CORAL REEF ALLIANCE
NOAA CRCP FINAL REPORT
Report Period: **9/1/2019 – 4/30/2021**
July 31, 2021

A. Project Identifiers

1) *Project Title:* ***Improve Coral Reef Health by Expanding and Leveraging Stream Gulch Restoration Actions in Wahikuli, West Maui***
2) *NOAA Grant Award Number:* **NA19NOS4820116**
3) *Project Manager:* **Jennifer Vander Veur, Program Manager**
4) *Period Covered by this Report:* ***9/1/2019 – 4/30/2021***
5) *Program Officer:* **Liz Fairey**

B. Project Summary

The Coral Reef Alliance (CORAL) has worked to save coral reefs in West Maui since 2009. Our program centers on restoring the natural function of a watershed to filter stormwater and absorb nutrients, sediments, and other chemicals to ensure clean water for healthy reefs. This restoration effort is critical, as West Maui is designated a priority conservation site by both the state and federal government in an effort to address land-based pollution and corresponding declines in coral cover.[1] Several West Maui watershed plans identify erosion from degraded agricultural fields, dirt roads, and areas of bare soil as major threats to nearby coral reefs. Experts estimate that significant volumes of sediment are transported into stream gulch drainage ways from the degraded landscape and dirt roads.[2]

The Wahikuli-Honokōwai Watershed Management Plan recommended a number of management strategies to address the issue of sedimentation. In 2016, CORAL facilitated a Stream Restoration Knowledge Sharing Group that identified a suite of best management practices (BMPs) that can be executed to achieve this goal. After a reconnaissance survey identified dirt roads and road kickouts[3] along the top of stream gulches as significant contributors of sediment into streams, CORAL began to address the most problematic kickouts in the Wahikuli and Honokōwai watersheds utilizing a combination of BMPs. In 2017, CORAL began reducing erosion in Honokōwai Watershed by stabilizing the riparian buffer zone along the top of the stream gulch. Monitoring results showed that each kickout with BMPs prevented an average of 3 tons of sediment from reaching the stream gulch.

CORAL is grateful to the National Oceanic and Atmospheric Administration for this funding towards a successful stream gulch restoration project to ensure that the corals of West Maui are healthy and continue to populate nearby reefs in Maui, Lana'i, and Moloka'i. Specifically, NOAA

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[1] Coral Reef Assessment and Monitoring Program; Trends in Coral Cover 2012
[2] Oleson, K.L.L.; Falinski, K.A.; Lecky, J.;Rowe, C.;Kappel, C.V.; Selkoe, K.A. and White, C. (2017). Upstream solutions to coral reef conservation: The payoffs of smart and cooperative decision-making. Journal of Environmental Management 191, 8018. https://www.sciencedirect.com/science/article/pii/S030147971631060X
[3] A road 'kickout' is a standard road building and maintenance practice utilized on agricultural dirt roads nationwide. Kickouts are designed to channel stormwater off of the road surface (see aerial image photos). However, when used in Hawai'i in steep, highly erosive areas next to stream gulches, kickouts become major delivery mechanisms for sediment to adjacent gulches and hence to the nearshore environment.

provided funding for the installation of an additional 34 BMPs along a 1,000 ft. stretch of highly erosive stream gulch zone in the Wahikuli Watershed. We also advanced an effort to protect these zones from future development across West Maui and Hawai'i by raising awareness about this approach and worked with Maui County to identify a policy instrument to protect these areas from future development as a ridge-to-reef approach to mitigate sedimentation on coral reefs across West Maui and the rest of the state. CORAL will continue to monitor the effectiveness of the BMPs and share results with practitioners, funders, and decision makers.

The success of this project has been a stepping stone towards the overall goal to undo damage from industrial agriculture by reconnecting our forest from the mountain to the ocean in order to save coral reefs. CORAL is exploring several options for the next phase of the on-the-ground restoration work and we have a strong plan for the policies and monitoring necessary to scale up and sustain the impacts of the restoration. The work will require the following initiatives within the next 3-5 years:

1. Policy to Inform Scaling: CORAL plans to step-up our engagement of stakeholders at multiple levels to ensure that formal recommendations related to this work are included in both county and state plans. We are in the process of creating an engagement plan that will focus on:
    a. Local level (Maui County) - Identify and engage stakeholders who can influence land use, stream gulch buffers, and no development zones to ensure county plans and policy address these issues.
    b. State - Engage state-level stakeholders to create a mechanism to fund restoration projects over time and assign ownership. This may include the development of watershed councils to address key watersheds on each island and bring attention to restoration across the state.
2. Monitoring: Ensuring performance of existing BMPs is important because many of the plants can take 3-5 years to fully establish and reach maturity. Monitoring for plants that have the highest survival rates will help ensure sediment is stabilized. As trees mature, their canopies and root systems act as physical barriers that reduce raindrop energy and slow stormwater runoff, increasing in efficacy as trees mature and age. Monitoring will help determine which BMPs are able to trap the highest proportion of fine sediments; this is critical for future BMP placement to ensure these particularly damaging sediments do not reach our coral reefs. Finer grain sediments are more easily transported on land and resuspended once in the water column and can take a long time to fall out of suspension, which can result in sediments delivered to a reef during one storm event to cause repeated damage to the coral for months to years. By monitoring the effectiveness of BMPs, and their maintenance needs over a 5-year period, we can quantify the benefits of the BMPs in terms of tons of sediment retained on land, and apply adaptive management to future restoration work and guide appropriate management actions to restore Hawai'i's damaged watersheds. These results will be shared throughout Hawai'i as well as other Pacific Island jurisdictions.
3. Restoration: CORAL is in the process of assessing areas across Hawai'i that are considered problem areas - areas with high amounts of sedimentation - and are looking to NOAA's watershed priority areas to determine where our restoration project can expand.

Funding from NOAA positioned CORAL for the next phase of this work and we are actively pursuing additional funding to continue critical elements of maintenance, expansion, and policy work related to ridge-to-reef restoration. With additional support, we can empower communities to restore riparian buffer zones and advocate for permanent line items in the state budget to fund wider adoption and scaling up of watershed restoration projects.

C. Progress toward Objectives and Outputs

Objective 1: *Stabilize a highly erosive site in Wahikuli Watershed by installing 30 sediment reduction Best Management Practices (BMPs) within a 1,000 ft. x 100 ft. stream gulch area along the edge of Wahikuli Gulch.*

Funding from NOAA CRCP stabilized a highly erosive site in the Wahikuli Watershed and will eliminate a range of ~44.2-68 tons of sediment from entering the ocean each year. In total, CORAL installed 34 Best Management Practices (BMP) to reduce sediment moving across the landscape and entering Maui waterways. We installed a variety of BMP types including vetiver (*Chrysopogon zizanioides*), a non-native, sterile grass that has an extensive root system that is excellent at stabilizing soil, and coconut coirs--biodegradable logs made of coconut husks that excel at trapping sediment at steeper slopes. To promote the establishment of native plants and soil stabilization, we also planted Uki Uki (*Dianella sandwicensis)*, pili (*Heteropogon contortus*), and kawelu (*Eragrostis variabilis*). We have found from our previous restoration work that pili grows the healthiest when planted in double rows. In Location 7c, we installed 20 vetiver BMPs, 8 coconut coirs, 1 uki uki BMP, 3 double pili BMPs, and 2 kawelu BMPs. In addition, we planted 86 native plants in accumulated soil. Native outplantings included: 23 ‘a’ali’i (*Dodonaea viscosa*), 25 ilima (*Sida fallax*), 5 kamani (*Terminalia catappa*), 3 koai’a (*Acacia koaia*), 1 naupaka (Scaevola gaudichaudiana), 4 ohia (*Metrosideros polymorpha*), 6 uki uki, and 6 wili wili (*Erythrina sandwicensis*).

CORAL successfully stabilized and restored a degraded agricultural road and stretch of fallow land closest to an intact native forest. Restoring a riparian buffer zone in this area will extend the native forests down the mountain and slow the velocity of stormwater near the ‘headwaters’ of the degraded roads that formerly allowed the initial velocity of the stormwater to build. This section of decommissioned road is less than 5ft from the edge of the gulch and also connects to a road that crosses the stream. By installing BMPs in this area, we reduced the volume, velocity and erosive properties of the stormwater running through this area, and increased the native plant cover within the riparian buffer zone. We also seeded the area with native plant ground cover which over time will further serve to stabilize the area and prevent sediment from entering West Maui waterways and nearshore environment.

CORAL’s approach for stream gulch restoration includes ensuring that the BMPs are installed and managed so that they are effective in the long-term. Within the scope of this project, we expanded the existing catchment area and installed an additional catchment area, leveraging funds from another grant. The additional catchment area will provide water for the native seedlings outplanted, helping them establish and thrive, and ultimately re-establish the native plant community in this degraded landscape.In addition to expanding these catchment areas in location 7 we built a catchment system for our Location 5 restoration area as well as the Maui Animal Farm.

CORAL is able to achieve the objectives of this project with the support of dedicated volunteers and partners. For this reason, volunteer engagement is increasingly important as we look to expand our impact. Throughout the project period, we held several volunteer days, including five field days installing BMPs, three days at the Maui Animal Farm planting and building the Hawai'ian native garden, one day at the Pacific Biodiesel greenhouse planting seeds and transplanting, and two contractor days installing BMPs. We also hosted four outreach events to kickoff and manage a program for volunteers to grow native plants from seed at home.

