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Sediment in Stormwater for the Ala Wai Watershed

Background:

The Ala Wai watershed is an important watershed located in urban Honolulu, which includes a significant resident population, the main campus of the University of Hawaii, as well as the main economic engine of the state, Waikīkī. The watershed consists of three main tributaries, the Mānoa, Pālolo, and Makiki Streams. The three streams merge and drain into the Ala Wai Canal. The Ala Wai Canal was man-made in the 1920s and is about 2 miles long, originally built to drain the wetlands and formed Waikīkī (McMurtry, Snidvongs, and Glenn, 1995). Stormwater runoff-contributes to the streams during heavy rains. Stormwater runoff is from rains that flow from rooftops, paved streets, sidewalks, parking lots, bare soil areas, lawns, and storm drains (Mid-American Regional Council, 2020). Other sources of water that enter the Canal are from the Ala Wai Golf Course, natural springs, and seawater that comes from the Ala Wai Yacht Harbor (McMurtry, Snidvongs, and Glenn, 1995). Stormwater that is polluted can harm plants, fish, and wildlife, along with degrading the water quality. (Mid-American Regional Council, 2020). As runoff travels through the watershed there is a collection and transportation of soil, animal waste, salt, pesticides, fertilizer, oil, and other pollutants. (Mid-American Regional Council, 2020). During heavy rains each stream has greater amounts of water than the daily flow.

The canal is considered as an impaired waterbody due to accumulation of sediments, nutrients, and several toxic pollutants from the watershed. The classification of “impaired” means that one or more the water quality standards are not met (U.S. Environmental Protection Agency, Region 9 & Hawaii Department of Health, 2002). The Environmental Protection Agency (EPA) ranks sediment as the most common pollutant in streams. (Mid-American Regional Council, 2020). Even though the EPA ranks sediment as the most common pollutant there are not many studies done to better understand the impacts. Sediments are loose materials located on the bottom of the water body such as clay, silt, sand, gravel, and decaying organic matter (Environmental Protection Agency, 2018.) Elevated rates of sediment can reduce overall ecological heterogeneity and lower diversity and abundance (Thrush et al., 2004). Adding sediment to the watershed can alter habitats and ecosystems along with changing the water quality. With large amounts of sediment in stream beds, natural food chains can become disrupted by destroying the habitat of where smaller stream organisms live causing massive declines in fish populations (Mid-American Regional Council, 2020).

The watershed has changed over the years, only 54% of the surface is permeable (Dashiell, Harrigan, and Ho, 1998). The definition of 100% permeability in this case means that when rain falls, 100% of the land surface is permeable and able to absorb the rain. Due to urbanization and development, the water falling onto the ground is no longer being completely absorbed but goes into streams and down to the Ala Wai Canal. The land use of the watershed is 46% conservation land (located higher in the watershed) and about 53% urban land use for the lower areas (U.S. Environmental Protection Agency, Region 9, & Hawaii Department of Health, 2002). The introduction of non-native plants and animal species, along with the building of roads, sidewalks, parking lots, and covered roof area have altered the Ala Wai Watershed ecologically and hydrologically (U.S. Environmental Protection Agency, Region 9, & Hawaii Department of Health, 2002.). Lands that were once able to absorb rainfall are now covered by impervious surfaces, which increase the flow of sediment and other pollutants in runoff (U.S. Environmental Protection Agency, Region 9, & Hawaii Department of Health, 2002). The main focus of channelized streams was to mitigate floods and protect property along the streams but did not take into account the environmental health impacts. By the 1930s, there were water quality issues that were detected in the Canal, which indicates that water quality impairment has been a long-standing issue (Hawaii State Department of Health, 2018).

McMurtry et al. 1995 studied sediment accumulation in the Ala Wai Canal in which they observed that the sediment ranged in color from dark brown to black anoxic muds with the main component being detrital clays. They also found that the sediment had high organic carbon contents that were a mixture of marine/terrigenous origins, authigenic calcium carbonate of abiotic origin, and abundant diatom tests and pyrite (McMurtry, Snidvongs, and Glenn, 1995). This could help indicate where the sediment is coming from. Due to different uses of the land, origins of contaminants can be from vehicle residues, termiticides and breakdown products of termiticides, other chemicals, and numerous other wastes (Dashiell, Harrigan, and Ho, 1998).

