Consolidated Final Project Report

Recipient: AMERICAN SAMOA POWER AUTHORITY
Project Title: "Improving Water Use Data in American Samoa FY2020"
Project Period: 09/30/2020 through 08/31/2024
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Project Summary
This work aims to address critical water use data gaps identified in the 2018 American Samoa Water Use Workplan. To address these gaps we focus on three distinct components: (1) developing an IT infrastructure to manage and share municipal water use data, (2) assessing and documenting traditional Samoan village water systems, and (3) improving water metering infrastructure at the American Samoa Power Authority (ASPA).

In the first component, the project established a data pipeline to consolidate, format, and publicly share water use data according to Water Data Exchange (WaDE) 2.0 standards. The pipeline automates ingestion and processing of data from ASPA departments while ensuring compliance with privacy standards. This system enables automation of both groundwater production and village-level aggregate water usage reporting, making the data accessible through a public API to support water management and conservation outreach efforts.
The second component involved surveying Samoan village leaders across the main island of Tutuila to assess the operational status and current use of surface-water through traditional village water systems. We documented and mapped water usage in 44 villages, and found 27 that still have community members that use these systems. We also analyzed watershed characteristics, streamflow, and future climate projections in each of the villages to understand water availability and potential vulnerabilities now and into the future.
In the third component, the focus was on improving ASPA's water metering infrastructure to reduce non-revenue water (NRW) losses, which account for up to 64% of total water production. New metering technologies were implemented, and the development of a hydraulic model was initiated to better manage and reduce water loss across the island's water system.

Looking ahead, addressing the unmetered use of surface water for village water, irrigation, and aquaculture would be helpful for completing the picture of water use in American Samoa. With surface water plants currently offline, there is a growing interest in reintroducing surface water as a resource, reversing the previous shift towards groundwater. As these plants come online, integrating their flows into the existing data framework will be important. Additionally, the data collected through this project offers a strong foundation for enhancing water conservation efforts. Although public outreach was not within the project's scope, initiating a comprehensive water conservation program could significantly benefit the community. Simple strategies, such as promoting low-flow fixtures and repairing leaks, could be highly effective in reducing domestic water usage and addressing the island's water availability challenges.

PURPOSE AND OBJECTIVES

Background and Introduction

The American Samoa (***Figure 1***) Water Use Workplan, originally developed in 2018 by the American Samoa Power Authority (ASPA), inventoried approximately a dozen water use data gaps which iif filled would increase the availability and quality of territorial water use data as defined by the Water Use Data and Research (WUDR) program's tiered data standards. Of these identified gaps, three overlap with serious territorial water sustainability and security concerns. In terms of the WUDR framework tier levels, the most important water use data gap needing to be addressed is the lack of a territorial water use database for collection, quality assurance and/or quality control (QA/QC), and transmission of water use data to a publicly available archive. In reference to the WUDR standards, this aspect of data availability was at or below a tier 1 level. A secondary need identified is to bring data availability in the "Self-Supplied Domestic" water use category up to a tier 2 level by developing a better understanding of withdrawals from small surface water delivery systems, termed village water systems. These systems are used by some residents in American Samoa, but there exists almost no documentation regarding their capacity, volumes of use, or locations. An identified third data gap, need to improve assessment of non-revenue water (NRW) losses from the municipal water delivery system, through additional study and in- line metering, if addressed would contribute to bringing the "public supply" water use data availability category to a tier 3 level.

Therefore the project was organized into primary objectives relating to three components:

Component 1: Developing infrastructure to manage and share water use data

Component 2: Assessing and documenting village water systems

Component 3: Improving water metering infrastructure at ASPA

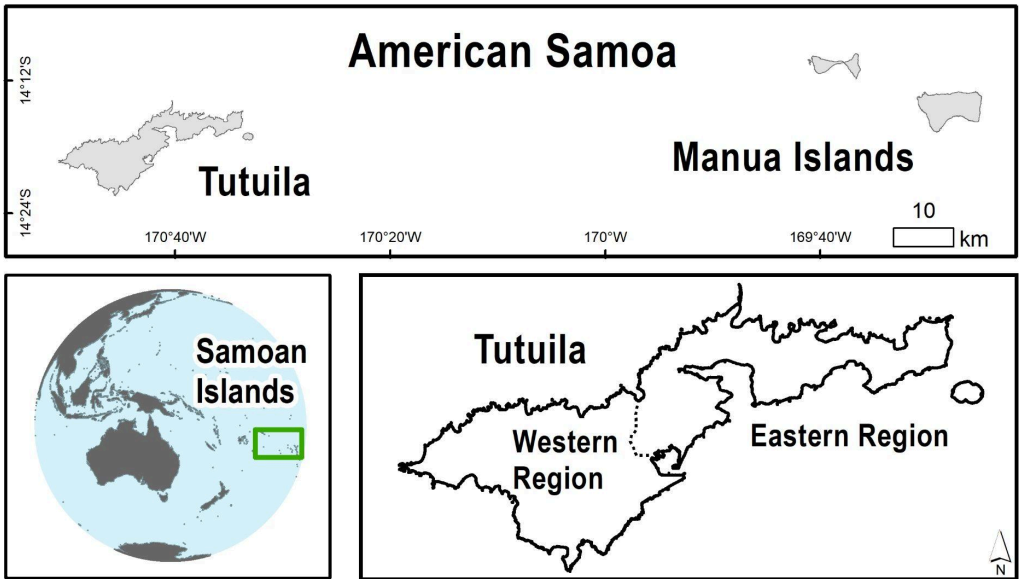

Figure 1: Map of American Samoa, showing Tutuila, and the Manua Island group which consist of the islands of Ofu-Olosega and Tau. Due to limited perennial streams and no information regarding village water use in the Manua Islands, this study focuses exclusively on Tutuila, American Samoa's political and population center.

Background - Component 1: Infrastructure for Water Use Data

American Samoa Power Authority (ASPA) Municipal Water System Data

In American Samoa, the municipal water production and delivery services are managed by ASPA, the island's utility provider for water and power. Approximately all of the island's public water supply is sourced from groundwater, drawn from wells with pumping capacities ranging from 15 to 400 gallons per minute (GPM). Tutuila has 45 active municipal wells, Aunuu has 1, Tau has 3, and Ofu-Olosega has 2 (2018 data). After extraction, groundwater is pumped into a water delivery system that, on Tutuila, comprises roughly 600 km (375 miles) of pipeline, 19 booster stations, 800-900 valves, and 41 water storage tanks (***Figure 2***). The main water system is interconnected along Tutuila's south shore, with eight separate satellite systems serving communities on the north shore or on other islands such as Ofu, Olosega, and Tau. The water delivery network includes about 240 km (150 miles) of main lines, ranging from 24 inches to 2 inches in diameter, predominantly made of PVC pipe, with some older asbestos-concrete pipes still in use. Additionally, there are approximately 360 km (225 miles) of service lines, primarily 1-inch polyethylene (PE) pipes, connecting the main lines to customer meters.

As of April 2018, the ASPA system included 51 active, 8 standby, and 9 drilled but not yet connected production wells, with 6 of these wells located in the Manu'a Islands. By August 2024, there are now 56 production wells reporting data in ASPA's water meter and flow database. Groundwater pumping rates are measured by ASPA at each well on at least a monthly basis, with continuous measurements taken at wells equipped with electromagnetic MagFlux flow meters (MJK Inc.). Currently, the highest time resolution for data collection across all wells is on a monthly basis.

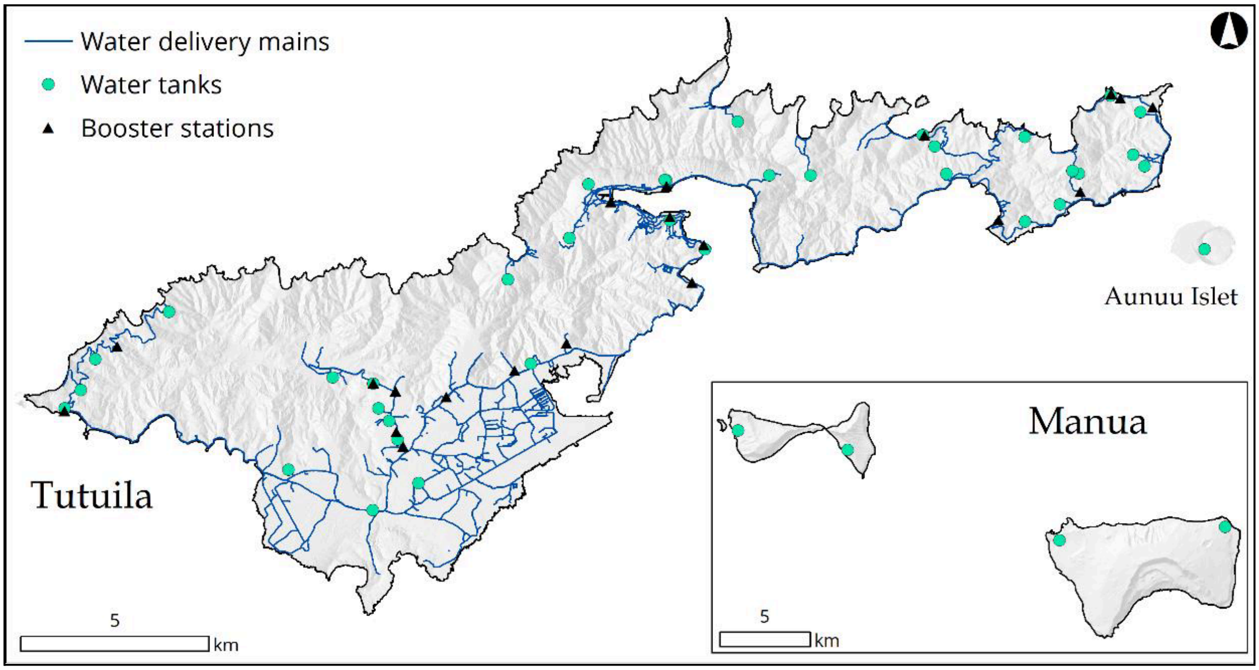

Figure 2: Map of ASPA municipal water system features including water transmission main lines (service lines not shown), water storage tanks, and booster pump stations. Note that booster and water line data for Manua Islands was not available from ASPA.

