REPORT

Water Treatment Plants: On-site Discharges

Environmental Impact Assessment

Prepared for
To Tatou Vai Limited
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Executive summary

The Cook Islands Government is currently upgrading Rarotonga's water infrastructure, through the Te Mato Vai (TMV) project. TMV is currently upgrading ten water intakes and constructing water treatment plants for each intake. In some cases, storage capacity has been created.

Treatment process

The water from the ten intake sites will be treated through a standardised treatment process. This includes:

- Coarse screening at the in-stream intake
- Sedimentation (settling): Removal of suspended material in a settling tank including the use of a coagulant to enhance fine particle removal.
- Filtration: Passing settled water through a sand filter for further removal of suspended materials including microbiological contaminants.
- Provision for disinfection of treated water (if disinfection is used).

Settled material from the sedimentation stage and sediment laden water from cleaning of the sand filters (known as backwash) is held in sludge ponds for further settlement. After further settling the clear water (supernatant) from the sludge ponds is discharged to an adjacent stream at each site. Settled sludge will be periodically removed for disposal at an appropriate location.

Currently, the water supply is untreated with the exception of coarse screening at the in-stream intakes. Monitoring of in-stream water quality and water in the reticulation network demonstrates the presence of microbiological contamination above levels that are protective of public health.

In addition, the flow in each catchment can change very quickly in response to rainfall events with associated increases in water turbidity. This, combined with the dispersed nature of the intakes, makes it difficult to make ongoing adjustments in response to flow or water quality changes.

The proposal is to use Polyaluminium chloride (PACl) as a coagulant that can be added to incoming water to enhance the removal of suspended material. The coagulant also improves the removal of microbiological contamination in the sand filter. The TMV project team are currently trialling the use of PACl at the upgraded water intakes.

Alternatives

A number of alternatives to enhance the removal of fine sediment and microbiological contaminants have been assessed, including diversion of water during times of high flows. Alternative options do not remove microbiological contamination (bacteria/protozoa) which is present in untreated water (even when the water appears clear / has low sediment loads). Currently, diversion is unlikely to be a feasible option. Moringa seed extract was trialled as a natural option however, this was ineffective. PACl is the preferred option for a number of reasons, including the local water characteristics, particularly the pH range, and operational constraints.

Potential environmental impacts

PACl is an aluminium based coagulant, and therefore the potential environmental impacts are those associated with the release of aluminium into the environment. Potential impacts of aluminium on freshwater ecology include 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 diversity and abundance (GHD, 2020).

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

An assessment of fate and transport of PACl through the treatment process has found that under normal operations, the main points at which PACl may be discharged into the environment are:

- from the sludge ponds via the discharge of supernatant into the stream,
- during removal of the sludge for disposal to an appropriate location,
- from the settling tank during maintenance operations, and
- from the reservoir or mains during maintenance operations.

During heavy rainfall, surface flooding may occur in the area immediately adjacent and upgradient of the sludge ponds. The ponds have been designed so that water is directed around the ponds during heavy rainfall.

Taking into account pH, dissolved organic carbon (DOC), temperature and hardness at each of the streams where PACl will be discharged, the following comments apply.

- The streams where the water intakes are located are all relatively neutral, with measured pH values ranging from 7.01 pH units to 7.61 pH units. The pH of each stream has the greatest influence on toxicity. The neutral pH of the streams will result in low toxicity of any aluminium released into the streams from the sludge or scour ponds. Further, at this pH there is a low risk of aluminium bioaccumulation because the solubility and therefore bioavailability of ionic aluminium is very low.
- Water parameter tests indicate that water hardness has an average range of 50-80mg/L, with a range from 34.2mg/L (the lowest measurement at the Avana site) to 102.6mg/L (the highest measurements at Avatiu and Ngatoe).[1]
- Waterways on Rarotonga typically had a low proportion of organic matter (plant and animal material) with the exception of the occasional slow flowing pool such as at the upstream site at Takuvaina where organic matter accumulates. The presence of organic matter in these pools indicates that DOC is likely to be present in varying concentrations within the waterway.

While data on hardness and DOC is not conclusive, the toxicity of the PACl discharge is considered to be low due to the pH of the streams. Despite this, 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.

For the assessment and ongoing operations, trigger values for dissolved aluminium within Rarotonga streams are:

- Based on the neutral pH levels within the streams, the maximum value over the long-term that could be tolerated is in the range of 290-630 µg/L.[2]
- The highest concentration of aluminium to which the aquatic community can be exposed briefly without resulting in an unacceptable effect is in the range of 570-1100 µg/L.
- In a scenario where pH decreases within the receiving environment (below 6.5) the maximum acceptable concentration would decrease to 78 µg/L.

[1] Based on water parameter tests undertaken by TTV in April/May 2019 for all intake sites.

Based on typical residual dissolved aluminium concentrations in outflows from other water treatment plants[3], and initial trials of the Rarotonga water treatment plants, the residual concentrations of dissolved aluminium in the discharge would be below the derived long-term specific criteria for Rarotonga of 290 µg/L (at a typical dosage rate and normal operations), and allowing for variable stream water characteristics).

Aluminium concentrations in sludge are likely to be significantly higher than in the supernatant. In normal conditions, this will not be discharged into the stream (i.e. it will be removed off-site and taken to an appropriate disposal area). Ponds are bunded although under flood conditions there is potential for sludge to be discharged straight to the stream if surface flooding enters the ponds.

Assessment of environmental impacts

Based on this, the addition of PACl is generally considered to have a low impact on the environment. In particular:

- The impacts on freshwater ecological values, and on land and groundwater at the WTP sites, are considered low and acceptable.
- Given the low impact on downstream water, the impacts from the use of PACl at the water treatment plants on land use downstream of the water treatment plants (e.g. agricultural uses) are considered to be low.
- A safe, reliable and potable drinking water supply has well established social benefits, supporting public health outcomes at local, regional and national levels (WHO, 2011). This is further supported by the Cook Islands national policy framework, including the NSDP and the IWRM. Overall, the use of PACl is considered to have a positive effect on potable water quality. Overall, the use of PACl is considered to be appropriate in relation to social and cultural values.
- Provided appropriate protocols are followed, the health and safety impacts of PACI will be sufficiently managed.

Operation Environment Management Plan

The framework for an Operation Environment Management Plan is included in this EIA, setting out environmental performance objectives, responsible parties and a monitoring plan to check that the environmental impacts are as expected.

Proposed water quality monitoring is set out in Section 10 and Appendix F. For each water treatment plant this includes:

- Sampling of pH, dissolved oxygen (DO) and temperature;
- Sampling for dissolved aluminium (Al^{3+}) at three locations in the stream on a weekly basis for the first six months of operation[4] :
  - upstream of the WTP (baseline flows),
  - immediately downstream of the discharge (compared to highest concentration of dissolved aluminium to which the aquatic community can be exposed briefly without resulting in an unacceptable effect, being 570 µg/L in the receiving water)
  - approximately 200 m downstream of discharge (compared to the maximum value of dissolved aluminium that could be tolerated over the long-term, being 290 µg/L in the receiving water);

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[3] See Appendix C, Section 5.2.2 (p43)

[4] The plants will be considered operational once PACl trials currently underway have been completed, and the respective plants have been formally commissioned.

- Sampling of supernatant / clear water at:
  - mid-level drain from the settling tank,
  - the outlet from the settling tank,
  - the outlet from the AVG filter, and in the ponds at each WTP (ideally the discharge or if not, a sample from the surface).

This sampling can reduce to monthly with agreement from the National Environmental Service, if monitoring over time shows that-dissolved aluminium (Al^{3+}) concentrations in the stream are below the trigger values noted above. If the dissolved aluminium concentration in the upstream sample location exceeds the trigger values, To Tatou Vai will work with the National Environmental Service to identify the source of Al^{3+} and evaluate the change in concentrations attributable to the on-site environmental discharges.

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1 Glossary and abbreviations

Term	Definition
AVG Filters	'Automatic Valveless Gravity' Filters, the types of sand filters constructed at the Rarotonga water treatment plans
Alum	Aluminium Sulphate – a coagulant
Backwash pond	A pond that holds backwash generated during the backwash (cleaning) of the AVG filters, described in Section 5.3 of this EIA.
CCC	The USEPA guidance refers to the Criterion Continuous Concentration (CCC) which is an estimate of the highest concentration of a material in the water column to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect i.e. the maximum value over the long-term.
CMC	The USEPA guidance refers to the Criterion Maximum Concentration (CMC) is an estimate of the highest concentration of a material in the water column to which an aquatic community can be exposed briefly without resulting in an unacceptable effect.
coagulant	A chemical added to water which helps finer particles clump together in larger particles, which then sink to the bottom to the settling tank.
coarse screening	A screen which blocks leaves and other detritus from entering the water treatment system.
Dangerous Goods	As defined by the Dangerous Goods Act 1984 and subsequent Regulations
DOC	Dissolved Organic Carbon
floc	Larger particles made from a combination of finer particles
flocculation	The process of adding a coagulant to the water to improve the ability of fine particles to combine into larger particles known as 'floc'. This process speeds settlement of suspended sediments out of the water.
Main / sub main	The main pipe and supporting pipes used for supplying water
NES	National Environment Service
NTU	Nephelometric Turbidity Unit used to measure the turbidity of a fluid or the presence of suspended particles in water. The higher the concentration of suspended solids in the water is, the dirtier it looks and the higher the turbidity is.
NZ	New Zealand
PACl	Poly Aluminium Chloride – a coagulant
potable water	water that is safe to drink
reticulated water supply network	Piped water network
settling process	The process of allowing heavy particles in raw water (e.g. soil) to settle for later removal. This is undertaken in settling tanks, which are described in Section 5.2 of this EIA.
scour pond	A pond that holds sludge formed in the settling process, removed from the settling tanks on a regular basis and placed in scour ponds to dry prior to disposal (see Section 5.5 of this EIA).
sludge ponds	Used to refer to scour ponds, backwash ponds and combined ponds that hold sludge, produced from the settling process and backwash from the AVG filter, as set out in Section 5.5 of this EIA. On some sites, these are separated into two ponds known as the 'scour pond' and the 'backwash pond' (these are defined separately).

Term	Definition
supernatant	The clear water/liquid overlying settled material (sludge)
T+TI	Tonkin + Taylor International Limited
TMV	Te Mato Vai
TOR	Terms of Reference
TTV	To Tatou Vai (Ltd)
WTP	Water treatment plant
Watercare	Watercare Services Limited, New Zealand
10% w/v solution	10% weight to volume solution (used where a solid chemical is dissolved in liquid)

2 Introduction

The existing reticulated water supply network in Rarotonga is collected from streams and freshwater sources located around the island. Stream water is feed directly into a distribution network consisting of one ring main pipe which circumnavigates the whole island, and a series of cross mains and submains connecting water users. The reticulated network supplies residential homes, commercial and industrial sectors and major public institutions on Rarotonga.

Currently, the water supply is untreated with exception of coarse screening at the in-stream intakes. Monitoring of in-stream water quality and water in the reticulated network demonstrates the presence of microbiological contamination above levels that are protective of public health.

The Cook Islands Government is currently upgrading Rarotonga's water infrastructure, through the Te Mato Vai (TMV) project. TMV is currently upgrading ten water intakes, constructing water treatment plants (WTPs) for each intake. In some cases, storage capacity has been created. Operational trials of each of the new water treatment plants are currently underway.

The flow in each catchment can change very quickly in response to rainfall events with associated changes in water quality. This, combined with the dispersed nature of the intakes, makes it difficult to make ongoing adjustments in response to flow or water quality changes. The intake sites are also remote with no power supply. Therefore, the water from the ten intake sites will be treated through a standardised treatment process using gravity rather than pumping to move water and residual materials. This includes:

- An intake weir to provide coarse screening at the in-stream intake.
- Sedimentation (settling), which involves the removal of suspended material in a settling tank including the use of a coagulant to enhance fine particle removal.
- Filtration: Passing settled water through a sand filter for further removal of suspended materials including microbiological contaminants.
- Provision for disinfection of treated water (if disinfection is used).
- Ponds for sludge from the settling process and backwash from the filter.

There are a range of potential coagulants that can be added to incoming water to enhance the removal of suspended material and microbiological contamination at the settling stage. The coagulant also improves the removal of microbiological contamination in the sand filter. The proposal is to use Poly aluminium chloride (PACl) as coagulant.

2.1 Scope of this assessment

This Environmental Impact Assessment (EIA) considers the potential environmental impacts of the activity of using PACl as a coagulant during the operation of the WTPs. Specifically, the focus of this EIA is on the on-site management of residual materials from the settling tank and sand filter including discharges to the adjacent streams. Off-site disposal of sludge will be covered in a separate EIA. This EIA does not consider impacts arising from disinfection of water (by chlorination or other means).

This EIA is prepared by T+TI on behalf of To Tatou Vai Limited (TTV) in accordance with the Environmental Act 2003. This report has been undertaken in accordance with the Terms of Reference (TOR) agreed by TTV with the National Environment Service (NES) for the Project. The report is structured as follows:

- Section 1: Glossary
- Section 2: Introduction (this section)

- Section 3: Policy and legal framework
- Section 4: Environmental setting
- Section 5: Overview of the water treatment process
- Section 6: Use of coagulants in the water treatment process
- Section 7: Analysis of Alternatives
- Section 8: Community, Landowner and Stakeholder Consultation
- Section 9: Impact Assessment
- Section 10: Operational Environmental Management Plan
- Section 11: Conclusion and Recommendations
- Section 12: References
- Section 13: Applicability statement

All relevant matters required to be included by the TOR have been addressed in this EIA. **Appendix A** provides a table listing how the TOR has been addressed, cross-referenced to relevant sections of the EIA report.

3 Policy and legal framework

This section reviews the policy and legal framework relevant to the use of PACl, including:

- National laws and related government approvals (Section 3.1),
- Relevant policy framework (Section 3.2),
- Industry policies or codes of practice (Section 3.3).

In addition, the storage of PACl at the main TTV depot requires a Dangerous Goods licence, to be sought outside of this EIA process. The proposal does not trigger additional requirements under multilateral environmental agreements, including those related to pollution and hazardous wastes.

3.1 Environment Act 2003

The Environment Act 2003 provides for the protection, conservation, and management of the environment in a sustainable manner. This Act provides the legal framework for assessing the environmental impacts of development.

Section 36 of Part 5 (Environmental Impact Assessment) states that:

> *(1) No person shall undertake any activity which causes or is likely to cause significant environmental impacts except in accordance with a project permit issued under this section.*
>
> *(2) A person who proposes to undertake an activity of the kind referred to in subsection (1) shall apply to the permitting authority for a project permit in respect of the activity in accordance with the procedures (if any) prescribed by regulations.*
>
> *(3) Every application for a project permit shall be submitted to the Service and shall include an environmental impact assessment, setting out details of-*
>
> > *(a) the impact of the project upon the environment and in particular -*
> >
> > > *(i) the adverse effects that the project will have on the environment; and*
> > >
> > > *(ii) a justification for the use or commitment of depletable or non-renewable resources (if any) to the project: and*
> > >
> > > *(iii) a reconciliation of short-term uses and long-term productivity of the affected resources; and*
> >
> > *(b) the proposed action to mitigate adverse environmental effects and the proposed plan to monitor environmental impacts arising out of the project; and*
> >
> > *c) the alternatives to the proposed project.*

This report complies with the requirements of s36 as set out above, and the agreed TOR which are attached to this EIA (see **Appendix A**).

3.2 Relevant policy framework

Two policy documents are of particular relevance to this proposal:

- Te Kaveinga Nui: National Sustainable Development Plan 2016 – 2020 (NSDP), and
- Cook Islands National Integrated Water Resources Management Policy 2014 (IWRM),

3.2.1 Te Kaveinga Nui: National Sustainable Development Plan 2016 – 2020

The NSDP articulates the national vision and development outcomes desired by Cook Islanders.

Goal 4 of the NSDP is "Sustainable management of water and sanitation". The NSDP states:

> *Water and sanitation are basic necessities for our health, economy and environment. With the impacts of climate change and the inherent limited fresh water reserves, preserving and managing fresh water is a key development issue*.

The NSDP aims to improve access to sufficient and safe water. Indicator 4.1 is "Percentage of population with access to sufficient and safe water in their homes." This indicator looks at Cook Islanders' access to sufficient and safe water in their homes. The NSDP considers this a fundamental right and basic human need that is of the highest priority, reflected in the country's recent significant investment in water infrastructure.

The TMV project seeks to implement the NSDP by provision of potable (safe) water via a reticulated water system. The role of PACl in producing potable water is set out in Section 6 below.

3.2.2 Cook Islands National Integrated Water Resources Management Policy 2014

The purpose of IWRM document is to establish policies that will guide planning, actions and efforts in ensuring the sustainable integrated water resources management across the Cook Islands.

Policy Objective 1 of the IWRM is, "Reliable, potable water for all who reside in the Cook Islands and the establishment of standards for water quality and resource management." This includes:

> *Drinking Water for Human Consumption: We will ensure all persons in the Cook Islands shall have access to reliable, safe and potable drinking water.*
>
> *Water for Domestic Usage: We will have reliable access to safe water for bathing, cooking and cleaning for all persons in the Cook Islands.*
>
> *We will have reliable access to safe water 'fit for purpose' for Business and Commerce to use in a manner consistent with efforts to conserve fresh water resources and minimise any waste water to ensure the economic viability and environmental sustainability of the country.*
>
> *We will have adequate, appropriate and reliable water for horticultural and agricultural production.*

The use of PACl as a component of a reticulated water system to provide potable drinking water is set out in Section 6 below, and adverse effects are considered in relation to water for domestic usage, business and commerce and horticultural and agricultural production are considered in Section 8 below.

3.3 Industry policies / codes of practise

The following industry policies / codes of practise are relevant to this report:

- Water New Zealand, Standard for the Supply of Poly Aluminum Chloride for use in Water Treatment, Second Edition, 2013. This standard provides purchasers, manufacturers and suppliers with the minimum requirements for PACl, including physical, chemical and testing requirements.
- United States Environmental Protection Agency, Final aquatic life ambient water quality criteria for aluminium, 2018 (USEPA 2018). This derives a dynamic guideline which can be adapted to the specific pH, hardness and DOC observed in the receiving environment.
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC 2000) – Tropical Australia Upland River. These guidelines were chosen as a comparison for these sites as the Rarotongan environment closely resembles that of tropical Australia.

- The World Health Organisation (WHO) Drinking Water Standards - Fourth Edition 2011 have been used by TTV as a basis for achieving appropriate potable water supply standards.

4 Environmental setting

4.1 Site location

The ten water intakes currently being upgraded are shown in Figure 4.1 below. The water takes are located inland, away from residential settlements. Detailed plans showing the size and layout of each of the WTPs being constructed are attached in **Appendix B**.

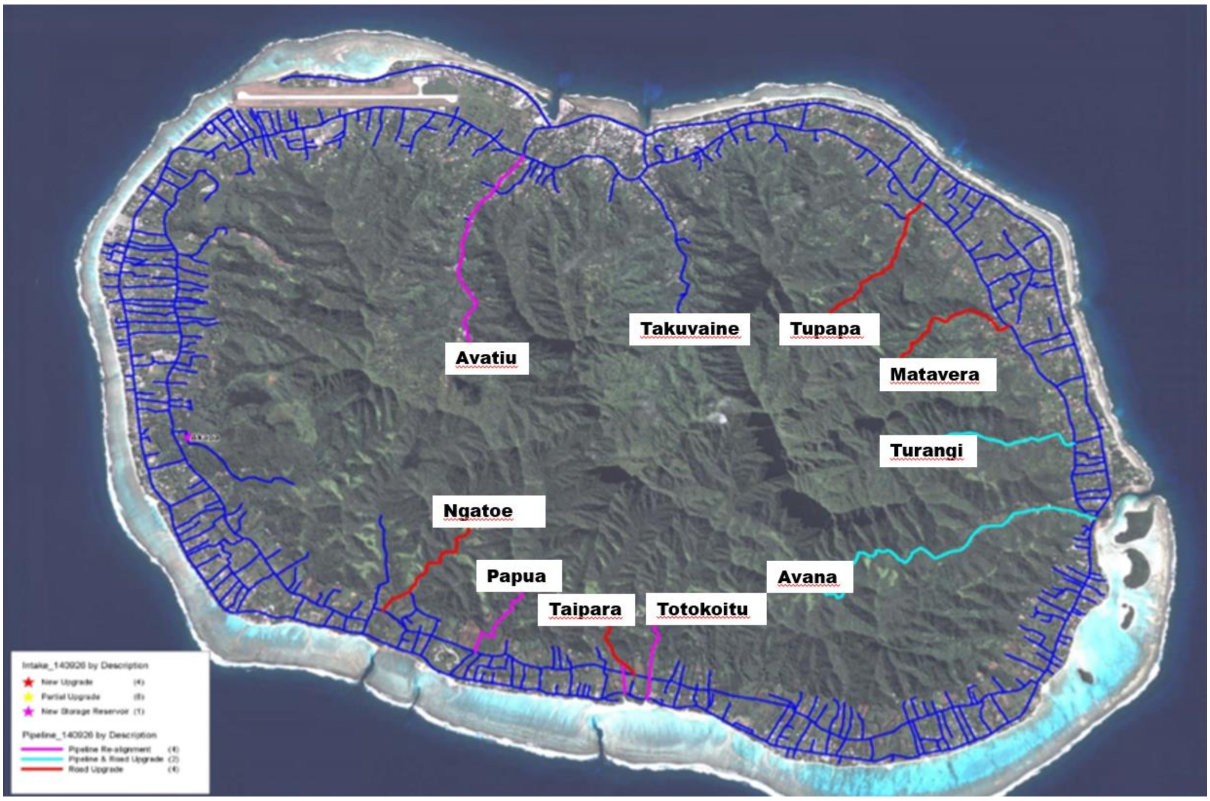

Figure 4.1: Aerial plan showing the approximate location of each of the water takes. Source: GHD, 2014

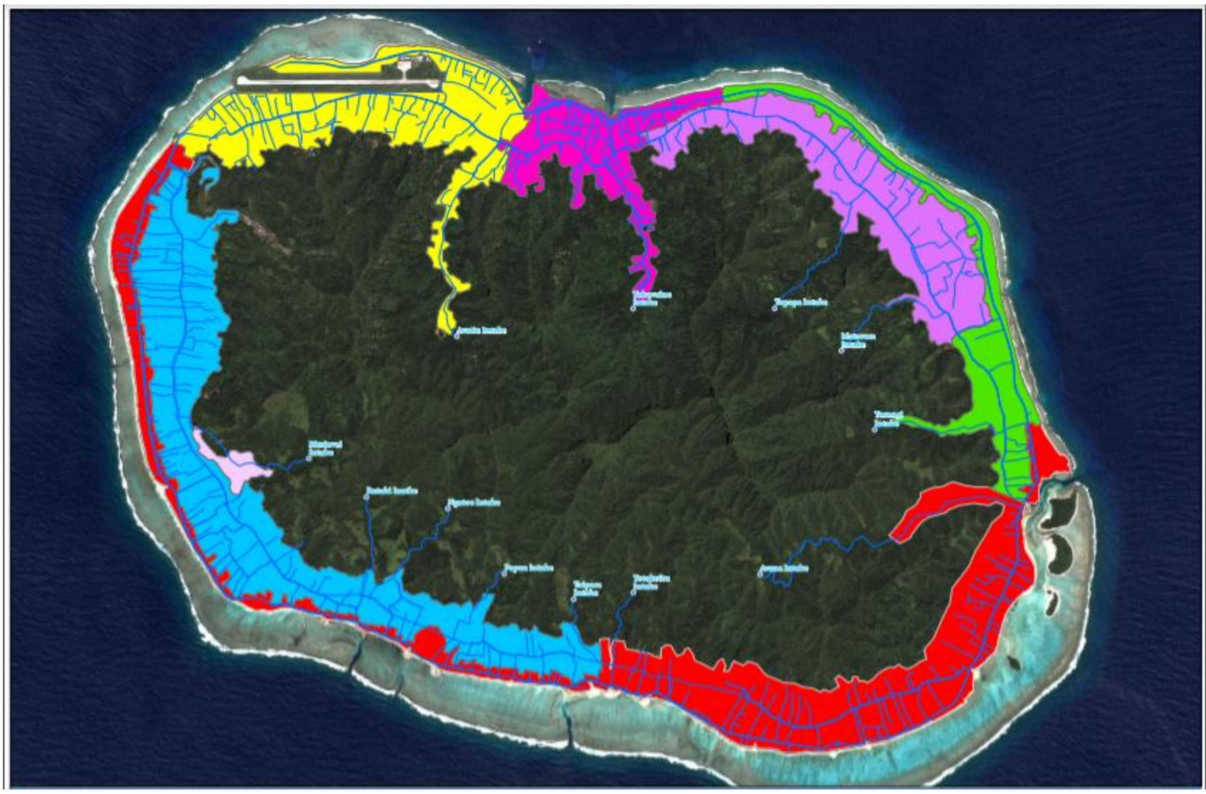

Figure 4.2: Map showing the Rarotonga reticulation system distribution zones. Source: TTV, February 2020

4.2 Description of the baseline environment

This section provides information on the baseline environment, including a description of:

- Climate,
- Topography, geology and soils,
- Catchment characteristics,
- Water quality,
- Ecological values, and
- Social and cultural context.

4.2.1 Climate

The Cook Islands experiences a tropical climate with two seasons:

- Wet season: Typically November to May, characterised by high humidity, sudden downpours, strong winds and tropical cyclones (hurricanes).
- Dry season: Typically June to October, characterised by cooler temperatures.

In the Southern Cook Islands (including Rarotonga and Aitutaki) there is a slight difference between the wet (warmer) and dry (cooler) months.

Climate projections for the Cook Islands (Pacific Climate Change Science Programme, 2013) indicate:

- Temperatures will increase in the order of 0.5 – 1.0°C by 2030 (high emissions scenario),
- Changing rainfall patterns and more extreme rainfall days, and
- Sea level will rise in the order of 40-150 mm by 2030 under a high emissions scenario.

4.2.2 Topography, geology and soils

As set out in the Te Mato Vai Aquatic Ecology Baseline Report (GHD, 2020, **Appendix C** to this report):

> Rarotonga has a land area of 67.4 km^2, a circumference of 32 km and maximum elevation of 652 m. The central part of the island consists of mountains with narrow valleys covered in tropical vegetation. Surrounding this is a flat coastal ring which has been developed for residential, commercial and agricultural purposes. Fringing the island is an upraised coral reef and lagoons.
>
> The interior upland sediment is basaltic volcano bedrock which produces dark red clay-rich sediments through the process of weathering. These sediments are generally less fertile due to nutrient deficiencies. Conversely, sediment of the coastal ring is nutrient rich due to the naturally high concentrations of phosphorus.

4.2.3 Catchment characteristics

There are twelve water catchments in Rarotonga, of which ten (10) have recently had the addition of treatment facilities. These catchments comprise of streams, wetlands and a few small freshwater lakes. The three major streams on Rarotonga are Takuvaine, Avana and Avatiu, all of which have water intakes located on them.

As noted above, Rarotonga is surrounded by a flat coastal ring which rises steeply in the middle of the island. Rainfall is characterised by sudden downpours (particularly in the wet season), with more extreme rainfall days expected as a result of climate change. As a result, stream levels can change rapidly. As set out in **Appendix C**, water flows within the majority of catchments are expected to cease during the dry season and the waterways will exist as a series of isolated pools interspersed with dry riverbeds.

The water intakes are located inland on vegetated land that in the upper catchments of each of the streams, located away from residential settlements which are more prominent on the lower land, near the back road / main road (GHD, 2014). Figure 4.3 shows the land use surrounding the Papua intake, including vegetation and pastoral areas adjacent to the existing intake site.

Figure 4.3: Aerial photo showing the Papua intake and surrounding landscape. Source: GHD, 2014.

4.2.4 Water quality

Surface water often contains fine soil particles, or organic matter and dirt that make the water look murky and cloudy. These particles are normally not easily visible with the naked eye and due to their size/weight it takes a long time until they settle to the bottom of the water body. This is a problem because potentially dangerous bacteria can stick to these particles, as well as aesthetic issues associated with turbid water. Microbiological contamination can also be present in clear water.

Water quality at the water intake sites varies depending on the level of recent rainfall. Raw water samples taken from water intakes on Rarotonga, analysed at Watercare Services Limited (Watercare, 2014), found samples taken during wet weather are characterised by:

- high turbidity (fine suspended solids),
- high colour (brackish-brown), and
- a variable low to moderate soluble iron and manganese content.

Samples taken from the same water intake sites under dry weather conditions had low turbidity and colour content, and both iron and manganese concentrations were below the WHO aesthetic guideline values.

The Cook Islands Te Marae Ora (Ministry of Health) have intermittently carried out water quality monitoring at all 12 water intakes since 2007. This includes monitoring for faecal coliforms such as *Enterococci coli*. *E. coli,* specific to faecal material from humans and other warm-blooded animals, are a strong indicator of human or animal faecal contamination and can pose a serious risk to human health. WHO (2017) states that, "In general terms, the greatest microbial risks are associated with ingestion of water that is contaminated with faeces from humans or animals (including birds). Faeces can be a source of pathogenic bacteria, viruses, protozoa and helminths."

Sampling undertaken by Te Marae Ora (Cook Islands Ministry of Health} has shown that faecal coliforms are present at all intakes, albeit at variable concentrations. For the most part, faecal coliforms attribute to about 15 % of the total coliform concentration in all Rarotonga intakes (GHD, 2014). Recent sampling from community water stations analysed by Watercare found that of the 40 samples tested, 33 contained E.coli and 21 of these had high or very high counts (see **Appendix D**).

Additional water quality testing was carried out in association with the ecological field survey undertaken by GHD in January 2020, described in Section 4.2.5 below.

4.2.5 Ecological values

A field survey was undertaken in January 2020 by GHD to describe the existing aquatic ecological values at the water intake sites and discharge locations (GHD, 2020, **Appendix C** to this report). The survey was undertaken at each of the ten water intake sites. Sites were sampled both upstream and downstream of the water intake, with the exception of Takuvaina, Matavera and Turangi which were sampled in two downstream locations due to access limitations. The Papua catchment was sampled in one location due to access limitations and no additional suitable site identified downstream of the water intake (see GHD, 2020, Figure 3-1).

The GHD survey assessed the following indicators:

- **Aquatic habitat:** Habitat assessments were undertaken at each site to describe the existing habitat values and rate the condition of key aquatic habitat features and overall condition of each site. A general description of the observed values was developed for each site, and an overall score calculated to provide an account of conditions during the survey. The scoring system was adapted from the standardised Australian Rivers Assessment System methodology.

- **In-situ environmental water quality:** Measurements included water temperature (°C), pH (pH unit), electrical conductivity (µS/cm), and dissolved oxygen (% saturation and mg/L). Surface water quality data was compared against the guideline ranges given in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC 2000) – Tropical Australia Upland River. These guidelines were chosen as a comparison for these sites as the Rarotongan environment closely resembles that of tropical Australia (there are no published guidelines for environmental water quality in the Cook Islands).

  pH values are of particularly relevance to this EIA, as the pH of the receiving waters directly impacts the potential toxicity of aluminium compounds, including PACl. At pH values less than 5.5 or greater than 9, toxicity and bioaccumulation of aluminium increases (see Section 5.2.2, **Appendix C**).
- **Aquatic flora:** Observed at each sampling location.
- **Aquatic macroinvertebrate communities:** Where possible, one sample was collected from each of two habitat types – edge and composite pool-bed.
- **Fish communities:** Habitat suitability for fish species was recorded at each site and any fish opportunistically observed during sampling were identified where possible. Additional information on the existing fish community present at each site was obtained though discussions with the local communities regarding fish sightings and fishing activities.
- **Turtle communities:** Habitat suitability for turtle species was recorded at each site and any opportunistic turtle observations noted during sampling were identified where possible. Additional information on the existing turtle community present at each site was obtained though discussions with the local communities regarding turtle sightings and fishing activities.

The field survey results are detailed in Section 4 of the report attached in **Appendix C**. In summary, these found that:

- **Aquatic habitat:** Aquatic habitat and environmental values of the waterways between the 10 catchments were similar. Each waterway consisted of a relatively narrow irregularly meandering channel with flowing, clear, shallow water. The exception to this was the upstream sampling site for Avana, which was deep and turbid due to recent heavy rainfall. Water flow alternated between areas of faster runs and riffles and slower pools. During the dry season, water flows within the majority of catchments is expected to cease and the waterways will exist as a series of isolated pools interspersed with dry riverbed. The wetted width of these waterways varied from approximately 0.5 m to 4 m and had a variable depth of 0.1 m – 0.5 m. Overall, all catchments had either good or excellent quality at all sites (see Table 4-2, **Appendix C**).
- **In-situ environmental water quality:** Results of testing for temperature, pH, electrical conductivity and dissolved oxygen saturation are set out in Section 4.3 in **Appendix C** (noting that these samples were taken once and as such, are a snapshot of water quality values at the time of sampling).

  Stream pH values range from 7.01 pH units to 7.61 pH units. Results complied with the ANZECC 2000 guideline range (pH 6.0 - 7.5) at the majority of sites but seven sites had results greater than 7.5 pH units. These included: Avatiu (upstream sample site), Takuvaine (upstream), Tupapa (both upstream and downstream sites), Matavera (upstream), Papua, and Ngatoe (downstream). This is consistent with recent monitoring provided by TTV, which found pH near the intakes generally varies from 6.9 – 7.8, with Takuvaine Intake measuring 8.3 pH units (see **Appendix C**).
- **Aquatic flora:** There are no threatened freshwater aquatic plant species recorded on Rarotonga (and none were found during the field survey). Aquatic flora had limited diversity, and species and abundance were similar between the upstream and downstream sites at all

sites. These aquatic plants provide some in-stream habitat for macroinvertebrates and fish and help stabilise stream bed and banks. This reduces erosion and sedimentation and improves water quality conditions. Examples of species found are shown in Photograph 4.1 (including *Azolla filiculoides*, an invasive species).

Photograph 4.1: Aquatic plants found at multiple WTP sites. Clockwise from top left: Umbrella sedge (Cyperus involucratus), taro (Colocasia esculenta), scour pond containing red water fern (Azolla filiculoides), red water fern (Azolla filiculoides) (GHD, 2020)

- **Aquatic macroinvertebrates:** Macroinvertebrate diversity was low. All species found were considered to be tolerant of pollution, based on a Stream Invertebrate Grade Number (SIGNAL) which indicates sensitivity to pollution. Upstream sites tended to have higher or equivalent taxa richness to downstream sites. Macroinvertebrate communities varied considerably within the Avatiu catchment, with just freshwater shrimp (Palaemonidae) present at both the upstream and downstream locations. As set out in GHD, 2020, differences in taxa richness between sites and locations (upstream and downstream) are likely due to site-specific habitat characteristics, such as flow, substrate composition and available cover.
- **Fish community:** Fish diversity was limited throughout the catchments with only three species identified and small unidentified fish noted across eight of the ten catchments. Abundance of eels was low with only one to two eels observed per site. Goby had a higher abundance of upwards of 20 – 30 individuals per site. Guppy (an introduced species) were sparse with only three individuals caught during macroinvertebrate sampling.
- **Turtle community:** No turtles were observed.

4.2.6 Social and cultural context

As set out above, water intakes are located inland in the upper catchments, away from residential settlements which are generally located on lower land, near the back road / main road. Access roads provide access to the existing water supply infrastructure and for landowners to visit their lands.

Prior to the development of the water intakes, the main valleys of the island, namely, Avatiu, Takuvaine and Avana, and the more accessible locations to major populations, namely, Turangi, Tupapa and Matavera, were common wetland taro planting areas. However, Takuvaine Valley is the only remaining valley that still has wetland taro beds (GHD, 2014). Other agricultural activities include small-scale pig, goat and poultry farming (GHD, 2020).

Recreational or tourism activities identified in the area include nature trekking by foot or by quad bikes and safari tours (GHD, 2014), along with fishing and swimming in some catchments.

The EIA for construction of the WTPs identifies important cultural sites like mountain peaks such as, Ikurangi, Te Manga, Te Kou, Te Rua Mangā (the Needle), and landmarks like Papua Waterfall (more commonly known as the Wigmore Waterfall) (GHD, 2014). Discussions between TMV and landowners have identified some additional sites of cultural significance e.g. trees within the works footprint (GHD, 2019).

We also note that there are significant cultural values attached to land and water in the Cook Islands. There is a fundamental link between these values and the relationship between land and identity (Coffey, 2019). There has been discomfort expressed by some community members and landowners, particularly in relation to the addition of chemicals to the water treatment process. This is detailed further in relation to community, landowner and stakeholder consultation, in Section 8 below.

5 Overview of water treatment plant process

As set out in Section 2 above, the water will be treated through a standardised treatment process which is the same at each of the ten intake sites. In general, the system is relatively simple and provides conventional (standard) water treatment. The intent of the design is to avoid the need for complex or costly maintenance and minimising ongoing operation costs, while providing consistent and potable water for Rarotonga.

All ten of the WTPs rely on gravity. This avoids the need for power connections at each site. The key variables at each site are:

- the size of corresponding components at each site (an outcome of the different flow regimes), and
- whether there is the inclusion of storage tanks/reservoirs or not (eight out of ten sites include new storage tanks).

