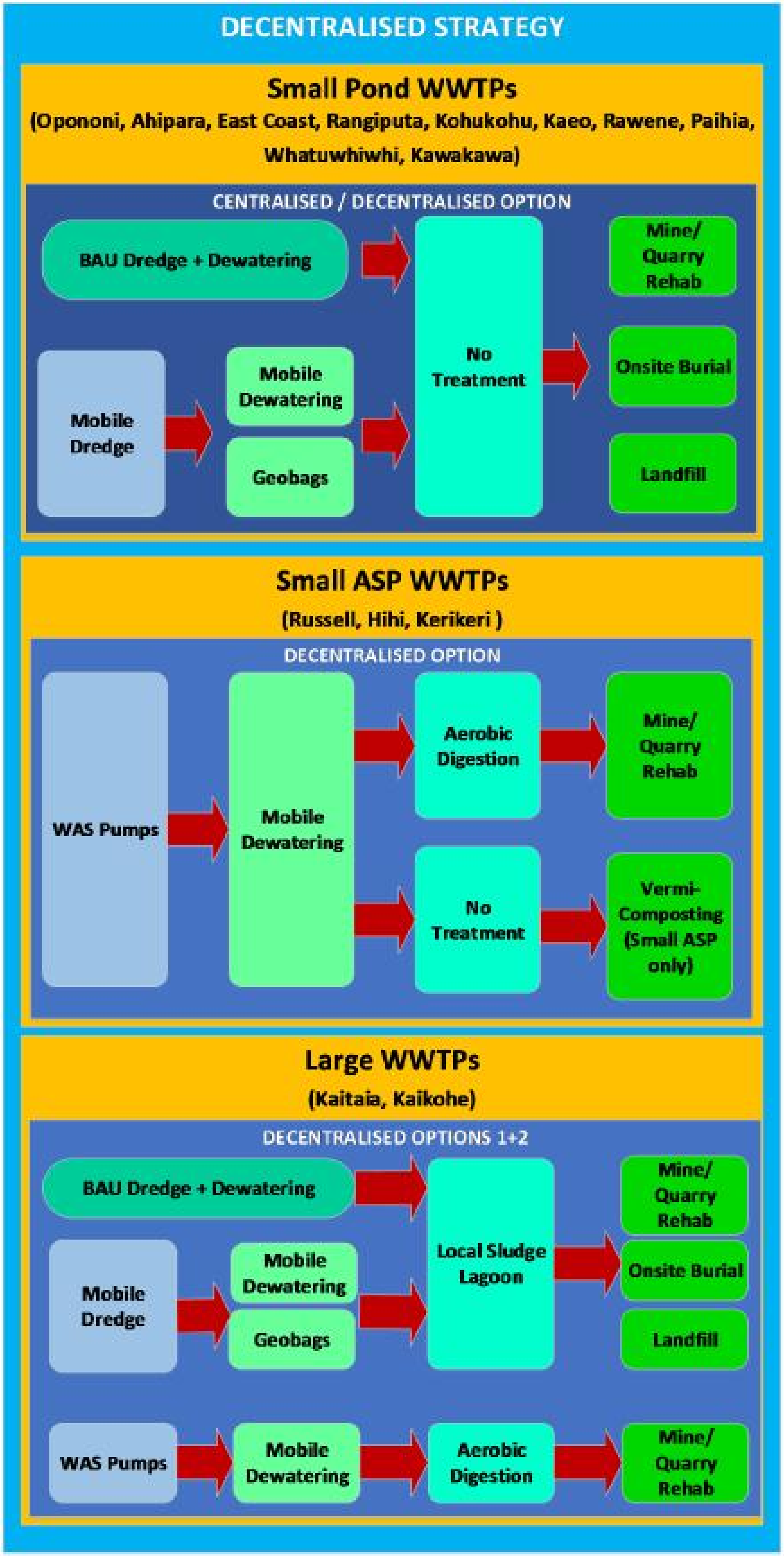
Costs have been developed for a number of strategy options to enable further evaluation. The costed options are outlined below:

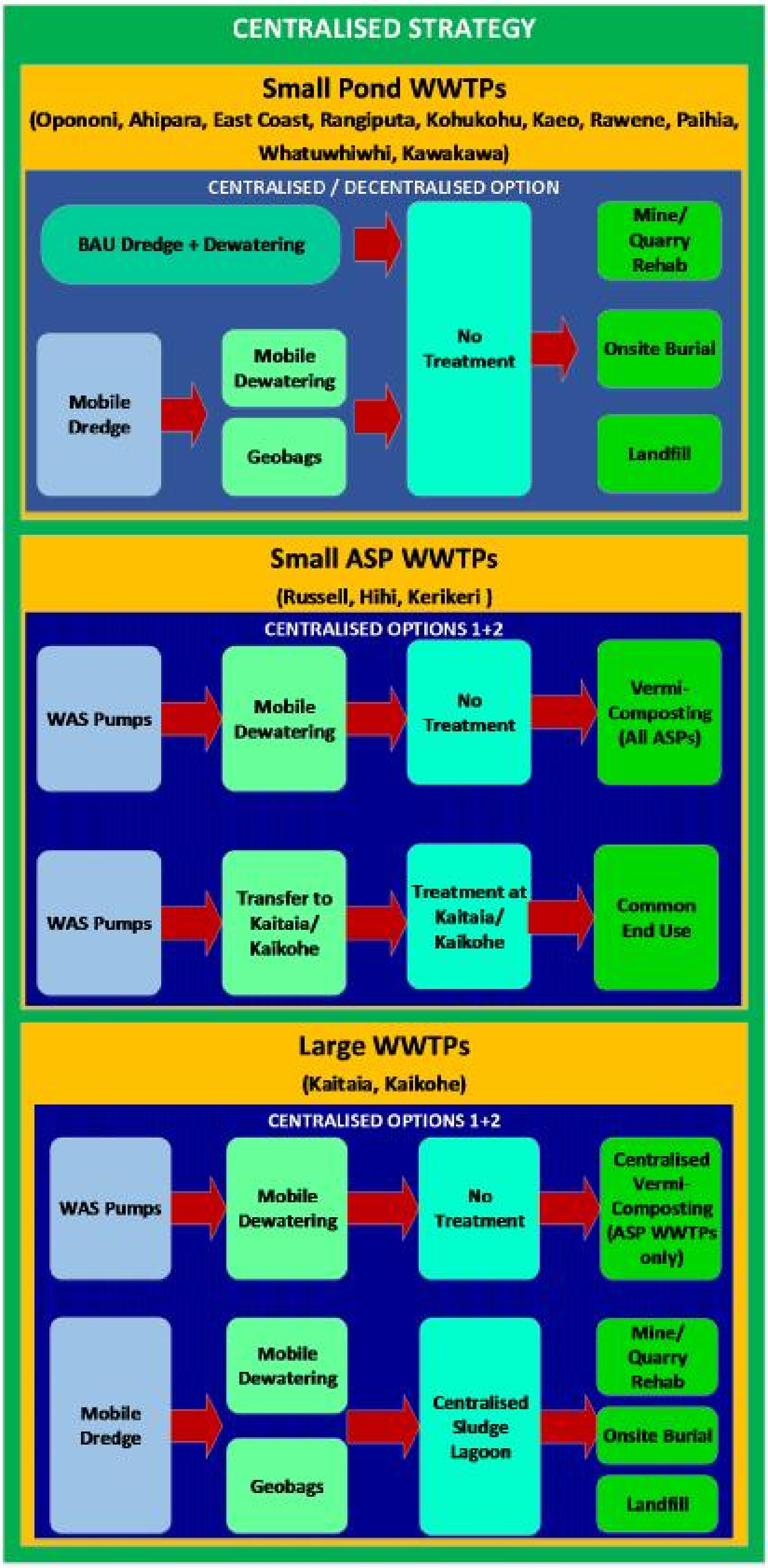
- **Business as Usual (BAU) Scenarios** – the current practice at FNDC's WWTPs. This comprises of the "Current BAU" scenario and "Future BAU scenario" as detailed following:
  - ***Current BAU*** – The current practice utilising Kaitaia WWTP and Kaikohe WWTPs as "Centralised" treatment ponds for the WAS from Hihi, Russell, and Kaerikeri WWTPs. Contractor dredging and dewatering will be employed for removal of sludge from the ponds, with the dewatered sludge disposed of to landfill This practice is unlikely to continue into the future as the Kaitaia and Kaikohe WWTP consents are approaching expiry and expected to be upgraded into ASP WWTPs in the near term. In addition the landfill availability in the region is limited and therefore it has been assumed that sludge would be trucked to Redvale Landfill.
  - ***Future BAU*** – Conversion of the existing oxidation ponds at Kaitaia and Kaikohe WWTPs into sludge ponds to treat the transferred WAS from Hihi, Russell, and Kerikeri. Contractor dredging and dewatering will be employed for sludge removal from the ponds, which will then be disposed of to landfill (also assumed to be Redvale Landfill).

- **Decentralised Strategy Option** – Providing each individual WWTP with their own respective sludge treatment, dewatering, and disposal options. The decentralised strategy option comprises of the following components:
  - Common Decentralised Strategy for Small ASP WWTPs (Hihi, Russell, Kerikeri).
  - Common Decentralised Strategy for Large WWTPs (Kaitaia, Kaikohe).
  - Common Strategy for Small Pond WWTPs – note that this is the same option for centralised and decentralised strategy (All remaining FNDC WWTPs).

- **Centralised Strategy Option** – Providing one or two centralised sludge processing facilities to treat sludge from the Small ASP WWTPs and Large WWTPs (expected conversion to ASP WWTPs in the near future). The decentralised strategy option comprises of the following components:
  - Common Centralised Strategy for all ASP WWTPs (Hihi, Russell, Kerikeri, Kaitaia, Kaikohe).
  - Common Strategy for Small Pond WWTPs – note that this is the same option for centralised and decentralised strategies (All remaining FNDC WWTPs).

The following graphics summarise the components of the Decentralised and Centralised Strategy Options which were then costed for evaluation.


DECENTRALISED STRATEGY
Small Pond WWTPs
(Opononi, Ahipara, East Coast, Rangiputa, Kohukohu, Kaeo, Rawene, Paihia, Whatuwhiwhi, Kawakawa)
CENTRALISED / DECENTRALISED OPTION
BAU Dredge + Dewatering
Mobile Dredge
Mobile Dewatering
Geobags
No Treatment
Mine/ Quarry Rehab
Onsite Burial
Landfill
Small ASP WWTPs
(Russell, Hihi, Kerikeri)
DECENTRALISED OPTION
WAS Pumps
Mobile Dewatering
Aerobic Digestion
No Treatment
Mine/ Quarry Rehab
Vermi-Composting (Small ASP only)
Large WWTPs
(Kaitaia, Kaikohe)
DECENTRALISED OPTIONS 1+2
BAU Dredge + Dewatering
Mobile Dredge
Mobile Dewatering
Geobags
Local Sludge Lagoon
Mine/ Quarry Rehab
Onsite Burial
Landfill
WAS Pumps
Mobile Dewatering
Aerobic Digestion
Mine/ Quarry Rehab



Costs were then developed for the identified sludge strategies for FNDC. Where various sub-options exist within each option (e.g. multiple disposal options, multiple dewatering options), the sub-option with the lowest

Net Present Cost (NPC) was selected to form the overall strategy option. The components of the sludge strategies, along with their respective costs, are summarized below.

Component	BAU – Current	BAU – Future	Decentralised	Centralised
Small Pond WWTPs	▪ No treatment ▪ Third party dewatering ▪ Landfill	▪ As BAU Current	▪ No treatment ▪ Mobile Dredge + Geobags ▪ Mine/Quarry Rehabilitation	▪ No treatment ▪ Mobile Dredge + Geobags ▪ Mine/Quarry Rehabilitation
Small ASP WWTPs	▪ ASP Transfers	▪ As BAU Current	▪ No treatment ▪ Mobile Dewatering ▪ Vermicomposting	▪ ASP Transfers
Large WWTPs (Kaitaia/Kaikohe)	▪ No treatment ▪ Third party dewatering ▪ Landfill	▪ ASP, with Centralised Sludge Ponds ▪ Third party dewatering ▪ Landfill	▪ Local Sludge Ponds ▪ Mobile Dredge & Geobags ▪ Mine/Quarry Rehabilitation	▪ Centralised Sludge Ponds ▪ Mobile Dredge & Geobags ▪ Mine/Quarry Rehabilitation
Capital Cost ($)	$13,800	$2,215,400	$3,417,100	$2,908,400
O&M Cost ($ p.a.)	$1,027,800	$1,038,900	$506,400	$448,600
NPC ($M)	$11.80	$14.13	$9.22	$8.05

Sensitivity analysis was also conducted to assess the impacts of changing key unit rates for the preferred sludge strategy. These were identified as inputs that are considered critical and have high risk of changing in the near future. The sensitivity analysis considered the following scenarios.

- Changes in sludge haulage costs (increase and decrease).
- Changes in Vermicomposting fees.
- Changes in FNDC variables, both within and outside of FNDC’s control (labour, polymer, maintenance).
- Changes in civil works and land purchase costs.
- Changes in FNDC maintenance costs.

The strategy cost evaluation, including the sensitivity analysis, has identified the Centralised sludge option as the preferred option from a cost perspective, having the lowest NPC. The sensitivity analysis further demonstrates that the Centralised option is preferred from a cost perspective and is considerably robust, being the option with the lowest NPC across all considered scenarios. However, the sensitivity analysis identified that the preferred dewatering sub-option can change depending on several input factors, including the cost of civil works and land purchase. More detailed assessments should be undertaken by FNDC to confirm the preferred dewatering option, which should include concept level design and costing to allow a more detailed assessment. This is required as for this high level strategy, the NPC level of accuracy is less than the cost difference between the dewatering options..

A QBL analysis was completed to select the preferred sludge strategy option, incorporating both cost and non-cost considerations. Sensitivity was also done on the QBL for the different weightings assigned to both the cost and non-cost criteria. The QBL analysis identified the Centralised sludge strategy as the preferred strategy option for various assigned weighting combinations, provided the cost criteria has a weighting of greater than 30%. At weightings of less than 30% for the cost criteria (and more than 70% for the non-cost criteria), the preferred sludge strategy option was found to shift to the Decentralised option, which is the option with the highest non-cost score. Nonetheless, due to the high commercial risk identified with the

Decentralised strategy, coupled with the project objectives of identifying a low-cost strategy solution for the sludge management of FNDC's WWTPs, a cost criteria weighting of at least 50% appears prudent. Reducing the cost weighting below 50% is unlikely to be accepted by the wider stakeholders and consequently, the Centralised sludge strategy option is the preferred sludge strategy option which should be implemented by FNDC.

We consider that the Centralised strategy is the preferred option for implementation at FNDC's WWTPs as it has been proven to best satisfy the main project objectives of being a cohesive and cost-effective strategy. The Centralised sludge strategy comprises of the following components:

- Continuing the existing WAS transfers from Hihi to Kaitaia, and Russell & Kerikeri to Kaikohe for treatment.
- Conversion of the existing Kaitaia WWTP and Kaikohe WWTP treatment ponds (Pond No. 1) into sludge ponds for treatment of the transferred ASP WAS[1].
- Purchase of two (2) mobile dredges for removal of sludge from FNDC's pond WWTPs.
- Purchase of geobags (quantity and size as required) or a mobile dewatering system for dewatering of the sludge dredged from all FNDC's ponds.
- Beneficially reusing the produced sludge for Mine/Quarry Rehabilitation.

The following next steps should be completed by FNDC to better refine and optimise the overall Centralised sludge strategy:

- The Kaitaia WWTP and Kaikohe WWTPs are the two largest WWTPs included in this assessment, which have consents nearing expiry. Upgrades to these plants are expected to occur within the next 3-6 years, consequently the sludge strategy will need to incorporate the expected sludge production from the future upgraded Kaitaia WWTP and Kaikohe WWTP, given the 20 year planning horizon of this study. At the time of this study no investigation into the future upgrade has been completed and therefore no process information regarding the likely modifications to Kaitaia and Kaikohe WWTP's is available to use as the basis of this assessment. In the absence of this information, and to enable this investigation to proceed, we have assumed that the Kaitaia and Kaikohe WWTPs will be upgraded to mechanical plants (most likely ASPs), in line with the recent WWTP upgrades in the Far North District. This may not be accurate, and consequently, the results of this assessment should be considered with this in mind. Should the results of subsequent investigations by FNDC show that the Kaitaia and Kaikohe WWTPs will be upgraded to ASPs, we recommend that FNDC take steps to adopt the Centralised sludge strategy for implementation.
- The preferred dewatering system for Pond WWTPs was found to shift between Geobags and a Mobile Dewatering system (the latter when land purchase costs and civil works costs were increased). Consequently, given the scope and limits of accuracy of this study, we consider it prudent that FNDC undertake a more detailed assessment to identify the most cost-effective dewatering system for implementation using actual cost data available to FNDC, coupled with land availability data and purchase costs. Conceptual level design would also enhance the process and increase costing accuracy.
- The preferred market for the produced solids in this instance was identified to be Mine/Quarry Rehabilitation, which scored highly due to the high availability of mines and quarries for rehabilitation in the Far North Region, as identified by FNDC provided information. However, we have not undertaken any

[1] Upgrade to Kaitaia and Kaikohe WWTPs will occur in the next 5 – 8 years. The likely treatment process is yet to be investigated and confirmed, however, to enable this project to proceed we have assumed the upgrade would be to ASP, in line with recent WWTP upgrades in the Far North district.

market assessment or discussion with mine and quarry operators in the region, as the market assessment was not taken up as part of the project scope. Therefore, we recommend discussions with quarry operators are undertaken to confirm the feasibility of this option and the expected costs.

