WASTEWATER MANAGEMENT IN FIJI – CHALLENGES AND DIFFERENCES IN APPROACH

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ABSTRACT
Fiji is one of Australia's closest neighbours, which relies heavily on the injection of tourism to fund its economy. Being a developing country, Fiji experiences a wide variation between locations in relation to the age and condition of infrastructure. The Water Authority in Fiji (WAF) controls all water and wastewater treatment operations in Fiji. This case study focuses on a recent project completed with WAF to assess the upgrade options for four (4) wastewater treatment plants (WWTPs), highlighting the challenges faced and key differences in operational maintenance, technology familiarity and resourcing of wastewater treatment systems between Australia and Fiji.

INTRODUCTION

According to the Fiji Bureau of Statistics, the population of Fiji residents has increased by 6% over the last 10 years. However, tourist numbers have increased by approximately 50% over the same time (Fiji Bureau of Statistics, 2017, United Nations, 2019). Although this has been stunted by the current COVID-19 pandemic, with restrictions now easing, it is beginning to return towards pre-pandemic trends. The significant numbers illustrate the rapid increase in population and holiday loadings on wastewater treatment assets within Fiji. Tourism contributes approximately $1.35 Billion or 25% (World Bank Group, 2020) of Fiji's gross domestic product (GDP). Tourism increases demand on the wastewater treatment infrastructure assets, however, due to the contributions of tourism dollars to the Fiji economy is critical to growth and funding of growth within the country. Figure 1 compares Fiji's population, tourism spending and GDP from 2007 to 2019 (post 2020 was excluded due to the COVID pandemic and cessation of international tourism into Fiji). The plot shows an increase in population steadily over time of an average 0.5% per year with a similar trend seen with GDP increasing on average 3.5% per year. Toursim is slowly increasing linearly each year on average at 15% each year however sits between 20 and 25% of GDP. Due to this increase in population, tourism and loadings to WWTP in Fiji, WAF are looking to take a proactive approach to the upgrade of their existing WWTPs to cater for demand.

Wastewater treatment plants in Fiji were largely developed in the early 1970s with upgrades and expansion occurring rapidly since then. However, some of the country is still reliant upon septic tank systems. As part of this upgrade process, WAF are looking to connect more homes and villages to dedicated centralised wastewater treatment plants and decommission the septic systems to improve health and environmental outcomes. However, due to the residential nature of Fiji still being village-based and the long distances between villages, it often results in smaller treatment plants spread out across the various islands of Fiji. Areas such as Suva and Labasa are exceptions to this where populations are above 20,000 people. However a large portion of treatment plants in Fiji are designed for approx. 500 – 5,000 equivalent populations (EP), with some exceptions including Kinoya, Navakai, Natabua, Votua and Olosara. The required upgrades to cater for population growth and improved operation for four WWTPs were investigated:

- Adi Cakobau School (ACS) WWTP (550 EP)
- Pacific Harbour WWTP (2,500 EP)
- Naboro Prison WWTP (2,500 EP)
- Namara WWTP (15,000 EP)

Figure 2 outlines the location of the various WWTP investigated for this study.

METHODOLOGY

To assist in the augmentation and upgrade of the various WWTPs, WAF was looking to investigate various options to address the increase in flow and loads experienced by the various wastewater treatment plants (WWTP's) to improve environmental discharge requirements.

Subsequently through this upgrade, condition and reliability of equipment and technology will be upgraded. The following sections outline the methodology used at each stage to develop and compare upgrade options for the selection of a preferred option.

Background data review and analysis of data
Prior to the onsite assessment, existing water quality data including sampling of raw sewage and final effluent was provided monthly by WAF as well as masterplan documentation for each of the WWTPs. The masterplan documents provided long term planning of influent loadings, site layouts and previous growth and development plans. This review allowed for a cursory desktop review of the system and identification of preliminary issues to further investigate during the site inspection. Figure 3 and Figure 4 present photos from site visits at Naboro and Pacific Harbour WWTP.

