CONSERVATION INNOVATION GRANT

Final Programmatic Report

Agreement Number 69-3A75-12-180 with the National Fish and Wildlife Foundation

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Creating a Toolkit for Assessment and Mitigation of Agricultural Operations to Benefit Coral Reefs

9/21/2012 – 09/30/2016

Project Deliverables from the Proposal

- Established threshold values for sediment and nutrients on coral reef health in 2-4 watersheds as case studies to allow for a guide or model for U.S. island jurisdictions.
- Increase the use of specific and measurable sediment and nutrient reduction targets in developing watershed management plans for U.S. priority watersheds.
- Rapid Assessment Tool that can create prioritized source maps of threats from sedimentation, nitrogen and phosphorus for U.S. priority watersheds in the Pacific and Caribbean.
- Direct mitigation projects to address threat sources for 2 -4 watersheds to test ability to measure impact to reefs.
- Local manager training for uptake of new models and monitoring tools for each of the above bullet points and to help assimilate and utilize biomarkers as a management tool.

Photos on cover: Pacific Coral Scene from Istock photos; Watershed Assessment Tool Summary Schematic from Horsley Witten Group; Water retention pond in Puerto Rico from Roberto Viqueira

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Executive Summary

In 2010, the Natural Resource Conservation Service (NRCS) co-founded the US Coral Reef Task Force (USCRTF) Watershed Partnership Initiative with the National Fish and Wildlife Foundation (NFWF) and the National Oceanic and Atmospheric Administration's Coral Program (NOAA) to facilitate and coordinate federal agency resources to address threats from land based sources of pollution (LBSP) to coral reefs. This cooperative approach has been very successful in coordinating efforts across federal, territorial governments and NGOs, however initial watershed management plans (WMP) did not incorporate current baseline data or threat reduction targets for reduction of LBSP and priority source lands for mitigation were not identified. Therefore, while the WMP and collaborative effort of the USCRTF has enabled participating agencies to intensify efforts within the watersheds, it does not provide the tools necessary to determine when the partners can claim success from their investments.

This $230,000 Conservation Innovation Grant from NRCS was awarded to build an innovative toolkit for managers to improve performance and evaluation capabilities in regards to reducing common agricultural sourced pollutants (sediment, nitrogen and phosphorus) to coral reef ecosystems. Together the tools proposed would serve to overcome three important barriers facing coastal resource managers: (1) increase accuracy and standardize the process of establishing baseline and threshold information for inclusion in watershed management plans; (2) target limited funds to the most impactful projects; and (3) utilize tools to evaluate impact of mitigation measures in real time.

This very ambitious proposal targeted six objectives over a two-year period of performance.

1. Provide guidance on the threshold of where negative impact begins for corals from common ag-producing threats of LBSP;
2. Develop a tool that can monitor corals for these LBSP categories (sediments, turbidity, nutrients (N, P), toxins) against the thresholds in Ob. 1 in real-time, and through a tool that is not cost prohibitive;
3. Develop a protocol for conducting watershed assessments that can be used by a novice, on a budget, and inform the development of a targeted watershed management plan in 1-2 years;
4. Establish standardized protocols and metrics for minimum baseline data collection and establish baselines for 2-4 watersheds;
5. Implement projects that target the reduction of sediments and nutrients to coral reef systems and employ different and innovative approaches while building local capacity; and
6. Disseminate the Toolkit to US Coral Reef Managers and Practitioners.

Like visiting the doctor to monitor blood pressure, new research tools take a small sample from coral and evaluate stress based on specialized protein response. Photo: R. Richmond

The project targets coral reef managers and practitioners in US jurisdictions, but held a specific focus on the three geographies (four watersheds) that had been selected for increased coordination and support by the USCRTF: Guanica, Puerto Rico; Wahikuli and Honokowai, Hawaii and Faga'alu, American Samoa. Support for establishing monitoring programs and implementation demonstration projects were focused in these locations. However the tools that are under development are to serve all jurisdictions and therefore while watershed

coordinators have been heavily engaged in the development of tools, managers, researchers and NGO representatives from areas even outside the 'priority watersheds' have been surveyed or interviewed through the implementation of this project.

Our initial timeline of two years and budget for these activities and products were not realistic given the exploratory and developmental nature of the products and the number of partners that need to be engaged to build them correctly. Most of what we have supported is pushing the envelope in current science and management practices and the project also suffered significant implementation delays in the sub-awards through changes in leadership, coral bleaching, permitting and course corrections in methodology.

At this time all funds have been allocated in this agreement and in addition to the $230,000 committed by NRCS, NFWF partners and grantees have brought over $3M in funding for this body of work. While many of the objectives have not yet been completed at the time of this report's writing, the progress has been significant and the tools that are being developed could very well lead to a paradigm shift in the way coral reefs are managed. At a time when budgets are continually shrinking and we are on the heels of a three-year global bleaching event, managers need more sophisticated tools more than ever before.