Figure 5.1 below shows a diagram of the treatment process which includes:

- An intake weir to provide coarse screening at the in-stream intake.
- Sedimentation (settling), which involves the removal of suspended material in a settling tank including the use of a coagulant to enhance fine particle removal.
- Filtration: Passing settled water through a sand filter for further removal of suspended materials including microbiological contaminants.
- Provision for disinfection of treated water (if disinfection is used).
- Waste material / water is directed to ponds which hold sludge from the settling process and backwash from the filter.

Treated water from the filter is either delivered directly to the reticulation network or piped into reservoirs for storage.

Sections 5.1 to 5.5 detail the various components and processes of the WTP relevant to this EIA.

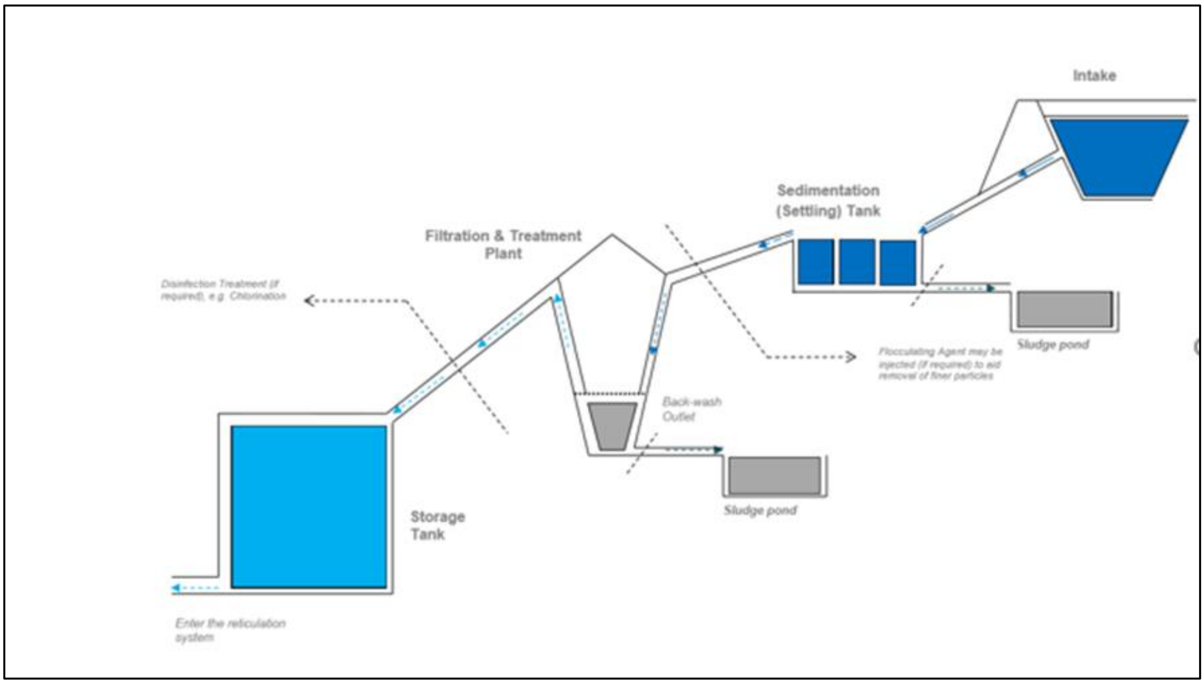

Figure 5.1: Indicative diagram of how the gravity operated water supply and treated system works. Source GHD, EIA 2014.

5.1 Intake Weir

A protected intake provides a stable place in the bed of the stream, from where water can flow into the delivery pipe. The weir intake screen is made up of stainless-steel wedge wire. This provides coarse screening of large sediment and floating debris e.g. leaves and logs. The screen prevents most material from entering the intake pipe. It is built to withstand damage by floods and to minimize problems caused by sediment and floating debris.

The water intake structure takes water from the stream whenever it is flowing. Storage reservoirs are present at eight of the treatment sites. If these are full, a series of valves will divert the water back to the stream without treatment with diversion occurring prior to the addition of coagulant.

5.2 Sedimentation (settling)

Water collected through the intake is piped to a settling tank. Settlement tanks are designed to allow heavy particles to settle for later removal. These tanks slow the water down, allowing time for heavy sediment / material (suspended sediment) to settle to the bottom of the tank.

The use of a coagulant is proposed to enhance fine particle removal. A coagulant helps contaminants to clump together, allowing faster settling at the bottom of the tank. In addition to removing sediment, the coagulant assists in the removal of any microorganisms present. This process is detailed further in Section 6 below.

The settling tank has three components.

- The inlet, where water from the intake is introduced into the tank and combined with coagulant. This part of the tank has baffles that mix the stream water and coagulant before it flows to the next stage.
- The settling zone, a long rectangular section that slows water flow and allows sediment and particles formed with the coagulant to settle. It generally takes 3 to 3.5 hours for the water to travel from the inlet to the outlet.

- The outlet that takes water from the surface leaving the settled materials in the base of the tank for periodic removal to sludge ponds.

Figure 5.2: Sedimentation pond on the Tupapa catchment. Source GHD, 2020

5.3 Filtration

Following sedimentation (settling), water is filtered by passing it through sand filters. The sand filters which are being used for the WTPs are rapid gravity filters known as 'Automatic Valveless Gravity' (AVG) filters

These filters further remove fine suspended material including microbiological contaminants. Residual coagulant carried through from the settling tanks assists in this process by ensuring that contamination present is combined to form particles which are large enough to be captured in the sand filter ('floc'). Filtered water is collected from the bottom of the tank and then sent to storage tanks on site or directly to the reticulation system.

In order to keep the filters clean and maintain adequate flow, flow is periodically reversed through the filter (a process known as backwash) with the backwash water removed to the sludge pond

Figure 5.3: Sand filter on the Avatiu catchment. Source GHD, 2020.

5.4 Disinfection

There is provision in the treatment plant design to disinfect the treated water. The disinfection step is a final protection against microbiological contamination and typically provides some protection from contaminants introduced in the transport of water from the treatment plant through to the reticulated network / property boundaries. As stated in Section 2.1, this EIA does not consider the impacts of disinfection or the use of chlorine as a disinfectant.

5.5 Waste material / water

The water treatment process generates two types of waste material / water:

- The solids that settle on the bottom of the settling tanks ('sludge'), as a result of the settling process. When sludge has accumulated in the settling tank the liquid above the sludge, "supernatant", is removed and discharged directly to adjacent stream using a mid-level drain. The remaining supernatant (below the mid level drain) and sludge is then conveyed to the ponds for treatment (see below),
- Backwash water including suspended material removed by the filter cleaning process. Backwash water is conveyed directly to ponds for treatment (refer below)

Sludge from the settling tanks and backwash water from the sand filters are treated in ponds located at each of the WTP sites. On some sites, two ponds have been constructed to treat sludge and backwash water separately (respectively known as 'scour ponds' and 'backwash ponds'). On other sites, one combined pond holds both sludge and backwash water ('sludge ponds').

The ponds are designed to remove sediment through a second settling process, before releasing water back to the waterway. The ponds have been designed to decant through manually adjusted pipes to the nearest waterway once the water level in the ponds is high enough (refer to Figure 5.4).

Sludge from the ponds will be periodically removed for disposal at an appropriate location. Appropriate locations are currently being investigated, and off-site sludge disposal will be subject to a separate EIA once the location is confirmed.

Maintenance operations also produce periodic discharges from cleaning out the system, including:

- from the settling tank discharged from the settling tanks from the mid-level drain directly to the stream,
- from the reservoir or mains discharged to land or nearby culverts.

Figure 5.4: Scour pond on the Ngatoe catchment. Source: GHD, 2020.

6 Use of coagulants in the water treatment process

6.1 The use of coagulants

As set out in Section 4.2.4, surface waters often contain soil particles, or organic matter and dirt that make the water look murky and cloudy. These particles are normally not easily visible with the naked eye and due to their size/weight it takes a long time until they settle to the bottom of the water body. This is a problem because potentially dangerous bacteria can stick to these particles, which can affect the water quality.

As set out in Section 5 above, the proposed system provides conventional (standard) water treatment. Following coarse screening of large sediment and floating debris, water is directed to settlement tanks. These are designed to allow heavy particles and finer materials including some microbiological contamination to settle for later removal.

Under normal operations (i.e. outside periods of heavy rain), the following process steps apply:

1. PACl is mixed with stream water at the settling tank inlet.
2. The majority of PACl becomes attached to sediment and other fine particles and settles to the base of the settling tank. The material in the base of the settling tanks is periodically removed to sludge ponds.
3. A small proportion of the PACl carries through with the clear water/supernatant to AVG filters. This is retained in the AVG filter with periodic removal (backwashing) to the sludge ponds.
4. The sludge from the settling tanks and backwash is allowed to settle in sludge ponds.
5. The clear water lying above the sludge ('supernatant') is periodically discharged via a decant system to the adjacent stream.
6. Where the sludge ponds are configured as two compartments with one active and one on standby, the collected sludge will be allowed to dry in the standby pond. This sludge will be periodically removed for disposal at landfill, anticipated to be every 6-12 months.

The use of a coagulant enhances fine particle removal, by improving the ability of fine particles and microbiological contamination to combine into larger particles known as ‘floc’. This assists with the treatment process by:

- removing suspended solids.
  - The larger particles / floc settles faster, reducing the time required to achieve adequate removal of suspended material. Importantly, this process removes a significant portion of the microbiological contamination (bacteria/protozoa) present in untreated water.
- reducing colour.
  - Colour is dissolved in the water so cannot settle out through gravity over time.
- removing metals.
  - Removal of both suspended and dissolved metals is greatly increased through the flocculation process.

This process is particularly important on Rarotonga during periods of wet weather, as water quality during wet weather is characterised by:

- high turbidity (fine suspended solids),
- high colour (brackish-brown), and
- a variable low to moderate soluble iron and manganese content.

In addition, the settling process improves the effectiveness of sand filters as removing the majority of suspended material reduces the need to backwash the sand filter. Finer floc that is formed as a result of coagulant addition may not be removed in the settling tank but is captured in the filter.

The coagulant added at the inlet to the settling tank stays associated with the suspended material as it moves through the treatment process. This means coagulant will be present in:

1. Settling tank sludge (removed to the sludge or scour ponds),
2. Fine material suspended in water entering the filters,
3. Suspended material captured in the filter (removed in the backwash cycle to the sludge or backwash ponds),
4. Sludge accumulated in the ponds (removed for disposal at an appropriate location),
5. Water discharged to each stream from the ponds.

Figure 6.1 is an indicative diagram of how the gravity operated water supply and treated system works. The red numbers show where coagulant may be present in the process and align with the numbering set out above.

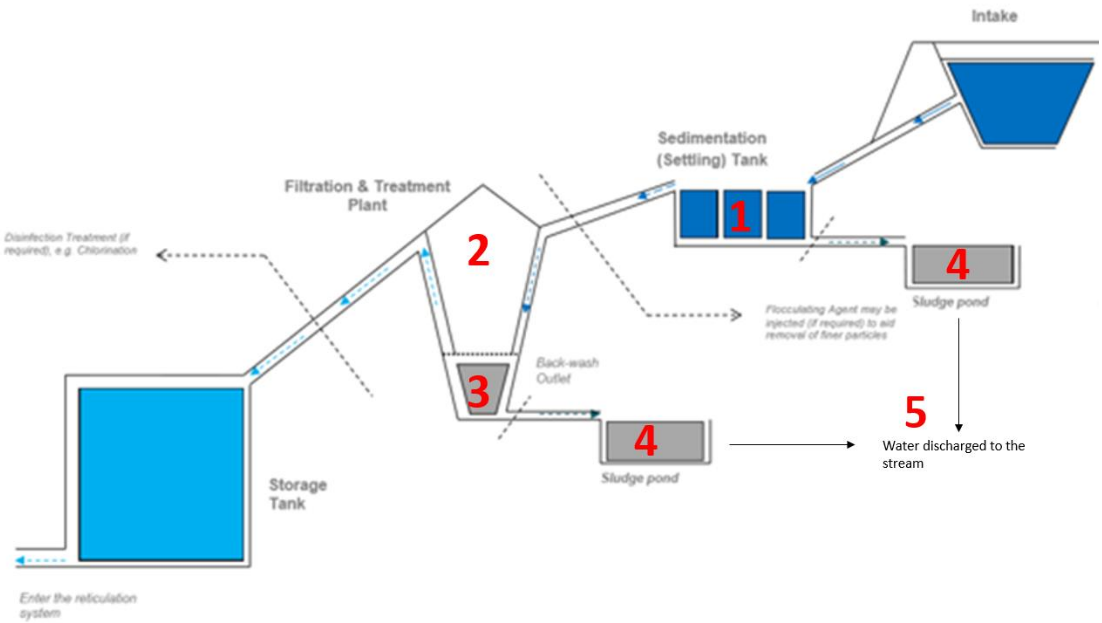

Figure 6.1: Indicative diagram of how the gravity operated water supply and treated system works. Source GHD, EIA 2014. The red numbers show where coagulant may be present in the process and align with the numbering set out above.

6.2 Dosing of coagulant

The coagulant is added to water entering the settling tank with baffles in the tank designed to ensure full mixing with the incoming water. The treatment system will be configured to dose coagulant at a standard rate based on the incoming water flow rate. The rate can be adjusted manually by the treatment plant operators.

The proposed dosing rate is around 15 mg/L PACl to achieve the desired level of fine sediment and microbiological contamination removal in the sedimentation and filter processes. The optimum coagulant dosage has been estimated by doing a 'jar test'.. This involves:

1. Samples of incoming water are collected from at the inlet to the settling tank.
2. Different doses of coagulant are injected into each jar fitted with mixers and mixed to achieve full mixing.
3. The jars are then observed as the solids to settle.
4. The resulting liquid/clear water (being the 'supernatant') is measured using a turbidity meter.
5. The optimum dose is determined by the minimum dose beyond which the supernatant does not improved in clarity.

Each site will require periodic jar tests as the water quality in each site will vary and require different dose rates[5]. The dosage estimated through jar tests have also been tested in field trials, where the inlet water associated with different weather conditions will have been assessed.

When a reservoir is at capacity, a float closes the valve on the inlet pipe at the base of the reservoir. This backs up the waterflow to the AVG which has a similar float valve shut off system. The settling tank then fills up which then redirects the incoming flow back to the stream without treatment. The rise in level in the settling tank level shuts off the coagulant dosing float valve which stops the coagulant flow.

6.3 Potential carry forward of coagulant to the filters (AVG units)

While most of the coagulant will be incorporated in the sludge from the settling tanks, some suspended material incorporating coagulant will carry through to the AVG units. This suspended material is captured in the filter and removed during the backwash cycle. The presence of coagulant in sediment captured in the sand filters enhances the performance of the filters.

6.4 Drying and removal of sludge

The sludge that accumulates in the ponds will be periodically removed. The ponds are configured in two compartments to allow sludge to dry in one compartment while new backwash and/or settling plant sludge is directed to a second pond.

[5] After the optimum dose rate is determined for the site, the PACl metering valve is adjusted to the PACl solution flow-rate which will provide the required PACl dose rate in relation to the raw water flow-rate entering the settling tank. The PACl metering valve dosing rate can be determined from the dose rate (mg/L) determined from the jar tests and the water flow-rate determined from the flow-meter reading in the AVG.

Figure 6.2: Photo of pond showing the two compartments, at the Avana Water Treatment Plant location.

It is intended that sludge will be removed from the ponds periodically for disposal at an appropriate location. Initial trials at the Ngatoe water treatment plant suggest that the sludge dewaters to a high solid content and could be disposed of directly in an appropriate facility as a solid. Some contingency for dewatering sludge should be allowed for in operations planning, for example during periods of wet weather.

6.5 Predicted resource and public infrastructure requirements

Predicted resource and public infrastructure requirements are set out in Table 6.1 below.

Table 6.1: Predicted resource and public infrastructure requirements

Resource	Comment
Energy	The coagulant will be mixed using a portable generator powered pump and stored in a tank elevated above the dosage point. Dosing of coagulant, mixing, removal of sludge and decanting clear water (supernatant) from the sludge ponds will all be via gravity i.e. no additional energy inputs.
Water	All of the water used will be from the treatment system, in turn sourced from the relevant stream.
Labour	The treatment system relies on regular supervision by trained and qualified staff. Activities including ongoing maintenance, preparing coagulant and testing incoming and outgoing water. The staff required to operate the treatment plants include:

Resource	Comment
	• Water Treatment Manager • Water Treatment Supervisors • Treatment Technicians
Transport	General vehicles for operational activities are dual cab utilities accommodating the teams of 2 or 3 technicians. These will be used to transport staff, maintenance equipment and coagulant to each of the treatment sites. Removal of sludge from the sludge ponds will require the use of a suction truck or a digger and dump truck. There is an excavator, trailer and suitable sized dump truck for this purpose. A tipper truck will be used to transport dry PACl to the site.
Minerals	No additional minerals are required in relation to the addition of PACl.
Hazardous materials	PACl powder is noted as a skin and eye irritant. PACI will be stored in a centralised location in a secure shed. Treatment chemicals will be mixed and stored on site in small quantities.
Waste outputs	As noted above, the treatment process will produce sludge and backwash water. These materials will be managed in one or more sludge ponds on each site with each pond having arrangements to decant water at the top of the pond to the adjacent stream. Sludge from the ponds will be periodically removed off site for disposal at an appropriate location. The water decanted from the ponds will be discharged when the level reaches the decant mechanism. The height of this mechanism can be manually adjusted by the operators. For maintenance of the settlement tank there will be periodic drainage of the supernatant water (approximately one meter depth) from the mid-level drain to the stream.
Timeline for implementation, operation and expected lifespan of using PACL	The treatment system is designed to be used with coagulant on an ongoing basis. Dose rates will be determined during the commissioning of each treatment plan and regular assessed based on treatment plant performance. The use of coagulant will be optimised to minimise the amount used while provide acceptable removal of suspended material and microbiological contamination.
Activity cost estimates	TTV has estimated that $250,000 is required annually for treatment chemicals. This estimate will be revised once the plant is operational.

6.6 Justification and benefits for the proposed activity

6.6.1 Benefits to the community – locally, island, and country wide

As set out on the Te Mato Vai webpage:[6]

> *The purpose of the Te Mato Vai project is to replace Rarotonga's aging water network, improve storage and introduce treatment to provide our people with a reliable and safe water supply.*
>
> *Addressing a number of environmental and health risks associated with the island's current water network, it is one of the largest and most important projects ever to be undertaken in the Cook Islands. The Te Mato Vai project is a development milestone for the Cook Islands and will have significant national health, economic and environmental benefits.*

[6] See https://www.totatouvai.co/te-mato-vai-1

As set out in Section 2, the water supply is currently untreated with the exception of coarse screening at the in-stream intakes. Monitoring of in-stream water quality and water in the reticulated network demonstrates the presence of microbiological contamination above levels that are protective of public health.

The use of a coagulant supports the effective treatment to provide a potable water supply for Rarotonga, through removal of suspended material and some microbiological contamination at the settling stage and in the sand filter.

6.6.2 Consistency of the activity with national development objectives and plans

As set out in Section 3, the National Sustainable Development Plan 2016 – 2020 and the Integrated Water Resources Policy are relevant to this proposal.

The NSDP articulates the national vision and development outcomes desired by Cook Islanders. The TMV project seeks to implement the NSDP, particularly Goal 4, by improving access to sufficient and safe water via a reticulated water system. The use of PACl as a component of this water system is consistent with the direction contained in the NSDP.

The IWRM document sets out its purpose as, "to establish policies that will guide planning, actions and efforts in ensuring the sustainable integrated water resources management across the Cook Islands". Policy Objective 1 of the IWRM is, "Reliable, potable water for all who reside in the Cook Islands and the establishment of standards for water quality and resource management. The use of PACl in water treatment to provide potable drinking is consistent with the relevant objectives of the IWRM, particularly Objective 1.

6.6.3 Requirement for coagulation/flocculation

The requirement for coagulation/flocculation is set out in Section 6.1. In summary, the use of a coagulant enhances fine particle removal. This assists with the treatment process by:

- removing suspended solids (including microbiological contamination),
- reducing colour, and
- removing metals.

This process is particularly important on Rarotonga to remove the microbiological contamination present in the source waters but is also important during periods of wet weather when turbidity is high. A number of alternatives have been considered (as set out in Section 7 below) with PACl being the preferred option.

7 Analysis of alternatives

As set out above, the focus of this EIA is on the impact and management of residual materials from sedimentation (augmented by coagulants) and filtration. This section sets out alternatives that have been considered or tested by the Project Management Unit (PMU) in relation to the use of PACl and subsequent disposal of waste material / liquid.

Sections 7.1 to 7.3 consider:

- Alternatives to the proposed use of PACl including chemicals, technologies, treatment processes or disposal methods.
- Advantages and disadvantages of these alternatives (cost, practicality, feasibility).
- Explanation for choice of the preferred option.

For clarity, we note that the scope of this EIA does not cover the broader water treatment process or operation, as this has already been assessed through a prior EIA process (GHD, 2014).

7.1 Alternatives to the proposed use of PACl

This section of the EIA sets out potential alternatives to the proposed use of PACl, including:

- Coagulants which could be used as part of the water treatment process including chemicals (Section Coagulants 7.1.1),
- Technologies and treatment processes (Section 7.1.2).

7.1.1 Coagulants

This section considers the use of coagulants in the flocculation process as part of the water treatment process including chemicals[7] (specifically aluminium sulphate and PACl) and moringa seeds[8].

As set out in Section 6, the use of a coagulant is intended to speed up and improve the removal of suspended materials, including sediment and microbiological contaminants, in the settling tank and filter components of the treatment system.

The two chemical coagulants considered for the water treatment process (GHD, 2018) were:

1 Aluminium sulphate (alum); and
2 Polyaluminium chloride (PACI).

Both alum and PACl are commonly used in water treatment processes, and were considered based on variables included:

- changes in turbidity (from fine suspended particles) and colour (from dissolved leaves etc.),
- the impact of weather and
- water chemistry, particularly alkalinity.

[7] Defined as "a substance obtained by a chemical process or producing a chemical effect", see https://www.merriam-webster.com/dictionary/chemical

[8] [8] The proponent has also considered GEO40 colloidal silica as a coagulant alternative: As a coagulant, colloidal silica's active ingredients are aluminium and iron. It also contains other chemicals including boron, arsenic, berylliumand antimony. This is a potential concern to health which would require management. The component constancy of the supply is also questioned. These factors have excluded further consideration.

Both alum and PACl are supplied as powder or granular form in 20kg bags, or in the case of alum also in 500kg bags. The chemicals can be safely stored in dry conditions in a normal shed. Both chemicals are typically mixed in a mixing tank in a shed, prior to being transferred to a “on site” storage tank. The solution will flow into a small reservoir controlled by a ball float valve. It will then drip feed, by gravity., to the raw water at the inlet of the sedimentation tank where the flocculation process is initiated.

Moringa seeds have also been trialled as an alternative coagulant to alum and PACl.

7.1.2 Technologies and treatment processes

There are two main alternatives to the use of coagulants in the treatment process:

1. To divert stream water from the treatment plant when sediment loading (turbidity) is high;
2. To use no coagulant in the settling process.

There are two other treatment technologies that may be implemented after coagulation and settlement but are worth noting briefly here. These are:

- **UV (ultra-violet light) treatment:** This is a form of disinfection, typically applied at the same time as chemical disinfection (rather than a coagulant). This relies on a suitable power source and treated water free of suspended material i.e. a coagulant would need to be used earlier in the process to achieve this. Therefore, UV is not a feasible alternative to the use of coagulants such as PACl at this site. The coagulant has a different purpose and would be used earlier in the process.
- **Membrane treatment:** A range of membrane treatment systems are used to remove various contaminants as part of water treatment systems. They typically require pre-treatment specific to the water being treated, often including removal of suspended materials. The coagulant has a different purpose and would be used earlier in the process. Membrane treatment is an alternative to sand filters rather than a replacement for a full treatment system, and would need regular cleaning (with associated discharges). Membrane filtration also relies on pumping to move water through the membrane i.e. they rely on a suitable power source, which is not available at the sites.

7.1.2.1 Diversion of stream water

Diversion of stream water from the treatment plant when sediment loading is high (e.g. during flood conditions) has been considered. The intent of this would be to reduce the amount of sediment in the water which reaches the settlement tanks, hence reducing the need for coagulant to be added to the water.

Diversion requires a rapid response to changes in stream water quality to manage the effectiveness of the settling tank and filter components of the process. A manual process is not considered feasible due to the remoteness of some of the treatment plant sites and rapidity of flow and quality changes experienced in the streams. In times of heavy rain some sites are inaccessible or unsafe to access in order to divert flows manually.

This implies an automated process is required to divert water in response to high sediment loads. A typical system involves sensors measuring incoming water quality (automated turbidity detectors). and flow alongside remotely actuated valves This requires a permanent power supply at every site. As noted in Section 5 there is no power supply to any of the sites.

Additional points to note are:

- Diversion will not address microbiological contamination (bacteria/protozoa) which is present in clear untreated water (even when the water appears clear / has low sediment loads). This

means coagulant would still be required during normal treatment plant operations to enhance the removal of microbiological contamination.

- Currently, there is very little water storage in the Rarotonga water reticulation system. Water storage is being improved as part of the TMV project, to increase resilience of the water supply during periods of low flows. When there is a rainfall event, the intent is to capture as much water for storage as possible. Bypassing wet weather flows (when sediment loads are likely to be high) will not allow for full replenishment of water in the storage system.

We have considered advantages / disadvantages of this option alongside others in Table 7.1.

7.1.2.2 Use no coagulant in the settling process

As noted in Section 6, settlement tanks are designed to allow heavy particles to settle for later removal. The use of coagulant speeds the removal of suspended solids, some of which would happen naturally over time. Therefore, an alternative approach is to not use coagulant at all.

Advantages / disadvantages of this option are set out in Section 7.1.2 below. We note that, as set out above in relation to diversion, settlement with no coagulant would not contribute to the removal of microbiological contamination (bacteria/protozoa) which is present in untreated water (even when the water appears clear / has low sediment loads). These materials will not settle without the additional coagulant. Settling without coagulant would also not reduce colour.

7.2 Disposal methods for residual waste

Two substances are required to be disposed of:

1. Sludge accumulated in the sludge ponds
2. Water accumulated in the sludge ponds (supernatant).

7.2.1 Sludge accumulated in the sludge ponds

As set out in Section 6, TTV proposes to remove sludge from the ponds periodically for disposal at an appropriate location. Water will be discharged into the nearby stream from the sludge ponds through a manually adjusted decant system.

Appropriate locations are currently being investigated, and off-site sludge disposal will be subject to a separate EIA once the location is confirmed.

These alternatives are examined in Table 7.2.

7.2.2 Water accumulated in the sludge ponds

Alternatives for disposal of water from sludge ponds includes:

- discharge into nearby streams (the current proposal),
- discharge of water from sludge ponds to settling tank inlet, and
- discharge of water from sludge ponds to land.

Advantages and disadvantages of these alternatives are examined in Table 7.2 below.

In relation to the discharge of supernatant from sludge ponds to the settling tank inlet, we note that some WTPs pump supernatant from sludge ponds to the settling tank inflow, effectively treating this water like incoming stream water. This approach would require pumping the sludge pond water up to the settling tank inlet because the sites are configured with each treatment component below the other. This would require pumps and sensors with an associated power supply at each treatment plant site, which is not available. Therefore, this has not been considered as an alternative.

7.3 Advantages and disadvantages of alternatives

In summary, alternatives to the proposed use of PACl including chemicals, technologies, treatment processes or disposal methods have been considered. The following options were considered for the generic treatment process to be adopted by TTV:

1. Coagulants, including:
   - Aluminium sulphate (alum)
   - Polyaluminium chloride (PACl)
   - Moringa seeds
2. Treatment processes including:
   - Diversion of stream water from the treatment plant when sediment loading is high
   - To use no coagulant in the settling process
3. Disposal methods for supernatant including:
   - Disposal of supernatant from sludge ponds to nearby streams
   - Disposal to land for both sludge and supernatant.
   - Discharge of supernatant from sludge ponds to settling tank inlet.

As set out above, sludge disposal will be subject to a separate EIA once the disposal location is confirmed.

As set out in Section7.1.2, there are no other alternative technologies that present a feasible alternative to the use of a coagulant.

Table 7.1 compares the alternative treatment options (i.e. alternatives to the use of PACl) and draws on more detailed analysis completed by the Project Management Unit (PMU) for TMV (GHD, 2018) and additional tests and discussions with TTV.

Table 7.2 considers alternative disposal methodologies.

Table 7.1: Advantages, disadvantages and risks of alternative treatment options

	Coagulant			Treatment processes	
	Aluminium sulphate (alum)	**Polyaluminium Chloride**	**Moringa seeds**	**Diversion, no coagulant**	**No coagulant**
Advantages	• Cost of a kg of alum is low. • Dosing systems can be a simple drip-feed system or a dosing pump. • The same physical dosing system can be used for alum and PACl. • Non hazardous. • Water chemistry is important, particular Ph.	• Effective over a wide pH range from pH 5 to pH 8. • Non-acidic - so does not affect the main chemical characteristics of the water being treated. • Forms strong readily settleable floc. • Concurrent dosing of chemicals for pH correction and a polyelectrolyte are not required. • Develops about 2/3 less sludge when compared to alum. • Prepared solutions are stable for 4-5 months. • The same physical dosing system can be used for alum and or PAC. • Non-hazardous in general use (the powdered form is a classified as a respiratory and skin irritant). • Equivalent PACl dose rate is about 1/3 that of alum for the same water quality situation. • Under normal operating conditions filter runs should be longer and water quality will be better because of the improved floc formation and settling characteristics when using PAC	• A natural / non-chemical coagulant which appears to have had some success in other trials.	• No cost for chemical coagulant. • No residual chemicals in sludge or overflow water from sludge ponds. • Only treating relatively high-quality water. • No residual chemicals in sludge or overflow water from the sludge ponds.	• No cost for chemical coagulant. • Removes a component of the treatment system (coagulant dosing), one less point of potential failure. • No residual chemicals in sludge or overflow water from the sludge ponds.
Disadvantages	• Only works within a very narrow pH range (about 5.5- 6.5) • Requires concurrent dosing of a polyelectrolyte and pH correction to be effective for TMV related Rarotonga waters. • Effective removal of colour and turbidity needs good operational skills. The optimal dosing pH range for colour removal is different to the optimal pH range for turbidity removal. • Floc formed tends to be buoyant and fragile. • Prepared solutions are unstable and tend to stratify. • Dosing rates need to be regularly adjusted to match raw water quality.	• Per kilogram it is more expensive than alum. • Residual aluminium is present in supernatant water from sludge ponds.	• Moringa seed extract was trialled in a jar test, which compared moringa seeds with PACl and a control jar (which had nothing added to it). Moringa seed extract performed consistently worse than the control jar i.e. settlement was slowed when compared with natural conditions. • Moringa seed mixed as a coagulant has a very short shelf life of a few days before it decomposes and produces a strong smell of hydrogen sulfide.	• Requires sensors to measure water quality and flow. • Requires remotely actuated valves to control flow to the treatment plant. • These require power, which is not supplied to the plant. • Does not address lighter suspended materials (incorporated in 'normal flow') including microbiological contaminants in the filter stage. • Additional time required for removal of heavier suspended materials. This translates to larger or additional settling tank.	• Ineffective removal of lighter suspended materials including microbiological contaminants in the filter stage. • Additional time required for removal of heavier suspended materials. This translates to larger or additional settling tanks (noting these have already been constructed).

	Coagulant			Treatment processes	
	Aluminium sulphate (alum)	**Polyaluminium Chloride**	**Moringa seeds**	**Diversion, no coagulant**	**No coagulant**
	• Residual aluminium is present in supernatant water from sludge ponds.				
Risks	• Mismatched dose rates may cause significant floc overflow to the sand filters resulting in the shutdown of the filters. • Under low to moderate turbidity conditions short-circuiting of floc may shorten filter runs. • Mistakes associated with dosing alum, polyelectrolyte and soda ash/lime may affect treated water pH leading to after-floc formation in the reservoir and network. • If any one of the dosing chemicals is not available under moderate to high turbidity conditions, then the treatment plant will have to be closed down. • Over-dosing or under-dosing has the potential for the aesthetic guideline value of 0.1 g/mP3P for aluminium in treated water to be exceeded.	• The risks are similar to those outlined for alum, but because PACl has a wider tolerance for coping with water quality variations, problems due to operational matters are potentially less likely to happen and if they do the impacts will be more manageable.	• Ineffective removal of suspended material and microbiological contaminants. • Short shelf life excludes ability to use this treatment a large-scale water treatment plant (including storage considerations).	• Ongoing maintenance (for sensors, remote actuated valves and power supply). • Ineffective removal of lighter suspended material and microbiological contaminants.	• Ineffective removal of lighter suspended material and microbiological contaminants.
Conclusion	• Not preferred	• **Preferred**	• Not preferred	• Not preferred	• Not preferred

Table 7.2: Advantages, disadvantages and risks of alternative disposal options for supernatant

	Discharge of water to nearby streams	**Discharge of water from sludge ponds to settling tank inlet**	**Discharge of water from sludge ponds to land**
Advantages	• Discharge can be achieved through gravity flow. • Manual adjustment of the decant pipes can be used to avoid discharge for periods of time if required. • Discharge may occur during high rainfall i.e. when there is high flow in the stream providing dilution of the pond water.	• Retains relatively high-quality water (settled) in the treatment system • Avoids a discharge of semi-treated water to the stream.	• Avoids a discharge of semi-treated water to the stream. • Discharge can be achieved through gravity flow.
Disadvantages	• No system in place to manage the risk of uncontrolled discharge during high rainfall. • Residual aluminium in water will be discharged to the stream.	• Requires pumping (due to plant configuration) with associated requirement for power for pumps and sensors (not available on site). • Due to remote location for the treatment plant will require automated system with associated maintenance and control requirements. • Pumping system is likely to be overloaded in times of heavy rainfall.	• No system in place to manage the risk of uncontrolled discharge during high rainfall. • Residual aluminium in water will be discharged to the stream.
Risks	• Risk of uncontrolled discharge during periods of high rainfall (manage through operational procedures to maintain capacity for stormwater run-off). • Risk of discharge during times of low flow	• Risk of uncontrolled discharge during periods of high rainfall (manage through operational procedures to maintain capacity for stormwater run-off).	• Risk of uncontrolled discharge during periods of high rainfall (manage through operational procedures to maintain capacity for stormwater run-off).
Conclusion	• **Preferred**	• Not preferred	• Not preferred

7.4 Explanation for choice of the preferred option

7.4.1 Proposed use of PACl

In summary, a number of alternatives have been considered to the addition of PACl, including diversion of water during periods of high flow / high turbidity and the addition of a natural coagulant (moringa). However, the use of a coagulant is considered to be the best option, given the characteristics of the water and the requirement to settle suspended solids and microbiological contaminants as part of an effective treatment system.

In addition, we note that diversion is unlikely to be a feasible option as set out in Section 7.1.2 above. Moringa seed extract was trialled as a natural option however, this was ineffective.

Therefore, the use of a coagulant is considered an integral component of the water treatment system for Rarotonga. An assessment of the potential coagulant chemicals completed by GHD (GHD, 2018) concluded the following:

1. Investigations and research have shown that the source water quality is not best suited to alum. In particular, alum only works within a very narrow pH range (about 5.5- 6.5). The alkalinity of the stream water is not always high enough to support chemical reactions when alum is added to raw water. This is most apparent during high turbidity conditions.
2. Therefore, the addition of alum would require concurrent dosing of a polyelectrolyte and a pH adjustment chemical such as soda ash or lime, to be effective. Mistakes associated with dosing alum, polyelectrolyte and soda ash/lime may affect treated water pH leading to impacts on the reservoir and network. If any one of the dosing chemicals is not available under moderate to high turbidity conditions, then the treatment plant will have to be closed down.
3. In order to deal with the variability of the alkalinity of the TMV source water the dosing system should be partially, or fully, instrumented. With no power at most of the TMV sites, limited backup technical support in Rarotonga and the requirement to fully man the WTPs to support the instrumentation, alum is not suitable.
4. PACI does not require concurrent dosing of a polyelectrolyte and pH adjustment chemical so offers significant advantages in terms of operation ease and ability to cope with a wider range of source water variations without the need to change dose rates as frequently as with alum.
5. PACI forms heavier denser floc with good settling characteristics so that the quality of water from the sedimentation tank onto the filters is normally expected to be of consistently better quality compared to alum treated water.
6. PACI provides more operational flexibility and has a comparable operational cost.

As such, the use of PACI as the coagulant is considered to be the preferred option.

7.4.2 Disposal method

Any water treatment process adopted will produce residual material requiring disposal or management. For the settling tank and filter components of the process, the residuals are sludge and supernatant water.

In terms of disposal options, the disposal of supernatant water to the stream is preferred for the reasons set out in Table 7.2. Environmental impacts of this process are discussed further in Section 9.

As set out above, sludge disposal will be subject to a separate EIA once the disposal location is confirmed.