Our project partners include Pacific Biodiesel, Maui Animal Farm, The Westin Nanea Ocean Villas, West Maui ridge-to-reef Initiative, and Maui Nui Botanical Gardens. Pacific Biodiesel and Maui Animal Farm have been key partners, helping us to achieve the following:

- Leveraging our partnership with *Pacific Biodiesel*, we now have a 1,000-square foot nursery space within one of their donated greenhouse spaces we are using for expanding our plant inventory. We can use this space to hold our volunteer days to continue growing our volunteer program. We planted just over 7,500 seeds at this site, and can easily transplant them onto our restoration sites when needed. The volunteers have currently returned over 1,500 plants that are now growing at the greenhouse. We have been able to outplant 155 pili grasses and 22 kawelu grasses that volunteers have grown, resulting in $650 in cost savings.

- CORAL has partnered with *Maui Animal Farm* to create an educational space including a kiosk and picnic tables. Within this project period, we continued to expand the educational site. The animal farm provides tours, giving visitors an opportunity to learn and feed the animals they house. The tours now include a stop at CORAL's nursery to share information about our partnership and how we will use the native plants to restore local watersheds. Through this partnership, CORAL can host volunteer days, care for the plants, check on irrigation needs, and help with the animal farm as a give-back. The education kiosk provides in-depth content on coral reefs, their main stressors, CORAL's work to restore the watersheds of West Maui, why native plants are important, and how volunteers can participate.

Funding from NOAA CRCP contributed to the completion of the following activities related to project Objective 1:

Activities completed

- Land clearing and an initial site survey of BMP survivorship and sediment retention
- Engaged partners for advice on planning the appropriate location of BMPs
- Surveyed slope and contour for the placement of 34 BMPs
- Extended the catchment area at Location 7b
- Built a new catchment area in Location 5
- Volunteer Days accomplished:
    - 5 in-field planting days

    - 3 days at the Maui Animal Farm
    - 2 contractor days
    - 1 at the Pacific Biodiesel greenhouse
    - 2 data collection days
    - 8 total data collection days
- Added more plants and planting thousands of seeds at a greenhouse to continue growing our plant inventory for future BMP and native plant row installations
- Maintained volunteer schedules to ensure plants are watered daily
- Conducted site surveys of BMP survivorship and sediment retention in August 2020 and March 2021 for 7c
- Conducted one site visit each with University of California, Berkeley and University of Hawaiʻi, Maui students and faculty
- Hosted four outreach events for volunteers to pick up their at-home planting kit
- Participated in two outreach opportunities; one at Whale Tales in February 2020 and one at Down the Hatch passing out planting kits in September 2020
- Continued expansion of the educational area at the Maui Animal Farm

Objective 2: *Quantify the effectiveness of stream gulch restoration along Wahikuli Gulch.*

CORAL is deeply grateful to NOAA CRCP for investing in this project because it has enabled us to gather stream gulch restoration data. Monitoring the effectiveness of our restoration actions to retain sediment on land and reduce sediment load throughout this project period gave us key data to inform future conservation and restoration work in Maui. We know that our BMPs were effective due to the data provided in the "Monitoring Data Summary for Phase 1 of Location 7c" showing preliminary results at Location 7c and at our more established restoration site in Location 5 (Appendix 1). In addition, the native plants have successfully begun to develop seeds, helping to further increase the native plant population in the area, and downslope of this restoration work.

To further quantify the effectiveness of our BMPs, we installed four erosion transects to record baseline sediment loss between Locations 6 and 7; two within Location 7, one at the intersect of Location 7 and 6 and one at the bottom of Location 6. These erosion transects were surveyed prior to BMP installation for baseline data, and annually after BMP installation. The one at the top of Location 7 was damaged by dirt bikers and we replaced the damaged BMPs. Two surveys of each transect were taken and then measurements were averaged to assess the erosion rate of the degraded dirt road both before and after restoration efforts. Initial comparisons of the erosion transects showed erosion is occurring at an average rate of 10% outside our restoration area, and land accretion is occurring at a rate of 3% inside of our restoration area. This suggests that our restoration work is already successful as it not only stops erosion, but also increases the amount of sediment on the dirt road.

The sediment collected by these BMPs will continue to be monitored for the next 2-3 years. Data collection will include the health of BMPs and individual plants, sediment collection by BMPs, and grain size analysis to assess what sizes of sediment are being trapped by the BMPs. In addition, we will monitor rainfall to better understand the impacts of stormwater mobilizing sediment across the landscape. However there is also the possibility of stormwater mobilizing ‘legacy sediments’ within the streams and streambanks. The Environmental Protection Agency (EPA) defines legacy sediment as soil “that was eroded from upland areas after the arrival of early settlers and over the centuries of intensive land uses”, such as agriculture. This sediment accumulates along stream corridors, building up higher and higher as the years pass. In Maui, legacy sediments are deep piles of sediment that were historically bulldozed into stream gulches when ridgetops were flattened to create areas for industrial agricultural cultivation. Today, the legacy sediment in the gulches distribute brown water in the ocean following storms events.

To understand how legacy sediment contributes to turbidity in stream water and the input to near shore environments, we installed erosion pins within the Wahikuli Stream Gulch. Calculating the rate of stream erosion in the gulch will tell us how fast stream erosion is occurring, and may provide insight into whether it is a significant source of sediment found on coral reefs. The Wahikuli stream was divided into three sections: Upper, Middle, and Lower. Within each section, one location of erosion pins was established. The location of erosion pins was determined by both accessibility and where erosion was seen on both sides of the stream bank. Once a suitable location was found, the erosion pins were installed on either side of each bank at each location, in a vertical line from the foot of the stream to the top of the bank and about 5-centimeters apart. Pins were pushed into the stream bank until they were flush with the bank (with 0cm showing) at initial installation. Additionally, on each side of the bank, a 12-centimeter nail was placed with hot pink flagging tape to mark the location. We will measure the installed pins every 6 months to show us any potential difference between the wet and dry season erosion.

The combination of sediment retention onland and streambank erosion and how that correlates to rainfall will demonstrate the amount of rainfall needed to mobilize sediment both in fallow agriculture land dirt roads and ‘legacy sediments’ within the streams. This will determine how much each of these areas are contributing to the sedimentation of nearby coral reefs. In addition, this monitoring will determine the restoration strategies that function the best over time, are the most effective at stabilizing fine sediments, and are the most economically feasible to scale up for riparian buffer zone restoration activities in other areas.

Funding from NOAA CRCP contributed to the completion of the following activities related to project Objective 2:

Activities completed

- Installed four road erosion monitoring transects between Location 6 and Location 7
- Completed 2 data collection days for location 7c
- Updated and added results to Data Summary Report outline
- Installed 3 transects for stream bank erosion monitoring

Objective 3: *Leverage monitoring results from restoration sites to raise awareness among conservation practitioners and decision makers across Hawai'i about the benefit of restoring and protecting stream gulch zones from future development; and identify a policy instrument to ensure state-wide adoption of this approach.*

Funding from NOAA CRCP positioned CORAL to demonstrate the importance of stream restoration and educate the community, county, and other stakeholders on how to create meaningful impact at scale. We were delighted to leverage this federal funding for a broader impact and leverage local funding to achieve the restoration outcomes necessary to protect coral reefs.

As a result of our engagement in the West Maui Community Plan (also referred to as “the Plan”), we are thrilled to report that our list of recommended policies was included in the draft Plan. The Plan now addresses specific priority areas, including the gulches of West Maui and an area of land adjacent to our current project. Gulches are identified as an “Area of Stability” in the Plan, signifying their importance: “As water moves through these gulches, it picks up soils, decaying plant matter and any contaminants it comes into contact with. Prohibiting development and impervious surfaces in these areas ensures that the water that runs through the gulches is filtered and treated by vegetation and soils, recharges the aquifers, and comes out as clean as it can be before it reaches the reefs. Additionally, protecting these natural drainage ways and adjacent floodplains from development helps to reduce the risk of flooding.”[4]

Through our engagement with the West Maui Community Plan, CORAL has been asked to consult on the Kahana Solar Farm project and provide input on the site design. As a result of our involvement, the Kahana Solar Farm altered their designs to include stream gulch buffers and will be incorporating other recommended BMPs including a native plant habitat adjacent to the solar farm.

An ongoing challenge to restoration is access to privately owned land. Therefore, as part of our community engagement activities, we brought County Planners to our restoration site and explained our access challenges as well as the need for both stream gulch and in-stream restoration. We were pleased to see that as a result, the Plan now includes a County proposal to purchase and designate 97 acres of private land upslope (*mauka*) of Honoapiilani Highway, between the Lahaina Civic Center and Wahikuli Gulch, for future park and open space uses. This County action would enable restoration of this area as a way to improve water quality along the shoreline near Hanaka‘ō‘ō Beach Park. We were also pleased to see that the community has expressed support for the County’s proposal to purchase private land. We believe CORAL's engagement activities with County planners, coupled with our broader engagement with the local community, were instrumental in obtaining support for these important Plan components. Purchasing the area adjacent to our current sites will allow us to create a restored county park that educates the community on the need for riparian buffers and provides the opportunity to enjoy a restored area. The Plan also includes direct action items that highlight funding and support for restoration as high priority.

