INVENTORY AND ASSESSMENT OF EXISTING SEWAGE TREATMENT FACILITIES AND EXCESS SLUDGE HANDLING PRACTICES IN THE FEDERATED STATES OF MICRONESIA

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ABSTRACT

A survey of wastewater treatment facilities in the Federated States of Micronesia revealed a lack of fully functional treatment systems and conditions that potentially could lead to adverse environmental impacts and public health concerns. Due to inadequate facilities and equipment, the amount and composition of wastewater entering the plants as well as the degree of treatment being achieved is largely unknown. In some cases it appears raw sewage is being discharged directly into the ocean and excess sludge is regularly taken by local residents for agricultural purposes without adequate treatment. In addition, the need to establish best management practices for placement and maintenance of septic tanks is being sought after with a sense of urgency. Furthermore, treatment of wastewater from industrial and agricultural sources merits further attention in an effort to achieve ecofriendly solutions to current pollution problems. Comparisons of methods being used and problems encountered at different locations in the islands would provide valuable information to aid in the development of sustainable treatment practices throughout the region.

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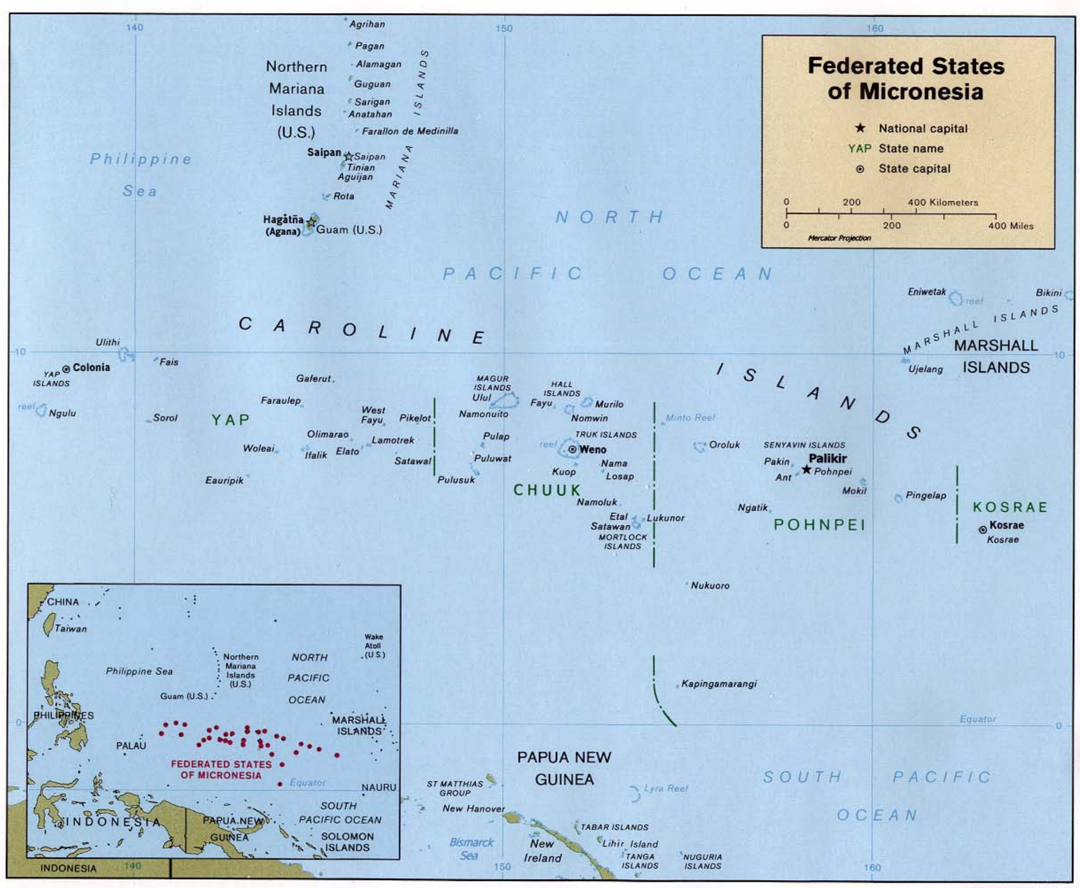
INTRODUCTION

Vast distances separating the dispersed populations of island countries in the Pacific Ocean have traditionally hindered their development due to the high cost for providing services, including the basic infrastructure required to address sanitation issues. The Federated States of Micronesia (FSM) alone consists of 607 islands scattered over more than one million square miles (three million square kilometers) of ocean [1]. In addition to the geographical distances, cultural and linguistic heterogeneities among the island communities of the FSM, while serving as a hallmark of national identity, also potentially add to isolation effects. Located in the Caroline archipelago of the western Pacific (Figure 1), the islands of the FSM are grouped into the four geopolitical states of (from east to west) Kosrae, Pohnpei, Chuuk, and Yap. The nation's capital is located in Palikir on the island of Pohnpei.