The table below outlines the proposed implementation plan for the Centralised Sludge Strategy, and presents the required actions ranging from immediate short-term actions, to longer term action items which will depend on the final process selected for the Kaitaia WWTP and Kaikohe WWTP future upgrades.

Table 1: Proposed Implementation Plan

No.	Action Item	Timing of Works	Priority
1	Continue WAS transfers from Russell and Kerikeri (to Kaikohe WWTP) and Hihi WWTP (to Kaitaia WWTP), whilst awaiting the results of the selected process upgrade for Kaitaia WWTP and Kaikohe WWTP.	Short Term (1-3 years)	High
2	Commission market assessment studies and commence discussions with quarries and mine sites to confirm the suitability and viability of using FNDC's pond sludge for rehabilitation of quarries and mines in the Far North District, and identify preferred disposal sites	Short Term (1-3 years)	High
3	Purchase two (2) mobile dredges for removal of sludge from FNDC's ponds in the near term, in the following order of priority: ▪ Kaitaia. ▪ Kaikohe. ▪ Rawene. ▪ Kohukohu. ▪ Kawakawa. ▪ Kaeo.	Short-Medium Term (1-5 years)	High
4	Purchase short term dewatering solutions for Kaitaia WWTP and/or Kaikohe WWTP pond sludges (most likely in the form of Geobags), whilst undertaking more detailed options assessment to select the most cost effective dewatering option for pond WWTP sludges (mobile dewatering vs Geobags)	Short Term (1-3 years)	High
5	Purchase most cost effective dewatering option for pond WWTP sludges based on options assessment outcomes, for dewatering of subsequent pond sludges	Medium Term (3-5 years)	Medium
6	Conversion of the existing Kaitaia WWTP and Kaikohe WWTP ponds into centralised sludge treatment ponds, following the Kaitaia and Kaikohe WWTP plant upgrades, if found to be appropriate.	Long Term (>5 years)	Medium-Low

Contents

Appendices

Acronyms & Abbreviations

%	Percent
ASP	Activated Sludge Plant
BAU	Business as Usual
BOD	Biological Oxygen Demand
d	Days
DS	Dry Solids
DT	Dry Tonnes
EP	Equivalent Populations
FNDC	Far North District Council
ha	Hectares
hr	Hours
HRT	Hydraulic Residence Time
kg	Kilograms
km	Kilometers
kmph	Kilometers per hour
kW	Kilowatts
kWh	Kilowatt hours
L	Liters
LTP	Long Term Plan
m	Meters
m^3	Cubic meters
$M	Million dollars
MCA	Multicriteria Analysis
NPC	Net Present Cost
O&M	Operating and Maintenance
p.a.	Per annum / yearly
QBL	Quadruple Bottom Line
SBR	Sequencing Batch Reactor
Sqm	Square meters
Ton	Tonnes
UV	Ultraviolet
VS	Volatile Solids
VSS	Volatile Suspended Solids
WAS	Waste Activated Sludge
WT	Wet Tonnes
WWTP	Wastewater Treatment Plants

1 Project Background

1.1 Introduction

Far North District Council (FNDC) is seeking a cost effective and practical solution to the current backlog and future projection of sludge production across the district. To this end, FNDC engaged CH2M Beca to develop a cohesive sludge management strategy for the seventeen (17) wastewater treatment plants (WWTPs) currently owned and operated by FNDC. The WWTPs which were considered in the assessment and their locations are showed in Figure 1.

Figure 1: Map of FNDC's WWTPs Considered in Sludge Strategy

The WWTPs being considered in this study, its treatment process, and current sludge management strategies (if any) are summarised in Table 2. This table also outlines proposed (or potential) future upgrades to these plants, with WWTPs expected to require an imminent upgrade highlighted in blue. Table 2 shows that FNDC's plants are predominantly pond based, with only five (5) of its seventeen (17) WWTPs being activated sludge based plants.

Table 2: Proposed FNDC WWTP Sludge Treatment and Disposal Routes

WWTP	Current Process	Consent due to Expire	Proposed / Possible Future Process
Opononi	Aerated Ponds	2019	Upgrade scheduled in near future
Ahipara	Aerated Ponds	2033	Prescription enzyme for sludge reduction in ponds currently being dosed as a trial – note there is no control being implemented to compare against to evaluate outcomes
East Coast (Taipa)	Aerated Ponds	2008	N/A – this consent lapsed 10 years ago. A new consent was lodged but has never been processed.
Rangiputa	Oxidation Ponds	2032	N/A
Kohukohu	Oxidation Ponds	2016	N/A – consent lapsed 1 year ago. A new consent has been lodged. Unsure of status.
Kaeo	Oxidation Ponds	2022	N/A
Kaitaia	Oxidation Ponds	2021	Consent is due to expire in near term. Upgrade to Mechanical Plant (for this study we have assumed Activated Sludge Plant) likely as consent conditions will become more stringent. Budget of $5.2M has been included in the Long Term Plan (LTP) for the financial year 2025/2026
Rawene	Anaerobic Ponds + Maturation	2023	N/A
Paihia	Anaerobic Ponds + Maturation	2034	N/A
Kaikohe	Anaerobic Pond + Maturation	2021	Consent is due to expire in near term. Upgrade to Mechanical Plant (for this study we have assumed Activated Sludge Plant) likely as consent conditions will become more stringent. Budget of $3.2M has been included in the Long Term Plan (LTP) for the financial year 2023/2024.
Whatuwhiwhi	Activated Sludge Plant (MBBR)	2025	N/A
Hihi	Activated Sludge Plant	2022	Recent tertiary upgrade (UV Filters)
Russell	Activated Sludge Plant	2024	N/A
Kerikeri	Activated Sludge Plant	2016	Consent has lapsed. New mechanical plant (activated sludge plant) being installed (SBR), with onsite thickening of sludge to 18%. New consent application lodged.
Kawakawa	Activated Sludge Plant	2036	N/A (was upgraded from Ponds in recent years)
Matauri Bay	Not operational	N/A	N/A
Whangaroa	Holding tank only	N/A	N/A – holding tank only. Waste from tanks is tankered to Kaeo

1.2 Study Objective & Constraints

The objective for this study is to determine a direction for the management of sludge from the Far North District WWTPs for the next 20 years, with particular focus on identifying a feasible, cost effective and long term sustainable sludge management strategy incorporating beneficial reuse applications where practicable. Of note is the community goal to protect and enhance the environment, with a specific statement to reduce waste along with increased recycling to decrease the use of landfills and promote the sustainable management of resources. Therefore, beneficial reuse strategies will be preferred over straight disposal options.

As apparent in Table 2, the consents for Kaitaia and Kaikohe WWTPs are due to expire in the near future, and in line with recent WWTP upgrades in the Far North district, an upgrade to mechanical plants is likely. The proposed treatment process is yet to be investigated and confirmed, but in order to allow this assessment to proceed, we have assumed that the Kaitaia and Kaikohe WWTPs will be upgraded to Activated Sludge Plants (ASPs). This will mean that the current practice of trucking and disposing of WAS from the nearby ASP WWTPs to these two pond based WWTPs is unlikely to be continued, further cementing the urgency of identifying an appropriate long-term sludge management strategy, particularly for the ASPs likely to be affected by this change. This also means that the current practice is unsustainable and cannot be continued.

1.2.1 Project Scope

The following tasks, and their status, comprise the Project Scope:

Stage 1

1. Kick-off meeting with FNDC and Alliance Operations Staff to understand the scope and requirements of the project (Complete).
2. Information collation and review, identification of gaps, and agreement on assumptions to allow project progression (Complete).
3. Calculation of sludge volumes and sludge generation assessment (Complete).
4. Updated sludge volume estimates (Complete).
5. Provision of standard rates for options development (Complete).
6. Options Identification (Complete).
7. Risk Assessment (Complete).
8. Ranking of Plants in order of priority (Complete).

Stage 2

1. Multi Criteria Analysis of Options (MCA) including consultation with stakeholders (Complete)
2. Analysis of Centralised vs De-Centralised options (Complete)
3. Costing of feasible options (Complete)
4. Economies of scale for Centralised or shared sludge management facilities (Complete)
5. Quadruple Bottom Line (QBL) Assessment (Complete)

Stage 3

1. Final Recommendations and Reporting (This Report).

1.2.2 Purpose of Report

The purpose of this report is to summarise the outcomes of Stages 2 and 3, documenting the strategy development, costing, and evaluation process, including the QBL assessment for selection of the preferred strategy option. The outcomes of Stage 1 have previously been submitted to FNDC and this report is included as Appendix A.

1.3 Project Background

1.3.1 Previous Studies

FNDC has commissioned two studies into sludge treatment and disposal options, one in 2010 and another in 2012:

- FNDC Council Sludge Disposal Strategy (Doc No: A1096848, July 2011).
- FNDC District Sludge Management Options (Transfield Services, May 2012).

The studies and their key findings are summarised in the Stage 1 report in Appendix A attached.

1.3.2 Target Biosolids (Sludge) Quality

Applying Biosolids to land is generally considered a viable option for sustainable disposal in New Zealand. This is supported by the Guidelines for Safe Application of Biosolids to Land in New Zealand (MfE/NZWWA, 2003), or 'the Guidelines', which apply international and national scientific evidence through standardised practices. This allows the disposal route to be managed in a safe and sustainable manner. The Guidelines also provide guidance to regional authorities on suitable activity statuses for applications of biosolids to land. The biosolids grading system is made up of two parts. The first part, which is denoted by a capital 'A' or 'B', represents the stabilisation grade. The second part, denoted by a lower case 'a' or 'b', represents the contaminant grade.

The Stage 1 report concluded that the sludge from FNDC's ponds are expected to satisfy the requirements for stabilization Grade B and possibly contaminant Grade b. This allows beneficial reuse applications and markets to be considered in the assessment.

1.4 Overview of Existing WWTPs

This section provides an overview of the existing WWTPs and insight into the existing and future sludge production expected, along with the historical sludge management procedures which have been adopted at FNDC's WWTPs. The key assumptions adopted in the options assessment work during Stage 1, which forms the basis of the sludge production numbers for the Stage 2 Report, are presented in Appendix B.

1.4.1 FNDC Sludge Disposal Routes (Current and Past)

FNDC's current practice is to remove sludge from the full ponds and transfer the wet sludge into other ponds within FNDC's operational area. However, this is both costly and not sustainable in the long term due to the following:

- In several cases the transfer of sludge between WWTPs has led to compliance issues at the receiving WWTP(s), with exceedances of discharge consent conditions sometimes being attributed to the additional sludge transferred.
- No reduction in sludge volume with no sludge being disposed of, treated, or reused.

Geo-textile bags have been employed for dewatering of the sludge removed from FNDC's WWTP sludge ponds (i.e. at Kawakawa) in the past. When they have been employed, the resultant geobags with dewatered sludge have been buried on site for disposal. This method of sludge management requires the use of relatively large areas on which the geobags can be left to drain and then be buried. Many of FNDC's WWTPs have land availability constraints, and consequently investigations into alternative disposal methods with smaller land requirements have been considered, with options for offsite disposal being included.

1.4.2 Current Sludge Production and Capacity Limitations

A capacity assessment of the sludge related process units has been completed for the seventeen (17) WWTPs, and is documented in the Stage 1 report (refer Appendix A). It should be noted that Matauri Bay WWTP and Whangaroa WWTP were excluded from this assessment as they are either non-operational (Matauri Bay) or only comprise of a holding tank periodically emptied by tankers (Whangaroa).

The design assumptions outlined in Appendix B were used to assess the available capacity of the sludge related process units. Table 3 presents the key findings of the sludge capacity assessment, with high priority plants highlighted in red, along with the reasons behind the high priority of the sites shown in bold red. Table 4 presents the proposed parameters which shall be adopted for the strategy options development and assessment.

Table 3: Summary – Sludge Capacity and Risk Assessments

WWTP	Total EP treated by WWTP – 2017 (EP)[1]	Total Sludge Production Rates[2] (gDS/EP/d)	Estimated Total Sludge Volumes Produced (m^3 p.a.)	Year Oxidation Pond Capacity is Reached	Year Anaerobic Pond Capacity is Reached	Current HRT (incl Sludge) as % of Design HRT	Current BOD Loading Rates in Oxidation Ponds (kgBOD/ha/d)	Priority
Kaitaia (incl Hihi)	16533	14.1	1173	**2013**	-	**49%**	50	High
Kaikohe (incl Russell and Kerikeri)	27259	15.3	2995	**2013**	**2014**	**71%**	68	High
Rawene	1014	9.6	77	**2013**	2090	**75%**	59	High
Kohukohu	253	10.9	13	**2016**	-	315%	**221**	High
Kawakawa - Actual	6268	15.8	1206	**-**	**2015**	-	-	High
Kawakawa – Design	6268	8.7	665	**-**	**2017**	-	-	-
Kaeo	616	8.2	43	2019	-	89%	55	High
Ahipara	1320	22.4	171	2023	-	**60%**	**171**	Medium
Opononi	770	8.9	34	2032	-	**39%**	**335**	Medium
Paihia	4180	40.5	1821	2027	2035	100%	**136**	Medium
East Coast	2310	9.6	164	2072	-	138%	**112**	Medium
Rangiputa	83	9.7	6	2035	-	122%	24	Low
Whatuwhiwhi	550	15.6	61	2078	-	161%	53	Low
Hihi (see Kaitaia)	352	45.0	365	-	-	-	-	-
Russell (see Kaikohe)	1980	34.6	834	-	-	-	-	-
Kerikeri (see Kaikohe)	2332	58.8	1669	-	-	-	-	-
TOTAL	61155	-	-	-	-	-	-	-

Notes:
1. Includes all transferred loads (WAS and septage), and includes the 10% summer population factor
2. Includes Anaerobic Ponds and Oxidation Pond sludge production rates per unit population.

Table 4: Summary – Sludge Parameters for Options Development

WWTP	Total EP treated by WWTP – 2037 (EP)[1]	Sludge Production – Main Process – 2017 (gDS/EP/d)	Sludge Production – Main Process – 2037 (gDS/EP/d)	Sludge Production Rates – Septage (gDS/EP/d)	ASP - Daily Sludge Production (kgDS/d)	ASP – VSS/TSS Ratio of WAS (%)
Opononi	851	8.9	8.9	-	-	-
Ahipara	1458	22.4	22.4	-	-	-
East Coast	2552	9.6	9.6	-	-	-
Rangiputa	91	9.7	9.7	-	-	-
Kohukohu	280	10.9	10.9	-	-	-
Kaeo	681	8.2	8.2	-	-	-
Kaitaia	17878	14.1	45.0[2]	14	466	51%[3]
Rawene	1120	9.6	9.6	-	-	-
Paihia	4618	40.5	40.5	-	-	-
Kaikohe	25354	15.3	45.0[2]	14	516	47%[3]
Whatuwhiwhi	608	15.6	15.6	-	-	-
Hihi	389	45.0	45.0	-	17	75%
Russell	2188	34.6	34.6	-	76	75%
Kerikeri	2577	58.8	58.8	-	152	75%
Kawakawa	6925	10.0	10.0	-	70	75%
TOTAL	67,570					-

Notes:
1. Excludes all transferred WAS loads, includes the 10% summer population factor, and incorporates a 0.5% growth rate
2. Kaitaia and Kaikohe sludge production rates have been updated to reflect the assumption that they will be converted into an ASP process
3. Kaitaia and Kaikohe VSS% is much lower due to the high volumes of septage received as a proportion of the total treatment capacity, with the septage containing mostly inerts.