Status of Water Use Data in American Samoa

The existing monitoring and database infrastructure at ASPA has the capacity to generate water production and distribution data, but there is limited perceived value in the tasks of consolidating, storing, and formatting this data in a manner consistent with WUDR standards. This project bridges that gap by ingesting the existing data, formatting it, and making it publicly accessible through a simple Application Programming Interface (API).

The customer service department at ASPA monitors water use through approximately 11,000 individual water meters installed on service lines that supply water to residences and commercial businesses on Tutuila and the Manu'a Islands. Currently, most of these meters are mechanical totalizing magnetic drive meters (***Figure 3a***), which require manual reading. ASPA is in the process of transitioning to digital electromagnetic meters, such as the Sensus iPERL meter (***Figure 3b***), which offer wireless downloading and communication capabilities. Water meter data is collected by a meter reading crew within ASPA's customer service department. The crew services various parts of the island each day to manually or electronically read each meter (***Figure 4***). The data is stored using Itron FC300 Handheld Computers and uploaded to a database within the Daffron platform via MV-RS software, which is designed for data collection and meter route management. Monthly water usage data can be accessed by querying the Daffron database, which organizes the data by individual meter number, date (at a monthly resolution based on a rotating schedule), and customer type, such as residential, small business, large business, and industrial.

The ASPA customer service department can generate monthly reports that detail individual water usage or aggregate data for sub-groups like residential users, government entities, the community college, commercial users, and industrial users. Notably, the island's only operational tuna cannery, which has a dedicated water supply line and is the largest single water user, is closely monitored through both billing meter records and in-line flow meters on upstream water mains.

For this project, we developed an operationalized data pipeline to ingest monthly water meter data provided to ASPA's water engineering department by ASPA’s customer service department. The engineering department uploads the monthly report to a private GitHub repository, and our code queries the repository every two weeks and executes the data processing script, thereby ensuring the monthly resolution data is updated on our API in a timely manner. This private GitHub repository is used to protect sensitive data within the customer service reports. Our open-source code for processing the data is public and is located in a separate repository. Additionally, we developed an interactive GIS-based dashboard to display the village-aggregated water use data for outreach purposes and to support public water conservation campaigns. All links are given below.

Figure 3: Water meters currently used by ASPA showing (a) (left) older type mechanical totalizing magnetic drive meters that must be read manually, and b) (right) digital electromagnetic meter with wireless data transmission.

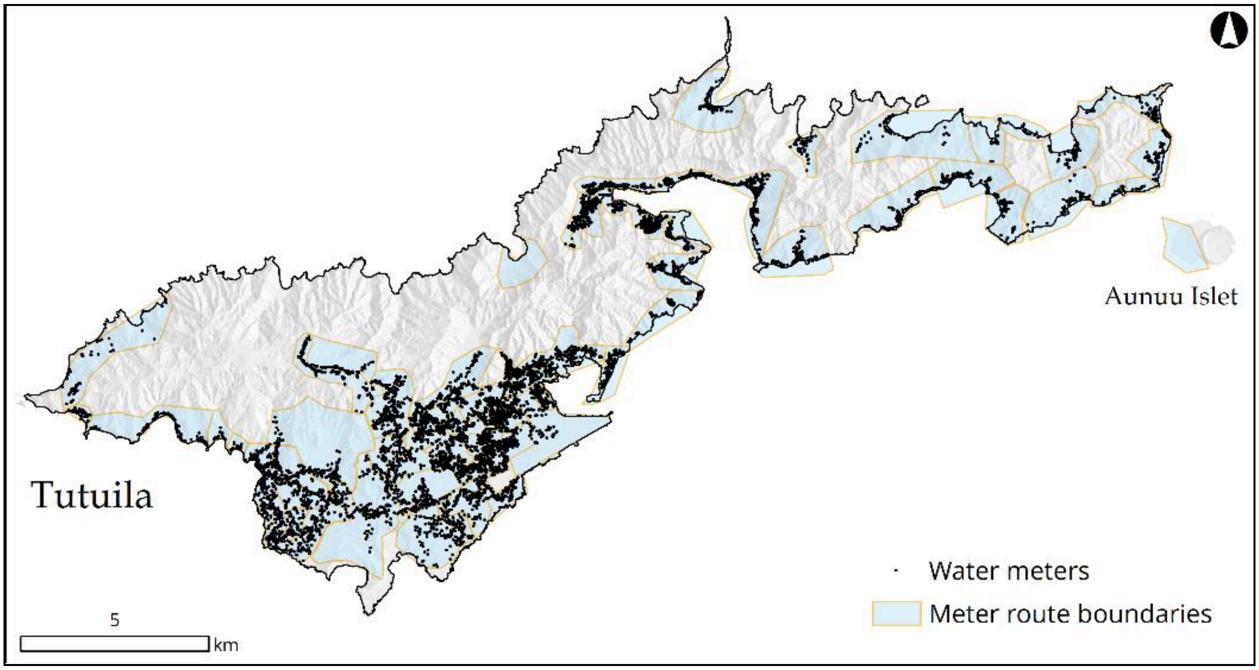

Figure 4: Map showing locations of Tutuila's 11,000 water meters and the boundaries of the 92 meter reading routes for Tutuila.

Background - Component 2: Village Water Systems

Traditional Use and Design of Village Water Systems

Before the 1970s, village water systems were the primary source of water for all villages in American Samoa. These systems were typically constructed with a small check dam placed across a stream, with a delivery pipe embedded in the dam structure. The design of these intake sites leveraged the natural channel geometry to create a standing pool of water, ensuring the intake remained continuously submerged (***Figure 5***). Water was then delivered via the pipe to a communal faucet in the village's central area, though in some instances, the water supply was directly connected to the homes of wealthier families or village chiefs. Despite the development of municipal water systems and small reservoirs during this period, the operation of surface water treatment plants proved challenging, leading to their eventual phase-out.

Transition Away from Village Water Systems

Village water systems in American Samoa, reliant on surface water sources, are inherently susceptible to contamination from soil, debris, and pathogens, resulting in highly variable water quality. The islands, despite receiving abundant annual rainfall, are prone to short-term droughts that exacerbate water shortages due to the limited natural storage capacity of the island's soils and aquifers. By the late 1970s, these challenges prompted a strategic shift towards groundwater development. The American Samoa Public Works Department (ASDPW) initiated a comprehensive program to establish a more robust network of groundwater-based municipal infrastructure, including the development of groundwater sources and an island-wide water transmission system. This program was managed by ASDPW until the American Samoa Power

Authority (ASPA) assumed responsibility around the year 2000. The American Samoa Environmental Protection Agency (ASEPA) played a key role in promoting the transition from village water systems to the more reliable groundwater systems, which met Safe Drinking Water Act standards. However, the transition was not entirely successful, and many residents continued to rely on village water systems due to financial considerations or traditional practices. Despite their declining use, these systems remain crucial during emergencies, underscoring the need to document and understand their current status and function.

Figure 5: Photos of typical village water systems and types. (a) Abandoned village water system valve in a streambed; (b) pipe carrying diverted stream water through Masefau village; (c) concrete dam across Maloata stream with abandoned outlet pipes visible; (d) pool created with rocks in a low-flowing stream, as an example of how simplified versions of village water systems may have been traditionally constructed prior to the advent of pipes.

Present-Day Village Water Use and Knowledge Gaps

While the use of village water systems is recognized in modern times, they are often overlooked by the public and underappreciated by regulatory bodies. Village systems are generally considered inferior and problematic, with regulatory efforts focused on discouraging their use, especially on Tutuila, the territory's capital. However, in certain areas, particularly where groundwater salinity levels are high, village water systems remain a necessary alternative. Despite their shortcomings, these systems are invaluable during water shortages or emergencies, especially given the vulnerabilities of the groundwater system, which relies heavily on diesel-powered pumps and has limited storage capacity. Understanding the historical and present use of village water systems is essential not only for future surface water development but also to ensure equitable resource management, particularly for underrepresented communities.