8 Community, Landowner and Stakeholder Consultation

8.1 Consultation undertaken in relation to this EIA process

During the initial site visit for this EIA, a number of meetings were held. These are summarised in Table 8.1 with full minutes of these meetings attached in **Appendix E.**

Table 8.1: Consultation undertaken 17 January 2020 – 18 January 2020

Organisation / Person	Date	Summary
Chair of the TTV Board	17 January 2020	• Update on Court process being undertaken in relation to Rarotonga Water Ordinance however, confirmed that the EIA process (this report) is separate to the Court process. • Potential environmental impacts and likely assumptions discussed. • TTV arranged a meeting between T+TI and concerned landowners.
NES	17 January 2020	Discussion between T+TI and the NES relating to the EIA process, along with an overview of the PACl process.
TTV Operations Team	17 January 2020	Discussion with the Operations Team to provide T+TI with an oversight of their testing and operations. The Operations Team discussed: • characteristics of stream water (which affects treatment), • the testing that has been run on PACl, and monitoring to be undertaken during commissioning of the WTPs, • operational processes and constraints under high and low flow conditions.
Infrastructure Cook Islands	17 January 2020	Discussion about disposal of sludge at the landfill
Te Ipukarea Society (TIS)	17 January 2020	T+TI gave an overview of the PACl and EIA process. TIS have a number of concerns with the use of PACl, including environmental and social / cultural issues. While TIS are not arguing there is no issue with the water, they question whether the water quality is at a level that requires the level of response proposed. TIS believe that alternatives to flocculation should be considered in the EIA. TIS also recommended that T+TI meeting with Te Vai Ora Māori.
Te Vai Ora Māori along with some landowner representatives (Travis Moore, Darlene Nicholas, Ta'i Nicholas)	18 January 2020	Te Vai Ora Māori and the landowner representatives are opposed to the use of chemicals in the water treatment process. They do not agree that there is any issue with the current (untreated) water and highlighted a number of concerns with the Te Matou Vai process.

Following these discussions, a number of emails have been received from Mr Andy Kirkwood of Te Vai Ora Māori. The following matters have been raised in these emails:

- Email dated 31 January 2020: Mr Kirkwood supplied a list of information summarised for Te Vai Ora Māori and raised the potential impact of chemically treated water on agriculture and food security.
- Email dated 15 February 2020: The investigation of alternatives to PACl to be included in the EIA report should include automatic turbidity detection and diversion systems.
- Email dated 25 February 2020: Separate permits should be applied for abstraction and water collection, 'one-off' discharges and long-term storage of wastes at the landfill.
- Email dated 25 February 2020: Queries about the EIA process.

With respect to these matters:

- T+TI have reviewed the information and where relevant, the issues raised have been assessed as part of the impact assessment in Section 9 below,
- The assessment of alternatives in Section 8 above includes consideration of diversion systems,
- The EIA process undertaken has been set out in this report, with the scope of this EIA confined to the use of PACl only. T+TI understand that TTV have the necessary permits for construction of the WTPs and the water take.

TTV has ongoing discussions with landowners and relevant government agencies regarding this project.

8.2 Consultation undertaken in relation to Te Mato Vai

In addition to the consultation undertaken specifically in relation to this project, broader consultation was undertaken in relation to the Te Mato Vai project between April 2019 to June 2019. The first meetings were held with the intake landowners as a way of on-going respect and strengthening relationships with the landowners. These were then followed by meetings with the members of the House of Ariki, Koutu Nui and Religious Advisory Council (RAC), and Members of Parliament, before going public to the Vakas, followed by the non-government organisations and the Chamber of Commerce. In addition, feedback on the project was gathered via social media (Te Mato Vai Facebook page) and traditional media including newspaper articles (GHD, 2019).

This consultation largely focussed on disinfection of the treated water, particularly on chlorination.

However, some feedback from this consultation is relevant to the use of PACl in the treatment process. In particular, questions were asked about:

- The process of clearing organic material before chlorination,
- Alternative options e.g. UV systems, other systems that have been adopted around world,
- Impacts of the treatment process on people's health, environment, agriculture and the lagoon.

In response:

- PACl is directly linked to settling organic material in the settling tank, prior to any disinfection process, as set out in Section 6.
- Alternatives are discussed in Section 7.
- The key issues regarding potential impact of using PACI on the environment raised through consultation have been addressed by way of inclusion in Section 9, which assesses the impacts of the use of PACl and outlines the proposed mitigation.

9 Impact Assessment

9.1 Introduction

This impact assessment details negative and positive, immediate, short-term and long-term, permanent and temporary impacts that may arise from the use of PACI. The impact assessment considers:

- A toxicity, fate and transport assessment of PACl.
- All relevant aspects of the environment identified in Section 4 and how they are likely to be changed or affected by the use of PACL, either directly or indirectly. In particular:
  - Impacts on potable water quality
  - Impacts on ecological values
  - Impacts of contaminants on land and groundwater
  - Impacts on land use
  - Impacts on social and cultural heritage,
  - Health and safety impacts
- The nature of the changes or effects, including negative consequences and/or benefits.
- The scale and magnitude of the changes likely to occur (over what area, or on what scale).
- The changes or effects that will arise at different stages of the water treatment process (settlement, drying and disposal).

These potential impacts associated with the use of PACI can be managed with appropriate mitigation strategies and management plans that focus on the natural environment and needs of the community. The following paragraphs summarise the potential environmental impacts associated with the use of PACI and summarise the proposed mitigation strategy for addressing these impacts and outcome achieved.

The infrastructure for water treatment (sedimentation, filtration and disinfection) is already in place and therefore impacts relating to construction of the water treatment plant are not assessed.

9.2 Fate and transport assessment

The focus of this EIA is on the fate of the PACl used in the treatment process and associated dissolved aluminium in water. The following sections set out an assessment of fate and transport of PACl through the treatment process under normal operations, and during heavy rainfall.

The toxicity of PACl is addressed in Section 9.3 below.

9.2.1 Discharges during normal operations

As noted in Section 5.1 above, the water intake structure takes water from the stream whenever it is flowing however, when storage reservoirs (present at eight of the treatment sites) are full, a series of valves will divert the water back to the stream without treatment (i.e. prior to entering the settling tank).

As set out in Section 6.1 above, the coagulant added at the inlet to the settling tank stays associated with the suspended material as it moves through the treatment process. As set out in Section 6.1, under normal operations (i.e. outside periods of heavy rain), the following process steps apply:

1. PACl is mixed with stream water at the settling tank inlet.
2. The majority of PACl becomes attached to sediment and other fine particles and settles to the base of the settling tank. The material in the base of the settling tanks is periodically removed to sludge ponds.
3. A small proportion of the PACl carries through with the clear water/supernatant to AVG filters. This is retained in the AVG filter with periodic removal (backwashing) to the sludge ponds.
4. The sludge from the settling tanks and backwash is allowed to settle in sludge ponds.
5. The clear water lying above the sludge ('supernatant') is periodically discharged via a decant system to the adjacent stream.
6. Where the sludge ponds are configured as two compartments with one active and one on standby, the collected sludge will be allowed to dry in the standby pond. This sludge will be periodically removed for disposal at landfill, anticipated to be every 6-12 months.

Therefore, under normal operations, the main points at which PACl may be discharged into the environment are:

a From the ponds via the decant system discharge the supernatant into the stream.

b During removal of the sludge for disposal to an appropriate site.

c From the settling tank during maintenance operations, and

d from the reservoir or mains during maintenance operations.

The ponds will only discharge if the water level reaches the decant pipe. The water level in the sludge ponds will only increase if the sludge is removed from the settling tanks (anticipated to be every few months) or if there is a backwash cycle (anticipated to be every 1 - 3 days). The decant system can be manually adjusted to lower the pond levels or allow the water level to increase as required. Dissolved aluminium entering the stream via the discharge will associate with sediment in the stream to form flocs that will settle in the region of the discharge.

The removal of sludge from the settling tanks (Via the mid level drain) include discharge of supernatant to the stream can be scheduled to ensure any resulting discharge from the sludge ponds takes place at times of acceptable flow in the stream.

The toxicity of the discharge is discussed further in Section 9.3 below.

9.2.2 Discharges during surface flooding events

During heavy rainfall, surface flooding may occur in the area immediately adjacent and upgradient of the scour or backwash ponds. In this scenario, surface flood water could enter the ponds, resulting in overtopping of the pond and water or sludge containing PACl discharging directly from the ponds.

The ponds have been designed so that water is directed around the ponds during heavy rainfall. In addition, any discharge to the stream will be diluted by the addition of rainwater. A rain event causing surface flooding will also result in high flows in the stream. This means a discharge to the stream will be subject to significant dilution.

9.3 Toxicity assessment

The following paragraphs summarise the findings of the aquatic ecological report (GHD, 2020, **Appendix C**) in relation to impacts of this discharge.

PACl is an aluminium based coagulant, and therefore the potential environmental impacts are those associated with the release of aluminium into the environment. Potential impacts of aluminium on freshwater ecology include degradation of water quality, riparian vegetation dieback, loss of aquatic flora, reduction in diversity and abundance of macroinvertebrate communities, and an increase in susceptibility of fish to disease, predation and death and overall reduction in fish species diversity and abundance (GHD, 2020).

9.3.1 Bioavailability of aluminium at the WTP sites

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 (dissolved aluminium / Al^{+3}) in the discharged water.

Factors such as pH, dissolved organic carbon (DOC), temperature and hardness regulate the solubility of aluminium compounds in water. High temperature, acidic or alkaline pH and soft water increase the toxicity (solubility) of aluminium, whereas, dissolved organic carbon decreases the toxicity (solubility). In particular:

- pH has the greatest influence on toxicity, and solubility of aluminium in water is very low when the pH of the receiving water is between 5.5 and 9. Kennedy and Cooke (1982) studied the solubility of aluminium in water and concluded that regardless of the dose, dissolved aluminium remained below 50 µg/L in the pH range 5.5 to 9.
- Aluminium toxicity is also influenced by the water hardness, being more toxic in soft water (low in ions, particularly calcium and magnesium) <40 mg/L.
- The presence of DOC in the environment also reduces aluminium toxicity. DOC reacts with Al^{+3} forming colloidal aluminium precipitates and reducing the bioavailability of aluminium.

Taking into account these factors at each of the streams where PACl will be discharged:

- The streams where the water intakes are located are all relatively neutral, with pH values ranging from 7.01 pH units to 7.61 pH units.
- The ecology report (Appendix C) found that electrical conductivity of the waterways on Rarotonga ranged between 80-196 µS/cm indicating that it is possible that hardness is below 40 mg/L. Subsequent water parameter tests indicate that water hardness has an average range of 50-80mg/L, with a range from 34.2mg/L (the lowest measurement at the Avana site) to 102.6mg/L (the highest measurements at Avatiu and Ngatoe).[9]
- Waterways on Rarotonga typically had a low proportion of organic matter (plant and animal material) with the exception of the occasional slow flowing pool such as at the upstream site at Takuvaina where organic matter accumulates. The presence of organic matter in these pools indicates that DOC is likely to be present in varying concentrations within the waterway.

The pH of each stream has the greatest influence on toxicity. The neutral pH of the streams will likely result in low toxicity of any aluminium released into the streams from the sludge or scour ponds. Further, at this pH there is a low risk of aluminium bioaccumulation because the solubility and therefore bioavailability of ionic aluminium is very low. However, ongoing testing of pH, hardness and DOC is recommended to monitor potential bioavailability of the dissolved aluminium (see Section 10 below).

[9] Based on water parameter tests undertaken by TTV in April/May 2019 for all intake sites.

9.3.2 Residual aluminium discharge

Despite the low toxicity of the sludge pond discharge, 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. However, dilution will reduce this effect and therefore the risk of harm to receiving waters.

The impact on freshwater ecological values will vary based on the concentration of aluminium discharged. This is linked to the concentration of aluminium in the water decanted from the ponds. The impact will also depend on the flow in the stream during the discharge period.

Section 5.2.2 of **Appendix C** reviews guidelines for maximum acceptable levels of aluminium in freshwater from United States Environmental Protection Agency (USEPA) and Australian and New Zealand Environment and Conservation Council (ANZECC).[10] A value for maximum acceptable concentrations of aluminium within Rarotonga streams has been derived from the USEPA guidelines, as follows:

- Based on the pH levels within the streams (pH 7.0-7.6), the long-term/continuous concentration that could be tolerated in the streams is in the range of 290-630 µg/L ('criterion continuous concentration' or CCC).[11]
- Based on the same stream conditions / 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 under the USEPA guidelines in the streams.

On-site trials of the Rarotonga water treatment plants and associated monitoring of residual aluminium discharge (post settling tank and post AVG i.e. sludge) have found that dissolved aluminium levels are consistently below 200 µg/L. During these trials natural occurring dissolved aluminium was also measured at 50 m below the discharge point. Monitoring during the trial and some historic readings have shown that the natural dissolved aluminium levels can sometimes be greater than the conservative ANZECC limit (55 µg/L) within the streams. Natural occurring dissolved aluminium levels have been measured to date up to 0.170 µg/L following rainfall events. The monitoring of releases from the treatment plant has shown that at 50 m downstream of the point of release, no elevation of dissolved aluminium is occurring as a result of any discharge, with results consistently showing lower readings than in the ponds. See **Appendix D** for further information on measurements.

[10] The ANZECC 95% default guideline value for aluminium, indicating the concentration at which 95% of species is expected to be protected, is 55 µg/L. This is based on streams with pH greater than 6.5, but does not take into account the specific pH, hardness and DOC observed in the streams. Australia & New Zealand Guidelines for Fresh & Marine Water Quality reports that the lowest chronic 'No Observed Effect Concentration' (NOEC) for aluminium, being the concentration in an environmental compartment (water, soil, etc) which below an unacceptable effect is unlikely to be observed, is 170 µg/L for fish and 136 µg/L for crustaceans. Therefore, 55 µg/L is likely to be very conservative. Considering all this, the USEPA approach is considered to be appropriate. See https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/toxicants/aluminium-2000.

[11] The USEPA guidance refers to the Criterion Continuous Concentration (CCC) which is an estimate of the highest concentration of a material in the water column to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect i.e. the maximum value over the long-term. The Criterion Maximum Concentration (CMC) is an estimate of the highest concentration of a material in the water column to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. This estimated range for this (adapted to the receiving environment) for the CMC is significantly higher, in this case between 570-1100 µg/L (see Appendix C).

This is consistent with typical residual aluminium concentrations in outflows from water treatment plants have been observed to be in the range 10-84 µg/L.[12] This indicates that at a typical dosage rate and normal operations, and allowing for variable stream water characteristics, the residual concentrations of aluminium in the discharge would be below the derived long-term specific criteria for Rarotonga of 290 µg/L even with no dilution in-stream. The discharge from the sludge ponds will be diluted further when entering the stream.

Aluminium concentrations in sludge are likely to be significantly higher than in the supernatant. However, in normal conditions, this will not be discharged into the stream (i.e. it will be removed off-site and taken to an appropriate site). Under flood conditions there is potential for sludge to be discharged straight to the stream if surface flooding enters the ponds. However, if this does occur, the discharge will be diluted by a significant factor through high flows in the stream. As set out above, trial results indicate that dissolved aluminium levels in sludge (post AVG results) are consistently below 200 µg/L.

The impacts of the residual aluminium discharge on the environment are considered further in the following Sections 9.4-9.9.

9.4 Potable water quality

The intent of the WTPs is to improve access to safe and reliable water for human consumption and domestic usage, along with reliable access to safe water 'fit for purpose' for business and commerce.

As set out in Section 4.2.4 above, untreated water quality at the water intake sites varies depending on the level of recent rainfall. During wet weather, the stream water is characterised by:

- high turbidity (fine suspended solids),
- high colour (brackish-brown), and
- a variable low to moderate soluble iron and manganese content.

During dry weather conditions, water is clear with low to nil turbidity and colour content, and both iron and manganese concentrations were below the WHO aesthetic guideline values. Microbiological contaminants (faecal coliforms) are present at all intakes, albeit at variable concentrations, in both dry and wet weather.

The purpose of using PACl is to accelerate and improve the removal of suspended materials, including microbiological contaminants, in the settling tank and filter components of the treatment system. The use of a coagulant will contribute to an effective and consistent water treatment process. This is the case both during wet weather (when there is high turbidity in the water), and during dry weather when PACl will assist in effective removal of microbiological contaminants. Therefore, the use of PACl is considered to have a positive effect on potable water quality.

Naturally occurring aluminium as well as aluminium salts used as coagulants in drinking-water treatment are the primary sources of aluminium in drinking-water. Dissolved aluminium in drinking water is managed for aesthetic rather than health purposes. WHO notes that the aluminium at concentrations in excess of 0.1 – 0.2 mg/l (100 - 200 µg/L) often leads to consumer complaints as a result of deposition of aluminium hydroxide floc and the exacerbation of discoloration of water by iron[13]. Data obtained in trials to date indicate dissolved aluminium can be maintained below this level.

[13] Guidelines for Drinking-water Quality, fourth edition incorporating the first addendum, WHO, 2017.

9.5 Impacts on ecological values

Ecological values have been identified via a field survey, as set out in Section 4.2.5 above. In summary:

- Aquatic habitat and environmental values of the waterways between the 10 catchments were similar. During the dry season, water flows within the majority of catchments is expected to cease and the waterways will exist as a series of isolated pools interspersed with dry riverbed.
- Streams at all sites provided either good or excellent habitat quality.
- There are no threatened freshwater aquatic plant species recorded on Rarotonga (and none were found during the field survey). Aquatic flora had limited diversity, and species and abundance were similar between the upstream and downstream sites at all sites.
- Aquatic macroinvertebrate diversity was low. All species found were considered to be tolerant of pollution.
- Fish diversity was limited throughout the catchments with only three species identified and small unidentified fish noted across eight of the ten catchments. No turtles were observed.

Aquatic flora and fauna in the streams may be adversely impacted by the discharge of water containing residual PACl from the scour ponds directly in the streams.

As set out in Section 9.2 above, this will occur periodically via the decant system. This could also occur when there is high rainfall with surface water running to the ponds leading to treated water, settlement tank sludge or backwash overtopping the sludge ponds.

However, as set out in **Appendix C** and Section 9.3 above):

- The neutral pH of the streams will likely result in low toxicity of any aluminium released into the streams from the sludge or scour ponds. Further, at this pH there is a low risk of aluminium bioaccumulation because the solubility and therefore bioavailability of ionic aluminium is very low.
- A value for acceptable long-term/continuous concentrations (CCC) of aluminium within Rarotonga streams has been derived, being 290-630 µg/L. The highest concentration of aluminium to which the aquatic community can be exposed briefly without resulting in an unacceptable effect (CMC) is in the range of 570-1100 µg/L in the streams.
- Based on a typical dosage rate, the residual concentrations of aluminium would be below 290 µg/L prior to discharge into the stream. At typical dosage rates and normal operations, it is anticipated that aluminium would be below the guideline for environmental protection at the point of discharge from the ponds.

Overall, the impacts on freshwater ecological values associated to the use of PACl are considered low and acceptable.

9.5.1 Mitigation / monitoring measures

In order to confirm that the anticipated levels of residential aluminium in the discharge is below the long-term specific criteria for Rarotonga of 290 µg/L and maximum concentration of 570 µg/L, monitoring and reporting is proposed as follows:

- Regular sampling (every week) for Aluminium, turbidity, DOC, hardness (electrical conductivity) and pH for the first six months. At the same time, an estimate of the stream level (or water flow) should be taken.
- In addition, pH the stream at the discharge point will be tested more regularly (at least bi-weekly) as part of operational checks.

- After six months, if results show Al^{3+} concentrations are stable and below the threshold, the sampling required will be decreased to once every month until 4 consecutive samples are compliant, then reduced to seasonal sampling once every 6 months for perpetuity i.e. one sample in dry season and one sample in wet season.
- The proposed sampling shall be undertaken in agreed locations at each water treatment plant site as follows:
  - Sampling at three locations in adjacent 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).
    - approximately 200 m downstream of discharge (compared to the CCC value for dissolved aluminium of 290 µg/L in the receiving water).
  - Sampling of supernatant / clear water outlet from settling tank, the outlet from AVG filter, and in the ponds at each WTP. This is proposed in order to understand aluminium fate through treatment, and to confirm aluminium concentration in the discharge.
- In addition, specific protocols will apply to:
  - Sampling from the settling tank during maintenance operations:
    - Sampling will be conducted half an hour after the mid-level drain has been opened in the following locations:
      - Upstream of the mid-level drain discharge point (this is also upstream of the discharge from the ponds).
      - Immediately downstream of the mid-level drain discharge point (also upstream of the discharge from the ponds).
      - In the stream approximately 200m downstream of the mid-level discharge point.
    - Sampling will be conducted every time the mid-level drain is utilized for the first year then removed with consent from NES.
  - Testing where there is a dry stream bed:
    - Sampling conducted once every week for six months of operation in the following locations:
      - Immediately outside the discharge from the ponds if possible.
    - The dissolved aluminium results for this sample will be compared to the CMC value for dissolved aluminium of 570 µg/L.
- Different monitoring pathways can be triggered based on the results of the regular sampling. The risk of toxicity of PACl can be mitigated further by controlling the dosage and by adjusting the dilution rate to keep the aluminium below the toxicity threshold concentrations in the receiving environment (while ensuring the coagulant dosage remains effective). This provides an adaptive mitigation measure.
- A bi-annual report will be produced to provide transparency, data and outline how the mitigation measures have been adhered to.

This is also set out in the environmental mitigation/management commitments made in this EIA attached in **Appendix F**.

9.6 Impacts of contaminants on land and groundwater

The potential contaminant impacts associated with the use of PACI include:

- **Storage of PACI** (in its powder form) at a centralised location, as spillage of PACl may cause localised contamination.
- **Storage of PACl solution** (at each treatment plant site) in tanks, as spillage of PACl solution may cause localised contamination.
- **Storage of sludge** in the sludge ponds. Without appropriate management of the water treatment plant including maintenance methods in place, contaminants from the sludge could enter the surrounding land and adversely affect the associated land-based ecological values. Storage of sludge in the sludge ponds also has potential impacts on groundwater.
- **Disposal of sludge**, which will be removed from the ponds periodically for disposal at an appropriate site.

In order to avoid or mitigate impacts on the surrounding land from the storage of PACl in storage tanks and sludge in scour and backwash ponds at the WTP sites, the following measures are proposed:

- Minimising the risk of spills through the storage of PACI solution within a shed with an impervious concrete floor. In addition, methods for handling PACI correctly will include restricting the use of PACI to authorised trained staff. This will further reduce risk of spills onto land.
- A WTP Operations Manual will include reviewing the level/volume of sludge within the ponds so that it is removed in a timely manner. The ponds will be managed including the removal of sludge to ensure sludge settling can occur and to manage discharge of supernatant via the decant system. This will reduce the potential for overspill of sludge or disruption within the water treatment process.

Sludge will be removed from the ponds periodically for disposal at an appropriate authorised disposal site.

There is not anticipated to be a significant discharge from the ponds to underlying soil or groundwater. Sludge will settle in the active pond with supernatant removed (discharged to the stream). The sludge remaining in the standby pond will be allowed to dry prior to removal.

Overall, the impacts associated with the use of PACl on the surrounding land will be low and acceptable.

9.6.1 Mitigation / monitoring measures

Adherence to health and safety methods and a WTP Operations Manual are proposed in order to avoid or mitigate the impacts of potential discharges of PACI to land. Key protocols include:

- Careful management and storage of PACl solution at each WTP site.
- Proactive management of sludge and supernatant levels in each for the scour and backwash ponds.
- Disposal of sludge removed from the scour and backwash ponds at an appropriate site
- Appropriate training of operational staff.

9.7 Impacts on land use

This section considers the potential impact of PACl on land use further downstream, for example, horticultural and agricultural production. As set out in Section 4, wetland taro beds remain in Takuvaine Valley (GHD, 2014). Other agricultural activities include small-scale pig, goat and poultry farming which may use stream water (GHD, 2020).

As set out in Section 9.5 above, based on the receiving environment conditions and the expected residual aluminium in the discharge, the impacts on downstream freshwater ecological values from the use of PACl is considered low and acceptable. At typical dosage rates, aluminium would be below the guideline for environmental protection at the outflow from the settlement tanks. The discharge will be further diluted on entry to the stream. Dissolved aluminium present in the stream water is likely to bind to fine sediment and settle further reducing the concentration of dissolved aluminium in stream water downstream from the water treatment plant.

Given the low impact on downstream water, the impacts from the use of PACl on land use downstream of the water treatment plants (e.g. agricultural uses) are considered to be low.

9.8 Social and cultural impacts

This section of the EIA addresses the positive and negative impacts on social and cultural values from the use of PACI within the water treatment process.

As set out above, water intakes and water treatment plants are located inland in the upper catchments, away from residential settlements which are generally located on lower land, near the back road / main road. In addition to agricultural and horticultural activities, some recreational or tourism activities are undertaken in the catchment, along with fishing and swimming in some catchments.

The use of PACl is not anticipated to have a direct negative impact on these activities given the low impacts immediately adjacent to the water treatment plants. As set out in the previous section, the impacts from the use of PACl on land use downstream of the water treatment plants (e.g. agricultural uses) are considered to be low. In addition, the use of a coagulant has no direct negative impact on physical cultural sites, in addition to impacts already considered as part of the construction of the WTPs.

We note that there has been strong opposition to the addition of chemicals to the water treatment process (including PACl) expressed by some community members and landowners. A clear statement of cultural values relating to the introduction of PACl into the water treatment process is not available. However, based on discussions in January 2020, we understand that there are deeply held views from parts of the community that chemicals of any type should not be added to water (see minutes in **Appendix E**). We note there are significant cultural values attached to land and water in the Cook Islands and there is a fundamental link between these values and the relationship between land and identity (Coffey, 2019).

However, we note that while a number of people are strongly opposed to the addition of chemicals into the water treatment process, there are also a number of people who have expressed support for the upgrade (see Section 8.2). While some have expressed the view that the water does not require treatment as they do not get sick from it, the evidence unfortunately indicates that there is regular microbiological contamination above safe levels, and this increases the risk of water-related health issues.

As stated by WHO (2011):

> *Faecally derived pathogens are the principal concerns in setting health-based targets for microbial safety. Microbial water quality often varies rapidly and over a wide range. Short-term peaks in pathogen concentration may increase disease risks considerably and may trigger outbreaks of water-borne disease. Furthermore, by the time microbial contamination is detected, many people may have been exposed. For these reasons, reliance cannot be placed solely on end-product testing, even when frequent, to determine the microbial safety of drinking water…*
>
> *The potential health consequences of microbial contamination are such that its control must always be of paramount importance and must never be compromised.*

A safe, reliable and potable drinking water supply has well established social benefits, supporting public health outcomes at local, regional and national levels (WHO, 2011). This is further supported by the Cook Islands national policy framework, including the NSDP and the IWRM. Therefore, on balance, the use of PACl are considered to be appropriate in relation to social and cultural values.

9.9 Health and safety impacts

This section of the EIA addresses the potential health and safety impacts of using PACI within the water treatment process. The main health and safety impacts relate to:

- Workers handling and storing PACI and PACL solution;
- Potential members of the public/visitors accessing the storage shed and PACl Solution storage at each of the water treatment plants.

To maintain health and safety the following is proposed:

- The shed containing PACI shall be secured at all times. The shed should have a warning sign identifying that it contains hazardous chemicals.
- Restrict the access of PACI to persons suitably experienced, trained and qualified to work with this chemical.
- The Safety Data Sheet provided by the manufacturer shall be kept in the shed to ensure all relevant information about PACI is easily available.
- The water treatment sites shall be secured at all times.

Provided that the above is complied with, the health and safety impacts of PACI will be sufficiently managed.

10 Operation Environmental Management Plan

The following section provides a draft operational environmental management plan framework (OEMP Framework) that includes the following:

- Environmental performance objectives for the activity
- Responsible parties
- Monitoring plan
- Relevant government agencies
- Staffing and equipment requirements
- Process for engagement with stakeholders.

These matters will be addressed in the Operations Manual for each treatment plant site.

10.1 Environmental performance objectives for the activity

As set out in Section 9.3.2 above, trigger values for acceptable concentrations of aluminium within Rarotonga streams have been derived from USEPA guidance. Based on these values, TTV proposes the following environmental performance objectives:

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

These objectives are incorporated into the proposed monitoring at each of the WTPs.

Sludge removed from each of the treatment plant sites will be managed appropriately. This EIA has assumed that the sludge will be removed for management and disposal at an appropriate site, in accordance with the statutory approvals for that site.

10.2 Responsible parties

The Operations Manual will clearly note who will have responsibility for overseeing the implementation of different mitigation measures, incident response, environmental monitoring and reporting.

10.3 Monitoring plan

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 intended to start once the current trials of the water treatment plants, which include the use of PACl, are complete[14].

[14] We note that the contractor led trials have been assessed against the ANZECC 95% default guideline value for aluminium, indicating the concentration at which 95% of species is expected to be protected, is 55 µg/L. This is based on streams with pH greater than 6.5, but does not take into account the specific pH, hardness and DOC observed in the streams. Australia & New Zealand Guidelines for Fresh & Marine Water Quality reports that the lowest chronic 'No Observed Effect Concentration' (NOEC) for aluminium, being the concentration in an environmental compartment (water, soil, etc) which below an unacceptable effect is unlikely to be observed, is 170 µg/L for fish and 136 µg/L for crustaceans. Therefore, 55 µg/L is likely to be very conservative. Considering all this, the USEPA approach is considered to be appropriate and we have used this approach in this monitoring plan.

1. Sampling conducted once every week for six months of operation in the following locations:
    a. In the streams adjacent to the WTPs:
        i. Upstream of the water treatment plant intake structure
        ii. Immediately downstream of the discharge from the ponds
        iii. In the stream approximately 200m downstream of the discharge point from the scour / backwash ponds.
    b. Sampling of supernatant / clear water outlet from settling tank, the outlet from AVG filter, and in the ponds at each WTP.
2. The samples will be tested for dissolved aluminium, turbidity, DOC, hardness (electrical conductivity) and pH. At the same time, an estimate of the stream level (or water flow) should be taken.
3. The pH of the stream at the discharge point will also be recorded at least bi-weekly as part of regular checks.
4. The dissolved aluminium results for sample 1(a)(ii) will be compared to the CMC value for dissolved aluminium of 570 µg/L in the receiving water. The trigger value (CMC) will be adjusted to 78 µg/L. if the stream pH measured in sample (a)(i) is below 7.
5. The dissolved aluminium results for sample 1(a)(iii) will be compared to the CCC value for dissolved aluminium of 290 µg/L in the receiving water. The trigger value will be adjusted to 78 µg/L if stream pH measured in sample (a)(i) is below 6.5.
6. In addition, specific protocols will apply to:
    a. Sampling from the settling tank during maintenance operations:
        i. Sampling will be conducted half an hour after the mid-level drain has been opened in the following locations:
            - Upstream of the mid-level drain discharge point (this is also upstream of the discharge from the ponds).
            - Immediately downstream of the mid-level drain discharge point (also upstream of the discharge from the ponds).
            - In the stream approximately 200m downstream of the mid-level discharge point.
        ii. Sampling will be conducted every time the mid-level drain is utilized for the first year of operation.
    b. Testing where there is a dry stream bed:
        i. Sampling conducted once every week for six months of operation in the following locations:
            - Immediately outside the discharge from the ponds.
        ii. The dissolved aluminium results for this sample will be compared to the CMC value for dissolved aluminium of 570 µg/L.
7. If any result for samples taken at locations 1(a)(ii), 1(a)(iii) or 6 exceed the relevant trigger, then the dissolved aluminium results from the other locations are compared to determine if the discharge is the likely principal cause, or a likely significant contributor to the exceedance.

8. If it is determined that the discharge is the likely principal cause, or a likely significant contributor to the trigger value exceedance, then alternative coagulants, or operational approaches will need to be developed to reduce the concentrations.
9. If after six months of operation, results show Al^{3+} concentrations are stable and below the threshold, the sampling required will be decreased to once every month until 4 consecutive samples at locations (a)(ii) and (a)(iii)are compliant, then reduced to seasonal sampling once every 6 months for perpetuity i.e. one sample in dry season and one sample in wet season.
10. If an exceedance occurs in any test, then the testing regularity will revert to the next highest level of testing regularity until the issue is resolved.
11. The treatment plant produces a bi-annual report summarising the monitoring and sampling undertaken, critical analysis of compliance and potential adverse environmental effects and any recommendations. This will be issued internally to TTV and to NES.
12. The NES can review and change the conditions of the consent annually.

As noted in Section 9.5.1 above, the risk of toxicity of PACl can be mitigated further by controlling the dosage and by adjusting the dilution rate to keep the aluminium below the toxicity threshold concentrations in the receiving environment (while ensuring the coagulant dosage remains effective i.e. that the amount of PACl effectively settles heavy particles and finer materials including some microbiological contamination for later removal).

Environmental mitigation/management commitments made by the proponent are contained within **Appendix F.**

10.4 Relevant government agencies

The Operations Manual produced by TTV will clearly note the names of the government agencies and key contacts that TTV will report their outcomes and monitoring results to.

10.5 Staffing and equipment requirement

The Operations Manual will clearly note staffing and equipment requirements, any training programmes or capacity development necessary to ensure successful OEMP implementation.

10.6 Process for engaging with stakeholders

A process for managing and responding to stakeholder concerns or complaints. Provision is to be made for periodic review of the OEMP once the activity becomes operational.

11 Conclusions and Recommendations

TTV have commissioned T+TI to undertake an independent EIA to assess the potential environmental impacts of the activity of using PACl as a coagulant during the operation of the WTPs. Specifically, the focus of this EIA is on the management of residual materials from the settling tank and sand filter.

The Rarotonga water supply is currently untreated with the exception of coarse screening at the in-stream intakes. Monitoring of in-stream water quality and water in the reticulated network demonstrates the presence of microbiological contamination above levels that are protective of public health.

The use of a coagulant supports the effective treatment of a potable water supply for Rarotonga, through removal of suspended material and microbiological contamination at the settling stage and in the sand filter. This process is particularly important on Rarotonga to support the removal of microbiological contamination present in the stream water to be treated. The process is also important for the removal of suspended materials during periods of wet weather when turbidity is high.

This EIA report draws the following conclusions:

- The works are consistent with the relevant policy provisions, including the NSDP and the IWRM. The TMV project seeks to implement the NSDP, particularly Goal 4, by improving access to sufficient and safe water via a reticulated water system. The use of PACl as a component of this water system is consistent with the direction contained in the NSDP. Policy Objective 1 of the IWRM is, "Reliable, potable water for all who reside in the Cook Islands and the establishment of standards for water quality and resource management". The use of PACl as a component of a reticulated water system to provide potable drinking water is consistent with the relevant objectives of the IWRM, particularly Objective 1.
- A number of alternatives have been considered with PACl being the preferred option.
- The addition of PACL is generally considered to have a low impact on the environment. In particular:
  - The expected impacts on freshwater ecological values, and on land and groundwater at the WTP sites, are considered low and acceptable.
  - Given the likely low impact on downstream water, the impacts from the use of PACl on land use downstream of the water treatment plants (e.g. agricultural uses) are considered to be low.
  - A safe, reliable and potable drinking water supply has well established social benefits, supporting public health outcomes at local, regional and national levels (WHO, 2011). This is further supported by the Cook Islands national policy framework, including the NSDP and the IWRM. The use of PACl is considered to have a positive effect on potable water quality. Therefore, on balance, the use of PACl are considered to be appropriate in relation to social and cultural values.
  - Provided appropriate protocols are followed, the health and safety impacts of PACI can be managed to an acceptable standard.
  - Sludge generated through the water treatment process will be disposed of an appropriate and approved location.

The monitoring plan set out in Section 10.3 provides appropriate monitoring to check that the environmental impacts are as expected.

12 References

Coffey (2019) Mei Te Vai Ki Te Vai Wastewater Project Social-Cultural Impact Assessment

GHD (2014) Draft Environmental Impact Assessment Report undertaken for the Detailed Design for Stage 2

GHD (2018) Memorandum "TMV – Options for Coagulant Dosing"

GHD (2020), Te Mato Vai: Aquatic Ecology Baseline Report

Pacific Climate Change Science Programme (2013), current and future climate of the Cook Islands

Te Mato Vai Project Management Office (2019) Disinfection Consultation meetings for TMV, Stage 2, Draft Report

Te Mato Vai Project Management Office (2019) Six Monthly Activity Progress Report 1 January 2019 – 30 June 2019, Revision: Rev 1

World Health Organization (2017) Guidelines for drinking-water quality: fourth edition incorporating the first addendum

13 Applicability

This report has been prepared for the exclusive use of our client To Tatou Vai Limited, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor International Ltd

Report prepared by:

....	....
Sarah McCarter Senior Planner	Chris Purchas Sector Director, Waste

Authorised for Tonkin & Taylor International Ltd by:

....

Chris Freer
Project Director

28-May-21
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Appendix A: Term of Reference requirements

The following table provides a summary of the information required in the Terms of Reference and a quick reference to its location in this report.