CORAL staff participated in the Hawai'i Island Sustainability Summit and we engaged with a variety of restoration practitioners, sharing our idea of a watershed council for each island, which was widely supported. Through this event CORAL staff also established new connections and garnered support for our goal of increasing funding to scale riparian buffer restoration efforts throughout the Main Hawai'ian Islands. CORAL also started communications with the 30x30 Initiative representative for both the watershed and coral reef components to share what we have learned and to contribute to the discussion and decisions to protect watersheds and coral reefs.

[4] https://westmauidraftplanreview.wearemaui.org/wp-content/uploads/2021/01/1.21.21-MPC-Draft-Plan-Online.pdf

A persistent challenge with our restoration effort at the site is from dirt bikers riding through the restoration area and damaging BMPs. This damage reduces the effectiveness of restoration and increases maintenance costs. We aim to encourage bikers to use alternative routes. To engage them in our work, we invited them to participate in planting events and the ‘at-home planting kits’ project, and met with active members of the dirt bike community. We identified one individual who agreed to lead the engagement process and has been very helpful in shaping messages and methods so as to be most effective with the biking community. This individual has also agreed to distribute mud cookies (soil and mud with native plant seeds in them) to fellow bikers so that they can disburse them throughout the landscape during their rides. Through biker feedback we have been discouraged from creating a design guideline as it will not be used by the community. We have found a much more effective approach is to directly engage with bikers on site, and to provide signage with information and alternative routes. We also found that a fence with simple signage of ‘Native Forest Restoration’ effectively decreased the number of bikers riding through restoration sites.

Finally, we created an online story map in GIS about how important watershed restoration is to the marine environment. The story map includes links to our data and information about participating in our restoration projects. With the restrictions of COVID-19, this is a great user-friendly resource to share information through pictures and maps. These data will be updated monthly so partners and students can access it for educational purposes. This link to the GIS story map is here: https://arcg.is/1jiaym

Funding from NOAA CRCP contributed to the completion of the following activities related to project Objective 3:

Activities completed

- Developed a COVID-safe volunteer engagement plan and distributed tree kits throughout the community.
- Conducted an educational live online Zoom presentation, teaching volunteers who picked up their planting kit how to plant their variety of seeds. We recorded it and used it for those who signed up later.
- Developed a dirt bike trail engagement plan, worked directly with bikers, installed signage, and constructed fencing to protect the site. Also produced a flyer, inviting dirt bikers to attend an online meeting.
- Educated Maui County officials and the West Maui Community Plan Action Committee on the importance of stream gulch protection.
- Developed a native plant guide for volunteer briefing, education, and engagement
- Developed a COVID-safe volunteer engagement plan and distributed grass and shrub planting kits throughout the community.
- Created an educational video to guide volunteers through planting seeds in ‘at-home planting kits’ and how to follow the Hawai'ian moon calendar.

Outputs

- Created educational resources to engage local stakeholders in supporting restoration efforts including:

  - Native plant planting kits and associated educational resources providing information on how to successfully propagate seeds
  - Poster to educate bikers about the restoration site and alternative biking routes
- Increased volunteer participation with over 130 people volunteering remotely to grow native plants at home. This includes the grass kits we started last year and the new tree kits we passed out in March and April.
- Ensured the draft of West Maui Community Plan and the Department of Hawai'ian Home lands includes steam gulch protection.
- Ensured that the Kahana Solar Farm project will preserve vegetation around gulches and has included riparian buffers within the development plan as well as BMPs and native plantings within these gulch setbacks
- Created an online Story Map in GIS. It also links our data that are updated monthly so partners and students will have access.

D. Conclusion

Support from NOAA has been critical to successful stream gulch restoration in West Maui and will inform future replicating and scaling of this work across Hawai'i. As soon as CORAL successfully installed the BMPs in the Wahikuli Watershed, they immediately started accumulating sediment after storm events. We were not only able to gather data needed to inform future efforts, but we also learned many lessons that will benefit future restoration and policy instruments that guide how restoration projects should be implemented across Hawai'i. Solutions for restoring Hawai'i's degraded watersheds due to abandoned industrial agriculture will help expand our native forest, reconnect fragmented landscapes, and ultimately help protect our coral reefs from the damaging impacts of brown water events generated from excess sediments in our coastal waters. Tested, monitored, and vetted solutions such as these will help the state of Hawai'i reach both of the 30x30 challenges for watershed restoration as well as coral reef preservation.

CORAL's stream gulch restoration project has highlighted the importance of adaptability and partnership in our work. Without being willing to adapt to the circumstances of the COVID-19 pandemic and relying on support from our partners, we would not have been able to achieve project objectives and activities.

The community engagement component of our work has helped us identify where we can scale this work across other sites in Hawai'i and communities that would welcome this type of restoration project. With funders who are invested in our mission, we hope to support these replication efforts in the long-term. Community engagement through our volunteer program is also important because when there are policy instruments developed, people in the community will have participated in the process and feel more vested in this work. In alignment with the state's coastal zone management plan, we also intentionally integrated and elevated traditional ecological knowledge (TEK) into our restoration work. For long-term sustainability, we looked to the solutions of the past to inform our BMPs. By planting native plants where they best thrive, we are helping to restore the ecosystem to its native ecology and function.

The on-the-ground component of this project helped us to understand the amount and type of resources required for sucessful installation of BMPs. By experiencing challenges like underestimating the amount of water that would be needed to sustain BMPs, helped us to identify where we needed to expand catchment areas. Using native grasses proved to be more effective in jump starting the functionality of the ecosystem. Attempting a new approach for installation, hydroseeding, we were able to further reduce erosion rates and improve the health of the forest.

We also learned that we need to keep monitoring to understand what a successful ridge-to-reef restoration program looks like. We know it requires at least a 5 year investment because that's how long it takes for trees to become established. As trees establish their canopies and root systems to provide physical barriers to slow water, the trees are then able to absorb and infiltrate this storm water, excess nutrients while capturing carbon. In the few years we have been installing these BMPs, we have observed the BMP efficacy increase with time as more sediment fills in spaces the water moves through finer grain sediments that are able to fall out of suspension. By observing these BMPs over a period of 5 years, we will be able to determine which function the best, retain the most fine grain sediment, which are the most robust and resilient, and which will require the least amount of maintenance. As part of growing and innovating, we remain open to the many various ways of knowing and monitoring the effectiveness of our efforts on the ground. By reflecting and adapting what works best or how we can do things better, we consider new methods and technologies to help us iterate and enhance the effectiveness of our work.

In order to say that we have restored an entire watershed, we have learned that we need to be creative in navigating issues of land ownership. If a specific "hotspot" with high rates of sedimentation is located on private land, then there are unique challenges in implementing BMPs. And these "hotspots" are the areas where we will get the biggest impact for our investment.

We recognize that restoring the land is an intensive and expensive proposition. However, this work is critical and cannot be ignored as the benefits accrued by reducing sedimentation at the source is well worth it as it pays back many times over. Given the long residence time of fine sediments on a reef, the threat of a single particle of sediment can keep "cutting" the reef many times over before it is flushed off the reef, if the coral survives at all. We cannot afford inaction and we know the best return for our resource allocation is to work upstream and to scale up our impact. Clean water for reefs is the single biggest helping hand we all can give to reefs to give them a fighting chance so that they can not only survive, but adapt, evolve and thrive into the future. And while this critical support from NOAA has helped us achieve sediment reduction within a watershed, it must not end there. There is momentum to scale up this important work by broadly engaging with many other partners. We cannot do it alone and to scale up this work's impact, we truly need to embody the "Alliance" in our name and effectively engage, convene and collaborate with many stakeholders and partners. We have built up a strong foundation and critical mass in expanding this restoration work. It truly takes an ahupua'a to restore the land, and in doing so, we will have healthier oceans. This work underscores the interconnectedness of our island ecosystems and absolute necessity to work upstream as our future and well being depends on the health of the ocean.

With the groundswell of biocultural approach to conservation or mālama ‘āina ethos across Hawai'i, there is increasing equity and awareness across all sectors that the health of the ocean begins with the health of the land and everybody has a role to help lift and make an impact.

CORAL believes that there are many on-ramps to conservation that are long and gradual, like ridge-to-reef restoration, but which cannot be underestimated in terms of lasting impact. It will take sustained ongoing measures and we can’t do this without continued generosity from partners like NOAA. Thank you again for your belief in and support of our work.

Attachment: 7c Monitoring Report summary: https://coralreef.egnyte.com/dl/F5hToTWJvF

Appendix 1: CRCP Monitoring Data Summary Report For Phase 1 of Location 7c

Length of grant: 9/1/2019 - 4/30/2022

Introduction

Restoration and Study Area

CORAL's main restoration work occurs in the West Maui Wahikuli watershed. The Wahikuli watershed has significant archeological sites, but upon the advent of commercial agriculture on Maui, the lands surrounding Wahikuli were used for sugarcane and pineapple farming. This intensive farming led to the construction of roads, inputs of sediments into the streams, increases in nutrient inputs from fertilizers, and high erosion rates from degraded landscapes overrun with invasive species.