Projects supported by this agreement targeted local capacity for restoration and tested new strategies for mitigating common agricultural run-off, like sediments, in watersheds adjacent to coral reefs like this one in Puerto Rico.
Photo R. Viqueira

Introduction

This project is part of a larger effort by the National Fish and Wildlife Foundation (NFWF) and its partners to increase the capacity of coral reef managers to actively mitigate the multitude of anthropogenic threats to produce measurable gains in coral health and resilience to climactic influences. NFWF in partnership with the NOAA Coral Reef Conservation Program (NOAA) and leadership from a number of Coral Reef Institutes developed this Conservation Innovation Grant project to develop a suite of tools that would assist coral reef managers in assessing and prioritizing for mitigation, threats from land-based sources of pollution. The partners further sought to improve performance and evaluation of mitigation activities on agricultural operations in coastal watersheds adjacent to coral reefs in a cost and time-effective manner.

Innovative conservation practices to reduce sediment and nutrient erosion are integral components of sustainable agricultural industries, especially in coral reef watersheds. Resource and land managers must implement targeted conservation actions in order to avoid the devastating effects of sediment, fertilizers, herbicides and pesticides transported onto coral reefs in unsustainable quantities. As part of NFWF's engagement in the US Coral Reef Task Force Watershed Partnership Initiative, it became clear that while managers and conservationists acknowledged that run-off from land-based sources, such as agricultural practices were a threat to coral reef health, critical gaps in understanding of the tipping points of these threats prevented effective management.

The proposed toolkit was to be comprised of:

- **Thresholds Matrix**: Begin to establish ranges of tipping points in coral health for a range of species/types for primary threats of sedimentation, nitrogen, phosphorus and toxicants.
- **Rapid Assessment Model**: Methodology on conducting a rapid assessment including mapping and prioritization of sources of threats in the watershed;
- **Biomarker Analysis:** Development of efficient tests for managers to evaluate the health of coral reefs in response to specific inputs into the system (sedimentation, nitrogen, phosphorus and toxicants) and evaluate coral response to reduction of those inputs in a shorter timescale.

Fig. 1 Maps of the three primary watersheds targeted for investment by the US CRTF and this award. Guanica watershed (130 sq mi) has pronounced agriculture and a heavily modified hydrology. Wahikuli-Honokowai (30 sq mi) has historic and converting agriculture and heavy resort influences. Faga'alu (1-2 sq mi) is the least developed.

The project targeted priority coral reef watersheds that had been nominated by the jurisdictions and adopted by NOAA with a priority focus on the four watersheds that had been selected by the US Coral Reef Task Force (CRTF) (See Figure 1). In order to evaluate the performance of these tools, the project further outlined baseline monitoring and mitigation projects in these locations. The Foundation and its partners worked with the watershed coordinators from these and other priority watershed sites as the initial 'target audience' for the development of the tool-kit.

This $230,000 grant was awarded to build an innovative toolkit for resource managers (specifically on island jurisdictions) to improve performance and evaluation capabilities in regards to reducing sediment, nitrogen and phosphorus from land based sources of pollution to coral reef ecosystems. While the direct support of this agreement supported six projects (some of which remain in progress with other funding), the objectives of this award have become the main focus of the Foundation's investments in coral reef conservation over the last four years. While the official leverage on the six projects that received funding from this award meets the 1:1 matching commitment proposed and reported in the fiscal report, to date the Foundation has administered over $3.1 million across 28 grants and contracts for the objectives listed in this agreement leveraging the Natural Resources Conservation Service (NRCS) contribution over ten times the initial investment (see table of projects in Appendix A).

Background

Researchers have directly linked intensive land clearing and agricultural development to the widespread degradation of coral reefs, showing that sediment and nutrient loads on coral reefs are five-to ten-fold higher in watershed with agricultural operations than those without them (Acevedo and Morelock 1988, Acevedo et al 1989, Clark and Wilcock 2000, Goenaga and Cintron 1979, Larson 2000, Larson and Santiago-Roman 2001McCulloch et al 2003, Morelock et al 1980, Morelock et al 1985, Torrest and Morelock 2002, Weil 2004). Sediment can smother corals, reduce light availability for coral growth, and cover habitat necessary for coral recruitment; nutrients can promote algal and bacterial growth, trigger coral death and effect fish populations (Crossett et al 2008).

Despite the known linkage, little information has been gathered about the thresholds for agricultural run-off that result in these impacts or the ability of current conservation practices to counteract these stressors as intended. This cause-and-effect scenario is particularly delicate on island communities where watersheds are steep, agriculture practices are highly diversified and marine environments are so important to economic stability.