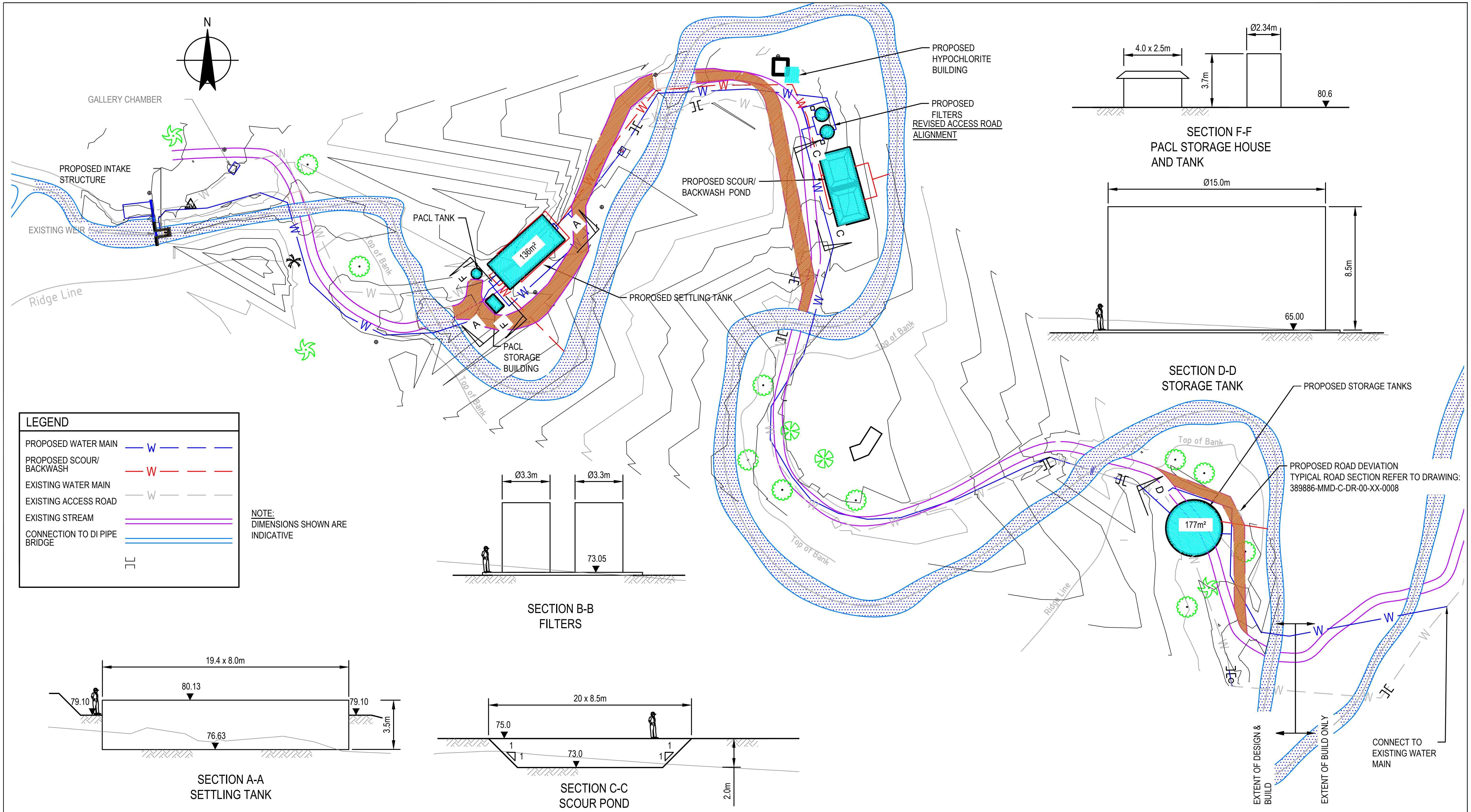
Terms of Reference requirements	Location within report
Executive summary Present a concise, non-technical outline of the proposed use of PACL and each chapter of the EIA report. Include the results of impact and risk assessments, the proposed management/mitigation actions, and the conclusions reached.	Executive Summary
Table of contents	Table of contents
Glossary List acronyms/abbreviations.	Section 1
Introduction Provide a high-level overview of the TMV project and associated water treatment plants. Provide a description to the proposed use of PACL in the water treatment process including the purpose and objectives.	Section 2
Policy and legal framework Outline the relevant policies and laws that apply to the use of use of PACL and identify any approvals needed from government agencies. For example: • National laws and related government approvals • Multilateral Environmental Agreements • Industry policies or codes of practice • Health, safety, hazard and risk management standards	Section 3
Activity description and justification Present a detailed description of the proposed activity, including:	
• The location of TMV project water treatment plants, size and layout, including a description of their proximity to watercourses, towns/villages, transport infrastructure and cultural/ecological assets.	Section 4.2, Appendix B
• The water treatment plant components, processes, infrastructure and design, including technology and equipment likely to be used.	Section 5
• The use of PACL for coagulation in the settlement tank.	Section 6.1
• Method used to determine PACL usage.	Section 6.2
• The removal of PACL-laden sludge from the settlement tanks.	Section 6.4
• The potential carry forward of PACL to the AVG units.	Section 6.3
• The drying of sludge in scour ponds and digging out the ponds.	Section 6.4
• The transportation and disposal of dried sludge.	Section 6.4
• The predicted resource and public infrastructure requirements, including for example, energy, water, labour, transport, minerals, hazardous materials.	Section 6.5
• Predicted type and quantity of waste outputs (liquid, solid and gas emissions).	Section 6.5

Terms of Reference requirements	Location within report
• Timeline for implementation, operation and expected lifespan of using PACL. • Activity cost estimates.	Section 6.5 Section 6.5
Analysis of alternatives: • Alternatives to the proposed use of PACL including chemicals, technologies, treatment processes or disposal methods. • Advantages and disadvantages of alternatives (cost, practicality, feasibility). • Explanation for choice of the preferred option.	Section 7
Provide justification for the activity and its benefits • Benefits to the local area, island, country (more efficient/cost-effective infrastructure, improved environmental outcomes, improved treatment outcomes). • Consistency of the activity with national development objectives and plans. • The need for the use of PACL.	Section 6.6
Section 7 – Description of the baseline environment Detail baseline (existing) environmental conditions relevant to where PACL will be used in the water treatment process. The level of examination and effort will depend on the scale of the activity, its physical setting and its area of influence. Where relevant, the following aspects of the environment should be described: • Climate (temperature, rainfall, winds, extreme weather events, climate change projections). • Topography, geology and soils (landscape gradient or slope, seismic characteristics, areas vulnerable to landslides, erosion). • Sensitive environmental areas or land uses immediately surrounding PACL storage areas, the scour ponds and sludge disposal locations. Identify any high value or threatened flora, fauna or herpetofauna that may be present immediately surrounding these areas. • Water (surface and groundwater quantity and quality; site hydrology; local catchment area; downstream water uses/users; areas vulnerable to flooding, inundation or storm surges). • Air (existing sources of air emissions or odour; ambient air quality, location of nearest sensitive receptors). • Social context of the areas surrounding where PACL will be used (towns/villages; housing; transport and other community infrastructure; cultural traditions and community activities). • Cultural resources and heritage (objects or sites of social/cultural significance, cultural values or beliefs relevant to the use of PACL).	Section 4 Section 4.2.1 Section 4.2.2 Section 4.2.5, Appendix C Section 4.2.4 N/A Section 4.2.6 Section 4.2.6

Terms of Reference requirements	Location within report
Impact assessment Assess and describe the potential impacts of the activity on the environment, social and cultural values identified in Section 7. The impact assessment should detail negative and positive; immediate, short-term and long-term; permanent and temporary impacts. The impact assessment should consider: • A toxicity, fate and transport assessment of PACL. • All relevant aspects of the environment identified in Section 7 and how they are likely to be • changed or affected by the use of PACL, either directly or indirectly. • The nature of the changes or effects, including negative consequences and/or benefits. • The scale and magnitude of the changes likely to occur (over what area, or on what scale). • The changes or affects that will arise at different stages of the water treatment process (settlement, drying and disposal). • Explain the methods used for the impact assessment, such as modelling, site surveys, or review of existing information or previous studies.	Section 9 =
Operation environmental management Provide a draft operational environmental management plan framework (OEMP Framework) that includes the following: • Environmental performance objectives for the activity. • Who will have responsibility for overseeing the implementation of different mitigation measures, incident response, environmental monitoring and reporting. • A monitoring plan, including performance criteria for measuring the extent of environmental impacts, and/or the success of mitigation measures. • The names of the government agencies the proponent will report their outcomes and monitoring results to. • Staffing and equipment requirements, any training programmes or capacity development necessary to ensure successful OEMP implementation. • A process for managing and responding to stakeholder concerns or complaints. • Provision should be made for periodic review of the OEMP once the activity becomes operational.	Section 10

Terms of Reference requirements	Location within report
Community, landowner and stakeholder consultation Landowner and stakeholder engagement for the use of PACL will be led by TTV. The EIA should include a summary of this consultation including: • Meetings, workshops or other forms of consultation held to date. • The outcomes of consultation, including issues and concerns raised by different groups or affected parties. • A discussion of how issues and concerns have been addressed. • An overview of future planned consultation and engagement activities.	Section 8
Conclusions and recommendations • Present the main conclusions of the EIA report and the proponent's suggested recommendations for progressing with the activity, including key environmental management and mitigation measures that should be undertaken.	Section 11
References Appropriately reference all information sources that have been used or consulted during EIA report preparation.	Section 12
Appendices Include appendices that support the main text, including: • Relevant environmental studies and reports. • Detailed technical information. • A table listing how this TOR has been addressed, cross-referenced to relevant sections of the EIA report. • A table listing environmental mitigation/management commitments made by the proponent. • Evidence of activity support from stakeholders.	See Appendices A-F

Appendix B: Water Treatment Plant Plans



INFORMATION FOR CONSTRUCTION

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TE MATO VAI

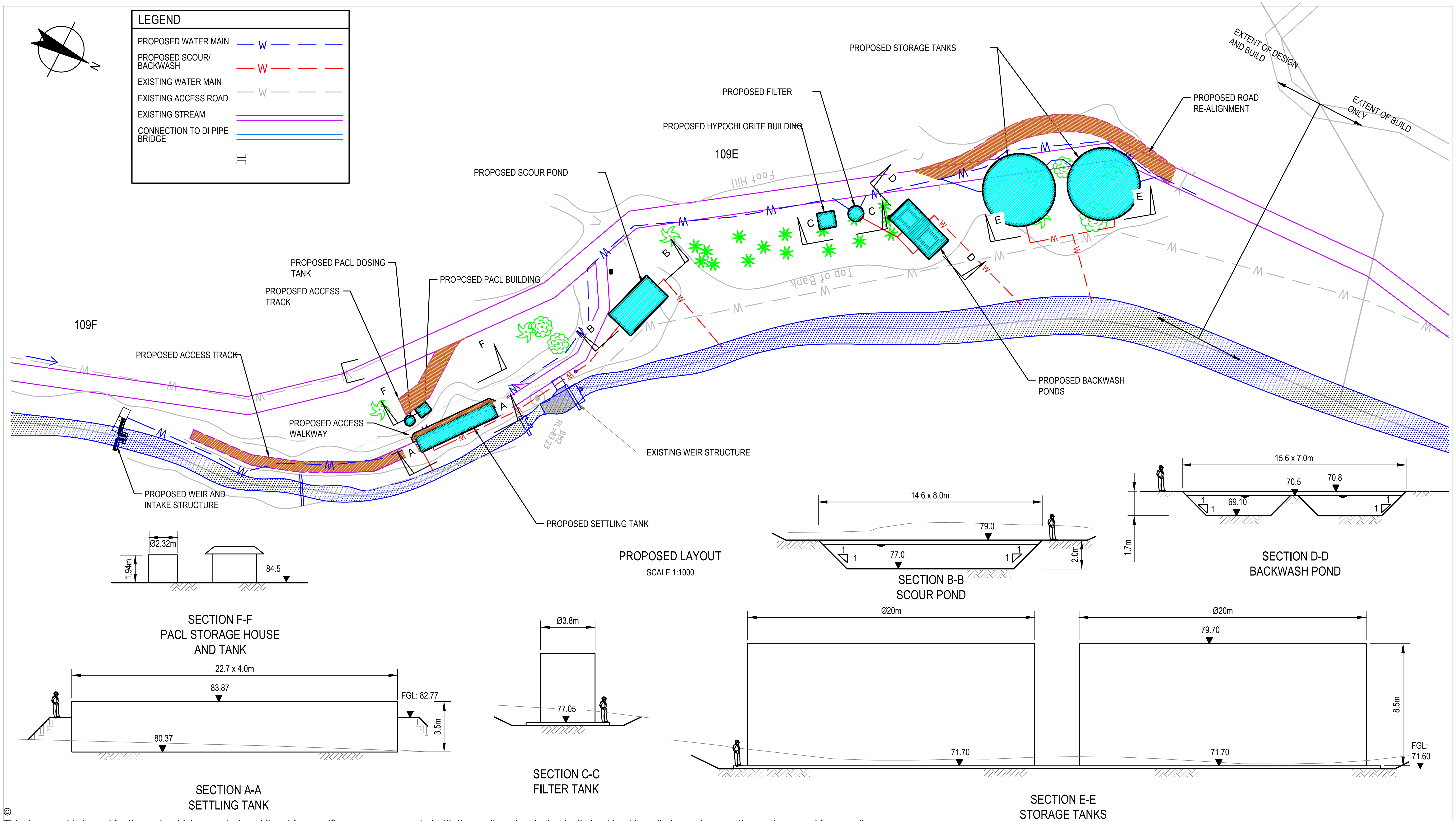
Rev	Date	Drawn	Description	Ch'k'd	App'd
A	08-03-19	FM	FOR CONSTRUCTION	ET	ND

Title
TE MATO VAI - STAGE 2
AVANA WATER SUPPLY
WTP LAYOUT PLAN

Drawn	FM
Checked	ET
Approved	ND
Scale at A3	AS SHOWN

Drawing Number: 389886-MMD-Z-DR-01-XX-0002

Security	Status	Rev
STD	CON	A



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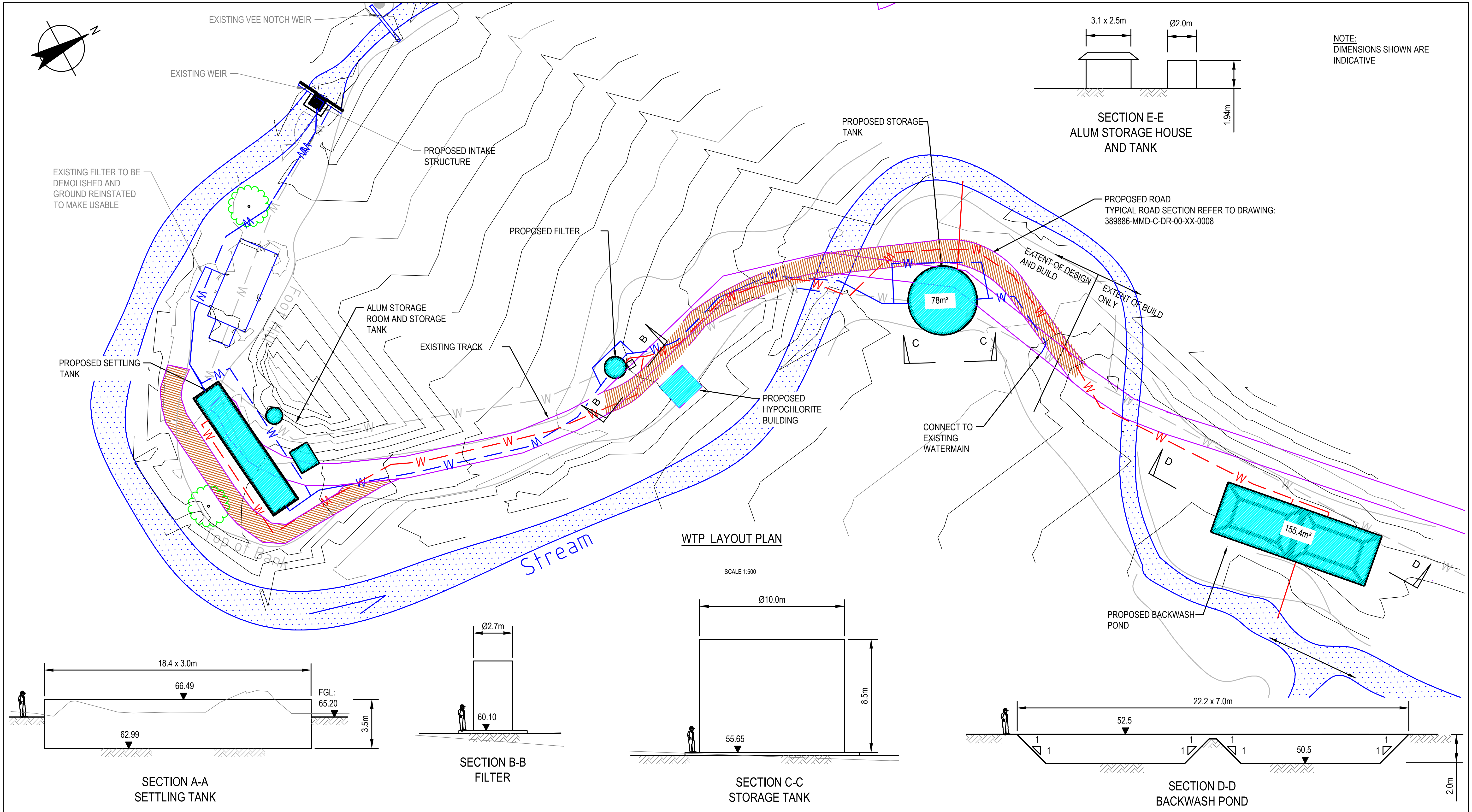
Rev	Date	Drawn	Description	Ch'k'd	App'd
A	08-03-19	FM	FOR CONSTRUCTION	ET	ND

Title
TE MATO VAI - STAGE 2
AVATIU WATER SUPPLY
WTP LAYOUT PLAN

Drawn	FM
Checked	ET
Approved	ND
Scale at A3	AS SHOWN

Drawing Number: 389886-MMD-Z-DR-02-XX-0002

Security	Status	Rev
STD	CON	A



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TE MATO VAI

Rev	Date	Drawn	Description	Ch'k'd	App'd
A	08-03-19	FM	FOR CONSTRUCTION	ET	ND

Title
TE MATO VAI - STAGE 2
MATAVERA WATER SUPPLY
WTP LAYOUT PLAN

Drawn	FM
Checked	ET
Approved	ND
Scale at A3	AS SHOWN

Drawing Number	Security	Status	Rev
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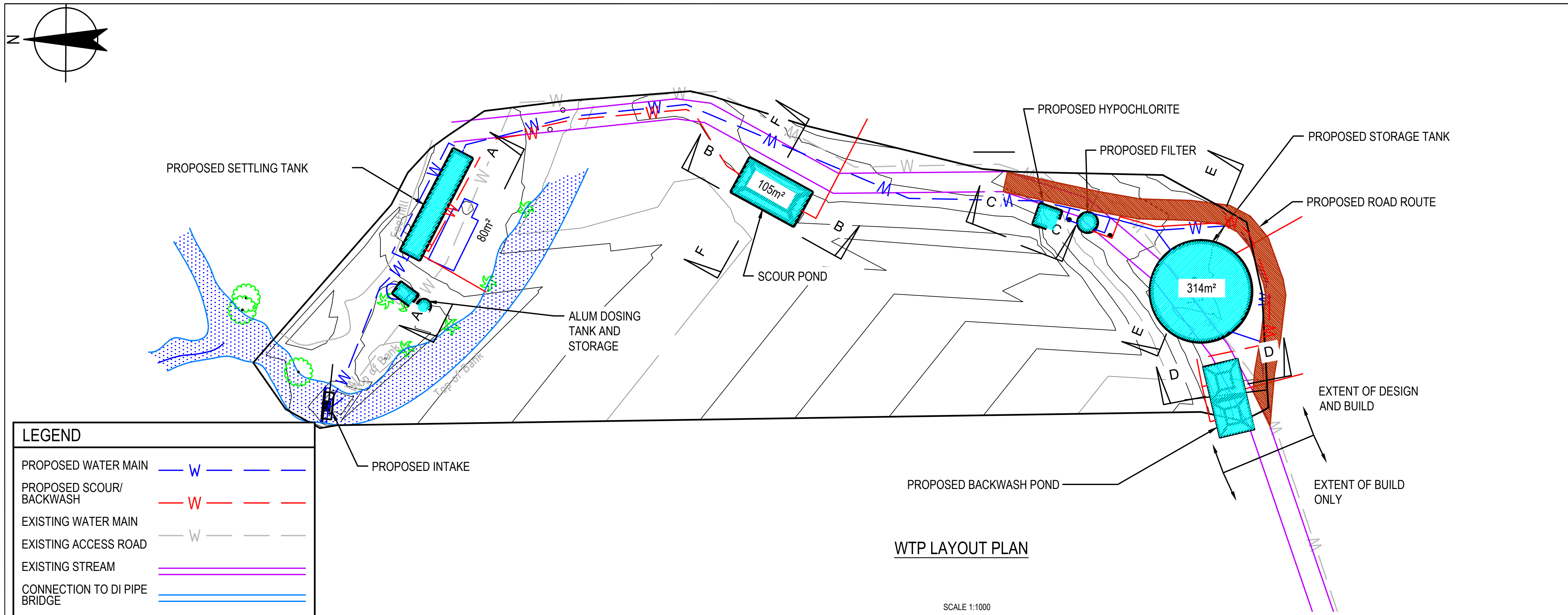


LEGEND

PROPOSED WATER MAIN	— W — — —
PROPOSED SCOUR/ BACKWASH	— W — — —
EXISTING WATER MAIN	— W — — —
EXISTING ACCESS ROAD	
EXISTING STREAM	
CONNECTION TO DI PIPE BRIDGE	

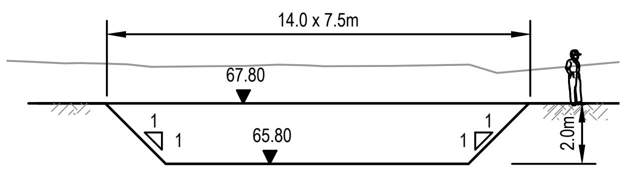
WTP LAYOUT PLAN

SCALE 1:1000

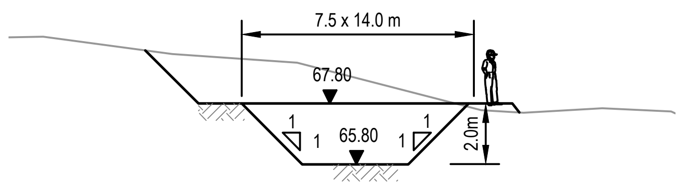
WATER CATCHMENT:

DISTRICT: UNINVESTIGATED LAND
TAPERE:
SECTION:
SECTION NAME:

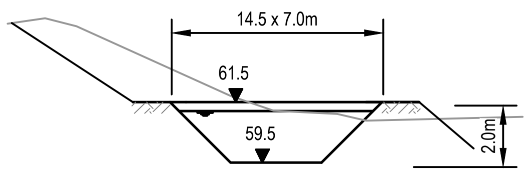
NOTE:
DIMENSIONS SHOWN ARE INDICATIVE



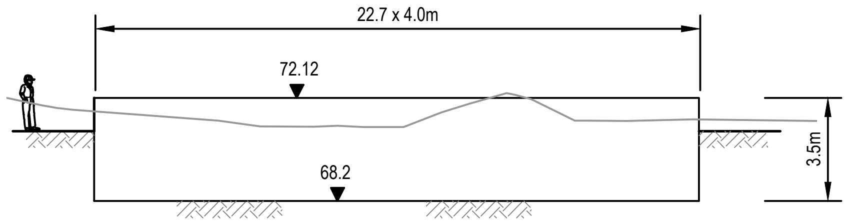
SECTION B-B SCOUR POND



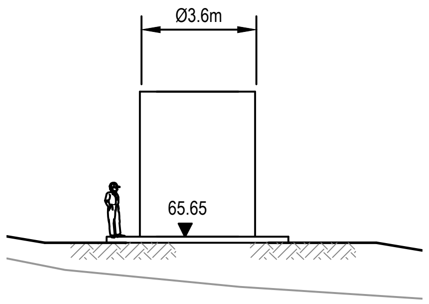
SECTION F-F SCOUR POND



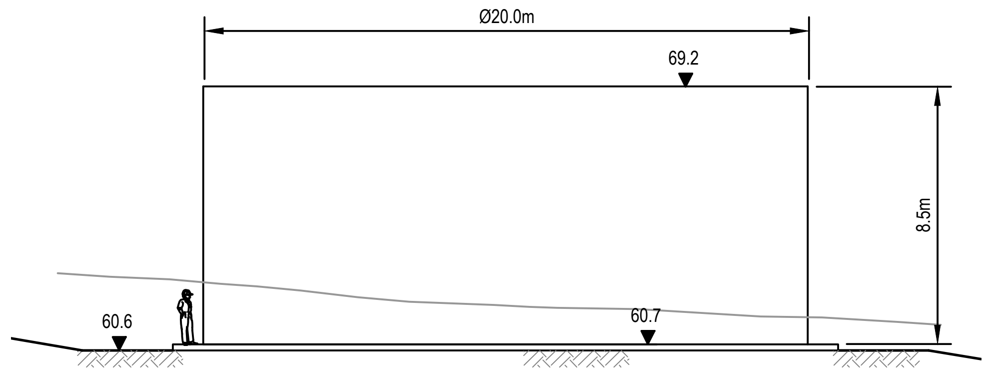
SECTION D-D PROPOSED BACKWASH



SECTION A-A SETTLING TANK



SECTION C-C FILTER



SECTION E-E STORAGE TANK

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GOVERNMENT OF COOK ISLANDS

TE MATO VAI

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Title

TE MATO VAI - STAGE 2
NGATOE WATER SUPPLY
WTP LAYOUT PLAN

Drawn	FM	
Checked	ET	
Approved	ND	
Scale at A3	AS SHOWN	

Drawing Number
389886-MMD-Z-DR-05-XX-0002

Security	Status	Rev
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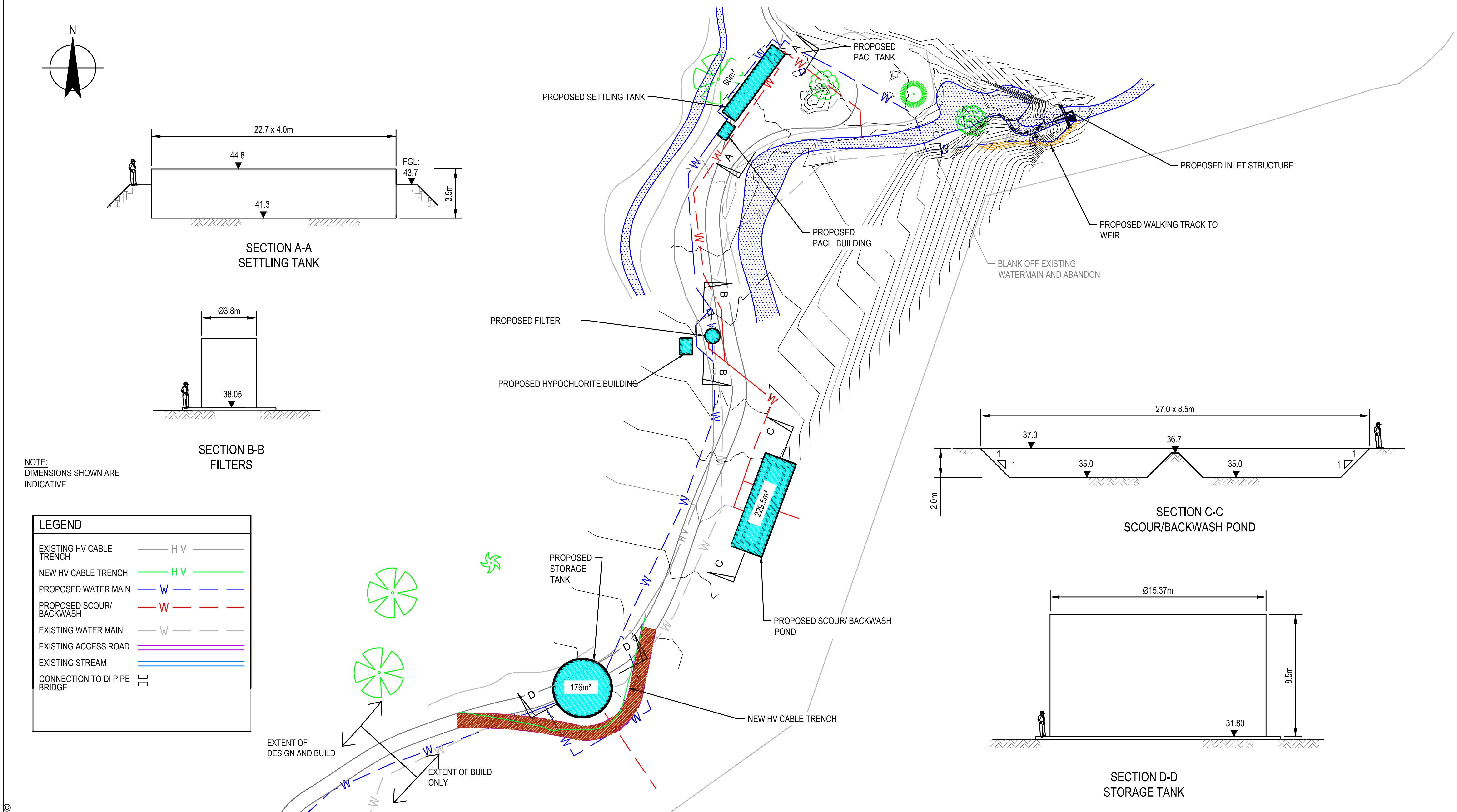

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Title
TE MATO VAI - STAGE 2
PAPUA WATER SUPPLY
WTP LAYOUT PLAN

Drawn	FM
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Approved	ND
Scale at A3	AS SHOWN

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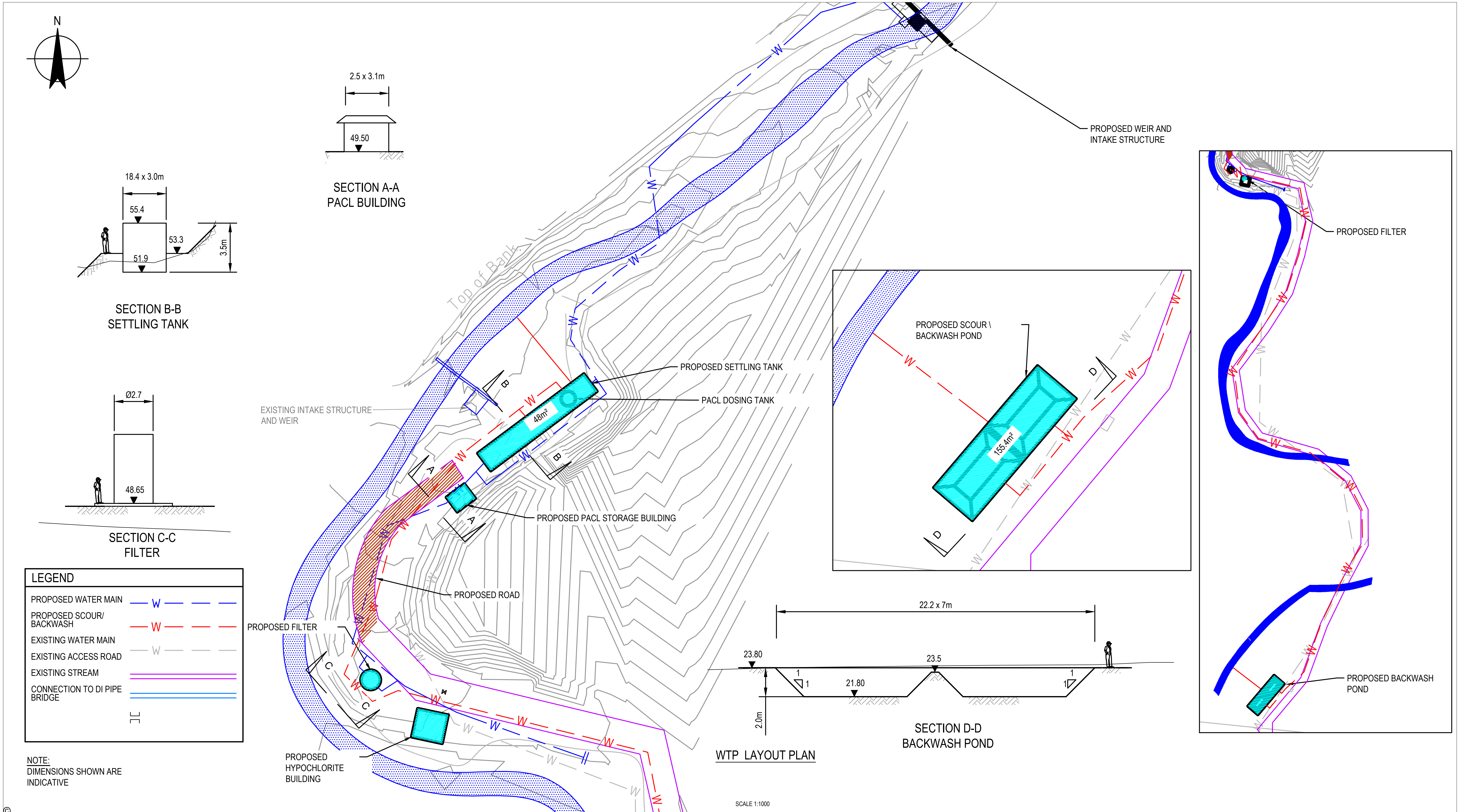

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Title
TE MATO VAI - STAGE 2
TAIPARA WATER SUPPLY
WTP LAYOUT PLAN

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Approved	ND

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Drawing Number
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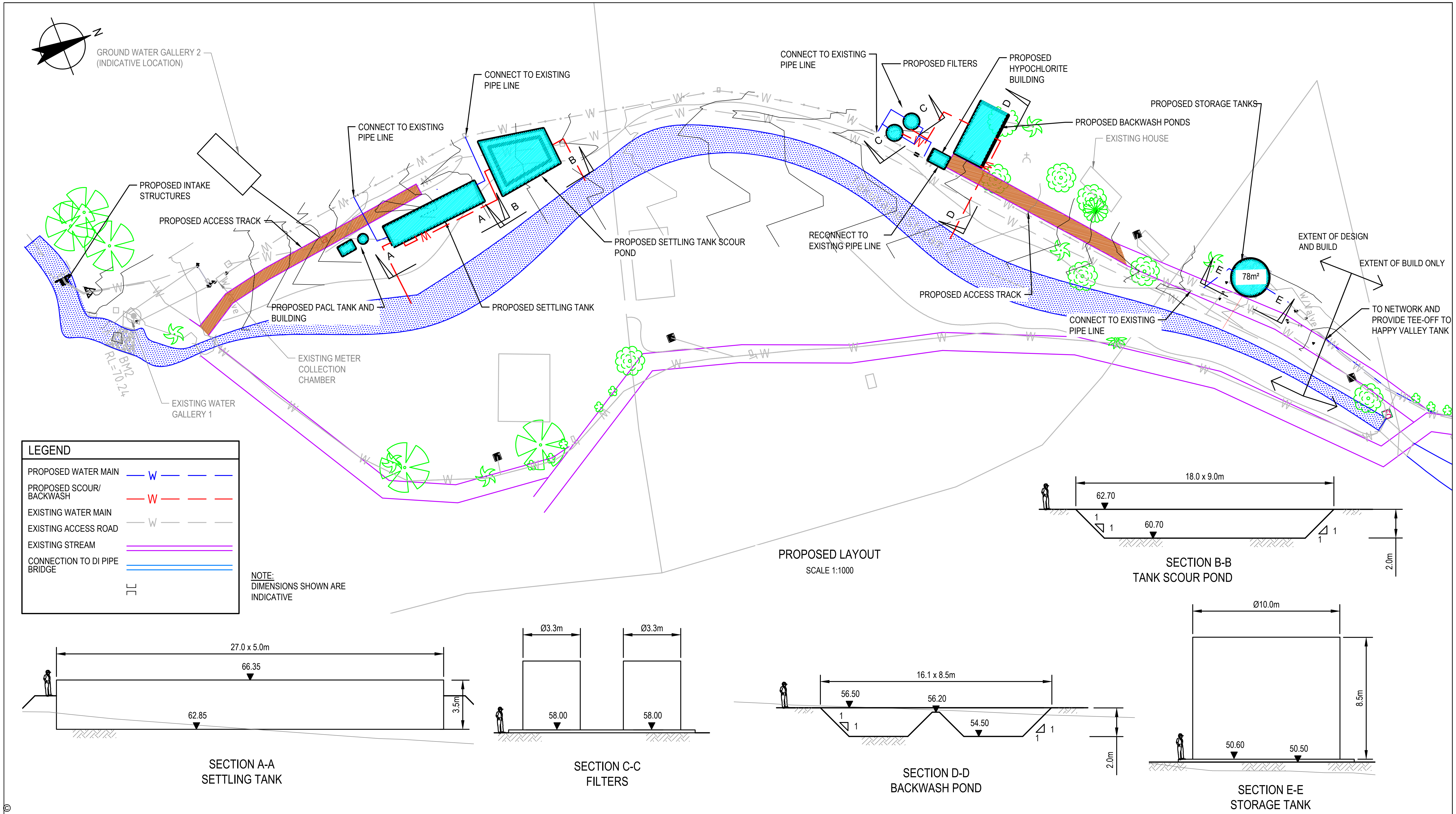