In 1997, a study found that the Ala Wai Canal's mean total nitrogen concentrations greatly exceeded the state's standard as well as the total phosphorus levels (U.S. Environmental Protection Agency, Region 9, & Hawaii Department of Health. 2002). Due to the storm flow in the watersheds, the sediments and nutrients come down into the Canal and build up. When there is a combination of runoff from storms and higher stream flows, concentrations of nutrients provide substantially higher daily nutrient loads than during low flow conditions (U.S. Environmental Protection Agency, Region 9, & Hawaii Department of Health. 2002).

Late in 2018 a notice was released that the Army Corps was planning on working with the Department of Land and Natural Resources (DLNR) to dredge the Ala Wai Canal. Because of the sediment build-up in the Canal, the sediment and water holding capacity has been affected, which has reduced the Canal's ability to temporarily contain and release storm water during heavy rains (US Army Corps of Engineers Regulatory Branch, 2018). This is a red flag because with an increase in sediment and decrease in water holding capacity, the Canal is more susceptible to flooding and having sediment discharged into the ocean (US Army Corps of Engineers Regulatory Branch, 2018).

Back in 2002 the Ala Wai Canal was dredged and currently there is a new dredging project taking place along with two wall repair projects. These projects started in late 2019 and are expected to take about a year to complete and will cost roughly $21 million (Hawaii News Now, 2019). There is a clear need for more information and studies to look at sediment because of the high cost to dredge the Canal. Sediment entering the watershed is inevitable but there can be more efforts to reduce heavy loads and mitigate these particles from reaching the Canal. The 100-year flood was estimated to cost the state over a billion dollars, so there is a need for maintenance and upkeep of the watershed as a whole (Hawaii News Now, 2019).

Motivation:

On O'ahu, Waikīkī is a popular hotspot for tourists to lodge in or visit for beaches, shopping, and eateries (Waikiki, 2020). There were over 9.8 million visitors in 2018 that spent roughly $17.64 billion while on vacation (Hawaii Tourism Authority, 2018). O'ahu received over 5.9 million visitors and spent around $8.16 billion in 2018 (Chan, 2019). Efforts to keep the watershed clean are important to avoid negative impacts on the tourism industry as well as improve the quality of the water.

The University of Hawai'I is engaged in research on the hydrological function and potential improvements to the Ala Wai Watershed. *Strategic Monitoring and Resilience Training in the Ala Wai Watershed* (SMART Ala Wai) is a project that is composed of faculty, staff, graduate and undergraduate students from the University of Hawai'i at Mānoa, as well as numerous community stakeholders to establish a monitoring and sampling network, data analysis and outreach plan. "The watershed has been heavily impacted by, and remains at risk from, episodic flooding hazards, runoff pollution, and habitat destruction, all of which remain to be fully quantified and understood from a holistic ecosystem function perspective" (SMART Ala Wai, 2018). This project is a collaboration of different groups that is endorsed by the Hawai'i Legislature to significantly improve the understanding of the hydrological and biogeochemical functioning of the complete Ala Wai ecosystem (SMART Ala Wai, 2018). SMART Ala Wai has been taking monthly water samples for baseline data on the watershed since August 2018.

Sediment as a pollutant has gotten little attention and needs to be further studied to get a better understanding of the extent of damage caused by sedimentation in waterways. (Thrush et al., 2004). Total suspended sediment (TSS) in storm water is common water quality measurement. The canal is considered as an impaired waterbody due to sediments, nutrients, and several toxic pollutants from the watershed and accumulate faster than they can be flushed out of the canal (U.S. Environmental Protection Agency, Region 9 & Hawaii Department of Health, 2002). Due to sediment being one of the largest water pollutants in the watershed, there are questions as to why there are few studies done on the topic. Study is needed to direct remediation of these negative impacts and improve the watershed's overall health. There are water reports done every two years for the Ala Wai Watershed (Hawaii State Department of Health, 2018). In addition, a Total Maximum Daily Load (TMDL) assessment was completed for the Ala Wai Watershed in 2002 which focused on the maximum amount of total nitrogen and phosphorus in surface waters (U.S. Environmental Protection Agency, Region 9 & Hawaii Department of Health, 2002). Too many nutrients can create algal blooms and other negative impacts to the ecosystem. The amount determined is based on the federal Clean Water Act to help support aquatic organisms and safety for recreational uses (U.S. Environmental Protection Agency, Region 9 & Hawaii Department of Health, 2002).