In 2010, NRCS co-founded the CRTF Watershed Partnership Initiative with NFWF and NOAA to facilitate and coordinate federal agency resources to address threats from land based sources of pollution (LBSP) to coral reefs. In the pilot geography, Guánica-Rio Loco watershed, Puerto Rico, all partners worked from a finalized watershed management plan (WMP) to determine how to invest both their technical and financial resources. NFWF worked with funding and implementation partners to transfer the WMP into a logic framework to identify the theories of change within each of the four targeted strategies of the plan and the steps that would need to be taken for successful implementation (see Appendix B). This cooperative approach has been very successful in coordinating efforts across federal, territorial governments and NGOs, and has even resulted in an increase of EQIP contracted land owners by 300%.

Unfortunately, as we have now learned is typical of WMPs, the initial Guanica plan did not incorporate current baseline data or threat reduction targets for reduction of LBSP and priority source lands for mitigation were not identified. Like many WMPs, the document outlined what actions should be taken (stream restoration, lagoon restoration, treatment wetlands) but not the extent of the mitigation needed to meet tipping points in coral health and recovery in Guanica Bay. Therefore, while the WMP and collaborative effort of the USCRTF has enabled participating agencies to intensify efforts within the watershed, it does not provide the tools necessary to determine when the partners can claim success from their investments.

Literature review by NFWF staff found that while some work on thresholds of coral health from agricultural run-off (sediments, nutrients, toxicants) had been done in the lab, threshold models or even rough benchmarks of

run-off levels did not exist for coral reef systems. Further, given the long timescale needed for measurable coral growth, a causal feedback loop to mitigation efforts in the watershed could take decades to see if the threat was reduced to sustainable levels. Therefore, local managers had no existing tools to know how much effort was needed in restoration to protect, conserve or recovery their nearshore reef systems. Perhaps because of this gap in information, while the EPA criteria listed measurable targets and outcome-focused elements to prioritization and planning, few plans actually contain them. Instead, as depicted in Figure 2a, the emphasis was on identifying actions 'Have a Plan' and then finding funding for them 'Implement the Plan'.

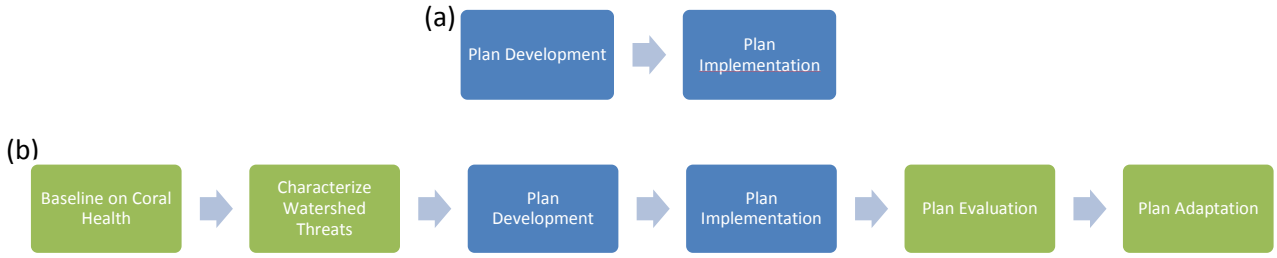


Fig. 2: Simple process diagrams of the focus of priority watershed management during the time of the Guanica pilot (a), and the key steps in the process that partners felt were missing, in large part because tools, time and resources prohibited them.

As part of this Conservation Innovation Grant (CIG), NFWF staff interviewed several coral reef managers and practitioners to further understand the specific gaps and needs that a tool-kit could provide, and have modified this simple process model into a series of steps or components that are needed to make informed management decisions for coral reef systems based on these discussions. Figure 3 outlines this new framework, which became the visual characterization of NFWF's approach to this award and the toolkit it seeks to produce.

The objective of the toolkit is to enable resource managers to establish baselines, thresholds and reduction targets for land based sediment and nutrient sources in watersheds containing coral reef systems to evaluate the need for management intervention. Then once the decision was made to mitigate, additional tools would enable quantification and prioritization of possible mitigation strategies to identify the feasibility for reaching targets prior to writing the plan. Finally, after implementation projects are underway, managers need a tool that can provide a real-time assessment of the success of these efforts in resulting to positive change on the reef. Together these tools will serve to overcome three important barriers facing coastal resource managers: (1) increase accuracy and standardize the process of establishing baseline and threshold information for inclusion in watershed management plans; (2) target limited funds to the most impactful projects; and (3) utilize tools to evaluate impact of mitigation measures in real time.