As noted previously, there is a strong likelihood that Kaitaia and Kaikohe WWTP will be upgraded to Mechanical based WWTPs in the near future (highlighted rows in blue), and for this study we have assumed this will be ASPs. The Kaitaia and Kaikohe WWTPs will therefore only be considered as pond WWTPs for the purposes of calculating the expected costs of continuing the current operations (i.e. Business as Usual or BAU). All other options will consider Kaitaia and Kaikohe WWTPs as standalone ASPs in the development of total costs. The expected costs to dredge and dewater the sludge currently present in the Kaitaia and Kaikohe ponds prior to conversion of these WWTPs to ASP WWTPs have been excluded in this analysis to prevent double counting, as we consider that this cost will form part of the Kaitaia WWTP and Kaikohe WWTP upgrade costs for conversion to ASP WWTPs. The dredging and dewatering costs for Kaitaia WWTP and Kaikohe WWTP have been included in the current BAU scenario for completeness.

The Kaitaia WWTP and Kaikohe WWTP both have considerable pond volumes available, which presents opportunity to reuse these ponds for stabilisation of the sludge produced by the ASP process. This also presents an opportunity to continue the current practice of using Kaitaia and Kaikohe WWTPs as Centralised treatment facilities for the smaller ASP plants. Centralised options for the smaller ASP plants will therefore consider the use of the existing ponds at Kaitaia WWTP and Kaikohe WWTP as Centralised sludge treatment ponds, once the WWTPs have undergone the upgrade. It should be noted that the assumption that Kaitaia and Kaikohe WWTPs will be converted to ASP WWTPs, and that the existing ponds will become redundant as a result of this upgrade, underlies the Centralised sludge strategy. This is a critical assumption on which this sludge strategy hinges, and the developed strategy should be viewed with this in mind. Should the upgrades to Kaitaia and Kaikohe WWTP be delayed, or an alternative upgrade process be selected, the preferred sludge strategy for implementation at FNDC's WWTPs should be re-evaluated, as the findings of this report may not hold and the most cost-effective strategy may alter.

2 Strategy Development and Costing

The sludge strategy development has been performed over three stages, with the ultimate objective being to develop a cohesive and cost-effective strategy for all FNDC's WWTPs. The developed strategy will also provide input to the council's Long-Term Plan (LTP). The selection of the preferred strategy for implementation will be based on a Quadruple Bottom Line (QBL) analysis which is effectively a Multi-Criteria Analysis (MCA) which incorporates both cost and non-cost considerations. This section will present the strategy development process, starting from the initial long listing stages to the selection of the preferred strategy from a cost perspective.

2.1 High Level Options Screening

The Stage 1 report identified an extensive list of feasible options which can be implemented at FNDC's WWTPs for sludge management. The identified options were then reduced to a long list by adopting a high-level screenings assessment of the options. The suitability of each sludge removal and treatment option for pond or ASP systems was assessed, and the resulting long list of options for further assessment is summarised in Table 5. The full breakdown of the options assessment is presented in the Stage 1 Report included in Appendix A. Below are the key outcomes of the high-level options screening:

- Due to the push for beneficial reuse applications for sludge, onsite burial and landfill disposal options will only be considered for pond sludges which are expected to have limited to no beneficial nutrient content remaining in the sludges.
- Vermicomposting will only be considered for ASP sludges due to the requirement for a sludge that still contains good quantities of volatile matter and the need for a continuous feed source for the worms. Pond sludges are already very well stabilised with little volatile matter and require no further treatment prior to potential beneficial reuse and / or disposal, making vermicomposting an unattractive end use solution due to the higher associated costs.
- Further treatment/stabilisation of pond sludges are considered unnecessary due to the highly stable nature of the pond sludges, and direct disposal or beneficial reuse applications will be considered.

Table 5: Long List of Options for Further Assessment

<table>
<tr><th>WWTP Type</th><th>Sludge Removal Option</th><th>Dewatering Option</th><th>Treatment Options</th><th>End Use</th><th>Option Number</th></tr>
<tr><td rowspan="6">Ponds and ASP WWTPs</td><td rowspan="6">Sludge Rat</td><td>Sludge Box</td><td rowspan="2">Nil</td><td rowspan="2">Mine/Quarry Rehabilitation</td><td>1A</td></tr>
<tr><td>Mechanical Dewatering</td><td>1B</td></tr>
<tr><td>Sludge Box</td><td rowspan="2">Nil</td><td rowspan="2">Landfill Capping</td><td>2A</td></tr>
<tr><td>Mechanical Dewatering</td><td>2B</td></tr>
<tr><td>Sludge Box</td><td rowspan="2">Nil</td><td rowspan="2">Onsite Burial (Monofill)</td><td>3A</td></tr>
<tr><td>Mechanical Dewatering</td><td>3B</td></tr>
</table>

WWTP Type	Sludge Removal Option	Dewatering Option	Treatment Options	End Use	Option Number
ASP WWTPs Only	Sludge Rat for Whatuwhiwhi WAS pump (possibly to sucker trucks depending on final use)	Mechanical Dewatering	Vermi-composting	Agricultural Land Application	4A
			Windrow composting		4B
			Sludge Ponds		4C
			Aerobic Digesters		4D
		Sludge Reed Beds	Nil		5A

2.2 Technology Selection MCA Workshop – 6 November 2017

To select the most appropriate technologies for costing, a technology selection MCA workshop was held on the 6 November 2017 and attended by key technical staff from CH2M Beca. The results of the MCA workshop are summarized in the meeting minutes from the Technology Selection MCA Workshop dated 6 November 2017 which is provided in Appendix C, and was previously issued to FNDC for endorsement prior to proceeding with the costing of the options.

2.2.1 MCA Criteria & Scoring Methodology

Table 6 presents a summary of the adopted criteria, along with an explanation of each criteria, and the weightings assigned to each criterion adopted in the MCA process. Table 7 below outlines the adopted methodology for scoring.

Table 6: MCA Criteria Adopted for Shortlisting

Criteria	Explanation	Raw Weighting	Overall Weighting
Environment	This theme encompasses all effects on living and non-living natural systems	100%	30%
Ecological/ Habitat Effects (Air, Water, Soil quality)	The potential for the treatment method to influence the ecological or habitat values of surrounding area (i.e. surrounding air, water, and soil quality)	25%	7.5%
Resource Efficiency (material/resource use, waste minimisation)	The potential efficiency of the treatment method in utilising resources/materials (e.g. chemicals) and minimising waste (i.e. minimising the quantity of biosolids disposed to landfill)	25%	7.5%
Land use efficiency (footprint)	Does the option make efficient use of available land considering conflicting demands?	25%	7.5%
GHG Emissions	The potential to improve GHG emission levels over current levels (also includes minimisation of power consumption or power usage)	25%	7.5%

Criteria	Explanation	Raw Weighting	Overall Weighting
Social	This theme encompasses all effects on the wellbeing and quality of life of customers, employees and local community	100%	30%
Amenity impacts (odour, visual amenity, noise, transport)	The potential for the option to increase/decrease amenity value of the surrounding area including recreational resources, due to the potential odours, visual character, noise, and transport impacts arising from the treatment option	25%	7.5%
Public Acceptability (Iwi cultural perception, community perception of options, outcomes)	Is the option acceptable to the public (stakeholder) in terms of Iwi cultural perceptions, community perception of options, and potential community outcomes from the treatment option	25%	7.5%
Public Safety (community health and safety, OHS)	The ability of the treatment option to limit risk to health and safety, both to the community, and to the plant operators and associated workers (treatment, transport, and disposal)	25%	7.5%
Reputation enhancement	The potential for the option to increase/decrease reputation of FNDC	25%	7.5%
Technical	This theme encompasses all effects of a technical nature	100%	40%
Technology Performance (treatment efficiency, established process, long term sustainability)	The ability of the option to satisfactorily meet its treatment objectives reliably and intended functions (treatment, utilisation method, disposal options), including adapting to changing conditions (technology, market factors, regulation) over the time frame of the project	20%	8.0%
Reliability (operational reliability, reliability in meeting product requirements)	The ability of the option to maintain uninterrupted operations and consistently produce products of acceptable quality to reduce the disposal of off-spec products to landfill	20%	8.0%
Operability (compatibility with existing technology and processes, operability based on operator skills)	The ability of the option (treatment, utilisation / disposal) to be easily integrated with the existing operations (includes operator skills, commonality of processes, ease of operation)	20%	8.0%
Maintainability	The ability of the option to be easily maintained (includes maintenance staff skills, commonality of equipment, ease of maintenance)	10%	4.0%
Constructability	The ease of which the option can be integrated into the existing process	10%	4.0%
Ease of meeting Statutory Requirements (now and anticipated future requirements)	The ability of the option to comply with consent requirements, both current and anticipated future consent requirements	20%	8.0%
	TOTAL		**100%**

Table 7: Scoring Methodology

Score	Interpretation
0	Significantly worse than current BAU
1	Moderately worse than current BAU
2	Slightly worse than current BAU
3	Comparable to current BAU
4	Better than current BAU
5	Significantly better than current BAU

In scoring, we have assumed that the BAU scenario (i.e. current practice) can be continued indefinitely. However, we know that this is not feasible as the ponds have a finite capacity and the sludge will need to be removed and either treated and reused, or disposed of. It is also important to note that the Kaitaia and Kaikohe WWTPs are likely to be upgraded to a Mechanical based process in the very near term, as the current consents are due to expire in 2021. The "Business as Usual" (BAU) scenario is therefore not sustainable, and will need to be modified in the short term to accommodate for these changes. Because of this fatal flaw of the BAU scenario, a "future" BAU scenario was developed to reflect the expected changes to Kaitaia WWTP and Kaikohe WWTP, which shall be used as a benchmark for comparison. We have assumed that the future BAU will reuse the Kaitaia and Kaikohe WWTP ponds as sludge ponds for treatment of the WAS transferred from Hihi, Russell, and Kerikeri, with the produced solids then disposed of to landfill (which is not the current practice), which is subject to FNDC confirmation.

2.2.2 Shortlisted Options from MCA

Following the technology selection MCA workshop, the technical criteria, which includes factors such as established technology, along with reliability, operability, and ease of meeting statutory rights, were identified as key factors which resulted in the elimination of several options which have been previously identified as "preferred" options in studies completed by others. These include:

- The "Sludge Box" is not known to be an established dewatering technology, and consequently it was eliminated from further assessment.
- "Reed Beds" have been widely implemented overseas particularly in European countries, but with no known full-scale implementation in the southern hemisphere. This option was therefore eliminated from further assessment.
- "Landfill Capping" was eliminated as there are only two operating landfills in the region (Russell and Ahipara), which are due for closure in the near term (i.e. within the next 5 years). This option is not sustainable and was eliminated.

The following should also be noted:

- Although agricultural land applications were initially identified as a potential disposal option for ASP sludge, further evaluation has identified that this option does not appear to be viable in the Far North district due to the lack of suitable agricultural or forestry application sites. This option was therefore no longer considered in the assessment.
- For simplicity in the assessment, dredging and dewatering of ponds were considered under one common criteria, "Dewatering". Additional sub-options for dewatering, comprising geobags and mechanical mobile dewatering will be considered under "Dewatering".
- Geobag dewatering will not be considered for ASP sludges, due to the highly dilute nature of the WAS, making this an unsuitable option. Geobag dewatering will only be considered for pond sludges.

The nominated technology options for further development into an overall sludge strategy are summarised in Figure 2.

Figure 2: Nominated Technology Options for Strategy Development

2.3 Strategy Development

The technology options which have been shortlisted can be grouped as illustrated in Figure 3. Each of the strategy components will be further detailed in the following sections.

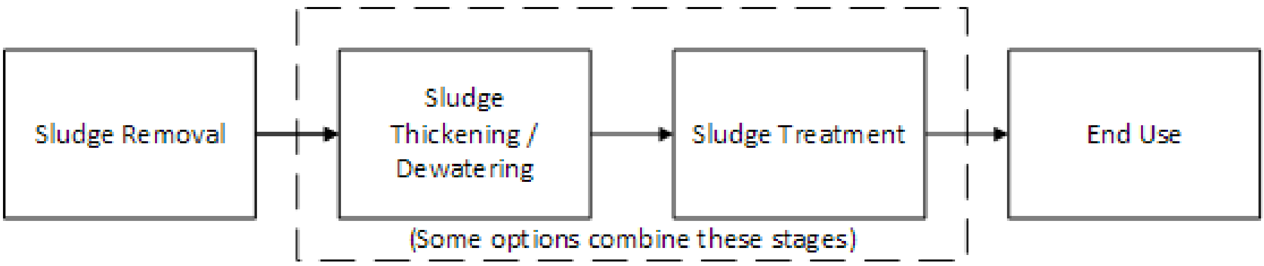


Figure 3: Combination of Technology Options for Strategy Development

2.3.1 Market/End Use

Market assessment and the end use of the biosolids was not part of the scope of this project. However, it is important to consider end use in the strategy development as a strategy needs to be considered holistically as it is critical to the success of the project. Consequently, the potential biosolids target market (end uses), along with the required biosolids stabilisation grade and quality will be a critical consideration in selection of the most appropriate sludge treatment and sludge dewatering technology. This is required to ensure that the produced biosolids can be marketed in the selected target end use. Each of the potential biosolids end uses, along with the expected required sludge treatment and dewatering to achieve this end use, is outlined briefly in the following sub-sections.

2.3.1.1 Mine/Quarry Rehabilitation

The general requirements for sludge sent to mine/quarries for rehabilitation include:

- Adequately stabilised sludge (Stabilisation Grade Bb), to minimise the risk of methane formation during sludge stabilisation.
- Adequately dewatered sludge, to minimise the quantity of leachate requiring management.

For the above reasons, sludge from pond based WWTPs or sludge ponds can be directly applied to the mines/quarries if they have been adequately dewatered to a sufficiently high solids content (typically over 20%). Sludge from ASP plants will be required to undergo an initial sludge stabilisation/treatment process to reduce the amount of volatile matter and achieve the target stabilisation grade Bb, and be dewatered prior to application.

2.3.1.2 Onsite Burial

The general requirements for sludge burial onsite is typically relaxed, with no prior stabilisation mandated. This disposal route is also capable of receiving untreated biosolids which do not meet the stabilisation grade Bb requirement. However, this disposal route is limited to burial of dried sludge, and consequently requires a sludge dewatering process prior to burial of the sludge. Further, unstabilised ASP sludges are considered incompatible for this disposal method, as it contains high volatile matter that will undergo an anaerobic decomposition process in the absence of oxygen (i.e. anaerobic digestion) during and after the burial process. This process will release methane gas, potentially creating an explosive atmosphere in air pockets under the layer of topsoil. This raises occupational health and safety (OHS) implications to operators or residents in the immediate vicinity, and consequently the onsite burial disposal option will only be considered for pond based sludges.

2.3.1.3 Landfill Disposal

FNDC has advised that the current business as usual (BAU) approach which shall be considered for this assessment shall include disposal of the produced and dewatered biosolids to landfill. This disposal method does not require any upstream treatment steps, apart from the provision of adequate dewatering facilities to reduce transport and tipping fees. However, given the imminent closure of nearby landfills, this option is expected to entail substantial transport costs to Redvale (as advised by FNDC), which has been identified as the closest operational landfill for FNDC, and is not considered a sustainable long-term strategy. Nonetheless, landfill disposal end use has been retained to allow costing of the BAU scenario, both current and future, to indicate the true cost to FNDC of “doing nothing”.

2.3.1.4 Vermicomposting

Vermicomposting uses various earth worms for composting of sludge, producing vermicast. Preliminary discussions with MyNoke, the main vermicomposting provider in the North Island, notes that both dewatered pond and ASP sludges are acceptable for vermicomposting without prior stabilisation. However, previous reports by others documented in the report titled "*Beneficial Land Utilisation of Dewatered Sludge from Oxidation Ponds in the Far North District through Vermicomposting*" by Quintern Innovation (December 2013) notes that the pond sludges are contaminated with rubbish and expected to contain metals, making it unlikely to be suitable for direct feed for vermicomposting without prior blending with other materials.

The report notes that the pond sludges are expected to require pre-blending with large quantities of fibre prior to feeding into a vermicomposting facility due to these limitations. Consequently, due to the expected quality issues with pond sludges and the need to undertake detailed quality assessments of the pond sludges to confirm its suitability for vermicomposting, we consider that accepting the use of pond sludges for vermicomposting poses a high risk that the sludge will be rejected and required to be disposed of in landfills if it doesn't meet the required product criteria. For this reason, vermicomposting options will only be considered for ASP sludges and provided with an upstream dewatering process, with no sludge treatment/stabilisation required.

2.3.2 Stabilisation / Sludge Treatment

Based on the final market/end use products identified, the required level of sludge stabilisation to achieve the required sludge product quality can be identified. Figure 2 previous outlines the potential sludge stabilisation options for implementation in FNDC. As sludge from ponds will be very well stabilised, the discussions on further sludge stabilisation below will focus primarily on ASP sludges.