Governance and Data Sovereignty

Village water systems fall under the jurisdiction and management of the traditional Samoan governance system, rather than the American Samoa Government (ASG). This report acknowledges the enduring significance of the Traditional Samoan Matai system in managing essential community resources. The data collected for this report was provided by indigenous leaders of modern-day, functioning, traditional governance areas, and these data remain under the ownership of each village and its leadership. The authors have taken steps to respect this sovereignty, ensuring that the information shared does not encroach on it or contain identifiable information regarding individuals, families, or infrastructure locations.

Detailed background information is provided in a village water focused companion report titled *Operational Status and Estimated Flows of Village Water Systems in American Samoa,* Available here:
(https://github.com/cshuler/Am_Samoa_WUDR_ASPA/tree/main/Village_Water/Writing/Report)

Background - Component 3: Improving Water Metering Infrastructure at ASPA

Probably the most critical issue for ASPA at this time relates to non-revenue water (NRW) losses within the municipal water delivery system. The utility has identified the need to improve assessment of losses through innovative approaches such as hydraulic modeling and enhanced in-line metering. NRW, which represents the largest single "end-user" of groundwater, accounts for up to 64% of the water produced by the public system. From 2012 to the present, ASPA records indicate that non-revenue public-supply water has ranged between 7 and 10 million gallons per day (MGD), equating to approximately 53% to 73% of total water production. This significant loss is the island’s greatest barrier to long-term water sustainability, and its effective management is hindered by a lack of understanding of where and how these losses are occurring.

Currently, NRW is estimated as the difference between island-wide water production and consumption, which does not allow for geographic discretization of losses or the identification of specific causes, such as leakage from pipes, broken meters, or illegal connections (water theft). To address this, ASPA is developing a hydraulic model to better understand and predict flows and loss locations within the system. Hydraulic models enable the assessment of system losses at higher spatial resolutions, allowing for more accurate attribution of losses to specific causes in particular areas. To develop a robust and accurate hydraulic model, it is essential to gather real-time flow and pressure data, improved chloride readings—particularly for newly drilled wells to understand sustainable pump rates—and tank level meters to provide precise head and storage parameters. These data are crucial for calibrating and parameterizing ASPA's hydraulic model, which will ultimately lead to more effective management and reduction of NRW losses across the island's water system.

Project Objectives

Component 1: Developing infrastructure to manage and share water use data

Objectives:

- Develop the information technology (IT) infrastructure needed to access and consolidate site-specific public supply water production and use data
- Format data according to the Water Data Exchange (WaDE) 2.0 data schema
- Process and transfer these data to USGS at a high temporal resolution
- Publicly post water use data online to promote water conservation outreach efforts

Component 2: Assessing and documenting village water systems

Objectives:

- Assess the state and current usage of village water systems
- Perform site visits to village water systems
- Survey village leaders and community members to develop a provisional catalog of present day and historical village water systems
- Document results in a peer-reviewed publication

Component 3: Improving water metering infrastructure at ASPA

Objectives:

- Install and apply useful metering equipment on water infrastructure such as wells, mains, and tanks to generate essential data for continued development of existing hydraulic system models

ORGANIZATION AND APPROACH:

Methods - Component 1: Infrastructure for Water Use Data

Data Pipeline

To acquire and process water usage data from ASPA, we developed and operationalized a data pipeline designed for the automated ingestion of water use data from ASPA's customer service database. This process involved first connecting with key ASPA personnel who were responsible for managing ASPA databases, and designing a process for reports to be generated and sent to the water engineering department where they can be uploaded to a shared repository. Since the water usage data contains sensitive information, such as location data tied to names of individual customers, this sensitive data is first uploaded to a secure GitHub repository with no public access. From this repository, the data is then pulled into our system for processing, analysis, and anonymization, thereby ensuring that we maintain data integrity and security throughout the process.

Mapping and Transformation Of Water Use and Production Data Into the Wade 2.0 Schema.

To create accessible and standardized data, we mapped and transformed the raw water usage and well production data into the WaDE 2.0 schema. Water usage reports were keyed and aggregated based on various dimensions including spatial, by village or well ID, temporal, by month, and on BeneficialUseCategory, e.g. "domestic use". The raw input data provided by ASPA essentially had a water flux, measured in number of gallons per month at every metered location in the system. Therefore we were able to separate out usage data from production data, and aggregate each site at will. Usage data was identified as meters associated with locations including homes, businesses, commercial, and industrial facilities. These data were aggregated by location within village boundaries in order to anonymize data and protect sensitive personally identifiable information. Production data was identified as meter readings at production wells and point location information was retained. Metadata for each production well location and consumption site, represented as the centroid of the polygon covering each village, are available in the "sites.csv" endpoint located here (https://aspa-wudr.sfo3.digitaloceanspaces.com/Sites.csv). Locations and ID numbers of production wells are shown in ***Figure 6***, and village boundaries, labeled with corresponding names and numbers are given in ***Figure 12*** and ***Table 3.***

We performed basic Quality Assurance and Control (QA/QC) procedures on raw data to identify suspect entries and remove outliers. Specifically for the water use data at individual villages, the mean and standard deviation across all available months of data are calculated for each location and BeneficialUseCategory, with any data points exceeding three standard deviations getting removed. For production well data, any data points indicating usage greater than 17,520,000 gallons per month (the maximum pumping rate of any of Tutuila's well pumps, 400 GPM) were filtered out.

To ensure the data's integrity and adherence to the WaDE standards, we created WaDE schema-specific metadata tables to provide detailed information about the dataset structure and content. The metadata tables support specific columns to provide information not included in the main dataset. The metadata table supporting site information contains location information, organization name identifiers, and a description of the site. The organization metadata table exists to provide contact information and specific information relating to the organization providing the water use data. The variables metadata table supports the different labels in the VariableCV column of the main dataset and provides unit information as well as a description. The water sources metadata table details the source of the water for all uses and production in the main dataset. All of these tables and additional explanation are available at our documentation site (https://am-samoa-wudr-aspa.readthedocs.io/en/latest/index.html)

Ultimately the cleaned and formatted water use and water production data was aggregated by location, month, and category of use. The resulting dataset is formatted as a CSV file and pushed to an online storage bucket each time the formatting script is run. The final data is located at: (https://aspa-wudr.sfo3.digitaloceanspaces.com/Final_Aggregated_Data.csv)

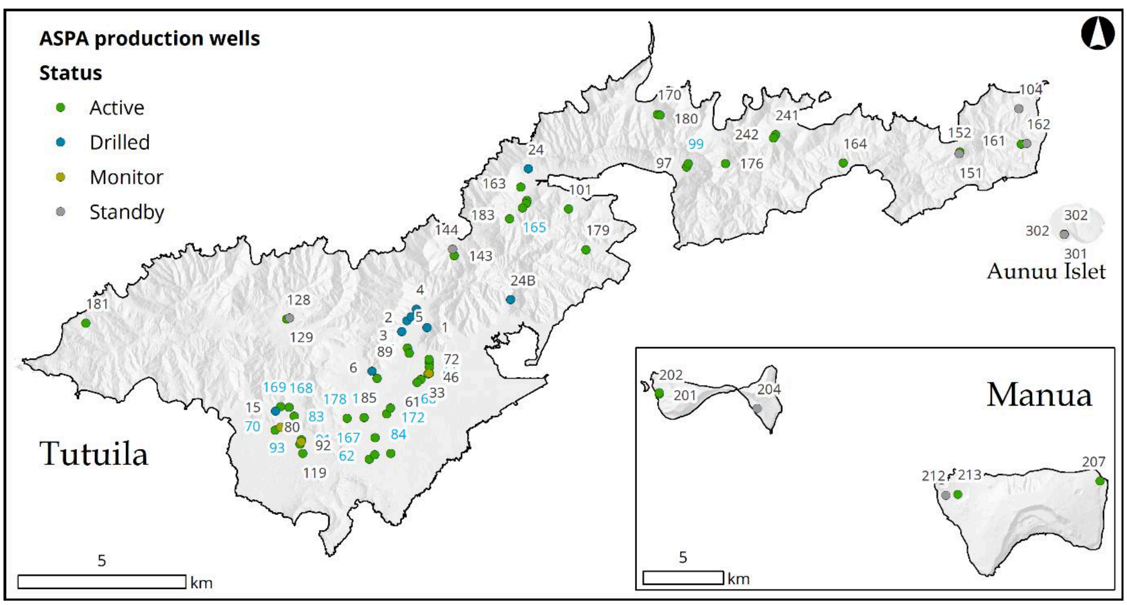

Figure 6 : Locations of ASPA production and monitoring wells. Labels indicate ASPA well ID number. Color of symbol indicates well status as active as of April 2018 or inactive (monitoring, standby, or drilled but not connected). Label color indicates presence (blue label color) or absence (grey label color) of MagFlux flow meter to digitally record flow rates.

Data processing is scheduled to run by triggering a serverless function developed and deployed on the secure Digital Ocean cloud service platform. The deployment process was conducted by formatting the data processing code to run within the serverless function, setting permissions, and defining resource limits, including a memory of 1024 MB and a timeout setting of 6 minutes. Specific environmental variables, including Github access tokens and object endpoint space APIs, are required for successful deployment that are defined within the Digital Ocean interface.