NFWF put forward an ambitious proposal to improve the capacity for each of the six boxes in the process model 2b. After considerable time and investment our report will show that the development of tools to increase the quality of any one of these steps would have been a significant achievement. Still, the management paradigm for these systems needs to be updated. The notion of 'any amount of threat reduction is helpful' will not address the significant declines we are seeing in coral reef globally. Resources continue to shrink and therefore managers need better tools to assess, prioritize and evaluate their investments for the greatest impact.

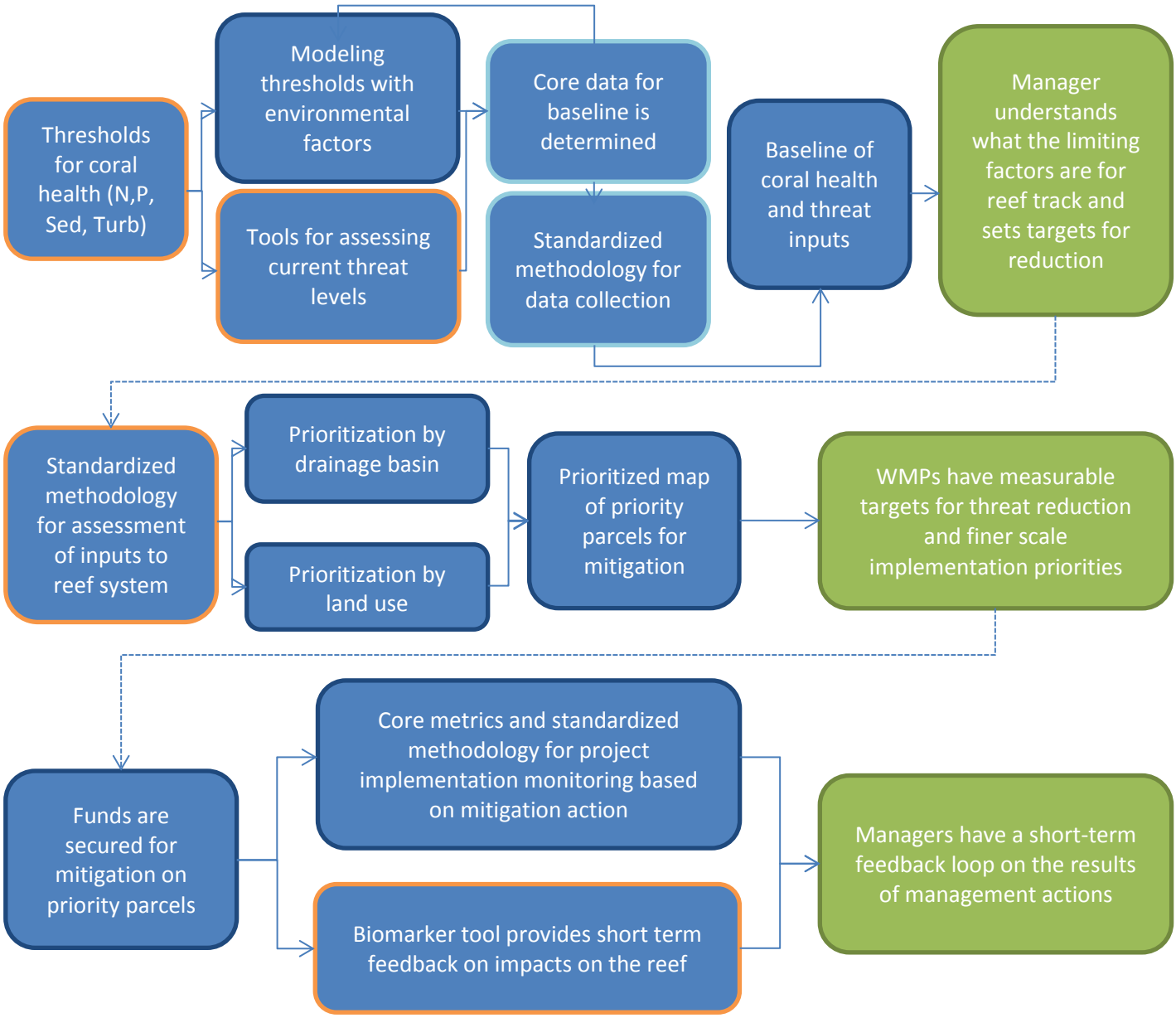


Fig. 3: Flow diagram of the three critical elements for successful management of land-based sources of pollution in a coral reef watershed (in green) and the conditions needed to feed these elements (in blue). The blue boxes outlined in orange represent the tool-kit elements that were proposed for implementation by the Coral Reef Institutes and in light blue represent the elements that were planned as part of NOAA's investments and the efforts of the US Coral Reef Task Force Watershed Partnership Initiative. Most of the conditions in the blue boxes are missing from the watersheds that were targeted in this project, even though all have watershed management plans (WMP).

