CH2M Beca

www.ch2mbeca.com

Report

FNDC Sludge Strategy Options Review Report

Prepared for Far North District Council

Prepared by CH2M Beca Ltd

23 November 2017

Revision History

Revision Nº	Prepared By	Description	Date
A	Azaria Rahardjo, Gokul Bharambe	Draft Report – Gaps Analysis, Problem Definition and Option Identification	28/8/2017
B	Azaria Rahardjo	Draft Report – Updated with additional information provided by FNDC	18/10/2017
C	Kate Simmonds	Final Report – Incorporating FNDC Comments	23/11/2017

Document Acceptance

Action	Name	Signed	Date
Prepared by	Azaria Rahardjo / Gokul Bharambe / Kate Simmonds		23/11/17
Reviewed by	Humphrey Archer / Ron Haverland	Ron Haverland	23/11/17
Approved by	Rachael Shaw		23/11/17
on behalf of	CH2M Beca Ltd		

Executive Summary

Far North District Council (FNDC) is seeking an affordable and practical solution to the current backlog and future projection of sludge production across the district. FNDC have engaged CH2M Beca to develop a cohesive sludge management strategy for the seventeen (17) wastewater treatment plants (WWTPs) currently owned and operated by FNDC.

FNDC's plants are predominantly pond based, with only five (5) of its seventeen (17) WWTPs being activated sludge based plants. There has been little to no investment in its sludge management systems over the past 30 years, and a cohesive plan will be required to direct the district's sludge management for the next 20 years.

Due to the lack of a sludge management strategy, sludge management to date has largely been reactionary and typically comprises moving sludge between WWTPs to eliminate the requirement for sludge disposal. In the past, some ponds have been dewatered via geobags (i.e. Kawakawa Ponds) which have then been buried onsite.

FNDC have previously commissioned its own investigations into the sludge content of its pond based WWTPs, which provides valuable insight into their current operation and expected capacity. These studies, evaluated in conjunction with available WWTP information, have been used to obtain project understanding and direct the development of sludge treatment options.

The objective for this project is to determine a direction for the management of Biosolids from the Far North District WWTPs for the next 20 years. The focus is on identifying feasible sludge reuse and/or disposal options, and outlining the processes required to allow these disposal pathways to be implemented.

The FNDC Long Term Plan (LTP) should be considered in development of the study objectives. 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, the study objectives have preferential criteria for reuse options above straight disposal options, where practicable.

The sludge production rates and sludge storage capacities have been assessed for each of the WWTPs owned by FNDC. The WWTPs were prioritised for remedial works based on the sludge capacity assessments. The operating parameters of the ponds was also considered in conjunction with the sludge storage capacities in the prioritisation, as they have been widely documented to be closely linked. The prioritisation has incorporated a risk assessment based on the potential of consent non-compliance and includes the following considerations:

- Sludge storage capacities
- HRT Analysis
- BOD loading rates.

The results of the sludge storage capacity and risk assessments are summarised in the table below. WWTPs which have been identified as high priority (short term) WWTPs have been highlighted in red, and are listed in descending order of priority. The factors which contribute to the selection of these WWTPs as high priority WWTPs (i.e. where values exceed recommended design values) have also been highlighted in **bold red**.

WWTP	Total EP treated by WWTP – 2017 (EP)[1]	%age Septage (EP)	Total Sludge Production Rates[2] (gDS/EP/d)	Estimated Total Sludge Volumes Produced (m^3 p.a.)	Year Oxidation Pond Capacity is Reached[3]	Year Anaerobic Pond Capacity is Reached[3,4]	Current HRT (incl Sludge) as % of Design HRT	Current BOD Loading Rates in Oxidation Ponds (kgBOD/ha/d)	Priority
Kaitaia (incl Hihi)	16533	60%	14.1	1173	**2013**	-	**49%**	50	High
Kaikohe (incl Russell and Kerikeri)	27259	67%	15.3	2995	**2013**	**2014**	**71%**	68	High
Rawene	1014	36%	9.6	77	**2013**	2090	**75%**	59	High
Kohukohu	253	0%	10.9	13	**2016**	-	315%	**221**	High
Kawakawa - Actual	6268	72%	15.8	1206	**-**	**2015**	-	-	High
Kawakawa – Design	6268	0%	8.7	665	**-**	**2017**	-	-	-
Kaeo	616	0%	8.2	43	2019	-	89%	55	High
Ahipara	1320	0%	22.4	171	2023	-	**60%**	**171**	Med
Opononi	770	0%	8.9	34	2032	-	**39%**	**335**	Med
Paihia	4180	0%	40.5	1821	2027	2035	100%	**136**	Med
East Coast	2310	0%	9.6	164	2072	-	138%	**112**	Med
Rangiputa	83	0%	9.7	6	2035	-	122%	24	Low
Whatuwhiwhi	550	0%	15.6	61	2078	-	161%	53	Low
Hihi (see Kaitaia)	352	0%	45.0	365	-	-	-	-	-
Russell (see Kaikohe)	1980	0%	34.6	834	-	-	-	-	-
Kerikeri (see Kaikohe)	2332	0%	58.8	1669	-	-	-	-	-
TOTAL	**61155**	**54%**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

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.
3. Assessed using a "base" year of 2013, which is the time at which the Sludge Surveys were completed
4. Assessed assuming an initially empty pond in 2013, due to lack of available information on sludge content in the ponds.

Options for the biosolids end uses and treatment processes have been identified, with the options to be carried forward for development outlined below.

WWTP Type	Sludge Removal Option	Dewatering Option	Treatment Options	End Use	Option Number
	Sludge Rat	Sludge Box	Nil		1A

WWTP Type	Sludge Removal Option	Dewatering Option	Treatment Options	End Use	Option Number
Ponds and ASP WWTPs		Mechanical Dewatering		Mine/Quarry Rehabilitation	1B
		Sludge Box	Nil	Landfill Capping	2A
		Mechanical Dewatering			2B
		Sludge Box	Nil	Onsite Burial (Monofill)	3A
		Mechanical Dewatering			3B
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 Lagoons		4C
			Aerobic Digesters		4D
		Reed Beds	Nil		5A

The following recommendations will allow CH2M Beca to further refine this study:

- Limited process information is available for the Activated Sludge Plants (ASPs). Plant log sheets were missing valuable information such as sludge retention times (SRTs), Waste Activated Sludge (WAS) loads, Mixed Liquor Suspended Solids (MLSS) concentrations, Return Activated Sludge (RAS) flowrates, and RAS concentrations. Consequently, assessment of the sludge production from the ASPs cannot be considered to have been done to a fine level of accuracy, and collation of additional process information such as those listed above will be beneficial to confirm the findings of this study.
- The WAS flowrates recorded in the plant log sheets for Kawakawa suggests that it is currently operating at 8 days SRT, which is substantially lower than the design SRT documented in the O&M manual of 20 days. However, the available plant log sheets were missing the MLSS information, which is a critical parameter which will provide insight as to the underlying reason behind the low operating SRT. As a conservative step, we have assumed that the plant is currently operating at its design operating MLSS of 4,000mg/L (i.e. assuming that the plant is currently overloaded). However, this may have led to an overestimate of the sludge production rates for Kawakawa. Further, operating the WWTP at an SRT significantly lower than its design SRT typically carries substantial process risk. For these reasons above, we recommend that further investigations be undertaken by FNDC to ascertain the reason behind the much reduced SRT currently adopted for Kawakawa. Our analysis suggests that returning Kawakawa to its original design intention has the potential to reduce the frequency of Anaerobic Pond desludging by up to 50% and reduce overall operational costs.
- There is limited available information on septage, apart from the total volumes going into the WWTP, and we have assumed that the septage comprises fully of domestic septic tank sludge. However, with the known high variability in typical septage concentrations, FNDC should undertake sampling of the incoming septage to validate the findings of this study, and confirm that the incoming septage is indeed of a domestic nature.

- In our assessments, where WWTPs are noted to have issues meeting its consent limits for ammonia, we consider that this is predominantly a wastewater treatment issue which cannot be solved by desludging of the ponds and improving the available HRT given the extremely low ammonia consent limits which require almost complete nitrification.
- We recommend that FNDC undertake additional effluent sampling and commission a separate study to examine the liquid treatment capacities of the pond WWTPs and determine the best way forward to address the compliance issues identified. There are many methods to enhance ammonia removal from pond systems. Some examples which could be considered, are listed below:
  - An emerging low-cost alternative process capable of achieving this level of wastewater treatment reliably is a CH2M proprietary, low cost, fill and drain wetland process which achieves reduction of Ammonia-N. This technology has been installed and operated successfully by CH2M for several overseas clients. It is soon to be trialled within NZ and CH2M Beca have completed the design of this system. CH2M Beca will also be overseeing the trial. If FNDC wishes, we can further discuss possible treatment options to achieve the effluent consent discharge limits, as part of a separate assignment.
  - Further to this, where rock bunds have to be installed for other reasons, pond effluent can be sprayed over the rocks to mimic a rock trickling filter which are reliable reducers of ammonia – first used for this purpose in the UK about 1880. CH2M Beca has done this at Motueka (late 2016) and so far, the complete ammonia reduction has occurred in summer and autumn.
  - Bioshells or Biodomes. These are currently being installed by Clutha DC to existing ponds to enhance the overall total nitrogen removal.
- The sludge analysis study and risk assessment identified several issues with the current pond WWTPs. Several WWTPs were identified to have excessively high BOD loads, which raise the risk of pond failure and long-term consent compliance issues. Consequently, we recommend that a separate study into the wastewater treatment process of the following WWTPs should be done as a matter of urgency, due to the excessive BOD loads identified, to minimise further breaches of consent conditions in the short term:

1. Opononi WWTP
    a. Kohukohu WWTP
    b. Ahipara WWTP
    c. Paihia WWTP
    d. East Coast WWTP

- In the absence of available information, the development of biosolids end use options had assumed that the biosolids from FNDC's WWTPs are capable of meeting Grade b contamination limits. However, it should be noted that this is a key assumption which may render several of the end use options unviable if this requirement is not met. We therefore recommend that FNDC undertake a sampling campaign as follows:
  - Collection of composite samples across several locations at each pond WWTP to verify the following:
    - That the contamination levels in the pond sludge will meet stabilisation Grade b limits; and
    - That the adopted sludge decomposition rate (i.e. 60% in the first year and 100% thereafter) is a reasonable assumption to adopt.
  - Collection of composite influent samples across all its WWTPs to ascertain the following information:
    - Verification of the influent loads to each catchment
    - Verification of the sludge production rates for each catchment.

Contents

Appendices

Acronyms and Abbreviations

ASP	Activated Sludge Plant
BFP	Belt Filter Press
BOD	Biological Oxygen Demand
CBA	Cost Benefit Analysis
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DS	Dried Solids
EP	Equivalent Population
FNDC	Far North District Council
GDD	Gravity Drainage Deck
HRT	Hydraulic Retention Time
LTP	Long Term Plan
MAD	Mesophilic Anaerobic Digestion
MBBR	Moving Bed Bioreactor
MCA	Multi-Criteria Analysis
MLSS	Mixed Liquor Suspended Solids
PFD	Process Flow Diagram
QBL	Quadruple Bottom Line
RAS	Return Activated Sludge
RFI	Request for Information
SCD	Suction Cutter Dredge
SBR	Sequencing Batch Reactor
SRT	Sludge Retention Time
SS	Suspended Solids
TPAD	Temperature Phased Anaerobic Digestion
TS	Total Solids
TSS	Total Suspended Solids
VSS	Volatile Suspended Solids
WAC	Works as Executed
WAS	Waste Activated Sludge
WWTP	Wastewater Treatment Plant

1 Introduction

1.1 Background

Far North District Council (FNDC) is seeking an affordable and practical solution to the current backlog and future projection of sludge production across the district. FNDC have engaged CH2M Beca to develop a cohesive sludge management strategy for the seventeen (17) wastewater treatment plants (WWTPs) currently owned and operated by FNDC.

FNDC's plants are predominantly pond based, with only five (5) of its seventeen (17) WWTPs being activated sludge based plants. There has been little to no investment in its sludge management systems over the past 30 years, and a cohesive plan will be required to direct the district's sludge management for the next 20 years.

Due to the lack of a sludge management strategy, sludge management to date has largely been reactionary and typically comprises moving sludge between WWTPs to eliminate the requirement for sludge disposal. In the past, some ponds have been dewatered via geobags (i.e. Kawakawa Ponds) which have then been buried onsite.

FNDC have previously commissioned its own investigations into the sludge content of its pond based WWTPs, which provides valuable insight into their current operation and expected capacity. These studies, evaluated in conjunction with available WWTP information, have been used to obtain project understanding and direct the development of sludge treatment options.

The WWTPs being considered in this study, the treatment process, and current sludge management strategies (if any) are summarised in Table 1. This table also outlines proposed (or possible) future upgrades to these plants.

1.2 Sludge Definition

Sewage sludge refers to the residual, semi-solid material that is produced as a by-product during sewage treatment of industrial or municipal wastewater. The term septage also refers to sludge from wastewater treatment but is linked to simple on-site sanitation systems, such as septic tanks.

When fresh sewage or wastewater enters a primary settling tank or pond, suspended solid matter will settle out in the bottom of the tank. This collection of solids is known as raw sludge or primary solids and is said to be "fresh" before anaerobic (without oxygen) processes become active. Sludge can then be digested in anaerobic ponds or tanks where it is decomposed by anaerobic bacteria, resulting in liquefaction and a reduced volume of sludge. After digesting for an extended period, the result is called "digested" sludge and may be disposed of by dewatering and then landfilling, burying in geobags, or beneficially reused following further treatment (which is becoming more common as landfill space becomes scarce, and sustainability drivers become prevalent).

The NZWWA Guidelines for the Safe Application of Biosolids to Land in New Zealand (2003) describes Biosolids as a term often used in conjunction with reuse of sewage sludge after sewage sludge treatment. Biosolids are sewage sludges or sewage sludges mixed with other materials that have been treated and/or stabilised to the extent that they are able to be safely and beneficially applied to land. Biosolids have significant fertilising and soil conditioning properties as a result of the nutrients and organic materials they contain. The term 'biosolids' does not therefore include untreated raw sewage sludges or sludges solely from industrial processes. Neither does it include animal manures, or food processing nor abattoir wastes.

1.3 Study Objective

The objective for this project is to determine a direction for the management of Biosolids from the Far North District WWTPs for the next 20 years. The focus is on identifying feasible sludge reuse and/or disposal options, and outlining the processes required to allow these disposal pathways to be implemented.

The FNDC Long Term Plan (LTP) should be considered in development of the study objectives. 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, the study objectives have preferential criteria for reuse options above straight disposal options, where practicable.

Table 1: 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, therefore upgrade to Mechanical Plant (Activated Sludge Plant) is likely as consent conditions will become more stringent.
Rawene	Anaerobic Ponds + Maturation	2023	N/A
Paihia	Anaerobic Ponds + Maturation	2034	N/A
Kaikohe	Anaerobic Pond + Maturation	2021	Plant is due to expire in near term – upgrade to Mechanical Plant (Activated Sludge Plant) potentially required
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 at old quarry site (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

WWTP	Current Process	Consent due to Expire	Proposed / Possible Future Process
Whangaroa	Holding tank only	N/A	N/A – holding tank only. Waste from tanks is tankered to Kaeo

1.4 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)
   a. Information collation and review, identification of gaps, and agreement on assumptions to allow project progression (Complete)
   b. Calculation of sludge volumes and sludge generation assessment (Complete)
   c. Updated sludge volume estimates (Complete)
   d. Provision of standard rates for options development (Complete)
   e. Options Identification (Complete)
   f. Risk Assessment (Complete)
   g. Ranking of Plants in order of priority (Complete)

Stage 2 (to be completed):

1. Multi Criteria Analysis of Options (MCA) including consultation with stakeholders
   a. Analysis of Centralised vs De-centralised options
   b. Costing of feasible options
   c. Economies of scale for centralised or shared sludge management facilities
   d. Quadruple Bottom Line (QBL) Assessment

Stage 3 (to be completed):

1. Final Recommendations and Reporting.

1.5 Purpose of Report

The purpose of this report is to summarise the outcomes of Stage 1, including the following:

1. Information review and gap identification
   a. Assumptions
   b. Quantify the volume of Biosolids to be disposed of including the design basis for progressing options
   c. Disposal Options
   d. Treatment Options
   e. High level assessment of identified options
   f. Risks and Prioritisation of WWTP Sites.

2 Information Review

2.1 Summary of Information Reviewed

Following the project kick off meeting, and receipt of the information requested via formal Request for Information (RFI) CH2M Beca reviewed the available existing information and material supplied by FNDC staff.

A summary of the information received from FNDC as of 03 October 2017, any information gaps, the criticality in addressing these gaps, and our proposed path forward in the absence of the requested information is included in Appendix A.

It should be noted that in addition to the 17 WWTPs highlighted in the proposal documents, Houhora WWTP was mentioned in the Kick-off Meeting on 20th July 2017, which would bring the total number of WWTPs for evaluation to eighteen (18) which is more than the agreed number of seventeen (17) plants in the project brief. In the absence of available information on Houhora WWTP, it has been assumed that this WWTP lies outside of the project scope and will not be included in the evaluation.

2.2 Gaps and Assumptions

A number of gaps were identified during the information review, which were subsequently closed out due to further information being supplied, or assumptions being agreed with FNDC. The key assumptions which have been carried through in the disposal options assessment work are outlined in Table 2.

Table 2: Adopted Assumptions for FNDC Sludge Study

Design Assumption	Value	Notes
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 lagoon sludge breakdown rates, and no site-specific sludge data available. Assumption adopted to enable

Design Assumption	Value	Notes
		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 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 in the vicinity of 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

Design Assumption	Value	Notes
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/load 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

2.3 FNDC Sludge Disposal Routes (Current and Past)

2.3.1 Sludge Storage Ponds

Uncovered Anaerobic Ponds followed by Maturation Ponds are the main treatment process at several of FNDC's WWTPs, namely at Rawene WWTP, Paihia WWTP, and Kaikohe WWTP. This process utilizes ponds which are unaerated and open to atmosphere where the solids from the wastewater influent settles and undergoes a decomposition process under anaerobic conditions. Treated wastewater then flows to the Maturation Ponds where carbonaceous material is removed and some disinfection occurs via natural means by UV penetration from sunlight. The uncovered Anaerobic Ponds therefore effectively function in a similar nature to sludge ponds which receive primary sludge and can be considered sludge storage ponds.

Independent sludge studies conducted by Conhur and Transfield Services Corporation (TSC) in 2013 and 2012 respectively have concurred that the Anaerobic Ponds at Rawene WWTP, Paihia WWTP, and Kaikohe WWTP are well approaching the trigger rate for sludge removal, which they identified as 20% full.

FNDC's current practice is to remove sludge from the full ponds and transfer the wet sludge into other ponds in FNDC's operational area. However, this is both costly and not sustainable in the long term as in several cases, this transfer of sludge between plants has led to compliance issues at the receiving WWTPs, with exceedances of discharge consent conditions sometimes being attributed to this additional sludge transferred. A more targeted approach is required for FNDC's WWTPs to ensure that the sludge management practices are sustainable in the long term, and do not pose a risk to compliance with discharge consent conditions.

2.3.2 Geo-textile Bags (Geobags)

Geo-textile bags are bags constructed of special membrane material which affords separation of the solids from the liquids phase by percolation of the liquids through the membrane. Geobags are a relatively low technology option which is well known to FNDC and has been employed for dewatering of the sludge removed from FNDC's WWTP sludge ponds (i.e. at Kawakawa). 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. Most of FNDC's WWTP do not have sufficient spare land available on which such systems can be constructed, and consequently alternative disposal methods with smaller land requirements are being sought.

2.4 Previous Studies

FNDC has commissioned two studies into sludge treatment and disposal options, one in 2010 and another in 2012. The studies and their findings are summarised below.