Onsite assessment and identification of issues
The onsite inspection involved assessing the existing asset conditions and plant issues at the four WWTPs. The findings from the site inspection were captured in a site inspection report and are summarised as follows:

- Visual assessment of assets
- Suggested improvements to plant operation
- Assessment of odour impacts
- Identification of environmental risks
- Identification of data gaps
- Determination of training opportunities
- Main infrastructure summary

Capacity assessment
After the assessment of the asset conditions and identification of issues, capacity assessments were conducted for each of the plants using operational data provided by WAF in conjunction with information and measurements gathered during the site visits. The intention of these capacity assessments was to assess the existing treatment process to assess performance as to whether the plant is operating within designed capacity and determine if any existing equipment can be reused as part of the upgrade. This assessment of overloaded or poor condition unit processes and equipment assists in identifying potential issues associated with the existing effluent quality and comparing to the typical limits set by the Fiji Department of Environment (DoE). There are two general effluent quality limits within Fiji, which are 'General' or 'Significant Ecological Zone' dependent on location of point of discharge and use of the water body. During the capacity assessment, there was a simultaneous assessment to determine if the assets were capable of contributing to effectively achieving the required effluent quality into the future. The effluent criteria for each of these plants is outlined further in Table 1. The capacity assessment of each of the plants is critical to determine which items within the existing plants might be retained to potentially offset financial outlay by WAF for these upgrades. This is important, since as outlined earlier, whilst population is consistently increasing within Fiji, tourism money entering the country, although increasing, is not occuring at a commensurate rate for appropriate allocation to these essential services.

Development of preferred options
Following the site inspections and assessment of existing capacity of the WWTPs, a long list of options were developed in conjunction with WAF to determine potential upgrade options to address the identified issues and meet the required effluent limits. These long list of options were then reduced to 4-6 options (all site specific to each WWTP) to be further developed with preliminary engineering design undertaken and estimation of budget costs to inform the selection of the preferred option. The short listed options investigated are:

Pacific Harbour WWTP (TF plant)
1. Base Case (refurbishment of existing assets as base option)
2. Replace old TF's - Modern Trickling Filter Plant (plastic media)
3. New Intermittently Decanted Extended Aeration (IDEA) system
4. New Modified Ludzack Ettinger (MLE) process
5. Trickling Filter / Activated Sludge Hybrid

Naboro Prison WWTP (Oxidation ditch plant)
1. Base Case
2. Convert oxidation ditch to anoxic tank with new downstream bioreactor
3. New IDEA system
4. Oxidation ditch with primary clarifier and anaerobic digestion
5. Convert oxidation ditch to anoxic tank with downstream bioreactor and new clarifier

ACS WWTP (TF plant)
1. Base Case
2. Replace old TF's - Modern Trickling Filter Plant (plastic media)
3. Conversion to Lagoon Based Plant
4. Combined Trickling Filter and Activated Sludge Arrangement
5. Lagoon Plant with PETRO Process

Namara WWTP (lagoon based plant)
1. Base Case
2. Expansion of pond based system
3. Trickling Filter Plant downstream of Anaerobic Lagoons
4. New IDEA
5. Trickling Filter Plant downstream of Anaerobic Lagoons with PETRO process
6. New Biological Nutrient Removal process

Following the development of these options, a multi criteria analysis (MCA) was conducted for each of the plants to assess both cost and non cost criteria. Weightings were specific to each plant and their intricacies e.g. operational complexity, system robustness / reliability, footprint constraints, future flexibility, ability to provide the required treatment, existing issues and capacity limitations. From the MCA workshops, preferred options were selected for each of the WWTPs to be used to inform the next stage of works where concept and detailed design will occur prior to contractor engagement.