Review of Methods:

Proposed vs. Actual

The original proposal was comprised of a block grant to members of the Coral Reef Institutes (Institutes) that helped NFWF develop the proposal. The block grant would allow the Institutes to conduct the necessary research called for to develop the primary elements of the tool-kit (thresholds, biomarkers, protocols for rapid assessment) while ensuring collaborative sampling and analysis across their regional leads. At the same time, support through NFWF and NOAA would be provided for baseline monitoring through the annual Coral Reef

Conservation Fund (Coral Fund) using standardized metrics that were in development by the USCRFT members at the time of the proposal writing. Finally, NFWF would identify a small number of implementation projects through the Coral Fund that would focus on mitigating sediment run-off and look to use the tools developed by the Institutes to evaluate the ability to measure reductions in loading from baseline to target.

In the first few months of implementation it became clear that the Institutes would not be able to assist NFWF in the execution of the grant objectives. As block grant moved from proposal to contracting, each Institute's budget more than doubled and due to some changes in leadership, the new principle investigators had different priorities on the CIG products within their research schedules. This resulted not only in significant delays for the primary tool development piece, but also increased difficulty in piecing together all of the elements of this grant independently while keeping the coordinated, step-wise approach originally proposed. Ultimately the Foundation chose to work predominantly with the University of Hawaii for the core threshold and biomarker elements of the tool and Villanova and San Diego state universities for baseline data collection in Guanica and Faga'alu respectively. Work in the watersheds was conducted in coordination with the respective Watershed Coordinators and the final tool – Rapid Watershed Assessment, was conducted via contract with Horsley Witten Group.

Similar challenges occurred in the baseline monitoring portion of the proposal in that the USCRTF did not approve standardized ecological metrics until late 2015 and made the decision NOT to include watershed indicators; therefore, standardized run-off monitoring metrics and methodologies were never established. Monitoring efforts and implementation projects were funded through the Coral Fund in four priority watersheds as planned, but without the coordinated monitoring protocols across sites as originally planned. As a result, instead of a step-wise process that had coordinated baselines with assessment of thresholds finishing at the same time then leading to prioritization process based on the biomarker and rapid assessment tools, which lead to selection of implementation projects...in reality each of these different components happened out of order at each watershed. Therefore while progress was made in each of the different elements proposed, data for a measurable causal link to a mitigation of a LBSP threat was only able to be established in the Faga'alu watershed in American Samoa.

Delays have been further compounded by the research and development nature of these grants and the three-year global bleaching event that impacted field testing and permits for coring. NFWF and its partners are actively working to develop, test and disseminate tools that will revolutionize our ability to manage coral reefs; which is a worthy goal, but slow in development. While all of the projects have made significant progress, most are continuing their work beyond this grant. While initially extension requests were made to capture the final products, eventually the decision was made to report out on progress to date on this award. Funds have been spend down on this agreement, but the Foundation remains committed to achieving the objectives listed in this proposal and has secured other funding to continue this work.

Approach by Objective

While there are several elements to the original proposal and ways that objectives and products can be listed, there were six primary objectives. What follows is a breakdown of the CIG supported efforts that were employed to meet each of these six objectives.

Objective 1: *Provide guidance on the threshold of where negative impact begins for corals from common ag-producing threats of LBSP.*

The underlying management need was to move the capacity to evaluate coral health from 'alive' and 'dead' to understanding levels of stress and tipping points where mitigation can be most impactful in bolstering resilience and recovery.

Objective 2: *Develop a tool that can monitor corals for these LBSP categories (sediments, turbidity, nutrients (N, P), toxins) against the thresholds in Ob. 1 in real-time, and through a tool that is not cost prohibitive.*

Knowing the points at which coral becomes stressed is only valuable if we can monitor that stress in real time and via a test that measurable and can be replicated across sites. For example, a dosing study in the lab can identify the point in which a toxicant prevents coral reproduction, creating living 'coral zombies', but unless there is monitoring coral colonies in the field during all potential spawning events, it is impossible to know where the reef colonies are on that threshold gradient. Mangers need a tool that can isolate specific threats and monitor the impact of that threat on coral colonies on their reef track both to understand when mitigation is needed prior to irreversible damage and to monitor recovery based on mitigation efforts. Currently a visual census of benthic shifts in live or dead coral or algal growth are the primary methods of assessment which are quick to show decline, and at the point where mitigation is the most expensive, and are very slow (decadal) to show re-growth and recovery.

To enhance management capacity for Objectives 1 & 2, the Foundation supported work in the genomics field that had been showing significant promise. Investments supported the develop biomarker assays that could depict specific genes that respond to changes in the target threat inputs. These isolated genes were tested against lab dosing to establish thresholds and in the field to test environmental influence. The following three projects were supported, all from the University of Hawaii for a collaborative analysis. The first two projects received direct support from this agreement but all three will have collaborative analysis of the biomarker tool. There was a fourth project support as seen in the table in Appendix A that falls under this category of thresholds and biomarkers, but it was a for a non-agricultural threat (sewage) so not reported on here.