2.3.2.1 Centralised / Local Sludge Ponds

Sludge ponds are simple, low technology anaerobic digestion reactors capable of achieving excellent stabilisation of sludge, typically achieving more than 60% VS reduction within 12 months of storage. Assuming that the Kaitaia and Kaikohe WWTPs will be converted into ASP based WWTPs, we foresee that there is an opportunity to reuse the existing oxidation ponds as sludge ponds for treatment of the WAS produced from these plants. Conversion of the oxidation ponds into sludge ponds will allow the use of up to 90% of the available pond volume for sludge stabilisation, which may mean that little to no dewatering will be required over the next 20 years given the size of the ponds. Further, given the immense size of the oxidation ponds, there also exists an opportunity to effectively "continue" the current practice of providing Centralised treatment of the WAS produced from smaller ASP plants in the Kaitaia and Kaikohe sludge ponds. This will form the "Centralised" option for costing as part of the strategy development. Odour management for these ponds can be readily achieved by providing a water cap layer (typically 1 m water depth) on the top layer of the sludge to minimise the expected odour impacts.

2.3.2.2 Decentralised Aerobic Digestion

Aerobic digestion is the biological transformation of organic material in the presence of oxygen, normally supplied by supplemental oxygen addition via surface aerators or a diffused aeration system. For the purposes of costing and assessment, Aerobic Digestion options shall consider the use of a new purpose built concrete tank with surface aerators. Given the highly stable nature of pond sludges, aerobic digestion will only be considered for all ASP sludges.

2.3.3 Dewatering (incl Dredging)

Prior to treatment or offsite disposal/reuse, sludge from the WWTP must be removed and/or dewatered. All options for dewatering of pond sludges will be considered together with dredging, to reduce the number of permutations for costing.

2.3.3.1 ASP WWTP Dewatering Options

a. Mobile Dewatering only (ASP WWTPs)

Digested and undigested sludge from ASP WWTPs are typically dewatered using mechanical dewatering systems. These typically comprise of centrifuges, belt filter presses, or rotary fan presses, and can be both permanent or mobile systems. Sludge from the ASP WWTPs is normally removed by sludge pumps or intermittently discharged via a discharge valve at nominated times of the day. The removed sludge is then usually dewatered prior to offsite disposal or reuse.

Given the relatively small throughput of WAS at each of the individual ASP WWTPs (excluding Kaitaia and Kaikohe WWTPs), a mobile dewatering system shared across the ASP WWTPs appear to be the most economical option. WAS produced at the smaller ASP WWTPs can be stored in the respective bioreactors (provided adequate capacity is available) or in a holding tank on site, and then dewatered weekly or as required.

- Preliminary assessment suggests that one common mobile dewatering system comprising of a large rotary fan press (48Q unit, with 78m^3/hr and 1760kg/hr hydraulic and solids throughput) can be shared across all FNDC's ASP WWTPs. Kaitaia WWTP and Kaikohe WWTP will require a dedicated mobile dewatering unit shared across these two sites. Under this option, it is assumed that an aerobic digester will be implemented at each individual ASP site for stabilisation.
- For scenarios where the Kaitaia WWTP and Kaikohe WWTP adopt sludge ponds as the sludge management strategy, the Kaitaia and Kaikohe WWTP will be considered part of the Pond WWTP dewatering options (due to its infrequent dewatering requirement) and utilise the dewatering equipment for the pond WWTPs. Under this scenario, a smaller rotary fan press (the 48S unit) will be sufficient to provide the required dewatering throughput of the smaller ASP WWTPs, and a larger rotary fan press for dewatering of sludge from Kaitaia and Kaikohe WWTPs.

2.3.3.2 Pond WWTP Dewatering Options

Sludge removal from ponds can be performed using a smaller mobile dredge, or a larger dredge such as a suction cutter or auger dredge. Dewatering of the pond sludges can also be achieved using both mechanical dewatering systems such as those employed for ASP sludges, or a low technology system such as geobags.

a. Third Party (BAU) Dredging and Dewatering

The use of nominated third party contractors for dredging and dewatering of the pond sludges is the current practice at all FNDC's pond WWTPs. The third-party contractors typically utilise a suction cutter dredge equipped with a rotating cutter head mounted at the front of the suction head, allowing it to cut into hard soil or rock into fragments for removal by the dredge pumps. The dredged material is then mixed with polymer and pumped into geobags where the sludge is dewatered.

b. Mobile Dredging and Mobile Dewatering

Dredging of all FNDC's pond based WWTPs can be achieved using a mobile dredging system, such as a "Sludge Rat" system. The mobile dredge comprises of a submersible centrifugal pump mounted on a floating pontoon, and is controlled by operators on shore. Sludge from the bottom of the pond is pumped using a floating pipeline, and directly fed into the intended dewatering system on site. This option will consider the use of mobile mechanical dewatering systems such as centrifuges, belt filter presses, or rotary fan presses mounted on trailers, owned and operated by FNDC.

Preliminary assessment suggests that one common Mobile Dredge and one common Mobile Dewatering system, owned and operated by FNDC, can be shared across all WWTPs given the long lag times between dewatering of ponds. A second mobile dredge will be required to facilitate timely dewatering of the two (2) larger ponds (Kaitaia WWTP and Kaikohe WWTP), and can serve as a standby unit when dewatering the smaller ponds. The mobile dewatering system for FNDC's pond WWTPs will be separate to the mobile dewatering system required for the ASP based WWTPs, given the high frequency of dewatering which will be required for the ASP based WWTPs.

c. Mobile Dredging and Geobag Dewatering

Similar to the mobile dredging with mobile dewatering option, this option will utilise a mobile dredge ("Sludge Rat") owned and operated by FNDC across all its pond based WWTPs. A second mobile dredge will be required to facilitate timely dewatering of the two (2) larger ponds (Kaitaia WWTP and Kaikohe WWTP), and can serve as a standby unit when dewatering the smaller ponds. Sludge collected from the bottom of the pond will be mixed with polymer within the sludge pump lines and pumped into geobags purchased by FNDC, where it is dewatered. Geobags will then need to be stored onsite for an extended period to allow dewatering of the solids, with greater than 25%DS possible for longer storage times (in the order of 12 months or more).

It should be noted that land may not be available at all of FNDC's WWTPs, and FNDC may be required to purchase additional land from neighbouring properties for this purpose. Preliminary assessment from aerial photographs (Google Earth) shows that there is currently good availability of land surrounding most of FNDC's WWTPs, with all but five (5) WWTPs having available land for geobag setup with the current site footprint. Further, the nearest sensitive receptors to all of FNDC's WWTPs are located approximately 200m away, which suggests that land purchase for geobag setup may be possible at the 5 remaining WWTPs. In costing this option we have assumed that where inadequate FNDC owned land is available, FNDC would look to purchase this land at the market rate from neighbouring properties. If this is not something FNDC wish to pursue mobile dewatering would be required.

2.4 Strategy Options for Costing

2.4.1 Business As Usual (BAU) - Current and Future BAU

The "Business as Usual" (BAU) approach is the continued practice of utilising the Kaitaia WWTP and Kaikohe WWTP as "Centralised" treatment ponds for the WAS produced at Hihi WWTP, Russell WWTP and Kerikeri WWTP. Contractor dredging and dewatering will be employed for the removal of sludge from all ponds, with the dewatered sludge disposed to landfill.

As outlined previously, this current practice has a fatal flaw and is unlikely to continue due to the Kaitaia and Kaikohe WWTP consents approaching expiry, and the expected upgrade of these WWTPs into ASP WWTPs in the near term. Consequently, a modified "future" BAU scenario was developed, which considers the use of local sludge ponds at Kaitaia and Kaikohe WWTP to treat the ASP WAS. Under the future BAU practice, the current BAU practice of using contractor dewatering and disposal to landfill will be continued.

2.4.2 Sludge Strategy Combinations

The nominated technology options were then further developed into an overall sludge strategy based on the considerations outlined above. Both Centralised and Decentralised strategy options were considered in the development of the overall sludge strategy.

2.4.2.1 Decentralised Sludge Strategy

For a Decentralised sludge strategy, each individual WWTP will be provided with their own respective sludge treatment, dewatering, and disposal option, with a common optimal strategy for the Small Pond WWTPs, a common optimal strategy for the Small ASP WWTPs, and a common optimal strategy for the large WWTPs (Kaitaia and Kaikohe WWTP). The components of the decentralised sludge strategy is shown graphically in Figure 4, along with the various sub-options contained within each strategy component.

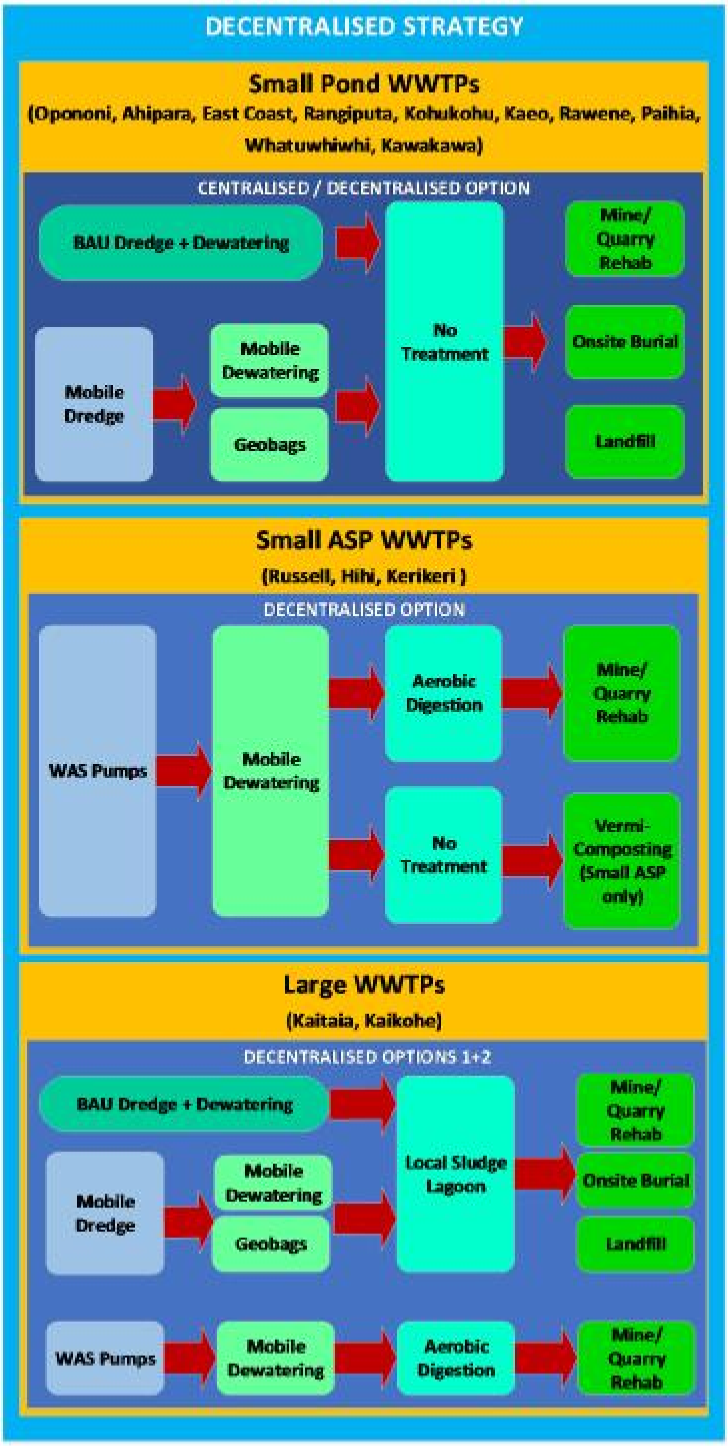


Figure 4: Decentralised Sludge Strategy Components and Sub-Options

2.4.2.2 Centralised Sludge Strategy

In the selection of a Centralised sludge treatment facility, all FNDC's sites were assessed for suitability based on the following considerations:

- Central location, with respect to neighbouring WWTPs.
- Good availability of land.
- Good protection from flooding (i.e. above the 1:100 year flood line).
- Good availability of buffer distance to the nearest sensitive receptors (i.e. ideally more than 500m from nearest urban property).
- Good access routes suitable for frequent truck access.
- Relaxed consent conditions, due to the high nutrient content in recycles typical of Centralised sludge treatment facilities.

Based on the above considerations, provision of one or two centralised Vermicomposting facilities accepting dewatered ASP sludge from all ASP WWTPs (Russell, Hihi, Kerikeri, Kaitaia and Kaikohe) was identified as an attractive solution. With this approach, two mobile dewatering systems, one (1) for the smaller ASPs to share, and another for the larger ASP WWTPs to share, will be required to dewater the sludge prior to offsite disposal to the Vermicomposting facility for treatment.

In addition to offsite Vermicomposting, the Kaitaia, Kaikohe and East Coast WWTPs have been identified as potential locations for a Centralised sludge treatment facility. Out of the three potential sites, Kaitaia WWTP and Kaikohe WWTP have been identified as having the most potential for conversion into an ASP WWTP in the near future, with the existing ponds likely to be decommissioned and removed from service. This presents as an attractive opportunity for reuse of these existing facilities to provide a Centralised form of sludge treatment utilising sludge ponds, which is similar to the current practice of sending WAS from Hihi, Russell, and Kerikeri to these two WWTPs. Adopting aerobic digestion for treatment of the transferred sludge is not expected to be cost effective, given the high capital and operational cost of aerobic digesters when assessed for just Kaitaia WWTP and Kaikohe WWTP as Decentralised systems. Consequently, the second Centralised ASP strategy option will not consider the use of aerobic digesters and will be based solely on Sludge Pond based treatment which reuses the Kaitaia WWTP and Kaikohe WWTP treatment ponds as sludge ponds.

A Centralised sludge strategy for sludges from pond based WWTPs is not considered in the assessment due to the high cost of sludge removal and transport from the ponds to a centralised dewatering and/or treatment facility, coupled with the fact that the pond sludge is highly inert and has little volatile matter remaining. Consequently, Centralised sludge treatment facilities will only be considered for ASP based WWTPs.

The overall sludge strategy for a Centralised option will therefore comprise of a common Small Pond WWTP strategy, coupled with a Centralised ASP WWTP strategy. The components of the centralised sludge strategy is shown graphically in Figure 5, along with the various sub-options contained within each strategy component.

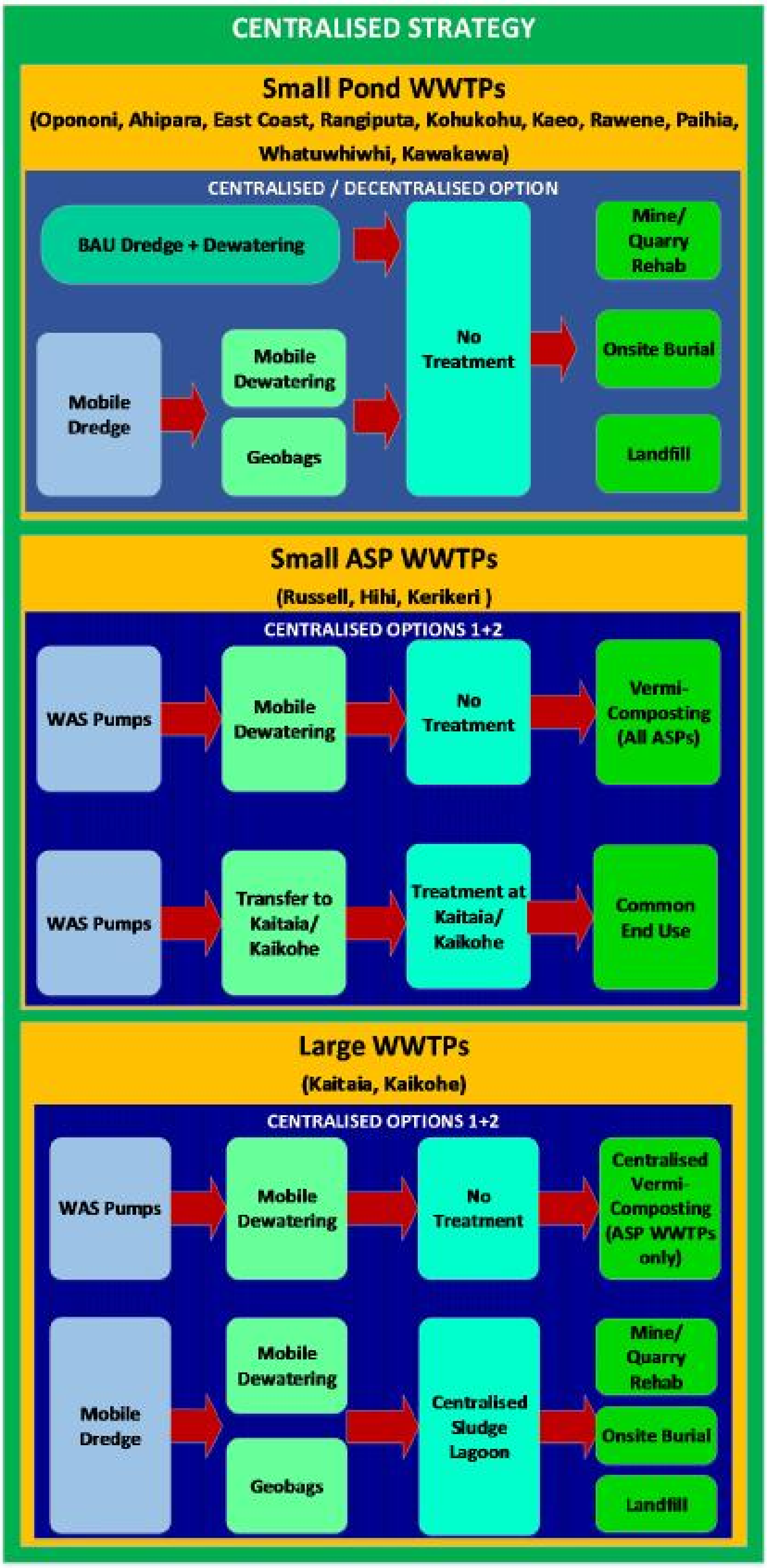


Figure 5: Centralised Sludge Strategy Components

2.4.2.3 Nominated Strategies for Costing

Based on the above combinations, the resulting strategy options for costing are summarised in Table 8. Where sub-options exist, such as in the case of dewatering options, they will be considered together and the lowest NPC sub-option carried forward for selection of the final strategy.