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Objectives:

The overall objective for my capstone project was to gather storm water samples from the Mānoa, Pālolo, and Makiki Streams. Using those storm water samples, I wanted to understand which stream was contributing the greatest amount of TSS during a storm into the watershed. TSS is sediment that is suspended in the water column and not on the streambed. Determining which stream was contributing the most TSS is important to better understand the watershed as a whole as well as identify future studies to add to data sets. The long-term goal of this study is to reduce TSS entering the Ala Wai Canal and improve the water quality of the watershed. There is no protocol for TSS sampling in the Ala Wai watershed, so providing researchers with a protocol and preliminary data set can be beneficial. The two main tasks that were completed for my capstone project were:

1. Develop a protocol for in-field sampling of storm water for TSS using an ISCO sampler.
2. Collect TSS data on the three main streams in the watershed (Mānoa, Pālolo, and Makiki Streams) and to compare these sediment concentrations.

Methods/Approach:

In-field Sampling

In order to sample at the streams, I had to choose locations for samples, find volunteers to help with sampling, and also determine when there would be a storm. I also had to create a protocol for how to sample during a storm. I used the app Windy to track rainfall and determine what time the storm would start. My original goal for the sampling duration was six hours, but due to limitations the sampling duration varied. Limitations included being able to predict storms, volunteers for hands-on assistance of water sampling, duration of storms, as well as sampling protocols. However, while sampling, the timing between each sample stayed consistent at 15-minute intervals. All of the samples taken for TSS were done manually. To take my TSS samples I used a slip knot to secure the bottle to rope. Each sample was taken in a 500 mL bottle. I dropped the bottle into the stream using a "dunking" method in order to get my sample. While filling the bottle the hardest task was not disrupting the streambed. Originally, I planned to use an ISCO Sampler to gather water samples for myself and SMART Ala Wai, but never got the opportunity to use the samplers in the field. However, I created a protocol for sampling using the ISCO Sampler which can be found in Appendix A.

I attempted to take samples numerous times however I was only successful in capturing one entire storm from start to finish. The storm that I was able to sample was on May 4, 2019. This will be the only storm data used for my results to determine which stream has the most sediment during a particular storm.

Sample Site Description

When I started this project, my goal was to have 5 sites to sample, three in the lower part of the watershed and two in the upper parts. The two upper locations were going to be in Mānoa and Pālolo, but due to limitations of volunteers and the sampling period, I only focused on the lower three sites. The reason for wanting upper as well as lower sampling sites to possibly show where the sediments are coming from (i.e. from the upper portion of the watershed or if the sediment is coming from the lower more urbanized areas). Land use could be a huge factor to understand where management efforts need to be implemented. The Makiki and Mānoa sites have USGS gages, the Pālolo site has a sensor that measures the distance from the sensor to the water. The three sites are located lower in the watershed and are indicated by stars on Figure 1.