PI and Project Identifier: Francois Seneca, University of Hawaii, #44399

Title: Threshold and Reduction Targets for Land-based Stressors to Coral Reefs (HI, AS)

Purpose: to establish minimum response thresholds and threat reduction targets for sedimentation and turbidity in the main reef-building corals of Hawaii and American Samoa. This project will couple these targets with other tools in development which will allow managers to assess threats to coral reefs and monitor their recovery at a finer scale and in a shorter timeframe.

Abstract: The University of Hawaii - Manoa will provide stakeholders and reef managers with science-based nutrient and sediment concentration targets for preserving and restoring healthy coral reef systems. From 2002-2006 local action strategies were developed to reduce land based sources of pollution by 25% in watersheds on Kauai, Molokai and Maui according to the guidelines of the U.S. Coral Reef Task Force. However, basic biological information regarding the suitability and efficacy of the proposed reductions to alleviate threats to corals is still lacking. Prompt and effective management and conservation actions rely on the evaluation of response thresholds and threat reduction levels of pollution inputs, which have direct applications to the development of best land management practices to promote the recovery and persistence of reef-building corals. The University of Hawaii will use sequencing by synthesis to identify the key genes in the stress responses of corals exposed to sediment and nutrient pollutions. Antibodies designed to specifically target the proteins encoded by previously

identified genes will be used to measure how much of these biomarkers corals produce in response to a range of pollutant concentrations. Molecular data will be correlated with physiological measurements in order to determine the threat reduction levels for each stressor in four different main reef-building corals of the West Maui reef system.

PI and Project Identifier: Craig Nelson, University of Hawaii, #44447

Title: Setting Nutrient Thresholds to Coral Reef Health (HI, AS)

Purpose: Project will develop and apply a Nutrient Response Assay for two species of corals and their associated microbial communities in the West Maui and Faga'alu priority watersheds. This project will link water quality thresholds (nitrogen, phosphorus) to microbial and coral physiological responses to create a tool for management to assess impacts to reef systems before coral mortality.

Abstract: The University of Hawaii will work to link water quality thresholds directly to dynamic coral microbiome composition and physiological responses adaptable to habitats in the Pacific Islands region. Specifically, The University of Hawaii will :(1) Develop a coral/microbial nutrient response gene expression panel, (2) Document water quality gradients in the West Maui Priority Watershed: Honolua to Olowalu, (3) Assay nitrogen and phosphorus response genes in coral samples from field gradients and (4) Establish coral/microbial response thresholds to determine levels of N and P causing coral nutrient stress.

Existing numeric water quality thresholds do not consider effects of land based source pollution on corals. Visual biocriteria of disease or mortality are lagging indicators of pollution effects and once observed these impacts may be difficult to reverse. The methodology used in this project can be used as a tool for adaptive watershed pollution mitigation to monitor coral nutrient stress at timescales relevant to management objectives.

PI and Project Identifier: Robert Richmond, University of Hawaii, #34413 (funding from other sources)

Title: Effectiveness of Watershed Mitigation Activities on Corals (HI)

Purpose: Project will develop evaluation tools and metrics to measure the effectiveness of watershed-based mitigation activities on coral reefs in Hawaii. This project will establish thresholds for toxicants for coral reefs.

Abstract: The University of Hawaii will use molecular biomarkers of exposure, proteins produced by exposed coral to particular classes of stressors, to qualitatively and quantitatively measure the effectiveness of watershed-based mitigation activities on coral health and resilience. The biomarkers examine the coral's health, damage, stresses, and exposure to toxic materials. Recent research, some of which has been supported by funds from the National Fish and Wildlife Foundation, has demonstrated molecular biomarkers of exposure in corals can address the key management needs for assessing watershed discharge impacts on coastal coral reef ecosystems and can also be used for the development of performance measures on the effectiveness of management activities. Coral reefs throughout the world are in decline from a variety of both human and natural sources of disturbance. Land-based sources of pollution has been identified by the U.S. Coral Reef Task Force and the NOAA Coral Reef Conservation Program as one of the top three priority areas for management-directed actions. There are several watershed mitigation projects underway in the U.S. and affiliated jurisdictions focused on

reducing impacts of discharges on coastal reefs, but there has been a notable absence of quantitative performance measures to determine the effectiveness of associated management-directed activities.