2.4.1 FNDC Council Sludge Disposal Strategy (Doc No: A1096848, July 2011)

FNDC commissioned a study into the preferred strategy for the removal and treatment of sludge from their pond based WWTPs in July 2011. The key findings of this study were:

- FNDC's pond based WWTPs have mostly never been desludged (as of July 2011)
  - The maximum recommended percentage of sludge accumulation in pond based WWTPs was identified to be 20%, with any volumes exceeding that expected to significantly affect resource consent limits. Many of FNDC's ponds have either exceeded the recommended limit, or were close to exceeding the maximum volume at the time of the report.
  - Sludge from "Mechanical Treatment Plants" (i.e. Activated Sludge Plants) is transported to the pond based WWTPs for sludge treatment and disposal.
- Options for long term sludge management were identified and shortlisted as follows:
  - Sludge Removal
    - The "Sludge Rat", which is a fully containerised portable submersible pump system, was identified as the preferred sludge removal mechanism.
  - Sludge Dewatering[1]
    - **"Sludge Box"** - The Sludge Box is a fully covered container mounted on the back of a trailer, fitted with adequate supports to enable separation of solids by gravity settling. The report quotes that the Sludge Box can achieve dried solids concentration in the range of 12-20%. The Sludge Box also serves a second function of being able to be directly used for transportation of the dewatered sludge to the treatment and/or disposal facility. This option has been identified as the preferred sludge dewatering option as it has low operating costs and no moving parts.
    - **Reed Beds** - At several WWTPs, such as Kaikohe WWTP, purpose built reed beds have been identified as a potential combined dewatering and treatment option, where sludge pumped from the ponds can be left to drain and undergo anaerobic decomposition on site. This option was considered viable for further investigations.
    - **Geobags** - Geotextile membrane bags have been used in the past to dewatered sludge at FNDC's WWTPs, but require availability of land as the bags are typically buried on site for conditioning. Geobags are prone to rupture when lifted or moved, making it rather impractical when onsite

[1] Drying applies to >40%DS as achieved by sludge drying beds in lower rainfall climates e.g. Victoria and thermal drying plants which produce pellets >90%DS, e.g. at Christchurch. The terminology has been changed to conform with industry standard practice.

disposal of the dewatered sludge is not a viable option. Due to the limitations on available land at most WWTPs, this option was considered unsuitable.

- **Mechanical thickening and dewatering options** – This option encompasses thickeners; e.g. Rotating Drum Thickeners (RDTs), Rotating Screw Thickeners (RSTs), and Gravity Drainage Decks (GDDs) and dewatering methods such as centrifuges. These options were discounted due to the scale of their operations, difficulty in transportation, and their high operational and maintenance cost.

– Sludge Treatment and/or Disposal
  - **"Centralised" sludge disposal facilities** -
    "Centralised" facilities adopting Reed Beds identified at:
    - Northern – Kaitaia WWTP Reed Beds
    - Eastern – East Coast (Taipa) WWTP Reed Beds
    - Western – Kaikohe WWTP Reed Beds

    Reed bed cells of approximately 20m x 30m and 1.0m deep will be constructed adjacent to the WWTP ponds such that liquor from the sludge can be returned to the WWTP for treatment.
    The reed bed cells are expected to be filled over a number of years and the final product will then be removed from the beds for final conditioning by potentially mixing the sludge with green waste and windrowing it with tiger worms to produce high quality humus.
    Land will need to be purchased at Kaitaia WWTP, although sufficient land should be available at East Coast WWTP and Kaikohe WWTP.
  - **Landfill** - The closest landfill locations to FNDC's plants are at Whangarei or Auckland. The landfill site at Whangarei will be closing in the near future, making the potential transport costs to Auckland (which is a considerable distance away), potentially prohibitive. This option is not considered sustainable in the long term. CH2M Beca note that there is also a landfill in Ahipara which is due for closure in the very short term (<3years).

– Recommendations:
  - The report recommended the strategy of removing, dewatering and treatment of the sludge as follows:
    - Adopting "Sludge Rat" and "Sludge Box" for de-sludging and drying of sludge, at a cost of NZ$750,000 excl GST (July 2011);
    - Adopting a centralised sludge treatment facility at Kaitaia, Kaikohe, and East Coast WWTP utilising Reed Beds, at an estimated cost of NZ$900,000 for Kaitaia (July 2011), No cost estimates are available for East Coast WWTP or Kaikohe WWTP;
    - Final processing into humus at the treatment facilities prior to beneficial reuse.

2.4.2 FNDC District Sludge Management Options (Transfield Services, May 2012)

FNDC commissioned Transfield Services to investigate options for removal and disposal of sludge from FNDC's pond based WWTPs in May 2012.

The key findings of the investigation are summarized as follows:

- The assumptions adopted for the investigation were:
  – FNDC commits to the purchase of a mobile sludge removal system (Sludge Rat) and a mobile on-site dewatering system (Sludge Box) for rotating use at its numerous pond based WWTPs
  – FNDC commits to the development of a Reed Bed dewatering system at Kaitaia WWTP as originally presented in the investigation in July 2011.
  – That similar Reed Bed dewatering systems will be designed and constructed at the identified centralised locations, i.e. East Coast WWTP, Kaikohe WWTP, and Paihia WWTP.
- Sludge Treatment and/or Disposal
  – **"Centralised" sludge disposal facilities** -

"Centralised" facilities adopting Reed Beds identified at:
  - Northern – Kaitaia WWTP Reed Beds
  - North East – East Coast (Taipa) WWTP Reed Beds;
  - Eastern – Paihia WWTP Reed Beds
  - Southern – Kaikohe WWTP Reed Beds and
  - Western – Rawene WWTP.
- Proposed Desludging and Dewatering Process:
  - Sludge is proposed to be removed from the ponds by using a Sludge Rat
  - Sludge removed from the ponds to be dewatered using the Sludge Box process coupled with a polymer dosing system. The Sludge Box is a closed container with filtration screens along the sides and centre which retain the flocculated sludge and allows the water to drain freely via internal drains and out of the Sludge Box through discharge valves. A door is fitted at the rear of the container, controlled by a hydraulically assisted mechanism through which the dewatered sludge is emptied from.
  - The Sludge Box is noted to be able to hold 20 tonnes total weight, with an empty box weight of 5 tonnes gross.
  - Dewatered sludge from the Sludge Boxes would be disposed both onsite and offsite. Identified locations are as follows:
    - Onsite sludge disposal:
      - East Coast
      - Kaikohe
      - Kaitaia
      - Paihia
      - Rangiputa
    - Offsite sludge disposal (proposed disposal sites in brackets):
      - Ahipara (Kaitaia)
      - Kaeo (Kaikohe or East Coast)
      - Kohukohu (Kaikohe)
      - Opononi (Kaikohe)
      - Rawene (Kaikohe)
  - The proposed process is as follows:
    - The Sludge Rat will be used to remove sludge from the bottom of the pond, and will fill the Sludge Box within 10-15 minutes.
    - The Sludge Box will then be left to observe how well the sludge dewaters over 24-72 hours. The report notes that they expect that the sludge would dewater down to approximately 15%DS and generate approximately 7-8 tons of dewatered sludge.
    - The report recommends that operators start with a small volume of sludge when first setting up on site to determine the sludge dewaterability. This will then provide input into the most suitable procedure within the first 3-4 fills to best suit the specific sludge characteristics and truck sizes.
- Specific plant information was also provided for each WWTP.

3 Sludge Capacity and Risk Assessments

To enable prioritisation of the seventeen (17) WWTPs, a capacity assessment of the sludge related process units was completed for the seventeen (17) WWTPs. It should be noted that Matauri Bay WWTP and Whangaroa WWTP have been 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 Section 2.2 and Table 2 have been used as a basis to assess the available capacity of the sludge related process units. The adopted methodology and results of the sludge capacity assessment, along with our recommended prioritisation strategy are outlined below.

3.1 Categorising WWTPs

The FNDC's WWTPs largely falls under two (2) distinct categories which will require different methods of assessing the remaining capacities of its sludge related process units. The two categories are pond WWTPs, and activated sludge WWTPs.

3.1.1 Pond WWTPs

Pond WWTPs (which includes WWTPs utilising aerated ponds, oxidation/facultative ponds, and Anaerobic Ponds followed by Maturation Ponds), comprise the following:

1. Ahipara WWTP (aerated ponds)
    a. East Coast / Taipa WWTP (aerated ponds)
    b. Kaeo WWTP (Oxidation Pond)
    c. Kaikohe WWTP
    d. Kaitaia WWTP
    e. Kohukohu WWTP
    f. Opononi WWTP (aerated ponds)
    g. Paihia WWTP
    h. Rangiputa WWTP
    i. Rawene WWTP.

For the purposes of this assessment all pond WWTPs are considered a similar process irrespective of the nature of their treatment (aerobic, anaerobic or facultative/Oxidation Ponds) due to the following:

- The WWTPs designated as "aerated pond" systems appear to have undersized aerators, to provide complete mixing of the entire pond contents including the sludge blanket layer. The sludge in the "aerated pond" system is therefore expected to behave like sludge in an oxidation/facultative pond.
- The Anaerobic Ponds have been included in the capacity assessment and have been assumed to behave in a similar manner to a low technology primary sedimentation tank (PST) such as an Imhoff tank. It has been assumed that the sludge layer at the bottom of the Anaerobic Pond will undergo anaerobic degradation in a similar manner to the sludge in Maturation Ponds under the water cap.
- The sludge production and capacity estimates for the Anaerobic Ponds have been done separately to the Oxidation Ponds, as the Anaerobic Ponds are substantially smaller than the Oxidation Ponds and will have a very different sludge storage capacity to the Oxidation Ponds. The total sludge production from the pond based WWTP which utilises Oxidation Ponds and Anaerobic Ponds will therefore adopt the sum of the two numbers as they are cumulative.

3.1.2 Activated Sludge WWTPs (ASP WWTPs)

Activated sludge plants (commonly referred to as “Mechanical Plants” by FNDC) comprise the following:

1. Hihi WWTP
    a. Kawakawa WWTP
    b. Kerikeri WWTP
    c. Russell WWTP
    d. Whatuwhiwhi WWTP (Ponds retrofitted with Aquamats, which approximates a Moving Bed Bioreactor or MBBR process).

FNDC’s Activated Sludge Plants (ASPs) do not currently have any sludge treatment or dewatering facilities, except for Kawakawa WWTP, which has two on-site sludge ponds. The current sludge treatment and disposal methods for the ASP WWTPs are:

- Hihi WWTP – on average 1m^3/d of sludge is trucked to Kaitaia WWTP. The plant log sheet provided by Broadspectrum for Hihi does not note the location or the concentration of the WAS. The TSS and VSS content of the Hihi sludge was therefore calculated from first principles
- Kerikeri WWTP and Russell WWTP – sludge is trucked to Kaikohe WWTP, with known sludge volumes and concentrations.
- Whatuwhiwhi WWTP – sludge accumulates at the bottom of the ponds which are then de-sludged as required, in a similar manner to the pond WWTPs.
- Kawakawa WWTP – sludge is stored and treated at on-site sludge ponds. The design capacity of the sludge ponds has been estimated based on the known WAS flowrates in the plant log sheets provided by Broadspectrum. This information was compared against the operations and maintenance manual (O&M) for Kawakawa WWTP, which indicates that the onsite sludge ponds are designed to be emptied every 3-5 years.

As the sludge from most ASPs is trucked to a pond WWTP for treatment, we have included the sludge contribution from the ASP WWTPs using the total transferred TSS and EP contribution, to the sludge production numbers for the receiving pond WWTP. Available ASP sludge production estimates have also been verified based on first principles and are documented in Section 3.2.3.2.

The sludge capacity assessment for Whatuwhiwhi WWTP have been incorporated into the pond based sludge assessments documented in Section 3.2.3.3.

3.2 Sludge Capacity Assessments and Prioritisation

3.2.1 Methodology

Sludge capacity assessments were completed for the Anaerobic Ponds, and Oxidation Ponds, along with the Whatuwhiwhi WWTP. Where appropriate the pond WWTPs include the sludge contribution of the ASP WWTPs which are transferred to the relevant pond WWTP, as well as contributions from septic tanks (which is almost half of the EP for the region).

The following methodology was adopted in estimating the solids contribution rates from the tankered septage to the WWTPs, in the absence of septage quality and loads information:

1. The sludge production rate per EP (i.e. gDS/EP/d) and septage sludge solids composition fed to the WWTPs (%ISS) from septage was estimated based on first principles, adopting the assumptions outlined in Table 2 for septage, and assuming that septic tanks are emptied every 5 years as per FNDC’s guidelines.

   a. The total serviced EP in septage was obtained based on FNDC's direction, and applying the summer population factor. The annual solids contribution from each septage delivery was then determined for each WWTP which receives septage. Septage is generally assumed to be discharged to Anaerobic Ponds where available, to reduce the risk of process upsets and consent breaches due to shock loads caused by the septage deliveries.

The following methodology was adopted in estimating the sludge production rates for ASP based WWTPs:

1. The sludge production rate per EP (i.e. gDS/EP/d) was estimated based on first principles, adopting the assumptions outlined in Table 2 and Appendix A, and tankage information. Where WWTPs receive septage (i.e. Kawakawa WWTP), the combined population contribution was adopted.
   a. Bioreactor tankage information was obtained from available works as executed (WAC) drawings, and where the information appears suspect, it was checked against aerial measurements taken from Google Earth.
   b. Plant log sheets (where available) were used to ascertain the total sludge production rates (WAS volumes and WAS concentrations). This is particularly true for Russell and Kerikeri which have documented volumes and concentrations of the transferred WAS. Where plant log sheets were not provided, the required information to derive the total WAS production rates (Hihi and Kawakawa), the total solids wastage was derived from process information gleaned from the available process flow diagrams, and from first principles, adopting the assumptions outlined in Table 2, and Appendix A.
   c. The annual sludge production rate for each WWTP was calculated from the sludge production rate per EP for each WWTP and the known population serviced by each WWTP.

The following methodology was adopted in assessing the sludge production estimates and sludge storage capacities for pond WWTPs:

1. The sludge production rate per EP (i.e. gDS/EP/d) was estimated based on first principles, adopting the assumptions outlined in Table 2, and the sludge information outlined in the Conhur reports. Where WWTPs receive sludge from other WWTPs or septage, the combined population contribution was adopted, or the known tankered solids content (total TSS and total VSS) where data is available.
   a. The annual sludge production rate for each WWTP was calculated from the sludge production rate per EP for each WWTP and the known population serviced by each WWTP.
   b. The maximum sludge storage capacity for the ponds was calculated based on a minimum 1.0 m water cover over sludge, assuming a minimum sludge blanket depth of 0.30m, and adopting the average solids concentration in the sludge layer as documented in the Conhur reports. The 1.0 m water cover over the sludge blanket is the widely accepted minimum water level required to achieve adequate liquid/solids separation and minimise odours. When the accumulated sludge level in the pond rises and water cover above the sludge layer is less than 1.0 m depth, solids carryover into the discharge effluent is expected, which has the potential for consent breaches. The minimum sludge blanket depth applied was assumed to apply to ponds with depths in the range of 0.8-1.2m, as some ponds assessed were found to be very shallow.
   c. The pond sludge storage capacities were compared against the calculated annual sludge production rate, resulting in an estimated number of years for sludge storage within the ponds before they reach capacity, as defined by Point 3 above.

The following methodology was adopted in assessing the Anaerobic Pond capacities for WWTPs which utilise them (Rawene, Paihia, Kaikohe, and Kawakawa), and is largely similar to the pond WWTP assessment outlined above:

1. The sludge production rate per EP (i.e. gDS/EP/d) was estimated based on first principles, adopting the assumptions outlined in Table 2, and assuming an empty pond in the absence of available information on sludge depths.

2. Where the PFDs show that the WWTP receive sludge from other WWTPs, the combined population contribution was adopted, or the known tankered solids content (total TSS and total VSS) where data is available. For Kawakawa WWTP, the location of the septage discharge point at the WWTP is not shown on the PFD, and it has been assumed that the septage tankers discharge directly to the Anaerobic Ponds and bypasses the main activated sludge plant. This discharge location was selected as it appears to be the most likely discharge point to prevent process upsets of the secondary treatment plant and potential consent breaches.
   a. The annual sludge production rate for each Anaerobic Pond was calculated from the sludge production rate per EP for the Anaerobic Pond and the known population serviced by the WWTP.
   b. The maximum sludge storage capacity for the Anaerobic Ponds was calculated based on the available works as executed (WAC) drawings and adopting the assumptions as outlined in Table 2.
   c. The calculated Anaerobic Pond sludge storage capacities were compared against the calculated annual sludge production rate, resulting in an estimated number of years where sludge can be stored within the Anaerobic Ponds before they reach capacity.

3.2.2 Population

Table 3 below presents a summary of the population contributions adopted in this sludge study to estimate the total sludge production and WWTP capacities. The WWTPs where the produced sludge is transferred to other WWTPs for treatment (Hihi, Russell, and Kerikeri) have been highlighted in blue, and their sludge contributions will be accounted for in the respective WWTPs which receive the tankered WAS sludge.

A 10% summer population factor have been applied to all the population figures (base and septage) provided by FNDC, to account for the temporary increase in population in the region over summer. No population growth has been accounted for in Table 3 below.

Table 3: Population Contributions Adopted in Sludge Study

WWTP	Base Connected EP in 2017– includes Summer Contribution (EP)	Transferred WAS EP in 2017– includes summer contribution (EP)	Septate EP in 2017 – includes Summer Contribution (EP)	Total EP treated by WWTP in 2017 – includes Summer Contribution (EP)
Opononi	770	0	0	770
Ahipara	1320	0	0	1320
East Coast	2310	0	0	2310
Rangiputa	83	0	0	83
Kohukohu	253	0	0	253
Kaeo	616	0	0	616
Kaitaia (incl Hihi)	6292	352	9889	16533
Rawene	649	0	365	1014
Paihia	4180	0	0	4180
Kaikohe (incl Russell and Kerikeri)	4708	4312	18239	27259
Whatuwhiwhi	550	0	0	550
Kawakawa	1760	0	4508	6268
Hihi	352	to Kaitaia	0	352
Russell	1980	to Kaikohe	0	1980
Kerikeri	2332	to Kaikohe	0	2332

WWTP	Base Connected EP in 2017– includes Summer Contribution (EP)	Transferred WAS EP in 2017– includes summer contribution (EP)	Septate EP in 2017 – includes Summer Contribution (EP)	Total EP treated by WWTP in 2017 – includes Summer Contribution (EP)
Total	**28155**	**4664**	**33000**	**61155**

3.2.3 Sludge Production Estimates

3.2.3.1 Septage Sludge Solids Estimates

Table 4 below presents a summary of the estimated total solids contribution from the septage to the WWTPs. In the absence of available information, it has been assumed that the tankered septage to site consists solely of domestic septic tank sludges which are emptied every 5 years as per the general guidelines on septic tank management in the region. The estimated septage solids contributions were then incorporated into the total solids content entering the WWTP, at the selected septage discharge point.

Table 4: Septic Sludge Solids Estimates

WWTP	Septage EP in 2017 - incl Summer (EP)	Septage Volumes (m^3 p.a.)	Septage TSS (kg/d)	Septage VSS (kg/d)	Septage TSS Contribution (gDS/EP/d)	Assumed Septage Discharge Point
Kaitaia	9889	3580	137	59	13.9	Oxidation Pond
Rawene	365	132	5	2	13.9	Anaerobic Pond
Kaikohe	18239	6603	253	108	13.9	Anaerobic Pond
Kawakawa	4508	1632	63	27	13.9	Anaerobic Pond
Total	**33000**	**11947**	**459**	**196**	**-**	**-**

3.2.3.2 ASP WWTP Sludge Production

The estimated sludge production for each of the ASP WWTPs, as well as the estimated sludge generation rate per unit population for those respective WWTPs, is shown in Table 5 and graphically in Figure 1 below.