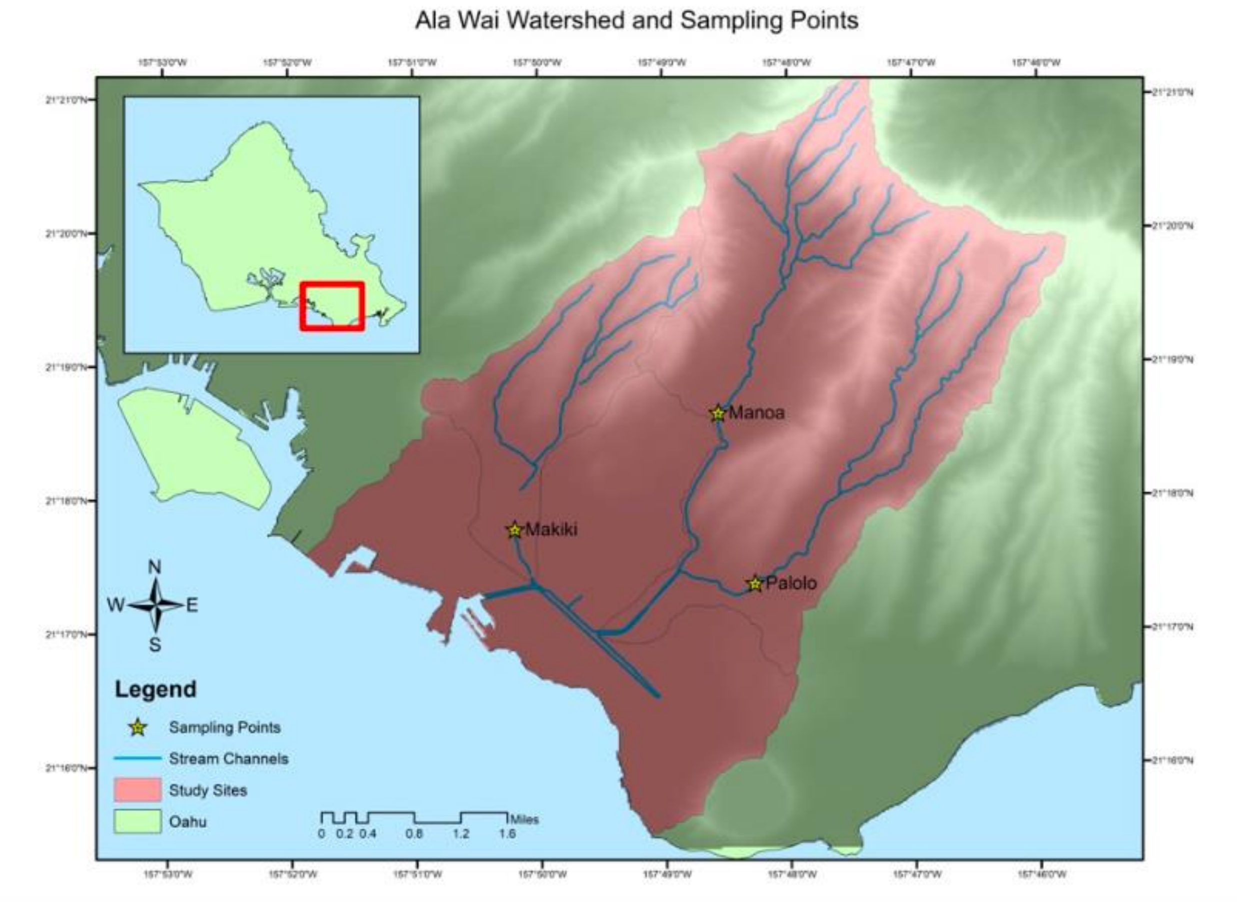

Figure 1. The layout of the watershed and where the three sampling sites are located in the watershed.

Mānoa Stream

The Mānoa Stream site is near the Woodlawn Bridge located next to Mānoa Shopping Center. The sampling site is also an Adopt-A-Stream location, where there are occasional removals of invasive fish as well as removal of non-native plants. There are several large trees in close proximity, larger stones in the water, as well as grasses and very minimal litter visible. I was responsible for sampling at this location every sampling event. During the sampling periods, I saw the stream water level rise and fall, as well as change color and visibility. On a side note, one of the sampling periods had no data from the USGS gage. Before I could call USGS to inform them, someone came to the site and had the gage up and running.

Makiki Stream

The Makiki Stream site is from the bridge next to the King St. bus stop. This location has a lot of human traffic. There are plants growing in the stream, but there is also a lot of plastics, trash, clothes, and other bulky items located in and around the stream. Out of my three sites this is the most difficult to get water samples from due to low flow and the fencing. This site had the greatest chance of disrupting the streambed while sampling because of distance between where we could stand as well as where the streamflow was. Sampling was done from the bridge majority of the time. However, the last sampling was done by one of my volunteers climbing into the stream.

