OPERATIONAL ENVIRONMENT MANAGEMENT PLAN

Rarotonga Water Treatment Plants

- The Main Report

Prepared for To Tātou Vai

By Tiu Te Matangi Ltd

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Acronyms and Explanations of some Terms

AVG	Automatic valveless gravity filter
Backwash Pond	A pond that holds backwash generated during the backwash (cleaning) of the AVG filters (Tonkin & Tylor July 2021).
CCC	The USEPA guidance refers to the Criterion Continuous (CCC) which is the estimate of the highest concentration of a material in the water column to which n aquatic community can be exposed indefinitely without resulting in an unacceptable effect, i.e., the maximum value of the long term (Tonkin & Tylor July 2021).
CEO	Chief Executive Officer
CMC	USEPA guidance refers to the Criterion Maximum Concentration (CMC) is an estimate of the highest concentration of a material in the water column which an aquatic community can be exposed briefly without resulting in an unacceptable effect (Tonkin & Tylor July 2021).
E. Coli	*Escherichia coli (E. coli)* bacteria normally live in the intestines of people and animals. Most *E. coli* are harmless and actually are an important part of a healthy human intestinal tract. However, some *E. coli* are pathogenic, meaning they can cause illness, either diarrhea or illness outside of the intestinal tract. The types of *E. coli* that can cause diarrhea can be transmitted through contaminated water or food, or through contact with animals or persons. (https://www.cdc.gov/ecoli/general/index.html)
EIA	Environmental Impact Assessment
NES	National Environmental Services
OEMP	Operational environmental management plan
Kg	Kilograms
PACl	Poly Aluminium Chloride
pH	A measure of the relative amount of free hydrogen and hydroxyl ions in the water or how acidic or basic water is. It is expressed in a scale from 1-14, where 7 is neutral and lower values are more acid and higher values are more alkaline. https://www.thoughtco.com/definition-of-ph-in-chemistry-604605
Sludge Pond	A pond that holds sludge formed in the selling process, removed from the settling tanks on a regular basis and placed in scour ponds to dry prior to disposal (Tonkin & Tylor July 2021).
SOP	Standard operating procedure

SS	Suspended solids
ST	Settling Tank
Supernatant	The clear water/liquid overlaying settled material (sludge) (Tonkin & Tylor July 2021).
TTV	To Tatou Vai
WTP	Water Treatment Plant
µg/L	milligrams per liter

Contents

Acronyms and Explanations of some Terms 1

EXECUTIVE SUMMARY 6

Rarotonga Water Treatment Plants (WTPs) 8

1. Introduction 8

1.1 Where are the WTP located? 8

1.2 What does WTPs do? 8

1.3 Why do we need an operational environment management plan (OEMP)? 9

2. What do we know from the EIA Report about PACl? 9

3. What do we know about the environmental hazards and risks affecting each WTP? 10

4. OEMP Setting: 11

4.1 PACl 11

4.2 Environmental Hazards and Risks 11

5. What is our Plan? 12

5.1 Our aim is: 12

5.2 We will: 12

6. Implementing the Plan 12

6.1 Environmental Management Activities and Controls 12

6.2 Environmental Inspection and Monitoring Plans 13

6.3 Environmental Performance Objectives 13

6.4 Monitoring Plan 13

6.4.1 Discharge Standards 13

6.4.2 Ambient Monitoring Requirements 13

6.4.3 Discharge Monitoring Requirements 14

6.4.4 Methodology for Sampling and Analysis 14

6.5 Environmental Management Structure and Responsibilities 14

6.5.1 Environmental Training 15

6.5.2 Emergency Contacts and Response 15

6.6 Approval and Licensing Requirements 15

6.7 Reporting 16

6.8 Grievance Redress Mechanism (complaints management) 16

6.9 Stakeholders 16

7. Recommendations 17

Appendix 1 19

Risk Assessment Methodology Used 19
Appendix 2 20
AP 2.1 Hazards and Risks Identified for PACl and their management 20
AP 2.2 Summary of Recommended Actions and Monitoring for PACl 34
Appendix 3 38
5. References 39

Figures

Figure 1 - Location of Rarotonga's Water Treatment Plants (WTP) 5
Figure 2 - How the Water Treatment Plant work (Source: TTV sign boards at each WTP) 18

Tables

Table 1 - Grievance Process for complaints 16
Table 2 - Level of risk impact and probability 19
Table 3 Matrix showing overall significance of the impact as a combination of the consequences and probability rating 19
Table 4 - Hazards and Risks Identified for PACl and their management 20
Table 5 - Capacity of each WTP 38

WHERE ARE THE RAROTONGA WATER TREATMENT PLANTS LOCATED?

Figure 1 - Location of Rarotonga's Water Treatment Plants (WTP)

EXECUTIVE SUMMARY

The Rarotonga water supply system is comprised of ten water treatment plants (WTPs) and are located deep in the interior of the island. Each WTP is located in water catchment areas that gave each plant its name. The ten WTPs are: Avatiu, Takuvaˈine, Tūpapa, Matavera, Turangi, Ngātoe, Pāpua, Taipara, Tōtokoˈitu and Avanā. Based on the average intake daily flow rate, around 2.6 million liters of water per day go through the ten WTPs to contribute to the island's water supply.

On November 25 2021 the WTPs were permitted to operate following an environmental impact (EIA) report and project permit application to the National Environment Services. This was followed by a permit to temporary store poly aluminium chloride (PACl) sludge at Vairauara 88H, Arorangi. The EIA report identified issues with the water treatment system and established specific guidelines that can be used to monitor the environment of and around each WTP to manage the disposal and leakage of PACl into the environment. PACL is a coagulant added to the water entering the system to clean it by removing dirt and micro-bacterial residue. The EIA report also provided a framework from which an operational environmental management plan (OEMP) can be developed to manage each WTP.

From the experience to date of To Tatou Vai, it has become apparent the system has design flaws and theses need to be addressed. This OEMP therefore identified those issues that hinder the effective operation of each WTP especially the use and disposal of PACl, as well as addressing environmental issues that may potentially have an adverse impact on each WTP.

For the use and disposal of PACl, the focus of the OEMP were mainly around the mixing, the use of PACl and the management of sludge from the cleaning process. There are two components of the WTP where water is cleaned; the settling tank where PACl is added and the automated valveless gravity (AVG) filter. The design flaws in this area are related to spill controls when mixing PACl and when transferring PACl from the mixing area to the storage tank, to the header tank and into the coagulation chamber of the settling tank. Spills occur at the PACl mixing area when PACl is mixed, at the storage tank when the unblocking process of pipes due to crystallized PACl is released directly into the environment and at the header tank when unchecked resulting in overflow of dozing PACl. At the coagulation chamber, there is the risk of backed up water from the settling tank where the float leaver arm at the coagulation chamber is at risk of breaking causing PACl to go into the stream outlet.

PACL sludge at scour ponds can also be problematic for some WTPs with high intake flow rate, especially during the rainy season, resulting in the AVG undergoing frequent backwash when water flow increases resulting in increased water level in the scour ponds. This is mainly a problem in Turangi and Avanā with their high intake flow rate. The poor drying conditions at these two sites caused by physical barriers such as massive tree canopy cover and unsuitable conditions to facilitate drying conditions hinder the drying of the sludge. For the time being, sludge is moved to the Pāpua WTP with better drying conditions and capacity to help dry the sludge before further removal for disposal.

The removal of debris from behind the weirs are particularly difficult for Avanā, Tōtokoˈitu and Pāpua. These are all design flaws where the system designed does not allow debris to be removed by mechanical means which puts pressure on the operators and TTV staff. This increases the opportunity for high dissolved carbon to develop and also hinder the effective capture of water at the weir and screen. A number of solutions are recommended and include; the Investigation into the installation of appropriate silt traps further inland of the weir, the gradual releasing of accumulated debris downstream as part of

the natural process could be looked into, and the removal of invasive species such as pīpī-vai, rau-māniota, kākā-enua as they contribute in accelerating soil erosion especially when they fall on steep slopes after a storm and in the case of kākā-enua by smothering and killing effective ground cover trees.

Some WTP are accessible to people and this is a security risk to the system from a public health safety perspective. Avatiu, Pāpua, Takuvaˈine, Tūpapa, Tōtokoˈitu and Avanā are catchment areas used for trekking and by tourists. For the Takuvaˈine WTP, landowners still work their lands at the back of the intake, and in the case of Pāpua when debris accumulation behind the weir is above capacity the risk of rockfalls through the waterfall is a safety concern.

For Avatiu, Matavera and Taipara closeness of settling tanks to the stream is a concern as the risk from stream damage has not been mitigated. This can be controlled through installation of properly designed structures pending on availability of funds. For the time being daily monitoring is recommended especially after heavy rainfall.

Physically impaired WTPs due to their location such as Avatiu, Turangi and Avanā affect their natural capacity to naturally dewater sludge in their sludge ponds. Moving of sludge to other locations with better natural drying conditions is currently the practice. The use of vetiver grass to protect pond bunds and to assist with dewatering is recommended. For Turangi and Avanā, the extension of the sludge pond for taro swamps is recommended.

Landslips and falling trees at the Tūpapa, Ngātoe, Taipara and Avanā WTPs have been experienced by TTV and these could have been mitigated during construction by negotiating a better deal with landowners on siting the plants and managing the trees along the accessways to the plants. Ongoing maintain and improved communication within the TTV team, keep good relationship with contractors and the eradication of invasive species are recommended in the vicinity of the plants are recommended.