Figure 1. The Federated States of Micronesia located in the Caroline Islands of the western Pacific. Image source: Micronesia: http://www.federatedstatesofmicronesia.org/ (link: Micronesia Maps).



Effective management of wastewater treatment plays a crucial role in protecting the health of people and safeguarding the fragile environments of the Pacific islands [2]. The existing treatment facilities in the FSM, though, are not adequately inventoried and the limited information that is available is largely esoteric in nature, thus making it difficult to evaluate their effectiveness. Accordingly, a knowledge base is needed to allow for comparisons of methods being used at different locations with the goal of building upon success and, where applicable, avoiding the duplication of mistakes. The objective of this study is to compile an inventory of the wastewater related infrastructure in the FSM that would be of use in identifying where potential weaknesses exist and prioritizing for future water-sector projects. This objective is met by conducting field surveys to document the existing wastewater treatment systems in the population centers of Kosrae, Pohnpei, Chuuk, and Yap. Items to be inventoried include the types of unit processes being used, degree of treatment being targeted, design capacities, degrees of treatment being achieved (removal efficiency, regulatory compliance), and locations where treated effluents are being discharged. Of equal concern is the handling of excess sludge generated at wastewater treatment plants, including the methods being used for treatment and disposal of waste sludge, or reuse of biosolids, as the case may be. In addition, characterization of industrial wastewater sources is also a critical issue worthy of inquiry.

METHODOLOGY

The methods employed over the course of this project involved civil and environmental engineering fieldwork. Prior to commencing fieldwork, points of contact were established in each state to explain the purpose of the investigation to local authorities. Preliminary inquiries were then conducted to gather as much relevant information as possible by correspondence prior to commencing with site visits.

Site visits started with meeting pertinent local officials on utility boards and other government agencies to review previously received preliminary information and gather additional information concerning locations and specific details of local facilities. Subsequently, visits were conducted to all known treatment facilities to document all pertinent factors and take photographs.

A concerted effort was made to glean a complete overview of the regional wastewater treatment and related sludge disposal practices including plans for future work from interviews with local officials and discussions with plant operators. Prior to leaving a particular area, every effort was made to synthesize the findings and see if any outstanding questions remained to be answered.

FINDINGS OF FIELDWORK

Kosrae

In Kosrae State water and wastewater related matters are managed under the Department of Transportation and Infrastructure; it is tentatively planned, though, that a Kosrae Utilities Authority (KUA) will be formed in the near future to focus solely on water and wastewater related issues. There is one centralized wastewater treatment system on the island of Kosrae constructed in 1983 called the Tofol oxidation pond, which is a system of three ponds functioning in series (Figure 2). Each pond has a footprint of approximately 150 ft by 50 ft; and with an assumed depth of 4 ft, this gives a total volume for the system of 90,000 ft^3 (700,000 gal). Input to the system is from a sewer line servicing the nearby hospital, community college, and high school. The average inflow is estimated to be less than 1,000 gal/day and the effluent (or treated outflow) discharges to the nearby Tofol River. By these numbers, the hydraulic retention time (HRT) would be some 700 days, or nearly 2 years; thus, even if this estimation is significantly off, the system does appear to have a luxuriously long HRT. Thus, it appears the hydraulics of the system would be largely controlled by rainfall, evaporation, and infiltration, rather than wastewater flow. In addition, about twice a month a 1,000-gal pump truck delivers sludge drawn from septic tanks to the first pond, which could constitute a significant contribution to the organic loading, but not the HRT. Water quality analyses are not being conducted, though the system does appear to be working well with evidence of fish flourishing in all three ponds; however, recently there had been some clogging in the 8-in (diameter) line between the first two ponds resulting in a brief overflow. As a natural, “built-in” safety factor, the pond system is buffered by a coastal mangrove bordering the site that would offer some assimilative capacity in the event of system failure.