Objective 3: *Develop a protocol for conducting watershed assessments that can be used by a novice, on a budget, and inform the development of a targeted watershed management plan in 1-2 years.*

Biomarkers and thresholds will greatly increase management's understanding of the health of their reefs and the types of threats that may be having the greatest detrimental effects, but it will not identify the sources of those threats or demonstrate the right strategy to mitigate the threat and at how many sources to achieve the threat reduction target. To address these management needs we move to the second row of the management decision-making process from Figure 3, the watershed assessment. This tool will help managers prioritize specific sources of the target threat for mitigation. While an EPA guidebook for developing a WMP includes assessment protocols, managers surveyed indicated that it was cumbersome and confusing. NFWF also felt it was important to create a tool that would be both coral centric and address some of the special considerations of tropical island environments that may not be covered in standard watershed assessment resource documents. It was also important to NFWF that the tool meet the wide variety of training levels and budgets found in the island jurisdictions.

To achieve this objective NFWF employed two different approaches. First, with the help of a summer intern from University of Virginia, NFWF convened a group of agency representatives in a series of meetings to identify programmatic priority synergies in forwarding watershed science. In previous interviews with individuals, it seemed that several agency representatives were interested in increasing the efficiency of watershed threat assessment and prioritizing sources but each with their own specific interests. The group explored the potential of hosting a joint workshop, potentially in coordination with a USCRTF meeting that would bring together experts across technical fields to develop a master list of the top '10' threats facing watersheds adjacent to coral reefs and processes to assess them. In doing this, the participants might shape a protocol for a standard, comprehensive watershed assessment that was organized by threat. While this was a desired outcome by all parties involved, it soon became clear that the timeline for coordinated implementation between multiple parties would take a year or more to implement and NFWF was encouraged to move forward on their own approach to this objective and to keep the group informed as appropriate.

In light of this recommendation, NFWF released a Request for Quotations (RFQ) on August 26, 2015 for development a watershed rapid threat assessment tool. The RFQ outlined a scope of work to develop an assessment protocol/decision tree that would simplify the steps for a comprehensive watershed assessment and build on the large array of resources that are available, but not easily accessible or digestible to state and territorial practitioners. Elements of the assessment tool would include pollutant identification (type and location), magnitude of impact or load and relative threat to coral reef health and to incorporate other elements of toolkit under development (i.e. thresholds) as they became available. The tool will link to specific methodologies at each step and, as appropriate, alternatives at different costs. A stated requirement is that the assessment from the tool should be in a format that can inform management plan development according to EPA criteria and the prioritization of mitigation activities by impact to coral reefs. Further, the project outlined a requirement for engagement with intended end users in development of the tool, testing in 1-2 of the priority watersheds and dissemination to the target audience as components of the Scope of Work. NFWF selected Horsley Witten Group, Inc. (HWG) as the recipient under the lead direction of Anne Kitchell. A second grant was also supported with other funding under this objective, but it was to assist with a very specific part of a watershed assessment and not tool development, so it is provided in the grants list but not reported on further.

Objective 4: *Establish standardized protocols and metrics for minimum baseline data collection and establish baselines for 2-4 watersheds.*

The Guanica pilot taught USCRTF members that in order to talk about accomplishments and results of investments from a watershed scale partnership the partnership needed to establish monitoring at both the watershed and the reef scale. While this was acknowledged early on, implementation of a monitoring effort was delayed by an interest in having standards across reefs and even jurisdictions to allow for greater data confidence, collaboration and analysis. Not all of the state and territorial governments monitor the same elements as proxies for reef health, and NGOs have other protocols and metrics that they use. While standardization is desired by all, long-term datasets need to be considered, as well as differences in budgets and capacity to implement monitoring. Finding the 'minimum standard' became the charge of a new USCRTF subcommittee in which NFWF was a member. This subcommittee met on a monthly basis to discuss what data was being collected, what metrics were needed and were the minimum standards should be established.

The second part of this objective was to establish the baselines through data collection in the 2-4 watersheds where we were implementing mitigation projects. Several elements for monitoring were called out as priority for both the watersheds (i.e. water quality data, sediment traps) and the reefs (benthic and fish surveys) at these locations. NOAA's commitment through the National Coral Reef Monitoring Program (NCRMP) process provides general reef survey information biannually in the Caribbean and on a triannual basis in the Pacific jurisdictions, but did not have any existing programming for more frequent watershed monitoring at priority locations. Therefore the Coral Fund cycles were used to establish watershed monitoring programs in the three focal jurisdictions. The following grant awards were not directly supported by this agreement, but contribute directly to this scope of work. Several other projects that support this objective can be found in the grants list of Appendix A including a second West Maui monitoring grant (for Urban run-off) and several small grants for Faga'alu (to encourage other partner engagement) but these core grants contributed the most to this scope of work.