The final strategy will therefore comprise of the following components:

- Decentralised strategy = A + B + C
  - Small Pond WWTPs strategy (A).
  - Small ASP WWTPs strategy (B).
  - Decentralised Large WWTP Strategy (C).

- Centralised strategy = A + D
  - Small Pond WWTPs strategy (A).
  - Centralised ASP WWTP Strategy (D).

The centralised and decentralised options will then be compared against the current practice, i.e. BAU and the future BAU, to quantify any cost implications and to identify the preferred low-cost strategy for FNDC.

Table 8: Matrix of Options for Costing, Evaluation and Strategy Development

				Biosolids End Use				Stabilisation		Dewatering			
Item	WWTP Type	Option	Description	Mine/ Quarry	Onsite Burial	Landfill	Vermi-Compost	Sludge Ponds	Aerobic Digester	BAU Dewatering	Mobile Dredge + Dewatering	ASP Mobile Dewatering	Mobile Dredge + Geobag
A	Small Pond	1	Mine/Quarry + Dewatering	✓						✓	✓		✓
		2	Onsite Burial + Dewatering		✓					✓	✓		✓
		3	Landfill + Dewatering			✓				✓	✓		✓
B	Small ASP	1	Vermicomposting + Dewatering				✓					✓	
		2	Mine/Quarry + Aerobic Digestion + Dewatering	✓					✓			✓	
C	Decentralised Large WWTPs (Kaitaia/ Kaikohe)	1	Mine/Quarry + Local Aerobic Digester + Dewatering	✓					✓			✓	
		2	Mine/Quarry + Local Sludge Pond + Dewatering	✓				✓		✓	✓		✓
		3	Onsite Burial + Local Sludge Pond + Dewatering		✓			✓		✓	✓		✓
		4	Landfill + Local Sludge Pond + Dewatering			✓		✓		✓	✓		✓
D	Centralised ASP WWTPs	1	Mine/Quarry + Sludge Pond + Dewatering	✓				✓		✓	✓		✓
		2	Onsite Burial + Sludge Pond + Dewatering		✓			✓		✓	✓		✓
		3	Landfill + Sludge Pond + Dewatering			✓		✓		✓	✓		✓
		4	Vermicomposting+ Dewatering				✓					✓	

As noted in Table 8, within each option, several sub-options exist for dewatering. Each of these sub-options will be evaluated concurrently to narrow down the preferred overall strategy for implementation. All the options will be compared against the BAU scenarios.

2.5 Costing of Strategy Options

2.5.1 Basis of Cost Assessments

Each of the identified sludge strategies above were costed to allow assessment between the options. The basis of assessment common across all options and presented in the Stage 1 report are outlined in Appendix B. Additional assumptions and cost items specific to the strategy costing process are presented in Table 9.

Table 9: Additional Assumptions – Costing of Strategy Components

Parameter	Value/Assumptions	Notes
Common Cost Assumptions		
Capital cost mark-ups	■ Contingency of 30% ■ Engineering, Design, and Project Management Fees of 10%	Typical values for assessment
Operational cost items	■ Electricity: NZ$0.46/kWh ■ Polymer: NZ$5/kg ■ Sludge haulage costs: – Landfill gate fees: NZ$115/load – Haulage fixed cost: NZ$15/ton – Haulage variable cost: NZ$3/km travelled – Haulage labour: NZ$160/hr – Operator labour cost: NZ$60/hr – Fuel costs: NZ$1.50/L – Fuelage for trailers 5km/L fuel – Average speed (haulage) 40kmph – Polymer dose rates 8-10kg/DT, at 40% – Land purchase costs $1.50/sqm	Unit costs as provided by FNDC Where costs are unavailable, typical operating and maintenance unit costs adopted for NZ projects were adopted. Average of land purchase costs as advertised in the area. Land prices ranged from $0.70/sqm in Kaikohe to $3.50/sqm in Kerikeri. The evaluation used a value of $1.50/sqm, considered the average value. Lower truck speeds selected to account for the less favourable roads (often unsealed) leading to the WWTPs.
Operational cost variables	■ Max effective working hours for dredging/dewatering equipment = 5h/d ■ Max working days per week = 5d/week ■ Max working weeks in a year = 50 weeks ■ Expected dewatered cake dryness = ■ 25%DS for pond sludges ■ 16%DS for undigested WAS ■ 18%DS for aerobically digested WAS	Typical operational cost variables adopted for similar studies in NZ.
Net Present Cost (NPC) Variables	■ Discount rate = 6% ■ Total periods for assessment = 20 years	Public Sector Discount Rates for Cost Benefit Analysis, The Treasury, NZ Government, October 2016. Evaluation period as agreed with FNDC

Parameter	Value/Assumptions	Notes
Option Specific Assumptions		
Pond sludge calculations	▪ 3.5%DS average concentration in sludge layer of all Ponds ▪ Sludge production rate of septage of 14.0g/EP/d on average	▪ Typically observed in the field ▪ Septage is typically well stabilised, having spent approx. 5 years under anaerobic conditions
Mobile dewatering unit assessment	▪ Dewatering unit assessment adequacy calculates the number of units required to provide dewatering of all ponds requiring dewatering within a 20-year timeframe, with approx. 20% downtime for maintenance. ▪ Assumes dewatering of ASP plants at least once every 7 days. ▪ Maintenance cost of mobile dewatering unit is between 3-5%, with an average of 4% ▪ Assumes a central storage site for the dewatering equipment, with average travel distances between sites on a yearly basis calculated based on the expected number of return trips from the expected central equipment storage site.	▪ Typical for mobile units
Geobag dewatering assessment	▪ Assumes land purchase for a dedicated geobag laydown area will be required at each site where inadequate land is available will form part of the capital costs. ▪ Assumes land purchase is a feasible option where inadequate land is available. ▪ Civil works for setup of the geobag laydown area will be incurred at every dewatering event and considered part of the routine opex	▪ Typical operational cost variables adopted for similar studies in NZ
Onsite burial assessment	▪ Land requirement for onsite burial is considered an ongoing operational cost, as new land will be required for each burial event. It is assumed that geobags will be used for dewatering of sludge and dried geobags will be buried onsite. ▪ Burial depth of 4m is assumed with an assumed excavation cost of $65/m3	▪ Typical
Mine/Quarry Rehabilitation assessment	▪ Assumed distance of 50km to mines/quarries in area ▪ Assumed gate fees of $10/Wet Tonne ▪ Assumed trailer hire costs in the order of $23/hr per trailer	▪ Assumed based on available information on mines/quarries ▪ Assumed cost parameters based on similar projects internationally. Assumption to be confirmed with FNDC for final report submission.

Parameter	Value/Assumptions	Notes
Vermicomposting assessment	▪ Assumed land purchase required for vermicomposting facilities = 1ha per 750 Wet Tonne of sludge ▪ Gate fees in the order of $60-85/WT, adopted $65/Wet Tonne and sensitivity for $85/Wet Tonne ▪ Biosolids reduction of 40% used to calculate the buyback amount, with up to 75% reduction possible ▪ Assumed distance of 50km to MyNoke vermicomposting sites.	▪ Preliminary discussions with MyNoke
Kaitaia and Kaikohe WWTP sludge pond assessment	▪ Assumes that only the largest pond at the WWTP will be converted into a sludge pond. All other ponds will be decommissioned and filled. ▪ Assumes 90% active volume to the embankment for sludge storage. ▪ Assumes no civil works for compacting the sides of banks or pond base will be required. This will add a significant cost should it be found to be required. However, the costs of relining the pond with HDPE liner has been included. ▪ Assumes 60% VS reduction year on year in all sludge ponds.	▪ Reasonable assumption given magnitude of ponds.

2.5.2 Business as Usual

As outlined previously, the current BAU practice is not sustainable and has been modified slightly to account for the conversion of Kaitaia and Kaikohe WWTP into ASP WWTPs in the near future. However, to enable a more objective comparison of the options, the current BAU was also costed to present a snapshot of the current practice, which shall serve as the minimum benchmark for comparison.

2.5.2.1 BAU Current Practice

Table 10 below presents the estimated overall costs for the current practice at all FNDC's WWTPs, broken down into each of the individual components.

Table 10: Cost Benchmark – BAU Current

Component	Description	Capital Cost ($)	Operational & Maintenance Cost ($ p.a.)	NPC ($M)
ASP Transfers	Hihi to Kaitaia, Russell and Kerikeri to Kaikohe	-	$130,000	$1.49
End Use	Landfill	-	$426,200	$4.89
Treatment	No treatment	-	-	-
Dewatering	Third party dredging and dewatering	$13,800	$471,600	$5.42
TOTAL	**BAU Current**	**$13,800**	**$1,027,800**	**$11.80**

2.5.2.2 BAU Future

As noted previously, the "future" BAU is in fact a modified BAU which reuses the existing ponds at Kaitaia and Kaikohe WWTP as sludge ponds for treatment of the transferred ASP WAS. Under the future BAU practice, the current practice of using contractor dewatering and disposal to landfill was assumed to be continued. Table 11 below presents the estimated overall costs for the expected modified BAU practice at all FNDC's WWTPs, broken down into each of the individual components.

Table 11: Cost Benchmark – BAU Future

Component	Description	Capital Cost ($)	Operational & Maintenance Cost ($p.a.)	NPC ($M)
ASP Transfers	Hihi to Kaitaia, Russell and Kerikeri to Kaikohe	-	$130,000	$1.49
End Use	Landfill	-	$521,200	$5.98
Treatment	Relining of sludge ponds at Kaitaia and Kaikohe	$2,201,600	-	$2.20
Dewatering	Third party dredging and dewatering	$13,800	$387,700	$4.46
TOTAL	**BAU Future**	**$2,215,400**	**$1,038,900**	**$14.13**

2.5.3 Decentralised Sludge Strategy

The Decentralised sludge strategy comprises of three separate components:

- Small Pond WWTPs strategy (A).
- Small ASP WWTPs strategy (B).
- Decentralised Large WWTP Strategy (C).

2.5.3.1 Small Pond WWTP Strategy (A)

Table 12 below presents the estimated costs for all the individual components, inclusive of the sub-options which will form the Decentralised Small Pond WWTP strategy. The lowest NPC sub-option (highlighted in blue) will be selected and will form part of the overall strategy for the Small Pond WWTPs.

Table 12: Small Pond WWTP Strategy Costs

Component	Description	Capital Cost ($)	Operational & Maintenance Cost ($ p.a.)	NPC ($M)
ASP Transfers	No transfers	-	-	-
End Use	Landfill	-	$166,900	$1.91
	Onsite Burial	-	$117,800	$1.35
	Mine/Quarry Rehabilitation	-	$49,600	$0.57
Preferred End Use	Mine/Quarry Rehabilitation	-	$49,600	$0.57
Treatment	No Treatment	-	-	-
Dewatering	Third party dredging and dewatering	$13,800	$167,200	$1.93

Component	Description	Capital Cost ($)	Operational & Maintenance Cost ($ p.a.)	NPC ($M)
	Mobile Dredging & Mobile Dewatering	$840,100	$75,400	$1.70
	Mobile Dredging & Geobags	$360,300	$109,000	$1.61
Preferred Dewatering	Mobile Dredging & Geobags	$360,300	$109,000	$1.61
TOTAL PREFERRED	No treatment + Mobile Dredging + Geobags + Mine/Quarry Rehabilitation	$360,300	$158,600	$2.18

From Table 12 above, the preferred strategy for Small Pond WWTPs is to provide no additional treatment, own and operate mobile dredge, with geobag dewatering and mine/quarry rehabilitation.

2.5.3.2 Small ASP WWTP Strategy (B)

Table 13 below presents the estimated costs for all the individual components, inclusive of the sub-options which will form the Decentralised Small ASP WWTP strategy. Given that particular sub-options are only compatible with particular treatment technologies, two options were developed. The lowest NPC sub-option will be selected and will form part of the overall strategy for the Small ASP WWTPs.

Table 13: Small ASP WWTP Strategy Costs

Component	Description	Capital Cost ($)	Operational & Maintenance Cost ($p.a.)	NPC ($M)
Option 1 – No treatment				
ASP Transfers	No transfers	-	-	-
End Use	Vermicomposting	$15,100	$88,100	$1.03
Treatment	No treatment	-	-	-
Dewatering	Mobile Dewatering	$493,600	$125,000	$1.93
TOTAL – Option 1		**$508,700**	**$213,100**	**$2.95**
Option 2 – Aerobic Digestion				
ASP Transfers	No transfers	-	-	-
End Use	Mine/Quarry Rehabilitation	-	$35,100	$0.40
Treatment	Aerobic Digestion	$3,616,200	$119,200	$4.98
Dewatering	Mobile Dewatering	$493,600	$125,000	$1.93
Total – Option 2		**$4,109,800**	**$279,300**	**$7.31**
TOTAL PREFERRED	**No treatment (on-site) + Mobile Dewatering + Vermicomposting**	**$508,700**	**$213,100**	**$2.95**

From Table 13 above, the preferred strategy for Small ASP WWTPs is to provide no additional treatment (on-site), own and operate mobile dewatering system, and send the dewatered sludge for vermicomposting at a small facility treating sludge from only the small ASP WWTPs.

2.5.3.3 Large WWTP Strategy (C)

Kaitaia WWTP and Kaikohe WWTP have been singled out as requiring a separate strategy distinct from the Small Pond WWTPs and Small ASP WWTPs, due to the vast difference in magnitudes of scale between these two WWTPs and the other WWTPs considered in this assessment.

Table 14 below presents the estimated costs for all the individual components, inclusive of the sub-options which will form the Decentralised large WWTP strategy. Given that particular sub-options are only compatible with particular treatment technologies, two options were developed. The lowest NPC sub-option (highlighted in blue and bold) will be selected and will form part of the overall strategy for the large WWTPs.

Table 14: Large WWTP Strategy Costs

Component	Description	Capital Cost ($)	Operational & Maintenance Cost ($p.a.)	NPC ($M)
Option1 – Aerobic Digestion				
ASP Transfers	No transfers	**-**	**-**	**-**
End Use	Mine/Quarry Rehabilitation	-	$97,800	$1.12
Treatment	Aerobic Digestion	$7,784,800	$201,200	$10.09
Dewatering	Mobile Dewatering	$1,589,300	$251,800	$4.48
Total – Option 1		**$9,374,100**	**$550,800**	**$15.69**
Option 2 – Local Sludge Ponds				
ASP Transfers	**No transfers**	**-**	**-**	**-**
End Use	**Mine/Quarry Rehabilitation**		**$51,159**	**$0.69**
Treatment	**Local Sludge Pond**	**$2,201,600**	**-**	**$2.20**
Dewatering	Third party dredging and dewatering	-	$220,556	$2.53
	Mobile Dredge & Mobile Dewatering	$1,935,800	$96,957	$3.04
	Mobile Dredge & Geobags	$346,500	$83,511	$1.30
Preferred Dewatering	**Mobile Dredge & Geobags**	**$346,500**	**$83,511**	**$1.30**
Total – Option 2		**$2,548,100**	**$134,670**	**$4.09**
TOTAL PREFERRED	**Option 2 – Local Sludge Ponds + Mobile Dredge & Geobags + Mine/Quarry Rehabilitation**	**$2,548,100**	**$134,670**	**$4.09**

From above, the preferred strategy for Large WWTPs is to provide local sludge ponds, own and operate a mobile dredge, utilise geobags for dewatering, and send the dewatered sludge for Mine or Quarry rehabilitation.