Design issues where surface water threatens the efficiency of the sludge ponds have been a concern especially for Tūpapa and Ngātoe WTPs. Redesign of drainage systems and the use of vetiver grass to protect slope and control drainage are recommended.

More details on the management of environmental risks are provided in the OEMP for each WTP, and for Turangi and Avanā their environmental improvement plan (EIP) which was informed by this main report include detailed environmental management plans on the recommendations to address the design flaws experienced by TTV since it began operating the Rarotonga water treatment system.

Rarotonga Water Treatment Plants (WTPs)

1. Introduction

1. From the experience to date of To Tatou Vai (TTV) in operating the newly designed Water Treatment Plant (WTP) system for Rarotonga, which was not time tested before it was replicated in ten different locations, it has shown the system have design issues resulting in the need for an operational environmental management plan or OEMP to be prepared and implemented.

2. The purpose of this report is to identify and address issues that may hinder the effective operation of each WTP regarding the use and disposal of PACl (described within), as well as addressing environmental issues that may potentially have an adverse impact on each WTP. This report therefore informs the operation of each WTP through operational environmental management plans (OEMPs) provided as a supplementary to this report. Each OEMP provide recommendations and strategies on how to address the PACL use and its disposal and the potential adverse impacts the environment may have on each WTP. When required environmental improvement plans can also be informed by this report.

1.1 Where are the WTP located?

3. The WTPs are located deep in the interior of Rarotonga. See Figure 1 above. See also Table 5.0 in the Appendix 3 showing the capacity of each WTP.

4. Five are referred to by the WTP management team for operational purposes as the north plants and they are: Avatiu, Takuvaˈine, Tūpapa, Matavera and Turangi. The remaining five are referred to as the south plants and they are: Ngātoe, Pāpua, Taipara, Tōtokoˈitu and Avanā.

5. The WTPs are located in water catchment areas that gave each plant its name and each site is made up of steep sided wooded valleys with very limited human access, and have a variety of animals that impact on the water source, from insects, geckos and skinks to birds, bats, rats, chickens and dogs. Droppings from animals such as birds, bats, rats, chickens and dogs contribute to the *Escherichia coli (*E. coli) level at these sites. E. coli is a bacteria found in the intestines of animals and can make people sick when large amount is found in drinking water. E. coli attaches itself on plant detritus on the floor of these wooded valleys and released into the water system by surface water flows during time of moderate to heavy rainfall.

6. Located in the interior of the island, each WTP sits on Pokoinu soils that are moderately acidic with high cation exchange capacity (Leslie, 1980). Calcium, sodium and potassium are typical ions in this soil type and their composition is medium in the upper levels and decreases in the lower levels of the soil profile (Leslie, 1980). With the high rainfall and wet conditions of the interior, Calcium, sodium and potassium are likely to be replaced through the leaching process by hydrogen and aluminium which can cause acidic conditions in the soil. Acid soils tend to be rich in iron and aluminium oxides and will combine with water releasing additional irons causing more acidic conditions. The soil is prone to soil erosion and where areas are exposed, staghorn ferns are predominant.

7. Some WTPs are accessible to people as they have trekking trails through them such as: Avatiu, Takuvaˈine, Tūpapa, Avanā, Tōtokoˈitu and Pāpua. Avatiu and Pāpua being on the cross the island trek is the busiest. Takuvaˈine catchment area behind the intake still have taro terraces worked by landowners and therefore have regular agricultural activities taking place behind the intake. This catchment is a protected area under the Environment Act 2003.

1.2 What does WTPs do?

8. Each WTP was designed to be gravity driven, which meant the processes involved is triggered by the force of the water as it flows downhill through the system. It collects and cleans water from the streams at each site, stores it and contributes to Rarotonga's water supply. The two main cleaners of the water are a chemical called poly aluminium chloride or PACl and the automatic valveless gravity

filter or AVG system. These are described in Figure 2 below.

1.3 Why do we need an operational environment management plan (OEMP)?

9. An OEMP is needed to make sure the plant is operating effectively at all times with insignificant impact on the environment. The plan will:

1. Manage and contain the sludge formed when the chemical PACl, a coagulant, is added to the water to clean it. A coagulant makes small particles of dirt (suspended materials and microbiological contamination) stick together and settle to the bottom of the settling tank forming the sludge; and
2. Manage hazards and risks to the Plant's operations caused by environmental conditions at each WTP.

10. The preparation of a OEMP was a recommendation by the Tonkin & Tylor EIA Report (July 2021) [1] focusing on the designed on-site management of residual materials from the settling tank and the AVG including discharges into the adjacent stream. The EIA considers the potential environmental impacts of the activity using PACl as a coagulant during the operation of each WTP as needing attention.

2. What do we know from the EIA Report about PACl?

11. PACl is an aluminium based coagulant, and therefore the potential environmental impacts are those associated with the designed use and release of aluminium into the environment.

12. There will be potential impact of the aluminium on freshwater ecology including degradation of water quality, riparian vegetation dieback, loss of aquatic flora, reduction in biodiversity and abundance of macroinvertebrate communities and an increase in susceptibility of fish to disease, predation and death and overall reduction in fish species and diversity and abundance.

13. The toxicity of PACl is related to the bioavailability of aluminium in the receiving environment. Aluminium bioavailability is directly correlated with the concentration of the actively toxic form of aluminium (Al^{3+}) in the discharged water.

14. Factors such as pH, dissolved organic carbon, temperature and hardness regulate the solubility of aluminium compounds in water.

15. The PH of each stream has the greatest influence on toxicity. The streams where all the intakes are has a measured PH value ranging from 7.01 to 7.61 PH units. The EIA report noted the neutral PH of the streams will result in low toxicity of any aluminium released into the stream from the sludge or scour ponds. At this PH there is low risk of aluminium bioaccumulation because of the solubility and therefore very low bioavailability of aluminium.

16. The EIA data on the hardness and dissolved organic carbon is not conclusive, despite this, the EIA Report concluded toxicity of the PACl discharge is considered low due to the pH of the streams. However, the EIA Report stated that there is still a limit to the amount of aluminium which can be discharged without causing a significant adverse impact. Aluminium lowers the pH causing the receiving environment to become more acidic over time.

17. The EIA Report further showed analysis of acceptable aluminium levels that can be tolerated in our streams by comparing the United States Environmental Protection Agency (USEPA) guidelines and the Australia & New Zealand Guidelines for Fresh & Marine Water guidelines (ANZECC) with same stream conditions as ours. The EIA report concluded the USEPA guideline of 55 µg/L

[1] [1] Treatment Plant On-site Discharge EIA Report, Tonkin & Tylor July 2021

was likely to be very conservative, and instead adopted the USEPA values. For the same pH levels as in our streams, the long-term/continuous concentration that could be tolerated in the streams conditions as ours is in the range of 290-630 µg/L ('criterion continuous concentration' or CCC). Based on the same stream conditions and pH levels, the maximum aluminium concentration is in the range of 570-1100 µg/L in the streams ('criterion maximum concentration' or CMC). In a worst-case scenario, where pH decreases within the receiving environment (below 6.5) the maximum acceptable concentration would decrease to 78 µg/L.

18. At each WTP, with normal flow of around 15L/sec, PACl with the concentration of 15µg/L is added, and when the turbidity increases, i.e., the flow of water into the WTP increases, resulting in increase in suspended solids, the amount of PACl release increases from 15µg /L to 30 µg/L. (Ross Dillon and Raututi Taringa)

3. What do we know about the environmental hazards and risks affecting each WTP?

19. Site visits and discussions with WTP and TTV personnel revealed there are common operational activities at each WTP site that has short- and long-term negative impact on the environment stemming from the WTP design. Such activities include: the use and disposal of PACl as discussed above. The removal of debris from behind the weir at each WTP intake; and falling trees around each WTP and long its access roads.

20. The removal of debris from behind the weir for some sites is a major undertaking for WTP operators especially at those sites where debris cannot be carried out with the use of machinery. Avanā has the dilemma of having the old water gallery right next to the intake weir making it not possible to remove debris by machinery. The Tōtokoˈitu intake and weir is about 500 meters into the catchment and accessible only by foot. Pāpua has to be monitored regularly to prevent debris falling over the weir and over the Papua Waterfall when debris has accumulated above capacity. This particular weir is a hazard and presents an added risk to local people and tourists swimming at the Pāpua waterfall.

21. Some WTP sites are more accessible to people as mentioned in section 1.1 and therefore would pose security risks to those WTPs. With the fencing that is provided for each component of the plants, security to the system from unauthorized people cannot be underestimated.

22. For Avatiu, Matavera and Taipara, the slow but continuous effect of stream scouring around the settling tank which could have been mitigated during the design phase is seen as a potential hazard in the future. This has the potential to threaten the stability of the structure of the settling tanks at those sites.

23. For some sites, that are physically impaired due to their location, whether it be the surrounding topography or the presence of large canopy cover, the dewatering process of sludge has become an issue. Such WTP sites as Avatiu, Turangi and Avanā have operational disadvantages to their dewatering process.