The serverless function automatically triggers every 2 weeks, pulling all raw files from the private GitHub repository and formatting them as described above to ensure that monthly raw data uploads are captured in a timely manner. One small speed bump lies in the ability to set the processed files permissions to public, so they can be accessed at the end point. This needs to be handled independently, therefore a cron-job is running at the same interval on a separate Digital Ocean server to set permissions on the serverless function to ensure the data files are set to public.

After processing, the final aggregated SiteSpecificUse data file, stored in a CSV, is updated and placed in a designated public bucket within the object storage. The metadata tables are reuploaded as well, but only need to be investigated if major changes, such as a new well being moved online. A public URL is generated for each data file, including metadata files and these URL's can be used to access the data through a browser or through automated applications. Online documentation describing API access and details about each data file can be found on our read the docs site: https://am-samoa-wudr-aspa.readthedocs.io/en/latest/. Finally, the publicly available CSV datasets are used to provide input data to a automatically updating GIS dashboard to graphically display water usage aggregated by village. The real-time GIS dashboard to interactively explore water use data is available via the American Samoa Climate Data Portal (https://www.hawaii.edu/climate-data-portal/americansamoaportal/), under the "Real Time Monitoring Data Portal", and is also available as a direct link to the web application at: (https://uhm.maps.arcgis.com/apps/dashboards/90e973b9e54b4d01ad54235da932f074).

Methods - Component 2: Village Water Systems

Collection of Village-Level Data:
To assess village water usage patterns, we obtained contact information for village leaders (Pulenuu) through public records and collaboration with the Office of Samoan Affairs (OSA). The OSA provided contact information for 53 village officials, considering overlaps in leadership structures across the 65 villages listed in the ASG database. Out of the 52 villages relevant for water use assessment (those with perennial streams), we successfully engaged 42 Pulenuu through phone calls, emails, and site visits. These engagements enabled data collection on the operational status of village water systems, the number of families relying on these systems, and historical and current surface water usage information.

Geospatial Analysis of Basin Characteristics and Future Climate Projections:
We also conducted geospatial analysis of watershed characteristics above the assumed village water intake locations. Intake sites were estimated based on proximity to the highest elevation urbanization or development, typically at the urban-wildland interface. This approach helped avoid privacy concerns and respected indigenous data sovereignty. Using hydrologically defined watershed boundaries, we calculated basin parameters such as land cover, average annual precipitation, basin slope, and population counts from geospatial datasets, census data and region-specific dynamically downscaled future climate projections. The climate scenarios

leveraged existing water budget rasters developed by Shuler et al. and are based on projections by Wang and Zhang (2016). Projections are representative of the late 21st century period, under modeled future climates from RCP 4.5 and RCP 8.5 emissions scenarios.These parameters provided insights into the water availability and resource dynamics of each village watershed.

Streamflow Quantification Methods and Low-Flow Statistics:
We analyzed the availability of surface water for village water systems using low-flow statistics derived from USGS gauged and ungauged streams. Our assessment focused on baseflow, as high sediment loads in runoff render it unsuitable for use in village water systems. Low-flow estimates, such as the 7-day 2-year and 7-day 10-year low flows, were calculated using regression equations developed by Wong (1996)[1]. These estimates help quantify the minimum baseflow available during typical and exceptionally dry years, providing a conservative measure of water availability in Tutuila's villages. The parameters for these equations included drainage area, gage altitude, basin relief, drainage density, and basin slope, and were applied separately for the distinct hydrological conditions of Western and Eastern Tutuila.

Detailed methods are provided in a village water focused companion report titled *Operational Status and Estimated Flows of Village Water Systems in American Samoa,* Available here: (https://github.com/cshuler/Am_Samoa_WUDR_ASPA/tree/main/Village_Water/Writing/Report)

[1]Wong, M. F. (1996). Analysis of streamflow characteristics for streams on the island of Tutuila, American Samoa (Vol. 95, No. 4185). US Department of the Interior, US Geological Survey. Retrieved from: https://pubs.usgs.gov/wri/1995/4185/report.pdf (Accessed 2024-08-10)

Methods - Component 3: Improving Water Metering Infrastructure at ASPA
The ASPA team applied their existing assessment of metering infrastructure at ASPA to identify gaps and prioritize locations for the installation of additional flow and salinity meters. Leveraging their institutional knowledge, particularly from their role in ASPA's leak detection crew, the team focused on high-priority sites where new equipment would provide the most significant benefits. Improvements in chloride monitoring methods were identified as a high priority for producing useful groundwater salinity data for hydraulic model parameterization. New salinity meters were procured to replace outdated titration-based methods used previously by ASPA operations staff. New meters were allocated to teams responsible for measuring salinity in newly drilled and existing wells. Additionally, the SCADA team installed three Vega C21 radar level transmitters at tank sites within the water system to provide remote level readings. One of these transmitters was installed on the upper Tramway system tank, which supplies the Utulei-Gataivai area, ensuring critical monitoring during the repair of a major 1-million-gallon tank.

4. RESULTS AND OUTCOMES

Results - Component 1: Infrastructure for Water Use Data
We were able to quantify and automate reporting of essentially all of American Samoa's groundwater use and production data (***Figure 7***). in our data pipeline. While a limited amount of surface water is used by residents via traditional village water systems (see component 2), and these systems also likely supply some irrigation water, there is no known metering of this usage making it impossible to quantify these flows, beyond the qualitative "number of users" estimate

performed for component 2. Additionally, ASPA owns two surface water filtration plants, but at the time of writing both of these plants are non-operational due to issues with procurement issues and limitations in operational staff. Currently groundwater meets all of the municipal demand.

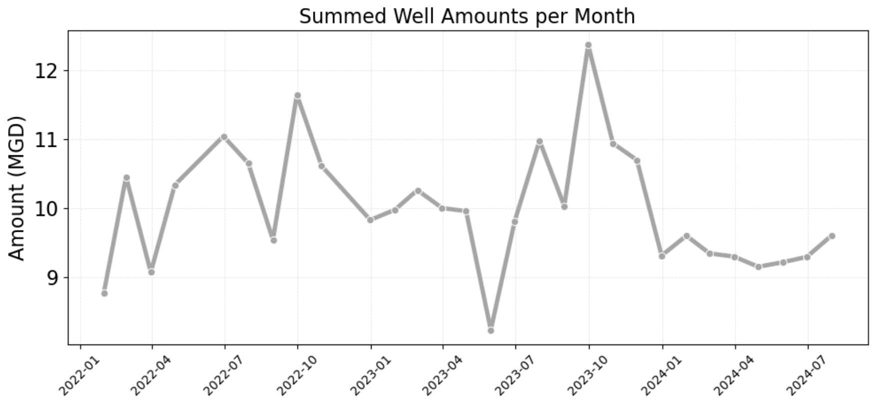

Figure 7: Total groundwater production across the ASPA system in Million Gallons per Day (MGD), over a period extending from January 2022 to July 2024.

Our data pipeline consolidates water usage at individual meters into spatial units of villages, and presents water production data at extraction points (wells). It also separates water used for different beneficial use categories into separate rows. All data has a monthly temporal resolution. As new data is recorded and reported by the ASPA customer service department, updates are automatically made to the Final_Aggregated_Data.csv file that can be easily pulled from the API at: (https://aspa-wudr.sfo3.digitaloceanspaces.com/Final_Aggregated_Data.csv).

The data can be summarized and visualized across multiple dimensions as provided in the charts and tables below. ***Figure 8*** displays the average annual water usage by village in both absolute magnitude (total gallons used) and after normalizing by the number of meters in each village to indicate usage “per each meter”. ***Figure 9*** shows the average annual production at each well location, and ***Table 1*** provides this data directly.