Around 15 years ago, by government directive 1,165 septic tanks were installed on Kosrae, which brought the total coverage for wastewater treatment services in the state to 94% (Table 1). Included in this total are an additional undocumented number of previously existing septic tanks. For a standard single-family unit, a new septic tank consists of a large first holding tank (600 gal) connected to a smaller second tank (300 gal), from which the effluent overflows into a leaching pit (400 gal) containing a gravel bed (for a double-family unit, the volumes are 1,000, 450, and 600 gal, respectively). It is said that in some cases leaching fields were installed rather than the standard leaching pit, but this could not be confirmed. Furthermore, in the densely populated Lelu Village – a residential bed-town – there is insufficient space for use of either leaching fields or pits, thus the basic design for septic tanks consists of only the first two compartments (i.e., no leaching pit), from which the effluent discharges to a sewer collection network servicing the whole islet village. This entire effluent flow is then directed to a concrete collection pit with an estimated capacity of 1,500 gal, which discharges by gravity flow through a half-mile long outfall line into the ocean.

Figure 2. Wastewater treatment system in Kosrae consisting of three oxidation ponds. The Tofol River and coastal mangrove can be seen bordering the facility. Image source: Kosrae Island Resource Management Authority.

Table 1. Numbers of septic tanks installed on Kosrae by government directive.
Source: Department of Transportation and Infrastructure, Kosrae State.

Village	Number of septic tanks installed	Reported date of installation
Lelu	350	1994
Tafunsak	340	1997
Utwa	200	1998
Malem	275	1999
Totals * :	1,165	---

Apparently, installation of septic tanks has not been governed by any specific design standards for setbacks or density (i.e., number of tanks per unit area). Typically, they have been constructed on a per-family basis and have included an adjoining “out-house” consisting of a partially enclosed concrete structure with shower, sink, and toilet (Figure 3). Maintenance of these septic tanks is the responsibility of the families that use them and the vast majority have not be serviced for removal of excess sludge during the 15 or more years since their installation. Nonetheless, the septic-tank culture does appear to be well functioning. However, septic tanks only provide a primary level of treatment, i.e., effluent is essentially raw sewage minus the solid materials that have settled out in the tank, thus the impact of discharges on receiving water bodies (both the ocean and groundwater) would be a point of concern.

A solid-waste landfill (Fukuoka type—a semi-aerobic landfill technology) was installed on Kosrae in 2010, which includes a leachate collection system. While the landfill, per se, would not be a part of this study, the leachate generated at the landfill would be of concern as an industrial wastewater. The leachate flow is mostly a function of the amount of rainfall over the exposed landfill and is collected in a catch pond with an impervious lining (see Figure 4). Out-flow from the pond passes through a gravel-sand bed and is discharged into the coastal mangrove. The leachate is tested for chemical oxidation demand (COD – an aggregate indicator of organic compounds) and pH on a monthly basis with each testing event consisting of multiple measurements taken directly from the leachate and nearby environmental samples. Test results have consistently been below the regulatory limits of 100 mg COD/l and pH of 10, which can be attributed to diligent segregation of waste materials prior to deposition. In the event of an effluent quality violation, the public must be alerted to avoid the discharge area. If discharge quality does become an issue in the future, some form of engineered treatment process would have to be considered.

Figure 3. Typical outhouse with adjoining septic tank in Lelu Village, Kosrae. Image source: author.

Figure 4. Lined leachate catch pond at the landfill on Kosrae. Image source: author.

Pohnpei

In Pohnpei State water and wastewater related matters are managed by the Pohnpei Utilities Corporation (PUC). In Kolonia Village, the main business center on the island of Pohnpei, there is a municipal wastewater treatment plant consisting of a contact-stabilization type activated-sludge process, which is apparently about 60 years old (Figure 5). The plant was designed for 700 house-hold connections, but is thought to be serving 2 to 3 times that amount now. However, data analyses for wastewater have not been conducted for over 10 years, thus the actual flow rate and treatment efficiency are not known. While the existing plant does appear to be functioning properly, by visual inspection the activated sludge in the aeration basin appears to be much too thin, which could be due to the hydraulic overload on the system in its current state. A new plant, though, of the same type with the same approximate capacity was under construction at the time the field work of this study was being conducted (July 2012). Upon completion, the new contact-stabilization unit will run in parallel with the old unit and should effectively double the current treatment capacity of the system. The outfall line discharges effluent into the adjoining crowded bay approximately 1,000 ft from the shore; however, there is a plan in effect to install a new outfall in the near future that would be about twice as long. From the site of the existing plant, though, construction of an outfall capable of discharging beyond the mouth of the bay into the open sea would not be practicable.