24. Landslips are predominant especially during the wet season at Tūpapa, Avanā, Ngātoe and Taipara. When it happens, these landslips can shut down access to these WTP sites. For Avanā, road conditions are impaired through washouts as a result of flooding. For Tūpapa, Ngātoe, and Taipara, the steep landscape and the weak and susceptible soil structure of the Pokoinu type is prone to erosion and land slips.

25. Tūpapa and Ngātoe have design and construction issue associated with the location of their sludge ponds due to limited land available for the WTP. This has, at times, resulted in surface runoff going directly into the sludge pond overflowing into the drainage system and into the stream. This happens especially during times of heavy rainfall at those two sites.

4. OEMP Setting:

4.1 PACl

26. On the basis of the designed use and release of aluminium into the environment and the EIA findings, an Environmental Permit was granted by the Rarotonga Environment Authority (REA) for the operation of the WTPs in November 2021 which noted that conditions of operation were to be in accordance with the recommendations laid out in the Onsite Discharges EIA. These conditions include environmental performance objectives pertaining to acceptable concentrations of dissolved aluminium within Rarotonga streams. The performance objectives adopted are the USEPA guideline values described above.

27. The EIA study presented a draft operational environmental monitoring plan (OEMP) framework to be further developed in an operational manual for each treatment site by TTV. The OEMP framework includes a detailed monitoring plan for measuring the extent of environmental impacts and/or success of mitigation measures in meeting the environmental performance objectives.

28. In short, the proposed monitoring plan included a layered approach to routine monitoring of the streams upstream of the WTP (baseline flows), immediately downstream of the discharge compared to the CMC value for dissolved aluminium of 570 µg/L in the receiving water) and approximately 200m downstream of discharge compared to the CCC value for dissolved aluminum of 290 µg/L in the receiving water.

29. Sampling of the supernatant outlet of the settling tank, the outlet from the AVG filter and in the ponds at each WTP was also required to understand aluminium fate through the treatment process, and confirm aluminium concentration at the discharge. No specific schedule was proposed for this. Protocols for sampling of the settling tank during maintenance operations involved sampling being undertaken half an hour after the midlevel drain has been opened with sampling locations proposed in the stream at the same locations as that for routine stream sampling around the plant as described above.

30. In the OEMP framework it is noted that should no exceedances be observed over a six-month period, then the frequency of water quality monitoring can be reduced to twice yearly - one wet season and one dry season environmental sampling run per year. This has been the case with over 4000 samples taken since commissioning and virtually none exceeding the performance objectives.

31. Dissolved aluminium testing has been reduced to monthly and will be further reduced to seasonally going forward. Corresponding tests for pH, turbidity (NTU) and conductivity are routinely taken with dissolved aluminium. Additional tests for total suspended solids were instituted as part of the extended permit conditions from 23 February 2023 to better gauge the potential carry over of solids into the streams in the supernatant discharges from the backwash and scour ponds. Other changes instituted during the extension period included:

- improved sampling methods involving replication and compositing for all water sampling,
- photographic evidence of stream bed status upstream and downstream at all WTPs,
- commitment to sampling benthic macroinvertebrates in streams on a seasonal basis (twice per year) upstream and downstream of WTPs,
- commitment to additional benthic invertebrate sampling sites to establish extent of impact zone if sludge carryover is occurring regularly.

32. On the storage and disposal of dried and wet PACl at the proposed site (Vairauara Section 88H, precautionary measures must be put in place to prevent discharge of material into the nearby stream until such time that tests conclude its safety for use whether it be for landfill cover or for agricultural purposes. In the case of the wet sludge disposal, pond construction and management at Vairauara 88H will need to follow what has been constructed at each WTP to ensure wet sludge do not end up in the stream.

4.2 Environmental Hazards and Risks

33. Relook at the PACl mixing area to prevent direct

release of PACl into the environment at each WTP.

34. The removal of debris from behind each weir has become an ongoing operational activity and for some sites as mentioned above this has to be done manually. It is noted that the debris is part of the natural process of the stream flow. Considerations to release the debris over the weir during their removal should be explored.

35. It is noted further unavoidable minor slips in the catchment due to the effect of falling trees caused by invasive species such as pīpī-vai, rau-māniota, kākā-enua will continue. This will continue to contribute to the problem of debris accumulation at the weir and supply of suspended solids to each WTP especially during heavy rainfall.

36. Sustaining a good relationship with contractors engaged to keep the outlet drainage areas at each sludge pond and at the marked 200meter point downstream clear of weeds and vegetation cover to allow sampling and for observational purposes to be effectively carried out.

37. Similarly, such relationships should be maintained with Contractors engaged in the clearing of access to WTPs affected by land slips and road washouts, and removal of sludge from Turangi to Pāpua. The maintenance of access roads so TTV vehicles continue to effectively access each WTP, and to keep the plant clear of any potential hazard from falling trees are very important.

5. What is our Plan?

5.1 Our aim is:

38. To manage the operations of each WTP in containing the effects of PACl on the immediate and surrounding environment, and any environmental risks affecting the ability of each plant to operate effectively.

5.2 We will:

39. Prevent the release of PACl into the environment to limit the amount of aluminum entering the environment at each WTP and avoid long term significant adverse impact on the immediate and surrounding environment.

40. In case of emergency hazards and risks in the containment of PACl at each WTP, keep the acceptable maximum levels of aluminum concentrations in the environment to below 55 µg/L and mitigate risk impacting each plant from the environment in an environmentally sustainable manner.

6. Implementing the Plan

41. The plan has two components, the first, to address the risk of PACl on the immediate and surrounding environment. This is provided in sections 6.1 – 6.9 below and in Appendix 2 (Operational Management Plan for hazards and risks of PACl).

42. The second component, to address the risk of identified environmental hazards that may have potential negative impact on each WTP. These are provided for each OEMP as supplementary to this report and include recommendations for improving each WTP.

43. It is to be noted the PACl plan is the same for all WTPs and will not be repeated in the OEMPs in the supplementary plans and the EIPs (if one is to be prepared for each WTP).

44. Risk assessment is based on the information provided in sections 2 and 3 and the interview information, site visits and notes with Mr. Ross Dillon, Manager of Treatment division at TTV and Mr. Raututi Taringa, Supervisor of Treatment division at TTV. The methodology used is described in Tables 1 and 2 in Appendix 1.

6.1 Environmental Management Activities and Controls

46. Mitigating strategies identified in the risk assessment apply to each of the 10 WTPs and in their respective operational environmental management plans (OEMP) and for Turangi and

Avanā the mitigating strategies informs their environmental improvement plans (EIP).

6.2 Environmental Inspection and Monitoring Plans

47. Environmental inspection and monitoring plans for the key risk areas identified in the risk assessment are provided for each OEMP and in the case of Turangi and Avanā this is also provided in their EIP. Checklists forms based on the monitoring plans for PACl and for environmental hazards will be prepared and used in day-to-day environmental management of each WTP.

6.3 Environmental Performance Objectives

48. As set out in Section 9.3.2 of the EIA Report, trigger values for acceptable concentrations of aluminum within Rarotonga streams have been derived from USEPA guidance. Based on these values, the following environmental performance objectives are proposed:

1. A continuous concentration (CCC) of no more than 290µg/L for streams were observed pH is 7.0-7.6,
2. A maximum concentration (CMC) of no more than 570µg/L for streams where observed pH is 7.0-7.6,
3. Where pH decreases within the receiving environment (below 6.5), the maximum acceptable concentration would decrease to 78µg/L.

49. These objectives are incorporated into the monitoring at each of the WTP. Sludge removed from each of the treatment plant sites will be managed appropriately.

6.4 Monitoring Plan

50. The proposed monitoring plan including performance criteria for measuring the extent of environmental impacts, and/or the success of mitigation measures, is set out below. This monitoring plan is an update of the original monitoring plan proposed in the EIA and takes account of a review of monitoring data collected during the first year of operation along with the results of an environmental audit of the facilities undertaken by NES in March 2023. It also reflects the WTP On site discharges permit renewal conditions of 25 May 2023.

6.4.1 Discharge Standards

51. The maximum discharge levels outlined below shall apply to all discharges from the water treatment plants (the supernatant discharges from sedimentation tank, backwash ponds, scour ponds and sludge ponds) into adjacent water courses. NES must be advised within 7 days of receiving laboratory results when these maxima or ranges are exceeded during monitoring efforts:

- Dissolved Aluminium concentrations shall not exceed the Criterion Maximum Concentration (CMC) value of 750µg/L where the pH is 7 or greater. Where the pH is below 7, the CMC will be 78 µg/L.
- pH ranges from 7.0 to 8.5.
- Turbidity less 10 NTU.
- Suspended Solids less than 30 mg/L.
- Electrical Conductivity less than 1,000 µS/cm.

48. Based on this discharge monitoring, TTV will assess the relationship between turbidity and suspended solids and determine if it is stable and statistically valid. If so, NES may discontinue the need for SS monitoring.

6.4.2 Ambient Monitoring Requirements

52. Monitoring shall be conducted in the streams adjacent to the WTPs four times per year or quarterly at the locations specified in Section 10.3 1a, i, i, ii and iii of the EIA. Samples to be tested for dissolved Aluminum, turbidity, pH, Suspended Solids and electrical conductivity. At the same time an estimate of stream level and flow rate should be undertaken.