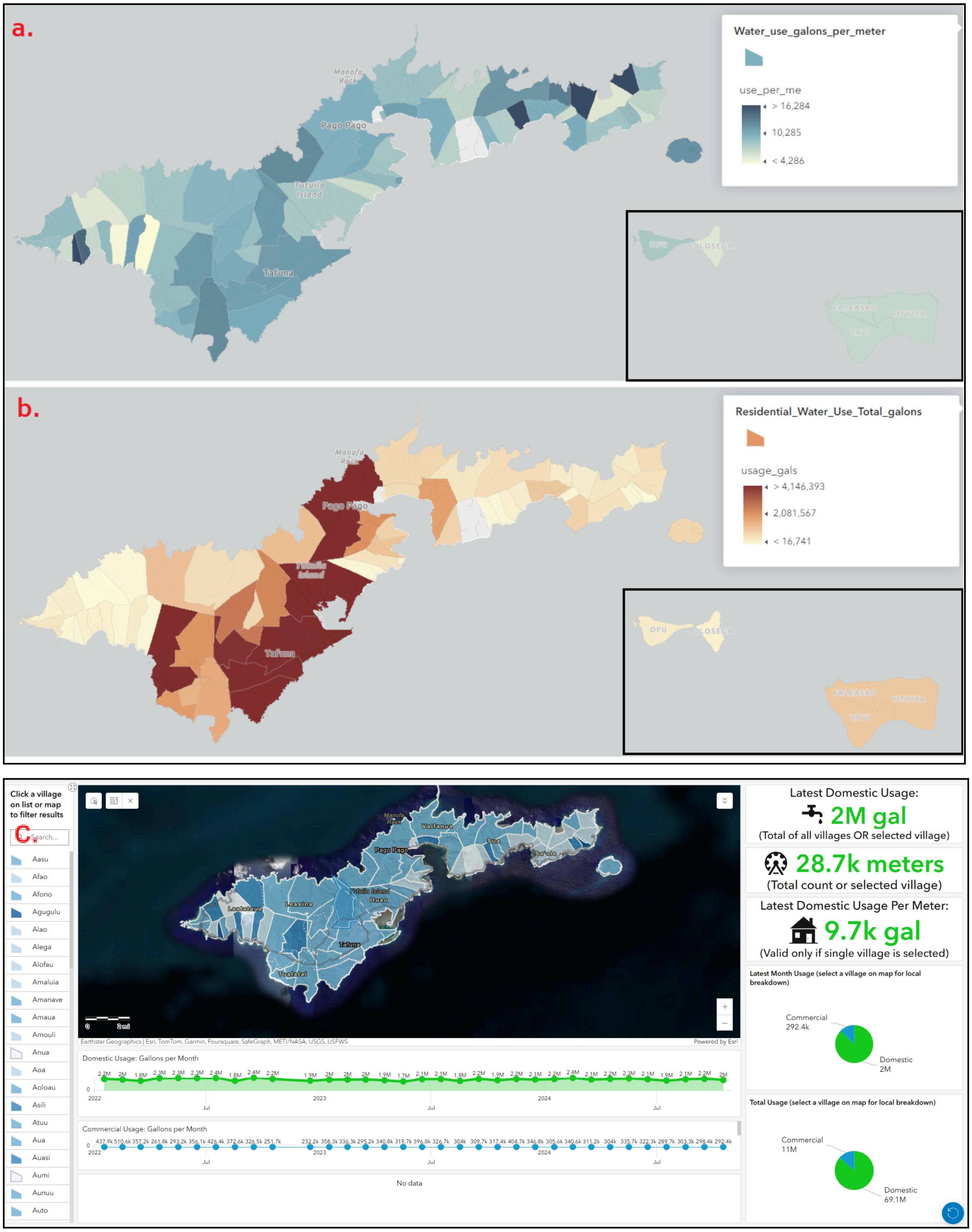

Figure 8: Maps of residential (domestic) water usage represented as the total number of gallons used per month at each water meter aggregated by villages on Tutuila and the Manua Islands (displayed in the inset box in the lower right corner of each panel). Panel (a.) shows total number of gallons used in each village divided by the number of meters in the village, panel (b.) shows the absolute amount of water used (in gallons), and panel (c.) shows these data in the real-time GIS dashboard produced for the project and hosted on the American Samoa Climate Data Portal.

Table 1: Water usage breakdown and population by village, including average daily use in gallons per day for industrial, domestic, and commercial sectors

Village	Population	Average Use in Gallons per Day		
		Industrial	Domestic	Commercial
Aasu	425	0	16,890	133
Afao	96	0	3,223	268
Afono	327	0	13,081	1,985
Agugulu	42	0	594	0
Alao	275	0	15,026	0
Alega	29	0	1,092	0
Alofau	296	0	14,777	3,054
Amaluia	163	0	2,052	389
Amanave	246	0	12,136	1,350
Amaua	68	0	2,913	0
Amouli	261	0	11,468	1,501
Aoa	344	0	13,633	845
Aoloau	650	0	41,812	3,453
Asili	157	0	8,444	144
Atuu	236	973,338	9,864	25,410
Aua	1549	0	46,392	11,011
Auasi	88	0	3,248	657
Aunuu	402	0	21,712	5,181
Auto	214	0	4,813	2,846
Avaio	34	0	998	834
Fagaalu	731	0	30,465	10,798
Fagaitua	287	0	23,819	3,426
Fagalii	163	0	6,666	4,655
Fagamalo	37	0	1,302	0
Faganeanea	93	0	3,941	92
Fagasa	577	0	32,707	3,384
Fagatogo	1445	0	61,074	37,832
Failolo	87	0	2,876	0
Faleniu	1953	0	88,078	7,666
Fatumafuti	72	0	3,348	1,500
Futiga	682	0	44,670	3,389
Iliili	3073	0	123,631	23,047

Table 1: Continued

Village	Population	Average Use in Gallons per Day		
		Industrial	Domestic	Commercial
Laulii	736	0	24,636	3,426
Leloaloa	365	0	18,164	7,938
Leone	1598	0	161,489	21,821
Malaeimi	1046	0	68,779	11,051
Malaeloa	1038	0	61,824	7,667
Maloata	6	0	640	0
Mapusagafou	1772	0	77,055	1,221
Masausi	134	0	8,332	0
Masefau	260	0	17,093	3,477
Matuu	317	0	12,021	432
Mesepa	415	0	20,994	285
Nua	150	0	6,233	505
Nuuuli	4991	0	190,192	79,418
Ofu	132	0	10,067	3,910
Olosega	138	0	6,052	2,550
Onenoa	100	0	3,614	0
Pagai	81	0	2,117	1,928
Pago Pago	3000	0	135,308	29,231
Pavaiai	2112	0	121,261	28,660
Poloa	130	0	7,019	0
Sailele	60	0	3,175	0
Seetaga	177	0	8,705	62
Tafuna	7988	3,001	472,275	250,821
Taputimu	709	0	41,474	771
Tau	790	0	33,891	16,683
Tula	308	0	13,340	611
Utulei	479	0	26,192	69,324
Utumea East	55	0	1,746	0
Utumea West	42	0	5,093	0
Vailoatai	1195	0	61,148	2,603
Vaitogi	1921	0	123,254	9,772
Vatia	460	0	18,035	1,118

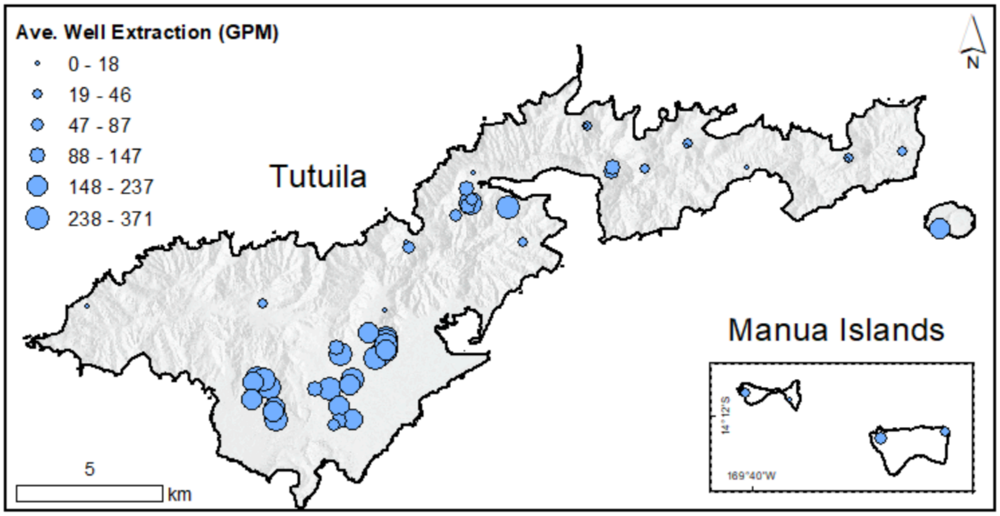

Figure 9: Average annual groundwater production in GPM, at each of the 56 active well sites across Tutuila and the Manua islands

Table 2 provides detailed information on the location and average pumping rates of municipal ASPA wells across Tutuila and the Manua Islands in American Samoa. Well ID numbers are correlated to those shown in ***Figure 6.*** The chart in ***Figure 10*** shows water usage from all meters (all village locations) broken down by beneficial use category, and quantified at the average daily usage across the period of record 2022-2024. Domestic water usage outpaces other categories, hovering around 2.5 Million Gallons per Day (MGD), reflecting a steady demand for household water use. According to the 2020 census, familial households make up a majority of the homes on American Samoa, with most containing 7 or more persons. Industrial water usage shows a more dynamic pattern based on variability in operations at the tuna cannery(ies), which represent the territory's only industry. Commercial water demand from businesses and offices is also fairly consistent.