Negotiations with Department of Environment

In addition to the development of suitable design upgrades, assisting WAF with identifying issues and the required upgrades for the various WWTPs, negotiations took place with the DoE to determine appropriate effluent limits. The process for these negotiations involved the preparation of a letter on behalf of WAF to the DoE outlining:

- Current plant conditions
- Effect this has on the effluent quality produced
- Investigating the associated discharge locations and corresponding downstream ecosystems
- Presenting the upgrade options of the WWTPs
- Selecting an effluent quality target

At the conclusion of the letter, a summary table was presented outlining the various issues with the plant, short term requirements to correct the shortcomings and the proposed effluent limits for each of the plants. Due to the existing quality, age and overloading of certain plant items, it was determined that 'General' limits should be imposed on each of the plants (none of the plants currently achieve consistent effluent quality). This allows for interim upgrades to occur to meet the 'General' limits reliably, then have future upgrades to to improve the WWTPs to meet the 'Significant Ecological Zone'. The effluent quality targets typically imposed by the DoE are presented in Table 1. Following the submission, discussions, including a presentation to DoE, occurred with GHD, WAF and DoE to determine suitable effluent quality limits.

Capacity building training

In addition to the assessment and recommendation of preferred options and discussions with the DoE to assist in the development of water literacy for all (in terms of treatment understanding, increased operability knowledge and availability of skilled personnel), capacity building training was conducted with 2 of WAFs staff. The intent of this capacity building training was to develop WAF staff knowledge and capabilities such that the options implemented for each of the WWTPs could be adequately operated and maintained. In addition, the lessons learnt and understanding gained by the WAF staff increase the level of understanding and general capabilities within WAF. This allows for personnel and community empowerment within the WAF organisation and assists in building stronger resources for future planning of essential services.
This aligns with WAF's intentions to continually develop its staff's wastewater treatment process skills through uplift planning. Topics covered generally included flow and quality characterisation, monitoring, treatment process unit operations, developing flow and load projections, process modelling, sludge management, undertaking capacity assessments, process optimisation opportunities and general troubleshooting of issues.

RESULTS/OUTCOMES

Options assessment results

The following options were selected for implementation for each of the studied WWTPs:

- Pacific Harbour WWTP – MLE. Key benefits to this option include the maximisation to provide consistent treatment for discharge and minimisation of footprint (ability to fit within site)
- Naboro Prison WWTP – Convert oxidation ditch to anoxic tank with downstream bioreactor and new clarifier. Key benefits to this option include the maximisation to provide consistent treatment for discharge and maximisation of system robustness and reliability
- ACS WWTP – Pond plant with PETRO process. Key benefits to this option include maximisation of flexibility and minimisation of operational complexity
- Namara WWTP – Trickling Filter Plant downstream of Anaerobic Lagoons with PETRO process. Key benefits to this option include maximisation of flexibility and maximisation of system robustness and reliability

Of the preferred options selected and shortlisted for each plant, these processes were regarded as simpler and easier to operate without significant requirement to automate or upgrade power. This is in comparison to other modern practice treatment options available such as membrane style bioreactors and advanced process control systems commonly adopted in Australia.

Outcomes and findings

During the WWTP assessment, numerous comparisons to approach and understanding of operational difficulties and public nuisance (odours) were made around the difference in approach between Australia and Fiji. A key consideration was to develop a practical solution which could be operated by the existing staff, without significantly increasing complexity. While some automation was proposed, design did not rely heavily on SCADA systems due to cost and inherent increases in infrastructure required. In addition, process technologies or preferences that are typical in Australia may not be appropriate for Fiji for numerous reasons including availability of spare parts or suppliers and sufficiently skilled operators.
A notable difference observed was WAF's preference to use chlorination as opposed to UV disinfection. It would be reasonable to assume from a hazardous chemical perspective that WAF would prefer to use UV disinfection over chlorination. This is under the provision that UV if installed and operated correctly, has less risk of safety related issues. This is from the perspective that UV lamps

are replaced annually, and a relatively simple operation compared to constant refilling and operating chlorine dosing systems. In addition, the potential production of trihalomethane compounds presents risks to both human health and the environment. However, UV disinfection via UV reactors is not a common technology within Fiji and there is an inability to source spare parts easily and conduct the required maintenance. In addition, chlorination is a typical approach used by WAF within their potable water treatment plants.