53. Inspection and photographic surveys of the stream bed shall be undertaken to assess the presence or otherwise of any sludge deposition areas in the annual low/no flow sampling activities for up to 200m downstream of all WTPs discharge locations, at reasonably accessible points. Photographs shall be sent to NES within one week of being taken and will be accompanied by a description of actions taken to reduce any sludge

deposition in the stream bed as may be necessary.

54. Benthic macroinvertebrates shall be sampled in all receiving streams and subsequently analysed on a quarterly basis. Samples will be collected upstream and downstream of discharge points at locations suitable for benthic sampling, but as close as possible to the discharge locations. Should benthic monitoring indicate significant environmental impact on the streams from WTP discharges, NES shall be notified within 7 days, and an action plan proposed by TTV to mitigate the impact.

55. Freshwater prawns immediately downstream of WTPs discharges are to be tested for aluminum levels. At least 4 tests should be conducted during the permit period. NES shall be notified of the results of the tests within one week of TTV receiving the testing results.

6.4.3 Discharge Monitoring Requirements

56. Monitoring of supernatant discharges from sedimentation tanks, backwash and scour ponds shall be conducted every month[2] for dissolved Aluminum, turbidity, pH, Suspended Solids and electrical conductivity.

6.4.4 Methodology for Sampling and Analysis

57. Ambient water sampling will be replicated as follows: a sample is collected every minute over a period of three minutes, and the three subsamples combined to provide the overall sample from which the individual sample bottles for the various tests will be filled.

58. Discharge samples from the sedimentation tanks will be collected at 1-minute intervals during the entire period of supernatant discharges and then composited.

59. Discharges from ponds will be collected at 1-minute intervals during the entire period of supernatant discharges from the ponds and then composited.

60. Analytical methods will conform to the American Public Health Association (APHA) "Standard Methods for the Examination of Water and Wastewater" or equivalent.

61. Training of TTV staff will be provided in respect of benthic macroinvertebrate sampling, identification and analysis methods prior to the commencement of this monitoring activity.

62. There shall be collaboration developed with the MMR water quality and inshore fisheries staff to ensure consistency in the methodologies developed and the sharing of data for their contribution.

6.5 Environmental Management Structure and Responsibilities

63. The TTV staff responsible for operation and environmental management of the WTPs comprises a team of approximately 12 staff including a Manager, Supervisor and 10 operators. The responsibilities of the management team are described below

Treatment Team Manager

- Leads the WTP operators,
- ensure SOP are followed and new ones added when required,
- trouble shoots WTP issues and has a good understanding of Drinking Water Series (DWS).
- Oversee training of staff in all aspects of their work.

Supervisor

- Manages operators and day to day operations; and
- Assist in the training of current and new operators.

Senior Leadership Team

- Acts as stand-in supervisor of issues as well as mentoring operators and new staff.

Operator

- Undertakes the day-to-day operations).

Trainee Operator

- (Do the day-to-day operations); and Operator on trial (new operators learning the system.

[2] A recommendation by both Ross Dillon and Raututi Taringa to keep the activity be part of the ongoing work of the operators. This will make sure the practice is not forgotten.

6.5.1 Environmental Training

64. For capacity building of operators to carry out their work including sampling, testing and understanding the science behind the function of each WTP, all operators must agree to do formal training including pursuing online training courses on water treatment.

65. A National Certificate in Water Treatment qualification through the Tepukenga Trade School in New Zealand, a Level 4 course model, has been arranged for WTP operators. The 12–20-month course provides once a monthly online tutorial once the operator is registered. To be eligible, level 2 or 3 NCEA is required with sound science, physics and mathematics background. The course provides operators a good understanding of the science behind the water treatment process which include the use of PACl.

66. Under the umbrella of a qualified laboratory Manager, TTV is able to provide training on water quality testing including the test for aluminium contamination. All staff in this area are trained after signing their respective employment contracts.

6.5.2 Emergency Contacts and Response

67. In the case of emergency situations arising at each of the WTPs and its substations, the Chief Executive Officer (CEO) is the senior responder. The CEO is contactable in-house through TTV communications.

68. In the event of an emergency at any of the TTV WTPs, the operations personnel will report directly to their supervisor who is the first point of contact for the operations team.

69. A safety incident that requires medical help will be managed like any accident. The staff is provided with all the medical support as quickly as possible, and movement and communications will be documented. There are in-house incident reporting protocols to follow. In an accident the CEO is informed as soon as practicable as the priority is the injured.

70. An environmental breach (Cyclone, Flood or strong wind damage at the WTP causing a breach) will be reported through the Supervisor and onto the CEO. The CEO will appoint a manager to oversee cleanup operations (machinery, ICI, etc.,) and manage the incident. The NES and Public Health will be informed. CEO will be kept informed on progress as he/she will also be informing the TTV Board Chairman. The media will be managed by the Relations Manager of TTV.

6.6 Approval and Licensing Requirements

71. Operation of the WTPs is subject to granting of a project permit under the Environment Act 2003 which provides for the protection, conservation and management of the environment in a sustainable manner. The Act provides the legal framework for assessing the environmental impacts of development including the requirement for a project permit to be obtained subject to submission and approval of an EIA.

72. A Project Permit was issued on 25 November 2021 following submission of the permit application by TTV to the Rarotonga Environment Authority[3] (REA) with an accompanying EIA[4] as required under Section 36 of the Environment Act 2003. The Project Permit was valid for a period of 12 months. A Project Permit for a Temporary Sludge Storage Facility (PP # 2021/019RAR) and Water Treatment Plants for all Intakes in Rarotonga (PP#2021/0004RAR) were issued on 25 November 2021 following approval of the EIA for that component.[5] In addition a Project Permit (PP# 2022/05RAR) for TTV's proposed Sludge Disposal Facility at Land Vairauara Lot 88H Arorangi District was issued on 18 April 2022 and is currently subject to renewal.

[3] Permitting Authority to determine applications for permits mandated under S.12 of Environment Act 2003.

[4] Water Treatment Plants On-site Discharge EIA (Tonkin & Taylor International Ltd, May 2021)

[5] Temporary Sludge Storage at Rarotonga Waste Facility EIA (Tonkin & Taylor International Ltd Oct 2021)

73. The On-site Discharges and Temporary Sludge storage facility permits have been renewed for a further 12 months from 25 May 2023 following two three-month extensions of the original permits.

6.7 Reporting

74. TTV produces an annual report summarizing the monitoring and sampling undertaken, critical analysis of compliance and potential adverse environmental effects and recommendations for changes to future permit conditions. The annual report will be issued internally to TTV and NES.

75. The NES can review and change the conditions of the consent annually.

76. During the operation of each of the WTP the TTV Team will undertake an ongoing 3 monthly compliance audit and also after major flood to ensure the commitments contained in this OEMP and its Supplementary OEMPs are being met.

77. A compliance report will be prepared that:

- Summarizes compliance with the OEMP conditions
- Provides details of any incidents of non-compliance with the OEMP conditions as well as corrective actions implemented.

78. Describe any complaints received during this time, if any.

79. All compliance report and records will be kept by TTV Team and available for inspection by the NES.

6.8 Grievance Redress Mechanism (complaints management)

80. In view of the strong concern shown by the members of the public, as in landowners, and NGOs, a Grievance Redress Mechanism (GRM) will be implemented to receive and facilitate the resolution of concerns, complaints and grievances about the WTP's environmental and social performance. When and where the need arises, this mechanism will be used for addressing any complaints that may arise during the ongoing operation of each WTP

81. Concerns, complaints and grievances will be directed to the TTV Relations Manager (RM). Within the TTV office the RM and Manager of the Treatment Division will be the focal point to receive, record, review, investigate and address the related concerns in coordination with the relevant stakeholder(s). A complaint register will be maintained that will record the date, details, and nature of each complaint, the name of the complainant, and the date and actions taken as a result of the follow-up investigation. The register will also cross reference any non-compliance report and or corrective action report or other relevant documentation.

82. At each WTP a sign will be placed providing the public with updated information about the operation of the plant and summarizing the grievance redress mechanism process including contact details of relevant persons.

Table 1 below provide the summarized GRM process.

Table 1 - Grievance Process for complaints

Stage	Process	Duration
1	Any concerned person (organization, traditional leader, elected person or individual) who takes grievance to PM (contactable via TTV Office)	Any time
2	PMU reviews and finds solution to th problem in consultation with the complainant and relevant agencies	2 weeks
3	PMU reports back an outcome to people who submitted the Grievance	1 week
If unresolved or not satisfied with the outcome at PMU level		
4	Concerned party takes grievance to T EO and NES)	Within two weeks of receip of decision in step 3.
5	National Agency reviews and finds a solution which may include recommendation of dispute resolutio including an appropriate body to oversee.	4 weeks
6	National Agency reports back to the complainant.	1 week
If unresolved or at any stage if concerned party is not satisfied		
Complainant can take the matter to appropriate Court.		As per the judiciary syster

6.9 Stakeholders

83. Those involved in the implementation of this plan include TTV staff, NES, MMR, other relevant Government Agencies, Water Catchment Committees and their respective members,

Contractors and members of the Public and other organizations.