The following should be noted:

- The plant log sheets provided by Broadspectrum for Russell and Kerikeri WWTP are incomplete and do not note any volumes or concentrations of the WAS. We have therefore adopted the known WAS transfer volumes and concentrations in the assessment, and utilised these values to back-calculate the expected sludge production rate of the WWTP. The overall sludge production of Russell and Kerikeri was then incorporated into the sludge production rates of the receiving WWTP, Kaikohe WWTP.
- The plant log sheets provided by Broadspectrum for Hihi WWTP does not note the location or the concentration of the WAS. The TSS and VSS content of the Hihi sludge was therefore calculated from first principles and incorporated into the sludge production rates of the receiving WWTP, Kaitaia WWTP. The following assumptions were adopted in the assessment:
  - Nominal operating SRT in the range of 15-20 days, which is typical for SBR type plants (as suggested by the WAC drawings)
  - Typical RAS flow pace rates for activated sludge plants of 15%-50% of the influent flow
  - 15% VS destruction is achieved over the 20 days SRT in the bioreactor

  - Assumed MLSS concentration of 2,500mg/L. We have assumed that the 250mg/L noted in the log sheet was a typographic error as the assessment indicates an extremely high SRT with extremely low solids concentrations which is very unlikely.
- The plant log sheets provided by Broadspectrum for Kawakawa WWTP suggests that it is currently operating at a much lower SRT than design (operating at 8 days vs design of 20 days). Due to the large discrepancy between the sludge production rates under design operation and current operation, both values (design and current operation) are presented below.
  - It should be noted that the plant log sheets do not have any record of the operating MLSS concentrations, and consequently it is not possible to ascertain the reason for the much reduced operating SRT.
  - In the absence of available information, the sludge production estimates presented below has assumed that the Kawakawa WWTP is currently operating at its design MLSS concentration of 4,000mg/L. This approach is on the conservative side, and has the potential to overestimate the volumes of produced sludge and reduce the potential capacity of the sludge ponds.
  - Further investigations should be undertaken by FNDC to ascertain the reason behind the much reduced SRT at Kawakawa. Our analysis suggests that returning Kawakawa to its original design intention has the potential to reduce the frequency of Anaerobic Pond desludging, and reduce overall operational costs.

Table 5: ASP Sludge Production Estimates

WWTP	Total EP to WWTP – Includes Summer & Septage (EP)	Adopted Sludge Production – Main Process (gDS/EP/d)	Adopted Sludge Production – Total (gDS/EP/d)	Estimated Sludge Production Rates (m^3 p.a.)	Transfield Estimated Sludge Production Rates (m^3 p.a.)
Whatuwhiwhi	550	15.6	15.6	61	70
Kawakawa – Design	6268	39.6	8.7#	665	Not provided
Kawakawa – Actual	6268	98.5	15.8#	1206	Not provided
Hihi (to Kaitaia)	352	45.0	45.0	365	Not provided
Russell (to Kaikohe)	1980	34.6	34.6	834	Not provided
Kerikeri (to Kaikohe)	2332	58.8	58.8	1669	Not provided
Total	**11482**	**-**	**-**	**4800**	

Table Notes:

The adopted overall sludge production rates for Kawakawa is based on the Anaerobic Pond sludge production rate (refer Section 3.2.3.4.). WAS produced by the secondary plant will be degraded in the Anaerobic Ponds, resulting in an overall sludge production rate which is equal to the Anaerobic Pond sludge production rate.

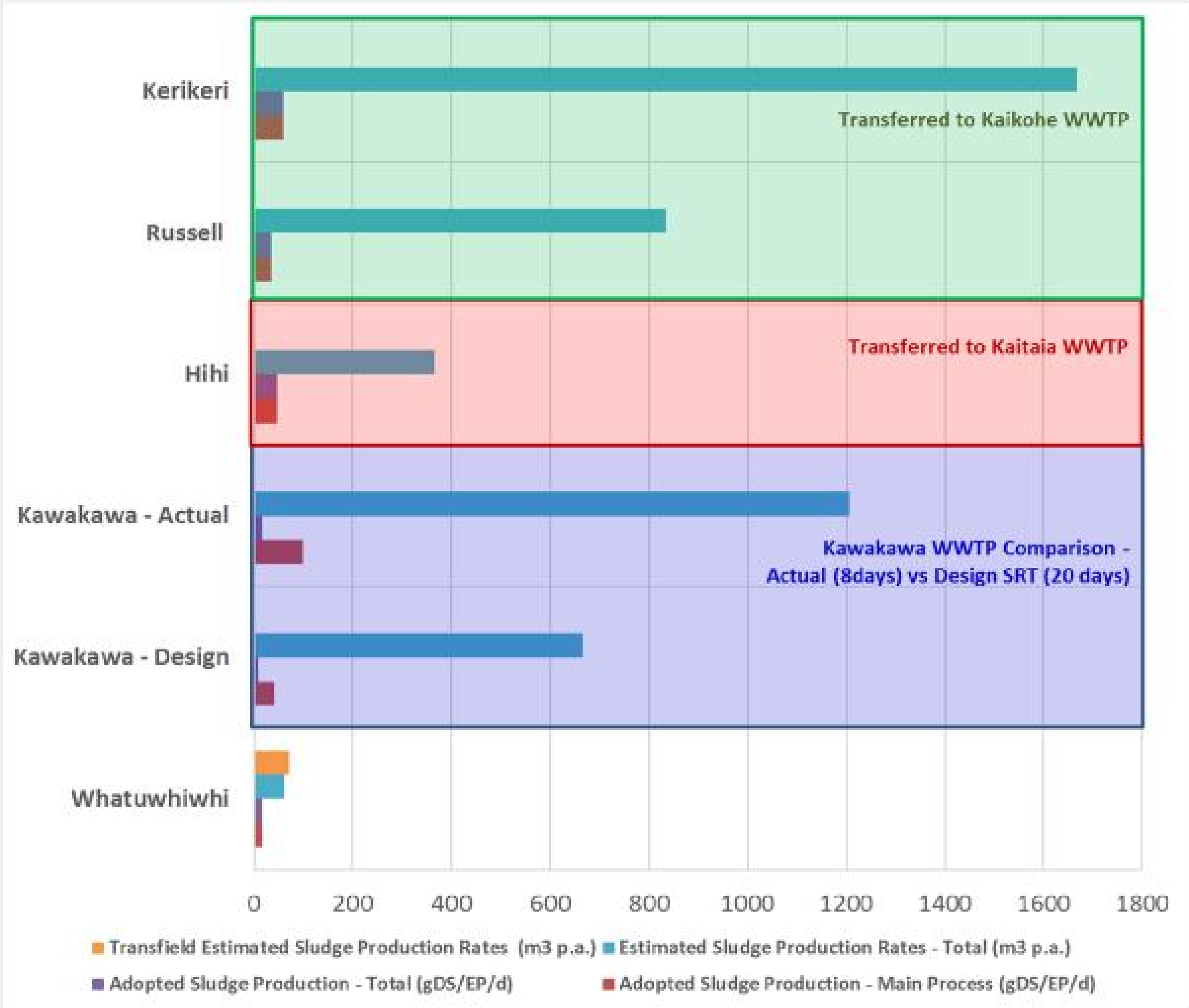

Figure 1: ASP WWTP Sludge Production Rates

From Table 5 and Figure 1, it is apparent that the sludge production rates from the ASP WWTPs are largely in line with expected literature values of 35-55gDS/EP/d, except for the Kawakawa WWTP under the current operating SRT. This suggests that the adopted design MLSS for this assessment is potentially an overestimate of the actual sludge generation from the WWTP, and a sludge production value between the two numbers presented (design and actual) is expected in the field. It should be noted that given the current practice of delivering trucked WAS from most ASP plants to the pond based plants, the above sludge production numbers from the ASPs were then incorporated into the pond WWTPs in assessing the pond capacities, presented in Section 3.2.2.5.

The main exception to this rule will be Kawakawa, which has two sludge storage ponds which effectively function as Anaerobic Ponds treating the WAS on site. The sludge production rates for the Anaerobic Ponds at Kawakawa will be presented in Section 3.2.2.4 along with the other Anaerobic Ponds assessed. The adopted overall sludge production rates for Kawakawa is based on the Anaerobic Pond sludge production rate as the produced WAS will be degraded in the Anaerobic Ponds, resulting in an overall sludge production rate equal to the Anaerobic Ponds.

The sludge production rate for Whatuwhiwhi of 15.6 gDS/EP/d is based on typical literature values for MBBR based plants. The sludge production rate for Kawakawa of 56 gDS/EP/d is based on the current operation which wastes on average 30m^3/d of WAS, which is then stabilised in Anaerobic Ponds on site, resulting in a much reduced operating SRT of 8 days when compared to the design SRT of 20 days.

3.2.3.3 Oxidation Ponds Sludge Production

The estimated sludge production volumes and sludge generation rates per unit population for each of the Oxidation Ponds which form the bulk of the treatment at the pond based WWTPs, are presented in Table 6 and graphically in Figure 2.

Table 6: Sludge Production Estimates – Oxidation Ponds

WWTP	Total EP Treated by Oxidation Ponds in 2017[1] (EP)	Adopted Sludge Production – Oxidation Pond (gDS/EP/d)	Estimated Sludge Production Rates – Oxidation Ponds (m^3 p.a.)	Transfield Estimated Sludge Production Rates - Oxidation Ponds (m^3 p.a.)
Opononi	770	8.9	34	118
Ahipara	1320	22.4	171	110
East Coast	2310	9.6	164	270
Rangiputa	83	9.7	6	13
Kohukohu	253	10.9	13	13
Kaeo	616	8.2	43	70
Kaitaia (incl Hihi)	16533	14.1	1173	1100
Rawene	1014	5.5	39	No Data
Paihia	4180	25.3	1242	1180
Kaikohe (incl Russell and Kerikeri)	27259	6.5	1163	1000
TOTAL	**54337**	**-**	**-**	**-**

Notes:

1. The total population number includes the summer population factor, and incorporates tankered septage and WAS contributions.

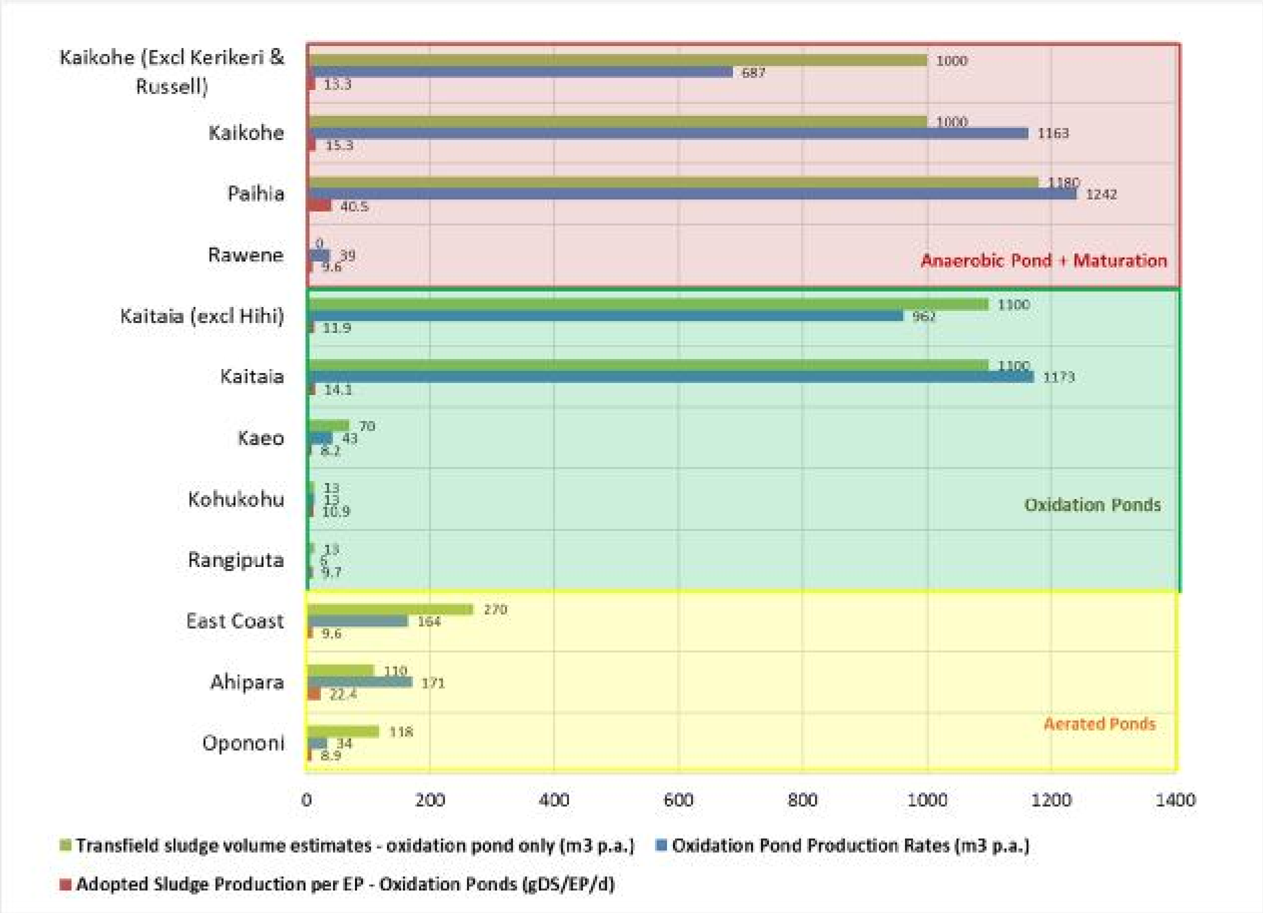

Figure 2: Sludge Production Estimates – Oxidation Ponds

From Table 6 and Figure 2, the estimated sludge production per EP for all the Oxidation Ponds are similar, ranging from a low of 8.2 gDS/EP/d to a high of 25.3 gDS/EP/d. This is consistent with those typically observed at similar pond based WWTPs in Australia, with typical sludge production being within the range of 12-27 gDS/EP/d. The main exception to this is Kaikohe WWTP, which is estimated to produce very low volumes of sludge per unit population, at 6.5gDS/EP/d. The low sludge production values for Kaikohe is likely attributed to the high septage contribution of the total EPs treated by the WWTP (approximately 67%, refer Table 3). The transferred septage at Kaikohe has been assumed to originate only from domestic septic tanks which are emptied every 5 years. Therefore, the sludge is well degraded, with very low solids contribution. Further, as the transferred septage is assumed to be deposited at the Anaerobic Ponds (as shown in the PFD), the total solids loads received by the Oxidation Ponds will be very low in proportion to the total equivalent population treated by the Oxidation Ponds.

The estimated sludge volume production numbers were also compared against the estimated Oxidation Pond sludge volume production numbers by Transfield in May 2012. Table 6 and Figure 2 show that the estimated sludge production figures are generally comparable to Transfield's estimates, except for Ahipara, Kaikohe, Kaeo, East Coast, and Opononi. The reasons behind the discrepancy cannot be ascertained as the Transfield report does not outline the methodology used to estimate the sludge production figures, and consequently cannot be verified. As we are unable to verify Transfield's sludge production figures, we have adopted the estimated sludge production rates and sludge volume estimates developed as part of this study.

3.2.3.4 Anaerobic Ponds Sludge Production

The sludge production volumes and sludge generation rate per unit population for the Anaerobic Ponds at the WWTPs are presented in Table 7**Error! Reference source not found.** and Figure 3 below and have been developed based on the assumptions adopted in Table 2. The estimated sludge production rates below will then be added to the Oxidation Pond sludge production rates, to result in an overall WWTP sludge production rate for the pond based WWTPs.

Table 7: Sludge Production Estimates – Anaerobic Ponds

WWTP	Total EP Treated by Anaerobic Ponds (EP)	Adopted Sludge Production Rates – Anaerobic Ponds (gDS/EP/d)	Estimated Sludge Production Rates (m^3 p.a.)
Rawene	1014	4.2	39
Paihia	4180	15.2	579
Kaikohe	22947	8.7	1831
Kawakawa - Design	6268	8.7	665
Kawakawa - Actual	6268	15.8	1206
TOTAL	**34408**	**-**	**-**

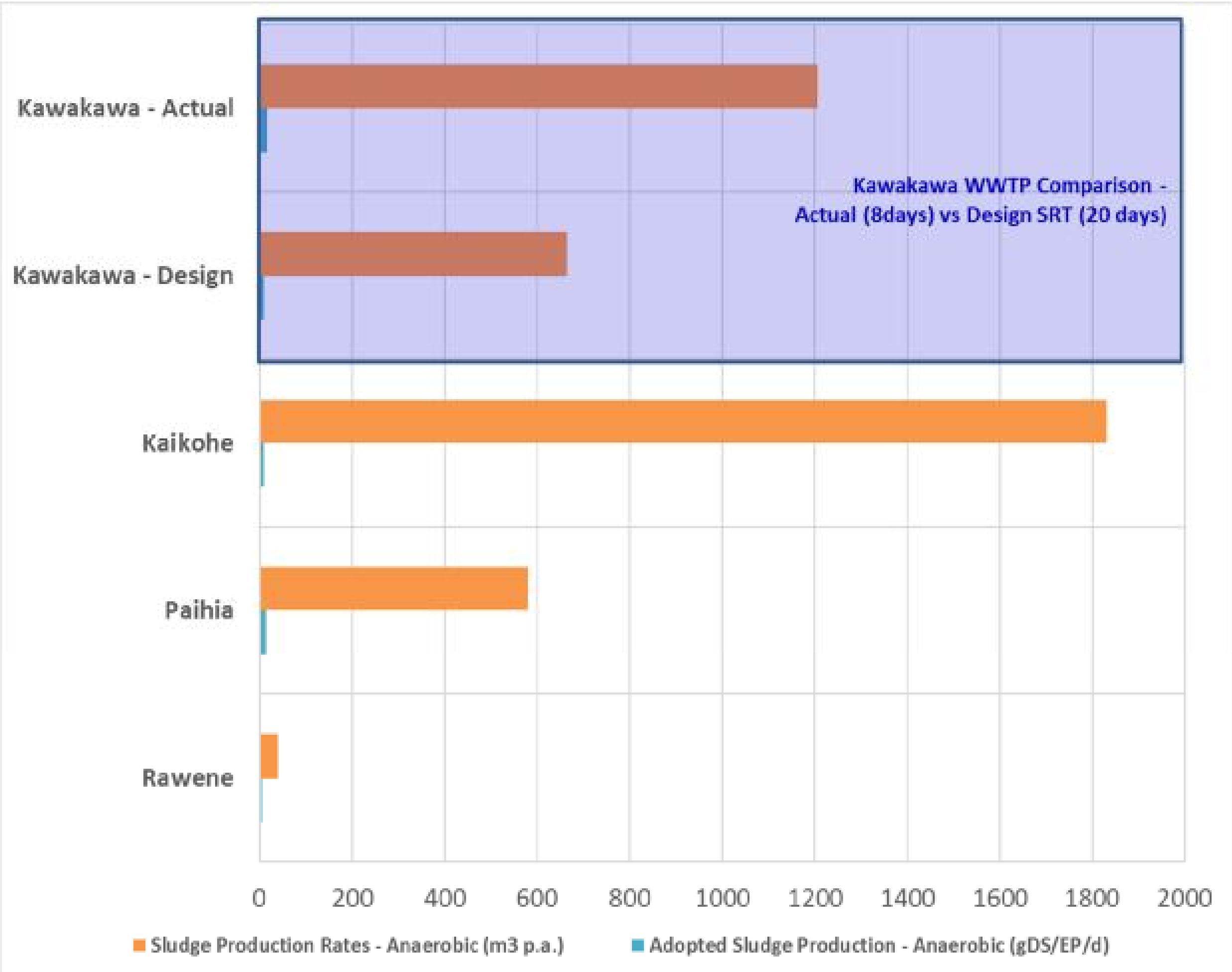

Figure 3: Sludge Production Estimates – Anaerobic Ponds

From Table 7**Error! Reference source not found.** and Figure 3, the estimated sludge production per EP for the Anaerobic Ponds are generally consistent with typical literature values which range between 8-

20gDS/EP/d. The main exception to this is for Rawene, which is on the low side of this range but still considered reasonable given the large size of the Anaerobic Pond. Due to the substantial Anaerobic Pond volume in comparison to the treated loads, the sludge at Rawene can undergo a higher level of degradation than that typically observed, due to the longer storage time possible. To provide some context, the Rawene ponds are approximately the same size as the Kaikohe ponds although Rawene treats approximately 4% of Kaikohe's loads.