This report will focus on CORAL's Wahikuli restoration site, specifically at a location designated "Location 7c." This location is at the highest elevation, has the steepest average slope, and receives the most amount of rainfall in the Wahikuli restoration area. Throughout the report, we will compare the preliminary results from Location 7c to our more established restoration site in Wahikuli, named "Location 5." This location has slight differences in geography, but provides we predict that our BMPs in Location 5 will act similarly in Location 7c in terms of efficiency.

Restoration solutions

CORAL engaged with local experts through field visists, extensive discussions and the West Maui Roundtable for reducing sediment transport. Together, experts identified a suite of potential solutions to the two key sources of pollution that have been identified:

- Landscape erosion and sediment transport to streams
- In-stream legacy sediment 'fill terraces' found along stream banks.

CORAL's monitoring plan is designed to measure the impact of practices implemented along stream gulches to mitigate this landscape erosion and sediment transport to streams. A detailed description of the best management practicess (BMPs) implemented can be found in our "Standard Operations Procedures" at www.coral.org/maui

In summary, our BMP solutions that mitigate landscape erosion and sediment transport to streams include but are not limited to:

- Vetiver and native plant sediment traps in road kickouts
- Vetiver and native plant sediment traps to decommission old agriculture roads

- Hillslope stabilization using vetiver and native plants
- Coconut coirs and check dams

After restoration planning and design, BMPs are implemented in three distinct phases, each specifically designed to become more effective over time as native vegetation grows and stabilizes sediment in place:

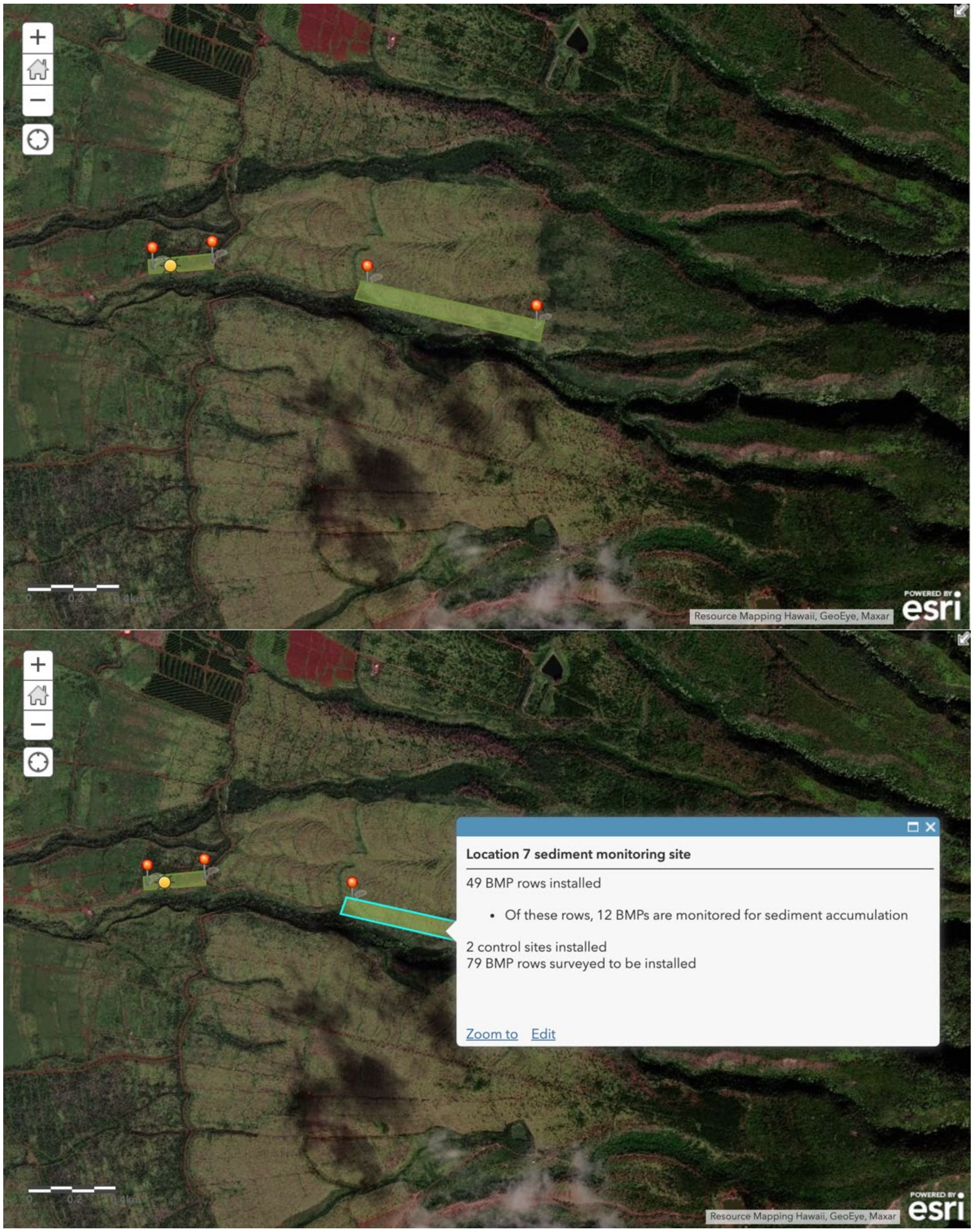
Restoration Planning and Design: Plan land preparation, elevation surveys and coordinate restoration logistics

Phase 1: Prepare land, install irrigation system, install vetiver and native grass rows and check dams to trap sediment

Phase 2: Vegetate captured sediment with native plants to increase efficacy and durability

Phase 3: Adaptively manage restoration design to increase effectiveness and monitor impact

Location 7c was installed with prior CRCP funding. Methodologies for all monitoring efforts can be found in the West Maui Watershed Restoration Effectiveness Monitoring Methods & Plan. We are currently wrapping up Phase I in our Location 7c area, and the results depicted in this document reflect the outcome of Phase I. The map on the next page shows where our monitoring site is geographically located and the progression of restoration efforts inside Location 7.



Map 1. Red pins signify the start and stop of Location 7 (upper) and Location 5 (lower). The sun signifies our Skye Instruments Minimet Automatic Weather Station. Top picture depicts geographic location of the Location 7 restoration area. Bottom picture includes a description of progression of restoration efforts.

These restoration efforts are monitored by monitoring sites including sediment accumulation, erosion rates, sediment grain size, native plant survivorship, and rainfall volumes. We do this to evaluate the effectives of both our BMPs and our overall restoration efforts.

Monitoring results

Sediment Accumulation

Phase I of our restoration project includes survey events for sediment accumulation of newly installed restoration sites every 3 months, and after heavy rain events. Restoration efforts began at Location 7c in January 2020, and the first survey event took place on April 22, 2020. To date, there have been 6 full survey events of Location 7c. These survey events include 4 regularly scheduled monitoring dates (every three months) and two additional monitoring surveys after heavy rain events. Below you can find a table on survey date and survey type. We are monitoring 24.4% of the BMPs we have installed. This is due to personal and financial constraints, and within this 24% we are including representation of each type of BMP types. Out of the 49 BMPs in Location C, 12 of the BMPs are monitored by sediment posts.

Survey Date and Name	Survey Type	Sediment Accumulation (Estimated)	Sediment Accumulation (Extrapolated)	# of Monitored BMPs
4.22.2020 (S0)	Scheduled Event	0.3 tons	*	5
7.30.2020 (S1)	Heavy Rain Event (27.4 mm of rainfall)	0.4 tons	0.5 tons	12
8.20.2020 (S2)	Scheduled Event	0.3 tons	0.4 tons	12
11.20.2020 (S3)	Scheduled Event	0.02 tons	-0.04 tons	12
2.8.2021 (S4)	Heavy Rain Event (20.4mm of rainfall)	0.4 tons	0.6 tons	12
3.4.2021 (S5)	Scheduled Event	0.3 tons	0.5 tons	12
5.20.2021 (S6)	Scheduled Event	0.4 tons	0.6 tons	12

Table 1. Survey name, date, and type are detailed in the left half of the table. Sediment accumulation (Estimated) is the sediment footprint created using the length of the sediment posts. Sediment accumulation (Extrapolated) is the sediment footprint created using the length of the BMP row. The # of monitored BMPs increased after the first survey event after Location 7c was further restored, and influences how much sediment accumulation is monitored.

Sediment Accumulation values represent the amount of sediment calculated at each individual survey event. We have extrapolated that there are 0.6 tons of sediment accumulated behind our 12 monitored BMP rows in Location 7c at our last survey date. This number was calculated by taking measurements from sediment posts (that were installed at the same time as the BMP row that will be monitored) and converting these measurements to tons. To understand how much sediment we have accumulated at our last survey event for the entire site, averages of sediment accumulation across the monitored BMP types were taken. These averages were then multiplied by the number of each type of BMPs installed at Location 7c to find the estimated accumulation in all of 7c. To date, we estimate that 1.5 tons of sediment have accumulated at our BMP rows in Location 7c. This process is detailed in the table on the next page.