2.5.3.4 Total – Decentralised Strategy

Table 15 below presents a summary of the Decentralised strategy components and the overall Decentralised sludge strategy recommended for FNDC’s WWTPs.

Table 15: Total Decentralised Strategy Costs

Component	Description	Capital Cost ($)	Operational & Maintenance Cost ($p.a.)	NPC ($M)
Small Pond WWTPs	No treatment + Mobile Dredge + Geobags + Mine/Quarry Rehabilitation	$360,300	$158,600	$2.18
Small ASP WWTPs	No treatment (on-site) + Mobile Dewatering + Vermicomposting	$508,700	$213,100	$2.95
Large WWTP Decentralised	Local Sludge Ponds + Mobile Dredge & Geobags + Mine/Quarry Rehabilitation	$2,548,100	$134,700	$4.09
TOTAL DECENTRALISED		**$3,417,100**	**$506,400**	**$ 9.22**

2.5.4 Centralised Sludge Strategy

The Centralised sludge strategy comprises of only two separate components:

- Small Pond WWTPs strategy (A).
- Centralised ASP WWTP Strategy (D).

2.5.4.1 Small Pond WWTP Strategy

The most optimum strategy for the Small Pond WWTPs are similar to that identified for a Decentralised strategy, as there is no Decentralised option for treatment and disposal of Small Pond WWTP sludges. Table 12 previous outlines the sub-options available for the Small Pond WWTP strategy, and the preferred strategy for the Small Pond WWTPs.

2.5.4.2 Centralised ASP WWTP Strategy

Two Centralised ASP strategies were costed:

- Transfer of liquid WAS from small ASPs to the Centralised ASP treatment facility.
- Transfer of dewatered WAS from all ASPs to the Vermi-composting facility.

Table 16: Centralised ASP WWTP Strategy Costs

Component	Description	Capital Cost ($)	Operational & Maintenance Cost ($p.a.)	NPC ($M)
Option 1 – Centralised Vermicomposting				
ASP Transfers	No Transfers	-	-	-
End Use	Vermicomposting	$75,800	$425,200	$4.95
Treatment	No Treatment	-	-	-
Dewatering	Mobile Dewatering	$2,082,900	$376,800	$6.40
TOTAL – Option 1		**$2,158,700**	**$802,000**	**$11.35**
Option 2 – Centralised Sludge Lagoons				
ASP Transfers	**Hihi to Kaitaia, Russell and Kerikeri to Kaikohe**	**-**	**$130,000**	**$1.49**
End Use	Landfill	-	$254,600	$2.92
	Onsite Burial	-	$148,300	$1.70
	Mine/Quarry Rehabilitation	-	$59,900	$0.69

Component	Description	Capital Cost ($)	Operational & Maintenance Cost ($p.a.)	NPC ($M)
Preferred End Use	**Mine/Quarry Rehabilitation**	**-**	**$59,900**	**$0.69**
Treatment	**Sludge Pond**	**$2,201,600**	**-**	**$2.20**
Dewatering	Third party dredging and dewatering	-	$260,500	$2.99
	Mobile Dredge & Mobile Dewatering	$1,935,800	$115,600	$3.26
	Mobile Dredge & Geobags	$346,500	$100,100	$1.49
Preferred Dewatering	**Mobile Dredge & Geobags**	**$346,500**	**$100,100**	**$1.49**
TOTAL – Option 2	**ASP Transfers + Sludge Pond + Mobile Dredge & Geobags + Mine/Quarry Rehabilitation**	**$2,548,100**	**$290,000**	**$5.87**
TOTAL PREFERRED	**ASP Transfers + Sludge Pond + Mobile Dredge & Geobags + Mine/Quarry Rehabilitation**	**$2,548,100**	**$290,000**	**$5.87**

From Table 16 above, the preferred strategy for Centralised ASP WWTPs is to enable ASP transfers, and provide treatment with sludge ponds onsite, own and operate a mobile dredge, with geobag dewatering and mine/quarry rehabilitation.

2.5.4.3 Total – Centralised Strategy

Table 17 below presents a summary of the Centralised strategy components and the overall Centralised sludge strategy recommended for FNDC's WWTPs.

Table 17: Total Centralised Strategy Costs

Component	Description	Capital Cost ($)	Operational & Maintenance Cost ($p.a.)	NPC ($M)
Small Pond WWTPs	No treatment + Mobile Dredge + Geobags + Mine/Quarry Rehabilitation	$360,300	$158,600	$2.18
Small ASP WWTPs	No treatment – transfer to Centralised ASP WWTP	-	-	-
Centralised ASP WWTP	ASP Transfers + Central Sludge Pond + Mobile Dredge & Geobags + Mine/Quarry Rehabilitation	$2,548,100	$290,000	$5.87
TOTAL CENTRALISED		**$2,908,400**	**$448,600**	**$8.05**

2.6 Strategy Evaluation

2.6.1 Cost Evaluation

Table 18 presents a comparison between the current BAU, future BAU, the Decentralised and Centralised strategy options.

Table 18: Strategy Cost Comparison

Component	BAU – Current	BAU – Future	Decentralised	Centralised
Small Pond WWTPs	▪ No treatment ▪ Third party dewatering ▪ Landfill	▪ As BAU Current	▪ No treatment ▪ Mobile Dredge + Geobags ▪ Mine/Quarry Rehabilitation	▪ No treatment ▪ Mobile Dredge + Geobags ▪ Mine/Quarry Rehabilitation
Small ASP WWTPs	▪ ASP Transfers	▪ As BAU Current	▪ No treatment ▪ Mobile Dewatering ▪ Vermicomposting	▪ ASP Transfers
Large WWTPs (Kaitaia/Kaikohe)	▪ No treatment ▪ Third party dewatering ▪ Landfill	▪ ASP, with Centralised Sludge Ponds ▪ Third party dewatering ▪ Landfill	▪ Local Sludge Ponds ▪ Mobile Dredge & Geobags ▪ Mine/Quarry Rehabilitation	▪ Centralised Sludge Ponds ▪ Mobile Dredge & Geobags ▪ Mine/Quarry Rehabilitation
Capital Cost ($)	$13,800	$2,215,400	$3,417,100	$2,908,400
O&M Cost ($ p.a.)	$1,027,800	$1,038,900	$506,400	$448,600
NPC ($M)	**$11.80**	**$14.13**	**$9.22**	**$8.05**

From Table 18, the Centralised strategy option appears to be the most cost-effective, having the lowest NPC of all the options. The Decentralised strategy option is a close second, with the BAU scenarios being significantly more expensive than both the Centralised and Decentralised options, approximately 30-75% more expensive than either option. Given the margin of error of this assessment (of 30%), the Centralised and Decentralised strategy option would at first glance seem comparable, and sensitivity will need to be done on the unit costs to ascertain the definitive best path forward. Sensitivity analysis on the options will be outlined in the following section.

2.6.2 Sensitivity Analysis

Sensitivity analysis was done on a number of unit cost items which are considered critical and has a high risk of changing in the near future. The scenarios considered are summarized in Table 19, along with the changes in unit rates for the individual scenarios.

Table 19: Sensitivity Analysis Parameters

No.	Item	Cost	Units	Current	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
	Description			**Current**	**Reduced haulage costs**	**Increased haulage costs**	**Increased Vermi-composting fees**	**Increased FNDC variables (labour, poly, maintenance)**	**Increased costs outside FNDC control**	**Reduced civil works & land purchase cost**	**Increased civil works & land purchase cost**	**Reduced FNDC variables (maintenance)**
1	Electricity Cost	$0.46	$/kWh	0.46	0.46	0.46	0.46	0.46	0.50	0.46	0.46	0.46
2	Haulage Cost - Fixed Cost	$15.00	$/WT	15.00	12.00	20.00	15.00	15.00	15.00	15.00	15.00	15.00
3	Haulage Cost - Variable	$3.00	$/km travelled	3.00	2.00	5.00	3.00	3.00	3.00	3.00	3.00	3.00
4	Haulage Labour Cost	$160.00	$/hr	160.00	140.00	180.00	160.00	160.00	160.00	160.00	160.00	160.00
5	Plant Labour Cost	$60.00	$/hr	60.00	60.00	60.00	60.00	70.00	60.00	60.00	60.00	60.00
6	Polymer	$5.00	$/kg	5.00	5.00	5.00	5.00	6.00	5.00	5.00	5.00	5.00
7	Cost of Petrol (for Mobile Units)	$1.50	$/L	1.50	1.20	1.80	1.50	1.50	1.50	1.50	1.50	1.50
8	Vermicomposting Gate Fees	$65.00	$/WT	65.00	65.00	65.00	85.00	65.00	65.00	65.00	65.00	65.00
9	Vermicompost Buy Back Cost	$42.00	$/DT sludge	42.00	42.00	42.00	60.00	42.00	42.00	42.00	42.00	42.00
10	Geobags - Civil Works for Laydown	$50.00	$/sqm	50.00	50.00	50.00	50.00	50.00	50.00	30.00	70.00	50.00
11	Maintenance (typ 3-5%)	4%	%	4%	4%	4%	4%	5%	4%	4%	4%	3%
12	Land Purchase	$1.50	$/sqm	1.50	1.50	1.50	1.50	1.50	1.50	1.00	3.50	1.50
13	Trailer Hire Cost	$22.50	$/hr per trailer	22.50	20.00	25.00	22.50	22.50	22.50	22.50	22.50	22.50
14	Quarry Gate Fees	$10.00	$/WT	10.00	10.00	10.00	10.00	10.00	15.00	10.00	10.00	10.00
15	Landfill Tipping Fees	$115.00	$/WT	115.00	115.00	115.00	115.00	115.00	125.00	115.00	115.00	115.00

The results of the sensitivity analysis are shown graphically in Figure 6. Details of the sensitivity analysis is presented in detail in Appendix D. Figure 6 shows that under all sensitivity scenarios, the preferred strategy continues to be the Centralised option. Scenario 2, where the sludge haulage costs were increased, resulted in a slight increase in the Centralised strategy costs such that it approaches the Decentralised strategy costs. Nonetheless, despite the increased haulage costs in Scenario 2, the Centralised option continues to have the lowest overall strategy cost. These results show that the Centralised sludge strategy is clearly the preferred option, and is considerably robust, with no changes in the preferred overall strategy despite all the changes in operating cost variables considered.

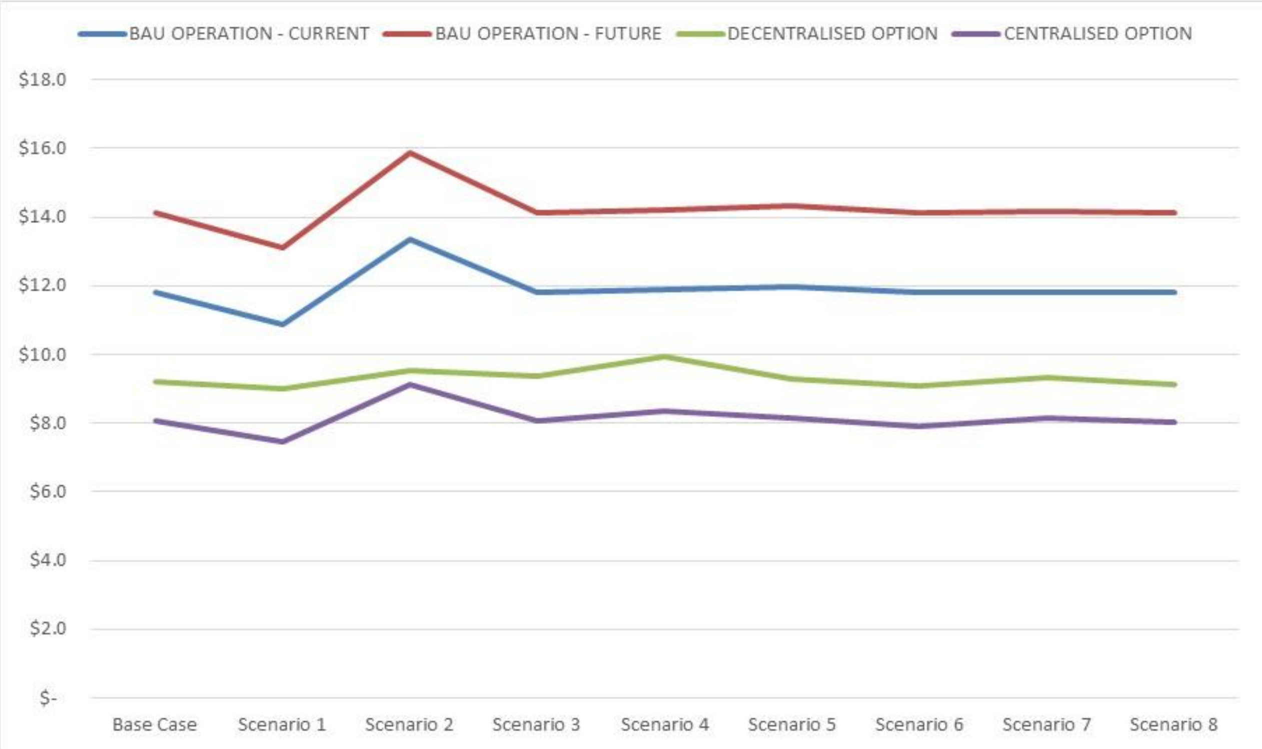


Figure 6: Sensitivity Analysis – Comparison of Strategies

This suggests that more detailed analysis will be required to select the most appropriate dewatering option for the Small Pond WWTPs. Such detailed analysis currently is outside the scope of this project. This analysis will further refine the identified sludge strategy, and should be done in the subsequent investigation stages of this project, prior to selection and implementation of the final sludge strategy. This will allow selection of the most appropriate dewatering sub-option for implementation at FNDC's WWTPs.

2.7 Summary

The strategy costs have been developed for potential sludge strategies identified for FNDC, and are summarized in Table 20.

Table 20: Summary of Strategy Costs

Item	Capital Cost ($)	Operational & Maintenance Cost ($ p.a.)	NPC ($M)
BAU Current	$13,800	$1,027,800	$11.80
BAU Future	$2,215,400	$1,038,900	$14.13
Decentralised	$3,417,100	$506,400	$9.22
Centralised	**$2,908,400**	**$448,600**	**$8.05**

A sensitivity analysis have also been undertaken on the strategy costs, to identify any risks of changes in the preferred strategy with changes in unit cost rates due to various circumstances. The sensitivity analysis demonstrates that the Centralised sludge strategy option is consistently the preferred sludge strategy option from a financial perspective, having the lowest NPC consistently across all scenarios evaluated. The overall preferred strategy option when considering both the cost and non-cost factors will be evaluated further in a Quadruple Bottom Line Analysis which is summarised in next section.

3 Quadruple Bottom Line Analysis

The Quadruple Bottom Line (QBL) analysis is a framework which enables both cost and non-cost aspects of a project to be considered when making an investment decision. The QBL incorporates the result of a qualitative MCA to assess the options in the context of a project's non-cost aspects, and the financial evaluation outcomes, to rank the options relative to their ability to meet the project objectives and success criteria. This section will present the results of the QBL analysis of the Sludge Strategy options for FNDC.

3.1 Non-Cost Scores

The sludge strategy was developed based on a combination of the shortlisted options from the Technology Selection MCA Workshop on the 6t November 2017 attended by technical staff from CH2M Beca, and consequently, non-cost scores can be compiled for the developed strategies based on a weighted average of the individual strategy components as outlined in Appendix C, accounting for the weight of sludge treated by each strategy component.

3.1.1 BAU

Table 21 summarizes the proposed scores for the BAU components, both current and future, for comparison. The future BAU scores were updated based on the expected changes to the BAU process based on the assumed upgrade of Kaitaia and Kaikohe WWTP into ASPs WWTPs, with the existing treatment ponds converted to sludge ponds for treatment of sludge from the respective WWTP and the transferred WAS.

Table 21: Non-Cost Scores - BAU

			BAU – CURRENT		BAU - FUTURE	
Primary Criteria.	**Sub-Criteria**	**Weights**	**RAW**	**WEIGHTED**	**RAW**	**WEIGHTED**
Environment	Ecological/ Habitat Effects (Air, Water, Soil quality)	8%	3	0.23	3	0.23
	Resource Efficiency (material/resource use, waste minimisation)	8%	3	0.23	3	0.23
	Land use efficiency (footprint)	8%	3	0.23	4	0.30
	GHG Emissions	8%	3	0.23	4	0.30
Social	Amenity impacts (odour, visual amenity, noise, transport)	8%	3	0.23	2	0.15
	Public Acceptability (Iwi cultural perception, community perception of options, outcomes)	8%	3	0.23	3	0.23
	Public Safety (community health and safety, OHS)	8%	3	0.23	3	0.23
	Reputation enhancement	8%	3	0.23	3	0.23
Technical	Technology Performance (treatment efficiency, established process/not, long term sustainability)	8%	3	0.24	4	0.32
	Reliability (operational reliability, reliability in meeting product requirements)	8%	3	0.24	3	0.24
	Operability (compatibility with existing technology and processes, operability based on operator skills)	8%	3	0.24	3	0.24

			BAU – CURRENT		BAU - FUTURE	
	Maintainability	4%	3	0.12	3	0.12
	Constructability	4%	3	0.12	3	0.12
	Ease of meeting Statutory Requirements (now and future requirements)	8%	3	0.24	3	0.24
	TOTAL NON-COST SCORE			**3.00**		**3.16**

3.1.2 Decentralised Option

Table 22 summarises the raw individual scores of each strategy component, along with the quantity of sludge produced, and the overall strategy scores based on a weighted average using the solids contribution of each component.