The estimated sludge production rates for Kaikohe WWTP is very high, at more than 1800m^3 p.a., and is the highest of the Anaerobic Ponds. Nonetheless, despite the very large volumes of sludge estimated to be produced from Kaikohe, the per unit population sludge production rate is on the low end of typical literature values, at 8.7gDS/EP/d. Further investigations note that Kaikohe WWTP receives a large volume of septage, at approximately 18,250 EP, which appears to have caused the extremely high sludge production rate observed at Kaikohe, and is considered reasonable.

The above Anaerobic Pond sludge production values were therefore considered reasonable and will be adopted for the pond capacity estimates which will be developed as part of this study.

3.2.3.5 Summary – Total Sludge Production Rates

The estimated total sludge production volumes and sludge generation rates per unit population for each of the assessed WWTPs, are presented in Table 8 below. The below total sludge production rates have included the summer population factor, the population growth in the region, and transfer of sludge between the ASP and pond based WWTPs. The WWTPs highlighted in blue have been included in the pond based WWTPs as indicated.

Table 8: Sludge Production Estimates – Summary

WWTP	Total EP Treated by WWTP in 2017[1] (EP)	Estimated Sludge Production Per Unit Population– Anaerobic Ponds (gDS/EP/d)	Estimated Sludge Production Per Unit Population – Main Treatment Process (gDS/EP/d)	Estimated Total Sludge Production Per Unit Population (gDS/EP/d)	Estimated Total Sludge Production Volumes (m^3 p.a.)
Opononi	770	-	8.9	8.9	34
Ahipara	1320	-	22.4	22.4	171
East Coast	2310	-	9.6	9.6	164
Rangiputa	83	-	9.7	9.7	6
Kohukohu	253	-	10.9	10.9	13
Kaeo	616	-	8.2	8.2	43
Kaitaia (incl Hihi)	16533	-	14.1	14.1	1173
Rawene	1014	4.2	5.5	9.6	77
Paihia	4180	15.2	25.3	40.5	1821
Kaikohe (incl Russell and Kerikeri)	27259	8.7	6.5	15.3	2995
Whatuwhiwhi	550	-	15.6	15.6	61
Kawakawa - Design	6268	8.7	39.6	8.7	665
Kawakawa - Actual	6268	15.8	98.5	15.8	1206
Hihi (to Kaitaia)	352	-	45.0	45.0	365
Russell (to Kaikohe)	1980	-	34.6	34.6	834
Kerikeri (to Kaikohe)	2332	-	58.8	58.8	1669
TOTAL	**61155**	**-**	**-**	**-**	**-**

From Table 8 above, the total sludge production rates per unit population appears to be consistent with literature values, with the exception of Paihia WWTP. Further investigations note that Paihia WWTP has a very high influent TSS contribution, which is based on actual composite sampling data from the Haruru Major Pump Station. Consequently, the high sludge production rate for Paihia is likely attributed to the high quantities of trade waste received in the catchment.

3.2.4 Sludge Storage Capacity Estimates

The estimated remaining sludge storage capacities will be estimated separately for the Anaerobic Ponds and the Oxidation Ponds, given the different storage capacities available in the Anaerobic and Oxidation Ponds. It should be noted that the below assessments have included the sludge contribution from both septage and transferred WAS to the respective ponds, as well as incorporating the summer population factor and population growth rate in the region.

3.2.4.1 Oxidation Ponds Storage Capacity Estimates

The estimated remaining sludge storage capacities of the Oxidation Ponds, and estimated point at which the sludge storage capacities will be reached, are presented in Table 9 and shown graphically in Figure 4. The estimates for Whatuwhiwhi is also presented in the table below. The estimates for Kaitaia WWTP has included the contribution of Hihi WWTP, and the estimates for Kaikohe WWTP has included the contribution of Russell, and Kerikeri WWTPs.

WWTPs which have exceeded their current sludge storage capacity or will exceed its sludge storage capacity in the next 2 years are highlighted red. The median effluent TSS records over the last 3 years (2014 to 2017), where available, are also presented to provide some context as to the urgency of desludging the WWTPs which are expected to have exceeded its current sludge storage capacities.

It should be noted that the remaining sludge storage capacity estimates were calculated based on the pond dimensions and pond sludge content as documented by Conhur in 2013. Consequently, the year at which capacity is reached has been calculated using 2013 as the “base” year in the assessment. Where the year at which capacity is reached is prior to the current year (i.e. 2017), it means that the Oxidation Pond is already overloaded with sludge and requires urgent sludge management measures to be implemented.

Table 9: Sludge Storage Capacity Estimates – Oxidation Ponds

WWTP	Sludge Volume when Dewatering Required (m³)	Current Sludge Volume in Pond (m³)	Max Sludge Weight in Pond (tTSS)	Years of Sludge Storage Left from 2013 (years)	Year at which Capacity is Reached (calculated from 2013)	Measured Median Effluent TSS (mg/L)	Median Effluent TSS – Consent Limits (mg/L)
Opononi	2365	1805	172	19	2032	22	35
Ahipara	5217	3450	330	10	2023	41	-
East Coast	15734	5995	781	59	2072	No data	-
Rangiputa	555	440	29	22	2035	No data	-
Kohukohu	249	210	20	3	2016	15	-
Kaeo	2664	2420	115	6	2019	35	-
Kaitaia (incl Hihi)	43152	66730	3141	0	2013	115	-
Rawene	2506	3800	131	0	2013	No data	15
Paihia	31702	14150	986	14	2027	No data	60
Kaikohe (incl Russell and Kerikeri)	19789	26680	1108	0	2013	57	-
Whatuwhiwhi	5158	1130	264	65	2078	No data	30

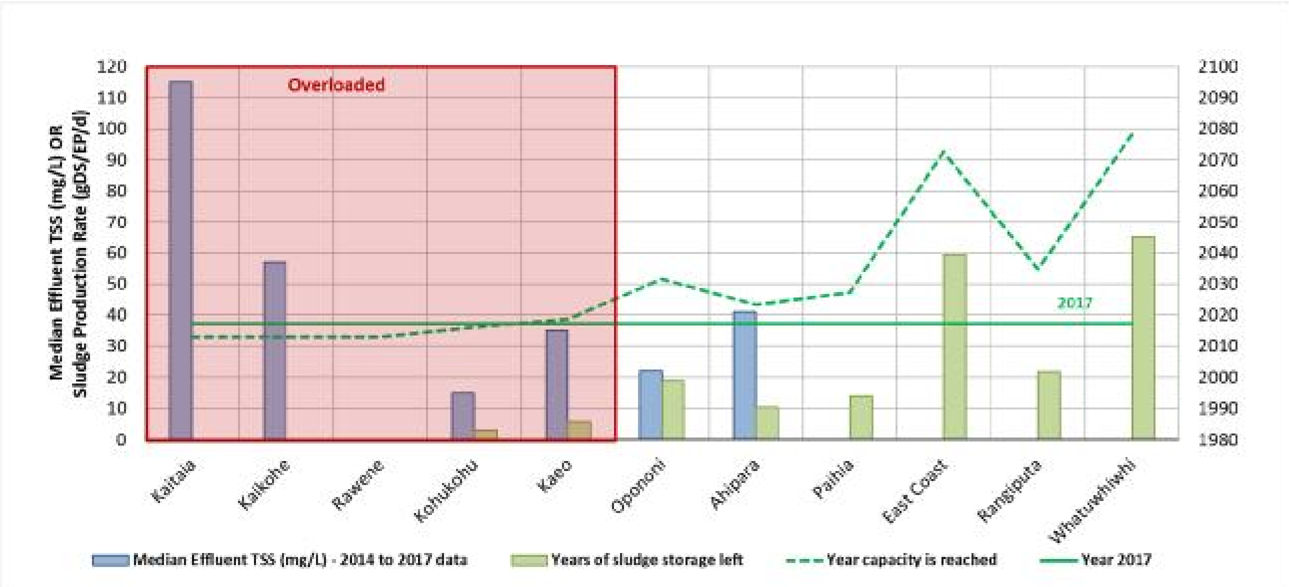

Figure 4: Sludge Storage Capacity Estimates and Prioritisation

From Figure 4, Kaitaia, Kaikohe, Rawene, Kohukohu and Kaeo WWTP appear to have reached their sludge storage capacities in the ponds at the time of the Conhur sludge survey in 2013, and are currently overloaded with sludge as of the time of this report in 2017. The above assessment largely agrees with Conhur's sludge studies which note that Kaitaia, Kaikohe, Rawene, Kohukohu and Kaeo WWTP are storing sludge >30% of its total pond storage volumes and require urgent desludging. The remaining ponds are estimated to have good sludge storage capacities of more than 10 years', except for Ahipara which will require desludging within the next 5 years.

The assessment of sludge storage capacities is supported by the available effluent TSS data. The available data as shown in Table 9 and Figure 4 shows that large quantities of solids are consistently being washed out of Kaitaia, Kaikohe, and to a lesser extent Kaeo and Ahipara WWTPs. We note that the high TSS observed at Ahipara WWTP is rather unusual, given that the assessment indicates that there should still be reasonable storage of sludge (approx. 5 years) available. This may be linked to the presence of Blue Green Algae at Ahipara as noted by FNDC at the kick-off meeting, which is typically linked to poor liquid treatment. This will be examined further in the risk assessment and prioritisation strategy outlined following.

3.2.4.2 Anaerobic Ponds Storage Capacity Estimates

There is no available information on the amount of sludge currently stored in any of the Anaerobic Ponds assessed as part of this study. Consequently, the below assessments will present a capacity estimate assuming an initially empty Anaerobic Pond, which will provide indicative desludging frequencies of the respective ponds.

The estimated capacity estimates are presented in Table 10 below. It should be noted that the estimated year at which the capacity is reached is based on a base year of 2013, to be consistent with the base year for the Oxidation Pond capacity estimates. It should also be noted that the Kaikohe WWTP Anaerobic Pond assessment only incorporates the septic tank contribution, but excludes the WAS transfer contributions, as the available information suggests that the WAS is transferred to the Oxidation Ponds at Kaikohe WWTP as opposed to the Anaerobic Ponds. Anaerobic Ponds with storage capacities less than 5 years are also highlighted in red, which indicates an urgent need to adopt a sludge management strategy for this Anaerobic Pond. Like the Oxidation Pond capacity assessment, where the year at which capacity is reached is less than the current year (i.e. 2017), it means that the Anaerobic Pond is already overloaded with sludge and requires urgent sludge management measures to be implemented.

Table 10: Sludge Storage Capacity Estimates – Anaerobic Ponds

WWTP	Treated EP in Anaerobic Ponds (EP)	Maximum Sludge Storage Volume in Pond (m^3)	Maximum Sludge Storage in Anaerobic Ponds (tTSS)	Years of Available Sludge Storage (years from 2013)	Year at which capacity is reached[1]
Rawene	1014	3000	120	77	2090
Paihia	4180	10710	514	22	2035
Kaikohe (includes Septage, no WAS)	22947	1831	73	1	2014
Kawakawa - Design	6268	2700	108	4-5	2017
Kawakawa - Actual	6268	2700	108	2-3	2015

Notes:
1. The estimated year at which the Anaerobic Pond capacity is reached was calculated using a “base” year of 2013, to be consistent with the base year for the Oxidation Pond capacity estimates.

From Table 10 above, it appears that the Anaerobic Ponds at Kaikohe and Kawakawa have relatively low sludge storage capacities when compared to Paihia and Rawene. The Anaerobic Ponds in Kaikohe only have sludge storage capacity of approximately 1 year, indicating that it will require yearly desludging. Given that the assessment has assumed a base year of 2013, this means that the Anaerobic Ponds at Kaikohe WWTP will have exceeded its available capacity, and requires urgent desludging. This may be attributed to the small volume of Anaerobic Pond active volume, and the relatively high loads treated by the Anaerobic Ponds at Kaikohe as evident from the high number of treated EPs.

The Anaerobic Ponds at Kawakawa under the current operating SRT will require desludging every 2-3 years, and is expected to have reached and exceeded its capacity at the time of this report in 2017. Optimisation of the process at Kawakawa to return its operation to the original design intent has the potential to almost double the storage capacity to 4-5 years, which has the potential to yield considerable cost savings for FNDC.

3.3 Risk Assessment and Prioritisation

Pond WWTPs are a cost-effective way of providing wastewater treatment which rely on a combination of hydraulic retention time (HRT), number of ponds in series, adequate temperature, and appropriate organic loading rate (BOD loading rate in kgBOD/ha/d) to achieve adequate nutrient removal and disinfection through the ponds. Consequently, in assessing the priorities of the pond WWTPs, all the above factors must be considered together to enable development of a holistic and cohesive prioritisation strategy which minimises the risk of consent non-compliance.

3.3.1 Risk Assessment – Consent Compliance

Where the kick-off meeting notes issues with consent compliance for several WWTPs, the nature of the compliance breaches were further investigated. FNDC's meeting minutes dated 27th April 2017 discussing Water and Wastewater Compliance to April 2017 (Doc No: A1850897) summarises the compliance issues at the WWTPs as follows:

1. Kaikohe WWTP – Ammonia and pH breaches (Median consent NH_4 limit = 2 mg/L)
    a. Kaeo WWTP – Bacteriophage breaches
    b. Paihia WWTP – Ammonia breaches (Median consent NH_4¬ limit = 2 mg/L)
    c. Ahipara WWTP – Faecal Coliform and volume breaches of leachate from Ahipara landfill.
    d. East Coast / Taipa WWTP – Ammonia breaches (Median NH_4 limit = 1 mg/L)

From the above, it is apparent that the consent breaches are predominantly related to:

- Incomplete Nitrification (Kaikohe, Paihia, and Taipa) – all with median ammonia consent limits of 1.0 - 2.0 mg/L
- Inadequate disinfection (Kaeo and Ahipara)
- Excessive overflow volumes (Kaitaia).

Each of the three license breaches noted above and their relation to sludge content in the WWTP ponds are outlined below, along with the reasons behind their inclusion or exclusion from the prioritisation strategy.

Breaches of Effluent Ammonia Levels (Consent Limits of 1.0-2.0 mg/L NH_3-N)

It is important to note the limitations of a pond WWTP in its ability to remove nutrients from the influent wastewater.

Facultative pond based WWTPs are known to have much higher variability in achieving ammonia and phosphorus removal from the wastewater influent when compared to ASP WWTPs. Considering that the typical ammonia content of New Zealand domestic wastewater is in the range of 12 gNH_3/EP/d, assuming approximately 100% of the typical TN contribution of 12 gN/EP/d for New Zealand domestic catchments comprises of Ammonia N corresponds to an average inlet Ammonia concentration of approximately 47 mg/L NH_3, when combined with the average flow contribution of 254 L/EP/d estimated for the FNDC region.

Literature suggests that only up to 90% ammonia removal (i.e. effluent Ammonia in the range of 5.0mg/L) can be expected with the right conditions during summer, which include but are not limited to: adequate HRT, elevated temperatures (above 15°C), adequate DO, ponds in series, and appropriate organic loading rates. This is further supported by CH2M Beca's experience with ponds in the Upper South Island and Lower North Island, which typically achieve Ammonia concentrations of <2mg/L in summer and autumn, but have minimal (or non-existent) nitrification in winter and spring. In our experience, ponds located further South in New Zealand were found to have no nitrification occurring at any time of the year, which suggests that elevated temperatures is a key factor to nitrification in ponds. The warmer conditions in Northland is therefore expected to lead to more complete nitrification across the ponds compared to that typically achieved at the Lower North Island, although the true nitrification rates achieved will be highly dependent on HRT and organic loading rates to the ponds, in addition to pond temperatures. Nonetheless, it should be noted that nitrification in ponds can also be upset by toxic compounds and solids washout during periods of wet weather

Evaluation of available recorded winter temperatures for FNDC's pond WWTPs note minimum temperatures much lower than 15^{o}C, which were linked to low DO within the discharged effluent. Consequently, this low effluent ammonia limit is not expected to be reliably met during Winter over the long term without additional modifications to supply of additional air (e.g. via mechanical aeration of the ponds) and additional surface area for biomass growth such as that adopted for high performance aerobic ponds (e.g. using proprietary systems including Aquamats or Biodomes).

Evaluating the consent limits for FNDC's pond based plants, it is apparent that the median ammonia consent limits for the WWTPs which have identified ammonia breaches as an ongoing issue (i.e. Kaikohe WWTP, Paihia WWTP, and East Coast/Taipa WWTP) are in the range of 1.0-2.0 mg/L. Based on the above analysis, FNDC's pond WWTPs can only be expected to reduce effluent Ammonia down to <2.0 mg/L under summer conditions with the right conditions such as having adequate HRTs and appropriate organic loading of the ponds. Achieving this level of nitrification on a consistent basis year-round will be difficult for pond WWTPs, particularly in winter, due to the high oxygen demand complete nitrification exerts.

Based on the above, where the WWTP is noted to have issues meeting its consent limits for Ammonia, we consider that this is predominantly a wastewater treatment issue which cannot be solved by simply desludging the ponds and improving the available HRT. Ammonia related consent breaches of this nature will not be evaluated further in this study.

We recommend that FNDC undertake additional effluent sampling and commission a separate study to examine the liquid treatment capacities of the pond WWTPs and determine the best way forward to address the compliance issues identified. On this note, an emerging low-cost alternative process which can achieve this level of wastewater treatment reliably is a proprietary CH2M fill and drain wetland process, currently being trialled at Wellsford WWTP (owned and operated by Watercare). If FNDC wishes, we can further discuss possible treatment options to achieve the effluent consent discharge limits, as part of a separate assignment.

Inadequate Disinfection

Disinfection at FNDC's WWTPs are achieved via dedicated mechanical ultraviolet (UV) disinfection systems (at Kawakawa WWTP, Whatuwhiwhi WWTP, and Kaeo WWTP), or using natural disinfection by sunlight irradiation as the effluent passes through the WWTP ponds.

- UV disinfection typically require a median effluent TSS below 20 mg/L to achieve the design pathogen log-reduction, as TSS concentrations above this limit will cause shielding of the pathogens and reduced disinfection efficacy.
  - Where sludge storage capacities have exceeded capacity, they will cause a reduction in HRT and potential washout of solids in the effluent, reducing the disinfection efficacy of mechanical UV systems, leading to potential consent breaches.
- Natural disinfection occurring within facultative ponds is a function of several factors which include but are not limited to: available HRT, pond depth, number of ponds in series, available oxygen, pond pH, and visible light penetration. Excessive sludge stored within the ponds is likely to reduce HRT substantially, leading to reduced disinfection capabilities.
- Provided that the pond is adequately loaded with BOD, increasing the available HRT will improve the amount of solids separation, improve effluent TSS, and improve both natural and mechanical UV

disinfection of the effluent. The prioritisation strategy will therefore examine HRT and BOD loading rates as contributing factors.

3.3.2 Prioritisation of WWTPs

Methodology

The prioritisation strategy has been developed considering the following factors:

- Remaining sludge storage capacities available, or conversely, the level of exceeded sludge storage
- The BOD loading rates, to determine the likelihood of achieving adequate liquid treatment upon sludge removal
- Hydraulic retention time (HRT), to determine the likelihood of achieving adequate liquid treatment, and adequate disinfection.