Pālolo Stream

The Pālolo Stream site is located behind Saint Louis School's Track. Samples were taken in the non-channelized portion of the stream about two meters from the channelized portion. There was a lot of trash at this location, plastics, large metal waste, clothes, and other debris. We also encountered some foot traffic from people as well as students from Saint Louis School conducting school activities such as fishing and stream beautification. There are a lot of tilapia and other fishes in the stream. This location also has occasional maintenance to remove some debris and remove some of the foliage that surrounds the stream. At this location there are a lot of tall trees as well as grasses. Due to this site not having a discharge gage, a sensor measuring the distance from the water level to the sensor was installed. However, because of limitations due to time I was not able to use a flow tracker to be able to convert the data to discharge. Without being able to convert the data to discharge, I will not include data from this stream to determine which of the three streams was contributing the greatest amount of TSS during the May 4, 2019 storm.

In-Lab Analysis

In order to separate the TSS from the water samples, I had to fire fiberglass filters, weigh the filters, process 250 mL of each sample through an air vacuum, dry filters, re-bake filters and then finally reweigh the filters. The final re-weigh of the filters allowed me to get the concentration of TSS for each sample. A more detailed protocol and tools needed for this process was summarized by Eric Welch and can be found in Appendix A.

Translating TSS Data

After separating the sediment from the water samples, I was able to weigh the sediment to get the concentration (mg/L) per sample. Next step was graphing the relationship of the storm water discharge with the TSS concentration. This relationship is important in helping to understand the precipitation intensity and areal distribution, the rate and amount of runoff, floodwater travel distances and rates, spatial and temporal storage-mobilization-depletion processes of available sediment, and the rates and distances that sediment travel (Williams, 1989). When analyzing the graph, the data is qualitative and analyzed by temporal graphs in terms of mode, spread, and the skewness (Williams, 1989). Once the relationship is analyzed a regression curve is created from the data. Using the regression curve, I was able to compare that data with the area of the stream in order to determine which stream had the greatest amount of sediment in the storm water samples. Due to Pālolo, Stream not having a gage that measures discharge and due to COVID-19 I was not able to take flow measurements, I will not be analyzing the sediment concentration for this site.

Outputs/Results:

Figure 1 (a) and (b) shows the time series of discharge (Q, in cms, in blue line) and the Total Suspended Solid (TSS, mg/L, in red line) during the storm sampling between 9am to 3pm on May 4, 2020. As it shows, Mānoa stream had relatively large amount of the streamflow (0.14 – 1.66 cms) during this storm event comparing to the Makiki stream (0.015 – 1.34 cms), and the TSS concentration (mg/L) in Mānoa stream were relatively less (1.2 – 104 mg/L) than in the

Makiki stream (0.4 – 205 mg/L) (Figure 1). A simple linear regression was adopted to regress the relationship between TSS and Q for the respective streams. The regression relation for Makiki stream TSS(mg/L) = 194 (Q, cms) + 19.9) existed higher R^2 (= 0.6), comparing to the relation for Mānoa stream (TSS(mg/L) = 25 (Q, cms) + 11.4) with R^2 (= 0.18). This suggests the carrying capacity of suspended sediments in Makiki Stream was relatively less variable, compared to Mānoa Stream. The regressed relations were applied to the stream discharge to calculate the total TSS during this storm event (9am to 3pm on May 4, 2019). We found about 54286.63 kg (598.40 ton) of sediment was discharged by Makiki stream, and 634149.35 kg (699.03 ton) were discharged by Mānoa stream, during this storm (Table 1). It shows that Mānoa contributed more sediment to downstream during the sampled storm. When standardized by the watershed area, Mānoa watershed still contributed slightly more sediment to downstream.