BMP Type	Average Extrapolated Sediment Accumulation at most recent survey event	Number of BMPs in 7c	Estimated Accumulation of all of 7c
Vetiver	-0.1 tons	28	-0.6 tons
Coconut Coir	0.04 tons	9	0.8 tons
Uki Uki	0.1 tons	3	0.6 tons
Double Pili	0.1 tons	8	0.5 tons
Kawelu	0.04 tons	3	0.2 tons
		Total Estimated Accumulation for all 49 BMPs in 7c	1.5 tons

Table 2. Calculations to determine the estimated sediment accumulation across all of the BMPs installed in Location 7c. Sediment accumulation (Extrapolated) is the sediment footprint created using the length of the BMP row. To date, we estimate that 1.5 tons of sediment have accumulated at our BMP rows in Location 7c.

A detailed analysis of accumulation rates at each monitored BMP row can be found below.

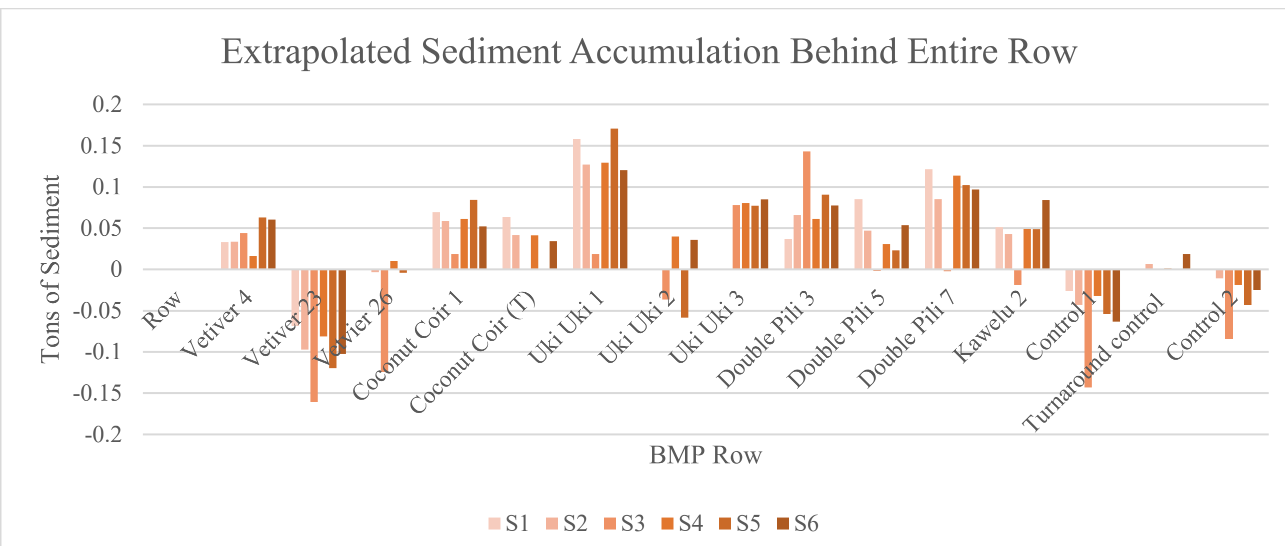
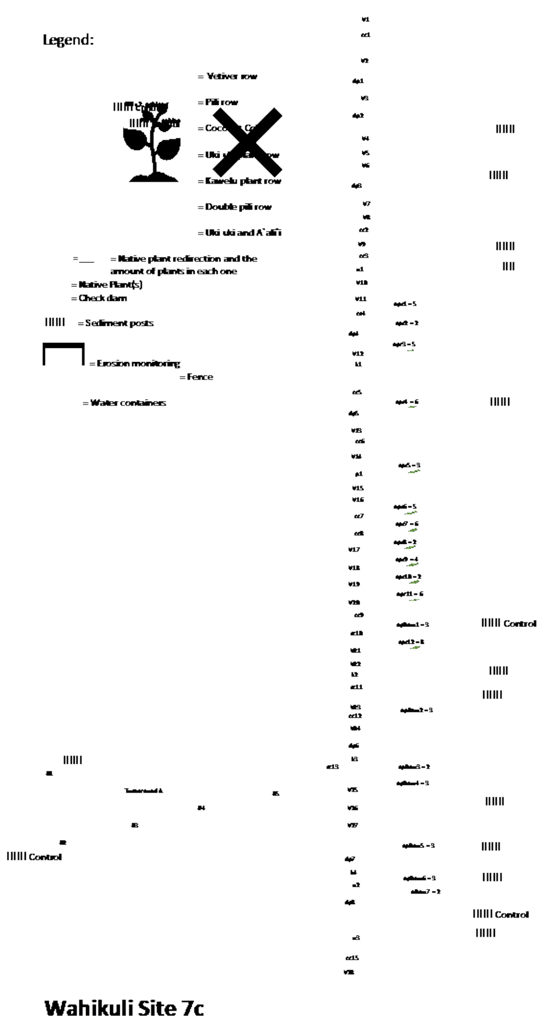


Figure 1. Histogram of sediment accumulation for each monitored BMP row at each survey event. Totals are a sediment footprint behind each BMP row, calculated through measurements of sediment posts at the BMP row.

There are a couple of different factors that we hypothesize affect the efficiency of our BMPs at catching sediment. The first is the season. During the wet season, more rainfall moves through the site and therefore more sediment is carried down the slope. Survey events S3, S4, and S5 occurred during the wet season, which could explain why on average we see more sediment accumulation at those dates. Survey event S6 occurred directly after the wet season. Additionally, due to dirt bikers riding through the restoration sites, some of the BMP rows have breaches. We also have BMP rows that have some plant death occurring. These two factors could account for the loss of sediment between surveys. Even with this sediment loss, we estimate our restoration site has the efficiency needed for successful restoration and sediment trapping.

Erosion Rates

Erosion pins were installed at the top and bottom of Location 7c. At each erosion pin, 10 measurements are taken from a permanent rebar, from the top of this rebar to the ground below. These 10 measurements are taken in a horizontal line to create a picture of erosion across the dirt road. Surveys are completed yearly and provide insight into the erosion rate of the degraded dirt road both before and after restoration efforts take place. The erosion pin at the top of Location 7c is installed above any BMP rows, and will give us information on the natural rate of erosion of Location 7c. The erosion pin at the bottom of Location 7c, when compared to the top erosion transect, will tell us how efficient our BMPs are at slowing erosion rates in this restoration area.



Map 2. *Wahikuli Site 7c.* Description of BMP and erosion pin locations. The erosion pin at the top of Location 7c is placed above all restoration work. The erosion pin at the bottom of 7c is placed at the end of restoration work.

Measurements began on March 30, 2020 and will be taken every year in March. Our most recent erosion pin survey took place on March 4, 2021. To date, these are the only two surveys that have been completed. The results from these surveys are below. We had previously installed erosion pins at these locations on January 9, 2019, however, we had to install new pins in January 2020 after dirt bikers ran over the original erosion pins. Due to this incident, our erosion pin measurements begin at March 30, 2020, after restoration work had already begun.

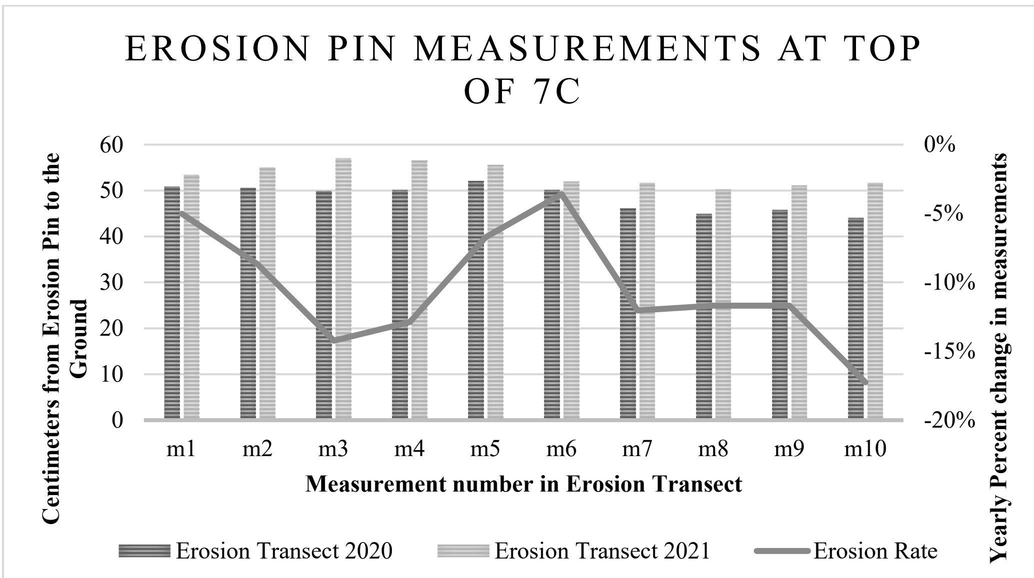


Figure 2. *Erosion Pin Measurements at Top of 7c.* 10 measurements were taken from numbered locations on a permanent rebar from the top of the rebar to the ground in March of 2020 and in March of 2021. Yearly percent change in the measurements was graphed on the secondary y-axis. Percent change was negative for every location, indicating erosion is occurring across the unrestored area of the road.