The prioritisation strategy will adopt the following approach:

1. Where the sludge capacity assessment has identified the WWTP as having exceeded its estimated capacity, the WWTPs are moved higher on the priority list. Where effluent TSS information is available, this information will be used to support the sludge capacity assessment, as solids washout from the ponds is expected if the sludge storage capacity has been dramatically exceeded.
    a. Pond WWTPs rely on a combination of hydraulic retention time (HRT) and appropriate organic loading rate (BOD loading rate in kgBOD/ha/d) to achieve adequate nutrient removal and disinfection through the pond treatment processes.
    b. BOD loading rates for each WWTP were estimated based on the adopted BOD contribution per unit population (and adjusted for WWTPs which receive sludge from neighbouring WWTPs), and the pond dimensions adopted for the capacity assessments. WWTPs with both excessive BOD loading rates and sludge accumulation issues were placed higher on the priority list. However, where WWTPs had excessive BOD loading rates but no sludge accumulation issues, these WWTPs were placed lower on the priority list as we consider this a liquid treatment stream process issue separate from the sludge accumulation issues identified.
    c. HRT for each WWTP was then estimated for the following:
    d. Design HRT (based on design flowrate and design pond volumes),
    e. Current HRT (based on current flowrates and current available pond volumes after accounting for sludge accumulation), and
    f. Estimated HRT (based on current flowrates and available pond volumes after desludging).

    Where the current HRT for the WWTP is much lower than the design HRT, these WWTPs were placed higher on the priority list. However, where the Current HRT is still well within range of the design HRT, these WWTPs were placed lower on the priority list as the accumulated sludge within the WWTPs is not expected to cause dramatic reduction in pond treatment performance.

WWTP Prioritisation

<u>Sludge Storage Capacities</u>

Figure 4 in Section 3.2.4 previous presents the sludge capacity estimates of the pond WWTPs and identifies the following plants as having the most sludge accumulation, in order from the WWTP with the largest amount of excess sludge:

- Kaitaia WWTP

- Kaikohe WWTP
- Rawene WWTP
- Kohukohu WWTP
- Kaeo WWTP.

The remaining WWTPs all appear to still have sufficient sludge storage capacities available for the short term, with only two WWTPs, Ahipara, and Opononi, expected to require desludging within the next 10 years. The Anaerobic Ponds at Kawakawa WWTP will require regular desludging every 2-3 years (based on current operating parameters), or once every 3-5 years (based on design operating parameters).

As also highlighted previously, Ahipara WWTP is noted to have high TSS values despite the sludge capacity assessment suggesting sufficient sludge storage capacity within the ponds, which will need to be further investigated. This could be attributed to Blue Green Algae caused by inadequate treatment, or the use of the “lagoon master” aerator which has the potential to maintain the solids in suspension and hence solids carryover into the effluent.

HRT Analysis

The HRT for each WWTP was calculated for the design condition (at the design flowrates and full pond volumes), the current HRT with sludge (at the current flowrates and pond volumes after accounting for sludge accumulation), and the current HRT with no sludge (at the current flowrates and pond volumes when there is no sludge accumulated). The results are shown in Table 11 and presented graphically in Figure 5. Where the current HRT (including the sludge accumulation) of the WWTP is much lower than the design HRT, these WWTPs have been highlighted in red.

Table 11: HRT Analysis

WWTP	Design HRT (days)	Current HRT (Excl Sludge) (days)	Current HRT (Incl Sludge) (days)	Current HRT (incl Sludge) as % of Design HRT (%)
Opononi	22	17	9	39%
Ahipara	43	36	26	60%
East Coast	30	54	42	138%
Rangiputa	53	89	64	122%
Kohukohu	5	24	17	315%
Kaeo	28	37	25	89%
Kaitaia	78	70	39	49%
Rawene	49	64	36	75%
Paihia	50	62	50	100%
Kaikohe	34	39	24	71%
Whatuwhiwhi	52	94	84	161%

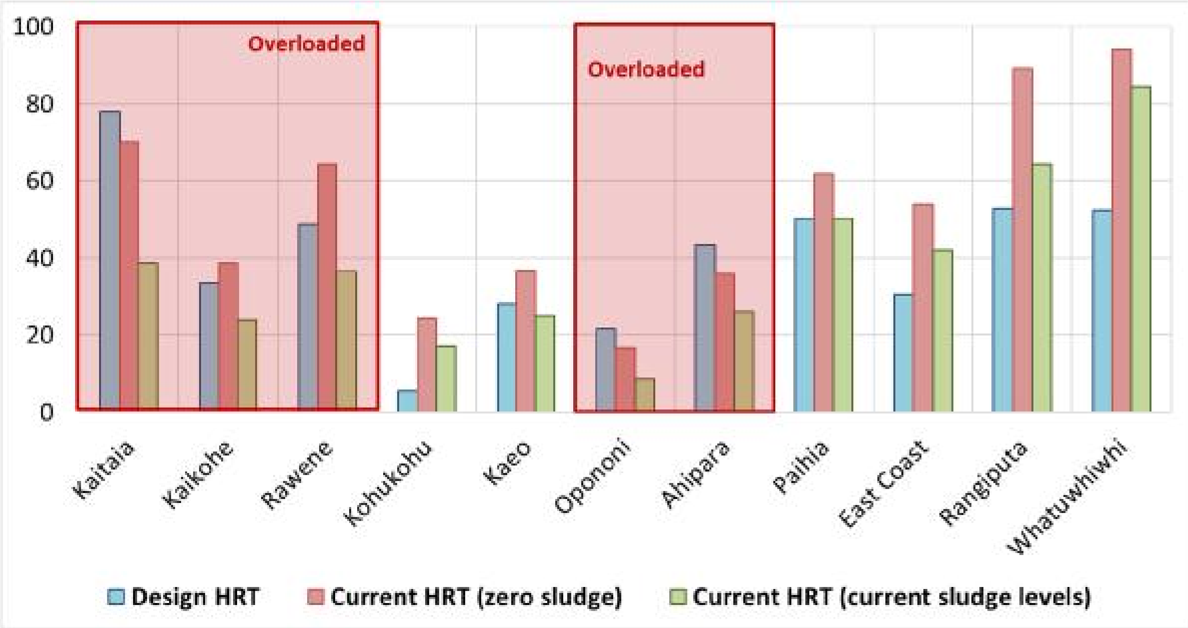

Figure 5: HRT Analysis of WWTPs

From Table 11 and Figure 5, five WWTPs are identified to have HRTs which are much lower than the design HRT due to sludge accumulation. The WWTPs are listed below in descending order of priority:

- Opononi WWTP
- Kaitaia WWTP
- Ahipara WWTP
- Kaikohe WWTP
- Rawene WWTP.

Of the above plants identified, Opononi WWTP and Ahipara WWTP were noted to still have adequate sludge storage capacity available, making it unusual that these WWTPs appear in this list. However, further investigation into the Opononi and Ahipara WWTPs indicate that these WWTPs consist of ponds which are deeper than the other WWTPs evaluated in this study, being of 2.8m and 1.7m depth respectively. The adopted 1.0m water level above sludge in determining the sludge storage capacities has therefore allowed for much higher sludge build up in these ponds over other WWTPs which have shallower ponds.

The high sludge build-up has dramatically reduced the available HRT for liquid treatment. Consequently, despite Opononi WWTP and Ahipara WWTP being designated as lower priority plants from the point of view of sludge storage, they will need to be assigned a higher priority, due to the potential for consent breaches being caused by the reduced HRT in the ponds due to sludge build up.

<u>BOD Loading Rates</u>

The BOD loading rates for each of the WWTPs were calculated based on the current serviced population, and the expected serviced population in 20 years' time (2037). The calculated BOD loading rates were then compared against the maximum design BOD loading rate of 80 kgBOD/ha/day as outlined in US EPA's Pond WWTW Design Handbook (2011), suitable for systems located in areas with average temperatures of >15^{o}C. The results are shown in Table 12 and presented graphically in Figure 6. Where the BOD loading rates at the WWTP exceed the maximum design BOD loading rate, these WWTPs have been highlighted in red.

Table 12: BOD Loading Rate Assessment

WWTP	BOD Loading Rates - 2016 (kgBOD/ha/d)	BOD Loading Rates - 2036 (kgBOD/ha/d)
Opononi	335	407
Ahipara	171	207
East Coast	112	136
Rangiputa	24	29
Kohukohu	221	269
Kaeo	55	67
Kaitaia	50	60
Rawene	59	71
Paihia	136	165
Kaikohe	141	171
Whatuwhiwhi	53	64

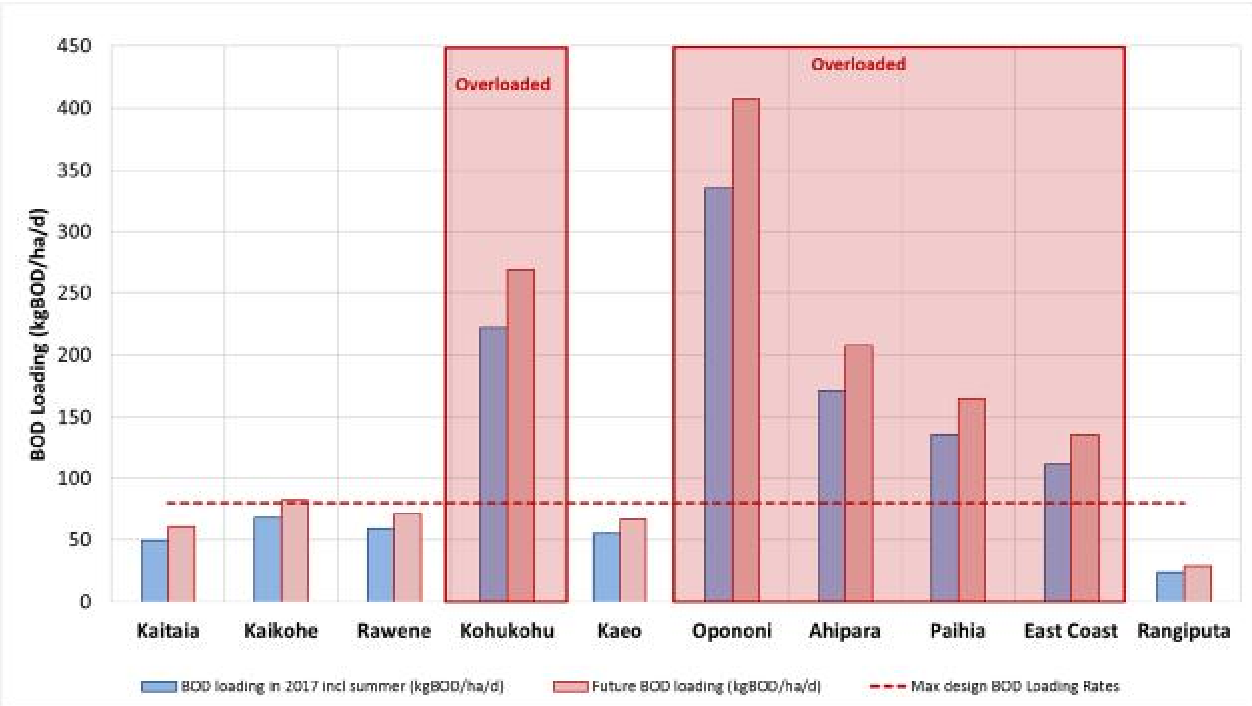

Figure 6: Comparison of Calculated BOD Loading Rates – 2016 and 2036

From Table 12 and Figure 6 above, five (5) WWTPs are identified to have BOD loading rates much higher than the recommended design BOD loading rate, in descending order of priority:

- Opononi WWTP
- Kohukohu WWTP
- Ahipara WWTP
- Paihia WWTP
- East Coast WWTP.

Section 3.2.4.1 notes that Ahipara has an unusually high level of effluent TSS despite having relatively low sludge content within the ponds. Figure 6 suggests that the TSS issues at Ahipara WWTP are likely related to overloading of the ponds and the limited detention times, potentially causing process upsets and the growth of unwanted Blue Green Algae blooms noted at the kick-off meeting. Excessively high TSS levels may also explain the consent breaches due to inadequate disinfection, which is exacerbated by inadequate HRT. The presence of high suspended solids will block the penetration of sunlight in the ponds, effectively reducing the level of disinfection achieved by sunlight alone.

Of the above WWTPs, only Kohukohu WWTP is noted to have sludge accumulation issues, and consequently, the problems encountered at the above WWTPs are largely due to issues with the wastewater treatment processes which lie outside the scope of this assignment. Nonetheless, we consider that further investigations into the performance of the wastewater treatment process and identification of solutions to overcome the excessive BOD loads should be completed for these WWTPs separate from this assignment, as a matter of urgency, to minimise further breaches of consent conditions in the short term.

3.3.3 Conclusion

Based on the above analysis, we recommend that the plants are prioritised as follows:

1. Short Term WWTPs – plants requiring sludge management in the immediate term to prevent further consent breaches and other process issues. The short-term WWTPs in descending order of priority are:
    a. Kaitaia
    b. Kaikohe
    c. Rawene
    d. Kohukohu
    e. Kawakawa
    f. Kaeo.
2. Medium and Long Term WWTPs – plants which require some form of sludge management within the next 5-10 years. The medium and long-term WWTPs in descending order of priority are:
    a. Ahipara
    b. Opononi
    c. Paihia
    d. East Coast
    e. Rangiputa
    f. Whatuwhiwhi.
3. In addition to the above, a separate study into the wastewater treatment process of the following WWTPs should be done as a matter of urgency, due to the excessive BOD loads identified, to minimise further breaches of consent conditions in the short term:
    a. Opononi
    b. Kohukohu
    c. Ahipara
    d. Paihia
    e. East Coast.

4 Options Identification

4.1 Overview

4.1.1 Options Assessment Approach

A two-staged approach is to be used to assess the treatment and disposal options for the sludge. The first stage (this stage) is to identify a list of feasible options and assess them through high level screening to shortlist viable options. The second stage will be completing an MCA and cost assessment of the shortlisted options, to develop a sludge strategy for FNDC. The Class of biosolids produced will also play a large role in determining the possible end uses and will be examined further.

4.1.2 Biosolids Grade

4.1.2.1 New Zealand Guidelines

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, although not all of these organisations have adopted them. 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 chemical contaminant grade.

- Grade 'A' biosolids are considered a high-quality product in which pathogens and vector-attracting compounds, such as volatile solids, have been substantially reduced or removed. To achieve stabilisation Grade A, the biosolids must have an accredited quality assurance system and meet at least one of the accepted pathogen reduction processes, plus one of the accepted vector attraction reduction methods and all the pathogen standards.
- To achieve stabilisation Grade B, the biosolids need to meet a lesser degree of stabilisation plus one of the VAR requirements for Grade A; no pathogen reduction processes or product standards are applicable. (Note: for Grade B, specified storage periods and/or access restrictions are recommended controls). If this standard is not met the product will not receive a stabilisation grade
- To achieve contaminant Grade 'a' the concentration of all the contaminants within the biosolids must be at or below the levels set out in the Guidelines. If any contaminant concentration is higher than this limit the biosolid must be classified as chemical contaminant Grade b. If any contaminant concentration is above the limit given for Grade b, then the product will not receive a contaminant grade.

If the product does not meet the minimum requirements for either stabilisation or contaminant grades then it is considered a sludge rather than a biosolid. Sludges are not considered suitable for application to land unless treated or blended with another substance to bring it up to the required quality standards. Consequently, to enable beneficial reuse of the biosolids, stabilization Grade B and contaminant Grade b must be achieved as the minimum criteria.

4.1.2.2 Expected FNDC Biosolids Quality

The sludge from FNDC's ponds are expected to satisfy the requirements for stabilization Grade B and contaminant Grade b for the following reasons:

- The Guidelines note that a minimum storage/exclusion period of 6-12 months or achieving a minimum of 38% reduction in volatile solids is required to meet stabilisation Grade B requirements.
  - FNDC notes that the sludges within their pond WWTPs have only very rarely been desludged, with some ponds never having been desludged before. Consequently, the minimum storage/exclusion period in the lagoons of 12 months will have been satisfied, and the sludge extracted from the pond WWTPs can be considered to meet stabilisation Grade B.
- The Guidelines provide the biosolids contaminant limits for Grade a and Grade b, outlined in Table 13. The contaminant limits are compared against the median known contaminant values for pond based sediments as documented in the National Study of the Composition of Sewage Sludge prepared by the NZWWA in 1998.
  - The median pond sediment composition is expected to meet Grade b contaminant requirements. In the absence of specific sludge sampling information and trade waste contribution information, we have therefore assumed that the sludge from the pond WWTPs can be considered to meet contamination Grade b.

Table 13: Biosolids Heavy Metal Contaminant Limits (NZWWA 2003) and Typical Pond Sediment Composition (NZWWA 1998)

Parameter	Grade a Max Concentration (mg/kg dry weight)	Grade b Max Concentration (mg/kg dry weight)	Pond Sediment Median Concentration (mg/kg dry weight)
Arsenic	20	30	11
Cadmium	1	10	2
Chromium	600	1500	129
Copper	100	1250	549
Lead	300	300	112
Mercury	1	7.5	1.5
Nickel	60	135	32
Zinc	300	1500	832

It is therefore likely that the sludge removed from FNDC's WWTPs will meet the minimum requirements for Grade Bb biosolids and so can be considered for beneficial reuse applications in the options assessment.

4.1.3 Options Categories

The options assessed in this section can be roughly grouped into the following categories:

- Sludge Removal – collecting or removing the sludge from the main process stream. In high-rate processes such as ASPs this is done continuously as a matter of course, but in wastewater ponds solids are only periodically removed.
- Sludge Thickening / Dewatering – removing water from the sludge, reducing the overall mass and volume of solids which requires further treatment.
- Sludge Treatment – for the purposes of this report this has been applied to processes which improve the quality of the sludge to a level which either allows it to be classified as a biosolid under the Guidelines or as discussed in Section 4.1.2, or improves the final grading.
- End use – the final destination of the sludge or biosolid. This can either be disposal, such as in a waste facility, or a beneficial use such as land application

These categories can also be thought of as stages, as illustrated in Figure 7.

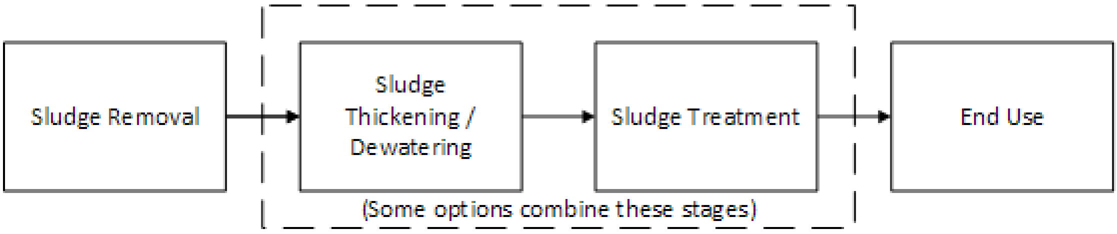

Figure 7: Options Category Summary

4.2 Biosolids Removal and Dewatering Process Options

Before treatment or disposal at most FNDC WWTPs sludge must be removed from where it has accumulated and excess water removed before treatment and end use can be realised. The options considered for this are summarized in this section and comprise:

- Sludge Removal:
  - Suction Cutter Dredge
  - Sludge Rat
- Sludge Thickening / Dewatering
  - Sludge Box
  - Reed Beds
  - Geobags
  - Mechanical Dewatering Methods (e.g. Centrifuges, Rotary Screw Presses, Belt Filter Presses (BFP), etc.).

4.2.1 Sludge Removal

Suction Cutter Dredge

Suction Cutter Dredgers (SCDs) are classified as hydraulic dredgers and are able to dredge nearly all kinds of soils (sand, clay, rock) and are used where the ground is too hard for the use of conventional suction dredges. SCDs are dredges equipped with a rotating cutter head mounted at the front of the suction head, which can cut into hard soil or rock into fragments, allowing them to be then sucked in by the dredge pumps. The dredged material is then pumped ashore using pumps and a floating pipeline or commonly fed directly into geobags on site. SCDs are typically mounted on boats and require operators to manually operate the dredge whilst on the water.