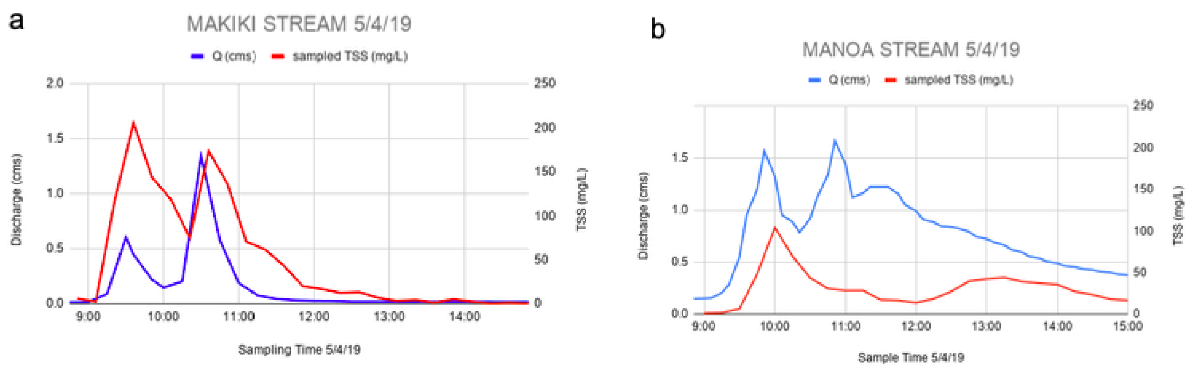

Figure 1. Time series of discharge (Q, cms, in blue line) and Total Suspended Solid (TSS, mg/L, in red line) during the storm sampling between 9am to 3pm on May 4, 2020 for (a) Makiki stream and (b) Mānoa stream.

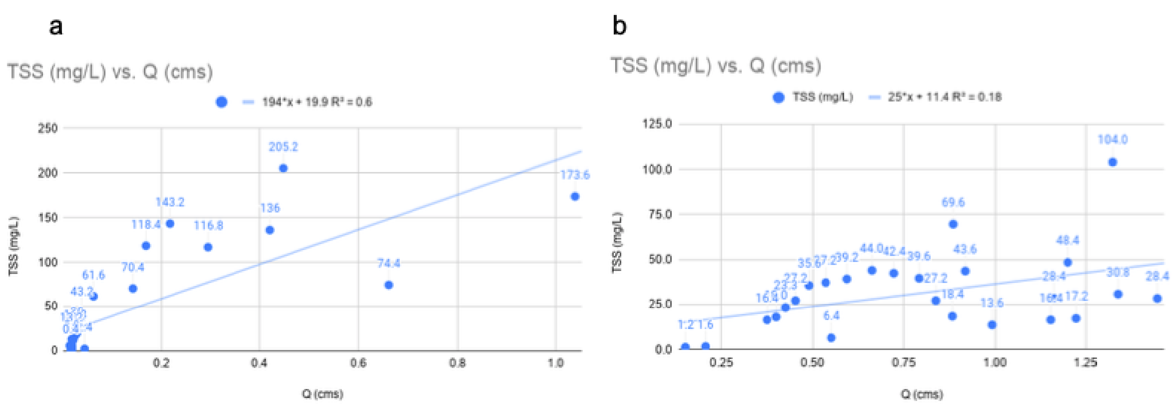

Figure 2. Linear regression between Total Suspended Solid (TSS, mg/L) and discharge (Q, cms) based on the storm sampling on May 4, 2020 for (a) Makiki stream and (b) Mānoa stream.

	Makiki stream	Mānoa stream

Watershed area	639.727ha	1108.515 ha^2
Total suspended solid during storm	598.404 ton	699.028 ton
Total suspended solid per contributing area	0.0849 ton/ha	0.0631 ton/ha

Table 1. The watershed characteristics and the estimated total suspended solid by each stream during storm 9am to 3pm on May 4, 2019

Interpretation/Conclusions/Outcomes/Expected Changes:

My capstone project gathering sediment in stormwater samples has never been done before and because of that there were many learning curves. My data is preliminary and there is uncertainty in determining which stream is contributing the most TSS due to only sampling one full storm. Due to COVID-19 I was unfortunately unable to go to Pālolo Stream to take flow rates to create a rating curve to analyze the sediment data and discharge. Comparing the three streams together for the May 4th, 2019 storm would have been very interesting. Comparing Mānoa and Makiki Stream during the May 4, 2019 storm, the data supported that Mānoa Stream contributed more sediment during that particular storm.

Another interesting item to look at is during the May 4th storm, Figure 1 has two discharge peaks in the data but for sediment only one stream has two peaks and the other only has one. Figure 1a represents Makiki Stream having two peaks in discharge and sediment, whereas Figure 1b represents Mānoa Stream only having a single sediment peak and two discharge peaks. My data and research cannot conclusively interpret or explain why this happened; however this is very interesting. More samplings during storms could make more concrete data and conclusive reasonings for this finding. There is also not enough evidence for me to assume that the two streams react differently to storms in the watershed.