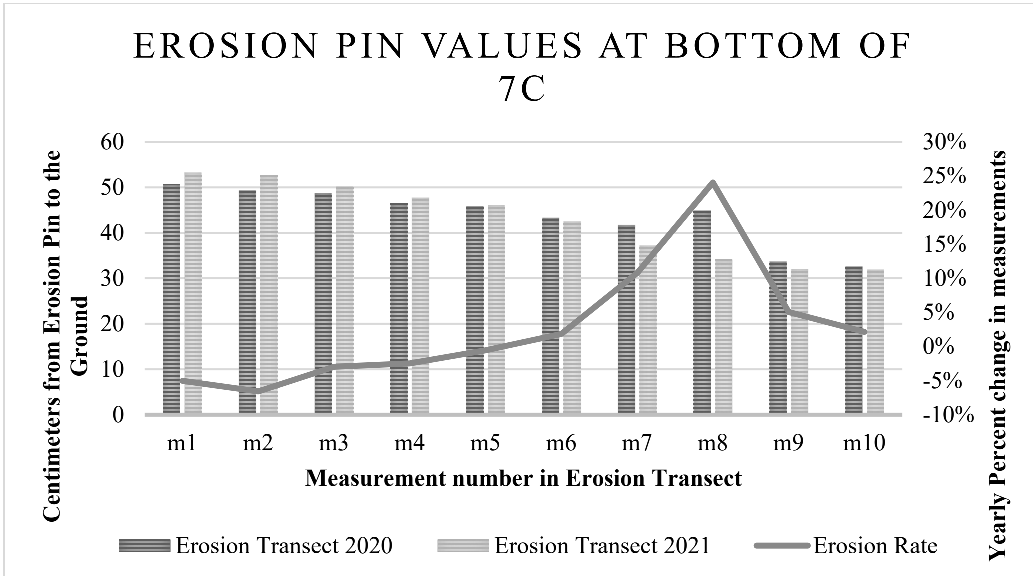


Figure 3. *Erosion Pin Measurements at Bottom of 7c.* 10 measurements were taken from numbered locations on a permanent rebar from the top of the rebar to the ground in March of 2020 and in March of 2021. Yearly percent change in the measurements was graphed on the secondary y-axis. Percent change was positive and negative, with a net positive change. This indicates land accretion is occurring across the restored area of the road.

From these erosion pin measurements, erosion rates were calculated for each individual measurement. The average of the 10 erosion rates at each erosion pin were then taken, and are represented in the graph below.

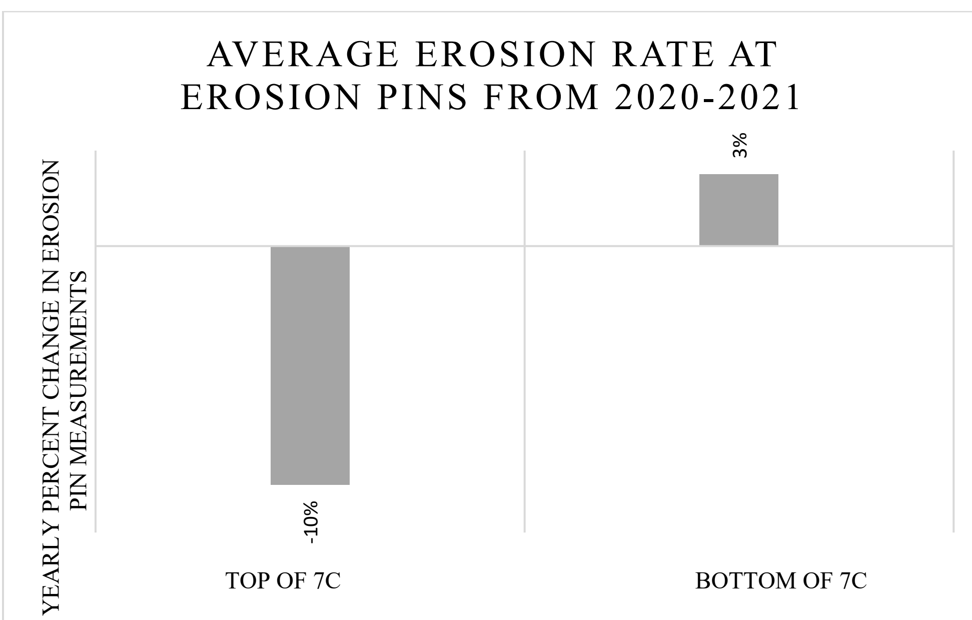


Figure 4. *Average Erosion Rate from 2020-2021*. Rate was calculated by taking the average percent change of each of the 10 measurements at each erosion pin. Erosion is occurring at an average rate of10% outside our restoration area, and land accretion is occuring at a rate of 3% inside of our restoration area.

Erosion is occurring outside of our restoration area, and land accretion is occurring within our restoration area. This suggests that our restoration work is already successful as it's not only working to stop erosion, but also increasing the amount of sediment on the dirt road.

Sediment grain size

Fine grain sediments are especially damaging to coral reefs and as such, one of our restoration goals is to reduce the amount of fine grain sediment reaching the coral reefs by retaining it on land.

A sediment grain size analysis has not been completed for Location 7c. This is because it requires 2 cups of sediment to be taken from behind each BMP row, and there is not enough sediment at this time to collect 2 cups from behind each row. However, we anticipate seeing similar results to Location 5 at Location 7c once enough sediment has accumulated.

Below are the preliminary results from our processing of sediment grain size at Location 5. For each monitored BMP, a sediment sample was taken from the accumulated sediment behind the BMP row. These samples were weighed and put through a sieve with five layers; (from largest to smallest) gravel, sand, silt, clay, and finer than clay. Each layer was weighed and compared to the original weight of the sample. We then organized the data into BMP type and took the averages of each layer within each kind of BMP. Our ultimate goal is to determine which BMP type is most fit for trapping finer sediments, because finer sediments pose the biggest threats to coral reefs in Maui.

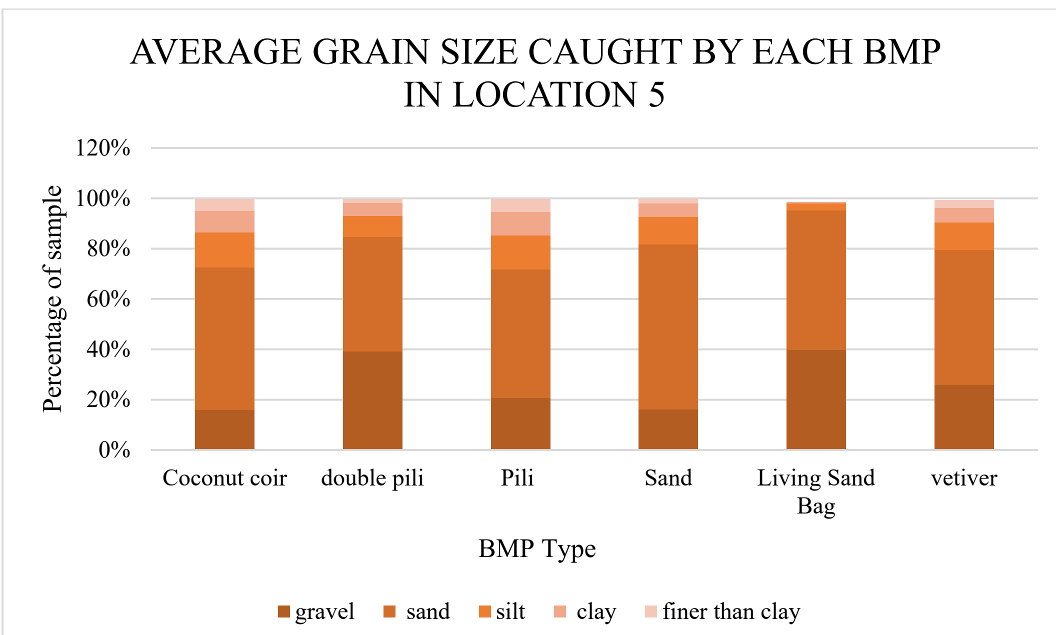


Figure 5. *Average Grain Size Caught by each BMP in Location 5*. Sediment grain size caught at each monitored BMP was determined from a dirt sample taken in front of each BMP. The data was then organized by BMP type, and averages were taken for each BMP type.

This data shows that coconut coirs and pili BMPs are the most effective at catching both clay and sediment finer than clay at Location 5. We hypothesize that the BMPs at Location 7c will catch similar profiles of sediment grain size once enough sediment has accumulated.

Native Plant Survivorship

Native plants and native plant seedlings are planted in the sediment accumulated behind each BMP. Ultimately, we hope that the BMPs will accumulate enough sediment to completely restore the decommissioned roads into native forests.

Our restoration project is wrapping up Phase I in Location 7c, which means native plants are still being planted in this area as we progress into Phase II. Once this phase has been completed, we will begin to calculate the native plant survivorship in this area.

To date, we have planted 87 native plants in Location 7c. Of these plants, 71% are healthy, 10% are declining, 16% are dead, and 2% are missing.