Due to the powerful cutting and suction action of the SCD, they are able to effectively handle a wide range of materials and are typically used for large scale dredging applications such as for harbours, large ponds, and land reclamation projects. The known smallest SCD motor is in the range of 20 kW, making it potentially unsuitable for application at FNDC's ponds.

Sludge Rat

The Sludge Rat is also a hydraulic dredge system, albeit on a smaller scale. The Sludge Rat is ITT's proprietary dredge comprising of a submersible centrifugal pump mounted on a floating pontoon controlled by operators on shore. It is commonly used for smaller ponds, where sludge from the bottom of the pond is pumped using a floating pipeline, and again commonly directly fed into the intended dewatering system on site. The Sludge Rat appears to be a suitable dredging mechanism for FNDC's ponds, although given the size of several of FNDC's ponds larger dredges may be necessary to reduce the dredging time from the ponds as a once-off.

4.2.2 Sludge Dewatering Options

Sludge Box

The sludge box unit consists of a closed container equipped with filtration screens to retain the flocculated sludge and allow water to drain outside via internal drains and through discharge valves. The rear of the sludge box is a full width door through which the dewatered sludge is later emptied. The sludge box is a mobile system which can be loaded and transported by a hook truck and has been documented in the Transfield report to achieve up to 15%DS. This appears a viable dewatering option and will be carried forward for further assessment.

Reed Beds

Reed beds are effectively sludge drying beds planted with reeds, which improve percolation and allow the accumulation of a deep sludge bed in between removals. Utilising reed beds for dewatering involves cycling through a number of reed bed basins, which are filled and rested in turn. The length of the filling (loading) and resting periods depend on the sludge characteristics, climate, and age of the basin. The semi-regular dosing assists with the reeds' agronomic requirements (i.e. watering). The biomass at the bottom of the reed beds are then removed every 8-12 years where it can then be used offsite. Reed beds are a widely accepted dewatering technology in Europe, but there are no known full-scale applications in New Zealand to date.

The reeds used in European beds are considered an invasive species in New Zealand. Gisborne District Council, in collaboration with ESR and NIWA, recently undertook pilot trials of sludge reed beds for their trickling filter sludge using New Zealand reed species and locally sourced media. The scaled-up facility would have been in the order of 5 to 10 hectares and the Council decided not to implement this due to concerns about managing operation risks (odour, insect attraction) and its viability with New Zealand's climate and reed species.

The regular dosing requirements of the reeds means that they are generally compatible with processes which continuously produce solids such as ASP. Whilst a reed bed could potentially be used for pond sludge, the batch process of pond desludging (i.e. all sludge removed over a period of weeks then left to accumulate again for ~20 years) is not considered compatible with the regular water requirements of the reeds. Centralisation of the reed beds is also not considered viable due to the high cost of transporting pond solids as a slurry. Reed beds will therefore only be considered for FNDC's ASP WWTPs.

Geobags

As discussed in Section 2.3.2 Geobags are constructed of special semi permeable membrane material which allows separation of the solids from the liquid phase. Geobags are a relatively low technology option which is well known to FNDC and has been employed for dewatering of the sludge removed from FNDC's WWTP ponds. When they have been employed, the resultant geobags with dewatered sludge have been then buried on site for disposal. This method of sludge management therefore requires the use of relatively large areas on which the geobags can be left to drain and be buried.

Most of FNDC's WWTP do not have spare land available on which such systems can be constructed. However, given legislative requirements to provide adequate odour buffers on site, FNDC may be required to purchase surrounding land to use as an odour buffer. If this occurs, there is an opportunity to utilise the odour buffer land as potential sites to bury the geobags as they are relatively odourless when filled with pond sludge, and are unlikely to breach the odour buffer land requirements. This appears a viable dewatering option, which can achieve up to 19% DS, and will be carried forward for further assessment. It is suited to de-centralised applications if land is available, but due to the high cost of transporting pond solids as a slurry, are not considered viable for a centralised facility.

Mechanical Dewatering

Mechanical dewatering involves the use of mechanical equipment, commonly with the addition of specialized polymer, to reduce the water content of the sludge. Permanent mechanical dewatering systems are typically installed at larger WWTPs due to their relatively high capital and operational costs. Nonetheless, the use of a mobile mechanical dewatering system which can be rotated across 17 of FNDC's plants may well be beneficial and render this option as a potentially cost effective option to carry forward.

Sludge thickening systems such as Rotary Screw Thickeners and Rotary Drum Thickeners will not be considered further as these systems will only enable thickening of the sludge to 4-8%DS, which is well below the typical dry solids concentrations achieved from dewatering systems and will have dramatically higher haulage costs than conventional mechanical dewatering equipment.

Some of the commonly utilized mechanical dewatering methods which will be considered further are described below:

- Centrifuges – are mechanical equipment comprising of a bowl and scroll which rapidly rotates, applying centrifugal force to the feed sludge, to separate the solids from the liquids. Centrifuges are typically capable of achieving up to 20%DS reliably for systems with high inert material content and with the addition of adequate polymer.
- Belt Filter Press – are mechanical equipment commonly combined with a Gravity Drainage Deck (GDD) for dewatering. The combined equipment operates in a similar manner, drawing liquid from the sludge located on the belt as it passes through the length of the equipment. As for centrifuges, belt filter presses are typically capable of achieving up to 18%DS reliably for similar sludges such as the pond based WWTP sludges
- Rotary Fan Presses – are mechanical equipment which utilises the differential pressure between the incoming and outgoing sludge cake, combined with a slow (<1 rpm) rotational motion of filter screens to move the sludge through the press. Water will take the path of least resistance through the filter screens, separating the solids from the liquid. Rotary fan presses are a relatively new technology and documented to be able to achieve cake solids dryness of up to 20%DS reliably with polymer addition.
- Rotary Screw Press – A rotary screw press is a mechanical dewatering unit which utilizes an inclined drum with a wedge wire screen (which forms the cylinder wall) and a screw conveyor. Sludge is flocculated with polymer before it enters the screw press through the inlet chamber. The sludge enters the front section of the screw press, which allows free drainage of water and thickens the sludge as it passes along the length of the screw press. As sludge reaches the outlet section of the screw press, the sludge is discharged through a restricted outlet. Due to the restriction at the sludge outlet, counter pressure is applied to the incoming sludge, causing liquid to be separated from the sludge cake. Rotary screw presses require low power and polymer consumption, but its benefit is offset by the relatively low dry solids concentration achieved, typically in the range of 16%DS. The press performance can also be variable for different sludge types and its track record with pond sludges is still relatively unknown and would need to be further evaluated. We propose that the rotary screw press be considered further as it appears to be relatively well suited to FNDC's requirements.

It should be noted that for the purposes of the current high level option screening stage, we will not select the most cost-effective mechanical dewatering method for implementation at FNDC's WWTPs, as the most cost-effective option will depend on a variety of factors including the type of sludge being dewatered and the location of the final product delivery, which cannot be accurately identified at this stage of the study. Consequently, we will use the generic term "mechanical dewatering" which encompasses the entire range of potential mechanical dewatering methods above. In the Stage 2 assessment where specific cost estimates may need to be developed for the mechanical dewatering options, we will identify one mechanical dewatering equipment that we consider to be most compatible with the type of sludge and end use application for costing.

4.3 Biosolids Treatment Process Options

The treatment technologies that would allow the collected sludge to be used in re-use or disposal application are summarised in this section, as follows:

- Thermal Drying
- Incineration
- Anaerobic Digestion including low rate pond digestion
- Aerobic Digestion
- Vermicomposting (MyNoke/Eco-cast)
- Traditional Composting (e.g. FNDC Owned and Operated Windrow Composting Facility)
- Solar Drying (with / without palletiser)
- Gasification
- Biological treatment (Sewer Rx)
- Microwaving of sludge
- Hydrophobic additive to produce pellets from sludge.

4.3.1 Thermal Drying

Thermal drying involves the application of heat and dry air to biosolids to evaporate the moisture content. The heat dried product has a dry solids content ranging from 90% to 95%, substantially reducing the biosolids transport costs and achieving stabilisation Grade A Biosolids. The footprint of the thermal dryer depends on the type of dryer used and can vary from compact to large facilities.

Thermal drying would result in a significantly reduced volume of product for disposal, and has the potential to produce a product either suitable for use as fertilizer (for ASP based sludge products) or incorporated into building materials. However, the market for these applications would have to be established in the Far North, and is likely to take a significant amount of time and dedicated resources to establish. Offering this as a free product initially may be an option, until the product is accepted by the public.

In addition, thermal drying is a high energy and high capital and operating cost option, requiring skilled operations staff. It is generally better suited to much larger facilities servicing large populations in the order of hundred thousand EPs, making thermal drying unlikely to be a viable option for FNDC. Therefore, this option will not be considered further.

4.3.2 Incineration

Incineration is the use of high temperature combustion processes which reduces organic solids to water vapour and carbon dioxide, leaving behind residual ash. Auxiliary fuel is typically required for dewatered solids with less than 40% DS and with lower calorific value. Lagoon / pond sludge has very low calorific value, hence the fuel required to achieve combustion temperature will be significant.

The most common incineration processes used worldwide are fluidised bed furnaces and multiple-hearth furnaces. This process is very energy intensive and complex in operation, involving a number of highly complex processing steps and requiring highly trained operations staff for facility operation.

The benefit of the incineration process is that the footprint is much smaller than other biosolids treatment technologies, and the volume of residual solids requiring disposal is significantly reduced. However, as described previously, the high costs associated with incineration are expected to make this option unviable for FNDC and this option will not be considered further.

4.3.3 Anaerobic Digestion including low rate pond digestion

Anaerobic digestion is the biological transformation of organic material in the absence of oxygen. There are many options available for anaerobic digestion of municipal wastewater sludge, ranging from simple pond-type reactors characterised by low capital cost and minimal process, mechanical and electrical complexity to more complex reactors with increased capital cost and complexity.

Pond WWTPs owned and operated by FNDC can largely be assumed to function as a low rate low temperature anaerobic digestion process with very long detention times. Consequently, the sludge at the bottom of the pond can be considered to have undergone extensive low rate low temperature anaerobic digestion. Further anaerobic digestion of the pond sludge using similar low rate low temperature anaerobic digestion processes are not expected to yield further reduction in volatile solids. Anaerobic digestion options will therefore only be considered for activated sludge plants where reduction in volatile solids is still possible using this technology.

Due to the low cost and low complexity preference of FNDC, conventional mesophilic anaerobic digesters (MADs) and their derivatives (such as temperature phased anaerobic digestion (TPAD) or Acid Phase Digestion) will not be considered further due to their high associated costs and level of complexity making it prohibitive for FNDC. For the purposes of this assignment, only sludge ponds will be considered for anaerobic digestion. It is one of the simplest forms of sludge anaerobic treatment, requiring minimal operator intervention.

4.3.4 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. There are many options available for aerobic digestion of municipal wastewater sludge, ranging from simple pond based reactors with floating surface aerators to complex reactors utilising diffused air systems in purpose built concrete tanks.

Similar to the anaerobic digestion option, the sludge at the bottom of the pond based WWTPs are considered to largely consist of material which will not benefit from further digestion processes. Further aerobic digestion of pond sludge is not expected to yield any further reduction in solids and aerobic digestion options will only be considered for activated sludge based plants where further reduction in volatile solids is still possible.

4.3.5 Composting

To enable composting, two requirements must be satisfied, which are:

- Availability of beneficial nutrients (Nitrogen, Phosphorus, and Potassium); and
- Continuous availability of the biosolids which serve as feed to the composting process

Based on the above requirements, sludge from the ASP’s are expected to be well suited for composting (both conventional and vermi-composting). ASP sludge is produced on a continuous basis and is expected to still contain relatively high nutrient values despite any digestion that occurs as part of the WWTP process. However, the sludge volumes available from these plants are relatively small and should be accounted for in the assessment.

Conversely, pond WWTP based sludges are not as suited to composting (both conventional and vermi-composting). Given the very long sludge detention times in the lagoons prior to desludging, sludge produced from pond based WWTPs is expected to be very well stabilized with minor to no beneficial nutrients remaining. Further, sludge from the pond WWTPs can only be produced on an intermittent basis. This contrasts with the requirements of vermi-composting facilities which require a continuous feed of sludge.

4.3.5.1 Vermicomposting

Vermicompost is the product of composting using various worms, to create a heterogeneous mixture of decomposing vegetable or food waste, bedding materials, and vermicast. Vermicast, also called worm castings, worm humus or worm manure, is the end-product of the breakdown of organic matter by an earthworm. These castings have been shown to contain reduced levels of contaminants and a higher saturation of nutrients than the organic materials contained before vermicomposting.

As noted previously, vermicomposting is considered unsuitable for pond sludges and will not be considered. For this reason, vermicomposting applications will only be considered for sludge from activated sludge plants.

There are currently two commercial-scale vermicomposting providers in New Zealand: MyNoke and Ecocast. Both operate primarily in the Central North Island. It is understood that MyNoke has expressed an interest in setting up a new facility in the Far North. The availability of bulking agent would be a vital component in setting up a new vermicomposting site and it is also understood that the Triboard mill may be a viable source of bulking agent. MyNoke also require incoming sludge to be in the range of 12-18% DS.

It should be noted that a common feature of biosolids vermicomposting agreements is a “buy back” policy whereby municipal customers will be expected to buy back a percentage of the of the vermicompost produced from their sludges at $30-35 per tonne – which excludes transport and the $65-75 per tonne gate fee[2]. Vermicomposting can result in an approximately 60-75% volume reduction in biosolids through their treatment process, but there would still be a significant volume of product that FNDC would need to buy back and find a use for.

The greatest risk for this option is the ability to secure a suitable and cost-effective long-term contract with a vermicomposting provider, and the risk (albeit small) of the company going out of business.

4.3.5.2 Traditional Composting

Composting involves the production of compost material by piling of the biosolids in long rows (windrows) and physically manipulating the biosolids to permit the biodegradation process to occur. The turning of the biosolids is typically achieved using heavy machinery to improve the oxygenation of the bio-materials; to redistribute the moisture content, and to control the heat produced during biodegradation.

Windrow composting has no direct process controls that can be automated. As a result, this technology is susceptible to product quality fluctuations. This process is therefore a relatively labour intensive technology. The critical control parameters for the process include oxygen and nitrogen content and temperature; all of which must be measured physically. It is important to maintain the correct ratio of bulking agent (i.e. green waste), which assists with air distribution during the process. However, the addition of a bulking agent will also increase the quantity of solids produced.

---

[2] Rates are based on Central North Island applications and would need to be confirmed for FNDC

A typical windrow composting facility will require approximately 90 to 120 days of composting, followed by 30 to 60 days of maturation and curing subject to the biosolids specific characteristics. Due to this prolonged processing time, a large footprint area is required for treatment.

A typical windrow composting schematic and an example of the turning machinery is provided in Figure 8.

Source: www.lesswaste.org.uk (left) and www.resrecovery.com.au (right)

Figure 8: Windrow Composting Schematic

Similar to vermicomposting, pond based sludges are considered less suitable for traditional composting applications than sludge from an ASP due to the well digested (stabilised) nature of the sludge. Consequently, composting applications will only be considered for sludge from activated sludge plants.

Kerigreen Compost, based in Kerikeri, produce compost (http://www.kerigreen.co.nz/compost-solutions/). FNDC therefore have the opportunity to compost biosolids at this existing site, if the compost producer finds this acceptable. Otherwise, FNDC would need to set up and manage their own facility for this to be viable. This will require purchase of land, designation of the land for composting, odour buffers, etc. It should also be noted that there have been cases in the past in New Zealand where composting plants have been closed down due to a lack of viable market for the compost and odour issues. One such case is the Living Earth Joint Venture composting plant, which co-composted dewatered raw sludge from a mechanical WWTP with green waste. Despite its success in marketing a range of compost products for Council, market gardens and domestic use, in October 2007 the Wellington City Council decided not to renew its contract with Living Earth and the plant closed in December 2008. Another example is Thames Coromandel DC, who operated a sewage sludge composting scheme and produced a publicly available Grade Aa compost. In November 2014, they determined there was no significant financial benefit to retain the composting operation and that it is cheaper to send biosolids to landfill rather than compost.

4.3.6 Solar Drying

Solar drying is a simple conventional drying technique used in New Zealand and internationally to decrease the water content of sludge and prepare it for land application. CH2M Beca is aware of two solar drying facilities in New Zealand.

There are two potential methods of solar drying:

- either via a greenhouse-like structure to capture solar radiation and increase the ambient air temperature of the biosolids,
- or using sludge drying pans which are effectively shallow sludge storage sites located in the open, to facilitate drying via direct solar radiation.

Greenhouse-like structures are typically comparatively capital intensive, with initial capital costs in the order of NZ$2M per greenhouse (depending on the ground conditions). Due to the scale of the application for FNDC, this approach will not be considered further in this study as it is likely to be cost prohibitive. Sludge drying pans are a lower cost solution which may still be viable for FNDC and will be discussed further.

Sludge drying pans are a well-documented and proven technology for stabilization and drying of sludge through natural sunlight and wind effects. One such example currently operating is at Western Treatment Plant in Victoria, Australia, which requires approximately one hectare to dry 500 dry tonnes of sludge per year from around 3-5% solids to 70-90% solids. The sludge for drying is pumped into sludge drying pans periodically in winter allowing solids to settle and the supernatant to be drained. The sludge is then dried during summer and harvested for stockpiling and future reuse. However, sludge drying using this method is affected by local rainfall which can lead to inadequate drying during summer, with the sludge left to remain in the pans for an additional year, significantly reducing treatment capacity.

Evaporation is facilitated through solar radiation, making its performance dependent on two key factors; 1) the heat supplied to evaporate water (by solar radiation) and 2) mass transfer of the water from the surface of biosolids to the air. Process performance is therefore heavily dependent on the relative humidity of air. As this is a natural process, the land area required to achieve the desired solids content is significant and hence this process is only beneficial where abundant land is available. Solar drying can also generate odour issues and large buffer distances to neighbours will be necessary.

The primary risk for the solar drying option are the same as for composting, in that there are no established markets for the product, so the end use is not guaranteed. However, there will be a smaller volume to dispose of than for traditional composting. In addition to this the high humidity and rainfall in the Far North region mean that solar drying pans may not perform well. Consequently, due to the high footprint requirements and potentially incompatible climate of the Far North attributed to high humidity, solar drying options will not be considered further.

4.3.7 Gasification

Gasification is a process to produce biogas from biomass under oxygen limited conditions, with much less char-like residue than obtained from other oxygen-limited processes such as pyrolysis. The key strength of gasification is the potential to produce energy by combusting the biogas product. The gasification process produces a char-like product that will contain all of the phosphorus from the Biosolids, while the nitrogen present in the biosolids is predominantly released as nitrogen gases. However, gasification is considered an emerging technology, with no known full-scale applications to date and still currently undergoing considerable investigation and development. This technology will not be considered further in this study for the above reasons although it has been included in this report for completeness.

4.3.8 Biological Treatment with Sewer Rx

Sewer RX is a brand of specialised bacteria which can be added to wastewater treatment ponds to enhance the sludge degradation process. These bacteria are claimed to promote and enhance sludge breakdown within the ponds with the addition of aeration. However, there are no known full-scale applications of this technology to date, and its success has been largely hit and miss. Successful applications are documented to require the supply of supplemental aeration air, which raises questions on whether the effectiveness of Sewer RX and improved sludge digestion rates are attributed to the provision of aeration air or to the specialised bacteria. The Sewer RX process is considered emergent and has not been considered further in this study, although it has been included in this report for completeness.