7. Recommendations

84. It is recommended that the activities of the two components of the implementation plan and listed below are carried out according to plan:

1. Address the risk of PACl on the environment as provided in sections 6.1 – 6.9 of this report; and

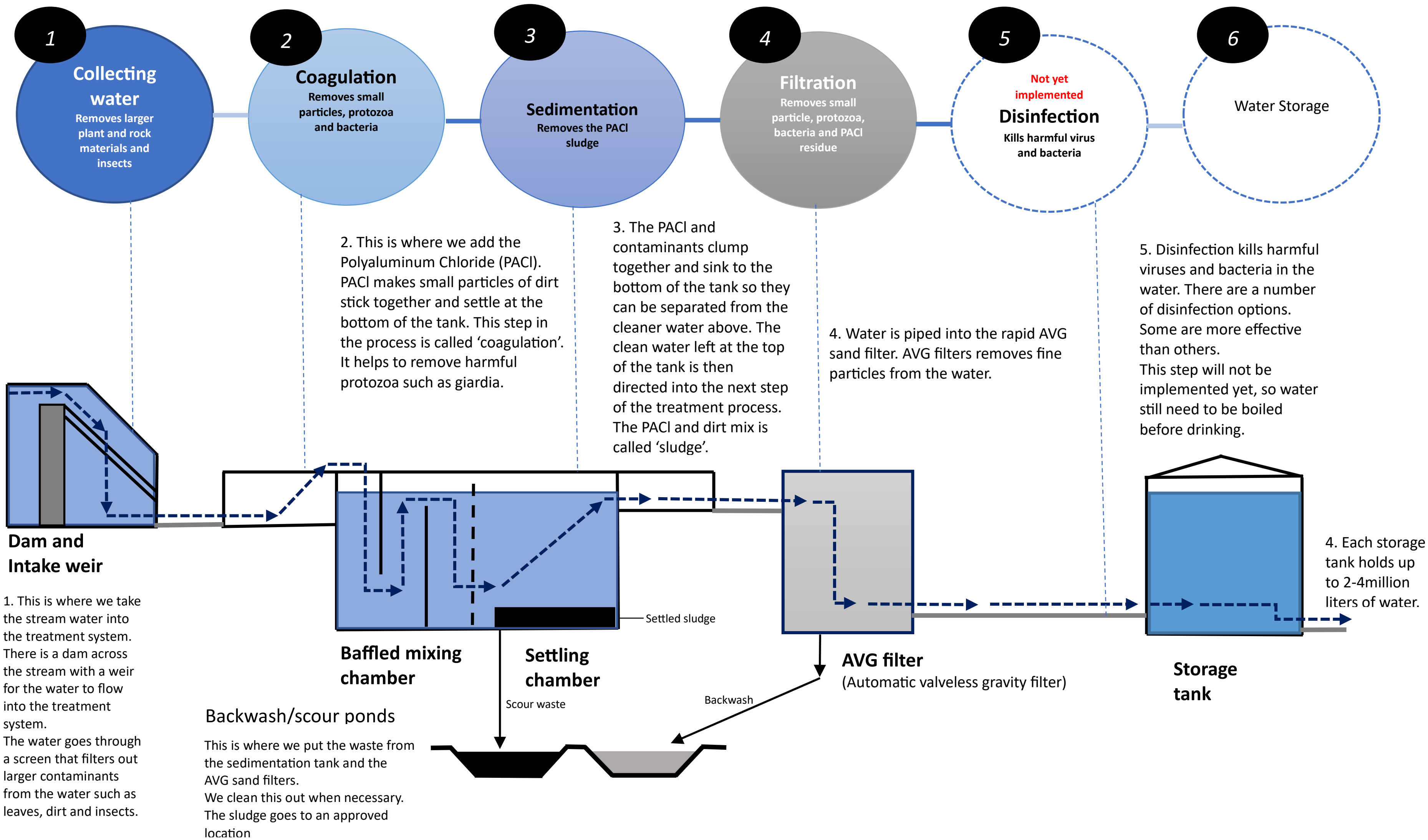
2. Address the environmental risks provided in the OEMPs attached to this report as supplementary documents for each WTP.

85. To support analysis of future impacts on the surrounding environment namely the stream and marine environment, it is strongly recommended that all data collected during the monitoring process are appropriately archived or shared with the relevant and accredited competent authorities for their future use. This will ensure accumulative effect of the use and disposal of PACl is properly monitored.

86. Further, as the WTP system relying on gravity and the lack of electricity at each site, where all procedures are manual or gravity driven such as the use of float valves to control water entering the settling tanks and the PACl entering the Settling tanks, improvement of the system would at this time focus on capacity building in the areas of personnel and equipment. It is therefore recommended that capacity building in these two areas be strengthened until such time the system can be semi and fully automated.

87. This report and its supplementary documents are to be reviewed every three years.

Figure 2 - How the Water Treatment Plant work (Source: TTV sign boards at each WTP)



Appendix 1

Risk Assessment Methodology Used

The assessment of risks involved for each hazard is provided below in Tables 1 and 2.

Table 2 - Level of risk impact and probability

Risk Criteria	Definition of Rating	Score
Impact (I)	**A:** Extent – The area over which the impact will be experienced	Local = 1; Island = 2; and National = 3
	B: Intensity – The magnitude of the impact, i.e., whether the impact will result in minor, moderate, major or catastrophic environmental, social and economic (including human health) changes	Low = 1; Medium = 2; and High = 3
	C: Duration – The time frame over which the impact will be experienced and its reversibility.	Short Term – 1; Mid Term – 2; and Long Term – 3
Impact Consequences (Combined Score): Minor 3 – 4; Moderate 5 – 6; Major 7 – 8; Massive 9 – 10.		
Probability (P) – Likelihood of the impact occurring	Improbable - Unlikely to occur during project lifetime	1
	Possible - May occur during project lifetime 20%-60% chance of occurring	2
	Probable - Likely to occur during the project lifetime >60-90% chance of occurring	3
	Highly probable - Highly likely to occur, or likely to occur more than once during project lifetime	4

Table 3 Matrix showing overall significance of the impact as a combination of the consequences and probability rating

		Probability of Occurrence			
		Improbable	Possible	Probable	Highly Probable
Consequences of Impact	Minor	Very Low	Very Low	Low	Low
	Moderate	Low	Low	Medium	Medium
	Major	Medium	Medium	High	High
	Catastrophic	High	High	Very High	Very High

Appendix 2

AP 2.1 Hazards and Risks Identified for PACl and their management

All hazards and risks are identified and using the risk assessment methodology attached in Appendix 1. The meaning of the color code: Red = Very High Risk, Brown = High Risk, Yellow = Medium Risk, Blue = Low Risk and Green = Very Low Risk.

Table 4 - Hazards and Risks Identified for PACl and their management

Main Components of the plant	**Hazards and Risks** (What they are and level of risk)	**Potential Impact**	**Mitigation Strategy**	**Monitoring Parameter**	**Monitoring Frequency**	**Responsibility**	**Staffing and equipment requirement**	**Oversight**
1. PACl Mixing	1.1 PACl Mixing Shed – Design flaw in the outflow pipe. IC = Major P = Medium	- Unable to contain spillage of PACl during manual mixing. - PACl is released onto the floor with no bunding wall and into the environment.	**Short term** + Hose down spill using supernatant water from the ST to dilute and disperse spill. **Long term** + Redesign outflow pipe to allow trapping of spill when/if it happens. + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report. + Explore the use of mechanical means for PACl mixing.	- Spill - Acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream.	+ While mixing. + when the mixed PACl in the tank is 20-30% full. + When there is medium to high rainfall in the area PACl level goes down. + Carry out sampling and testing once a month and after heavy rainfall.	+ Operator (s)	+ Operator (s) x2 + And if there is a shortage of staff this can be done by one operator.	+ Supervisor
	1.2 PACl Storage tank – Design flaw in the	- Unable to see the top part of the tank, it occasionally spills if	**Short term** + Require 2 x operators during the	- Spill - Acceptable CCC and CMC	+ While topping up the storage tank.	+ Operator (s)	+ Operator (s) x4	+ Supervisor

Main Components of the plant	Hazards and Risks (What they are and level of risk)	Potential Impact	Mitigation Strategy	Monitoring Parameter	Monitoring Frequency	Responsibility	Staffing and equipment requirement	Oversight
	inflow connection into the PACl storage tank. IC = Major P = Medium	operator guess measures are inaccurate. - PACl is released onto the base of the platform and into the environment.	PACl mixing, one at the PACl mixing shed and one at the PACl storage tank to keep an eye on the tank gauge to make sure there is no spillage. + Review and improve SOP. **Long term** + Redesign the storage tank so the operator has a way of knowing where the PACl level is without guessing its position. + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.	aluminum concentrations in µg/L in the receiving water 200m downstream.	+ need 4 operators to make the reading accurate.			
	1.3 Design flaw of the outflow pipe to the PACl header tank. IC = Major P = Medium	- PACl is released into an uncontained area when unblocking crystallized PACl cause by high (warm) temperatures. - PACl is released into the environment.	**Short term** + Using supernatant water from the ST hose down spill to dilute and disperse after release through bottom valve onto concrete platform. **Long term** + Redesign outflow pipe to the PACL Header tank to allow trapping of	- PACl crystallization. - Spill - Acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream.	+ Daily checking + Crystal formation in the outflow pipe. + Carry out sampling and testing the stream water once a month and after Heavy rainfall.	+ Operator (s)	+ Operator (s) X2 + 4 required to make the reading accurate.	+ Supervisor