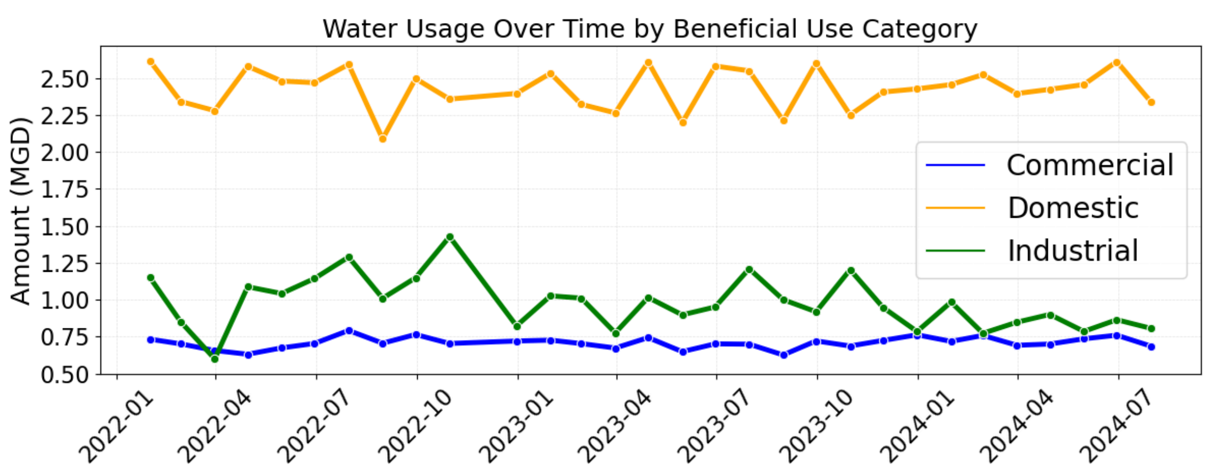

Figure 10: Water use broken down by the three beneficial use categories: Commercial, Domestic, and Industrial. In Million Gallons per Day (MGD), over a period extending from January 2022 to July 2024

Table 2: Location and average pumping rates (in Gallons Per Minute, GPM) for municipal ASPA wells across Tutuila and the Manua Islands, American Samoa. Figure 6 shows locations of wells on a map.

Well #	Village	Average Annual Pumping (GPM)	Latitude	Longitude
Well-128	Aasu	21.5	-14.309801	-170.771491
Well-176	Afono	31.5	-14.26778	-170.65048
Well-161	Alao	18.9	-14.26244	-170.56889
Well-151	Aoa	3.2	-14.26502	-170.58598
Well-152	Aoa	18.6	-14.26459	-170.58577
Well-97	Aua	141.6	-14.2687	-170.66118
Well-99	Aua	139.7	-14.26776	-170.6607
Well-302	Aunuu	191.3	-14.286658	-170.556946
Well-179	Fagaalu	19.6	-14.291027	-170.688929
Well-164	Fagaitua	11.0	-14.26756	-170.61795
Well-143	Fagasa	62.1	-14.29271	-170.72527
Well-144	Fagasa	0.0	-14.290934	-170.725792
Well-101	Fagatogo	351.3	-14.28003	-170.6938
Well-167	Iliili	182.8	-14.341723	-170.747101
Well-62	Iliili	66.8	-14.347566	-170.748702
Well-76 (offline)	Iliili	99.2	-14.346342	-170.747227
Well-84	Iliili	179.6	-14.34597	-170.74276
Well-119	Leone	238.7	-14.34596	-170.76707
Well-1 (offline)	Malaeimi	16.4	-14.31205	-170.732809
Well-67	Malaeimi	237.0	-14.31895	-170.73769
Well-81	Malaeimi	326.2	-14.320566	-170.732212
Well-15	Malaeloa	222.8	-14.334561	-170.774604
Well-168	Malaeloa	257.4	-14.33358	-170.77082
Well-169	Malaeloa	370.9	-14.33337	-170.77319
Well-70	Malaeloa	161.3	-14.33971	-170.77473
Well-83	Malaeloa	265.4	-14.336	-170.76941
Well-91	Malaeloa	206.9	-14.34232	-170.76744
Well-93	Malaeloa	163.6	-14.34348	-170.76787

Table 2: Continued				
Well #	**Village**	**Average Annual Pumping (GPM)**	**Latitude**	**Longitude**
Well-241	Masefau	18.7	-14.25994	-170.63665
Well-242	Masefau	14.7	-14.26088	-170.63721
Well-6	Mesepa	119.7	-14.32383	-170.748014
Well-85	Mesepa	317.2	-14.3258	-170.74657
Well-24 (offline)	Nuuuli	0.0	-14.269242	-170.704879
Well-201	Ofu	20.4	-14.170883	-169.676933
Well-202	Ofu	31.4	-14.171533	-169.676867
Well-204	Olosega	0.0	-14.179317	-169.6206
Well-105	Pago Pago	85.2	-14.277783	-170.705284
Well-107	Pago Pago	328.4	-14.27862	-170.70548
Well-163	Pago Pago	136.7	-14.27419	-170.70697
Well-165	Pago Pago	142.4	-14.279785	-170.706484
Well-183	Pago Pago	55.4	-14.282711	-170.710093
Well-171	Pavaiai	250.6	-14.33373	-170.74288
Well-172	Pavaiai	236.0	-14.33531	-170.74393
Well-177	Pavaiai	308.8	-14.33637	-170.75013
Well-178	Pavaiai	97.1	-14.33649	-170.75482
Well-181	Poloa	5.8	-14.31095	-170.827017
Well-33	Tafuna	178.5	-14.32437	-170.73215
Well-60	Tafuna	264.4	-14.326048	-170.734517
Well-61	Tafuna	251.6	-14.32686	-170.73554
Well-66	Tafuna	272.5	-14.324556	-170.73248
Well-72	Tafuna	298.5	-14.32154	-170.73219
Well-77	Tafuna	261.5	-14.32273	-170.73214
Well-207	Tau	36.7	-14.218809	-169.423106
Well-213	Tau	84.5	-14.226744	-169.505011
Well-170 (offline)	Vatia	6.1	-14.25455	-170.66925
Well-180	Vatia	19.4	-14.25476	-170.66857

Figure 11 provides a clear summary of village water use and production (aggregated by village) across domestic and commercial categories, and presents normalized water consumption by population as well.

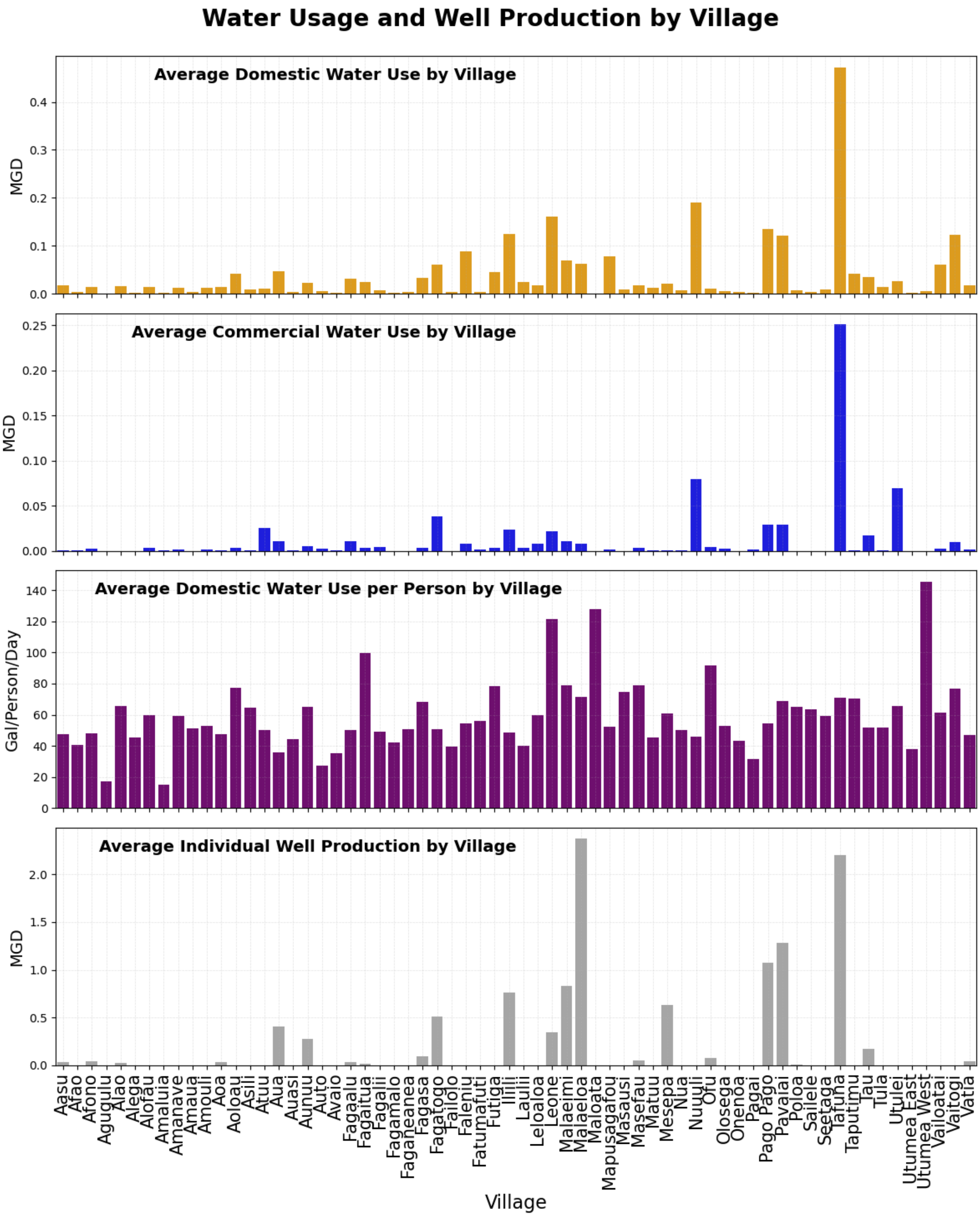

Figure 11: Comparison of water use and production across villages, showing differences in commercial vs domestic use, both absolute and normalized by village population (3rd panel).
Population normalized 3rd panel utilizes 2020 Census Data. Individual well data is aggregated by the village within which the wells are located, and it should be noted that almost all wells feed into a centralized system and water is transported across village boundaries for use. All villages depicted even if there are no data.