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Title
TE MATO VAI - STAGE 2
TAKUVAINE WATER SUPPLY
WTP LAYOUT PLAN

Drawn	FM
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Approved	ND

Scale at A3
AS SHOWN

Drawing Number
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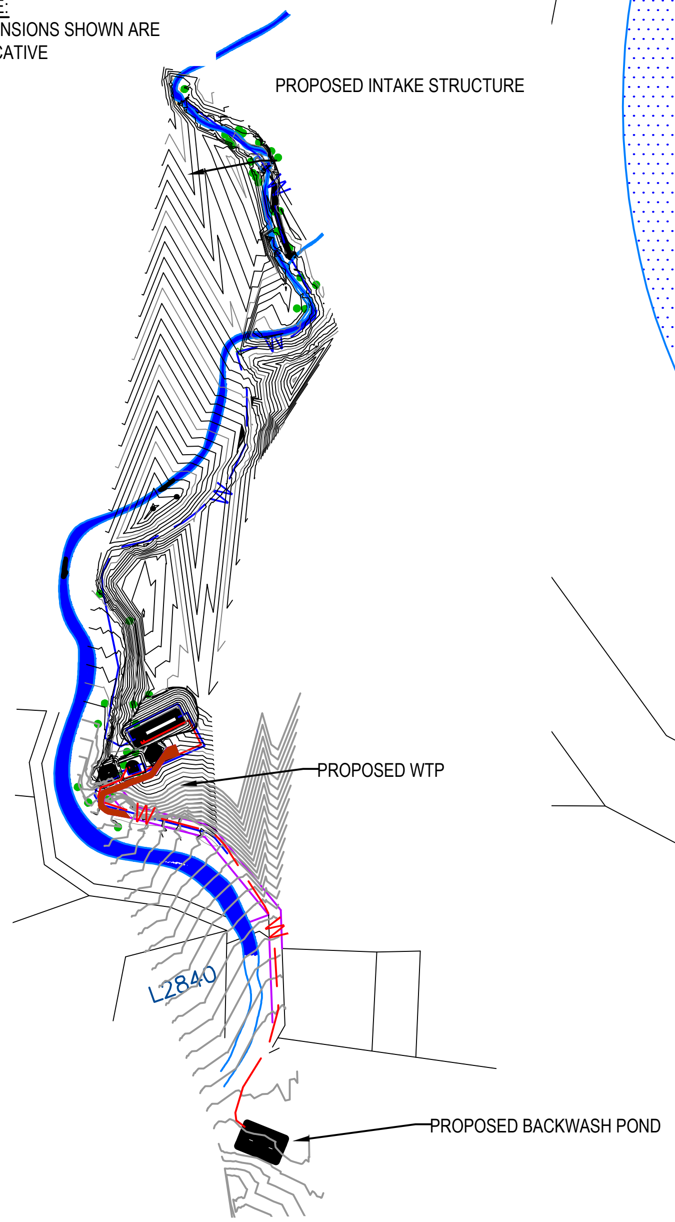
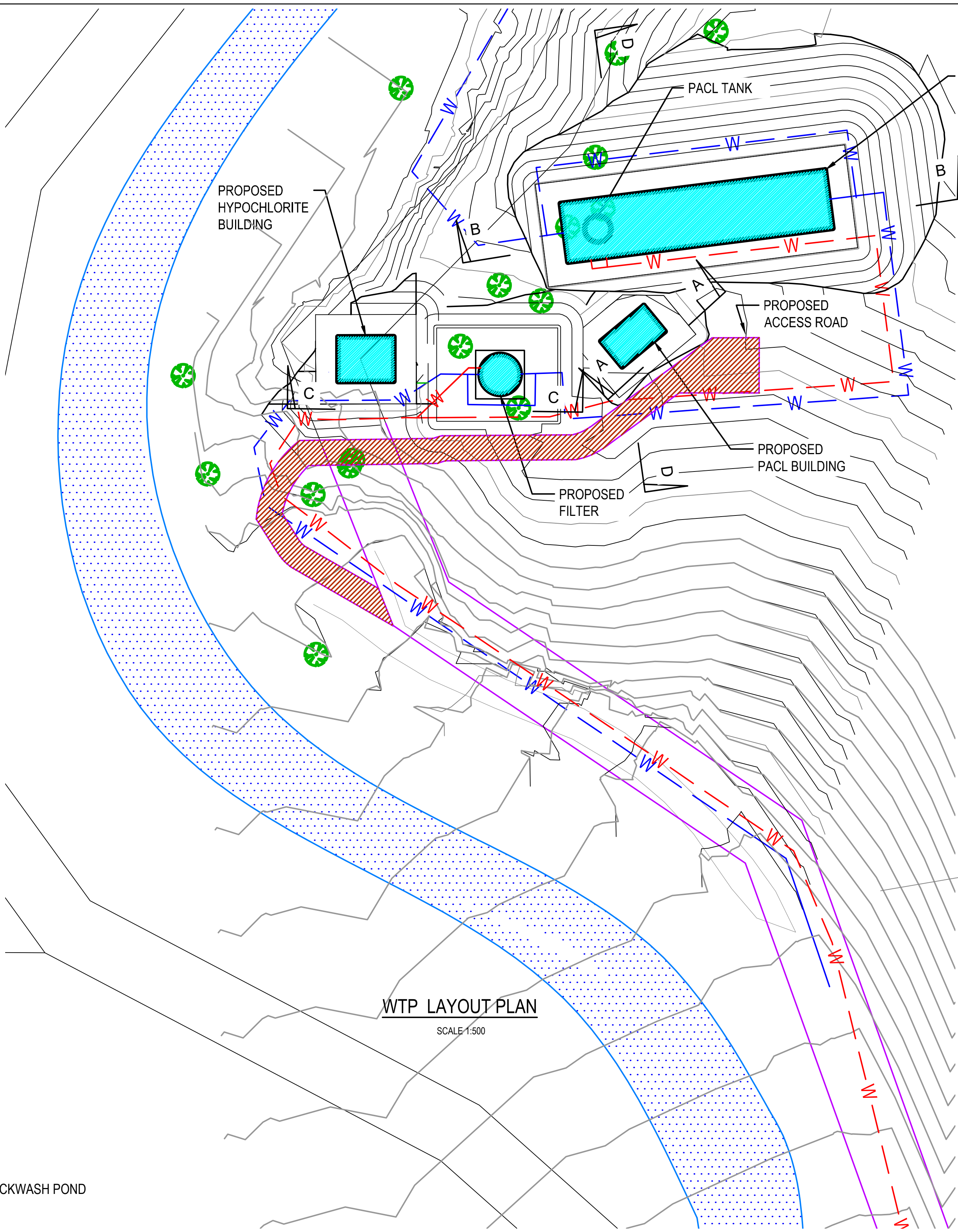
Security	Status	Rev
STD	CON	A

LEGEND

PROPOSED WATER MAIN	— W — —
PROPOSED SCOUR/ BACKWASH	— W — —
EXISTING WATER MAIN	— W — —
EXISTING ACCESS ROAD	
EXISTING STREAM	
CONNECTION TO DI PIPE BRIDGE	

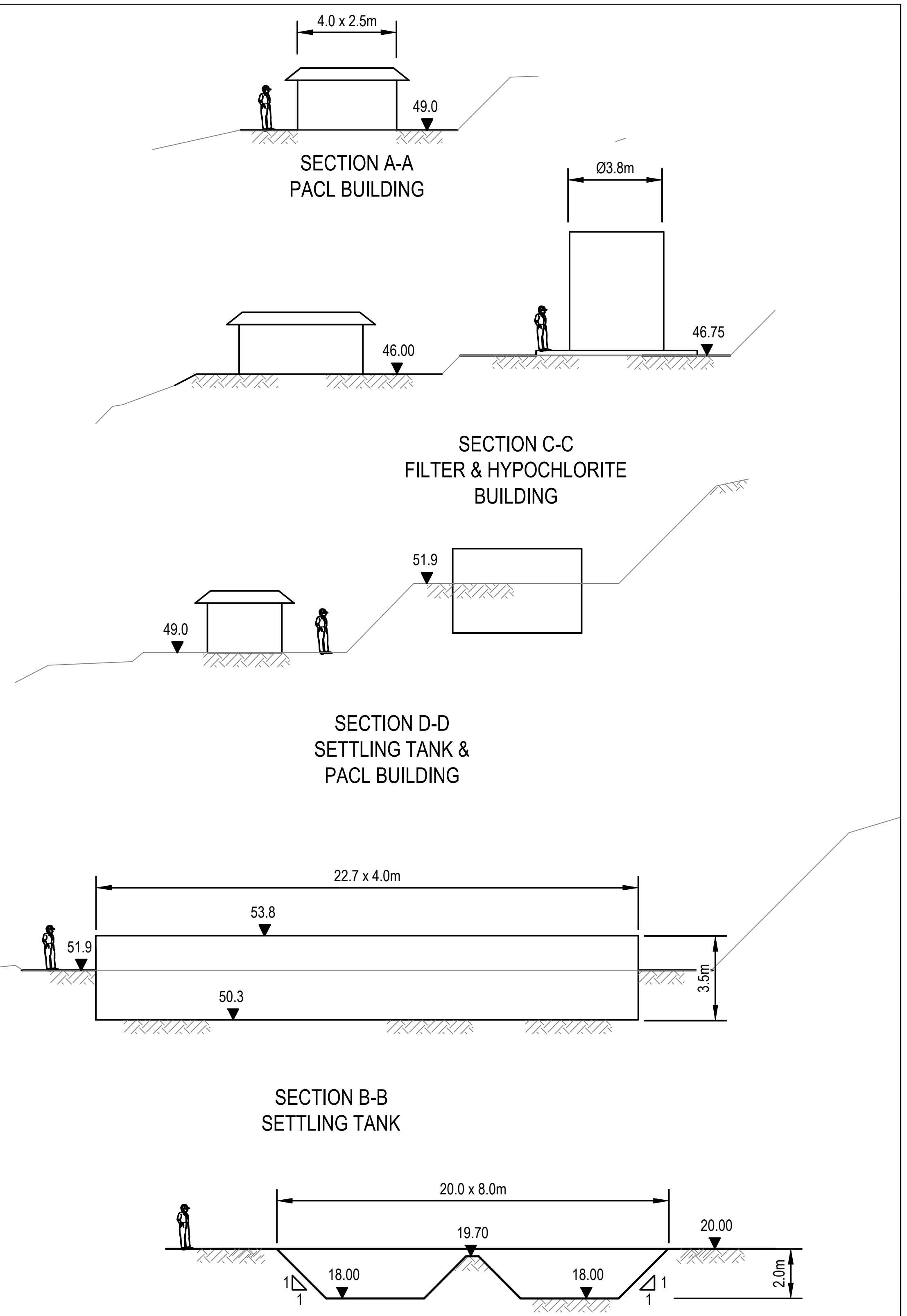
NOTE:
DIMENSIONS SHOWN ARE INDICATIVE





WTP LAYOUT PLAN

SCALE 1:500



SECTION D-D
SCOUR /
BACKWASH POND

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Title
TE MATO VAI - STAGE 2
TOTOKUITU WATER SUPPLY
WTP LAYOUT PLAN

Drawn	FM
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Approved	ND
Scale at A3	AS SHOWN

Drawing Number
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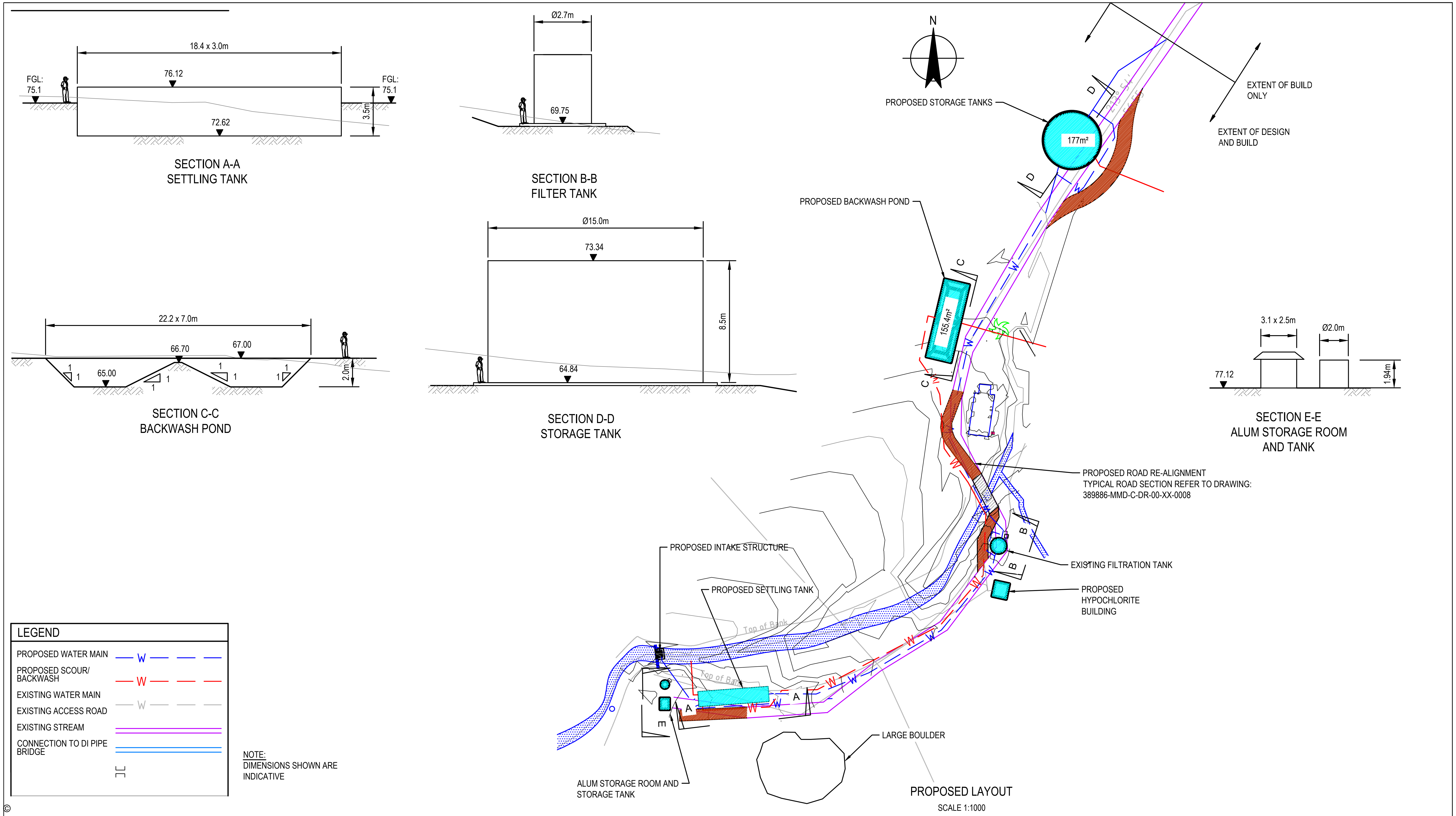

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Rev	Date	Drawn	Description	Ch'k'd	App'd
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Title
TE MATO VAI - STAGE 2
TUPAPA WATER SUPPLY
WTP LAYOUT PLAN

Drawn	FM
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Approved	ND
Scale at A3	AS SHOWN

Drawing Number	Security	Status	Rev
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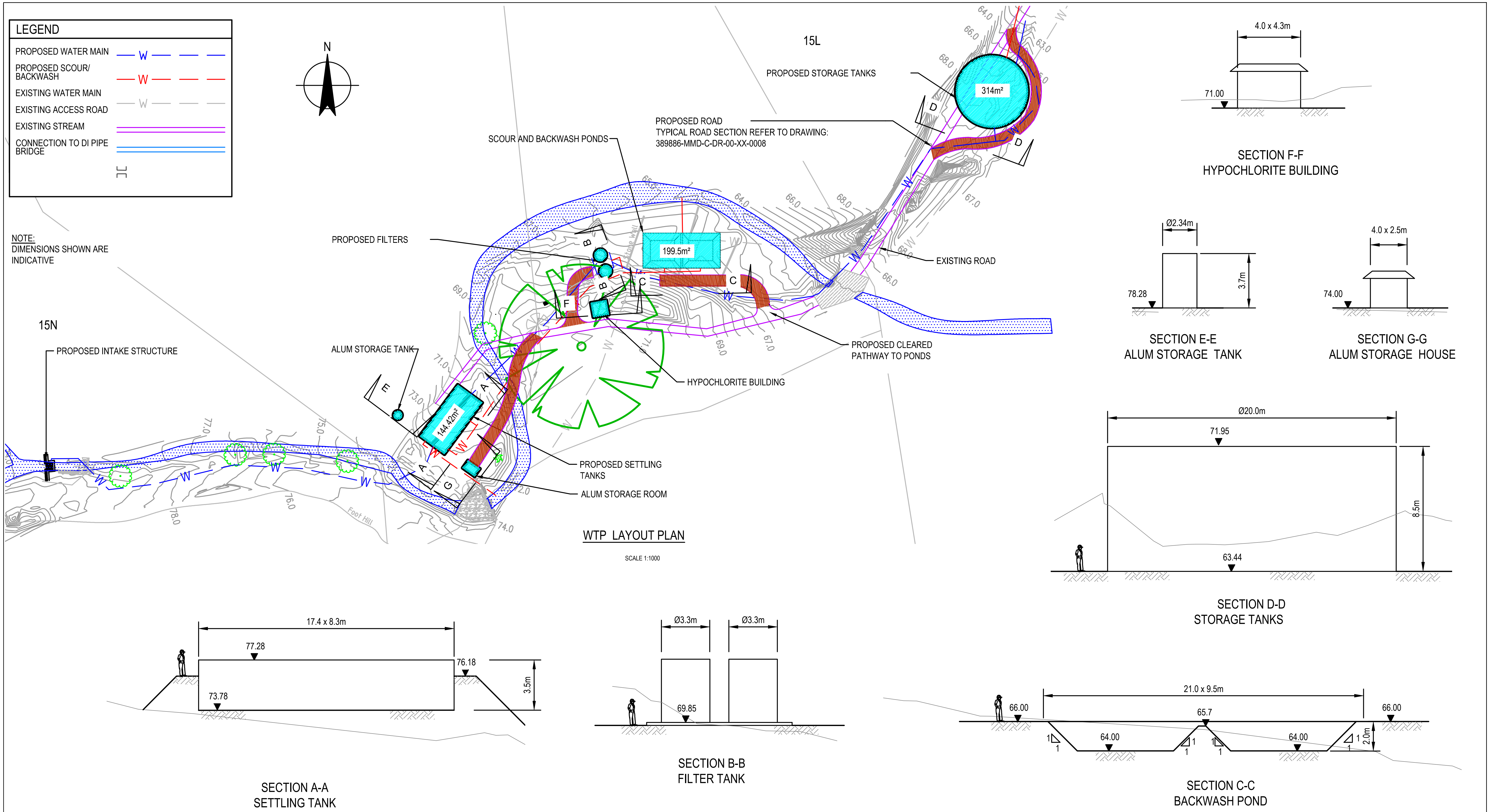

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Title
TE MATO VAI - STAGE 2
TURANGI WATER SUPPLY
WTP LAYOUT PLAN

Drawn	FM
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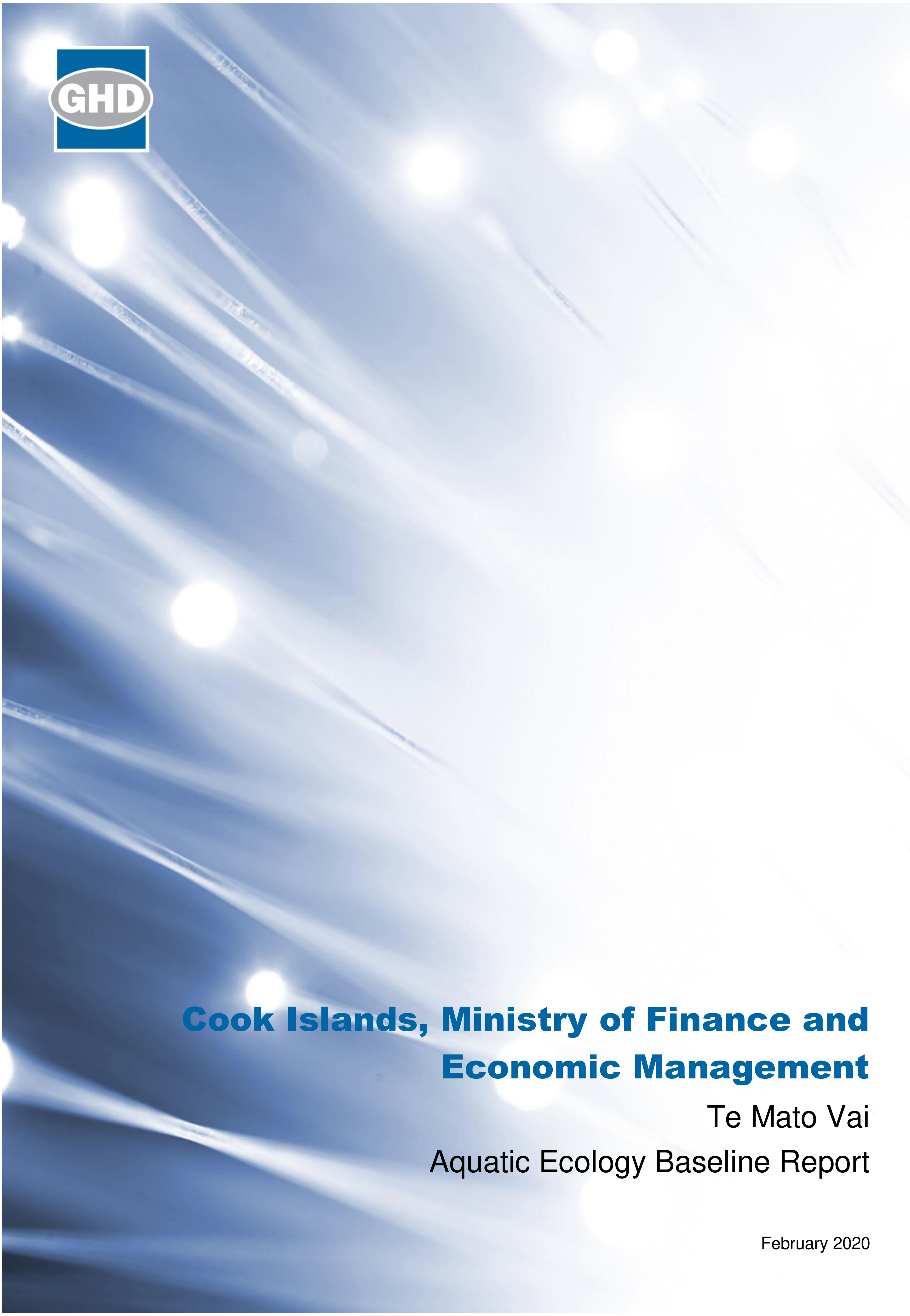
Appendix C: Aquatic Ecology Baseline Report



Cook Islands, Ministry of Finance and Economic Management

Te Mato Vai

Aquatic Ecology Baseline Report

February 2020

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Figure index

1. Introduction

1.1 Project background

The Government of Cook Islands is in the process of upgrading Rarotonga’s water supply system (Te Mato Vai project), with the goal of delivering reliable and safe drinking water to its people. Once the construction of the upgraded water supply network is completed, treated drinking water will be cleaner as debris, rock and sediment will be removed before entering the piped network. Disinfection, which will eliminate bacteria and viruses, has been included in the water treatment plant plans as a further treatment option, though the implementation of disinfection has not been confirmed at this stage.

The project involves the upgrade of 10 water intakes, creation of additional storage capacity, construction of treatment plants, replacement of trunk mains, ring mains and distribution to the boundaries of all properties serviced by the current water network.

Stage 1 of the Te Mato Vai project involved the improvement of the trunk and ring mains with Stage 2 (underway) involving the installation of new water treatment processes. The treatment process includes coagulation, flocculation and potential disinfection of stream water. Polyaluminium chloride (PACl) and/or calcium hypochlorite (chlorine) will be used to treat the water before it’s released to the network. Wastewater from the water treatment process will occasionally be discharged to the stream and as such an Environmental Impact Assessment (EIA) is required.

GHD Limited New Zealand (GHD) has been engaged by the Cook Islands Ministry of Finance and Economic Management to undertake an aquatic ecology assessment to inform the EIA. The objective of this aquatic ecology assessment was to describe the existing aquatic values at the water intake and discharge locations and assess the potential impacts of PACl and chlorine discharge on the existing environment.

1.2 Description of water treatment plant process

One water treatment plant has been constructed on each of the upstream reaches of 10 catchments on Rarotonga. The water treatment plant process involves the following steps:

1. *Sedimentation (settling)*: Water is collected at the intake where it is piped to the settling tank. Gravity is utilised to remove solids (dirt and leaves) from the water. The solids settle on the bottom of the tank.

Plate 1-1 Sedimentation pond on the Tupapa catchment

2. *Coagulation/flocculation*: PACl (a flocculent) is added to the settled water in a slow mixing process which clumps particles of dirt together to allow faster settling at the bottom of the tank. Wastewater is removed from the bottom of the tank to scour ponds.

3. *Filtration*: Water is filtered through sand using rapid gravity filters which aids in the removal (together with the flocculation step) of protozoa. Filtered water is collected from the bottom of the tank. Wastewater is removed from the top of the tank to scour ponds.

Plate 1-2 Sand filter on the Avatiu catchment

4. *Disinfection*: Chlorine is added to the water to disinfect against viruses and bacteria. Disinfection via chlorine is not currently part of the water treatment process but infrastructure has been constructed for its possible future use.

5. *Discharge*: The scour ponds are designed to let wastewater settle before being released back to the waterway, however there is no active control for this. Scour ponds will decant through pipes to the waterway once the water level is high enough. In extreme cases such as high rainfall, scour ponds may also overtop in to the waterway.

Plate 1-3 Scour pond on the Ngatoe catchment

1.3 Purpose of this report

The purpose of this report is to describe the existing aquatic ecological values of the 10 intake and discharge sites and assess potential impacts of the water treatment plant operations on these values. This report includes:

- Introduction – Provides background information on the project including a description of the water treatment plant operations.
- Environment of Rarotonga – Provides a desktop review of the existing condition of waterways on Rarotonga.
- Methodology – Details the field survey and impact assessment methods used to identify the existing environmental values and determine the potential risk of PACl and chlorine.
- Field survey results – Verification of desktop review findings and interpretation of field survey results.
- Impact assessment – Discusses the potential impacts of PACl and chlorine use and determines the likely risk to the environmental values of the waterways.
- Summary and conclusion – Provides an overview of the findings.

1.4 Assumptions and limitations

This report has been prepared by GHD for Cook Islands, Ministry of Finance and Economic Management and may only be used and relied on by Cook Islands, Ministry of Finance and Economic Management for the purpose agreed between GHD and the Cook Islands, Ministry of Finance and Economic Management as set out in Section 1.3 of this report.

GHD otherwise disclaims responsibility to any person other than Cook Islands, Ministry of Finance and Economic Management arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no

responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

2. Environment of Rarotonga

2.1 Location

The Cook Islands is a collection of 15 islands situated between Tonga, Samoa and French Polynesia in the South West Pacific Ocean (Island Friends 2004). These islands are split in to a northern and southern group of islands. Rarotonga is a member of the southern group and has an approximate latitude of 21° S and longitude of 159° W (Ministry of Marine Resources 2011).

2.2 Climate

The climate is typical of a tropical maritime island with the wet season occurring from November to April. Mean annual rainfall is approximately 2000 mm with temperature typically ranging from 20°C to 29°C (Time and Date 2020).

2.3 Physical environment

Rarotonga has a land area of 67.4 km^2, a circumference of 32 km and elevation of 652 m (Parakoti & Davie 2007). The central part of the island consists of mountains with narrow valleys covered in tropical vegetation. Surrounding this is a flat coastal ring which has been developed for residential, commercial and agricultural purposes. Fringing the island is upraised coral reef and lagoons.

The interior upland sediment is basaltic volcano bedrock which produces dark red clay-rich sediments through the process of weathering (Parakoti & Davie 2007). These sediments are generally less fertile due to nutrient deficiencies. Conversely, sediment of the coastal ring is nutrient rich due to the naturally high concentrations of phosphorus.

There are twelve water catchments in Rarotonga, however no large rivers or lakes exist (Nath. et al. 2006). These catchments comprise only of streams, wetlands and a few small freshwater lakes. The three major streams on Rarotonga are Takuvaine, Avana and Avatiu.

2.4 Landuse

Landuse is primarily residential, commercial or marginal lands (including sloping lands and wetlands) (Island Friends 2004). Of this land, the majority is considered marginal land not suitable for development. The remaining land (4.6 km^2) on the island is located within the coastal ring and used for agriculture, in particular piggeries, tomatoes, corn, peppers and taro farming and (Island Friends 2004; Parakoti & Davie 2007).

2.5 Environmental values

There are no legislated environmental values for the Cook Islands, however, based on the landuse, economy and culture the following environmental values are considered to be applicable:

- Aquatic ecosystems
- Agriculture (farm supply/use, irrigation, stockwater, aquaculture)
- Tourism (primary recreation, secondary recreation, visual recreation)
- Human consumer
- Cultural and spiritual values.

For the purposes of this report, only aquatic ecosystems were considered.

2.6 Water quality

Water quality (bacteria, nutrients, dissolved oxygen) of the streams on Rarotonga has been consistently poor from 2006 to 2013 (George et. al. 2007; Ministry of Marine Resources 2011, 2012, 2013). Bacteria (enterococci) concentrations are extremely high, often reading >500 cells/100 mL (George et al. 2007; Ministry of Marine Resources 2011, 2012, 2013). The high concentrations are likely due to adjacent landuse practices, where waste from pig, goat and poultry farms are washed in to the streams during farming processes and/or heavy rain.

Nutrient concentrations have been consistently elevated in most streams (George et al. 2007; Ministry of Marine Resources 2011, 2012, 2013). This is likely due to farming and the naturally high concentrations of phosphorus from the volcanic geology of Rarotonga.

Dissolved oxygen concentrations are variable amongst the streams depending on flow characteristics (George et al. 2007; Ministry of Marine Resources 2011, 2012, 2013). Faster flowing streams have a higher dissolved oxygen concentration whereas slower or stagnant water typically have much lower concentrations.

Water clarity has been consistently good with total suspended solids predominantly less than 6 mg/L (George et al. 2007; Ministry of Marine Resources 2011, 2012, 2013).

2.7 Aquatic flora

There are eight species of freshwater aquatic plants known or expected to occur on Rarotonga (Table 2-1). Four of these species (*Azolla filiculoides, Nymphaea capensis cvs., Pistia stratiotes* and *Eichhornia crassipes*) are considered to be invasive weed species. There are no threatened freshwater aquatic plant species recorded on Rarotonga.

Table 2-1 Freshwater aquatic plants known or expected to occur in Rarotonga

Common name	Species name
Native	
Dense waterweed	*Egeria densa*
Spike rush	*Eleocharis geniculata*
Polygonum	*Polygonum glabra*
Arrowhead	*Sagittaria sagittifolia leucopetala*
Invasive / Weed	
Azolla water-fern	*Azolla filiculoides*
Cape blue water-lily	*Nymphaea capensis cvs.*
Water lettuce	*Pistia stratiotes*
Water hyacinth	*Eichhornia crassipes*

McCormack (2007) Cook Islands Biodiversity Database

2.8 Aquatic macroinvertebrates

There is currently limited published knowledge on aquatic macroinvertebrate communities of Rarotonga. Currently, there are nine classes and 23 families known to or expected to occur in the area (Table 2-2). There are no pollution sensitive taxa currently known from Rarotonga.

Table 2-2 Freshwater macroinvertebrate species known or expected to occur in Rarotonga

Class / Family	Class / Family
Coleoptera (beetle)	**Epiproctophora (dragonfly)**
Dytiscidae	Aeshnidae
Hydrophilidae	Corduliidae
Decapoda (crustacean)	Libellulidae
Atyidae	**Zygoptera (damselfly)**
Palaemonidae	Coenagrionidae
Grapsidae	**Gastropoda (snail)**
Diptera (true fly)	Neritidae
Tipulidae	Thiaridae
Culicidae	Planorbidae
Simuliidae	**Hemiptera (true bug)**
Psychodidae	Mesoveliidae
Chironomidae	Veliidae
Stratiomyiidae	Gerridae
Ephydridae	**Nematoda (round worm)**
Oligochaeta (worm)	Metastrongylidae

McCormack (2007) Cook Islands Biodiversity Database

2.9 Fish community

Due to the remoteness of Rarotonga, the diversity of freshwater fish species is very low. There are 11 native species and four introduced species of freshwater fish known to occur in the area (McCormack 2007) (Table 2-3). Of the native species, only three of the 11 are considered to be common or very common, whereas three of the four introduced species are commonly found. One endemic species of goby has been recorded on Rarotonga. However, desktop review confirms that there are no threatened freshwater fish species on Rarotonga.

Table 2-3 Freshwater fish species known to occur in Rarotonga

Common name	Species name	Prevalence
Native		
Giant longfin eel	*Anguilla marmorata*	Uncommon
Polynesian longfinned eel	*Anguilla megastoma*	Uncommon
Pacific shortfinned eel	*Anguilla obscura*	Very common
Eyespot goby	*Awaous ocellaris*	Rare
Dusky sleeper	*Eleotris fusca*	Uncommon
Shorttail river pipefish	*Microphis brachyurus*	Rare
Striped mullet	*Mugil cephalus*	Present
Peppered goby	*Redigobius bikolanus*	Rare
Red-tailed goby	*Sicyopterus lagocephalus*	Common
Brokeline goby	*Stiphodon elegans*	Common
Latticed goby	*Stiphodon n.sp.watson*	Rare; endemic (new species)
Introduced		
Western mosquitofish	*Gambusia affinis*	Common
Mozambique tilapia	*Oreochromis mossambicus*	Very common
Shortfin molly	*Poecilia mexicana*	Uncommon
Guppy	*Poecilia reticulata*	Common

McCormack (2007) Cook Islands Biodiversity Database

2.10 Turtle community

The diversity of freshwater turtle species is very low due to the island's isolated location. Only two introduced species of freshwater turtle have been recorded on Rarotonga (McCormack 2007) (Table 2-4). The common long-necked turtle (*Chelodina longicollis*) was previously introduced to the island but is now extinct. The red-eared slider turtle is introduced and has the potential to become invasive but is currently rare. Desktop review confirms that there are no threatened freshwater turtle species present on Rarotonga.

Table 2-4 Freshwater turtle species known to occur in Rarotonga

Common name	Species name	Prevalence
Introduced		
Common long-necked turtle	*Chelodina longicollis*	Extinct
Red-eared slider turtle	*Trachemys scripta elegans*	Rare

McCormack (2007) Cook Islands Biodiversity Database

3. Methodology

3.1 Field survey

A field survey was undertaken to describe the existing aquatic ecological values at the water intake sites and discharge locations (refer to Section 3.1.1). The field survey was conducted from the 20th to 25th January 2020.

To understand the current conditions, environmental values and the potential impacts of the water treatment plant processes the following indicators were assessed:

- Aquatic habitat
- In-situ water quality
- Aquatic flora
- Aquatic macroinvertebrate communities
- Fish communities
- Turtle communities.

A detailed description of the methodology used for each assessment, and the analyses applied, is provided in Sections 3.1.2 to 3.1.6.