In my field work I struggled with several limitations that can be worked on in future projects studying TSS data. Weather will always be a fluctuating factor, planning and preparing ahead for storms is not always a successful task. Future recommendations for studies that want to look into TSS in stormwater would be to have more members available to assist in sampling events, more sample sites, and to use the ISCO Sampler protocol that I created.

Having more volunteers available for sampling is something I would highly recommend. With more volunteers that are available, there are more opportunities for gathering data. During my sampling period there were times that there was rain- but I could not go out to sample, anticipated rainfall which later changed to no rainfall, and when there were storms but sampling was either too early or late. I originally wanted to have two people per site for safety reasons and to allow relief when one person had to leave. Having four to nine more volunteers would allow studies to include more than one site per stream to sample from. With more volunteers there are also more opportunities for allowing more than one sampling site per stream as well as assistance with using the ISCO Sampler. My project required a minimum of three people to sample because one person (minimum) was needed at each site. Each time I went out to sample. I had the minimum amount of people able to assist, which also meant that sampling duration varied because I had no one to switch off or replace the volunteer.

Having additional sampling sites would be extremely beneficial in understanding the watershed better and where management efforts would be most effective. When I originally took on this project, I planned for two sampling sites per stream. One site would be in the higher part of the stream as well as the lower section. I only had one lower sampling site per stream, but having an additional site per stream that is higher in location could help with understanding storms in the watershed better. Having sites in the upper parts of the streams would help with identifying future restoration and management efforts. Also, both high and low locations in the streams would allow for more studies to be done on the land use which could be a contributing factor as to how the TSS is ending up in the stormwater. Understanding and studying the land use could be an entire project in itself. Looking into the different areas of the watershed and land use could also help with management efforts and understand where sediment is entering the streams and how to reduce these loads before they reach the Ala Wai Canal. Management efforts that are done in the upper watershed will have positive effects on the lower parts of the watershed.

Lastly, using the in-field protocol for the ISCO Sampler would be something to try and implement in future studies. I never had the opportunity to use the automatic sampler but would like to see someone use the protocol I created. The ISCO Sampler could allow sampling to be done in timed intervals without having someone there. For this to be possible, the "bubbler" attachment needs to be fixed. When setting up the ISCO and calibrating the sampler, the bubbler was not working so leaving the ISCO out with no supervision was completely out of the question. The bubbler senses when the stream level rises and activates the ISCO Sampler to start taking water samples. The samples taken with the ISCO Sampler could also be less susceptible to disrupting the streambed due to the sampling tube being left in the stream in the same spot. The tubing is secured in the stream with dive weights in order for the opening of the tubing to not sway in the flow or dip down into the streambed. As mentioned previously, the hand samples had a great chance of disturbing the streambed during sampling which could create uncertainties in TSS concentration. Decreasing uncertainties would allow for more conclusive data and conclusions. Something else to point out is that the ISCO samplers are costly, leaving the machines unattended during sampling was something that I felt was a huge risk. I worried that someone would tamper, steal, or destroy, the ISCO if left in the field. Last thing to consider the ISCO Sampler needed a lot of prepping for all the gear to be able to sit in a storm. The sampler had a hood to cover the display, but the battery needed protection of the rain. Getting all the gear to the site too was a challenge because of the bulky size of the ISCO sampler.

Citizen science is essential for these types of projects and efforts to be successful. The SMART Ala Wai is a good example of citizen science, where the public works and participates together to understand and address problems. There is a clear need for understanding the watershed issues, especially during storms. Storms bring excess water into streams causing an increase in TSS which can negatively impact the watershed and travel all the way to the ocean. Management efforts done in the upper parts of the ecosystem can have a positive impact all the way to the lower parts of the ecosystem.

Being the first person to sample TSS in a watershed during storms was exciting and challenging. With my preliminary data I gathered and the in-field sampling protocol I created should help future studies be more successful in their research. There is a need for more studies because TSS is traveling through the streams during storms and can gather and settle in the Ala Wai Canal. The most recent completion of the Canal being dredged was in 2002, and took 17 years for the next dredging project to start. The most recent dredging project is going to cost about $21 million. Dredging the canal has shown to be extremely costly but also a necessity. Sediment will always enter the streams during heavy rains and through other natural processes, but efforts can be made to mitigate the problem of TSS traveling down the streams and settling into the Canal.