Main Components of the plant	Hazards and Risks (What they are and level of risk)	Potential Impact	Mitigation Strategy	Monitoring Parameter	Monitoring Frequency	Responsibility	Staffing and equipment requirement	Oversight
			discharged PACl while clearing crystallized PACl. + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.					
	1.4 PACl Header tank – Risk of float valve arm breaking due to wear and tear, a design flaw. IC = Major P = Medium	- Raw PACl overflow at the header tank. - Spilling PACl into the environment.	**Short term** + Make sure PACl header tank lid is tightly closed. + Daily checking of float valve. **Long term** + Look into ways to ensure this does not happen + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.	- Condition of PACl Header tank lid. - Condition of float valve. - Spill - Acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream.	+ Daily check + Carry out sampling and testing the stream water once a month and after heavy rainfall.	+ Operator (s)	+ Operator (s) X2	+ Supervisor
2. Coagulation Chamber	2.1 Rapid Mixing Chamber – Risk of float valve (dozing leaver)	- PACl is discharged into the stream.	**Short term** + Daily check by operators. **Long term** + Redesign the position of the shut off valve to a calmer area where the	- Heavy Rainfall. - PACl level in the PACl storage tank (going down fast). - System backing up.	+ Daily check + Carry out sampling and testing the stream water once a month and after heavy rainfall.	+ Operator (s)	+ Operator (s) X2	+ Supervisor

Main Components of the plant	Hazards and Risks (What they are and level of risk)	Potential Impact	Mitigation Strategy	Monitoring Parameter	Monitoring Frequency	Responsibility	Staffing and equipment requirement	Oversight
	breaking[6]., a design flaw. IC = Major P = Medium		vibration is cancelled out. + Design a system to detect changes in the WTP that this will happened so it can be prevented. + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.	- Acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream.				
	2.2 Baffle Mixing Chamber – Health and Safety of Operators., a design flaw. IC = Minor P = Low	- Operators falling into the chamber during cleaning and scraping algal growth.	+ Improve and maintain Health and Safety Protocol as per SOP.	- PPE quality. - Operator health.	+ Daily check + PPE stock	+ Operator (s)	+ Operator (s) x2 + Optimum performance PPE.	+ Supervisor
3. Sedimentation Chamber	3.1 Settling Tank – Potential for release of sludge at mid-level drain of ST	- Sludge is released into the stream at the mid-level drain.	**Short term** + Ensure, at all times, the sludge is below the mid-level	- Sludge level. - Acceptable CCC and CMC aluminum concentrations	+ Daily check (when sludge level by visual	+ Operator (s)	+ Operators (s) x2, the more the better.	+ Supervisor

[6] When the settling tank backs up, i.e., when the reservoir is full, the water flow into the reservoir automatically shut off at the pressure return valve (PRV), water flow into the AVG will also automatically shut off at the PRV before AVG due to water build up in the filtering system, this will lead to building water pressure in the ST forcing the float valve at the rapid mixing chamber to shut the incoming water off by raising the release valve so water is diverted to the stream outflow. The vibration caused by the incoming water at the rapid mixing chamber can cause the ball valve arm to break. When this happens PACl will be released into the stream. It is therefore important that daily checks are made using the checklist data form to inform the team ahead of time of possible back up incidents. There is no part on the island and the TTV uses home-made part made from PVC. This has happened in some of the WTP during times of heavy rain and heavy flow. (Source: Mr. Ross Dillon and Mr. Raututi Taringa of the TTV Treatment Division)

Main Components of the plant	**Hazards and Risks** (What they are and level of risk)	Potential Impact	Mitigation Strategy	Monitoring Parameter	Monitoring Frequency	Responsibility	Staffing and equipment requirement	Oversight
	during desludging and maintenance work. IC = Major P = Medium		drain before letting out excess[7] . + Supernatant water above the mid-level drain is pumped before discharge[8]. + Review SOP to improve efficiency of operation. **Long term** + Design a system to remove reliance on human judgement when estimating sludge level below the mid-way drain pipe. + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.	in µg/L in the receiving water 200m downstream.	inspection is up to 60%)[9]. + Carry out sampling and testing the stream water once a month and after heavy rainfall.			
	3.2 Launder Champer – Leaves,	- Contaminate supernatant water going to the AVG.	**Short term** + Daily check **Long term**	- Leaves, branches and dead animals.	+ Daily check	+ Operator (s)	+ Operator (s) X2	+ Supervisor

[7] Supernatant water is either released into the stream or pumped into the AVG during desludging. It is important for the operators to make sure that the sludge level is well below the mid-level drain before the drain is opened to release supernatant water into the stream. If the sludge level is too close to the mid-level drain it can suck out the sludge and PACl is released into the stream. Sometimes sludge is raked across the ST to lower the level or to even out the sludge level. Sludge level is higher closer to the diffusing wall after the baffle chamber. (Source: Mr. Ross Dillon and Mr. Raututi Taringa of the TTV Treatment Division)

[8] Turangi and Avana can be desludged anytime when level is reached as they have two reservoir each so they can both keep contributing to the grid. (Source: Mr. Ross Dillon and Mr. Raututi Taringa of the TTV Treatment Division)

[9] Visual inspection by estimating sludge level from between the bottom and the mid-way drain level. (Source: Mr. Ross Dillon and Mr. Raututi Taringa of the TTV Treatment Division)

Main Components of the plant	Hazards and Risks (What they are and level of risk)	Potential Impact	Mitigation Strategy	Monitoring Parameter	Monitoring Frequency	Responsibility	Staffing and equipment requirement	Oversight
	branches, dead animals falling from above. IC = Moderate P = Low	+ Remove branches, dead animals and other rubbish.	+ Remove overhanging and close by canopy trees.					
	3.3 Vortex breaker – prevent air entering the AVG system. IC = Moderate P = Low	+ Removes small leaves and plant detritus from out-going water to AVG. + Reduces air flow into the AVG.	**Short term** + Daily check **Long term** + Require screen plate on the top to make it easier to clean smaller rubbish that may enter the AVG.	- Functionality	+ Daily check	+ Operator (s)	+ Operator (s)	+ Supervisor
4. Scour waste (sludge pond)	4.1 Surface water drainage – Risk of flooding the sludge pond and sludge ending up in the stream, a design flaw. IC = Moderate P = Low (Medium for Tupapa and Ngatoe)	- Impact Tupapa and Ngatoe sludge ponds as they are near the side of the mountain, there is potential for surface water to flow directly into the sludge pond.	**Short term** +Daily check **Long term** + Ensure the designed and constructed drainage continue to drain surface water away from the sludge ponds and strengthen the drainage through the installation of an earth bund or drain upslope of the ponds or open drains + Consider use of vetiver grass to protect the slope and sludge pond drainage.	- Water flowing into the sludge pond.	+ Daily visual check, especially during rainy days and days of heavy rain.	+ Engage contractor to do emergency work when required.	+ Operator (s) X2 + Supervisor	+ Supervisor

Main Components of the plant	**Hazards and Risks** (What they are and level of risk)	Potential Impact	Mitigation Strategy	Monitoring Parameter	Monitoring Frequency	Responsibility	Staffing and equipment requirement	Oversight
	4.2 Stream discharge outlet – Overgrown and hidden, a design flaw. IC = Moderate P = Medium	- Operators are unable to see the nature of what is discharged via the decant outlet. - Drainage outlet is inaccessible.	+ Keep the stream side of the sludge pond clear of weeds and visible. + Engage contractors.	- Weed level (overgrowth). - Visibility	+ Daily check	+ Supervisor engaging Contractors.	+ Operator (s) x2 and Supervisor	+ Supervisor
	4.3 Dewater of sludge (e.g., Turangi), a design flaw.	- Takes longer for the sludge to dry and it cannot cater for the ongoing operation of the plant. - sludge spill over into the drainage around the ponds and into the stream,	+ Access to sun drying and being protected by the tree environment and topography makes it difficult to improve the drying process, remove wet sludge to other sites to be dried and processed	- pond levels	+ Daily check	+ Supervisor engaging Contractors	+ Operator (s) x2 and Supervisor	+ Supervisor
	4.4 Decant operation – Discharge[10] of PACl into the stream, a design flaw. IC = Moderate P = Medium	- Possible discharge of sludge from decant pipe into the stream. - Can cause overflow if decants are damaged through flooding or blockage of holes due to build up of algae and grass cuttings. - Can cause suspended sediments entrained in	**Short term** + Rope tied to the decant arm to keep the decant from sucking in sludge into the draining pipe. + delaying the decant process until a clear supernatant has formed in the ponds	- Quality of supernatant water discharged through the decant drain. - Acceptable CCC and CMC aluminum concentrations in µg/L in the receiving	+ Every day after desludging is completed until sludge is dried. + Carry out sampling and testing the stream water once a month and after heavy rainfall.	+ Operator (s)	Operator (s) x2 and Supervisor[11].	+ Supervisor

[10] When decant is on or in the sludge supernatant water is attracted to the perforated end of the decant and water is drained out and discharged into the stream. So, the idea is to keep the decant arm just above the sludge level so the water draining out into the stream has minimal PACl content. (Source: Mr. Ross Dillon and Mr. Raututi Taringa of the TTV Treatment Division)

[11] To reduce PACl discharge into the stream, it is preferrable for someone to keep an eye out to make sure, minimum PACl enters the discharged supernatant. (Source: Mr. Ross Dillon and Mr. Raututi Taringa of the TTV Treatment Division)

Main Components of the plant	Hazards and Risks (What they are and level of risk)	Potential Impact	Mitigation Strategy	Monitoring Parameter	Monitoring Frequency	Responsibility	Staffing and equipment requirement	Oversight
		the supernatant going out into the stream.	+ Ensure that there is sufficient ullage within all ponds to retain discharges of scour or backwash to allow supernatant formation, prior to lowering that the decant arm and starting releases + Daily checking **Long term** Ensuring SOPs for sludge management are followed including efficient functioning of decanters. + Install sludge pond inlet baffles will help reduce suspended solids entrainment in supernatant discharges thereby minimizing dissolved PACl discharges to streams. + Consider installing appropriate baffles to prevent the resuspension of the sludge blanket underlying the supernatant during the high flows occurring during backwash events.	water 200m downstream.				