3.1.1 Survey locations

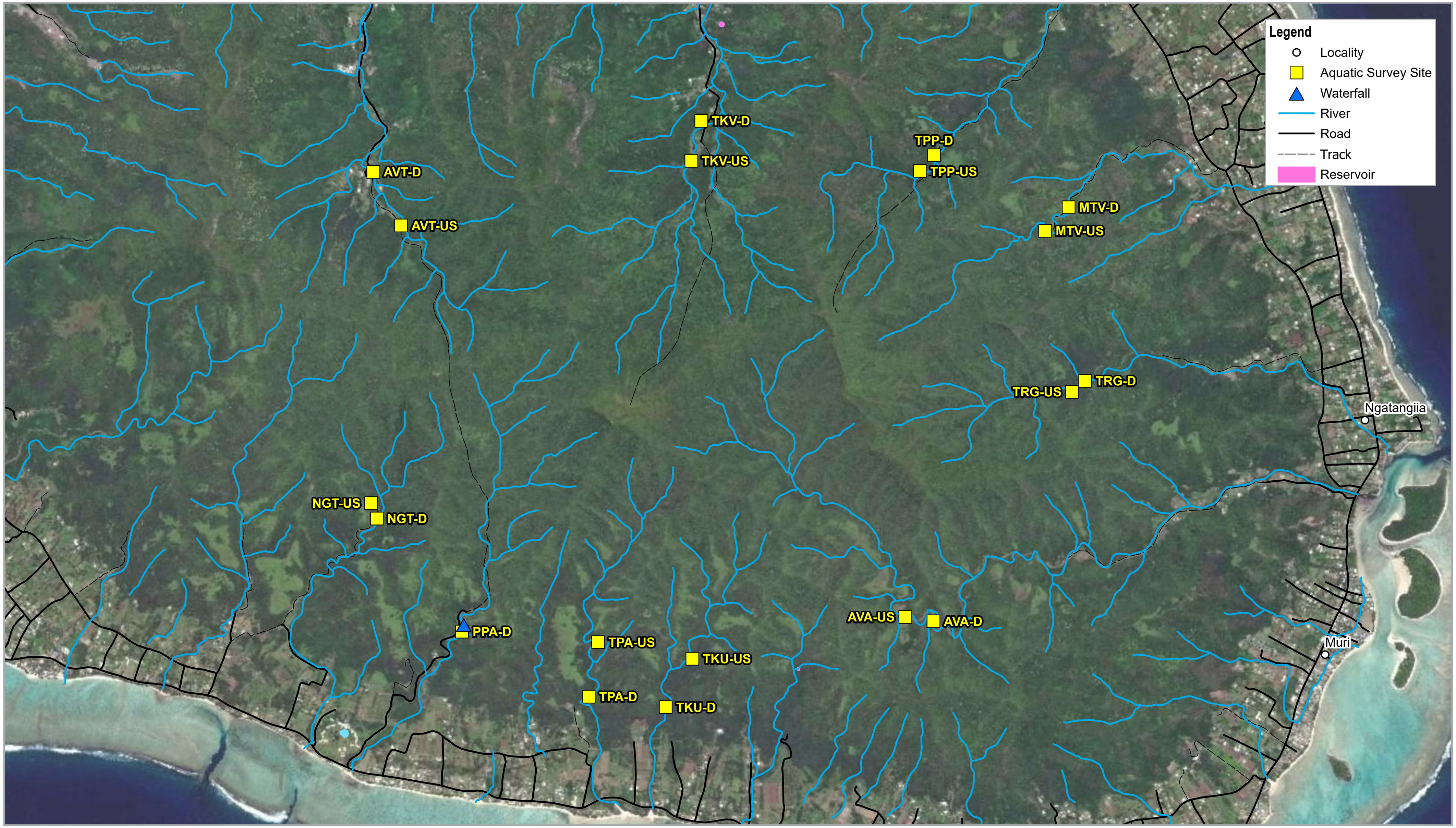
The aquatic baseline study was undertaken at 10 water intake sites, each within a different catchment on Rarotonga (Table 3-1; Figure 3-1). Upstream sites were sampled upstream of the water intake with the exception of TKV-US, MTV-US and TRG-US which were sampled downstream of the water intake due to access limitations. An upstream site for the Papua catchment was not assessed due to access limitations and no suitable site identified downstream of the water intake.

Table 3-1 Coordinates for the sites surveyed in January 2020

Site name	Catchment	Easting [1]	Northing [1]
AVT-US	Avatiu	417838	7652183
AVT-D	Avatiu	417650	7652545
TKV-US	Takuvaine	419798	7652620
TKV-D	Takuvaine	419865	7652890
TPP-US	Tupapa	421341	7652552
TPP-D	Tupapa	421437	7652657
MTV-US	Matavera	422188	7652147
MTV-D	Matavera	422346	7652306
TRG-US	Turangi	422369	7651059
TRG-D	Turangi	422458	7651133
AVA-US	Avana	421243	7649538

Site name	Catchment	Easting [1]	Northing [1]
AVA-D	Avana	421433	7649509
TKU-US	Totokoitu	419805	7649256
TKU-D	Totokoitu	419625	7648929
TPA-US	Taipara	419168	7649368
TPA-D	Taipara	419105	7649000
PPA-D	Papua	418250	7649439
NGT-US	Ngatoe	417635	7650307
NGT-D	Ngatoe	417674	7650203

[1] Datum: UTM Zone 4K
US = upstream site
D = downstream site



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0 0.25 0.5 0.75 1

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: WGS 1984
Grid: WGS 1984 UTM Zone 4S

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GHD

Cook Islands - Ministry of Finance and Economic Management
Project Management Unit (PMU)
Water and Wastewater Services

Location of aquatic ecology sites surveyed during January 2020

Project No. 12504023
Revision No. A
Date 13/02/2020

FIGURE 3-1

N:\AU\Brisbane\General\Services\GIS\Projects\12504023\GIS\Maps\APRX\12504023_AquaticEcology.aprx
Print date: 13 Feb 2020 - 15:42

Data source: LINZ: Locality, Roads, Waterfalls, Watercourses (2020), GHD: Aquatic Survey Sites (2020); World_Imagery: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: xlee

3.1.2 Aquatic habitat assessment

Habitat assessments were undertaken at each site to describe the existing habitat values and rate the condition of key aquatic habitat features and overall condition of each site. The assessments were conducted in accordance with recognised standards for tropical river systems (DES, 2018; DNRM, 2001). Photographs of each site were taken as an additional record of habitat conditions at the time of the survey.

A general description of the observed values was developed for each site, and an overall score calculated to provide an account of conditions during the survey. The scoring system was adapted from the standardised Australian Rivers Assessment System (AusRivAS) methodology. The scores were then compared between sites to identify patterns within the data and provide an ecologically relevant interpretation of the results.

Table 3-2 River bioassessment program: habitat assessment score criteria

Habitat variable	Poor	Fair	Good	Excellent
Bottom substrate	0 - 5	6 - 10	11 - 15	16 - 20
Embeddedness	0 - 5	6 - 10	11 - 15	16 - 20
Velocity and depth category	0 - 5	6 - 10	11 - 15	16 - 20
Channel alteration	0 - 3	4 - 7	8 - 11	12 - 15
Bottom scouring and deposition	0 - 3	4 - 7	8 - 11	12 - 15
Pool/riffle, run/bend ratio	0 - 3	4 - 7	8 - 11	12 - 15
Bank stability	0 - 2	3 - 5	6 - 8	9 - 10
Bank vegetation and stability	0 - 2	3 - 5	6 - 8	9 - 10
Streamside cover	0 - 2	3 - 5	6 - 8	9 - 10
Total	**0 - 38**	**39 - 74**	**75 - 110**	**111 - 135**

Source: Department of Natural Resources and Mines (2001)

3.1.3 Water quality

In-situ water quality measurements were recorded at each site using a YSI 556 multi-parameter water quality meter. The meter was calibrated as per manufacturer's requirements prior to use. Measurements included:

- water temperature (°C)
- pH (pH unit)
- electrical conductivity (µS/cm)
- dissolved oxygen (% saturation and mg/L).

There are no published guidelines for water quality in the Cook Islands. Therefore, surface water quality data was compared against the guideline ranges given in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* 2000 (ANZECC 2000) – Tropical Australia Upland River. These guidelines were chosen as a comparison for these sites as the Rarotongan environment closely resembles that of tropical Australia.

3.1.4 Aquatic macroinvertebrates

Macroinvertebrate community sampling was conducted in accordance with international standard techniques for surveying macroinvertebrates within tropical rivers (DES, 2018; DNRM, 2001).

Where possible, one sample was collected from each of two habitat types – edge and composite pool-bed. Sampling of the habitats was undertaken by sweeping a 250 µm mesh net in an upwards direction, perpendicular to the bank along a 10 m stretch. Each macroinvertebrate sample was collected from a series of sweeps within habitat at each site. For edge samples, areas of overhanging or submerged habitat (e.g. logs, leaf litter, tree roots) were targeted. Aquatic vegetation was avoided to maintain consistency between samples.

For each macroinvertebrate sample, the collected material was placed into a sorting tray and the macroinvertebrates were picked for 15 minutes using forceps and pipettes. If no new taxa (not previously detected in the sample) were found within 5 minutes of the time limit, then processing ceased. If new taxa were found, the sample was processed for a further 10 minutes. Samples were preserved in 70% methylated spirits, and were clearly labelled with site, habitat and date.

Aquatic macroinvertebrates were identified in the field to order level, but where possible to family level. Further microscopic identification within a laboratory was not available on the island.

Taxa richness was calculated for all sites. Richness refers to the number of different taxa contained in a sample. In general, the higher the richness scores, the better the ecological health, although, some exceptions do apply to this rule. For example, occasionally taxa richness may be higher in modified habitats where modifications have increased habitat supply or diversity, or increased food supplies. Therefore, the interpretation of taxa richness data occurred on a case-by-case basis, with consideration of multiple lines of evidence.

Macroinvertebrate taxa are also assigned a SIGNAL (Stream Invertebrate Grade Number) score which indicates the level of sensitivity to pollution, where one is the lowest (most tolerant) and ten is the highest (most sensitive). This information is used to determine the health of an ecosystem. Where a diverse community of high scoring taxa were present, this would indicate a healthy ecosystem.

The macroinvertebrate community data was also analysed to explore any spatial trends in the data.

Macroinvertebrate samples were not collected from sites AVA-US and PPA-US due to access limitations.

3.1.5 Fish community

Habitat suitability for fish species was recorded at each site and any fish opportunistically observed during sampling were identified where possible. Additional information on the existing fish community present at each site was obtained though discussions with the local communities regarding fish sightings and fishing activities.

3.1.6 Turtle community

Habitat suitability for turtle species was recorded at each site and any turtles opportunistic observed during sampling were identified where possible. Additional information on the existing turtle community present at each site was obtained though discussions with the local communities regarding turtle sightings and fishing activities.

3.2 Impact assessment

An impact assessment was conducted to identify the potential impacts of the water treatment plan operation on the existing aquatic ecological values at the intake sites and downstream of the discharge locations. The assessment involved:

- Identifying the nature of the potential risks from the water treatment plant operations
- Describing the sensitivity of the receiving environment based on the existing ecological values.

4. Field survey results

4.1 Survey conditions

In the one week prior to and during the week of the January 2020 survey, Rarotonga received heavy rainfall which caused a rise in water levels and velocity. It is likely that macroinvertebrate and fish communities were reduced at each site under these conditions. Temperature was in the high 20s °C to low 30s °C and humid.

Due to high flow conditions prior to and during the survey, data collected on aquatic fauna may not represent the breadth of aquatic fauna typically present in each catchment. However, based on species known to occur on Rarotonga and survey data that was gathered, confidence in the description of environmental values and impact assessment is retained.

4.2 Aquatic habitat

Aquatic habitat and environmental values of the waterways between the 10 catchments were similar (Table 4-1). Each waterway consisted of a relatively narrow irregularly meandering channel with flowing, clear, shallow water. The exception to this was AVA-US which was turbid and deep due to recent heavy rainfall. Water flow alternated between areas of faster runs and riffles and slower pools. During the dry season, water flows within the majority of catchments is expected to cease and the waterways exist as a series of isolated pools interspersed with dry river bed. The wetted width of these waterways varied from approximately 0.5 m to 4 m and had a variable depth of 0.1 m – 0.5 m. Land use adjacent to the survey sites was the water treatment plant infrastructure, pig farming, residential and native forest.

The bed was stable with the substrate primarily composed of boulders, cobbles, pebbles with varying proportions of bedrock, gravel, sand and silt/clay.

Riparian vegetation was moderately to highly disturbed due to the intrusion of exotic species and clearing. The longitudinal extent of riparian vegetation was predominantly semi-continuous to continuous and provided overhanging and trailing bank vegetation for cover.

In-stream habitat consisted of shallow and deep pools, shallow fast runs and riffles, occasional bars, terrestrial leaves and twigs, tree roots and aquatic macrophytes. Aquatic macrophytes and filamentous algae were occasionally scattered along the water's edge and bank. The macrophytes would support small bodied fish species such as the guppy.

Waterway barriers were present at most sites in the form of multiple existing weirs and the newly constructed water intakes. These barriers restrict flow and the movement of aquatic fauna until they are overtopped. Of the 15 species of fish known to occur on Rarotonga, three species of eel and the shorttail river pipefish (*Microphis brachyurus*) are catadromous, meaning they migrate between freshwater and marine water as part of their lifecycle. Waterway barriers can restrict this movement, however, eels are known to climb weir walls and can leave the water to avoid barriers if there is wet dewy ground adjacent to the waterway (Thomas 2004). The shorttail river pipefish inhabits the lower reaches of freshwater streams (below existing waterway barriers and the new water intakes) and is considered rare on Rarotonga. The water intakes are small and are likely to be overtopped frequently restoring fish passage. So it is expected that the waterway barriers would not pose a risk to these species.

At the time of the survey, most sites were overtopping with the exception of TPA-US and TPP-US. At site TPA-US, the intake weir wall is approximately 2 m higher than the water level. At present, water is allowed to bypass under the weir wall through pipes, however, once construction at this site has been completed, these pipes will be decommissioned. At site TPP-

US, the water intake is collecting all water which is then released further downstream leaving a series of isolated pools between these points.

All catchments were in either ‘good’ or ‘excellent’ condition with habitat assessment scores ranging from 93 to 116 (Table 4-2).

Plate 4-1 Top to bottom, left to right; pig farming on the bank of Takuvaine catchment; overhanging riparian vegetation; deep pool habitat; riffle habitat; tree roots providing habitat; waterway barrier; water intake at site TPA-US

Table 4-1 Habitat descriptions for each site during the January 2020 survey

Site	Habitat description	Upstream photo	Downstream photo
AVT-US Avatiu catchment	**Channel pattern:** irregular meanders **Mean wetted width:** 3 m **Mean water depth:** 0.2 m **Flow conditions:** at watermark; 0.05 m/s **Substrate:** boulder (10%); cobble (20%); pebble (30%); gravel (30%); sand (5%); silt/clay (5%) **Riparian vegetation:** native canopy / native and exotic understorey; semi-continuous with occasional clumps **In-stream habitat:** high – shallow and deep pool, run, riffle and undercut banks **Disturbance rating:** moderate **Waterway barriers:** water intake and old weir downstream		
		Aquatic values: Water quality, riparian vegetation, aquatic flora, and fauna (fish and macroinvertebrates)	
AVT-D Avatiu catchment	**Channel pattern:** irregular meanders **Mean wetted width:** 2 m **Mean water depth:** 0.15 m **Flow conditions:** < watermark; 0.2 m/s **Substrate:** boulder (3%); cobble (20%); pebble (40%); gravel (15%); sand (15%); silt/clay (7%) **Riparian vegetation:** exotic canopy / exotic understorey; semi-continuous with occasional clumps **In-stream habitat:** moderate – shallow pool, run and riffle **Disturbance rating:** high **Waterway barriers:** water intake and other weir upstream		
		Aquatic values: Water quality, riparian vegetation, aquatic flora and fauna (fish and macroinvertebrates)	

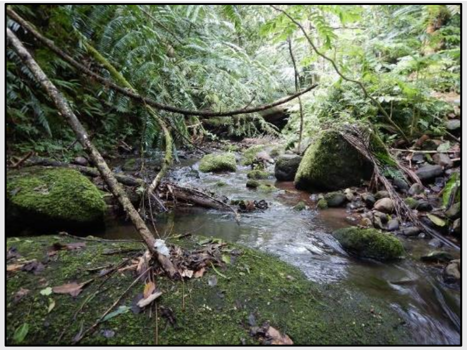
<table>
<tr><th>Site</th><th>Habitat description</th><th>Upstream photo</th><th>Downstream photo</th></tr>
<tr><td rowspan="2">TKV-US
Takuvaine catchment</td><td rowspan="2">Channel pattern: irregular meanders
Mean wetted width: 2.5 m
Mean water depth: 0.25 m
Flow conditions: at watermark; 0.25 m/s
Substrate: bedrock (5%); boulder (5%); cobble (10%); pebble (30%); gravel (30%); sand (10%); silt/clay (10%)
Riparian vegetation: native canopy / exotic understorey; continuous to occasional clumps
In-stream habitat: moderate – shallow and deep pool, run and riffle
Disturbance rating: moderate
Waterway barriers: old weir and new water intake at site</td><td></td><td></td></tr>
<tr><td colspan="2">Aquatic values:
Water quality, riparian vegetation, aquatic flora and fauna (fish and macroinvertebrates)</td></tr>
<tr><td rowspan="2">TKV-D
Takuvaine catchment</td><td rowspan="2">Channel pattern: irregular meanders
Mean wetted width: 2 m
Mean water depth: 0.2 m
Flow conditions: at watermark; 0.05 m/s
Substrate: boulder (25%); cobble (10%); pebble (40%); gravel (10%); sand (10%); silt/clay (5%)
Riparian vegetation: native canopy / native understorey; semi-continuous
In-stream habitat: moderate – shallow pool, run and riffle
Disturbance rating: high
Waterway barriers: old weir and water intake upstream</td><td></td><td></td></tr>
<tr><td colspan="2">Aquatic values:
Water quality, riparian vegetation, aquatic fauna (macroinvertebrates)</td></tr>
</table>

<table>
<tr><th>Site</th><th>Habitat description</th><th>Upstream photo</th><th>Downstream photo</th></tr>
<tr><td rowspan="2">TPP-US
Tupapa catchment</td><td rowspan="2">Channel pattern: irregular meanders
Mean wetted width: 2 m
Mean water depth: 0.1 m
Flow conditions: at watermark; 0.25 m/s
Substrate: bedrock (20%); cobble (15%); pebble (30%); gravel (10%); sand (10%); silt/clay (15%)
Riparian vegetation: native canopy / exotic understorey; semi-continuous to continuous with occasional clumps
In-stream habitat: moderate – shallow and deep pool, run and riffle
Disturbance rating: high
Waterway barriers: water intake blocking waterway; no flow immediately downstream</td><td></td><td></td></tr>
<tr><td colspan="2">Aquatic values:
Water quality, riparian vegetation, aquatic fauna (macroinvertebrates)</td></tr>
<tr><td rowspan="2">TPP-D
Tupapa catchment</td><td rowspan="2">Channel pattern: irregular meanders
Mean wetted width: 1 m
Mean water depth: 0.1 m
Flow conditions: at watermark; 0.15 m/s
Substrate: boulder (15%); cobble (15%); pebble (30%); gravel (20%); sand (10%); silt/clay (10%)
Riparian vegetation: native canopy / native understorey; continuous
In-stream habitat: moderate – shallow and deep pool, run and riffle
Disturbance rating: moderate
Waterway barriers: water intake upstream</td><td></td><td></td></tr>
<tr><td colspan="2">Aquatic values:
Water quality, riparian vegetation</td></tr>
</table>

<table>
<tr><th>Site</th><th>Habitat description</th><th>Upstream photo</th><th>Downstream photo</th></tr>
<tr><td rowspan="2">MTV-US
Matavera catchment</td><td rowspan="2">Channel pattern: irregular meanders
Mean wetted width: 1.5 m
Mean water depth: 0.1 m
Flow conditions: at watermark; 0.2 m/s
Substrate: bedrock (4%); boulder (2%); cobble (4%); pebble (30%); gravel (30%); sand (10%); silt/clay (10%)
Riparian vegetation: native canopy / exotic understorey; semi-continuous
In-stream habitat availability: high – shallow and deep pool, run, riffle and undercut banks
Disturbance rating: high
Waterway barriers: water intake upstream</td><td></td><td></td></tr>
<tr><td colspan="2">Aquatic values:
Water quality, riparian vegetation, aquatic flora and fauna (fish and macroinvertebrates)</td></tr>
<tr><td rowspan="2">MTV-D
Matavera catchment</td><td rowspan="2">Channel pattern: irregular meanders
Mean wetted width: 2 m
Mean water depth: 0.15 m
Flow conditions: at watermark; 0.2 m/s
Substrate: boulder (15%); cobble (30%); pebble (30%); gravel (15%); sand (5%); silt/clay (5%)
Riparian vegetation: native canopy / exotic understorey; semi-continuous
In-stream habitat: moderate – shallow and deep run and riffle
Disturbance rating: high
Waterway barriers: water intake and cascade upstream</td><td></td><td></td></tr>
<tr><td colspan="2">Aquatic values:
Water quality, riparian vegetation, aquatic flora and fauna (fish and macroinvertebrates)</td></tr>
</table>

Site	Habitat description	Upstream photo	Downstream photo
TRG-US Turangi catchment	**Channel pattern:** regular meanders **Mean wetted width:** 2 m **Mean water depth:** 0.4 m **Flow conditions:** > watermark; 0.15 m/s **Substrate:** boulder (5%); cobble (10%); pebble (10%); gravel (50%); sand (15%); silt/clay (10%) **Riparian vegetation:** native canopy / exotic understorey; semi-continuous **In-stream habitat:** high; shallow and deep pool, run, riffle and macrophytes **Disturbance rating:** moderate **Waterway barriers:** weir wall at site, water intake upstream		
		Aquatic values: Water quality, riparian vegetation, aquatic flora and fauna (fish and macroinvertebrates)	
TRG-D Turangi catchment	**Channel pattern:** regular meanders **Mean wetted width:** 0.5 m **Mean water depth:** 0.2 m **Flow conditions:** at watermark; 0.2 m/s **Substrate:** bedrock (2%); boulder (2%); cobble (35%); pebble (35%); gravel (20%); sand (5%); silt/clay (1%) **Riparian vegetation:** native canopy / native understorey; semi-continuous to continuous **In-stream habitat:** moderate – shallow run, riffle and LWD **Disturbance rating:** moderate **Waterway barriers:** culvert at site and water intake upstream		
		Aquatic values: Water quality, riparian vegetation, aquatic fauna (macroinvertebrates)	

<table>
<tr><th>Site</th><th>Habitat description</th><th>Upstream photo</th><th>Downstream photo</th></tr>
<tr><td rowspan="2">AVA-US
Avana catchment</td><td rowspan="2">Channel pattern: regular meanders
Mean wetted width: 3 m
Mean water depth: 0.5 m
Flow conditions: > watermark; 0.15 m/s
Substrate: boulder (20%); cobble (5%); pebble (30%); gravel (30%); sand (10%); silt/clay (5%)
Riparian vegetation: native canopy / exotic understorey; continuous to occasional clumps
In-stream habitat: high – shallow and deep pool, run, riffle and macrophytes
Disturbance rating: moderate
Waterway barriers: water intake at site and bed level crossings downstream</td><td></td><td></td></tr>
<tr><td colspan="2">Aquatic values:
Water quality, riparian vegetation, aquatic flora and fauna (fish and macroinvertebrates)</td></tr>
<tr><td rowspan="2">AVA-D
Avana catchment</td><td rowspan="2">Channel pattern: regular meanders
Mean wetted width: 4 m
Mean water depth: 0.4 m
Flow conditions: > watermark; 0.3 m/s
Substrate: bedrock (2%); boulder (10%); cobble (35%); pebble (15%); gravel (15%); sand (15%); silt/clay (8%)
Riparian vegetation: native canopy / exotic understorey; semi-continuous to continuous
In-stream habitat: moderate – shallow and deep run, riffle and macrophytes
Disturbance rating: high
Waterway barriers: bed level crossing at site and water intake upstream</td><td></td><td></td></tr>
<tr><td colspan="2">Aquatic values:
Water quality, riparian vegetation, aquatic flora and fauna (fish and macroinvertebrates)</td></tr>
</table>

<table>
<tr><th>Site</th><th>Habitat description</th><th>Upstream photo</th><th>Downstream photo</th></tr>
<tr><td rowspan="2">TKU-US
Totokoitu catchment</td><td rowspan="2">Channel pattern: mildly sinuous
Mean wetted width: 1 m
Mean water depth: 0.2 m
Flow conditions: at watermark; 0.1 m/s
Substrate: boulder (15%); cobble (10%); pebble (30%); gravel (25%); sand (15%); silt/clay (5%)
Riparian vegetation: native canopy / native understorey; semi-continuous to continuous
In-stream habitat: high – shallow and deep pool, run, riffle and LWD
Disturbance rating: moderate
Waterway barriers: water intake upstream</td><td></td><td></td></tr>
<tr><td colspan="2">Aquatic values:
Water quality, riparian vegetation, aquatic fauna (fish and macroinvertebrates)</td></tr>
<tr><td rowspan="2">TKU-D
Totokoitu catchment</td><td rowspan="2">Channel pattern: mildly sinuous
Mean wetted width: 3.5 m
Mean water depth: 0.25 m
Flow conditions: at watermark; 0.2 m/s
Substrate: boulder (5%); cobble (10%); pebble (30%); gravel (25%); sand (20%); silt/clay (10%)
Riparian vegetation: native canopy / exotic understorey; semi-continuous to continuous
In-stream habitat: low – shallow run and riffle
Disturbance rating: moderate
Waterway barriers: water intake upstream</td><td></td><td></td></tr>
<tr><td colspan="2">Aquatic values:
Water quality, riparian vegetation, fauna (macroinvertebrates)</td></tr>
</table>

<table>
<tr><th>Site</th><th>Habitat description</th><th>Upstream photo</th><th>Downstream photo</th></tr>
<tr><td rowspan="2">TPA-US
Taipara catchment</td><td rowspan="2">Channel pattern: irregular meanders
Mean wetted width: 2 m
Mean water depth: 0.2 m
Flow conditions: at watermark; 0.2 m/s
Substrate: bedrock (5%); boulder (10%); cobble (5%); pebble (40%); gravel (10%); sand (10%); silt/clay (15%)
Riparian vegetation: native canopy / native understorey; semi-continuous to continuous
In-stream habitat: moderate – shallow and deep pool, run and riffle
Disturbance rating: moderate
Waterway barriers: culvert through water intake at site</td><td></td><td></td></tr>
<tr><td colspan="2">Aquatic values:
Water quality, riparian vegetation, aquatic fauna (fish and macroinvertebrates)</td></tr>
<tr><td rowspan="2">TPA-D
Taipara catchment</td><td rowspan="2">Channel pattern: irregular meanders
Mean wetted width: 0.25 m
Mean water depth: 0.5 m
Flow conditions: at watermark; 0.25 m/s
Substrate: boulder (15%); cobble (20%); pebble (20%); gravel (20%); sand (15%); silt/clay (10%)
Riparian vegetation: native canopy / native understorey; semi-continuous to continuous
In-stream habitat: moderate – shallow and deep run, riffle and undercut banks
Disturbance rating: moderate
Waterway barriers: water intake upstream</td><td></td><td></td></tr>
<tr><td colspan="2">Aquatic values:
Water quality, riparian vegetation, aquatic fauna (macroinvertebrates)</td></tr>
</table>

Site	Habitat description	Upstream photo	Downstream photo
PPA-D Papua catchment	**Channel pattern:** irregular meanders **Mean wetted width:** 2 m **Mean water depth:** 0.2 m **Flow conditions:** at watermark; 0.3 m/s **Substrate:** boulder (5%); cobble (10%); pebble (30%); gravel (40%); sand (10%); silt/clay (5%) **Riparian vegetation:** native canopy / native understorey; semi-continuous to continuous **In-stream habitat:** moderate – shallow run, riffle and undercut banks **Disturbance rating:** moderate **Waterway barriers:** waterfall upstream	 **Aquatic values:** Water quality, riparian vegetation	
NGT-US Ngatoe catchment	**Channel pattern:** irregular meanders **Mean wetted width:** 1.5 m **Mean water depth:** 0.2 m **Flow conditions:** at watermark; 0.1 m/s **Substrate:** cobble (20%); pebble (40%); gravel (30%); sand (5%); silt/clay (5%) **Riparian vegetation:** native canopy / native understorey; semi-continuous to continuous **In-stream habitat:** high – shallow and deep pool, run and riffle **Disturbance rating:** moderate **Waterway barriers:** water intake at site	 **Aquatic values:** Water quality, riparian vegetation, aquatic fauna (fish and macroinvertebrates)	

Site	Habitat description	Upstream photo	Downstream photo
NGT-D Ngatoe catchment	**Channel pattern:** irregular meanders **Mean wetted width:** 2.5 m **Mean water depth:** 0.15 m **Flow conditions:** at watermark; 0.15 m/s **Substrate:** boulder (15%); cobble (10%); pebble (40%); gravel (20%); sand (10%); silt/clay (5%) **Riparian vegetation:** native canopy / native understorey; semi-continuous to continuous **In-stream habitat:** moderate – shallow run, riffle, undercut banks and LWD **Disturbance rating:** moderate **Waterway barriers:** water intake upstream		
		Aquatic values: Water quality, riparian vegetation, aquatic fauna (macroinvertebrates)	

Table 4-2 Habitat assessment scores for each site during the January 2020 survey

Habitat variable	Scale+	AVT-US	AVT-D	TKV-US	TKV-D	TPP-US	TPP-D	MTV-US	MTV-D	TRG-US	TRG-D	AVA-US	AVA-D	TKU-US	TKU-D	TPA-US	TPA-D	PPA-D	NGT-US	NGT-D
Bottom substrate	0-20	16	18	16	15	15	16	16	16	16	17	16	17	16	17	16	18	19	16	18
Embeddedness	0-20	15	19	15	15	15	16	16	17	13	18	15	18	16	19	15	20	19	19	19
Velocity and depth category	0-20	16	13	15	15	14	15	17	15	15	15	15	15	15	14	14	15	12	16	15
Channel alteration	0-15	9	9	9	13	9	14	11	12	9	9	12	14	12	13	10	13	15	11	12
Bottom scouring and deposition	0-15	8	10	9	11	9	15	12	12	9	11	12	12	12	13	9	12	15	11	12
Pool/riffle, run/bend ratio	0-15	11	8	11	12	11	14	12	12	11	11	11	12	12	11	12	12	11	11	11
Bank stability	0-10	9	6	8	9	7	8	8	9	6	9	7	8	6	6	5	7	8	8	6
Bank vegetation and stability	0-10	9	8	9	8	8	8	9	9	9	10	9	9	9	9	6	9	9	9	10
Streamside cover	0-10	9	6	7	9	5	10	8	6	8	8	8	7	9	7	8	8	6	7	6
Totals	**0-135**	**102**	**97**	**99**	**107**	**93**	**116**	**109**	**108**	**96**	**108**	**105**	**112**	**107**	**109**	**95**	**114**	**114**	**108**	**109**
Habitat score category*		**Good**	**Good**	**Good**	**Good**	**Good**	**Excellent**	**Good**	**Good**	**Good**	**Good**	**Good**	**Excellent**	**Good**	**Good**	**Good**	**Excellent**	**Excellent**	**Good**	**Good**

4.3 Water quality

Temperature was similar between upstream and downstream locations at each site, however, water temperature varied between catchments (Table 4-3 and Figure 4-1). The maximum water temperature was recorded at the downstream Taipara site (TPA-D 24.7°C). Whereas, the minimum water temperature was recorded at the upstream Turangi site (TRG-US 23.0°C). Water temperature was higher at the downstream site of each catchment with the exception of Totokoitu where the opposite was true and Avana which were equal.

pH complied with the ANZECC 2000 guideline range at the majority of sites but was outside the guideline range at seven sites (Table 4-3). Of these non-compliant sites, five were located within the upstream reach of the catchment. pH was consistent between the catchments and ranged from 7.01 pH units at Avana (AVA-D) to 7.61 pH units at Takuvaine (TKV-US) (Table 4-3 and Figure 4-1). Median pH for all sites was circumneutral (7.45 pH units).

Electrical conductivity complied with the guideline range at all sites. Electrical conductivity was similar between upstream and downstream locations at each site but were variable between catchments (Table 4-3 and Figure 4-1). The minimum electrical conductivity concentration was recorded at site AVA-US (80 µS/cm) with site NGT-US recording the highest electrical conductivity (196 µS/cm). Mean electrical conductivity for all sites was 147 µS/cm.

Dissolved oxygen saturation was lower than the guideline value at eight sites but complied at all remaining sites (Table 4-3). Dissolved oxygen saturation was relatively consistent between sites and catchments and ranged between 77.4% saturation (NGT-US) to 96.4% saturation (TKU-D) (Table 4-3 and Figure 4-1). Mean dissolved oxygen saturation for all sites was 89.5% saturation, marginally below the guideline range.

Table 4-3 In-situ water quality at each site in January 2020

Site	Temperature	pH	Electrical conductivity	Dissolved oxygen	Dissolved oxygen
Units	°C	pH units	µS/cm	mg/L	% saturation
ANZECC	–	6.0 – 7.5	20 – 250	–	90 – 120
AVT-US	23.8	7.59	180	7.72	91.1
AVT-D	24.1	7.49	191	7.88	93.8
TKV-US	23.7	7.61	164	7.33	89.7
TKV-D	24.4	7.23	170	7.02	82.0
TPP-US	23.9	7.60	171	7.28	87.4
TPP-D	24.4	7.52	172	7.73	92.4
MTV-US	23.5	7.60	163	7.73	90.2
MTV-D	23.9	7.45	166	7.66	91.0
TRG-US	23.0	7.40	125	7.74	90.4
TRG-D	23.2	7.39	130	7.94	93.0
AVA-US	23.2	7.10	80	7.08	78.3

Site	Temperature	pH	Electrical conductivity	Dissolved oxygen	Dissolved oxygen
Units	°C	pH units	µS/cm	mg/L	% saturation
ANZECC	–	6.0 – 7.5	20 – 250	–	90 – 120
AVA-D	23.2	7.01	85	8.10	94.7
TKU-US	24.3	7.33	125	7.55	89.5
TKU-D	23.6	7.15	118	8.17	96.4
TPA-US	24.0	7.30	111	7.90	93.9
TPA-D	24.7	7.45	116	7.14	87.4
PPA-D	24.2	7.54	144	7.46	88.9
NGT-US	23.7	7.58	196	6.31	77.4
NGT-D	24.0	7.47	187	7.83	92.5

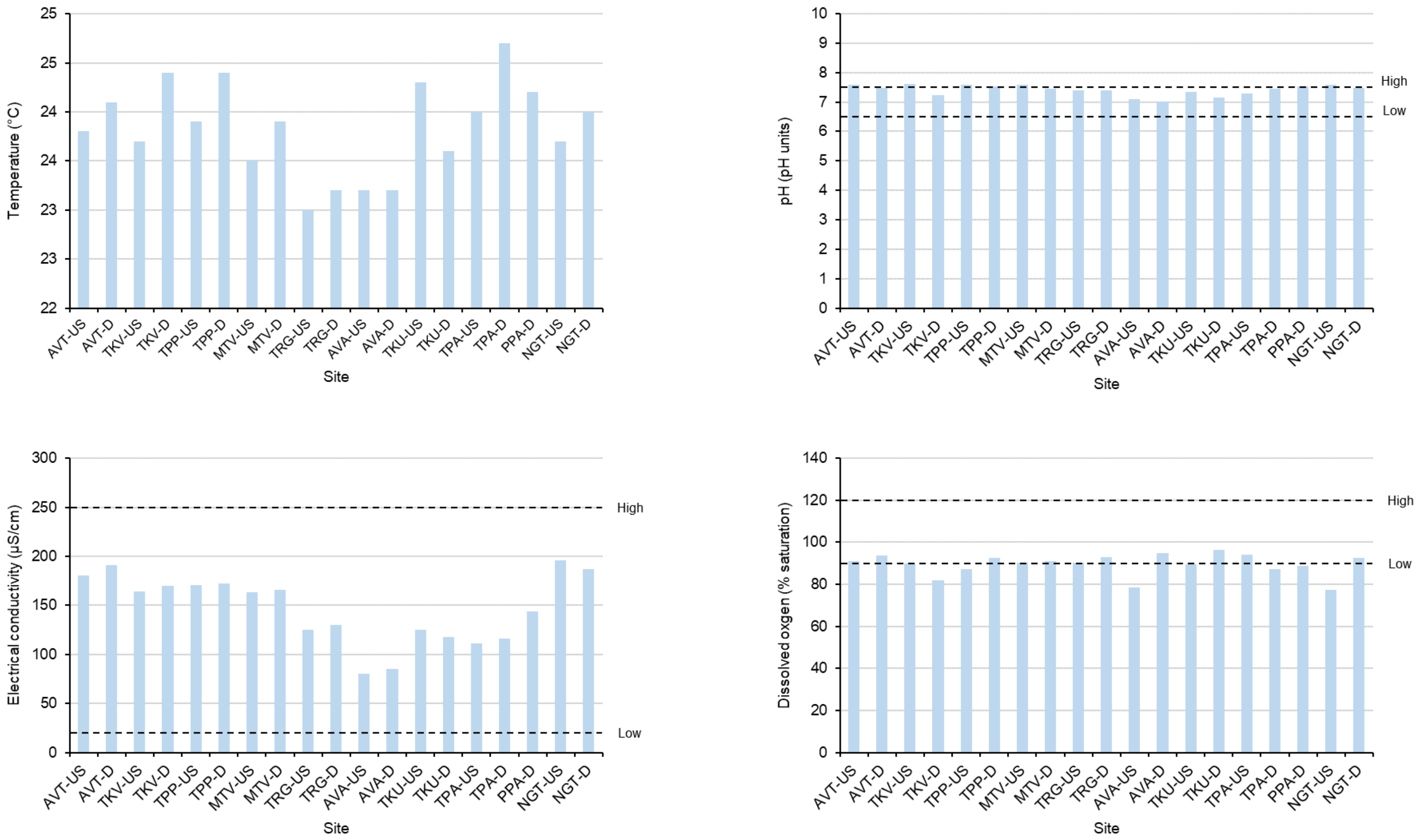


Figure 4-1 *In-situ* water quality for each site in January 2020

4.4 Aquatic flora

No threatened aquatic flora species were found at any site. Aquatic flora had limited diversity with three species (*Cyperus involucratus* – umbrella sedge, *Azolla filiculoides* – red water fern and *Colocasia esculenta* – taro) recorded at five catchments (Avatiu, Avana, Turangi, Matavera and Takuvaine) (Plate 4-2). Of these species, one (*Azolla filiculoides*) is considered to be an introduced species. However, *Azolla filiculoides* was only found in a bed within the scour pond at site TKV-D.