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Appendix A

Materials for in-field sampling, sedimentation gathering, and setup of ISCO for each site

In-Field Sampling materials:

ISCO 6700 (3 of them)
Suction Tubing total of 76 ft
5- 2lb Dive weights
3-3lb Dive weights
Sampling bottles for ISCO (24-500mL and 48-1L)
64-500mL hand sampling bottles per site
Timer
Pull-wagon
Car battery
Hand sampling pole
Rubbermaid container for battery

In-Lab Analysis materials:

Disposable Aluminum Dishes
Tweezers
Gloves
Suction Flask (1L)
Tubing to connect to vacuum
Vacuum
47mm glass micro-analysis filter holder
- -funnel
- -base
- -clamp

Glass microfiber filter disks 5.5 cm (0.7 um)
Furnace, ~100°C-~350°C

Large Volumetric Pipette (optional) or Volumetric Container (optional)
Desiccant
Desiccator
Balance Scale (capable of weighing to 0.01mg)
Distilled (DI) Water
Parafilm

ISCO Setup & Calibration for each site

-Mānoa:
1L ISCO
18 ft tubing
Programing for ISCO:
-4 m line for tubing setting
-980mL for volume of sampling
Dive weights: 1-3lb 2-2lb

-Makiki:
1L ISCO
18 ft tubing
Programing for ISCO:
-6m line for tubing setting
1000mL for volume of sampling
Dive weights: 1-3lb & 1-2lb

-Pālolo:
500mL ISCO
40 ft tubing
Programing for ISCO:
5.5 m for tubing setting
435mL for volume of sampling
Dive weights: 1-3lb & 2-2lb

In-Lab Analysis: (Summarized version of Eric Welch)

Preparation of Glass Fiber Filters

Use the Vulcan Oven for baking the sheets and samples. Place a sheet of tin foil (21x21cm) flat on the tray of the Vulcan Oven. Do not let the foil touch the coils in the oven. Place glass fiber filters on the foil sheet, do not let filters touch each other, about 10 can fit at a time per baking. Set the oven to ~350ºC (set at 3.5 on the white Celsius side of the scale), and then place the glass container with foil and filters inside for 3 hours. Shut off the oven after 3 hours and let cool for 24 hours. Once cool, use forceps to remove the filters and place on foil to create a pocket to take back to the lab. Place the foil pocket into the desiccator and store until sedimentation sampling.

Sediment Measurements using Filters

Using a scale that measures to milligram accuracy is needed for weighing the filters. Each filter will need a pre-weighed aluminum tray (labeled with corresponding sample number) that will be used. Place the filter that will be used for the sample with forceps onto the tared tray to get a “before weight” of the clean filter (without sediment residue). Log down the weight on the spreadsheet. Keep the filter in the same aluminum tray.

Set up suction flask and connect a vacuum to it. For each sample to be tested, use forceps to remove a prepped and weighed filter from the corresponding aluminum tray. Place filter on the base of the filter-holder, then clamp together with funnel, and set on top of the suction flask. Before running water through the filter, shake the sample bottle vigorously to let the sediment inside disperse into a colloid.

Measure 250mL of the shaken sample into the graduated cylinder. Transfer the measured sample of water into the funnel. Have the vacuum on to provide suction so the water will run through the filter. Once the sample has been filtered, remove all traces of water by continuing to apply the vacuum. Unclamp the funnel and base after every sample. With tweezers, carefully remove the filter and return the filter to the aluminum tray it was previously weighed in. Place the tray and filter into OL Model 10 oven to prep for heating. Rinse the volumetric container and the funnel between each sample. The suction flask is 1000mL which will allow up to four samples to be completed before emptying out. Run all samples from the field that were taken. After all samples have been filtered, dry in the oven for at least 1 hour at ~105^{o}C (turn knob to ‘5’). The oven takes about half an hour to warm up, total oven time will be 1.5 hours. Cool and dry in a desiccator for 24-48 hours.

Once cooled, weigh the filters (now with residue) on tare trays for their “after weights” and log these weights into a spreadsheet. On the spreadsheet, subtract the “before weights” from the “after weights,” to see how much TSS is present in each sample. Then divide this number by the Volume used to get TSS per liter or TSS per milliliter, depending on what is desired.