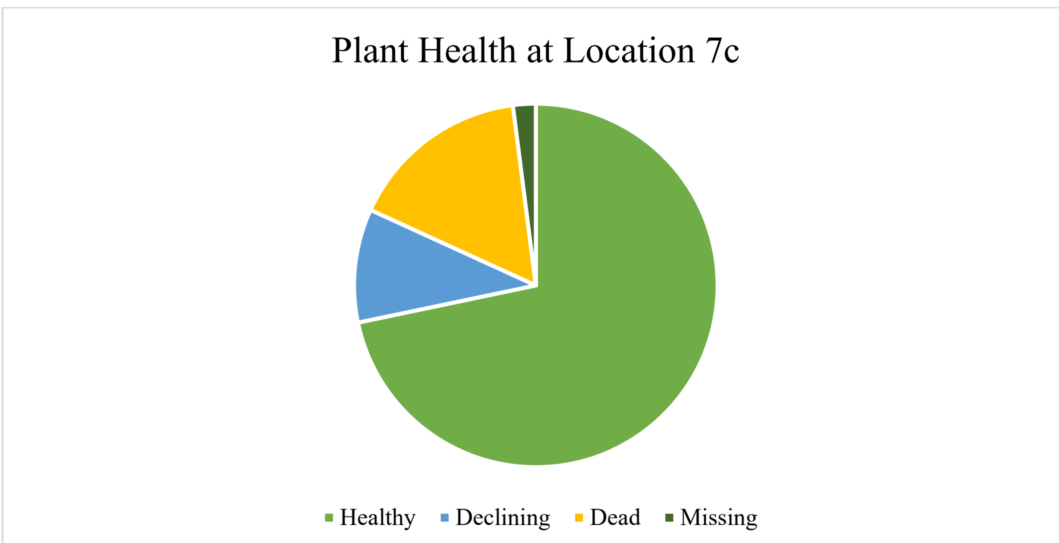


Figure 6. *Plant Health at Location 7c.* Of the 87 native plants currently planted at Location 7c, 71% are healthy, 10% are declining, 16% are dead, and 2% are missing.

We will continue to monitor native plant health as Phase II of restoration progresses and more native plants are added.

Rainfall volume

The amount of rainfall that runs through our restoration site can have a significant effect on how much sediment is accumulated because rainfall is what carries loose sediment down the mountain. We hypothesize that more rainfall that occurred in between data collection dates would mean more sediment accumulated behind our BMPs.

Our weather station that measures rainfall is located at a restoration location further downslope of Location 7c in Location 5. Location 7c receives more rainfall than Location 5, but this data can still give us a low estimate of the amount of rainfall Location 7c receives. The results from data collected by our weather station are below.

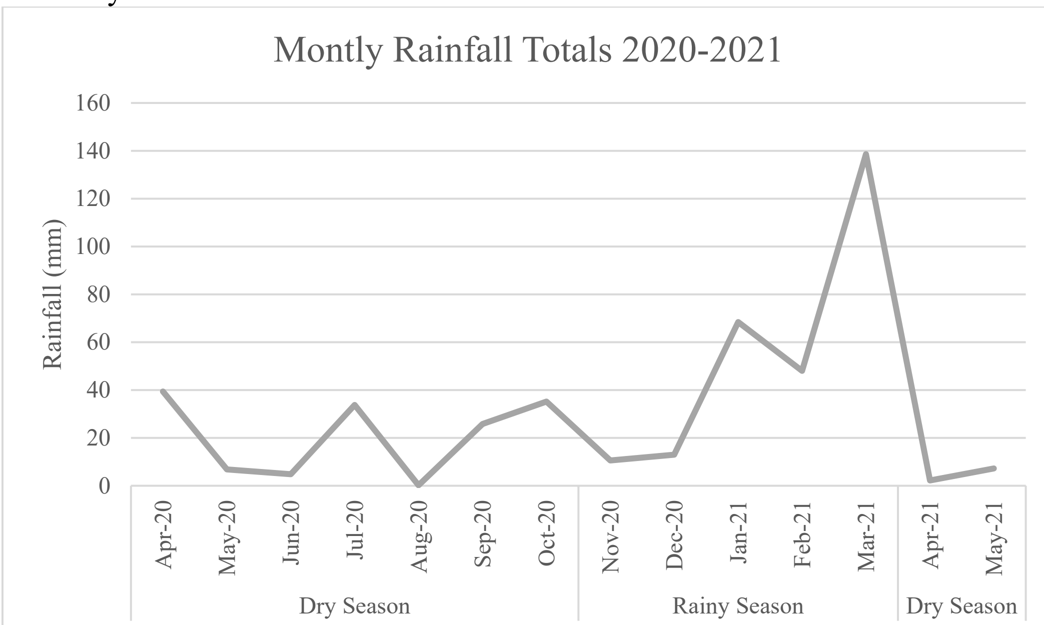


Figure 7. *Monthly Rainfall Totals 2020-2021.* Monthly rainfall totals were calculated from data received from our Skye Instruments Minimet Automatic Weather Station. The dry season in Hawai'i runs from April to May, and the Rainy Season runs from November to March.

Further analysis on how rainfall influences BMP efficiency will be conducted when we enter Phase II of our restoration project in 7c.

Stream Turbidity

Stream turbidity is another important indicator of the efficiency of our restoration efforts. As our restoration efforts advance, stream turbidity at the mouth of the Wahikuli stream gulch should decrease. To monitor this, a turbidity probe was installed at the mouth of the Wahikuli Stream Gulch with the help of Kim Falinski and Aaron Strauch. Data is accessed through the Commission of Water Resource Management online system. Stream depth, Turbidity High Range values, and Turbidity Low Range values are visualized using ADCON Telemetry below. Note: Turbidity probe was not functioning from August 2020 – November 2020, which is why there is a gap in the values on the graphs.

Stream Depth

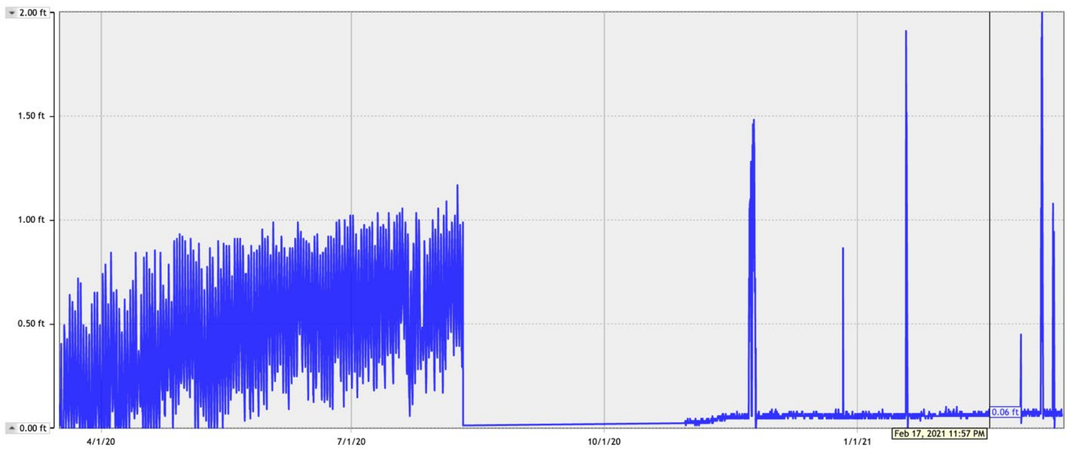


Figure 8. *Stream depth at Wahikuli Stream mouth*.