Cyperus involucratus and *Colocasia esculenta* were often found isolated and scattered along the banks and water's edge of the five catchments.

Aquatic flora species and abundance was similar between the upstream and downstream sites at all sites.

These aquatic plants provided some in-stream habitat for macroinvertebrates and fish, help stabilise bed and banks reducing erosion and sedimentation and improve water quality conditions.

Plate 4-2 Umbrella sedge (Cyperus involucratus) (top left); taro (*Colocasia esculenta*) (top right); red water fern (*Azolla filiculoides*); *Azolla filiculoides* as a bed in a scour pond

4.5 Aquatic macroinvertebrates

Macroinvertebrate diversity was low with only eight orders and ten taxa groups present. All taxa found were considered to be tolerant of pollution with sensitivity scores of two to five.

Of the groups present, Atyidae and Palaemonidae were the most common and abundant taxa found in edge habitat (Figure 4-2; Plate 4-3). Conversely, Lepidoptera and Oligochaeta were the

least commonly found taxa with only one record at the downstream Totokoitu and Avana sites respectively. The highest taxa richness was recorded at AVT-US and TPP-US sites with TPP-D and MTV-US recording the lowest taxa richness. Upstream sites tended to have higher or equivalent taxa richness to downstream sites. Macroinvertebrate communities varied considerably within the Avatiu catchment, with only one taxa (Palaemonidae) in common between the upstream and downstream locations. Differences in taxa richness between sites and locations (upstream and downstream) are likely due to site-specific habitat characteristics, such as flow, substrate composition and available cover.

Within the bed habitat, Atyidae and Chironomidae were the most common and abundant taxa (Figure 4-3). Whereas, Veliidae, Tipulidae, Amphipoda and Lepidoptera were equally the least common taxa being present at only one site each. The highest taxa richness was recorded at sites TPP-US and TKU-D. Conversely, sites TPP-D and PPA-D did not record any macroinvertebrates. Taxa richness in upstream sites was generally higher than the respective downstream site with the exception of Turangi, Totokoitu and Ngatoe. The macroinvertebrate communities of the upstream and downstream Takuvaine sites differed, sharing no common taxa.

Plate 4-3 Palaemonidae captured at site TPP-D within the Tupapa catchment

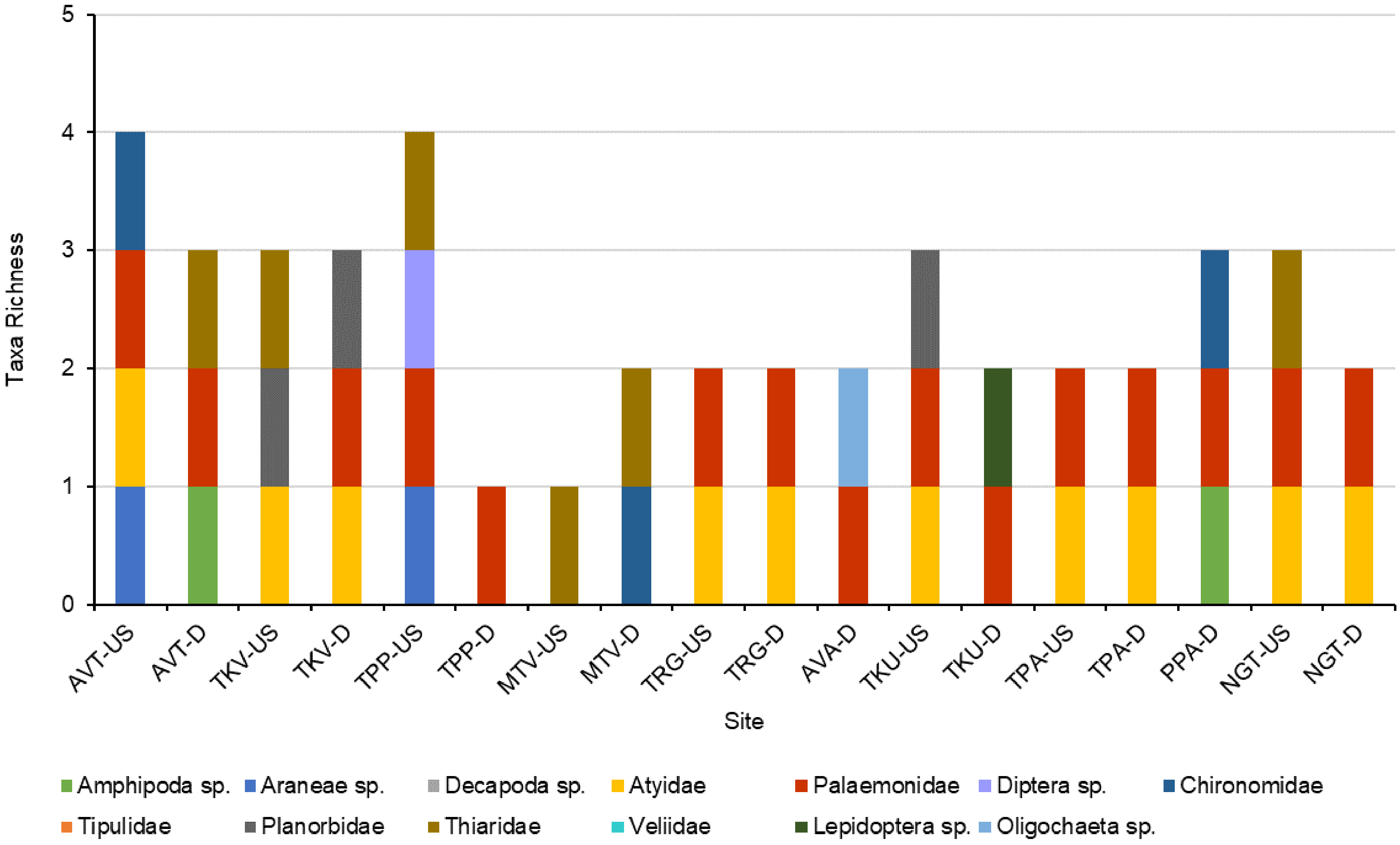


Figure 4-2 Taxa richness in edge samples at each site in January 2020

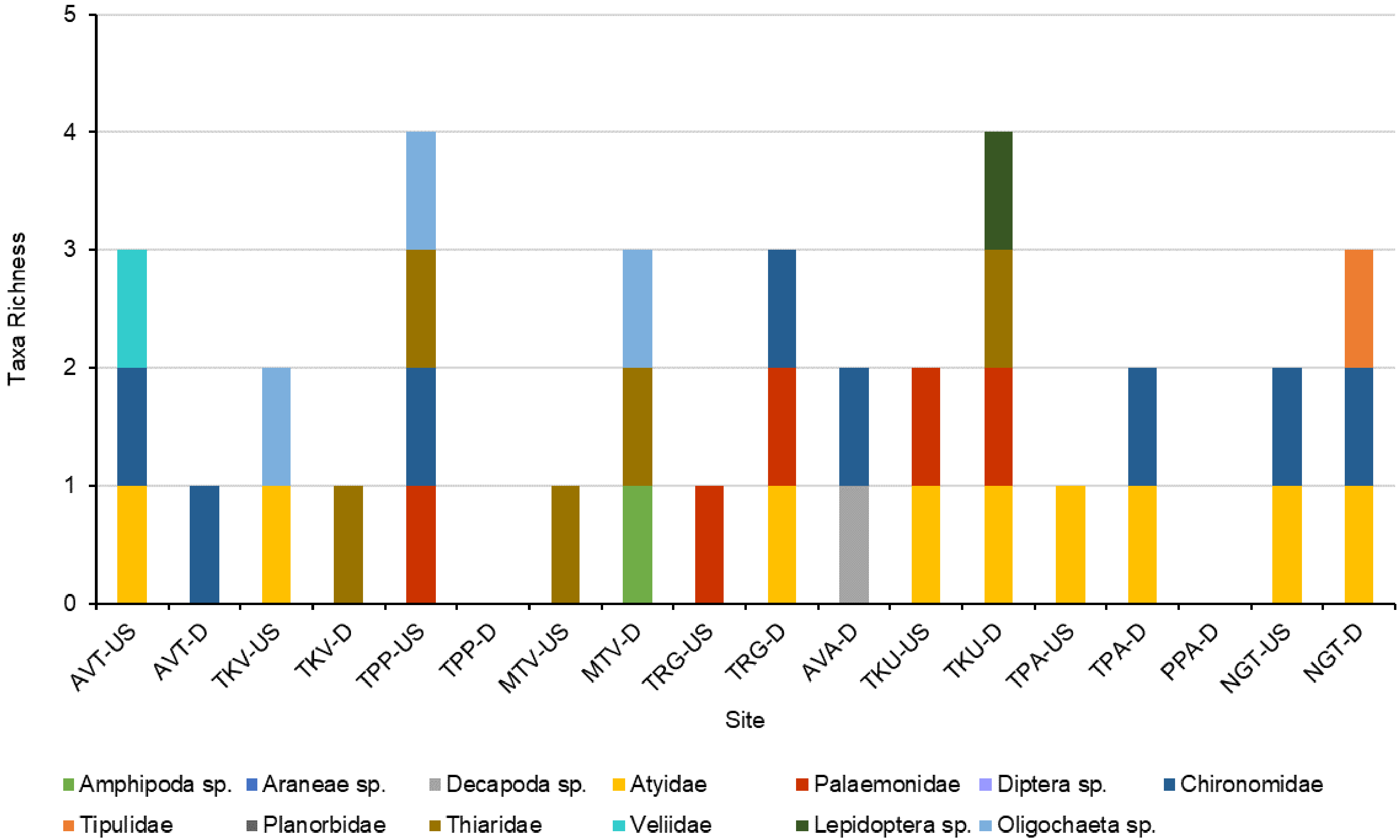


Figure 4-3 Taxa richness in bed samples at each site in January 2020

4.1 Fish community

Fish diversity was limited throughout the catchments with only three species identified and small unidentified fish noted across eight of the ten catchments. Of these species, one was an introduced species (guppy – *Poecilia reticulata*) (Plate 4-4). Eels were observed at three of the catchments (Totokoitu, Taipara and Ngatoe) with local reports of eels at Takuvaine. Gobies were observed at two sites, TKV-US (Takuvaine) and AVA-US (Avana) (Plate 4-4). Guppy (*Poecilia reticulata*) was only confirmed at one site AVA-D on the Avana catchment. Schools of small unidentified fish were also observed within the Avatiu, Matavera and Turangi catchments.

Abundance of eels was low with only one to two eels observed per site. Whereas, goby had a higher abundance of upwards of 20 – 30 individuals per site. Guppy were sparse with only three individuals caught during macroinvertebrate sampling.

Table 4-4 Fish observed or locally reported at each site during January 2020

Site	Catchment	Small fish	Goby	Guppy	Eel
AVT-US	Avatiu	X			
AVT-D	Avatiu	X			
TKV-US	Takuvaine		X		X
TKV-D	Takuvaine				X
TPP-US	Tupapa				
TPP-D	Tupapa				
MTV-US	Matavera	X			
MTV-D	Matavera	X			
TRG-US	Turangi	X			
TRG-D	Turangi				
AVA-US	Avana		X		
AVA-D	Avana			X	
TKU-US	Totokoitu				X
TKU-D	Totokoitu				
TPA-US	Taipara				X
TPA-D	Taipara				
PPA-D	Papua				
NGT-US	Ngatoe				X
NGT-D	Ngatoe				


Plate 4-4 Guppy (*Poecilia reticulata*) (left); goby species (right)

4.1 Turtle community

There were no turtles observed during the January 2020 survey. No suitable habitat was present for the red eared slider turtle as they prefer warm and still or slow flowing water where they can easily access the bank to bask.

5. Impact assessment

5.1 Nature of potential risks

5.1.1 Overview

During the water treatment process, wastewater is discharged to the scour ponds to settle before being released back to the waterway. Water that has been discharged to the scour ponds has been treated with PACl (and in the future, potentially chlorine). Since the scour ponds are not actively controlled (instead relying on water level), there is a risk that wastewater that has not sufficiently settled will be discharged back in to the waterway.

Potential risks to aquatic environmental values through the use of PACl and chlorine during the water treatment process are as follows:

- Concentrations of PACl and chlorine may be higher than guidelines and/or toxicity levels when water is released thereby increasing the risk of harm to the aquatic values
- Water quality variability within the waterways may influence the toxicity of PACl, and chlorine.

A desktop review of the potential ecotoxicology potential of PACl and chlorine is provided in Sections 5.1.2 and 5.1.3 with potential risk to environmental values discussed in the Section 5.2.

5.1.2 PACl

Polyaluminium chloride (PACl) is a commonly-used prehydrolyzed conventional coagulant (Gebbie 2001). Generally it is prepared by slow base-feeding using NaOH [Sodium hydroxide] or Na_2CO_3 [Sodium carbonate] as the basification reagent (Gebbie 2001). PACl as an aluminium coagulant (ARC 2004) is used commonly as a flocculant in water purification and in the treatment of potable water and wastewater. In natural waters, aluminium occurs commonly in the form of soluble salts, namely chlorides, sulfates and nitrates (Jancula et al 2011).

Globally, aluminium in the form of PACl has been incorporated into the treatment of freshwater bodies for the direct removal of cyanobacteria, or phosphorus (Jancula et al 2011). PACl is also used for the direct dosing of eutrophic lakes which has achieved significant reductions in suspended matter, nutrients, oxygen demand and turbidity (ARC 2004). When added to a body of water, aluminium quickly forms large precipitates of aluminium hydroxide that grow in size eventually sinking to the sediments. Aluminium coagulants can also bind small particles including algal and cyanobacterial cells into the flocks and thus, directly reduce biomass from the water column (Jancula & Marsálek 2012).

The impact associated with the use of PACl in wastewater treatment 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. Factors such as pH, dissolved organic carbon (DOC), temperature and hardness regulate the solubility of Al^{+3} in water, with pH having the greatest influence on toxicity.

The active toxic component of PACl, the free cationic aluminium ion (Al^{3+}), solubility drastically increases at a pH lower than 5.5. Solubility also increases when pH is greater than 9. However, solubility is very low when pH is between 5.5 and 9. This indicates that aluminium toxicity is especially dependent on the pH. Kennedy and Cooke (1982) studied the solubility of aluminium

in water and concluded that regardless of the dose, dissolved aluminium remained below 50 µg/L in the pH range 5.5 to 9.

The presence of DOC in the environment also reduces aluminium toxicity. DOC reacts with Al^{+3} forming colloidal aluminium precipitates and reducing the bioavailability of aluminium. Aluminium speciation and solubility is also affected by temperature (Gensemer & Playle 1999). Higher temperatures have been observed to increase toxicity of aluminium in Atlantic salmon likely due to faster aluminium polymerisation and higher metabolic rate of the fish (Poléo et al. 1991).

Aluminium toxicity is also influenced by the water hardness, being more toxic in soft water (low in ions, particularly calcium and magnesium) <40 mg/L. Some toxicity to fish has been associated with the use of aluminium based flocculants being used in soft water lakes (Tandjung, 1982; WDNR, 2003). Tandjung (1982) studied the influence of hardness on aluminium toxicity for brook trout (*Salvelinus fontinalis).* The EC50 (the median effective concentration) values for aluminium at water hardness values of 2, 18 and 40 mg/L were 0.36-0.39 mg/L, 2.8-4 mg/L and 6.2-7 mg/L respectively, indicating greater toxicity at low hardness levels.

5.1.3 Chlorine

Calcium hypochlorite (CH) is an inorganic compound with the formula $Ca(ClO)_2$ (Vogt et al 2010). It is the main active ingredient of commercial products such as bleaching powder, chlorine powder, or chlorinated lime, and commonly used for water treatment (Vogt et al 2010) due to its ability to kill algae, bacteria and viruses (Chem. Synopsis 1987 & *Lyster, WJ 1916*). CH can be manufactured in the form of a white powder, granule, or pallet with a strong chlorine-like odor (Chem. Synopsis 1987).

CH can be applied to water as chlorine gas, as sodium hypochlorite solution or as dry calcium hypochlorite, so that all three forms produce free chlorine in water (Garcia-Villanova et al 2010). For a number of years many small and medium-size water treatment plants (WTPs) have utilized the disinfectant properties of solid CH (Garcia-Villanova et al 2010).

CH (gaseous or liquid) is the most economical and widespread inactivator agent of pathogenic organisms present in raw water such as rivers, lakes and groundwater, being very efficient in the sterilisation of bacteria and viruses (Agnelo et al 2020). As such CH and other new disinfectants have been topically investigated. Agnelo et al (2020) conducted a study which observed that the greater concentration of each disinfectant provided a significant increase in the metabolic potential of microorganisms.

The chemistry of chlorine in natural water is complex. Free chlorine can be present in water as a molecular chlorine (Cl_2), hypochlorous acid (HOCl) or hypochlorite (OCl-). When combined with ammonia, chlorine forms monochloramine or combined chlorine (NH_2Cl) (Cooke and Schreer 2001). The sum of free and combined chlorine is referred as total residual chlorine (TRC). Most research studies have suggested that free chlorine is the most toxic form (Merkens 1958). For example, toxicity in rainbow trout, indicated by an avoidance response, was observed at 10 µg/L of free chlorine (Sprague and Drury 1969) but avoidance was not detected until concentration at 50-100 µg/L for TRC (Schumacher and Ney 1980).

Toxicity of free chlorine can be influenced by temperature. Several studies have found a greater effect on fish at higher temperatures (Bass and Heath 1977; Middaugh et at 1978; Cherry et al 1977).

Chlorine is very reactive but does not persist for a long period of time in water as it rapidly dissipates to the atmosphere when contact is made with air.

However, the by-products created through the chlorination process can lead to the formation of hazardous substances that have the potential to persist in the environment (ANZECCC 2000). These by-products have the potential to impact the environment and public health (Agnelo et al 2020). Byproducts may include trihalomethanes (THMs) an environmental pollutant with carcinogenic potential, and haloacetic acids (HAAs) which have been linked due to long-term exposure to cancer, birth defects and skin irritations (Park et al 2016). THMs and HAAs are a type of chlorination disinfection by-product (CDBP) that are formed when the chlorine used to disinfect drinking water reacts with naturally occurring organic matter (NOM) in water (Park et al 2016).

5.2 Risks to the aquatic environment in Rarotonga

5.2.1 Overview of aquatic values

The key values identified within the Rarotongan waterways during the desktop review and field survey were water quality, riparian vegetation, aquatic flora and aquatic fauna. In particular, these environmental values are important because:

- Good **water quality** promotes a healthy ecosystem by supporting biota. When water quality is degraded this reduces the diversity and abundance of biota.
- The presence of **riparian vegetation** (whether native of exotic) provides cover for aquatic fauna and helps to stabilise water temperature by providing shade. Riparian vegetation is also critical for maintaining bank stability, preventing erosion and sedimentation of waterways.
- **Aquatic flora** provides habitat for macroinvertebrates and fish. Aquatic flora also helps to stabilise channel beds and influences water quality through filtering and oxygenation.
- **Aquatic fauna** are a food source for birds, fish and the local population.

Aquatic values for receiving environment sites on Rarotonga based on the desktop review and the aquatic ecology survey are presented in Table 5-1.

Table 5-1 Aquatic environmental values for receiving environments

Site	Water quality	Riparian vegetation	Aquatic flora	Aquatic fauna
AVT-D	X	X	X	X
TKV-D	X	X		X
TPP-D	X	X		
MTV-D	X	X	X	X
TRG-D	X	X	X	X
AVA-D	X	X	X	X
TKU-D	X	X		X
TPA-D	X	X		X
PPA-D	X	X		
NGT-D	X	X		X

Based on the known susceptibility of environmental values to elevated concentrations of aluminium or chlorine the expected potential impacts to the sites from contamination could include:

- Degradation of **water quality** with these effects flowing through to riparian vegetation, macroinvertebrate assemblages and fish communities.
- **Riparian vegetation** dieback, changes in community structure and composition, encroachment of weed species leading to bank destabilisation, erosion and sedimentation of waterways and degradation of water quality.
- Loss of aquatic **flora** leading to an overall reduction in species diversity and abundance and decrease in availability of habitat for aquatic fauna.
- Reduction in diversity and abundance of **macroinvertebrate communities**, potentially limiting their availability as a food source.
- Increase in susceptibility of **fish** to disease, predation and death and overall reduction in fish species diversity and abundance.

5.2.2 PACI

Water quality within the catchments on Rarotonga was considered to be good with the majority of sites complying with guidelines. Considering that pH at all sites was circumneutral, any aluminium released to the waterways from the scour ponds is likely to have low toxicity. Further, at this pH there is a low risk of aluminium bioaccumulation because the bioavailability of ionic aluminium is very low. However, should pH conditions within the waterways change, the toxicity of aluminium may change. At pH values less than 5.5 or greater than 9, toxicity and bioaccumulation of aluminium will increase. This is supported by a study conducted by Cleveland et al (1986) who exposed brook trout to 0.3 mg/L aluminium at different pH values. Aluminium concentrations in fish were 112-398 mg/kg at pH 5.28 and only 12-33 mg/kg at pH 7.7.

Waterways on Rarotonga typically had a low proportion of organic matter (plant and animal material) with the exception of the occasional slow flowing pool such as at site TKV-US where organic matter accumulated. The presence of organic matter in these pools indicates that DOC is likely to be present in varying concentrations within the waterway. As discussed in Section 5.1.2, DOC reduces the bioavailability of aluminium.

The electrical conductivity of the waterways on Rarotonga ranged between 80-196 µS/cm indicating that it is possible that hardness is below 40 mg/L. As discussed in Section 5.1.2, aluminium is more toxic to aquatic organisms in soft water. In particular, the toxicity of aluminium to some fish species can increase considerably when hardness is less than 40 mg/L. However, there is currently no data available for hardness in the receiving environment to confirm aluminium toxicity in this respect.

Aquatic macrophytes were predominantly isolated and scattered at four receiving environment sites on Rarotonga (AVT-D, MTV-D, TRG-D and AVA-D). Aluminium toxicity in aquatic plants is principally through interfering in the uptake of cations and nutrients (particularly calcium and phosphorous) which causes detrimental effects in leaves and roots (Rout et al 2001). This is supported by studies with freshwater algae which also pointed to the competition of aluminium with essential cations (principally phosphorous) as the principal cause of toxicity (Exley et al 1993). For freshwater algae, the aluminium effect concentrations ranged from 50-6477 µg/L, with most effect levels below 1000 µg/L. Although studies of aluminium toxicity to macrophytes are limited, available data suggest that macrophytes are more tolerant to aluminium than freshwater algae.

Aquatic macroinvertebrate communities within the waterways of Rarotonga had limited diversity, were tolerant of pollution and had low abundance at all receiving environment sites. The mechanism for aluminium toxicity in macroinvertebrates is through disrupting the concentrations of principal anions, resulting in a loss of sodium (Hornstrom et al. 1984). Consequently, this affects the efficiency in respiration for some sensitive species (Sparling and Lowe 1996). Aquatic macroinvertebrates have reported a LC20 range of 29.5-6224 µg/L Al, and pH, hardness and DOC ranging from 5.1-8.7, 25-428 mg/L and 0.5-12 mg/L, respectively. Further, effective concentrations of PACl on crustaceans and zooplankton can differ markedly according to the conductivity of treated water (Jancula et. al 2011).

Fish communities within the waterways had limited diversity and had a relatively low abundance at most sites in the receiving environment. Fish are generally more sensitive to aluminium than aquatic macroinvertebrates (Sparling et al 1997; Khan 2006). Aluminium is a gill toxicant for fish, as it coagulates the mucous on the gills and causes osmoregulatory and respiratory problems (Khan 2006). However, studies of dissolved aluminium have shown no effect on rainbow trout (*Oncorhynchus mykiss*) at concentrations below 50 µg/L (Freemen and Everhart 1971). The range of LC20 values from three fish species (including *Salmo Salar*, *Salvelinus fontinalis* and *Pimephales promelas*) was 62-6,194 µg/L Al (USEPA 2018). These studies were conducted at very different conditions with pH, hardness and DOC ranging from 5.7-7.7, 12.3-220 mg/L and 0.25-1.9 mg/L, respectively.

International guidelines for the protection of environmental values from aluminium is presented in Table 5-2. The ANZECC 95% default guideline value (DGV), indicating the concentration at which 95% of species is expected to be protected, is 55 µg/L for aluminium. This guideline was derived based on studies with pH >6.5. Derivation hardness and DOC were not considered. The approach of the United States Environmental Protection Agency (USEPA) was to derive a dynamic guideline which could be adapted to the specific pH, hardness and DOC observed in the receiving environment (USEPA 2018). In this sense, the specific aluminium guideline that could be applied to the Rarotonga receiving environment with neutral pH, has been derived with a long-term criteria of 290-630 µg/L (Table 5-2). In a worst case scenario, where pH decreases within the receiving environment (i.e. to a minimum of 6.5) the criteria decreases to 78 µg/L. This concentration is slightly higher that the ANZECC 95% DGV, indicating that the ANZECC guidelines is considerably more conservative that the USEPA criteria.

Table 5-2 International criteria for aluminium

International guidelines for aluminium	Guideline type	Trigger value for freshwater (µg/L)	References
Australia and New Zealand	99% species protection (pH>6.5)	27	ANZECC (2000)
	95% species protection (pH>6.5)	55	
USEPA	CMC pH=7 Hardness=40 mg/L DOC= 1 mg/L	730	USEPA (2018)
	CCC pH=7 Hardness=40 mg/L DOC= 1 mg/L	330	
USEPA, adapted to receiving environment	CMC pH=7-7.6 Hardness=20 mg/L DOC= 1 mg/L	570-1100	
	CCC pH=7-7.6 Hardness=20 mg/L	290-630	

International guidelines for aluminium	Guideline type	Trigger value for freshwater (µg/L)	References
	DOC= 1 mg/L		
USEPA, receiving environment, worst case scenario	CCC pH=6.5 Hardness=10 mg/L DOC= 0.5 mg/L	78	
Notes: CMC: Criterion Maximum Concentration CCC: Criterion Continuous Concentration			

Overall, PACl is preferable to an alternative flocculent (alum) based on its effects on water quality. In an overview by the ARC (2004) it is stated that PACl is a less acidic product than alum which may be preferable to use at naturally acidic locations. Further, the effect of PACl on pH levels was also less in contrast to alum (ARC 2004), thus suggesting PACl would be more suitable for receiving waters within Rarotonga.

PACl is generally dosed to reach concentrations within 7-8 mg/L on the inflow (Jia et al 2018), with residual aluminium concentrations in outflow observed in the range 10-84 µg/L. This indicates that at a typical dosage rate, the residual concentrations of aluminium would be below the derived long-term specific criteria for Rarotonga of 290 µg/L, and in most cases, also below the most conservative ANZECC 95% DGV of 55 µg/L.

Overall, the risk of toxicity of PACl can be mitigated by controlling the dosage and by adjusting a dilution rate to keep the aluminium below the toxicity threshold concentrations in the receiving environment. However, at typical dosage rates, aluminium would be already below the guideline for environmental protection. During and immediately following very heavy rainfall events, discharge of water to the scour ponds or via the settlement tank's high level overflow may immediately enter the waterways. The large volume of water present via overland flows and within the waterways would dilute aluminium concentrations such that no significant impact would be expected.

In conclusion, considering the expected residual aluminium in the discharge and current receiving environment conditions, the risks for the aquatic organisms associated to the use of PACl is considered low and acceptable.

5.2.3 Chlorine

The chlorination of drinking water is designed to eliminate a large number of bacteria and pathogens typically associated with water. The presence of those pathogens in drinking water and the environment could be harmful for people and the aquatic communities and, hence, the beneficial effect of chlorination largely exceeds the disadvantages. Chlorine is known to dissipate to the atmosphere when contact is made with air and therefore discharge of water to the scour ponds will substantially decrease chlorine concentrations prior to entering the waterways. The potential effects associated with the presence of free chlorine in the receiving environment is discussed below.

Water quality in the receiving environment was good with most sites complying with guidelines. Temperature was consistent between downstream sites ranging between 23.2°C and 24.7°C. As discussed in Section 5.1.3, high water temperature can increase the toxicity of chlorine. However, as water temperature was not particularly warm, it is expected that chlorine toxicity would not be affected. Further, as these water temperatures were recorded during summer, it is likely that these will be maximum temperatures experienced, further demonstrating that chlorine toxicity is unlikely to be affected by temperature in the receiving environment.

Organic matter throughout the catchments tended to be sparse with the exception of the occasional pool where organic matter such as leaves and twigs would accumulate. As discussed in Section 5.1.3, naturally occurring organic matter can increase the toxicity of

chlorine by-products. Since organic matter was generally not prevalent, particularly in the receiving environment, the risk of increasing the toxicity of the chlorine by-products is low.

Within the receiving environment of Rarotonga, aquatic macrophytes were predominantly isolated and scattered at sites AVT-D, MTV-D, TRG-D and AVA-D. The toxicity effects of chlorine and chloramine in phytoplankton is related to the interruption of nutrients intake, principally nitrate and ammonia (Hall 1981). Chlorine can also physically damage algal cells by causing cytoplasm leakage (Betzer and Kott 1969). This has the potential to cause mortality in aquatic plants at elevated concentrations.

Macroinvertebrate communities in the catchments of Rarotonga have low diversity and are tolerant of pollution. Chlorine effects on aquatic macroinvertebrates are related to damage of the gills. Camargo (1991) observed detrimental effect in tracheal gills in a freshwater insect exposed to chlorine. However, macroinvertebrates confirmed to be present do not respire through gills and are therefore at a lower risk of harm. Some taxa such as Epiproctophora (dragonfly) and Zygopter (damselfly) do rely on gills for respiration and are known to be present on Rarotonga through desktop review. These taxa are at an increased risk of mortality where chlorine concentrations are elevated.

Fish species diversity in the Rarotonga receiving environment sites was limited with only three species noted. Fish were only confirmed present at four sites (AVT-D, MTV-D, TRG-D and AVA-D) during the January 2020 survey. The mechanisms of toxic action of chlorine in fish species is related to the gills (Block 1977) by creating internal hypoxia induced by gill hyperplasia and damage of lamellae epithelial cells. Other authors have found that alterations on fish haemoglobin, caused by chloramines, produced when ammonia is available, also causes hypoxia in fish (Grothe and Eaton, 1975). The effects of chlorine in freshwater fish species in terms of LC50 values ranges from 20 to 500 µg/L for the rainbow trout (*Oncorhynchus mykiss*) and smallmouth bass (*Micropterus dolomieu*), respectively (Bash et al, 1972 and Pyle, 1980). While species diversity was low, elevated chlorine levels may pose a risk to health for the fish that currently exist in the receiving environment.

According to literature (Section 5.1), a concentration of 2 µg free chlorine/L would protect most fish species for acute and chronic effects. This is consistent with the ANZECC 95% DGV established at 3 µg/L(Table 5-3) .This guideline is derived to protect 95% of the species of the receiving environment and is conservative compared to the guideline derived by USEPA for long-term exposures (CCC=11 µg/L). In the context of this report, the ANZECC 95% DGV for free chlorine has been considered sufficient to protect the environmental values (water quality, riparian vegetation, aquatic flora and aquatic fauna) in the receiving environment.

Table 5-3 International guidelines for chlorine

International guidelines for chlorine	Guideline type	Trigger value for freshwater (µg/L)	References
Australia and New Zealand	99% species protection	0.4	ANZECC (2000)
	95% species protection	3	
USEPA	CMC	19	US EPA (2019)
	CCC	11	

Notes:

CMC: Criterion Maximum Concentration

International guidelines for chlorine	Guideline type	Trigger value for freshwater (µg/L)	References
CCC: Criterion Continuous Concentration			

The concentration of chlorine in the discharge will depend primarily on the dosage. Concentrations of free chlorine should be limited to a maximum of 0.6 mg/L (GHD 2017) but in actuality are expected to be lower, i.e. approximately 0.1 mg/L. This concentration would exceed the guideline value unless a high dilution rate (greater than 1/50) is achieved. However, the discharge of water to the scour ponds is expected to rapidly reduce chlorine, which will dissipate to the atmosphere when contact is made with air. During and immediately following very heavy rainfall events, discharge of water to the scour ponds may immediately enter the waterways. The large volume of water present via overland flows and within the waterways would dilute chlorine concentrations such that no significant impact would be expected.

Overall, providing that the free chlorine is kept below the guideline before the wastewater is discharged into the environment, the risk for the aquatic fauna and flora associated to the chlorination would be low and acceptable.

6. Summary and conclusion

The Government of Cook Islands is in the process of upgrading Rarotonga's water supply system (Te Mato Vai project), with the goal of delivering reliable and safe drinking water to its people. The project involves the upgrade of 10 water intakes, creation of additional storage capacity, construction of treatment plants, replacement of trunk mains, ring mains and distribution to the boundaries of all properties serviced by the current water network. Wastewater from the water treatment process will occasionally be discharged to the stream and as such an EIA is required.

The objective of this aquatic ecology assessment was to describe the existing aquatic values at the water intake and discharge locations and assess the potential impacts of PACl and chlorine discharge on the existing environment.

A desktop review and field survey in January 2020 were undertaken to confirm the environmental values of the receiving environment. The aquatic environmental values were considered to be water quality, riparian vegetation, aquatic flora and aquatic fauna. Results of the review and field survey with respect to the environmental values are as follows:

- In-situ **water quality** was considered to be good with the majority of sites complying with guideline levels.
- **Riparian vegetation** was moderately disturbed but consisted of dense vegetation providing structure, bank stability and limiting erosion.
- **Aquatic plants** were typically either absent from sites or scattered/isolated in-stream and on the banks but in good condition.
- **Aquatic fauna** (macroinvertebrates and fish) had limited diversity and abundance.

An impact assessment of PACl and chlorine found that physico-chemical conditions of the water affect the toxicity of these chemicals. High temperature, acidic or alkaline pH and soft water increase the toxicity of aluminium in PACl, whereas, DOC decreases the toxicity. Low temperature and naturally occurring organic matter increase the toxicity of chlorine. Both of these chemicals interfere with ion and nutrient uptake pathways in aquatic flora and fauna often causing respiratory issues, including mucous coagulating on the gills of fish or causing damage to leaves and roots.

Based on the known susceptibility of environmental values to elevated concentrations (i.e. concentrations that exceed guidelines for environmental protection) of aluminium or chlorine, the expected potential impacts to the sites from contamination could include:

- Degradation of **water quality** with these effects flowing through to riparian vegetation, macroinvertebrate assemblages and fish communities.
- **Riparian vegetation** dieback, changes in community structure and composition, encroachment of weed species leading to bank destabilisation, erosion and sedimentation of waterways and degradation of water quality.
- Loss of **aquatic flora** leading to an overall reduction in species diversity and abundance and decrease in availability of habitat for aquatic fauna.
- Reduction in diversity and abundance of **macroinvertebrate communities**, potentially limiting their availability as a food source.
- Increase in susceptibility of **fish** to disease, predation and death and overall reduction in fish species diversity and abundance.

Neutral pH levels within the waterways of Rarotonga will result in low toxicity of any aluminium released from the scour ponds. Further, at this pH there is a low risk of aluminium bioaccumulation because the bioavailability of ionic aluminium is very low. The ANZECC 95% DGV for aluminium, indicating the concentration at which 95% of species is expected to be protected, is 55 µg/L. Consideration of the specific pH, hardness and DOC observed in the receiving environment within Rarotonga suggests environmental protection is likely up to concentrations of 290-630 µg/L (USEPA 2018). Overall, the risk of toxicity of PACl can be mitigated by controlling the dosage and by adjusting a dilution rate to keep the aluminium below the toxicity threshold concentrations in the receiving environment. However, at typical dosage rates, aluminium would be already below the guideline for environmental protection. In conclusion, considering the expected residual aluminium in the discharge and current receiving environment conditions, the risks for the aquatic organisms associated to the use of PACl is considered low and acceptable.

Discharge of wastewater to the scour ponds is expected to rapidly reduce chlorine, which will dissipate to the atmosphere when contact is made with air. The ANZECC 95% DGV for chlorine is 3 µg/L and is conservative compared to the guideline derived by USEPA for long-term exposures (CCC=11 µg/L). Overall, providing that the free chlorine is kept below the guideline before the wastewater is discharged into the environment, the risk for the aquatic fauna and flora associated to the chlorination would be low and acceptable.

7. References

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Final	L Pratt	N Clarke, Y Yang		E Reid		28/02/2020

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Appendix D: Sampling records

Te Mato Vai & To Tatou Vai

TTV public water supply test results

On 16 March and again on 18 May 2019, To Tatou Vai staff took samples from 24 randomly selected water intake and the water supply (tap) sites around Rarotonga. The purpose of this testing was to gain an understanding of the current water quality before taking over responsibility for water supply and water treatment. The test results are presented in this document.