There is notable variation in per capita water use among the villages. Some villages exhibit relatively high water use per person, while others demonstrate more conservative water usage. For example, Tafuna has an extremely large overall average domestic use but, per capita water use is relatively normal, indicating efficient water usage on an individual level despite high total consumption. Conversely, villages such as Utumea East exhibit the opposite trend. Despite having a low overall average domestic water use, Utumea East shows the highest per capita water use. This suggests that individuals in this village consume more water on average compared to those in other villages, which could be indicative of unique water-use behaviors or needs. In villages with high total consumption but low per capita use, efforts might focus on managing demand as the population grows. In contrast, villages with low total but high per capita use might benefit from initiatives aimed at promoting water efficiency at the household level. The majority of the villages show very low commercial water use. Tafuna and Nuuuli have the most commercial development, which is clearly reflected in commercial water usage trends.

Data Accessibility

To support end-user documentation, a "Read the Docs" website was created, providing easy access to endpoint URLs and offering an in-depth description of the data pipeline and the contents of each CSV file. The documentation is available at https://am-samoa-wudr-aspa.readthedocs.io/en/latest/. Additionally, the code used to process the data is publicly accessible on GitHub at our open-source code repository located here: (https://github.com/cshuler/Am_Samoa_WUDR_ASPA).

Once the data is made available at our endpoint the Western States Water Council (WSWC) ingests American Samoa data into the Water Use Data and Reporting pipeline used to ingest and synthesize data from all 54 states and territories. Their pipeline prepares site-specific public supply time series data from our endpoint for inclusion in the Water Data Exchange (WaDE) project. Their process is documented here: (https://github.com/WSWCWaterDataExchange/MappingStatesDataToWaDE2.0/tree/master/AmericanSamoa) and this repository provides detailed steps and methodologies used by WSWC staff to extract and prepare the data, ensuring it is compatible with WaDE's framework. This initiative is part of a broader effort to enhance data accessibility and interoperability among states while maintaining the integrity and authority of the original data sources. The real-time GIS dashboard to interactively explore water use data is available via the American Samoa Climate Data Portal (https://www.hawaii.edu/climate-data-portal/americansamoaportal/), under the “Real Time Monitoring Data Portal”, and is also available as a direct link to the web application at: (https://uhm.maps.arcgis.com/apps/dashboards/90e973b9e54b4d01ad54235da932f074)

Results - Component 2: Village Water Systems

Current Water Use in Village Systems

Among the 64 identified villages on Tutuila, 42 have perennial streams, making them relevant for this assessment of village water systems. Our team surveyed 44 villages total, achieving a 69% response rate, and found that 27 villages still rely on their traditional water systems for activities like drinking, bathing, and agriculture. This represents about 64% of the villages with perennial streams. However, 10 villages reported that their water systems are no longer in use, while 4 village leaders were uncertain but believed some residents might still be using them (***Figure 12***). Unfortunately, we could not reach the leaders of 10 villages, resulting in missing data for those areas. Among the 27 villages with active systems, 18 provided household usage estimates, ranging from a single household in Onenoa to over 70 households in Afao. The remaining villages either did not know or did not provide specific household numbers. This data highlights the varying degrees of dependence on village water systems across the island, with detailed status and usage information mapped and documented for each surveyed village.

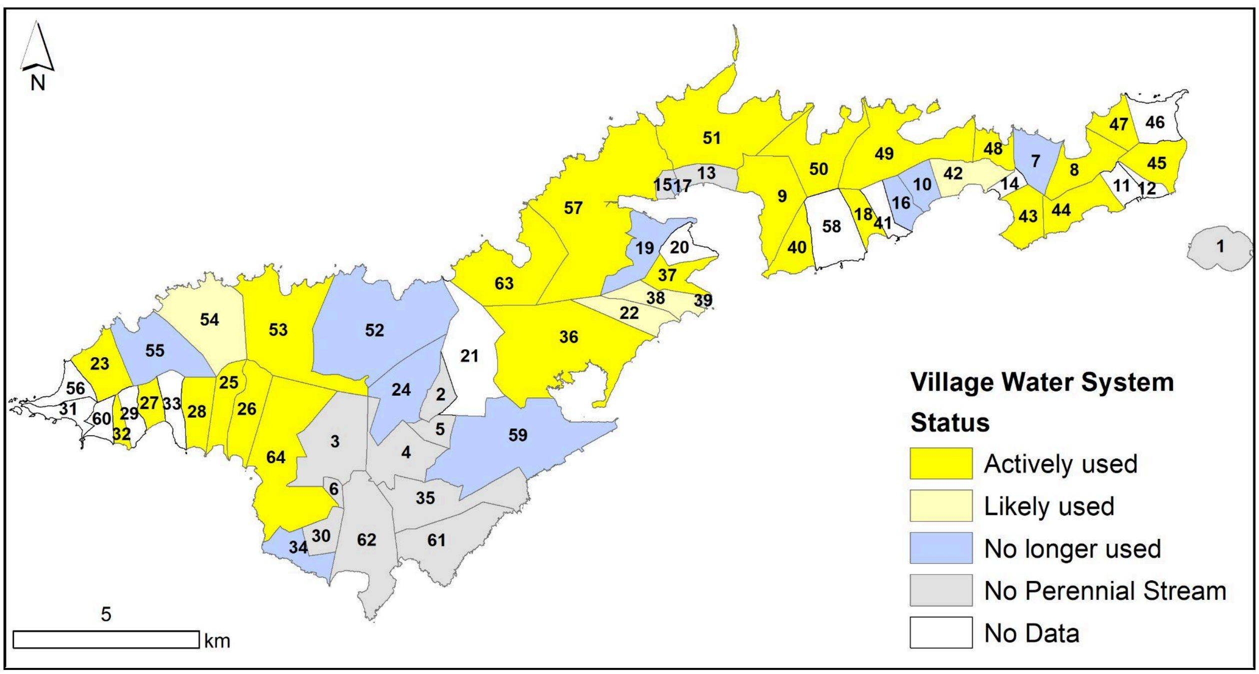

Figure 12: Map of known village water usage showing villages that actively use village water in yellow and where available, estimates of the number of households using village water. Numbers indicate an arbitrarily assigned village ID number which corresponds to villages in Table 3

Table 3: Generalized characteristics of villages with streams that support, or may support, village water systems on Tutuila, American Samoa. The table lists villages that were surveyed for this study, indicating whether village leaders participated in the survey, current status of village water systems, and number of households using systems. Population estimates are based on 2020 U.S. census data. Villages are categorized based on the presence or absence of perennial streams. Where villages lack perennial streams data was not collected.

Map Number	Watershed or Village Name	Village Leaders Surveyed	Village Water System Status	Number of Households using Village Water	2020 Population
1	Aunuu	Yes	No Perennial Stream	-	
2	Mesepa	Yes	No Perennial Stream	-	
3	Malaeloa Aitulagi	No	No Perennial Stream	-	
4	Pavaiai	No	No Perennial Stream	-	
5	Faleniu	No	No Perennial Stream	-	
6	Malaeloa Ituau	No	No Perennial Stream	-	
7	Sailele	Yes	No longer used	0	60
8	Aoa	Yes	Actively used	20+	344
9	Aua	Yes	Actively used	unknown	1549
10	Amaua	Yes	No longer used	0	68
11	Auasi	No	No Data	-	88
12	Utumea East	No	No Data	-	
13	Leloaloa	Yes	No Perennial Stream	-	
14	Pagai	No	No Data	-	81
15	Anua	No	No Perennial Stream	-	
16	Auto	Yes	No longer used	0	214
17	Atuu	Yes	No longer used	0	
18	Alega	Yes	Actively used	1+	29
19	Fagatogo	Yes	No longer used	0	1445
20	Utulei	No	No Data	-	479
21	Malaeimi	No	No Data	-	
22	Faganeanea	Yes	May be used	unknown	93
23	Fagalii	Yes	Actively used	30+	163
24	Mapusagafou	Yes	No longer used	0	
25	Asili	Yes	Actively used	17	157
26	Amaluia	Yes	Actively used	10	163
27	Seetaga	Yes	Actively used	10+	177
28	Afao	Yes	Actively used	70+	96
29	UtumeaWest	No	No Data	-	42
30	Taputimu	Yes	No Perennial Stream	-	
31	Amanave	No	No Data	-	246