Turbidity High Range

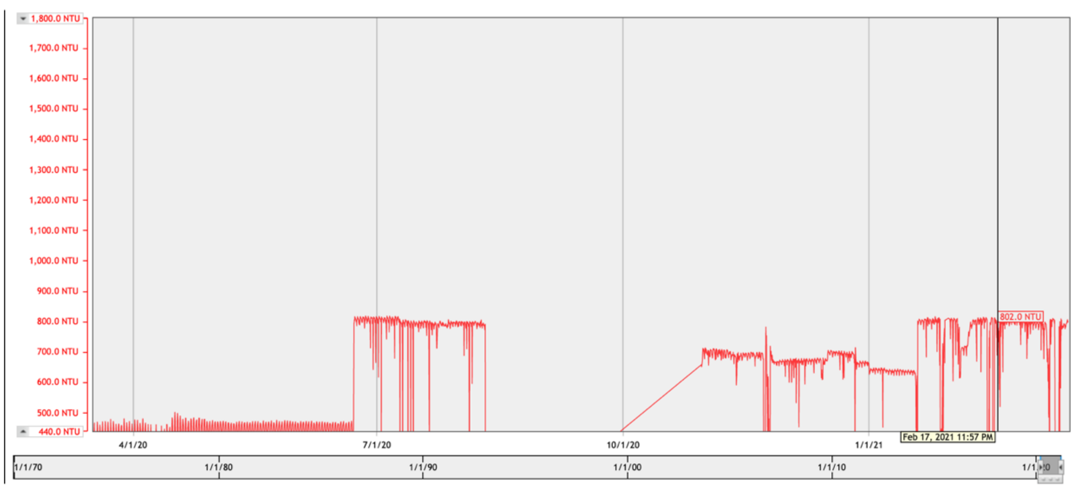


Figure 9. *Turbidity High Range at Wahikuli Stream Mouth.*

Turbidity Low Range

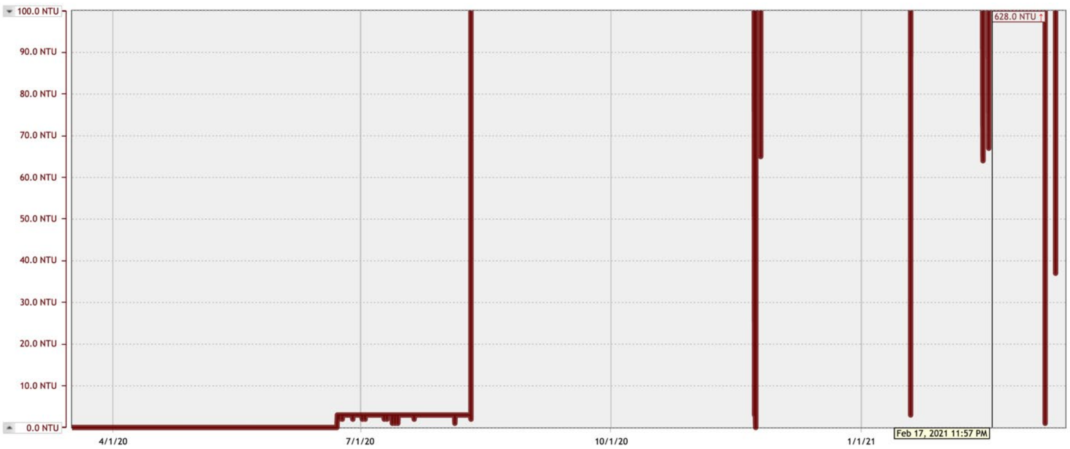


Figure 10. *Turbidity Low Range at Wahikuli Stream Mouth.*

These results will be further analyzed when our restoration projects are completed.

Turbidity and water quality of near shore water

In addition to turbidity data at the Wahikuli Stream mouth, we also examine the turbidity and water quality of near shore water.

Hui O Ka Wai Ola is a community water quality monitoring program that collects turbidity and water quality data for the near shore environment. This organization has highly trained volunteers and a stick data collection methodology with a state approved Quality Assurance Procedure to assure that the data collected meeting the State of Hawai‘i Department of Health standards.

Currently, Hui O Ka Wai Ola is collecting data for water turbidity at a variety of different sites across West Maui, including a Wahikuli near shore water site. CORAL utilizes this resource to determine the turbidity of near shore ocean water below our Wahikuli Restoration site. The turbidity data is collected in Nephelometric Turbidity Units (NTUs).

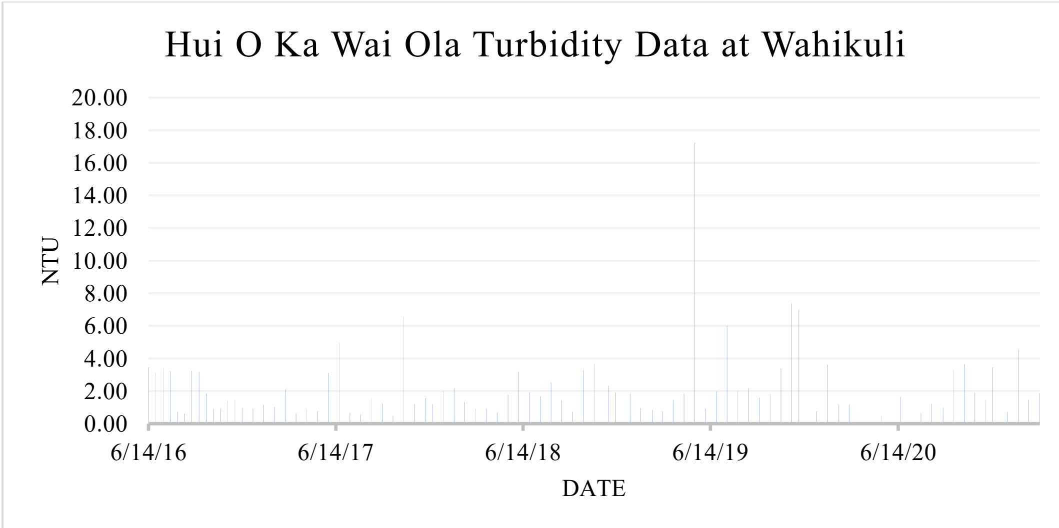


Figure 11. *Hui O Ka Wai Ola Turbidity Data at Wahikuli Near Shore Water Site*. This graph includes turbidity data for near shore ocean water below our restoration site from 2016-2020. Turbidity data was accessed through Hui O Ka Wai Ola's website (https://www.huiokawaiola.com/data.html), where their data is available for free download.

To address water quality, we utilize data available to the public through the Department of Health's Clean Water Branch. Brown Water Advisories (BWA) are issued by the Clean Water Branch when conditions are field conditions observed are consistent with a brown water event, or when the National Weather Service issues a flash flood warning. During these events, significant volumes of sediment is transported from the watershed and onto the coral reefs where sediment smothers and harms the coral. Tracking the duration of these events is important to understand the frequency with which sediment loads are transported to the reef. Correlating the duration of these events to the rainfall over time can also help us to understand the correlation between the severity of storms and these events. Our goal is to see these events reduced over time following implementation of watershed restoration due to a reduction in the amount of sediment that is transported to the coastline.

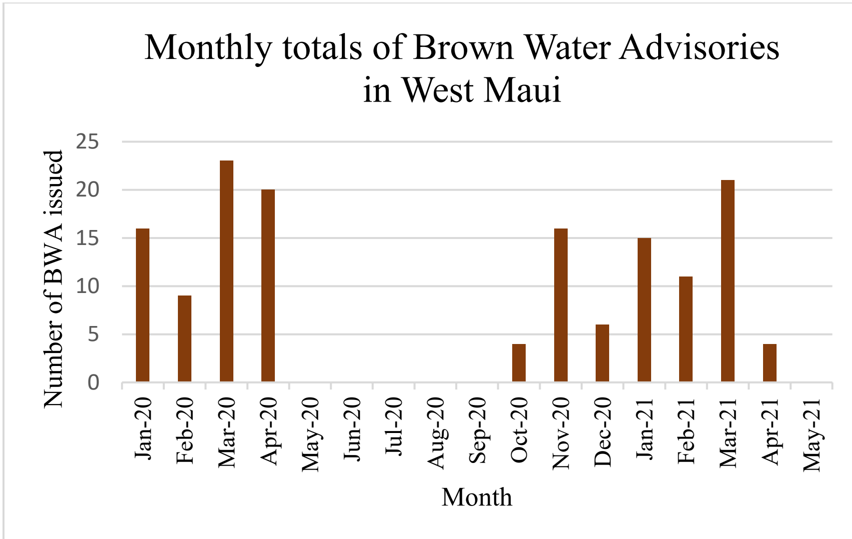


Figure 8. *Monthly Totals of Brown Water Advisories in West Maui*. Data was accessed through the Department of Health's Clean Water Branch System. Data was not collected from May 2020 – September 2020 due to the COVID pandemic.

Brown water days in West Maui occur most frequently during the rainy season, which is consistent with our hypothesis that stormwater is carrying sediment down the mountain, through the watershed, and onto the nearshore coral reefs.

Coral Health Monitoring and Sediment Accumulation on Coral Reefs

Along with The Nature Conservancy (TNC) and Division of Aquatic Resources (DAR), CORAL will be monitoring coral at two different sights, Hanakaoʻo and Kahekili once permanent coral tag permits are achieved. These are both important sites and have shown degraded coral reefs over time. The information collected will be helpful in showing the effects that sediment and water temperatures can have on specific corals and also if they are able to rebound after summer months.

We are also set to begin processing coral reef sediment traps with DAR this year that are located around Maui Nui's seascape to determine the amount of land based sediment that is currently on our reefs.

This data will also act as an important indicator of our restoration project efficiency. Over time, we hypothesize that we will see less sediment accumulation on our coral reefs at these sites and the amount of land-based sediment in the coral reef sediment traps will decline.

Discussion of findings

The preliminary analysis in this report demonstrates the results of the completion of Phase I of restoration in Location 7c. Within this stage, land was prepared for restoration work, an irrigation system was installed, and rows of vetiver, native grasses, and check dams were all put in place as best management practices. To date, Location 7c has already captured 1.5 tons of sediment sitewide. Additionally, the success and patterns seen in our more established restoration site, Location 5, suggests that our BMP rows will continue to perform better and better over time.

We also took time during Phase I to address problems that arose during restoration efforts. This includes issues with dirt bikers riding through Location 7c and complications in water availability. To address these problems, we installed fencing at the top and bottom of our restoration area with signs explaining that this project is a native restoration project that works to improve water quality for coral reefs. We also expanded our water catchment field that we have at the site to provide more water for our irrigation systems. Addressing these problems early in the restoration project gives us more insight into how to make future restoration efforts run more smoothly and efficiently.

Conclusion and next steps

Phase I of our restoration effort in Location 7c has been completed successfully. Out of all the BMP types installed, Uki Uki rows (a native plant row), on average, are performing the best at trapping sediment at this location. We hypothesize that this is because Location 7c is within Uki Uki's natural range of habitation. Additionally, our erosion pins suggest that erosion rates are slowing within the restoration area when compared to erosion rates outside of the restoration area. As time goes on and more data is collected and analyzed, a clearer picture of restoration efficiency will emerge.

Our immediate next steps include completing reef sediment data, and to install permanent tags on coral transects. Our long term goals is to complete another analysis of Location 7c after Phase II is completed, and 1-2 years of data is collected.