Main Components of the plant	Hazards and Risks (What they are and level of risk)	Potential Impact	Mitigation Strategy	Monitoring Parameter	Monitoring Frequency	Responsibility	Staffing and equipment requirement	Oversight
			+ Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.					
	4.4 Dewatered sludge entering the stream while being moved to drying beds. IC = Minor P = Very Low	- Semi-dried sludge on the drying bed ready for removal falling into the stream or drainage.	**Short term** + Careful moving of dewatered sludge onto the drying bed. + Careful turning of dried sludge to prevent it from falling into the stream or drainage. **Long term** + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.	- Dewatered sludge on the drying bed (volume). - Acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream.	+ Daily check + Carry out sampling and testing the stream water once a month and after heavy rainfall during the wet season.	+ Operator (s) x2 and Supervisor.	+ Contractor to removed dewatered sludge onto the drying bed.	+ Supervisor
	4.5 Removal – No risk	No impact	Nil	Nil	Nil	Contractor	Contractor	Supervisor

Main Components of the plant	Hazards and Risks (What they are and level of risk)	Potential Impact	Mitigation Strategy	Monitoring Parameter	Monitoring Frequency	Responsibility	Staffing and equipment requirement	Oversight
5. Filtration – AVG	5.1 High level of PACl and Rubbish in supernatant water, i.e., process in ST backwash has failed. IC = Minor P = Low	- AVG will undergo more frequent backwash causing backwash pond to overflow into the stream. - AVG become ineffective, sand filter in compartment #1 will require replacement sooner than 10 years.	+ Ensure all procedures from water intake to ST are followed. As per developed SOP. + Monitor aluminum concentration levels (sampling and testing water at the drainage outlet) to monitor effectiveness of AVG and WTP.	- Frequency of backwash - Acceptable CCC and CMC aluminum concentrations in µg/L from the samples.	+ Daily check + Carry out sampling and testing water from the drainage outlet once a month and after heavy rainfall.	+ Operator (s)	Operator (s) x2	+ Manager + Supervisor
	5.2 Increase backwash volume in the backwash pond entering the stream, a design flaw. IC = Minor P = Low	- PACl enters the stream and increase aluminum concentrations in the stream.	+ AS above + Considering extending backwash pond to link to prepared wetland taro ponds in Turangi and Avana. + Monitor aluminum concentration levels (sampling and testing water at the drainage outlet) to monitor effectiveness of AVG and WTP.	- Frequency of backwash. - Acceptable CCC and CMC aluminum concentrations in µg/L from the samples.	+ Daily check + Carry out sampling and testing water from the drainage outlet once a month and after heavy rainfall.	Operator (s)	Operator (s) x2	+ Manager + Supervisor
	5.3 Air expeller - Residual air in the AVG, a design flaw. IC = Minor P = Low	- Potential to upset the filtering and backwash process.	+ Make sure air expeller is functional. + Review SOP to improve efficiency.	- Presence of air in the system	+ Daily check	+ Operator (s)	+ Operator (s) x2	+ Supervisor
6. Backwash sludge pond	6.1 Surface water drainage – Risk of flooding	- Impact Tupapa and Ngatoe sludge ponds as	**Short term** +Daily check **Long term**	- Water flowing into	+ Daily visual check, especially during rainy days	+ Engage contractor to do emergency	+ Operator (s) X2 + Supervisor	+ Supervisor

Main Components of the plant	**Hazards and Risks** (What they are and level of risk)	**Potential Impact**	**Mitigation Strategy**	**Monitoring Parameter**	**Monitoring Frequency**	**Responsibility**	**Staffing and equipment requirement**	**Oversight**
	the backwash pond and backwash ending up in the stream, a design flaw. IC = Moderate P = Low (Medium for Tupapa and Ngatoe)	they are near the side of the mountain. - There is potential for surface water to flow directly into the sludge pond. - Pump backwash into the sludge pond in an emergency situation.	+ Ensure the designed and constructed drainage continue to drain surface water away from the sludge ponds and strengthen the drainage through the installation of an earth bund or drain upslope of the ponds or open drains + Consider use of vetiver grass to protect the slope and sludge pond drainage for some WTPs.	the sludge pond.	and days of heavy rain.	work when required.		
	6.2 Stream discharge outlet – Overgrown and hidden, a design flaw. IC = Moderate P = Medium	- Operators are unable to see the nature of what is discharged via the decant outlet. - Drainage outlet is inaccessible.	+ Keep the stream side of the sludge pond clear of weeds and visible. + Engage contractors	- Weed level (overgrowth). - Visibility	+ Daily check	+ Supervisor engaging Contractors.	+ Operator (s) x2 and Supervisor	+ Supervisor
	6.3 Dewater of sludge (e.g., Turangi), a design flaw.	- Takes longer for the sludge to dry and it cannot cater for the ongoing operation of the plant. - sludge spill over into the drainage around the ponds and into the stream,	+ Access to sun drying and being protected by the tree environment and topography makes it difficult to improve the drying process, remove wet sludge to other sites	- pond levels	+ Daily check	+ Supervisor engaging Contractors	+ Operator (s) x2 and Supervisor	+ Supervisor

Main Components of the plant	Hazards and Risks (What they are and level of risk)	Potential Impact	Mitigation Strategy	Monitoring Parameter	Monitoring Frequency	Responsibility	Staffing and equipment requirement	Oversight
			to be dried and processed					
	6.4 Decant operation – Discharge[12] of PACl into the stream. IC = Moderate P = Medium	- Possible discharge of sludge from decant pipe into the stream. - Can cause overflow if decants are damaged through flooding or blockage of holes due to build up of algae and grass cuttings. - Can cause suspended sediments entrained in the supernatant going out into the stream.	**Short term** + Rope tied to the decant arm to keep the decant from sucking in sludge into the draining pipe. + delaying the decant until a clear supernatant has formed in the ponds + Ensure that there is sufficient ullage within all ponds to retain discharges of scour or backwash to allow supernatant formation, prior to lowering that the decant arm and starting releases + Daily checking **Long term** Ensuring SOPs for sludge management are followed including efficient functioning of decanters. + Install sludge pond inlet baffles will help reduce suspended	- Quality of supernatant water discharged through the decant drain. - Acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream.	+ Every day after desludging is completed until sludge is dried. + Carry out sampling and testing the stream water once a month and after heavy rainfall.	+ Operator (s)	Operator (s) x2 and Supervisor[13].	+ Supervisor

[12] See footnote 10.
[13] See footnote 11.

Main Components of the plant	Hazards and Risks (What they are and level of risk)	Potential Impact	Mitigation Strategy	Monitoring Parameter	Monitoring Frequency	Responsibility	Staffing and equipment requirement	Oversight
			solids entrainment in supernatant discharges thereby minimizing dissolved PACl discharges to streams. + Consider installing appropriate baffles to prevent the resuspension of the sludge blanket underlying the supernatant during the high flows occurring during backwash events. + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.					
	6.4 Backwash pumped back into the sludge pond. IC = Minor P = Very Low	No impact	+ Prevent sludge pond overfilling and eventually overflowing into the stream. + For Turangi and Avana, this is taken out to Papua for further dewatering.	- Overfilling of sludge pond.	+ Daily check and when sucker truck is required.	Operator (s), Supervisor	Contractor to removed backwash from backwash pond or sludge pond.	Supervisor
7. Water Storage	7.1 Sterilization using chlorine, a design flaw. IC = Moderate	+ Large amount of chlorinated water is discharged into the environment.	+ Prohibit disposal of chlorinated sludge/water into the stream.	- Approved disposal mechanism of	+ When situation arises.	+ Operator (s)	+ Operator (s) and Contractors	+Supervisor + Manager

Main Components of the plant	Hazards and Risks (What they are and level of risk)	Potential Impact	Mitigation Strategy	Monitoring Parameter	Monitoring Frequency	Responsibility	Staffing and equipment requirement	Oversight
	P = Medium		+ Inform the public of the activity + Proper disposal of sludge	chlorinated water by NES.				
	7.2 Operation IC = Moderate P = Medium	+ Large amount of chlorinates water is discharged into te environment.	+ Ensure the coagulation, flocculation, sedimentation and filtration processes are working efficiently to prevent unclean water from entering the reservoir. + Follow SOP to prevent contamination of water in the reservoir.	- SOP developed for each stage of the WTP, i.e., at intake and weir, settling tank and AVG Filters.	- Daily check and as per SOP.	+ Operator (s)	+ Operator (s)	+ Supervisor + Manager
8. Sludge Storage	8.1 Leachate from wet dried sludge. IC = Minor P = Very Low	+ EIA Report concluded; dried sludge has no leachate.	**Short term** + storage site at Vairauara 88H to have ponding and filter fences towards stream to prevent dry sludge from entering the stream. + Currently: temporary storage of dried sludge at Vairauara 88H is in filter bags with bunds to direct runoff to septage treatment pond. **Long term**	- Soil quality	+ When required	+ Ministry of Agriculture.	+ Not applicable	+ Manager + Agriculture Officer.