Figure 5. Contact-stabilization type activated-sludge wastewater treatment plant on Pohnpei. Image source: author.

Influent to the wastewater treatment plant reportedly does not include industrial wastewater, though it does have input from restaurants and kitchens and thus would include some fats, oils, and grease (FOG). However, there is a tuna packaging plant in the industrial zone near the airport with its own wastewater treatment plant that is currently inoperative (Figure 6). Ownership of that treatment plant is said to have been transferred to PUC about a decade ago, though the tuna packaging plant is still in operation and, apparently, discharging untreated industrial wastewater directly to the bay. Though not actively investigated in this study, it is known that there are a lot of piggeries on Pohnpei, from which runoff of swine waste into the bay (or elsewhere) is considered to be a significant problem. While there are said to be a couple of digesters for larger operations, the vast majority of this waste discharge appears to be going untreated.

Additionally, there is a solid waste dump near the airport, concerning which there has been some discussion about the need to construct a proper landfill with leachate collection and the ability to generate energy from waste. Furthermore, the existing municipal wastewater treatment plant, discussed above, yields 500 to 600 gal of excess sludge per month, which is applied to a drying bed near the airport. After drying, the sludge is supposed to be transferred to the dump, though apparently it is always taken directly from the bed by local residents and used for agricultural purposes.

Figure 6. Inoperative industrial wastewater treatment plant of tuna packaging plant on Pohnpei. Image source: author.

Septic tanks on Pohnpei are typically constructed with an adjoining seepage pit rather than a leaching field and it is said that drawing excess sludge from the tanks is almost nonexistent – only one tank is serviced every 2 or 3 years – even though PUC does have a 1,000-gal pump truck for that purpose. The capital area in Pilikir Village is served by a very large septic tank (ca. 120,000 gal) with a footprint of approximately 20 ft by 40 ft and a leaching field said to extend about 100 yards. This facility appears to be intended for use by the government complex, though a lift-station has been installed to tie in nearby residences.

Chuuk

In Chuuk State water and wastewater related matters are managed by the Chuuk Public Utilities Corporation (CPUC). On the island of Weno (traditionally named Moen, the main population center located in the Chuuk Islands cluster, see Figure 1) there is a contact-stabilization type activated-sludge wastewater treatment plant located near the airport. The plant appears to be of the same construction as the one on Pohnpei and is about 40 years old (commissioned in 1973); however, it has only been operated intermittently over the years and is currently shut down (Figure 7). Untreated sewage thus bypasses the plant and is being discharged in the Chuuk lagoon, a world famous diving site. The amount being discharged, though, may not be very great because much of the sewer collection network has been out of operation due to grinder-pump stations and lift stations being out of service, and currently under repair. CPUC is actively making progress towards getting the network back on line in preparation for the anticipated refurbishing of the old treatment plant. The Weno sewer collection system is the most extensive network in the FSM, covering the full extents of the northern and western shores of Weno Island.

There are apparently no industrial wastewater sources on Weno that would contribute to the soon to be refurbished treatment plant other than FOG from restaurants and possibly discharges from laundry mats and automotive shops. However, there are various farming activities, including household pigpens, which could constitute sources for agricultural wastewater that would require some form of treatment if environmental discharges become an issue.

For solid waste disposal, there is only a waste dump on Weno, without leachate collection. Additionally, CPUC is called to draw excess sludge from septic tanks only about once every three months; though they are currently making an effort to teach proper operation and maintenance of septic tanks and grease traps to local residents and businesses on the island.

Figure 7. Inoperative sewage treatment plant on Weno Island in Chuuk state. Image source: author.

Yap

In Yap State water and wastewater related matters are managed by the Yap State Public Service Corporation (YSPSC). In Colonia, the main business center on the island of Yap, the municipal wastewater treatment plant consists of an Imhoff tank system, with duel units operating in parallel, which is about 40 years old (commissioned around 1974, see Figure 8). While Imhoff tanks are relatively easy to operate and have very low energy requirements due to the absence of aeration and internal recycle, they provide only a primary level of treatment consisting of a limited removal of suspended solids. Data analyses of influent and effluent are not being performed, thus treatment efficiency is not known; furthermore, the amount of intermittent flow entering the plant on a daily basis is not known, making it difficult to estimate loading rates. In addition, the outfall line from the plant is known to be broken and is discharging the partially treated effluent into a shallow part of the bay about 500 ft from shore. (Note: At the time of this study, a detailed study was being conducted (by a different party) under contract, which should address these concerns, suggesting potential solutions.)