Another difference observed in the sampling data provided by WAF was the levels of phosphorus in the influent to the WWTP. The values within the Fiji data were observed to be significantly lower than expected Australian values. It is believed the likely cause of this is the variation in amount of personal care and cleaning product uses within the counties which end up in wastewater and form part of WWTP influent. This has implications (advantageous), since future potential requirements to meet quality criteria would involve addition of less ferric or alum than would typically be dosed in Australia.

Whilst advantageous differences were observed, there were some challenges excluding the financial aspects outlined at the beginning of this paper. These include the age of the WWTP infrastructure and population increases since implementation. As a result, the plants within this study currently do not have stormwater storage, mechanical equipment redundancy or parallel treatment processes. This is partially due to their size (excluding Namara, all plants are less than 3,000 EP) and lack of automation. This creates an even greater reliance on operators' skill and knowledge to maintain the plant and produce the required effluent quality. In addition, this can create some risk due to an inability to store or bypass stormwater flows, an area which WAF are now looking to improve in their plants.

As there is no SCADA or online monitoring, there is a requirement for operators at times to work weekends to control flow through the plant and keep track of incidents and trends at a location-based level. In addition, sampling and testing currently occurs on an approximately monthly basis via grab samples (both inflow and outflow) and without any flow monitoring (influent or effluent). This makes it hard to analyse trends over time and collate information of the seasonal and influent variations on WWTP operation and performance.

CONCLUSION

Whilst some challenges and differences in approach are noted, it is important to recognise the efforts from WAF engineering and operational staff to treat the wastewater with these aging assets. In addition, WAF is committed to servicing their customers based on solid grounding with their potable water treatment and are now focusing on connecting more clients to WWTPs and removing their dependence on septic tank systems. WAF is actively trying to develop the technical skills and capabilities of their workforce, evident through the promotion of the capacity building training completed to date and investment they are making into further training of operational staff. These efforts combined with the funding of capital projects will allow them to service the population of Fiji and its tourists for better wastewater treatment and improvement of the environmental discharge quality entering nearby streams and ultimately the Pacific Ocean.

In undertaking these WWTP upgrade options assessments, numerous differences between the Australian and Fiji catchments and associated challenges were identified. WAF will require continued assistance to upgrade their infrastructure towards more modern designs to meet environmental criteria, as the region continues to develop, and tourism returns. However, it is critical that their individual circumstance is considered, and they are allowed to transition towards new technology in smaller intermediate steps. This is important from numerous aspects including ability to operate the technology, balancing capital investment and setting achievable milestones to encourage the continual improvement process WAF have begun. Each selected WWTP design involves a staged implementation approach to improve effluent quality in the interim, whilst managing capital expenditure and allowing the operation of potentially new infrastructure to be learnt, become understood by operational staff and with adequate spares storage and maintenance programs to be established.

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NOMENCLATURE

Abbreviation	Definition
ACS	Adi Cakobau School
DoE	Department of Environment
EP	Equivalent Population
FJD	Fiji Dollar
GDP	Gross Domestic Product
IDEA	Intermittently Decanted Extended Aeration
MCA	Multi-Criteria Analysis
MLE	Modified Ludzack Ettinger
PETRO	Pond Enhanced Treatment Operation
SCADA	Supervisory Control and Data Acquisition
TF	Trickling Filter
USD	United States Dollar
UV	Ultraviolet
WAF	Water Authority of Fiji
WWTP	Wastewater Treatment Plant