Table 3: Continued					
Map Number	Watershed or Village Name	Village Leaders Surveyed	Village Water System Status	Number of Households using Village Water	2020 Population
32	Agugulu	Yes	Actively used	10+	42
33	Nua	Yes	No Perennial Stream	-	
34	Vailoatai	Yes	No longer used	0	
35	Iliili	No	No Perennial Stream	-	
36	Nuuuli	Yes	Actively used	unknown	4991
37	Fagaalu	Yes	Actively used	unknown	731
38	Matuu	Yes	May be used	unknown	317
39	Fatumafuti	No	No Perennial Stream	-	
40	Laulii	Yes	Actively used	60+	736
41	Avaio	No	No Data	-	34
42	Fagaitua	Yes	May be used	unknown	287
43	Alofau	Yes	Actively used	6	296
44	Amouli	Yes	Actively used	20+	261
45	Alao	Yes	Actively used	10+	275
46	Tula	No	No Data	-	308
47	Onenoa	Yes	Actively used	1	100
48	Masausi	Yes	Actively used	2	134
49	Masefau	Yes	Actively used	10	260
50	Afono	Yes	Actively used	unknown	327
51	Vatia	Yes	Actively used	30	460
52	Aasu	Yes	No longer used	0	
53	Aoloau	Yes	Actively used	unknown	
54	Fagamalo	Yes	May be used	unknown	37
55	Maloata	Yes	No longer used	0	6
56	Poloa	No	No Data	-	130
57	PagoPago	Yes	Actively used	8	3000
58	Aumi	No	No Data	-	176
59	Tafuna	Yes	No longer used	0	
60	Failolo	No	No Data	-	87
61	Vaitogi	Yes	No Perennial Stream	-	
62	Futiga	Yes	No Perennial Stream	-	
63	Fagasa	Yes	Actively used	70	577
64	Leone	Yes	Actively used	unknown	1598

Water Availability and Streamflow Estimation

Villages located near Tutuila's highest peaks, such as Mount Matafao and Rainmaker Mountain, have the highest estimated baseflow and thus village water availability due to greater precipitation and larger, steeper watersheds. In contrast, villages in Eastern Tutuila, with smaller basins and less rainfall, generally have lower water availability. Streamflow estimates, as indicated by the 7-day 2-year and 10-year low-flow statistics, vary widely across villages, ranging from approximately 15 GPM in villages with the smallest streams to over 200 GPM in those with the largest (***Figure 13***). The highest estimated water availability is found in villages like Nuuuli, Fagaalu, and Pago Pago, while the lowest is in villages such as Avaio, Failolo, and Utulei. These differences highlight the varying potential for village water use across the island, influenced by local watershed characteristics and precipitation patterns.

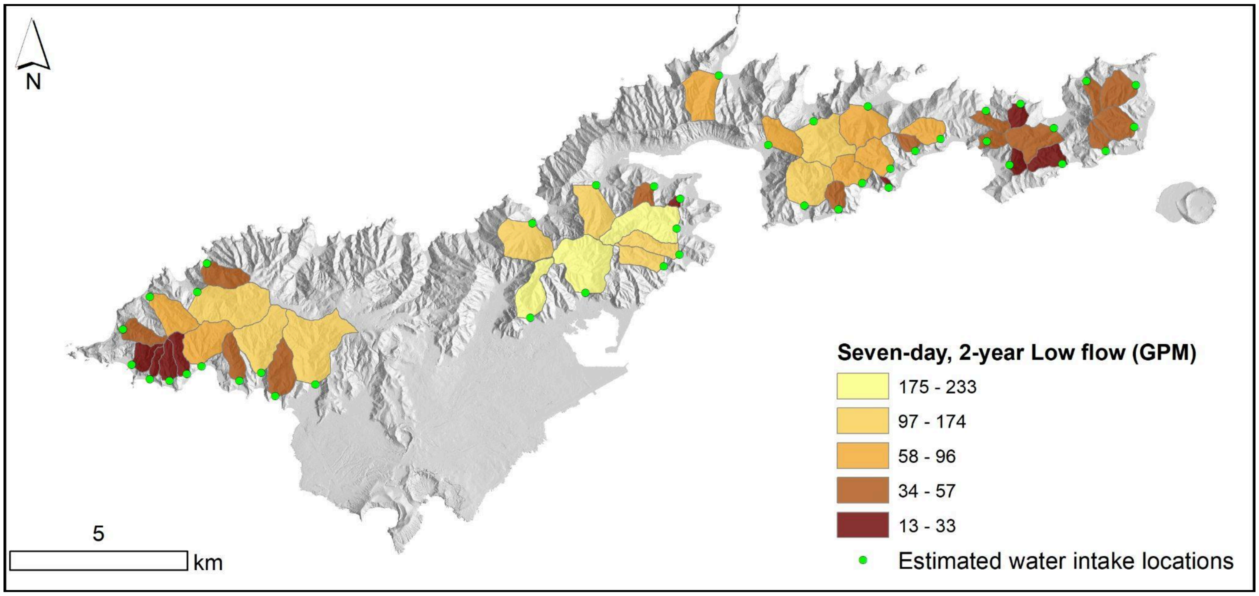

Figure 13: Map of village water availability based on calculated low-flow estimates of streams in GPM. Green dots represent estimated water intake locations and do not indicate actual water system infrastructure locations to protect village privacy and data sovereignty.

Basin Characteristics and Land Use

Water availability in Tutuila is influenced by watershed conditions, precipitation patterns, and land use. Central villages like Nuuuli receive up to 221 inches of rainfall annually, benefiting from orographic uplift, while eastern villages like Tula receive as little as 99 inches. Steeper slopes in central Tutuila generally lead to faster runoff, potentially reducing groundwater recharge, though this is offset by higher precipitation. Land cover also plays a critical role, with forested and grassland areas typically retaining more water compared to developed or agricultural lands, which are more prone to runoff. Analysis shows significant variation across the island, with the most pristine watersheds found in areas like Onenoa and Maloata, which have minimal development and high forest cover, while more developed villages like PagoPago and Aua face increased risks of runoff and potential water quality issues due to higher levels of human activity. These factors collectively influence the availability and quality of water resources across Tutuila's diverse landscapes.

Future Climate Predictions
Future climate projections for American Samoa suggest that current conditions and historical data may no longer be reliable indicators of future hydrology, necessitating a basin-wide analysis of water budget components to assess potential changes in village water availability. Climate scenarios, based on projections by Wang and Zhang (2016), indicate a significant increase in annual rainfall (10-25%) and a moderate rise in temperatures by the late 21st century, especially under high emissions scenarios (RCP 8.5). While the frequency of weak tropical cyclones is expected to decrease, the projected increases in precipitation and groundwater recharge could improve water supply reliability for many villages. However, significant increases in runoff, particularly under RCP 8.5, raise concerns about flood risks and potential water quality issues, particularly for villages like Sailele and Tula, where runoff may more than double. These changes highlight the need for strategic investments in water storage, stormwater management, and adaptation strategies to protect water quality and ensure resilient village water systems in the face of evolving climate conditions. The degree of adaptation required will depend on future global emissions trajectories, with greater challenges anticipated under more extreme scenarios.

Detailed results are provided in a village water focused companion report titled *Operational Status and Estimated Flows of Village Water Systems in American Samoa,* Available here: (https://github.com/cshuler/Am_Samoa_WUDR_ASPA/tree/main/Village_Water/Writing/Report)

Results - Component 3: Improving Water Metering Infrastructure at ASPA
Data collection efforts for component 3 were focused on producing useful calibration and parameterization data for hydraulic models and other operational tasks at ASPA. Because these efforts are ongoing and hydraulic modeling is still in progress no results from this component are available at this time.

5. NEXT STEPS AND RECOMMENDATIONS FOR FUTURE WORK:

Measuring Surface Water Use
Irrigation and aquaculture water use in American Samoa is currently unmetered, and regulatory action would be necessary to implement metering. Without such regulations, a qualitative assessment could be conducted, similar to the village water report, using interviews and survey data to estimate the magnitude of irrigation and aquaculture water use. Although all of ASPA's surface water plants are currently offline, there is interest in surface water as a promising resource, especially given the limitations and issues associated with groundwater. This interest represents a shift in focus, opposite to the transition from surface to groundwater in the 1970s. As ASPA brings surface water plants online, these flows could be integrated into the current data aggregation process by adding new sites and variables, though this would require additional effort. Metering these aspects of surface water use would nearly complete the picture

of water use in American Samoa as there are no Hydroelectric Power, Mining or Thermoelectric water uses that exist, or are likely to come online in American Samoa.

Improving Water Conservation

The data collected in this project can serve as a foundation to enhance water conservation outreach efforts. While public outreach was outside the scope of this project, it would benefit ASPA and the people of American Samoa to initiate a comprehensive water conservation program. Currently, there is little public awareness of the limitations in water availability, largely due to the perception that the island receives abundant rainfall. There are likely many easy-to-implement conservation strategies, such as installing low-flow toilets, fixing leaks in home plumbing, and other measures, that could be promoted to reduce domestic water usage.

Acknowledgements

We would like to extend our deepest gratitude to the leadership and staff of the American Samoa Power Authority (ASPA), particularly Director W. Young, for his consistent support throughout this and many other collaborative projects. We also extend our appreciation to the ASPA engineering and customer service departments for their critical contributions to this work. We recognize and appreciate the significant contributions of the director of the Office of Samoan Affairs and the village leaders for their collaboration, support, and their willingness to share their extensive traditional knowledge. We also must highlight the invaluable contributions of the co-authors, Valentine Vaeoso and Liza McLatchy who performed the majority of fieldwork and software engineering, respectively. Finally, we remember Brian Thompson, whose expertise and fiscal assistance were instrumental in making this project possible.