There are no known industrial wastewater sources on Yap Island now; however, there are some activities at the petroleum refinery in Colonia that could be of concern. In addition, there are some relatively small fish-cleaning operations and possibly FOG discharges from older establishments (including restaurants) that are not equipped with grease traps, all of which could be contributing to the treatment demand of the Imhoff tank system. Furthermore, various farming activities, including household pigpens, could constitute sources for agricultural industrial wastewater that would require some form of treatment if environmental discharges become an issue.

For solid waste disposal, there is only a waste dump on Yap, which does not employ leachate collection; though a new landfill is under construction (at the time of this report), which will include a leachate collection system as employed on Kosrae. The landfill leachate will constitute an industrial wastewater, which would require monitoring and treatment if discharge standards are not met.

At the municipal wastewater treatment plant (the Imoff tank system, discussed above) an unknown amount of excess sludge is periodically drawn from the tanks and applied to a drying bed. After drying, the sludge is supposed to be transferred to the dump, though apparently it is always taken by local residents or businesses and used for agricultural purposes.

Yap State has a relatively new 1,000-gal pump truck that is used to draw excess sludge from septic tanks about once per month, the contents of which are delivered to the treatment plant. YSPSC and regulatory officials are actively working on evaluating and upgrading various services, including efficiency of wastewater treatment and installation and governance of septic tanks.

Figure 8. Imoff tank wastewater treatment plant in Colonia Village on Yap. Image source: author.

DISCUSSION AND CONCLUSIONS

The distribution of wastewater treatment services across the four states of the FSM is summarized in Table 2. As shown, Kosrae has nearly complete coverage due to the extensive initiative to install septic tanks over a period of a few years from approximately 1994 to 1999. This apparent advantage over the other states, though, is influenced by the population and business activities in Kosrae being confined to only one island and thus not having inhabitants on outer islands, which would be largely accounted for under the "not covered" category. However, considering that septic tanks provide only a primary level of treatment, further treatment of the collected effluent from tanks in Lelu Village prior to discharge in the bay would be worth pursuing. In addition, investigating the means of extending the sewer collection line in Tofol Village to take advantage of the greatly under-loaded oxidation pond system would be a valuable avenue of inquiry.

In Chuuk State, the relatively low coverage for sewer connections (9%) may increase soon due to ongoing repairs of the sewer collection network and the pending restoration of the central treatment plant on Weno Island. However, given the difficulties experienced in trying to maintaining operation of the activated-sludge based wastewater treatment plant and the numerous grinder and lift stations in the collection network, installation of a few strategically located pre-fabricated package treatment plants might prove to be a more effective pursuit. Relying mostly on attached-growth, or biofilm technology, package plants offer a secondary (or greater) level of treatment in compliance with most regulatory standards with relatively low operation and maintenance requirements. Furthermore, with package plants, flexibility in scale would be possible by adding on capacity with modular units on an as-needed basis. This approach could be applicable on other islands too, though feasibilities studies would be needed on a case-by-case basis.

Table 2. Wastewater treatment services in the four states of the FSM. Source: Office of Statistics, Budget and Economic Management, Overseas Development Assistance, and Compact Management (SBOC), FSM (2010).

State:	KOSRAE	POHNPEI	CHUUK	YAP
Households *	1,143	6,289	7,024	2,311
Sewer connections	4%	17%	9%	12%
Septic tanks	94%	35%	31%	31%
Not covered or unknown	2%	48%	60%	57%

* One household represents approximately 6 persons.