Tests were for E.coli because it is a key health risk indicator

E. coli is an important bacteria as it exists (in huge numbers) in the gut of humans, animals or birds, and enters the natural environment when it is excreted. If it is found in water, it is an indicator that there is faeces in the water.

If there are faeces then it is likely that there will be pathogens in the water as well.

The acceptable level of E.coli in drinking water is zero

When commissioning the tests, TTV used a 'Maximum Acceptable Level' (MAV) for Escherichia coli (E. coli) in the water of zero (<1) per 100ml.

This aligns with the draft Cook Islands Drinking Water Standard (CIDWS) prepared by Ministry of Health with input from TTV.

Of the 40 samples tested, 33 contained E.coli, and 21 of these had high or very high counts

21 of the 24 samples tested in March 2019 had high or very high counts of E.coli. The May results were better - 12 of the 16 samples tested positive for E.coli but at lower levels. Overall, the E. coli counts are extremely concerning for a drinking water supply.

All samples taken from the water intake sites tested positive for E.coli.

TTV only took samples from some of the community water stations. The results for the water station samples were variable, with 17 May samples ranging from containing no E. coli, to the highest at 77 per 100ml.

Total coliform counts are also included in the results

The Watercare Services reports include Total Coliform (TC) counts and a metals test.

Total coliform counts are useful because they provide a background trend that may indicate a change of conditions and/or an increased or reduced risk of bacterial contamination. This is an indicator of the public health risk for people consuming water from that supply.

No metals or chemical constituents in the natural water exceeded Maximum Acceptable Values (MAV).

The test results provided are verifiable

TTV used an accredited laboratory in New Zealand, Watercare Services Ltd, to test the samples. TTV took the samples and sent them to Watercare Services using a standard sampling and 'chain of custody' procedure to ensure verifiable results.

The Watercare Services test results for both March and May 2019 samples are on the following pages. Each sample location is listed under 'description' - we have highlighted this in the first page.

A list of common questions and answers follows the test results.

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clientsupport@water.co.nz

Certificate of Analysis
Laboratory Reference: 190318-145

Attention:	Ian Calhaem	*Final Report:*	**310138-0**
Client:	**POOLS IN SCHOOLZ**	*Report Issue Date:*	**20-Mar-2019**
Address:	**6 Hunterville Court, Ellerslie, 1051**	*Received Date:*	**18-Mar-2019**
Client Reference:	**Raratonga Drinking & Stream Waters**		
Purchase Order:	**Not Available**	*Quote Reference :*	**10212**

Sample Details		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**190318-145-1**	**190318-145-2**	**190318-145-3**	**190318-145-4**
Client Sample ID:		Sampled By:Henry	Sampled By:Henry	Sampled By:Henry	Sampled By:Henry
Sample Date/Time:		16/03/2019 08:30	16/03/2019 09:00	16/03/2019 09:25	16/03/2019 09:45
Description:		A-Avatiu	B-Ngatoe	C-Papua	D-Taipara
Microbiology					
Escherichia coli by MPN(Colilert-18)					
Escherichia coli	MPN/100 mL	>200	200	>200	>200
Total Coliforms	MPN/100 mL	>200	>200	>200	>200

Sample Details		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**190318-145-5**	**190318-145-6**	**190318-145-7**	**190318-145-8**
Client Sample ID:		Sampled By:Henry	Sampled By:Henry	Sampled By:Henry	Sampled By:Henry
Sample Date/Time:		16/03/2019 10:15	16/03/2019 11:00	16/03/2019 11:02	16/03/2019 11:05
Description:		E-Totokoitu	S1-Papaaroa Pre Filter	S2-Papaaroa Post Filter	S3-Papaaroa School Post Filter
Microbiology					
Escherichia coli by MPN(Colilert-18)					
Escherichia coli	MPN/100 mL	>200	>200	>200	<1.0
Total Coliforms	MPN/100 mL	>200	>200	>200	<1.0

Sample Details		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**190318-145-9**	**190318-145-10**	**190318-145-11**	**190318-145-12**
Client Sample ID:		Sampled By:Henry	Sampled By:Henry	Sampled By:Henry	Sampled By:Henry
Sample Date/Time:		16/03/2019 11:10	16/03/2019 11:15	16/03/2019 11:16	16/03/2019 12:15
Description:		S4-Avana Nui Water Station Pre Filter	S5-George Maggie Pre Filter	S6-Tapapa George Maggie Post Filter	S7-Nukutare School Pre Filter
Microbiology					
Escherichia coli by MPN(Colilert-18)					
Escherichia coli	MPN/100 mL	>200	>200	>200	>200
Total Coliforms	MPN/100 mL	>200	>200	>200	>200

Sample Details		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**190318-145-13**	**190318-145-14**	**190318-145-15**	**190318-145-16**
Client Sample ID:		Sampled By:Henry	Sampled By:Henry	Sampled By:Henry	Sampled By:Henry
Sample Date/Time:		16/03/2019 08:30	16/03/2019 09:00	16/03/2019 09:15	16/03/2019 10:00
Description:		2-Takuvaine Pre Filter	3-Tapapa Pre Filter	4-Matavera Pre Filter	5-Turangi Pre Filter
Microbiology					
Escherichia coli by MPN(Colilert-18)					
Escherichia coli	MPN/100 mL	>200	>200	>200	170
Total Coliforms	MPN/100 mL	>200	>200	>200	>200

Sample Details	WATERS	WATERS	WATERS	WATERS
Lab Sample ID:	**190318-145-17**	**190318-145-18**	**190318-145-19**	**190318-145-20**
Client Sample ID:	Sampled By:Henry	Sampled By:Henry	Sampled By:Ross	Sampled By:Ross
Sample Date/Time:	16/03/2019 10:15	16/03/2019 11:00	16/03/2019 11:30	16/03/2019 11:45
Description:	6-Avana Pre Filter	RSA Tap Reticulation	Brent B House	Aorangi Water Station Pre Filter

Microbiology					
Escherichia coli by MPN(Colilert-18)					
Escherichia coli	MPN/100 mL	>200	130	>200	24
Total Coliforms	MPN/100 mL	>200	>200	>200	>200

Sample Details		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**190318-145-21**	**190318-145-22**	**190318-145-23**	**190318-145-24**
Client Sample ID:		Sampled By:Ross	Sampled By:Ross	Sample By: Chris G	Sample By: Chris G
Sample Date/Time:		16/03/2019 11:20	16/03/2019 11:00	16/03/2019 12:45	16/03/2019 13:00
Description:		Aorangi Church Pre Filter	Rimas A (Mun)	Grey Water PR	Grey Water Poly
Microbiology					
Escherichia coli by Membrane Filtration					
Escherichia coli	cfu/100 mL	-	-	650000	640
Escherichia coli by MPN(Colilert-18)					
Escherichia coli	MPN/100 mL	>200	>200	-	-
Total Coliforms	MPN/100 mL	>200	>200	-	-

Sample Details		WATERS	WATERS
Lab Sample ID:		**190318-145-25**	**190318-145-26**
Client Sample ID:		Sample By: Chris G	Sample By: Chris G
Sample Date/Time:		16/03/2019 12:20	16/03/2019
Description:		Bottle Water PR	Tap 33
Microbiology			
Escherichia coli by MPN(Colilert-18)			
Escherichia coli	MPN/100 mL	<1.0	24
Total Coliforms	MPN/100 mL	140	200

*Results marked with * are not accredited to International Accreditation New Zealand*

Where samples have been supplied by the client they are tested as received. A dash indicates no test performed.

Reference Methods

The sample(s) referred to in this report were analysed by the following method(s)

Analyte	Method Reference	MDL	Samples	Location
Microbiology				
Escherichia coli by Membrane Filtration				
Escherichia coli	USEPA Method 1603	2 cfu/100 mL	23, 24	Auckland
Escherichia coli by MPN(Colilert-18)				
Escherichia coli	APHA (online edition) 9223 B Colilert Quantitray	1 MPN/100 mL	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 25, 26	Auckland
Total Coliforms	APHA (online edition) 9223 B Colilert Quantitray	1 MPN/100 mL	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 25, 26	Auckland

The method detection limit (MDL) listed is the limit attainable in a relatively clean matrix. If dilutions are required for analysis the detection limit may be higher. For more information please contact the Operations Manager.

Samples, with suitable preservation and stability of analytes, will be held by the laboratory for a period of two weeks after results have been reported, unless otherwise advised by the submitter.

Watercare Laboratory Services is a division of Watercare Services Limited .

ilac-MRA IANZ ACCREDITED LABORATORY

Report Signatory 20/03/2019
Qi Zhu KTP Signatory

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Certificate of Analysis
Laboratory Reference:190520-137

Attention:	Brent Manning	*Final Report:*	**319043-0**	*Replaces Report*	**319042-0**
Client:	**TO TATOU VAI**	*Report Issue Date:*	**24-May-2019**		
Address:	**PO Box 965, Cook Islands,**	*Received Date:*	**20-May-2019**		
Client Reference:	**Freshwater**				
Purchase Order:	**Not Available**	*Quote Reference :*	**10192**		

Please Note: Unable to analyse for pH & Alkalinity. No samples supplied.

Sample Details		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**190520-137-1**	**190520-137-2**	**190520-137-3**	**190520-137-4**
Client Sample ID:					
Sample Date/Time:		18/05/2019	18/05/2019	18/05/2019	18/05/2019
Description:		Avana Intake	Avana Nui Intake	Turangi Water Station	Turangi Intake
Data Provided by Client					
Time		10:00:00 AM *	10:10:00 AM *	10:16:00 AM *	10:34:00 AM *
Microbiology					
Escherichia coli by MPN(Colilert-18)					
Escherichia coli	MPN/100 mL	52	<1.0	<1.0	22
Total Coliforms	MPN/100 mL	>2400	2.0	1.0	>2400

Sample Details		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**190520-137-5**	**190520-137-6**	**190520-137-7**	**190520-137-8**
Client Sample ID:					
Sample Date/Time:		18/05/2019	18/05/2019	18/05/2019	18/05/2019
Description:		Matavera Intake	Tupapa Intake	George Maggie Water Station	Avatiu Water Station
Data Provided by Client					
Time		11:05:00 AM *	11:32:00 AM *	11:54:00 AM *	12:22:00 PM *
Microbiology					
Escherichia coli by MPN(Colilert-18)					
Escherichia coli	MPN/100 mL	38	23	77	<1.0
Total Coliforms	MPN/100 mL	>2400	>2400	>2400	15

Sample Details		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**190520-137-9**	**190520-137-10**	**190520-137-11**	**190520-137-12**
Client Sample ID:					
Sample Date/Time:		18/05/2019	18/05/2019	18/05/2019	18/05/2019
Description:		RSA	Takuvaine Intake	Papaaroa Water Station	Totokoitu Intake
Data Provided by Client					
Time		12:31:00 PM *	12:10:00 PM *	09:30:00 AM *	10:00:00 AM *
Microbiology					
Escherichia coli by MPN(Colilert-18)					
Escherichia coli	MPN/100 mL	16	490	18	83
Total Coliforms	MPN/100 mL	>2400	>2400	2400	>2400

Sample Details		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**190520-137-13**	**190520-137-14**	**190520-137-15**	**190520-137-16**
Client Sample ID:					
Sample Date/Time:		18/05/2019	18/05/2019	18/05/2019	18/05/2019
Description:		Taipara Intake	Papua Intake	Ngatoe Intake	Arorangi Water Station
Data Provided by Client					
Time		09:54:00 AM *	10:09:00 AM *	10:36:00 AM *	11:06:00 AM *

Sample Details (continued)

		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**190520-137-13**	**190520-137-14**	**190520-137-15**	**190520-137-16**
Client Sample ID:					
Sample Date/Time:		18/05/2019	18/05/2019	18/05/2019	18/05/2019
Description:		Taipara Intake	Papua Intake	Ngatoe Intake	Arorangi Water Station
Metals					
Total Metals by ICP-MS—Trace (Default Digest)					
Arsenic (Total)	mg/L	-	-	<0.0001	-
Cadmium (Total)	mg/L	-	-	<0.00005	-
Chromium (Total)	mg/L	-	-	0.0016	-
Copper (Total)	mg/L	-	-	<0.0002	-
Lead (Total)	mg/L	-	-	<0.0001	-
Nickel (Total)	mg/L	-	-	0.00026	-
Zinc (Total)	mg/L	-	-	<0.001	-
Microbiology					
Escherichia coli by MPN(Colilert-18)					
Escherichia coli	MPN/100 mL	88	120	73	5.2
Total Coliforms	MPN/100 mL	>2400	>2400	>2400	190

Sample Details

		WATERS	WATERS	WATERS	WATERS
Lab Sample ID:		**190520-137-17**	**190520-137-18**	**190520-137-19**	**190520-137-20**
Client Sample ID:					
Sample Date/Time:		18/05/2019	18/05/2019	18/05/2019	18/05/2019
Description:		Nukutere College	Takuvaine Water Station	Avatiu Intake	CLCC Sunday School
Data Provided by Client					
Time		11:40:00 AM *	11:50:00 AM *	11:26:00 AM *	12:08:00 PM *
Microbiology					
Escherichia coli by MPN(Colilert-18)					
Escherichia coli	MPN/100 mL	<1.0	23	60	9.7
Total Coliforms	MPN/100 mL	<1.0	>2400	>2400	730

*Results marked with * are not accredited to International Accreditation New Zealand*

Where samples have been supplied by the client they are tested as received. A dash indicates no test performed.

Reference Methods

The sample(s) referred to in this report were analysed by the following method(s)

Analyte	Method Reference	MDL	Samples	Location
Data Provided by Client				
Time			All	Auckland
Metals				
Total Metals by ICP-MS—Trace (Default Digest)				
Arsenic (Total)	APHA (online edition) 3125 B by ICPMS	0.00010 mg/L	15	Auckland
Cadmium (Total)	APHA (online edition) 3125 B by ICPMS	0.00005 mg/L	15	Auckland
Chromium (Total)	APHA (online edition) 3125 B by ICPMS	0.0005 mg/L	15	Auckland
Copper (Total)	APHA (online edition) 3125 B by ICPMS	0.0002 mg/L	15	Auckland
Lead (Total)	APHA (online edition) 3125 B by ICPMS	0.00010 mg/L	15	Auckland
Nickel (Total)	APHA (online edition) 3125 B by ICPMS	0.00010 mg/L	15	Auckland
Zinc (Total)	APHA (online edition) 3125 B by ICPMS	0.001 mg/L	15	Auckland
Microbiology				
Escherichia coli by MPN(Colilert-18)				
Escherichia coli	APHA (online edition) 9223 B Colilert Quantitray	1 MPN/100 mL	All	Auckland
Total Coliforms	APHA (online edition) 9223 B Colilert Quantitray	1 MPN/100 mL	All	Auckland
Preparations				
Digest for Total Metals in Liquids	APHA (online edition) 3030 E (modified, 4:1 Nitric:Hydrochloric Acid)		15	Auckland

The method detection limit (MDL) listed is the limit attainable in a relatively clean matrix. If dilutions are required for analysis the detection limit may be higher. For more information please contact the Operations Manager.

Samples, with suitable preservation and stability of analytes, will be held by the laboratory for a period of two weeks after results have been reported, unless otherwise advised by the submitter.

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Report Signatory 24/05/2019
 Marina Fisher KTP Signatory

To Tatou Vai Water Test Q&A

The following questions and answers relate to the Watercare Services test results presented on the previous pages of this document.

How did the samples get to Watercare Services in New Zealand?
TTV sent the samples by air on the same day as sampling, in the custody of a water scientist travelling back to NZ.

How did you make sure the samples weren't mixed up?
TTV staff labelled the sample bottles with the location, date and time of sampling.

What tests did Watercare do?
Watercare tested for total coliforms and Escherichia Coli (*E. Coli*) using standard test methods for an accredited Laboratory. In May, we had Watercare do some additional tests for chemicals and metals. No metals or chemical constituents in the water exceeded Maximum Acceptable Values (MAV).

What method of testing did Watercare use?

The testing method was 'Standard Colilert -18 test – enumerated count'. This method enabled Watercare to establish a Most Probable Number (MPN) per 100ml.

What pathogens did you find in your test results? For example, which specific strains of e-coli?

The tests did not identify the type or source of the *E. Coli* as that requires a separate DNA marker test.

Which intakes and other locations did you take samples from?
To Tatou Vai staff took samples from 24 randomly selected water intake and the water supply (tap) sites around Rarotonga. The sample sites included intakes, community water stations, schools and private property.

Each sample site is listed in the 'sample details' tables within the Watercare test reports, under the label 'description'. We have highlighted this on the first page of the March 2019 Watercare report.

Did all sample sites have pathogens? Were they the same pathogens?
33 of 40 samples had positive counts of *E.coli,* 21 these had high or very high counts. We only tested for total coliforms and *E.coli*; the tests did not identify the type or source.

How did water stations get contaminated?
Where results show E.coli at water stations, this means the water supply contains *E.coli*, and the water station treatment system is not removing them.

What were the weather conditions when TTV collected the samples?

The weather preceding the March sampling round was heavy rain, intermittently widespread across Rarotonga for a few days, including on the morning of the tests.

The weather for the second (May) tests was generally settled, but included some rain showers in the week before the sampling was done.

For further information, contact To Tatou Vai via www.totatouvai.gov.ck.

Appendix E: Consultation records

Discussion with Brian Mason

Friday 17 January 2020

Attendees: Chris Purchas, Sarah McCarter (T+T), Brent Manning (TTV), Brian Mason

1. Update on the current Court process - two separate issues:
    a. Court process being undertaken in relation to Rarotonga Water Ordinance.
    b. EIA process - no permit to discharge at this stage. T+T's focus is on this.
2. Court landowner participants have asked for input into Terms of Reference (ToR). TTV declined because:
    a. TOR already sent to landowners for comment & no comments received;
    b. ToR are already agreed between TTV and NES. T+T will discuss this with NES;
    c. Ultimate responsibility for EIA lies with TTV.
3. The outputs from the Independent Expert are for the Court's purposes being a proceeding filed under the Rarotonga Water Ordinance. The Tonkin & Taylor engagement is for the purposes of the Environment Act 2003 and is not part of the Court proceeding.
4. Timeframes - not likely to lodge by end of Feb. (But will have a draft done by then). With current CEO leaving early February it is important new CEO has 'ownership'.
5. Brian - need to meet landowners. Brian to arrange meeting with landowners - likely Saturday morning (18.01.2020).
6. Discussion around environmental impacts:
    a. 6 month trial - make conservative assumptions in the EIA and then monitor.
    b. Discharges in low flow vs high flow - it will be important for operational staff to have ownership of this, if this is a recommended management option.
    c. Need to make sure any recommendations can be implemented - capacity / resourcing
7. Social / cultural impacts:
    a. This is currently a gap - to discuss with NES & landowners.

Discussion with National Environment Service (NES)

Friday 17 January 2020

Attendees: Chris Purchas, Sarah McCarter (T+T), Vavia Tangatataia, Phillip Strickland (NES)

Chris ran through an overview of the process
Passive system - good in that it operates by itself, but means that at high flows (high sediment) you can't switch it off

Vavia - confusion around what this EIA. People think it's about chlorination. How to clear this up?
Philip - go on CITV to explain?
Suggest this to TTV - can we explain this better to the community?

6 month trial = commissioning period
Vavia - Te Vai Ora Maori don't think this is included but NES are of the opinion that it's covered under the existing Stage 2 permit. The Director has provided an affidavit in the Court process in this regard.
Chris not sure if the discharge of supernatant is covered by the existing EIA permit.

Will have enough information with the GHD ecological report (in process) to make a call on what the ecological impacts are
Social / cultural impacts - want to know about the impacts on fish / freshwater prawns (food)
Have the social / cultural impacts of discharges have been discussed in relation to Te Matou Vai?

Vavia - over and above the biophysical impacts, there is a concern around putting contaminants into water fullstop.
Philip - can we discharge into the land area? Chris - the water will likely end up in the stream anyway - but would filter through the land.
Explanation of treatment train is important.

Vavia went through the EIA process - submit draft EIA to NES to review, then once finalised open for public consultation for 30 days. May send out for peer review. Two months from consultation closing to decision.
Peer review – if this is required, better early rather than later. Maybe the independent expert for the Court?

Discussion with Te Tatou Vai (TTV) Operations team

Friday 17 January 2020

Attendees: Chris Purchas, Sarah McCarter (T+T), Brent Manning (first half of meeting), Ross Dillon, (MCD), Karalaini Lomaiviti, Stephen Underhill (TTV)

Chris -ran through scope of assessment
The existing EIA approval for water take + construction, but no direct approval for discharges

Ross - note this is the same for chlorination - so no discharge permit if they need to drop a reservoir or flush the reticulation network with chlorinated water.

Focus of this EIA is coagulant (disinfection outside of scope)

ICI - Brent has spoken to ICI about sludge disposal, ICI have asked for information which will be provided to them as part of this process.

Discharges - buffering ability / low flows etc.

Ross:
Water different from water in NZ
pH is ideal for using PACL instead of aluminium sulphate (7-8.2)
PACL is more ideal for good quality drinking water - probably has more advantages in this environment as it can be used over large ranges. Exceptionally clean water except during peaks.
Jar testing only at this stage (have records of this) so based on this + experience.
No control over dosage but works better in dirty water so you can dose for light loads - type of flocculant falls out really fast anyway

Retention in settling tanks is 3.5 hours
Coagulant works over 0.5 hours

When clearing out the settlement ponds - supernatant goes to the stream. If you couldn't put it in the stream, it would need to go do sludge ponds (which don't have capacity for this)
Water quality is great except it's full of bacteria. Clarity is generally good (except during high flows).
Aluminium residual of about 0.1mg/L, streams about .02mg/L

Settlement of sludge ponds - some combined and separate
Ross - preference to discharge from second pond only (supernatant pond)

Will the backwash be reasonably clean? Will likely do this 1-2 times a week (manually if not automatically)
Settling tank once a year - but this is more uncertain

At the end of the day, it will all go down to the sludge ponds (ie as the sludge in the settlement tanks will eventually go to the sludge ponds along with the supernatant)

TTV to do a jar test to see what supernatant / sludge is going to look like in the sludge ponds.

Operational constraints around high/low flow conditions

Ross - pump the discharges so they can be managed. Could use the decant system in the second pond.
pH of stream may negate the effect of the supernatant - if it was lower there would be a different scenario.
Ideally discharge in full flow but limited times when this will happen so do it at full flow or low flow.
Automated system not practical - floods are dangerous for manual valves, no sewer lines, no power

Extensive testing of supernatant etc. for the first month or so. Upstream / downstream sampling.
Logistics will be an issue - 10 plants, amount of sampling will be an issue. Can we extrapolate out?
Stream chemistry is similar across the island.

pH and volume OK
Ngatoe probably the best stream to commission on

Discharge from AVG is around $15m^3$ (sizing varies)

Discussion with Infrastructure Cook Islands (ICI)

Friday 17 January 2020

Attendees: Chris Purchas, Sarah McCarter (T+T), Brent Manning (TTV), Jaime Short (ICI)

Discussion around disposal of sludge onto landfill
The landfill is likely to reach capacity in the next couple of years but will need to be capped with aftercare provided in the medium to long term duration (10+ years) - could the sludge be used as part of the cover design?
Jaime has previously discussed this with Brent and requested additional information from TTV about the likely level of contamination in the sludge to confirm acceptability of the waste material.

{Post meeting note – Brent, can you provide the request for additional information to us please?}

Discussion with Te Ipukarea Society (TIS)

Friday 17 January 2020

Attendees: Chris Purchas, Sarah McCarter (T+T), Kelvin Passfield, Teina McKenzie, Andrea (TIS)

Chris gave overview of project / ran through testing process
6 month trial - more of a commissioning process
Likely to be some time before generating sludge that needs to be taken off-site
EIA process
ANZECC guidance to be used as an indicator of environmental impacts

Kelvin - TIS disappointed that this EIA was about the impacts of PACl, under the assumption that it will be used, and looking at any impacts that can be mitigated. TIS strongly believe the EIA should have included in the TOR that the alternatives to flocculation should have been considered.

Teina
Chemical make up of coagulants?
PACL proposed, alum is historically used
Link to Alzheimers?

Chris confirmed backwash will likely happen 1-2 days a week. Sludge removal 6-12 months

Kelvin

1. Toxicity of sludge - landfill disposal. Could it be a problem in the future? Get into groundwater etc.
2. Risk of leakage into water - will level of aluminium fluctuate? Low flows vs high flows. Chris - operational thoughts to be made.
3. Fluoride - does putting in chlorine remove fluoride from the water? Will it flocculate out the beneficial minerals?
4. Alternatives to flocculation - sediment traps, grass, natural based alternatives. Chris - EIA will summarise the thinking that's been done.

Any aluminium that stays in the water system?

Cultural / social effects?
TIS article focussed on environmental aspects
See Te Vai Ora petition. Note this included paying for water in addition to environmental aspects (a lot of people don't want to pay)
Decisions were made before community consultation - off on the wrong foot.
Existing water quality - community debate around whether this is an issue. Already have water filters / storage tanks - is this not enough?

How does this impact on plants / growers?
Downstream effects - after the chlorination process
Flooding events / droughts might be an issue. How will contamination affect animals in the stream?

Alternatives to flocculation process should be addressed

Need to talk to Te Vai Ora - have put a lot of resources / science into opposition. E.g. Andy Kirkwood / Anna Rasmussen / Imogen from ISACI
Biggest value is health - not just human health but environmental health

How much can the soil/water/humans take, what is agreeable?
No-one is arguing that there is no issue with the water - more that is it at a level that requires this level of response?

Discussion with representatives from landowners / Te Vai Ora Maori (TVOM)

Saturday 18 January 2020

Attendees: Chris Purchas, Sarah McCarter (T+T), Travis Moore, Darlene Nicholas, Ta'I Nicholas, Anna Rasmussen

The notes below show Sarah McCarter's notes with underline/edits reflect review from Anna Rasmussen / TVOM.

Darlene - landowners – Manavarao (Phillip Nicholas) is spokesperson for the landowners
Anna - Chair of TVOM - Te Vai Ora Maori, represent community, people, have Petition 1500 signatures.
Tai explained the Court proceeding
Tai Counsel for all the landowners. Travis Moore is the solicitor / Court Representative. Coordinated custom / rights of landowners

Travis gave T+T a draft Minute from Court process outlining the independent expert scope in relation to that process (is this Minute confirmed?)

Darlene – need to look at sludge over the long-term

Tai - Interested in alternatives

Travis - consistently the Crown has acted first and come to the landowners last
2015 road connections as an example.
Feel that nothing has changed e.g. weren't pre-warned of T+T's appointment.

Anna - scope of EIA? What will this EIA cover
Anna feels it's illegal to do just one process.
Pre-testing at all the intakes
Social and environmental concerns
Problem with the water is that it fills up with mud but then it clears in 3 hours
If you can divert the water when it rains, you won't take in so much mud, which questions the need for any coagulant.
Have never had any deaths or serious illness - have requested records from MoH to prove claims made by Government and others of death and serious illness, but have not had any replies proving this to be true.
Consultations were actually public presentations of what the Government were going to do - most people don't want to chlorine in the water. 98% of people at the Muri district meeting against chemicals in their water. TVOM then called a meeting with interested parties which led to the petition which contained 1500 signatures and has been presented to the Clerk of Parliament to prep for Presentation to Parliament.

Te Vai Ora Maori (TVOM) are also concerned about the geography of where the people live on the Island; around the perimeter immediately next to the lagoon, approximately only 40-50sq kilometres. Concern about any waste being held in such a small area so close to the lagoon.

Also concerned about 10 streams at the 10 Intakes being affected by waste, chemical overflow. Basically affects all of the main waterways (streams) on Rarotonga.

Chris explained scope of EIA - environmental impacts of residual / by-products. Brief overview of process.

Decant system is a manual system - Chris acknowledged information gaps for T+T: upstream/downstream water quality, decant system. Purpose of visit is to gather information, so T+T are still gathering more information which we understand is available but have yet to see.. Discharge if/when appropriate

Darlene – need to emphasise that it would be **if** appropriate
Anna - downstream effects really important - people rely on streams for joy, food so this is very important.

Chris - GHD ecologist are coming to do an assessment on Monday.
Discussion around how the EIA process will assess the impacts - make conservative assumptions
Cultural and social assessment part of this process

Travis - how will you do the EIA without proper tests? Travis can't see how you can do the EIA without the trial run.
Chris - will make assumptions to do the EIA process. This is inherent in the EIA process - consider likely/potential impacts before an activity takes place.

Sarah explained the EIA process.

Travis doesn't understand how you can complete the EIA before you finish the trial. Travis thinks it's all theory until you've done the trials
Chris - e.g. backwash process for sand filters. Travis doesn't accept this.
Backwash - will the PACL marry up with the sediment - this will include aluminium. How long will it take the scour pad to settle? Jar tests. Travis - questions about this. Consultation extremely important. People want proof e.g. tests.

Anna - government lied to us at their May 2019 Consultations/Presentations, attendees asked if the use of chemicals was a done deal. They replied no, we later found out it was a done deal, a contract to supply PACl and chlorine had been sent out before the May 2019 Consult/Presentation, therefore because they have been dishonest about their intent, they should wait and this should not be hurried. Water is currently safe. Wait for the trial and complete a full EIA.

Anna- What happens to the sludge ponds when it rains. We have very heavy tropical rain. Rain will wash sludge into streams and down hill.
Travis - trials are going ahead. TTV are doing the trials (Travis says illegally) – however, TVOM accept these trials. (Post-meeting note: TVOM do not accept these trials). Trial has some parameters - not allowed to empty settlement tanks. TVOM's main focus on backwash. Cook Islanders aren't interested in theory, they want to see practise i.e. what's coming out of the tap.

Chris - we are not looking at what the make up of the potable water is.

Darlene - also concerned about permeability of scouring ponds and what happens in landfill - look at it in the long-term.

Tai - EIA theory - raise this in the Court
Need some input from a cultural assessment - landowners are caretakers of the land, water essential to Cook Islander's being
EIA process - NES haven't prosecuted anyone for environmental issues.
Are alternatives being considered?

Chris - need to capture thinking that's been done.

Darlene - social / cultural aspects are important - taking into account the past / present / future – water being the living essence of Cooks.

Trial period / independent expert clarification (Tai)

Darlene - a bit concerned about confusion between two independent experts.
Undertaking by Crown on 10 January - will only start the EIA once the trial is finished? T+T to check this.

Anna - has the independent expert appointed by the Court had experience in indigenous issues with water?

Travis - Brian has been clear that these are two independent processes - when will the Court appointed independent expert finish his report?
Alternatives to PACL: No PACL, diversion, or something else: Moringa seeds (have seen the results of the jar test).
Manual dosing - questions about this. Be clear on minimum dose. If the water is clear / zero rubbish, does the PACL go through and enter stream or water supply undiluted? {Post-meeting note: T+T to cover this component in the EIA}
Chris reiterated the scope of the EIA. Interested in PACL turning up in the ponds and what it looks like.
Need to check independent expert appointed by the Court - he is looking at what comes out of the taps?

Flooding of sludge ponds - this is also a question.
Tukuvaine - sludge ponds have already failed (groundwater ingress).

Anna: TVOM have a video of locals talking about the effects of backwash on their stream, loss of all Koura (freshwater shrimp) and Tuna (eel), that they regularly harvest, and landowners witnessing chlorine in ponds with fully suited workers. This was the location of the issue before Christmas.

Anna - seems that a piecemeal approach is not ideal.
Holistic approach to environment.

Anna – Andy Kirkwood advises that T+T should include an assessment of viability of non-chemical alternatives to PACL (diversion), true cost of PACL operation - not just annual chemical but including supply chain, transportation and storage, processing and disposal - either sludge processing or long-term management of sludge.

This may be the role of the Independent Expert appointed by the court rather than for T+T to comment on.

Dr Kepa Morgan - Darlene would like to have the mauri framework put into this EIA process.
Dr Morgan is already involved in the wastewater project - he's been engaged by traditional leaders.

T&T have met with Ops team TTV, NES, TIS Kelvin Passfield, ICI sludge acceptance. Anna; our landfill is already overflowing.

Sarah to send notes to:
Anna: Shoot.cookislands@gmail.com
Travis: mooreea@landcourt.co.ck

Discussion with Project Management Unit (PMU)

Monday 20 January 2020

Attendees: Sarah McCarter (T+T), Ying Yang (GHD), Tangi Taoro (PMU)

Discussion with Ying to check GHD/T+T scopes and overlap.

GHD is undertaking the ecological impact assessment. GHD to interpret results and provide advice on the level of ecological impact, which will inform the T+T Environmental Impact Assessment for use of PACL.
Sarah to confirm if ecological impact assessment should be reviewed by T+T ecologist for independent confirmation of robustness of results, in light of the likely interrogation during the EIA process.

There may be overlap between the scopes in relation to recommended environmental management measures. T+T and GHD to discuss once the ecological results are available

Discussion with Ying / Tangi in relation to consultation undertaken for the Te Matou Vai project. This focusses particularly on chlorination, but would give useful context for the EIA.
Ying to arrange for the 6-monthly report (Jan-June 2019) to be sent through to Sarah.
Sarah to contact Tangi if confirmation of landowner approval is required.
Sarah to contact Kate Woodruffe (GHD) once back in Auckland to get an overview of consultation process.

The above will provide context to the breadth and nature of any assessment of social / cultural impacts.

Appendix F: Environmental mitigation/management commitments made by the proponent

Report Section reference	Impact to be addressed	Commitments
9.5.1	Ecological values	In order to confirm the anticipated levels of residential aluminium in the discharge is below the CCC and CMC values for Rarotonga (290 µg/L and 570 µg/L respectively), monitoring and reporting is proposed as follows: • Regular sampling (every week) for turbidity, DOC , hardness (electrical conductivity) and pH for the first six months. At the same time, an estimate of the stream level (or water flow) should be taken. • In addition, pH the stream at the discharge point will be tested more regularly (at least bi-weekly) as part of operational checks. • After six months, if results show Al^{3+} concentrations are stable and below the threshold, the sampling required will be decreased to once every month until 4 consecutive samples are compliant, then reduced to seasonal sampling once every 6 months for perpetuity i.e. one sample in dry season and one sample in wet season. • The proposed sampling shall be undertaken in agreed locations at each water treatment plant site as follows: – Sampling at three locations in adjacent streams: o upstream of the WTP (baseline flows). o immediately downstream of the discharge (compared to the CMC value for dissolved aluminium of 570 µg/L in the receiving water). o approximately 200 m downstream of discharge (compared to the CCC value for dissolved aluminium of 290 µg/L in the receiving water). – Sampling of supernatant / clear water outlet from settling tank, the outlet from AVG filter, and in the ponds at each WTP. This is proposed in order to understand aluminium fate through treatment, and to confirm aluminium concentration in the discharge. – In addition, specific protocols will apply to: o Sampling from the settling tank during maintenance operations: ▪ Sampling will be conducted half an hour after the mid-level drain has been opened in the following locations: (a) Upstream of the mid-level drain discharge point (this is also upstream of the discharge from the ponds).

<table>
<tr><th>Report Section reference</th><th>Impact to be addressed</th><th>Commitments</th></tr>
<tr><td></td><td></td><td>(b) Immediately downstream of the mid-level drain discharge point (also upstream of the discharge from the ponds).
(c) In the stream approximately 200m downstream of the mid-level discharge point.
▪ Sampling will be conducted every time the mid-level drain is utilized for the first year then removed with the agreement of NES.
o Testing where there is a dry stream bed:
▪ Sampling conducted once every week for six months of operation in the following locations:
(a) Immediately outside the discharge from the ponds.
▪ The dissolved aluminium results for this sample will be compared to the CMC value for dissolved aluminium of 570 µg/L.
• Different monitoring pathways can be triggered based on the results of the regular sampling. The risk of toxicity of PACl can be mitigated further by controlling the dosage and by adjusting the dilution rate to keep the aluminium below the toxicity threshold concentrations in the receiving environment (while ensuring the coagulant dosage remains effective). This provides an adaptive mitigation measure.
• A bi-annual report will be produced to provide transparency, data and outline how the mitigation measures have been adhered to.</td></tr>
<tr><td>9.6.1</td><td>Impacts of contaminants on land and groundwater</td><td>Adherence to health and safety methods and a WTP Operations Manual are proposed in order to avoid or mitigate the impacts of potential discharges of PACI to land. Key protocols include:
• Careful management and storage of PACl solution at each WTP site.
• Proactive management of sludge and supernatant levels in each of the ponds.
• Disposal of sludge removed from the scour and backwash ponds at an appropriate location.</td></tr>
<tr><td>9.9</td><td>Health and safety</td><td>To maintain health and safety the following is proposed:
• The shed containing PACI shall be secured at all times. The shed should have a warning sign identifying that it contains hazardous chemicals.
• Restrict the access of PACI to persons suitably experienced, trained and qualified to work with this chemical.
• The Safety Data Sheet provided by the manufacturer shall be keep in the shed to ensure all relevant information about PACI is easily available.</td></tr>
</table>

Report Section reference	Impact to be addressed	Commitments
		• The water treatment sites shall be secured at all times (there are fences in the photo confirmation about whether there are lockable gates).
10	Operation Environmental Management Plan	The Operational Environmental Management Plan, including the monitoring plan, is set out in Section 10 of this EIA.