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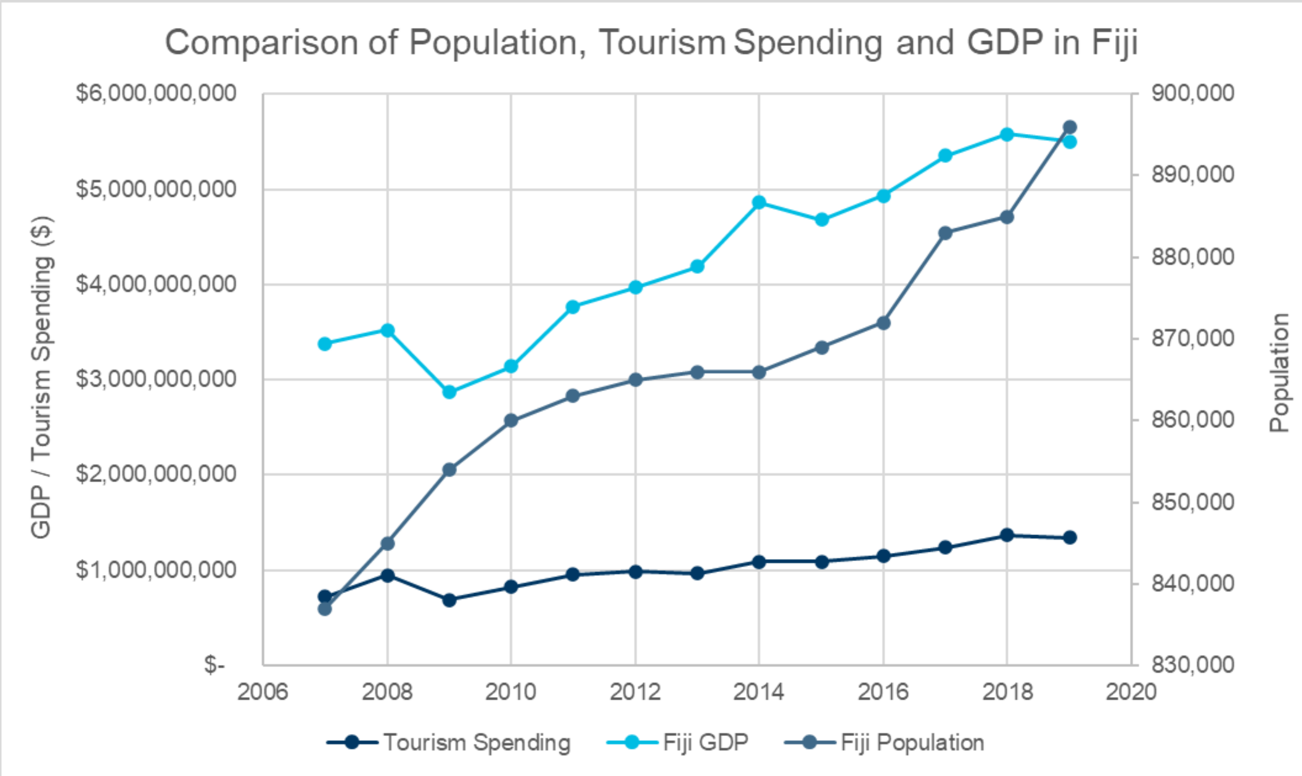

Figure 1: Comparison of Population, Tourism Spending and GDP in Fiji

Figure 2: Location of the various WWTPs investigated throughout this study

Table 1: Effluent Quality Targets (Fiji Department of Environment, 2007)

Parameter	**General**	**Significant Ecological Zone**
BOD (mg/L)	40	20
TSS (mg/L)	60	30
Faecal Coliforms (CFU/100mL)	400	200
Total Nitrogen (mg/L)	25	10
Total Phosphorous (mg/L)	5	2
Ammonia (mg/L)	10	5
pH	7-9	7-9

Figure 3: Trickling Filter and office building at Pacific Harbour WWTP

Figure 4: Oxidation ditch with surface aeration at Naboro WWTP