Table 22: Non-Cost Scores - Decentralised

			Decentralised				
Primary Criteria.	**Sub-Criteria**	**Weights**	**Small Pond WWTP (Mine Rehab)**	**Large WWTP (Sludge Pond)**	**Small ASP WWTP (Vermi-compost)**	**Weighted Average RAW**	**Weighted Average FINAL**
Solids Contribution (kgDS/d)			351	982	245	1,578	1,578
Environment	Ecological/ Habitat Effects (Air, Water, Soil quality)	8%	3	3	5	3.3	0.25
	Resource Efficiency (material/resource use, waste minimisation)	8%	4	4	5	4.2	0.31
	Land use efficiency (footprint)	8%	5	1	5	4.4	0.33
	GHG Emissions	8%	3	2	5	2.7	0.20
Social	Amenity impacts (odour, visual amenity, noise, transport)	8%	4	2	4	2.8	0.21
	Public Acceptability (Iwi cultural perception, community perception of options, outcomes)	8%	5	3	5	3.8	0.28
	Public Safety (community health and safety, OHS)	8%	5	5	5	5.0	0.38
	Reputation enhancement	8%	4	3	5	3.5	0.26
Technical	Technology Performance (treatment efficiency, established process/not, long term sustainability)	8%	4	3	5	4.2	0.33
	Reliability (operational reliability, reliability in meeting product requirements)	8%	5	3	5	3.8	0.30
	Operability (compatibility with existing technology and processes, operability based on operator skills)	8%	5	3	5	3.8	0.30

			Decentralised				
	Maintainability	4%	5	3	5	3.8	0.15
	Constructability	4%	5	3	5	3.8	0.15
	Ease of meeting Statutory Requirements (now and future requirements)	8%	4	3	5	3.5	0.28
	TOTAL NON-COST SCORE						**3.73**

3.1.3 Centralised Option

Table 23 summarises the raw individual scores of each strategy component, along with the quantity of sludge produced, and the overall Centralised strategy scores based on a weighted average using the solids contribution of each component.

Table 23: Non-Cost Scores - Centralised

			Centralised			
Primary Criteria.	**Sub-Criteria**	**Weights**	**Small Pond WWTP (Mine Rehab)**	**Large WWTP (Sludge Pond)**	**Weighted Average RAW**	**Weighted Average FINAL**
Solids Contribution (kgDS/d)			351	1227	1578	1578
Environment	Ecological/ Habitat Effects (Air, Water, Soil quality)	8%	3	3	3.0	0.23
	Resource Efficiency (material/resource use, waste minimisation)	8%	4	4	4.0	0.30
	Land use efficiency (footprint)	8%	5	4	4.2	0.32
	GHG Emissions	8%	3	2	2.2	0.17
Social	Amenity impacts (odour, visual amenity, noise, transport)	8%	4	2	2.4	0.18
	Public Acceptability (Iwi cultural perception, community perception of options, outcomes)	8%	5	3	3.4	0.26
	Public Safety (community health and safety, OHS)	8%	5	5	5.0	0.38
	Reputation enhancement	8%	4	3	3.2	0.24
Technical	Technology Performance (treatment efficiency, established process/not, long term sustainability)	8%	4	4	4.0	0.32
	Reliability (operational reliability, reliability in meeting product requirements)	8%	5	3	3.4	0.28
	Operability (compatibility with existing technology and processes, operability based on operator skills)	8%	5	3	3.4	0.28
	Maintainability	4%	5	3	3.4	0.14
	Constructability	4%	5	3	3.4	0.14
	Ease of meeting Statutory Requirements (now and future requirements)	8%	4	3	3.2	0.26

Centralised						
	TOTAL NON-COST SCORE					**3.47**

3.1.4 Final Non-Cost Scores

Table 24 below summarises the non-cost scores developed for each of the strategy options, which will be carried forward to the QBL analysis and evaluation.

Table 24: Summary – Weighted Non-Cost Scores for Strategy Options

Strategy Option	Non-Cost Score
BAU – Current	3.00
BAU – Future	3.16
Decentralised	3.73
Centralised	3.47

3.2 Financial Scoring

To determine the preferred option, financial criteria must be taken into consideration in conjunction with the non-cost scores outlined above. As indicated in Table 9, 20 years and 6% discount rate were adopted as the financial criterion for the assessment. The financial scores for all the strategy options were calculated based on a relative scale using the lowest cost strategy option as the reference point and assigned a score of 5.0, with the score decreasing as the costs increased. Table 25 presents the NPCs for each strategy option and the financial score for each strategy option.

Table 25: Summary – Financial Scores for Strategy Options

Strategy Option	NPC ($M)	Financial Score
BAU – Current	$11.8	3.39
BAU – Future	$14.1	2.84
Decentralised	$9.1	4.39
Centralised	$8.0	5.00

3.3 Preferred Strategy

3.3.1 Overall Score

The financial scores assigned in Table 25 above were considered in conjunction with the non-cost scores shown in Table 24 to determine the most preferable sludge strategy for FNDC's WWTPs. Table 26 below shows the results, based on a weighting of 50% for each financial and non-cost criterion.

Table 26: Overall Scores – Cost (50% Weight) and Non-Cost (50% Weight) Combined Scores

Component	Weighting	BAU - Current	BAU Future	Decentralised	Centralised
Non-Cost Score	50%	3.00	3.16	3.73	3.47
Cost Score	50%	3.39	2.84	4.39	5.00

Component	Weighting	BAU - Current	BAU Future	Decentralised	Centralised
Overall Score		**3.20**	**3.00**	**4.06**	**4.24**
Rank		**3**	**4**	**2**	**1**

Based on the results in Table 26, the Centralised option is the preferred sludge strategy when both costs and non-cost criteria are considered with equal weightings. However, it is noted that whilst this option is the cheapest, it is ranked second in terms of non-cost criteria.

3.3.2 Sensitivity Analysis

Sensitivity analysis was conducted by changing the financial criteria, and assessing the results considering 70% and 30% weighting for cost. The results are summarised in Figure 7. From the sensitivity analysis, the Centralised strategy option is clearly the preferred option when cost is given a weighting of 50% or more. However, when the non-cost criteria is given greater weighting, in the order of 70% or more, the Decentralised option becomes equally favourable, which is expected, given that the Decentralised option has the highest non-cost score.

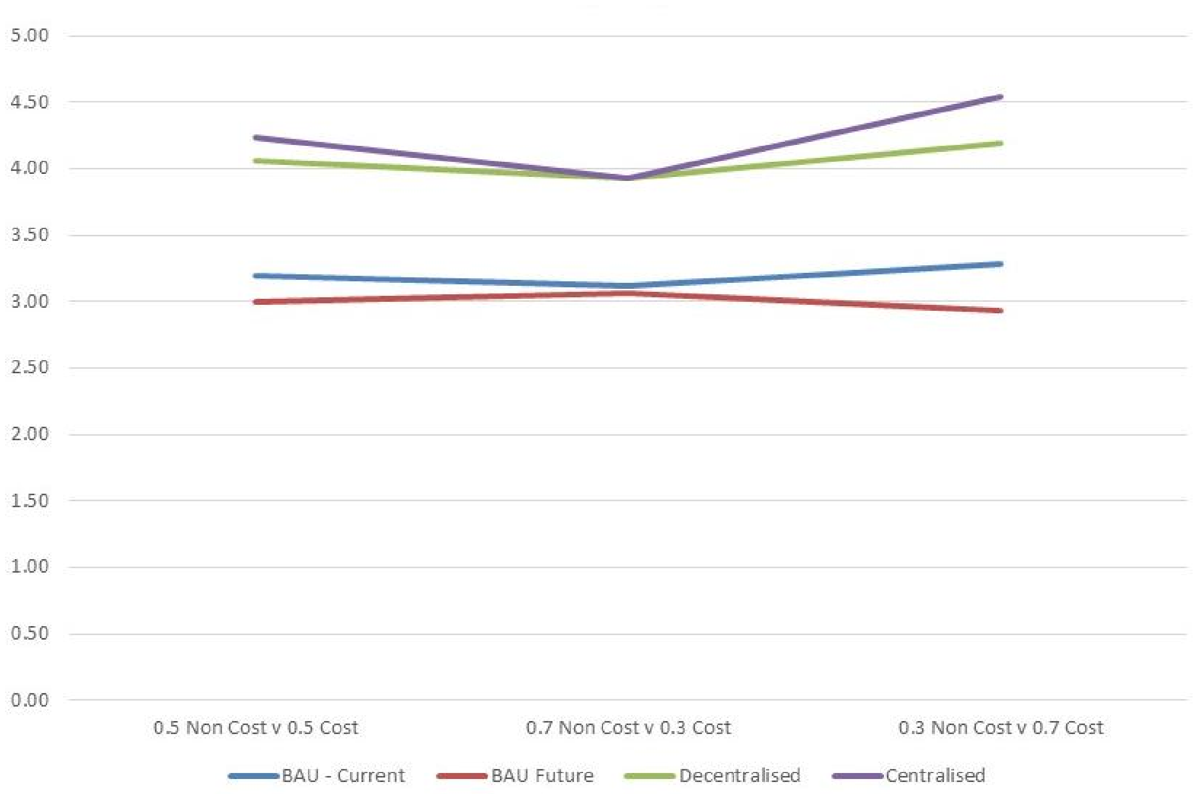


Figure 7: Sensitivity Analysis – Various Cost and Non-Cost Weightings

It should be noted that the high non-cost score of the Decentralised option is largely due to the expected favourable merits of Vermicomposting, which also has the lowest NPC for Small ASP WWTPs. However, there is considerable commercial risk associated with vermicomposting, which could not be incorporated into the assessment. Key risks which have been identified, and have the potential to impact the financial viability of Vermicomposting and its associated financial risk are:

- The risk of providers ceasing operation.

- The requirement to dispose of vermicompost (or use it) that is bought back under “buy back” policy.

There are only two (2) known vermicomposting providers in the Far North region, MyNoke and EcoCast. If either (or both) providers cease operation, at best there will be a monopoly by one single company who can arbitrarily set gate fees and rates to suit their financial goals, but at worst there will no longer exist a facility capable of accepting dewatered undigested WAS for beneficial reuse. Given the imminent closure of the Ahipara and Russell landfills and recent closure of the Whangarei landfill, if both companies were to cease operation in the Far North district, this will cause all dewatered WAS produced by FNDC’s ASP WWTPs to be sent to the nearest available landfill. The nearest operating landfill identified is Redvale, located more than 200km away from the nearest FNDC WWTP. This has the potential to cause considerable increase in WAS disposal costs and consequently the financial risk of this occurring must be considered thoughtfully.

Preliminary discussions with MyNoke has also indicated that FNDC will be contractually required to buy-back 75% of the produced vermicasts, with an expected solids quality of Aa. This will allow FNDC to beneficially reuse the vermicasts for agricultural uses within the region. However, Mynoke indicates that they are unable to guarantee the produced solids quality. Should the produced solids fail to meet grade Aa, FNDC will have to find suitable application sites for the produced solids. This gives rise to the risk of having to then still pursue disposal of the vermicasts within mines/quarries for rehabilitation, with considerable associated costs in addition to the vermicomposting fees.

Consequently, based on the above assessment, it appears prudent to consider a financial weight of at least 50% given one of the project objectives being the identification of a cost effective long term solution for sludge management of FNDC’s WWTPs.

Based on the selected financial weighting, and considering the risk associated with vermicomposting, the Centralised option (with sludge reused for mine/quarry rehabilitation) is considered the preferred option for FNDC’s sludge strategy. It is worth pointing out that, mine/quarry site rehabilitation is not a current established market for FNDC, hence it is anticipated that market development will be required to establish this market (with sufficient capacity) to achieve long term sustainable end use of the biosolids produced in the region.

3.4 Summary

A QBL analysis along with sensitivity for the different weightings assigned to both the cost and non-cost criteria, have identified the preferred sludge strategy for FDNC’s WWTPs to be the Centralised sludge strategy. The Centralised sludge strategy was identified to be the preferred option for various assigned weightings, up to 70% for the non-cost criteria. At weightings of greater than 70% for the non-cost criteria, the preferred sludge strategy option was found to shift to the Decentralised strategy, which has the highest non-cost score. Nonetheless, due to the high commercial risk identified with the Decentralised strategy, coupled with the project objectives of identifying a low-cost strategy solution for the sludge management of FNDC’s WWTPs, a higher cost criteria weighting of at least 50% appears prudent.

Based on the above analysis, the Centralised sludge strategy option appears to be the preferred sludge strategy option for further evaluation and assessment by FNDC. The Centralised strategy comprises of the following components:

- Continuing the existing WAS transfers from Hihi to Kaitaia, and Russell & Kerikeri to Kaikohe for treatment.
- Conversion of the existing Kaitaia WWTP and Kaikohe WWTP treatment ponds (Pond No. 1) into sludge ponds for treatment of the transferred ASP WAS.
- Purchase of two (2) mobile dredges for removal of sludge from FNDC’s pond WWTPs.

- Purchase of geobags (qty and size as required) or a mobile dewatering system for dewatering of the sludge dredged from all FNDC's ponds.
- Beneficially reusing the produced sludge for Mine/Quarry Rehabilitation.

Additional sub-options exist within this overall sludge strategy, and should be further evaluated by FNDC in subsequent stages of this study, to ascertain the most cost effective overall strategy for implementation. It should also be noted that the timing of implementation for this Centralised strategy will hinge on the timing of conversion of the Kaitaia WWTP and Kaikohe WWTP ponds into mechanical plants, which may be in the order of three – six years.

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4 Conclusions and Recommendations

4.1 Conclusions

The sludge strategy developed for FNDC's WWTPs was performed over three stages, with the ultimate objective being to develop a cohesive and cost-effective strategy for all FNDC WWTPs, and to inform FNDC's Long Term Plan. The preferred strategy was selected using QBL analysis which incorporates both cost and non-cost considerations.

Costs have been developed for a number of strategy options to enable further evaluation. The costed options are outlined below:

- **Business as Usual (BAU) Scenarios** – the current practice at FNDC's WWTPs. This comprises of the "Current BAU" scenario and "Future BAU scenario" as detailed following;
  - ***Current BAU*** – The current practice utilising Kaitaia WWTP and Kaikohe WWTPs as "Centralised" treatment ponds for the WAS from Hihi, Russell, and Kaerikeri WWTPs. Contractor dredging and dewatering will be employed for removal of sludge from the ponds, with the dewatered sludge disposed of to landfill This practice is unlikely to continue into the future as the Kaitaia and Kaikohe WWTP consents are approaching expiry and expected to be upgraded into Mechanical WWTPs in the near term (assumed to be ASPs in this study)
  - ***Future BAU*** – Conversion of the existing oxidation ponds at Kaitaia and Kaikohe WWTPs into sludge ponds to treat the transferred WAS from Hihi, Russell, and Kerikeri. Contractor dredging and dewatering will be employed for sludge removal from the ponds, which will then be disposed of to landfills.

- **Decentralised Strategy Option** – Providing each individual WWTP with their own respective sludge treatment, dewatering, and disposal options. The decentralised strategy option comprises of the following components;
  - Common Decentralised Strategy for Small ASP WWTPs (Hihi, Russell, Kerikeri).
  - Common Decentralised Strategy for Large WWTPs (Kaitaia, Kaikohe).
  - Common Strategy for Small Pond WWTPs – identical for centralised and decentralised strategy (All remaining FNDC WWTPs).

- **Centralised Strategy Option** – Providing one or two centralised sludge processing facilities to treat sludge from the Small ASP WWTPs and Large WWTPs (likely to be converted to ASP WWTPs). The decentralised strategy option comprises of the following components;
  - Common Centralised Strategy for all ASP WWTPs (Hihi, Russell, Kerikeri, Kaitaia, Kaikohe).
  - Common Strategy for Small Pond WWTPs – identical for centralised and decentralised strategies (All remaining FNDC WWTPs).

Table 27 below presents a summary table with the strategy components and corresponding capital, O&M, and Net Present Costs. Where various sub-options exist within each option (e.g. multiple disposal options, multiple dewatering options), the sub-option with the lowest NPC was selected to form the overall strategy option. The components of the sludge strategies, along with their respective costs, are summarized below.