Main Components of the plant	Hazards and Risks (What they are and level of risk)	Potential Impact	Mitigation Strategy	Monitoring Parameter	Monitoring Frequency	Responsibility	Staffing and equipment requirement	Oversight
			+ With technical advice[14], determine use of dried sludge locally in Agriculture. + Should future monitoring data show adverse accumulative effect on the environment from increased aluminium concentration, consider export to New Zealand[15] following developed protocols.					

AP 2.2 Summary of Recommended Actions and Monitoring for PACl

From the mixing of PACl to its application through the settling tank and through to the AVG sand filter, the sludge and backwash ponds, the removal of sludge (dried or not) and the maintenance of reservoirs, there are varying risks that can get PACl into the environment. As each WTP is located in the catchment area, any spill on any part of the Plant will end up in the stream.

The following are recommended strategies for each area identified as medium to high risk.

[14] There is a need to analyze the content of aluminum in dried sludge and compare to aluminum content of the various soil types on Rarotonga, especially in agriculture lands. It is noted, much of the sludge content are sediment from the local environment.
[15] The destination with the most direct route

Main Components of the plant	Hazards and Risks (What they are and level of risk)	Recommended Actions	Monitoring
1. PACl Mixing	1.1 PACl Mixing Shed – Design flaw in the outflow pipe.	+ Redesign outflow pipe to allow trapping of spill when it happens. + Use mechanical means for PACl mixing. + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.	+ Spill Contained + Test results within acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream. + Ensure mixed PACl in the tank is when 20-30% full. + Check and keep an eye out when there are medium to high rainfall in the area as the tank level goes down. + Carry out sampling and testing once a month and after heavy rain in the area.
	1.2 PACl Storage tank – Design flaw in the inflow connection into the PACl storage tank.	+ Review and improve SOP. + Redesign the storage tank so the operator has a way of knowing where the PACl level is without guessing its position. + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.	+ Improve reading of PACl position in the top part of the tank. + Spill contained + Test results within acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream.
	1.3 Design flaw of the outflow pipe to the PACl header tank.	+ Redesign outflow pipe to the PACL Header tank to allow trapping of discharged PACl while clearing crystallized PACl. + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.	- Spill contained - Test results within acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream. + Carry out sampling and testing the stream water once a month and after heavy rain in the area.
	1.4 PACl Header tank – Risk of float valve breaking due to wear and tear, a design flaw. IC = Major P = Medium	+ Look into ways to ensure this does not happen + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.	+ Spill contained + Better system preventing broken float valve + Test results within acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream. + Carry out sampling and testing the stream water once a month and after heavy rain in the area.
2. Coagulation Chamber	2.1 Rapid Mixing Chamber – Risk of float valve (dozing leaver) breaking, a design flaw.	+ Redesign the position of the shut off valve to a calmer area where the vibration is cancelled out. + Design a system to detect changes in the WTP that this will happened so it can be prevented. + Operators assigned on a rotational basis to react to the situation when it arises under a new detection system. + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.	- Early detection of PACl level in the PACl storage tank (going down fast). - System managed during system backing up. - Test results within acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream. + Carry out sampling and testing the stream water once a month and after heavy rain in the area.

Main Components of the plant	Hazards and Risks (What they are and level of risk)	Recommended Actions	Monitoring
3. Sedimentation Chamber	3.1 Settling Chamber – Potential for release of sludge at mid-level drain of ST during desludging and maintenance work.	+ Review SOP to improve efficiency of operation + Design a system to remove reliance on human judgement when estimating sludge level below the mid-way drain pipe. + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.	+ Better judgement of sludge level below 60%) + Testing results within acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream. + Carry out sampling and testing the stream water once a month and after heavy rainfall in the area.
4. Scour waste (sludge pond)	4.2 Stream discharge outlet – Overgrown and hidden, a design flaw.	+ Keep the stream side of the sludge pond clear of weeds and visible. + Engage contractors.	+ Improve visibility and access at stream discharge outlet
	4.3 Decant operation – Discharge of PACl into the stream.	+ Install leaky floats on the decant arms or insert a filter cached chamber below the decant that collects water from the sludge and is drained through the decant reducing further sludge discharged into the stream. + Monitor aluminum concentration levels (sampling and testing the stream water) at 200m marks recommended by the EIA Report.	+ Quality of supernatant water discharged through the decant drain is improved during and after desludging. + Test results within acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream. + Carry out sampling and testing the stream water once a month and after heavy rainfall in the area.
5. Filtration – AVG	5.1 High level of PACl and Rubbish in supernatant water, i.e., process in ST backwash has failed.	+ Ensure all procedures from water intake to ST are followed. As per developed SOP. + Monitor aluminum concentration levels (sampling and testing water at the drainage outlet) to monitor effectiveness of AVG and WTP.	- During backwash - Testing results within acceptable CCC and CMC aluminum concentrations in µg/L from the samples. + Daily check + Carry out sampling and testing water from the drainage outlet once a month and after heavy rainfall in the area.
	5.2 Increase backwash volume in the backwash pond entering the stream, a design flaw.	+ AS above + Considering extending links of backwash pond to taro swamps for Turangi and Avana. + Monitor aluminum concentration levels (sampling and testing water at the drainage outlet) to monitor effectiveness of AVG and WTP.	- During backwash. - Testing results within acceptable CCC and CMC aluminum concentrations in µg/L from the samples. + Daily check + Carry out sampling and testing water from the drainage outlet once a month and after heavy rain in the area.

Main Components of the plant	**Hazards and Risks** (What they are and level of risk)	**Recommended Actions**	**Monitoring**
	5.3 Air expeller - Residual air in the AVG, a design flaw.	+ Make sure air expeller is functional. + Review SOP to improve efficiency.	- Presence of air in the system + Daily check
6. Backwash sludge pond	6.2 Stream discharge outlet – Overgrown.	+ Keep the stream side of the sludge pond clear of weeds and visible. + Engage contractors	+ Improve visibility and access at stream discharge outlet + Daily check
	6.3 Decant operation – Discharge of PACl into the stream.	+ install leaky floats and insert a filter cached chamber below the decant that collects water from the sludge and is drained through the decant reducing further sludge discharged into the stream. + Monitor aluminum concentration levels (sampling and testing water at the drainage outlet).	+ Quality of supernatant water discharged through the decant drain is improved during and after desludging. + Test results within acceptable CCC and CMC aluminum concentrations in µg/L in the receiving water 200m downstream. + Carry out sampling and testing the stream water once a month and after heavy rainfall in the area.
7. Water Storage	7.1 Sterilization using chlorine, a design flaw.	+ Prohibit disposal of chlorinated sludge/water into the stream. + Inform the public of the activity + Proper disposal of sludge	- Monitor approved disposal mechanism of chlorinated water by NES.

Appendix 3

Table 5 - Capacity of each WTP

WTP	Intake					settling tank		AVG		Reservoir	
	Elevation (m)	Operating Head (RL)(m)	Catchment Size (ha)	Intake Flow Rate (liters/day)	Flow rate/tank (liters/Second) - Designed	Volume (liters)	Quantity	volume (Liters)	Quantity	Volume (liters)	Quantity
Avatiu	80	84.3	135	2,000,000	23	272,000	1	68,000	1	2,400,000	2
Takuvaʻine	69	71.5	161	890,000	35	396,000	1	51,000	2	600,000	1
Tūpapa	65	76.19	101	1,900,000	14	165,000	1	34,000	1	1,400,000	1
Matavera	65	66.74	83	2,600,000	14	166,000	1	34,000	1	600,000	1
Turangi	72	78.53	118	1,700,000	35	209,000	2	51,000	2	2,400,000	1
Avanā	81	80.38	243	4,200,000	39	233,000	2	51,000	2	1,400,000	1
Tōtokoʻitu	65	64.7	70	2,000,000	23	272,000	1	68,000	1	0	0
Taipara	50	56.3	84	1,200,000	14	166,000	1	34,000	1	0	0
Pāpua	49	55	163	2,000,000	23	272,000	1	68,000	1	1,400,000	1
Ngātoe	65	72.23	98	2,000,000	23	272,000	1	68,000	1	2,400,000	1

5. References

1. Treatment Plant On-site Discharge EIA Report, Tonkin & Tylor July 2021;
2. Sludge disposal site in Rarotonga – Environmental Impact Assessment, Tonkin & Tylor July 2021;
3. Temporary Sludge Storage at Rarotonga Waste Facility EIA, Tonkin & Tylor October 2021.
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5. Technical support report to NES prepared by ADB consultant, Lindasy Chapple, March, 2023.
6. D.M, Leslie. Soils of Rarotonga, Cook Islands. New Zealand Soil Report No. 49. NZDSIR (1980)
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