On the island of Yap, it would be beneficial to find a cost-effective means of upgrading the well-functioning Imoff tank system so as to provide a more advanced level of treatment. One positive feature of the existing system, though, is that no energy input is required to operate the plant (following the last lift-station in the collection network and potentially the chlorination unit if it were to be used). However, to achieve a secondary level of treatment, aeration of the tank would be necessary to enhance biological activity, which would constitute a significant energy requirement and thus operational cost factor. Furthermore, for traditional biological treatment, pumping is required to retain and circulate the biomass (activated sludge) in the system, which would be yet an additional energy requirement. However, another method to harness biological treatment power that requires less energy input would be to use an attached-growth process. With this method, effective biomass is retained in the unit process on a biocarrier support material, eliminating the need for internal pumping [3,4]. As a relatively simple retrofit, a frame with the attachment medium, or fabric, could be fitted to the existing tank. As a point of inquiry, though, some testing would be necessary to see what level of aeration (if any) would be required to achieve adequate results. Fortuitously, the existing Imhoff tank system consists of two parallel units, which would allow for retrofitting only one unit and making a comparison of results with the unaltered unit. However, as an unavoidable tradeoff for improved effluent quality, some increase in waste sludge production would occur; there are, though, some beneficial uses of waste sludge worth considering (see below).

A repeatedly encountered question during discussions with local regulators and operators addressed a need to define the required treatment levels for sewage sludge so that it can be considered safe for use as a biosolids product. Currently, at locations where settled sludge is collected and put on a drying bed, it is quickly whisked away and used for agricultural purposes despite the lack of adequate treatment, thus stressing the need for regulatory supervision. Though not binding in the FSM, the US EPA offers widely accepted definitions for different classes of biosolids that could serve as a guideline [5]. Exceptional quality (i.e., Class A) biosolids, which have no crop harvesting restrictions, consist of treated residuals that contain no detectible levels of pathogens and low levels of heavy metals. Technologies that can meet Class A standards must process the biosolids for a sufficient length of time at a temperature high enough to yield a product in keeping with the required pathogen cut. Composting is one such method, which can offer an environmentally friendly option to recycle the nutrients and organic matter found in municipal wastewater solids [6].A recent pilot project on the island of Guam demonstrated the feasibility of composting manure mixed with other organic materials, which when used as a soil amendment resulted in enhanced agricultural productivity as compared to use of synthetic fertilizers; furthermore, use of the compost helped correct various unfavorable soil properties commonly found on tropical Pacific islands [7].

In addition, the technologies involved in deriving energy from waste sludge (and solid waste in general) are becoming more and more practicable for small scale applications. For remotely located island communities, in particular, where petroleum based fuels are so costly, the impetus clearly exists for making progress toward energy independence, in addition to protecting the environment. While this approach might not be fully feasible at this time, before long a study on this topic would be in order.

Apart from the inoperative treatment plant at the tuna packing plant on Pohnpei, there do not appear to be any pressing issues concerning industrial wastewater treatment. With improvements to local economies, though, the (re)emergence of tuna packing and other industries on the islands may occur, along with the wastewater they yield, which will have to be followed closely. In addition, swine farming operations are known to be a source of agricultural industrial pollution on Pohnpei and, to a lesser degree, on the other islands as well. Apart from a few larger operations, much of the problem consists of runoff from pigpens at the household level, thus collection and transport of the waste to a central treatment facility would not be practicable. In this case, as a low-cost, ecofriendly solution, the use of vetiver grass merits consideration. This robust, yet noninvasive, grass can be strategically planted to intercept wastewater runoff and serve as a natural treatment system and a protective buffer [8], and has specifically demonstrated effectiveness for treatment of piggery waste in a pond application [9]. Furthermore, vetiver grass has been evaluated for use in watershed management in southern Guam [10].

Wastewater treatment requirements vary for different communities throughout the FSM; however, some underlying similarities among these tropical islands do exist. Accordingly, comparisons of methods being used and the results obtained at different locations will be of value for planning purposes. Such information is needed to assist in decision making for future improvements with a goal of developing sustainable wastewater treatment infrastructures in Micronesia and throughout the communities of the western Pacific.

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APPENDIX

Supplemental Photographs

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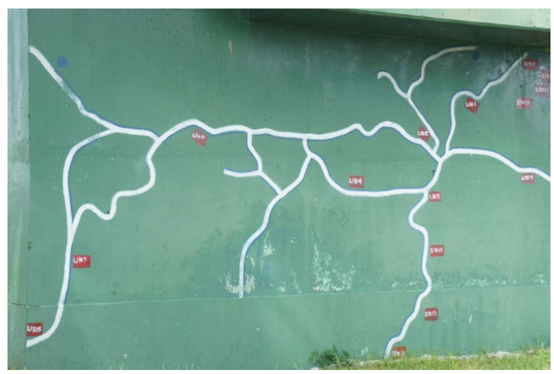

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