Table 27: Summary – Strategy Components and Associated Costs

Component	BAU – Current	BAU – Future	Decentralised	Centralised
Small Pond WWTPs	■ No treatment ■ Third party dewatering ■ Landfill	■ As BAU Current	■ No treatment ■ Mobile Dredge + Geobags ■ Mine/Quarry Rehabilitation	■ No treatment ■ Mobile Dredge + Geobags ■ Mine/Quarry Rehabilitation
Small ASP WWTPs	■ ASP Transfers	■ As BAU Current	■ No treatment ■ Mobile Dewatering ■ Vermicomposting	■ ASP Transfers
Large WWTPs (Kaitaia/Kaikohe)	■ No treatment ■ Third party dewatering ■ Landfill	■ ASP, with Centralised Sludge Ponds ■ Third party dewatering ■ Landfill	■ Local Sludge Ponds ■ Mobile Dredge & Geobags ■ Mine/Quarry Rehabilitation	■ Centralised Sludge Ponds ■ Mobile Dredge & Geobags ■ Mine/Quarry Rehabilitation
Capital Cost ($)	$13,800	$2,215,400	$3,417,100	$2,908,400
O&M Cost ($ p.a.)	$1,027,800	$1,038,900	$506,400	$448,600
NPC ($M)	**$11.80**	**$14.13**	**$9.22**	**$8.05**

Sensitivity analysis have also been completed to assess the impacts of changing key unit rates considered critical, and with high risk of changing in the near future, on the preferred sludge strategy. The sensitivity analysis considered the following scenarios.

- Changes in sludge haulage costs (increase and decrease).
- Changes in Vermicomposting fees.
- Changes in FNDC variables, both within and outside of FNDC's control (labour, polymer, maintenance)
- Changes in civil works and land purchase costs.
- Changes in FNDC maintenance costs.

The strategy cost evaluation, along with the sensitivity analysis, has identified the Centralised sludge option as the preferred option, with the lowest net present cost (NPC).The sensitivity analysis suggests that the Centralised option is clearly preferred from a cost perspective, and is considerably robust. Nonetheless, the sensitivity analysis identified that the preferred dewatering sub-option can change depending on several input factors, including the cost of civil works and land purchase. More detailed assessments should be undertaken by FNDC to ascertain the preferred dewatering option for implementation in the sludge strategy, as it lies outside the scope of this assessment.

A QBL analysis was done to select the preferred sludge strategy option, incorporating both cost and non-cost considerations. Sensitivity was also done on the QBL for the different weightings assigned to both the cost and non-cost criteria. The QBL analysis identified the Centralised sludge strategy as the preferred strategy option for various assigned weighting combinations, provided the cost criteria has a weighting of greater than 30%. At weightings of less than 30% for the cost criteria (and more than 70% for the non-cost criteria), the preferred sludge strategy option was found to shift to the Decentralised option, which is the option with the highest non-cost score.

FNDC are seeking a biosolids strategy that is cost effective with minimal risk; hence, reducing the cost weighting below 50% will unlikely be accepted by the wider stakeholders. Consequently, it can be concluded that the Centralised sludge strategy is the preferred biosolid management strategy which should be implemented by FNDC.

The preferred Centralised sludge strategy comprises of the following components:

- Continuing the existing WAS transfers from Hihi to Kaitaia, and Russell & Kerikeri to Kaikohe for treatment.
- Conversion of the existing Kaitaia WWTP and Kaikohe WWTP treatment ponds (Pond No. 1) into sludge ponds for treatment of the transferred ASP WAS.
- Purchase of two (2) mobile dredges for removal of sludge from FNDC's Ponds.
- Purchase of geobags (quantity and size as required) or mobile dewatering systems for dewatering of the sludge dredged from all FNDC's ponds (preferred dewatering method to be selected in subsequent stages of evaluation).
- Beneficially reusing the produced sludge for Mine/Quarry Rehabilitation (further studies required to verify viability of this end use).

4.2 Recommendations

The following next steps should be completed by FNDC to better refine and optimise the overall Centralised sludge strategy:

- The Kaitaia WWTP and Kaikohe WWTPs are the two largest WWTPs included in this assessment, which have consents nearing expiry. Upgrades to these plants are expected to occur within the next 3-6 years, and consequently the sludge strategy has incorporated the expected sludge production from the upgraded Kaitaia WWTP and Kaikohe WWTP given the 20 year planning horizon of this study. At the time of this study no process information regarding the proposed modifications to Kaitaia and Kaikohe WWTP's was available to use as the basis of this assessment. In the absence of this information, and to enable this investigation to proceed, we have assumed that the Kaitaia and Kaikohe WWTPs will be upgraded to mechanical plants (most likely ASPs), in line with the recent WWTP upgrades in the Far North District. This may not be accurate, and consequently, the results of this assessment should be considered with this in mind. Should the results of subsequent investigations by FNDC show that the Kaitaia and Kaikohe WWTPs will be upgraded to ASPs, we recommend that FNDC take immediate steps to adopt the Centralised sludge strategy for implementation.
- The preferred dewatering system for Pond WWTPs was found to shift between Geobags and a Mobile Dewatering system when land purchase costs and civil works costs were increased. Consequently, given the scope and limits of accuracy of this study, we consider it prudent that FNDC undertake a more detailed assessment to identify the most cost-effective dewatering system for implementation using actual cost data available to FNDC along with land availability data and purchase costs. Conceptual level design would also enhance the process and increase costing accuracy.
- The preferred market for the produced solids was identified to be Mine/Quarry Rehabilitation, which was scored highly due to the high availability of mines and quarries for rehabilitation in the Far North Region as identified by FNDC information. However, we have not undertaken any market assessment and have not had any contact with the mines or quarries in this region to confirm the feasibility of this option. FNDC should therefore start to undertake discussion with the mines and quarries within the region to confirm the expected costs and feasibility of pursuing this option for sludge reuse.

4.3 Summary

As outlined previously, the centralised sludge strategy has been identified as the preferred biosolids management strategy for the WWTPs owned and operated by FNDC. Table 28 below outlines the proposed implementation plan for the Centralised sludge strategy, ranging from immediate short term actions, to longer term action items which will depend on the final process selected for the Kaitaia WWTP and Kaikohe WWTP impending upgrades.

Table 28: Recommended Implementation Plan – FNDC Sludge Strategy

No.	Action Item	Timing of Works	Priority
1	Continue WAS transfers from Russell and Kerikeri (to Kaikohe WWTP) and Hihi WWTP (to Kaitaia WWTP), whilst awaiting the results of the selected process upgrade for Kaitaia WWTP and Kaikohe WWTP.	Short Term (1-3 years)	High
2	Commission market assessment studies and commence discussions with quarries and mine sites to confirm the suitability and viability of using FNDC's pond sludge for rehabilitation of quarries and mines in the Far North District, and identify preferred disposal sites	Short Term (1-3 years)	High
3	Purchase two (2) mobile dredges for removal of sludge from FNDC's ponds in the near term, in the following order of priority: ■ Kaitaia. ■ Kaikohe. ■ Rawene. ■ Kohukohu. ■ Kawakawa. ■ Kaeo.	Short-Medium Term (1-5 years)	High
4	Purchase short term dewatering solution for Kaitaia WWTP and/or Kaikohe WWTP pond sludges (Geobags), whilst undertaking more detailed options assessment to select the most cost effective dewatering option for pond WWTP sludges (mobile dewatering vs Geobags)	Short Term (1-3 years)	High
5	Purchase most cost effective dewatering option for pond WWTP sludges based on options assessment outcomes, for dewatering of subsequent pond sludges	Medium Term (3-5 years)	Medium
6	Conversion of the existing Kaitaia WWTP and Kaikohe WWTP ponds into centralised sludge treatment ponds, following the Kaitaia and Kaikohe WWTP plant upgrades, if found to be appropriate.	Long Term (>5 years)	Medium-Low

Appendix A

Stage 1 Report

Appendix B

Gaps and Assumptions in Stage 1 Assessment

Design Horizon	20 years	As per project brief
Population Growth Rate	0.5% p.a.	FNDC Social and Economic Profile
Summer population factor	10%	To be applied to all residential EP connections as provided by FNDC, and to the tankered septage population contribution calculation Figure of 10% provided by FNDC, to reflect the population increase over the summer period averaged across the entire year
Sludge Production Rates: ■ Activated Sludge Plants ■ Moving Bed Bioreactor (MBBR) ■ Pond based plants	45 gDS/EP/d, or as calculated based on available process information 15.6 gDS/EP/d Varies – calculated based on Conhur sludge survey reports & design assumptions	Typical for ASP Based on 0.12 gDS/gCOD (typical) Will be checked against typical literature values for pond based plants
Sludge Production Rates for Pond Based Plants Design Assumptions:	Up to 60% Volatile Solids Destruction at the end of each year for both anaerobic and Maturation Ponds	Limited available literature on pond sludge breakdown rates, and no site-specific sludge data available. Assumption adopted to enable estimation from first principles and produces “optimistic” sludge capacity predictions. Results of the capacity and risk analysis should be interpreted with this in mind.
Anaerobic Pond calculations	30% TSS capture 4.0%TS average concentration in sludge layer of Anaerobic Ponds Volumes as calculated from the works as executed (WAC) drawings and sludge survey information	Typical capture and solids concentration achievable in low technology primary sedimentation tank type structures such as Imhoff tanks
Dewatered sludge solids content	GDD-BFP dewatering of WAS = 18%DS	FNDC values. Typical range approx. 14-16%
Wastewater influent contributions	As per influent sampling data where available. The following contributions shall be applied for all remaining plants and is based on the Kerikeri catchment sampling results: ■ 56.5 gBOD/EP/d ■ 53.0 gTSS/EP/d ■ VSS/TSS of raw sludge = 85% ■ VSS/TSS of WAS = 75%	Site specific wastewater influent concentrations available for Ahipara, Kaitaia, Paihia, Kaikohe On the lower side of what is typical for New Zealand, but comparable to typical Australian contributions so still considered realistic and is based on actual sampling data.
Septage contributions	Assumes a total population contribution of 33,000EP (30,000EP plus the 10% summer population factor), with the population	

Design Horizon	20 years	As per project brief
	contribution proportional to the volume of septage tankered to site. Based on the following assumptions in determining the loads from septic tanks: ■ 5 years storage in septic tanks before delivery to WWTP ■ Population served per septic tank: - 2.53EP/tank ■ 56.5gBOD/EP/d 53gTSS/EP/d VSS/TSS of 85% Volatile solids destruction of 60% p.a. No population growth captured in septic tanks ■ Septage concentrations: - Average BOD concentration of 6,480mg/L - Average TSS concentration approx. 1.29%TS	Far North District average EP/ET, assuming 1 septic tank per property Adopts wastewater influent contributions for domestic catchments as calculated from the Kerikeri sampling results Average BOD and TSS of domestic septage as per US EPA design guide on domestic septage Table 11-1
Wastewater effluent concentrations	20 mg/L TSS	Adopted for conservativeness in estimating sludge production
Dimensions of ponds and structures	Conhur sludge survey drawings for Maturation Pond dimensions Sludge survey by Thomson and King for Anaerobic Pond dimensions at Kaikohe WAC drawings for Paihia and Rawene Anaerobic Ponds In absence of available information, as measured from Google Earth aerial projections and adopting nominal pond depth where pond depths are unknown	Adopted for assessment of pond capacities
Minimum mechanical equipment reliability	N + 0	As directed by FNDC
Operational cost items	Electricity: NZ$0.46/kWh Polymer: NZ$5/kg Sludge haulage costs: Landfill gate fees: NZ$115/ton Haulage fixed cost: NZ$15/ton Haulage variable cost: NZ$5/km travelled Haulage labour: NZ$160/hr Operator labour cost: NZ$60/hr	Typical operating and maintenance unit costs adopted for NZ projects
Net Present Cost Variables	Discount rate = 6% Total periods = 20 years	Public Sector Discount Rates for Cost Benefit Analysis, The Treasury, NZ Government, October 2016

Appendix C

Minutes of Technology Selection MCA Workshop (6th November 2017)

Appendix D

Sensitivity Analysis Results

Table 29: Sensitivity Analysis Results

Item	Current/ Base Case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Description	Current Rates / Base Case	Reduced haulage costs	Increased haulage costs	Increased Vermi-composting fees	Increased FNDC variables (labour, poly, maintenance)	Increased costs outside FNDC control	Reduced civil works & land purchase cost	Increased civil works & land purchase cost	Reduced FNDC variables (maintenance)
BAU Current	Current Practice	Current Practice	Current Practice	Current Practice	Current Practice	Current Practice	Current Practice	Current Practice	Current Practice
BAU Future	As per Current + Kaitaia/ Kaikohe converted into central sludge ponds	As per Current + Kaitaia/ Kaikohe converted into central sludge ponds	As per Current + Kaitaia/ Kaikohe converted into central sludge ponds	As per Current + Kaitaia/ Kaikohe converted into central sludge ponds	As per Current + Kaitaia/ Kaikohe converted into central sludge ponds	As per Current + Kaitaia/ Kaikohe converted into central sludge ponds	As per Current + Kaitaia/ Kaikohe converted into central sludge ponds	As per Current + Kaitaia/ Kaikohe converted into central sludge ponds	As per Current + Kaitaia/ Kaikohe converted into central sludge ponds
Decentralised	SMALL ASP - Mobile Dewatering + Vermi-composting	SMALL ASP - Mobile Dewatering + Vermi-composting	SMALL ASP - Mobile Dewatering + Vermi-composting	SMALL ASP - Mobile Dewatering + Vermi-composting	SMALL ASP - Mobile Dewatering + Vermi-composting	SMALL ASP - Mobile Dewatering + Vermi-composting	SMALL ASP - Mobile Dewatering + Vermi-composting	SMALL ASP - Mobile Dewatering + Vermi-composting	SMALL ASP - Mobile Dewatering + Vermi-composting
	LARGE WWTP - Local Sludge Pond + Mobile Dredging + Geobag + Mine/Quarry Rehab	LARGE WWTP - Local Sludge Pond + Mobile Dredging + Geobag + Mine/Quarry Rehab	LARGE WWTP - Local Sludge Pond + Mobile Dredging + Geobag + Mine/Quarry Rehab	LARGE WWTP - Local Sludge Pond + Mobile Dredging + Geobag + Mine/Quarry Rehab	LARGE WWTP - Local Sludge Pond + Mobile Dredging + Geobag + Mine/Quarry Rehab	LARGE WWTP - Local Sludge Pond + Mobile Dredging + Geobag + Mine/Quarry Rehab	LARGE WWTP - Local Sludge Pond + Mobile Dredging + Geobag + Mine/Quarry Rehab	LARGE WWTP - Local Sludge Pond + Mobile Dredging + Geobag + Mine/Quarry Rehab	LARGE WWTP - Local Sludge Pond + Mobile Dredging + Geobag + Mine/Quarry Rehab
	SMALL POND - Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Mobile Dewatering + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab

Item	Current/ Base Case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Centralised	SMALL ASP - Transfer to Kaitaia/Kaikohe	SMALL ASP - Transfer to Kaitaia/Kaikohe	SMALL ASP - Transfer to Kaitaia/Kaikohe	SMALL ASP - Transfer to Kaitaia/Kaikohe	SMALL ASP - Transfer to Kaitaia/Kaikohe	SMALL ASP - Transfer to Kaitaia/Kaikohe	SMALL ASP - Transfer to Kaitaia/Kaikohe	SMALL ASP - Transfer to Kaitaia/Kaikohe	SMALL ASP - Transfer to Kaitaia/Kaikohe
	LARGE WWTP - Mobile Dredging + Geobag + Sludge Ponds + Mine/Quarry Rehab	LARGE WWTP - Mobile Dredging + Geobag + Sludge Ponds + Mine/Quarry Rehab	LARGE WWTP - Mobile Dredging + Geobag + Sludge Ponds + Mine/Quarry Rehab	LARGE WWTP - Mobile Dredging + Geobag + Sludge Ponds + Mine/Quarry Rehab	LARGE WWTP - Mobile Dredging + Geobag + Sludge Ponds + Mine/Quarry Rehab	LARGE WWTP - Mobile Dredging + Geobag + Sludge Ponds + Mine/Quarry Rehab	LARGE WWTP - Mobile Dredging + Geobag + Sludge Ponds + Mine/Quarry Rehab	LARGE WWTP - Mobile Dredging + Geobag + Sludge Ponds + Mine/Quarry Rehab	LARGE WWTP - Mobile Dredging + Geobag + Sludge Ponds + Mine/Quarry Rehab
	SMALL POND - Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Mobile Dewatering + Mine/Quarry Rehab	SMALL POND -Mobile Dredging + Geobag + Mine/Quarry Rehab