4.3.9 Microwaving of Sludge

Microwaving of sludge is a process for pre-treatment of sludge prior to mesophilic anaerobic digestion to improve volatile solids destruction of sludge solids. The microwaving process assists the breakdown of cell walls and lysis within the anaerobic digesters. Microwaves, when passed through sewage sludge, cause water molecules in the sludge to vibrate constantly as the molecules attempt to align themselves with the microwave frequency. This vibration produces frictional heat and the water will begin to boil just as in a home microwave oven. Water molecules inside pathogens and other sewage microorganisms will also try to escape causing the cell lysis.

More recently, microwave drying of sludge has been gaining momentum, with numerous studies showing promising reduction in energy requirements for sludge drying. Microwaves will generate heat within the water molecules in the biosolids being heated, making it a very efficient method of heating a water load. Almost all the produced energy in the microwave is used to heat water molecules, resulting in very little energy loss when compared to conventional drying methods. Further, no extreme temperatures are generated which significantly increases operator safety. One known supplier offering this technology is the Burch BioWave process.

Independent full-scale microwave systems for the treatment of sewage sludge are commercially available through Burch BioWave, Inc. One known permanent full-scale system has been installed in Fredericktown, Ohio, and endorsed by the US EPA as being capable of producing Class A biosolids. Nonetheless, despite the promising results, there is very limited information on full scale installations of microwave sludge heaters to date globally, along with only limited available information on pilot trials. For this reason, the microwaving of sludge can only be considered emergent and will not been considered further in this study although it has been included in this report for completeness.

4.3.10 Microwave Enhanced Advanced Oxidation Process

This technology has not advanced beyond the pilot stage to our knowledge. It was developed mostly to pre-condition sludge for digestion and, like many other technologies developed for that purpose, has lost out to thermal hydrolysis. Note that this process requires microwaving (per the above) which is highly energy intensive, and the enhancement or advancement is the addition of an oxidant, in this case Hydrogen Peroxide (H_2O_2) to lyse the cells.

This process uses hydrogen peroxide and microwaving to generate hydroxyl radicals which reacts with the organic compounds. Given that this is a new / emerging technology which has not advanced beyond pilot trials, we would not recommend this option for further consideration.

4.3.11 Hydrophobic Additive

FNDC advised CH2M Beca that they are aware of a proprietary product where a hydrophobic additive is mixed with dredged sewage sludge, and it “expels” the water from the sludge. The resultant product is a pellet like product. However, the supplier has been reluctant / unable to provide any details of this process. Additionally, our research has come up with no available information and our global network has no experience with this product. Therefore, we would not recommend this option.

4.4 Biosolids End Use Options

The ability to secure an end use for the biosolids is critical to the success of the project. An important factor is changing the traditional perception of the biosolids material being considered a waste requiring disposal, to a product which can be beneficially re-used

CH2M Beca completed an assessment of the market opportunities, gained from our understanding of broader issues that affect the selection of potential treatment technologies (commercial viability assessment). This included identifying market routes for disposal, performance requirements around these markets, current and future issues with market perception/uptake and risk, and risks to public health and the organisation of adopting specific strategies. One of FNDC's goals is to reduce waste, therefore options which achieve beneficial reuse of their biosolids are preferred.

The key reuse options considered were:

- Land application (forestry, agriculture)
- Compost (windrow composted biosolids or vermi-composted biosolids for garden applications)
- Incorporation of biosolids ash into building materials (has not been done commercially in New Zealand as yet)
- Site rehabilitation (i.e. mine/quarry sites)
- Landfill disposal
- Energy generation.

4.4.1 Land Application of Biosolids / Compost (Forestry and Agricultural)

The application of biosolids to land has generally been deemed a viable option for sustainable waste management in New Zealand. This "end use" or market was encouraged in the original Biosolids Guidelines, and the composting and landscaping supplies market is well established with a number of manufacturers of compost and related products in the Far North District, as noted in Section 4.3.5.

Application to forestry is not considered practically viable due to issues with the produced wood properties where biosolids have been applied to the forest, and due to issues with the New Zealand terrain:

- The commercial value of naturally fast-growing trees is known to be reduced if a "growth enhancer" such as biosolids is applied to naturally fast-growing trees. One such example is Rotorua, which used to apply produced biosolids to forestry in the area, but has now ceased this operation due to the reported commercial impact on the forest value (amongst other reasons).
- Further, forestry land tends to be steep, making it difficult for application of the dewatered biosolids. Where biosolids have been applied to forests in New Zealand, it has largely been applied as a slurry via spray irrigation (e.g., at Rabbit Island). Forest application is therefore only viable for biosolids slurries, requiring the transport of non-thickened or non-dewatered sludge. The forestry block would need to be near the site to make the transport cost effective, making it an unlikely application in the Far North.

Consequently, in the case of FNDC WWTP sludges, land application is only considered suitable for agricultural applications (provided that the required grade is achieved).

4.4.2 Biosolids Ash for Building Materials

Well stabilised biosolids predominantly consist of inert material in the form of ash. When well dried, this residual ash product could be incorporated into building materials such as that for roadworks and buildings. The dried product can be achieved by either thermal drying (i.e. using heat to remove the water content of the biosolids), or by incineration (i.e. using high temperature oxidation to reduce organic solids to water vapour and carbon dioxide, leaving behind residual ash).

The production of biosolids ash for building materials requires an energy intensive process with high associated costs and is therefore better suited to WWTPs which service very high populations in the order of millions of EPs, such as those in Japan. It is not normally considered cost effective at the size and scale of

FNDC's WWTPs and will therefore not be considered further. It should also be noted that this application has not been done commercially in New Zealand to date.

4.4.3 Mine Rehabilitation

Biosolids have the potential to be used in the rehabilitation of quarry sites in the far North region. There are more than 50 quarries in the region per the Far North District Quarry Inventory (May 2014). As many of these quarries are closed (we are waiting to confirm the number of operational quarries with FNDC), there may be potential to provide biosolids to assist in the reinstatement (filling) of the mined areas, including topsoil cover and vegetation. The value in this application would be low or even nil as rehabilitation budgets are often limited. However, making the biosolids available at no-cost would provide beneficial reuse and avoid landfill fees. The demand will depend on the time of closure of the quarries and this would need to be explored in more detail and in discussion with the quarry operators.

The biosolids would need to be blended with a quarry spoil, topsoil or green waste to provide a suitable medium for vegetation to be established. Previous experience has shown that biosolids applied to inorganic capping materials has resulted in the establishment of an organic topsoil medium and the rapid establishment of dense surface vegetation. Given the limited public access a Grade Bb biosolid would be suitable.

Christchurch WWTP biosolids are currently used by Solid Energy New Zealand at the Stockton Mine on the West Coast for rehabilitation of disturbed (mined) soils. A 1:3 mix biosolids:soil is used and with the Grade Ab of the biosolids requires a consent for land application. In June 2013, the consent monitoring changed from 'commissioning' sampling to 'surveillance' sampling as consistent destruction of pathogens had been demonstrated. Christchurch City Council covers the costs of transport and pays a gate fee. However, for FNDC's application, there would be no gate fee cost as the quarry sites are owned by FNDC.

4.4.4 Landfill Disposal

Sludge disposal to landfill is a widely-adopted strategy in numerous WWTPs globally and is the simplest Biosolids end use which does not require any treatment steps. Landfill disposal of biosolids does not require any treatment, except for dewatering, which can significantly reduce overall biosolids volume, tonnage and disposal costs. However, long-term landfill availability is limited in the Far North region. The Ahipara and Whangarei landfills are the two nearest landfills, both of which have been targeted for closure in the near future. When this occurs, the nearest landfill for sludge disposal purposes will be in Auckland's North Shore, which is a significant distance from FNDC's WWTPs. For this reason, landfilling of biosolids is not considered as a viable long term sludge strategy. On site burial may be a feasible option if purchase of surrounding land around FNDC's WWTP is a viable option.

4.4.5 Landfill Capping

Landfill capping is a containment technology which provides a barrier between the contaminated media in the landfill and the exposed surface, to satisfy occupational health and safety regulations. Biosolids from the Christchurch area has been known to be applied as capping at the Burwood Landfill, making this a potential option for FNDC. The use of biosolids as capping material for landfill is a possible option, provided adequate lining is provided to prevent leachate seepage from the biosolids into the groundwater. As Ahipara and Whangarei landfills are due for closure in the short-term, this appears to be a viable option for some of the Biosolids from FNDC WWTPs.

4.4.6 Energy Generation

Energy generation from biosolids is achieved by digestion of sludge or co-digestion with other wastes. Digestion has the benefit of significantly reducing sludge volumes (up to 40%) and producing power to offset site operational costs. However, CH2M Beca do not consider digestion feasible for FNDC's WWTPs. Due to the size of the WWTPs and inert nature of the pond sludge, a digestion facility would not produce enough biogas to provide benefit on site.

5 High Level Options Screening

This section presents a high-level assessment of the options identified in Section 4 for sludge removal, dewatering, treatment and end use. Detailed assessment of the options will occur in the next stage of the project, where a detailed multi-criteria assessment of feasible options will be completed.

The suitability of each sludge removal and treatment option for pond or ASP systems was assessed with the outcome summarised in Table 14. The full options assessment breakdown is provided in Appendix B.

Many of the identified options are not recommended for further evaluation for the specific requirements of FNDC's WWTPs. The options which are recommended for further assessment have been combined into suitable systems, and are classified below based on the WWTP types, and the Biosolids end uses. These systems form the long list of options for consideration in the next stage of this project, and are summarised in Table 14.

Table 14: Long List of Options for Further Assessment

WWTP Type	Sludge Removal Option	Dewatering Option	Treatment Options	End Use	Option Number
Ponds and ASP WWTPs	Sludge Rat	Sludge Box	Nil	Mine/Quarry Rehabilitation	1A
		Mechanical Dewatering			1B
		Sludge Box	Nil	Landfill Capping	2A
		Mechanical Dewatering			2B
		Sludge Box	Nil	Onsite Burial (Monofill)	3A
		Mechanical Dewatering			3B
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 Lagoons		4C
			Aerobic Digesters		4D
		Sludge Reed Beds	Nil		5A

These options will be shortlisted further through an MCA assessment (internal workshop) and then the outcomes will be presented to FNDC for endorsement. The highest scoring options (potentially a maximum of 3, or as advised by FNDC) will then be costed and assessed further though quadruple bottom line assessment, to identify the preferred strategy for long term sludge management in the Far North region.

6 Conclusions and Recommendations

6.1 Conclusions

The sludge production rates and sludge storage capacities have been assessed for each of the WWTPs owned by FNDC. All the pond based WWTPs have been assessed as a similar treatment process. Due to the current practice of delivering waste sludge from the activated sludge plants to the pond WWTPs, the sludge production rates of most ASP WWTPs have been incorporated into the pond WWTPs, with the exception of Kawakawa WWTP. First principles calculations have been completed for the ASP WWTPs where sufficient information is available in determining WAS flowrates (Hihi WWTP and Kawakawa WWTP) and Anaerobic Pond capacities (Kawakawa WWTP).

The WWTPs were prioritised for remedial works based on the sludge capacity assessments. The operating parameters of the ponds must be considered in conjunction with the sludge storage capacities in the prioritisation, as they have been widely documented to be closely linked. The prioritisation has incorporated a risk assessment based on the potential of consent non-compliance and includes the following considerations:

- Sludge storage capacities
- HRT Analysis
- BOD loading rates.

The results of the sludge storage capacity and risk assessments are summarised in Table 15. WWTPs which have been identified as high priority (short term) WWTPs have been highlighted in red, and are listed in descending order of priority. The factors which contribute to the selection of these WWTPs as high priority WWTPs (i.e. where values exceed recommended design values) have also been highlighted in **bold red**.

Limited process information is available for the ASP WWTPs. Plant log sheets were missing valuable information such as sludge retention times (SRTs), WAS loads, MLSS concentrations, RAS flowrates, and RAS concentrations. Due to the limitation in process information, the following should be noted:

- The assessment for Russell and Kerikeri WWTP adopted the known WAS transfer volumes and concentrations and were incorporated into the Kaikohe WWTP pond assessment. No independent calculations were done from first principles for Russell and Kerikeri, apart from verification that the transferred WAS loads are in line with typical values for ASP WWTPs.
- The WAS loads for Hihi and Kawakawa WWTP were estimated from first principles, and many assumptions had to be adopted to undertake this assessment. Consequently, the sludge assessments for the ASP WWTPs cannot be considered as have been done to a fine level of accuracy.
  - The assessment for Hihi WWTP was then incorporated into the Kaitaia WWTP pond assessment as WAS from Hihi is directly transferred to Kaitaia WWTP
  - The assessment for Kawakawa WWTP was done based on the current operating parameters as documented in the plant log sheets, with an average WAS volume of 30m^3/d which correspond to an SRT of approximately 8 days, as opposed to the design 20 days SRT. The current operation of Kawakawa WWTP should be further investigated to ascertain the reason behind adopting the much lower operating SRT, as the Anaerobic Pond desludging frequency can potentially be increased by up to 100%, presenting significant cost savings, if the WWTP is operated based on its design SRT.

Table 15: 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 also includes the 10% summer population factor
2. Includes Anaerobic Ponds and Oxidation Pond sludge production rates per unit population.

Options for the biosolids end uses and treatment processes have been identified, with the options to be carried forward for development outlined in Table 16:

Table 16: Summary - Long List of Options for Further Assessment

WWTP Type	Sludge Removal Option	Dewatering Option	Treatment Options	End Use	Option Number
Ponds and ASP WWTPs	Sludge Rat	Sludge Box	Nil	Mine/Quarry Rehabilitation	1A
		Mechanical Dewatering			1B
		Sludge Box	Nil	Landfill Capping	2A
		Mechanical Dewatering			2B
		Sludge Box	Nil	Onsite Burial (Monofill)	3A
		Mechanical Dewatering			3B
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 Lagoons		4C
			Aerobic Digesters		4D
		Reed Beds	Nil		5A

6.2 Recommendations

The following recommendations will allow CH2M Beca to further refine this study:

- Limited process information is available for the ASP WWTPs. Plant log sheets were missing valuable information such as sludge retention times (SRTs), WAS loads, MLSS concentrations, RAS flowrates, and RAS concentrations. Consequently, assessment of the sludge production from the ASP plants cannot be considered to have been done to a fine level of accuracy, and collation of additional process information such as those listed above will be beneficial to confirm the findings of this study.
- The WAS flowrates recorded in the plant log sheets for Kawakawa suggests that it is currently operating at 8 days SRT, which is substantially lower than the design SRT documented in the O&M manual of 20 days. However, the available plant log sheets were missing the MLSS information, which is a critical parameter which will provide insight as to the underlying reason behind the low operating SRT. As a conservative step, we have assumed that the plant is currently operating at its design operating MLSS of 4,000mg/L (i.e. assuming that the plant is currently overloaded). However, this may have led to an overestimate of the sludge production rates for Kawakawa. Further, operating the WWTP at an SRT significantly lower than its design SRT typically carries substantial process risk. For these reasons above, we recommend that further investigations be undertaken by FNDC to ascertain the reason behind the much reduced SRT currently adopted for Kawakawa. Our analysis suggests that returning Kawakawa to

its original design intention has the potential to reduce the frequency of Anaerobic Pond desludging by up to 50% and reduce overall operational costs.

- There is limited available information on septage, apart from the total volumes going into the WWTP, and we have assumed that the septage comprises fully of domestic septic tank sludge. However, with the known high variability in typical septage concentrations, FNDC should undertake sampling of the incoming septage to validate the findings of this study, and confirm that the incoming septage is indeed of a domestic nature.
- In our assessments, where WWTPs are noted to have issues meeting its consent limits for ammonia, we consider that this is predominantly a wastewater treatment issue which cannot be solved by desludging of the ponds and improving the available HRT given the extremely low ammonia consent limits which require almost complete nitrification.

We recommend that FNDC undertake additional effluent sampling and commission a separate study to examine the liquid treatment capacities of the pond WWTPs and determine the best way forward to address the compliance issues identified. There are a number of methods to enhance ammonia removal from pond systems. Some examples which could be considered, are listed below:

  - An emerging low-cost alternative process capable of achieving this level of wastewater treatment reliably is a CH2M proprietary, low cost, fill and drain wetland process which achieves reduction of Ammonia-N. This technology has been installed and operated successfully by CH2M for a number of overseas clients. It is soon to be trialled within NZ and CH2M Beca have completed the design of this system. CH2M Beca will also be overseeing the trial. If FNDC wishes, we can further discuss possible treatment options to achieve the effluent consent discharge limits, as part of a separate assignment.
  - Further to this, where rock bunds have to be installed for other reasons, pond effluent can be sprayed over the rocks to mimic a rock trickling filter which are reliable reducers of ammonia – first used for this purpose in the UK about 1880. CH2M Beca has done this at Motueka (late 2016) and so far, the complete ammonia reduction has occurred in summer and autumn.
  - Bioshells or Biodomes. These are currently being installed by Clutha DC to existing ponds as a means to enhance the overall total nitrogen removal.

- The sludge analysis study and risk assessment identified several issues with the current pond WWTPs. Several WWTPs were identified to have excessively high BOD loads, which raise the risk of pond failure and long-term consent compliance issues. Consequently, we recommend that a separate study into the wastewater treatment process of the following WWTPs should be done as a matter of urgency, due to the excessive BOD loads identified, to minimise further breaches of consent conditions in the short term:

4. Opononi WWTP

    a. Kohukohu WWTP

    b. Ahipara WWTP

    c. Paihia WWTP

    d. East Coast WWTP

- In the absence of available information, the development of biosolids end use options had assumed that the biosolids from FNDC's WWTPs are capable of meeting Grade b contamination limits. However, it should be noted that this is a key assumption which may render several of the end use options unviable if this requirement is not met. We therefore recommend that FNDC undertake a sampling campaign as follows:
  - Collection of composite samples across several locations at each pond WWTP to verify the following:
    - That the contamination levels in the pond sludge will meet stabilisation Grade b limits; and

    - That the adopted sludge decomposition rate (i.e. 60% in the first year and 100% thereafter) is a reasonable assumption to adopt.
- Collection of composite influent samples across all its WWTPs to ascertain the following information:
    - Verification of the influent loads to each catchment
    - Verification of the sludge production rates for each catchment.

6.3 Next Steps

The next steps for this project are to progress with Stage 2, where the long-listed options will be assessed via multi-criteria analysis. The options shortlisted via the MCA process will then be costed, including at varying scales (small, medium and large) and considering centralised vs de-centralised options. This information will inform a Quadruple Bottom Line assessment, with the findings to be reported on as the Stage 2 report. This information, combined with the work contained in this Stage 1 report, will allow us to identify a preferred strategy, and make recommendations for moving forward, which will be developed and summarised in Stage 3 via the final overall project report.

Appendix A

Summary of Reviewed Information from FNDC

No.	Process Information Requested	Information Received	Findings/Information Gaps	Priority	Comments
1	Sewage flow / connected EP projections for each WWTP	Information received for the following 17 WWTPs: ▪ Ahipara WWTP ▪ East Coast WWTP ▪ Hihi WWTP ▪ Kaeo WWTP ▪ Kaikohe WWTP ▪ Kaitaia WWTP ▪ Kawakawa WWTP ▪ Kerikeri WWTP ▪ Kohukohu WWTP ▪ Matauri Bay WWTP ▪ Opononi WWTP ▪ Paihia WWTP ▪ Rangiputa WWTP ▪ Rawene WWTP ▪ Russell WWTP ▪ Whangaroa WWTP ▪ Whatuwhiwhi WWTP Information on population growth of 0.5% p.a. in the region presented in the FNDC Social and Economic Profile Summer population factor of 10% to be applied to the average connected population in the assessment as directed by FNDC., to account for the increase in population during summer holidays Annual septage volumes from each septage receival site, and FNDC's direction to adopt 33,000EP (30,000EP permanent population with 10% summer population factor) in calculations	Design horizon for the biosolids strategy is not available. Assessment of flow contribution per EP from each catchment notes an average flow contribution of 254 L/EP/day. The following WWTPs have very low flow contributions (<65% average flow contribution) which is likely due to the connected populations being on rooftop water collection (water tanks): ▪ Kohukohu WWTP (115 L/EP/d) ▪ Hihi WWTP (161 L/EP/d) ▪ Russell WWTP (129 L/EP/d) The following WWTPs have much higher flow contributions (>130% average flow contribution), but receive tankered septage. When the tankered septage population contributions are included in the flow contribution calculations, these WWTPs also have very low flow contributions which is in line with the other WWTPs on rooftop water collection tanks and septic systems ▪ Kaitaia WWTP (131 L/EP/d) ▪ Kaikohe WWTP (80 L/EP/d) ▪ Kawakawa WWTP (132 L/EP/d) Ahipara WWTP was noted to receive leachate from the Ahipara Landfill which has high heavy metal loadings.	Medium	The design horizon for the assessment is unclear. In the absence of such information we shall adopt an ultimate design horizon of 20 years as noted in the project brief (i.e. 2037). A population growth rate of 0.5% p.a. will be adopted in the assessment of WWTP capacities for each of the 17 plants in the absence of other data. The 2015/2016 National Performance Review (NPR) Report notes that the average infiltration across all schemes is 1.6% and varies from 0.2% to 7.0% (Table 5.3-1), and consequently the WWTPs with high flow contributions may require further investigations to ascertain the reason behind the high flowrates observed at the WWTP. This investigation is not within the scope of the sludge strategy. Summer population factor of 10% will be applied to the average connected population in the assessment as directed by FNDC., to account for the increase in population during summer holidays
2 & 10	Primary sludge and WAS production data for each WWTP Biosolids production (average daily and maximum month) / haulage records (indicating mass of biosolids per truck), if any	NPR spreadsheet outlining the total sludge production rates for fifteen (15) of the seventeen (17) WWTPs. Sludge production rates for Whangaroa WWTP and Matauri Bay WWTP are unavailable. However, as Matauri Bay WWTP is excluded from this study, this information will not be required. Desludging information for FNDC's WWTPs as outlined in the email from P Caldwell dated 31st July 2017. Sludge survey reports for 11 WWTPs Sludge haulage information from Kerikeri and Russell WWTP to Kaikohe WWTP WWTP log sheets for ASP plants (Hihi, Russell, Kerikeri, and Kawakawa) which indicate WAS flows (no TSS concentrations) Septic tank receival locations and volumes on an annual basis.	There is no information on the breakdown of Primary Sludge and WAS production rates. Sludge production rates for Whangaroa WWTP are required. Sludge survey reports for the following pond based plants are missing: ▪ East Coast WWTP WWTP log sheets are available for the activated sludge based plants but are missing the following information: ▪ WAS TSS concentrations or total WAS loads in kg/d ▪ Nominal operating SRT, RAS flowrates, bioreactor tankage sizes (not available for all plants) ▪ Operating MLSS information appear suspect as it is extremely low and approach the incoming wastewater TSS concentrations (<500mg/L) The sludge production rates presented in the NPR spreadsheet appear to be artificially low, averaging 8.0 gDS/EP/day for the pond based plants and 4.1 gDS/EP/d for the activated sludge based plants. Activated sludge based plants are expected to have sludge production rates in the range of 35-55 gDS/EP/d (depending on influent characteristics and sludge age of the secondary system), further raising questions on the reliability of the sludge production rates presented	High	The reliability of the sludge production rates reported appears questionable. Artificially low sludge production rates may cause the assessed WWTP sludge treatment capacity to be much higher than expected in the field. In the absence of specific sludge production data for activated sludge plants, we have calculated the expected WAS TSS and VSS content for ASP plants from first principles adopting the following assumptions: ▪ Nominal operating SRT in the range of 15-20 days for SBR type plants as suggested by WAC drawings ▪ Typical RAS flowrates for ASPs of 15-50% of the average wastewater flow ▪ 15% VS destruction is achieved through the secondary treatment plant (at 20 days SRT) A sludge production rate of 15.6gTSS/EP/d for fixed film based activated sludge plants such as the Aquamat which approximates an MBBR process (based on 0.12 gTSS/gCOD typical observed yield from experience). We also propose that the information from the sludge survey reports and desludging information as provided by FNDC be used as the basis for determining sludge production rates for the pond based plants for capacity assessments, where available. The sludge production rates for pond based plants will also be verified based on first principles, assuming up to 60% volatile solids destruction per year. The sludge production rates will then be adopted in the capacity assessment of the WWTPs.

No.	Process Information Requested	Information Received	Findings/Information Gaps	Priority	Comments
			There is no data on the septage composition entering the WWTPs, and Broadspectrum have advised there is no monitoring of septic tank quality. There is no specific monitoring data available for trade waste contributions for TSS and BOD, apart from formaldehyde and other contaminant information which is unrelated to this study.		Septage is assumed to only consist of domestic septic tanks. The concentrations of septage contributions were determined from first principles based on the following assumptions: ■ One septic tank per property, which averages 2.53EP/ET based on the FNDC region data ■ Only domestic contributions of BOD, TSS, and VSS are expected in the septic tanks ■ 5 yearly maintenance/removal of septic tank contents. ■ Typical concentrations of 1.29%TS and 6,480mg/L BOD adopted for septage concentrations as per the US EPA design guide on septage, Table 11-1,
3	Plant Log Sheets and lab data (preferably spanning the last 2 to 3 years), including: ■ Influent Sewage Composition Data ■ Effluent Composition Data ■ Any data on sludge and/or WAS composition (flow, % dry solids, VSS/TSS)	WWTP Logs for 9 plants, comprising the following information: ■ Influent treated flows ■ Effluent quality information, which include BOD, TSS, and NH_4-N, where available Influent quality data (grab samples) available for Ahipara, Kaitaia, Kerikeri, Paihia, and Kaikohe WWTPs, Kerikeri and Paihia WWTPs have composite sampling data. No information on trade waste inputs, apart from formaldehyde monitoring for the triboard mill at Kaitaia and Ahipara leachate information which is irrelevant to this study as it does not contain BOD or TSS information	WWTP logs are missing for the following plants: ■ East Coast WWTP ■ Paihia WWTP ■ Rangiputa WWTP ■ Rawene WWTP ■ Russell WWTP ■ Whatuwhiwhi WWTP WWTP influent sewage composition data is missing for many WWTPs. The only available sludge data consist of the sludge studies, emails on sludge dewatering and haulage No trade waste contribution information is available.	High	In the absence of specific WWTP influent sewage composition, it is proposed that the Kerikeri WWTP wastewater contributions be adopted, as it is the only WWTP influent data which comprise of composite samples: ■ 56.5 gBOD/EP/d ■ 12 gTN/EP/d (100% NH_3) ■ 53 gTSS/EP/d ■ VSS/TSS of raw sludge = 85% ■ VSS/TSS of WAS = 75% Where site specific influent wastewater data is available, it shall be used over the Kerikeri WWTP wastewater data. Where the influent wastewater data is much higher than the Kerikeri WWTP data, it is assumed that the increase in loads is due to the trade waste contribution in the catchment. No separate trade waste assessment will be undertaken. In the absence of reliable WWTP effluent composition data, it is proposed that the effluent concentrations of 20 mg/L be adopted for well operated pond based plants. This approach will also provide a conservative sludge production / accumulation.
4 & 5	WWTP Site Layout Plan & Works As Constructed Drawings for all WWTP sites	WWTP site layout plans as shown on the sludge survey reports for the 11 WWTPs provided by FNDC WAC drawings available for the following plants: ■ Hihi WWTP ■ Kaikohe WWTP ■ Kaitaia WWTP ■ Kawakawa WWTP ■ Opononi WWTP ■ Paihia WWTP ■ Rawene WWTP ■ Russell WWTP Harrison Grierson reports on sludge capacity assessments	Sludge survey reports are missing for some WWTPs (refer points 2 above for details of the missing information) The Anaerobic Pond information presented in the Harrison Grierson plant capacity assessment report appear to be significantly undersized, when compared to available WAC and aerial measurements from Google Earth.	High	Where WAC drawings are available, dimensions of structures will be measured from WAC drawings and operating manuals where available. The information in the Harrison Grierson plant capacity assessment report shall be disregarded as it appears to be significantly undersized. In the absence of available WWTP site layout plans and WAC drawings, dimensions of structures will be measured from Google Earth aerial projections, and a nominal pond depth will be adopted from literature values for pond based plants.
6, 7 & 8	Existing P&IDs and process drawings of the WWTP Process unit details for secondary treatment processes and biosolids handling equipment WWTP process flow diagrams	PFDs are available for 11 WWTPs P&IDs are only available for Russell WWTP.	PFDs are missing for the following WWTPs ■ East Coast WWTP ■ Kohukohu WWTP ■ Hihi WWTP No other P&IDs are available apart from Russell WWTP No process unit details are available for any of the secondary treatment processes or biosolids handling equipment apart from Kawakawa WWTP as documented in the Operations & Maintenance manual	High	In the absence of process unit details such as sludge retention times (SRTs) and Mixed Liquor Suspended Solids (MLSS), it is not possible to undertake any solids handling capacity assessments on the activated sludge plants to a good degree of accuracy. In the absence of specific sludge production data for activated sludge plants, we have calculated the expected SRTs, WAS TSS and VSS content for ASP plants from first principles based on available information Refer to Item #2 and #10 for further details on the adopted assumptions.
9	Details of effluent and environmental consents for each WWTP	Consents received as follows: ■ Ahipara WWTP ■ East Coast WWTP ■ Hihi WWTP ■ Kaeo WWTP ■ Kaikohe WWTP	Matauri Bay WWTP but we note this is to be excluded Whangaroa WWTP – we note the effluent is transferred from the tanks in Whangaroa to Kaeo WWTP Taipa WWTP – if this is to be included in assessment?	Low – aids in prioritization only	Nil

No.	Process Information Requested	Information Received	Findings/Information Gaps	Priority	Comments
		▪ Kaitaia WWTP ▪ Kawakawa WWTP ▪ Kerikeri WWTP ▪ Kohukohu WWTP ▪ Opononi WWTP ▪ Paihia WWTP ▪ Rangiputa WWTP ▪ Rawene WWTP ▪ Russell WWTP ▪ Whatuwhiwhi WWTP			
11	Current and potential locations of biosolids application / disposal	Information on potential applications received	N/A – currently sludge management is reactive and no management strategy for application and / or disposal exists. In the past Kawakawa WWTP ponds were dewatered in geobags and buried on site. Paihia WWTP sludge is discharged to land adjacent to the site.	N/A	No action required
12	Level of redundancy required for key equipment, in particular for process and reliability (i.e. n+1)	No information received to date	There is no information on the level of redundancy for key equipment	Low	As directed by FNDC we will assume no redundant mechanical equipment is required for process reliability.
13	Key operational fixed and variable cost rates, including: a) Rates for biosolids haulage, and application/disposal ($ per wet tonne) b) Rates for electricity, natural gas, labour, polymer, etc.	Electricity rates of $0.46/kWh as advised in email dated 28th August 2017	No information provided on rates of biosolids haulage and application/disposal No information on consumables which include natural gas, labour, polymers etc.	Low	In the absence of such information we will use following operating and Maintenance unit costs: ▪ Polymer - $5/kg polymer ▪ Haulage cost – – Landfill Tipping Fees for sludge - $115 – Haulage cost – Fixed cost - $15 / tonne – Haulage Cost - Variable cost - $5/km distance travelled, Haulage labour - $160/hr ▪ Plant Labour cost - $60/hr
14	Previous planning studies outlining recommendations for sludge management for all 17 WWTPs	FNDC District Pond STP De-Sludging Works Sludge Management Options Study (Transfield, May 2012) received FNDC Meeting Minutes on Sludge Disposal Strategy dated 14th July 2011. Paper on Biosolids application to Quarries for disposal	Several sludge management options have been proposed, which include: ▪ Sludge Removal & Drying/Dewatering Options ▪ Sludge Treatment & Disposal options	N/A	No action required
15	NPC (Net Present Cost) Spreadsheet	None to date	NPC spreadsheet required	Low	We require standard net present cost (or value) spreadsheet from FNDC (if there is one) for estimating whole of life costs. If there is not one, we can use our standard spreadsheet. Please advise. However, we will need to confirm the applicable discount rate – if there is not a standard value adopted by FNDC we would recommend using 6% from Public Sector Discount Rates for Cost Benefit Analysis, The Treasury, NZ Government, October 2016
16	Previous condition assessments undertaken	Sludge survey reports for 11 WWTPs available	The sludge survey reports only detail the current sludge fill rates of the WWTPs, with no details on the actual physical condition of the assets	Low	Please advise if any other condition assessments have been undertaken. If none are available, we will just note that there are no available condition assessments
17	O&M Manuals	Only one on Kawakawa WWTP provided. No other O&M manuals are available for the other WWTPs	Manuals ideally required	Low	Please advise if any manuals are available. If none are available, this should not impact our study too much.
18	Known key risks and constraints on biosolids management	Report on Tapu to Noa and papers on Biosolids application received	N/A	N/A	No action required
19	Additional Request for Composting Assessment	Some information provided on green waste contractors as well as the Draft Waste Management and Minimisation Plan 2017	Future plan for green waste collected at the Kaikohe Waste station. Green waste is sent to Keri Green for processing	Medium	Any additional data on green waste in the area (i.e. collection volumes if FNDC have this information) would be useful for consideration in options which include composting with sludge. Any seasonality in production would also be useful. Discussion with Keri Green to ascertain whether they would be interested in utilizing sludge in their composting process would also be beneficial.

Appendix B

High Level Options Screening

A key for the high level options screening table following is provided below:

Cell Colour	Key
White	Not suitable for further assessment
Blue	Further assessment for both ASP and pond systems
Green	Further assessment for ASP systems only

Category	Option	Proven technology	Cost	Operability / Required Treatment Process	Footprint	Consent Requirements	End Use Markets/ Suitable Dewatering Processes	Product Quality	Volume Reduction / Market Size	Power / Chemical Requirements	Suitability for Further Consideration?
Sludge Removal	Suction Cutter Dredging	Yes	High	Requires a minimum of 2 people to operate, with 1 operator on the water with the dredge.	High	N/A	N/A	N/A	N/A	Medium (minimum 20 kW dredge)	No – small sizes of FNDC ponds make this unsuitable
	Sludge Rat	Yes	Low	Requires only 1 operator, as operation can be done on the bank	Low	N/A	N/A	N/A	N/A	Low	Yes – small sizes of FNDC's ponds best suited for dredge size
Sludge Thickening / Dewatering	Sludge Box	No	Low	Low operator requirements	Low	N/A – normal WWTP process	N/A	15%DS	Med	Low	Yes – potential mobile dewatering system
	Reed Beds	Yes	Med	Low operator requirements	High	N/A – normal WWTP process	N/A	25%-40%DS	High	Low	Yes – only for ASP based WWTPs with sufficient space and continual "dosing" of the reed bed
	Geobags	Yes	Med	Low operator requirements	High	N/A – normal WWTP process	N/A	18%DS	Med	Low	Yes – where WWTPs have sufficient space
	Mechanical Dewatering	Yes	Med/High	Medium operator requirements, as mechanical dewatering equipment will need to be continuously monitored when operational	Low	N/A – normal WWTP process	N/A	Varies, typically 18-20%DS	Med	Med/High	Yes – potential mobile dewatering system
Sludge Treatment	Thermal Drying	Yes	High	Requires operator training Potential issues if sludge is heavily contaminated with metals	Low	N/A – normal WWTP process	Fertiliser (ASP sludge only)	Class Ab	High	High	No – Cost Prohibitive at the current scale
	Anaerobic Digestion (Ponds)	Yes	Med	Low operator requirements	High	N/A – normal WWTP process	Requires additional treatment to become usable product Landfill Mine rehabilitation?	Class Bb	Med	Low	Yes – only for ASP based WWTPs. Unsuitable for Pond WWTP as mostly inert sludge
	Aerobic Digestion	Yes	Med	Medium operator requirements due to the need to continuously monitor the aeration system operation	Medium	N/A – normal WWTP process	Requires additional treatment to become usable product Landfill Mine rehabilitation?	Class Bb	Med	High	Yes – only for ASP based WWTPs. Unsuitable for Pond WWTP as mostly inert sludge
	Vermicomposting	Yes	Low Capex Buy back policy	N/A – by others	N/A – by others	N/A – by others	Compost Land application (agriculture)	Class Bb	Low	N/A – by others	Yes – only for ASP based WWTPs Unsuitable for Pond WWTP due to mostly inert sludge and intermittent nature of sludge availability
	Windrow Composting	Yes	Low	Requires operator training	Very High	Odour	Compost Land application (agriculture)	Class Ab or Bb	Increased volume	Low	Yes – only for ASP based WWTPs Unsuitable for Pond WWTP due to mostly inert sludge and intermittent nature of sludge availability
	Solar Drying using Sludge Drying Pans	Yes	Med	Low operator requirements Requires low humidity for good operation	High	N/A – normal WWTP process	Requires additional treatment to become usable product Landfill Land application (forestry and agriculture) Mine rehabilitation?	25-50% DS	Med – High	Low	No – limited available footprint and high humidity in the Far North District.
	Incineration	Yes	Very High	Requires very specialized operator training	Low	Air Discharge Consents	Ash Building Aggregate	Class Ab	Very High	Very High	No – Cost Prohibitive at the current scale
	Gasification	No	High	Requires very specialized operator training	Low	Unknown	Compost Fertiliser	Class Ab	Unknown	High	No – Unproven Technology and cost prohibitive

Category	Option	Proven technology	Cost	Operability / Required Treatment Process	Footprint	Consent Requirements	End Use Markets/ Suitable Dewatering Processes	Product Quality	Volume Reduction / Market Size	Power / Chemical Requirements	Suitability for Further Consideration?
	Biological Treatment with Sewer Rx	No	Varies	Requires aeration for effective operation	Low	N/A – normal WWTP process	Compost Fertiliser	Unknown	Unknown	Unknown	No – Unproven technology. If desired, FNDC could perform trials with a control site, and then utilise aeration only and aeration with enzymes to quantify the benefits of Sewer RX.
	Microwaving of Sludge	No	Med-High	Requires specialized operator training	Low	N/A – normal WWTP process	Compost Fertiliser	Potentially Class Ab	High	High	No – Unproven Technology and likely to be cost prohibitive
	Hydrophobic Addition	No	Unknown	Unknown	Unknown	Unknown	Fertiliser	Unknown	Unknown	Unknown	No – Unproven Technology. Insufficient details to enable recommendation
End Use	Agricultural Land Application	Yes	Low	Vermicomposting/conventional composting	N/A	Application permits – potential community resistance	Sludge Box Reed Beds Geobags Mechanical Dewatering	Class Bb	Not established	Med	Yes – Suitable applications for ASP sludge only – not for forestry
	Biosolids Ash for building materials	Not in NZ	High	Incineration / thermal drying	N/A	N/A	Sludge Box Reed Beds Geobags Mechanical Dewatering	Class Ab	Not established	High	No – no established market and cost prohibitive production
	Mine/Quarry Rehabilitation	Yes	Low	No treatment	N/A	Land & leachate discharge consents	Sludge Box Reed Beds Geobags Mechanical Dewatering	Class Bb	Established in Far North	Low	Yes – suitable application for pond and ASP sludge
	Landfill Disposal/ Onsite Burying	Yes	High	No treatment	Medium	N/A	Sludge Box Reed Beds Geobags Mechanical Dewatering	Unclassed	Not established – nearest landfill site at Auckland	Low	No for landfill – no established landfill, likely cost prohibitive transport costs Yes, for onsite burying, provided adequate footprint is available
	Landfill Capping	Yes	Low	No treatment	N/A	Land and leachate discharge consents	Sludge Box Reed Beds Geobags Mechanical Dewatering	Class Bb	Established in Far North	Low	Yes – suitable application for pond and ASP sludge
	Energy Generation	Yes	High	Co-digestion with other wastes	N/A	Air discharge consents	Sludge Box Reed Beds Geobags Mechanical Dewatering	Class Bb	N/A	High	No – cost prohibitive