PI and Project Identifier: Lisa Rodrigues, Villanova University, #46613 (funding from other sources)

Title: A Toolkit for Managing River Inputs to Coral Reefs (PR)

Purpose: Project will create a cost effective, transferrable, and easy-to-use toolkit consisting of models and a management guide that will support watershed management. This project will use a multi-tiered sequential approach combining analyses of instantaneous water quality and coral health, riparian buffer efficacy, and the record of historic land use in coral and sediment cores to identify land-based sources of pollution and to reduce specific acute and/or chronic stressors on coral reefs in the Guánica watershed.

Abstract: Recent biogeochemical studies have shown that the health of nearshore coral reefs can be directly impacted by land use practices in the adjacent terrestrial environment. Rivers often facilitate the transportation of excess nutrients, sediments, and other pollutants, resulting in both acute and chronic impacts to corals. Although the conduits of delivery are understood, establishing riverine pollutant thresholds that directly impact coral reef health, has remained elusive. This is largely due to the lack of real-time sampling connecting both environments and archival sampling that links historical land use with original stress to reefs. We propose a multi-tiered approach that will lead to the following project outcomes: (1) To quantify watershed pollutant concentrations to discern the threshold for acute stress on coral health; (2) To identify point source impacts and mitigation success of existing riparian buffers; (3) To link historical land use practices with marine samples; (4) To develop a bibliographic library/ historical archive for Guánica related to watershed and oceanographic studies; (5) To integrate the

findings into a toolkit consisting of step-wise decision tree models and a management guide; and (6) To train the next generation of resource scientists and managers.

PI and Project Identifier: Dan DeLany, The Nature Conservancy, #46650 (funding from other sources)

Title: Quality-Assured Community Water Quality Monitoring (HI)

Purpose: Project will implement a community-based, quality-assured water quality monitoring program for the reefs of Wahikuli-Honokowai. This project will produce a quality assurance plan, standardized methods, training modules and baseline data.

Abstract: The Nature Conservancy - Hawaii will develop and implement a quality-assured, community-based coastal water-quality monitoring program for the Wahikuli and Honokowai watersheds of Maui. The coral reefs in this area are at risk of degradation due to declining water quality associated with urbanization and agriculture. Declining water quality also poses a risk for coral reefs in priority catchments of American Samoa and Puerto Rico. Despite these risks, accurate assessments of coastal water-quality and trends in the priority catchments are limited by inadequate monitoring. The community-based monitoring that will be conducted as part of this project is intended to generate the water-quality data needed for accurate assessments, and to inform land and coastal management decisions. The project has two primary aims: 1) produce a baseline water-quality dataset for the Wahikuli-Honokowai coast; and 2) provide stewardship groups in other watersheds with the instructional materials and guidance needed to develop quality-assured water-quality programs. To produce the baseline dataset, a volunteer team in west Maui will be trained in quality-assured monitoring, and will monitor six sites along the Wahikuli-Honokowai coast monthly for 24 months. The team will be supported by a project manager, quality-assurance officer, team leader, and a technical advisory group, and will operating under a quality assured project-plan with the approval and guidance of the Hawaii Department of Health.

PI and Project Identifier: Trent Biggs, San Diego State University Research Foundation #48808 (funding from other sources)

Title: Capacity Building for On-Island Impact Assessment of Sediment Load Reduction in Faga'alu Watershed, American Samoa

Purpose: To build capacity for sediment load reduction monitoring in the Faga’alu watershed, American Samoa. This project will provide an assessment of the impact of mitigation activities recently completed to address run-off from an active quarry.

Abstract: The San Diego State University Research Foundation will build capacity for sediment load reduction monitoring in the Faga’alu watershed, American Samoa. Sediment is the main pollutant impacting coral reefs at many locations in the South Pacific, including the NOAA Priority Watershed, Faga’alu, on Tutuila Island of American Samoa. Turbidity, sediment concentrations and sediment loads have been monitored by San Diego State University at three locations in Faga’alu watershed, during three field campaigns from 2012-2014. During the course of this work, an active quarry was identified as the predominant source of sediment. Mitigation plans were implemented in 2014 to address this source, and preliminary results suggest that sediment loading has decreased following the mitigation. This

project will continue monitoring of turbidity and sediment load to quantify the effectiveness of mitigation activities during storms of different sizes and over the long-term. University staff will build capacity on-island for field data collection and sample analysis during the course of the project to ensure that local management authorities will be able to continue monitoring after the project period concludes.

Objective 5: *Implement projects that target the reduction of sediments and nutrients to coral reef systems and employ different and innovative approaches while building local capacity.*

The priority watersheds have a wide diversity of land-use, complexity in threats, landscapes and management capacity. Testing several different mitigation approaches to addressing similar problems and analyzing their relative impact helps to build a resource of options for other managers to employ. This objective was to be NFWF's main focus as lead for implementation in the original proposal. Even though NFWF ended up administering a number of grants in the other objective categories, this objective holds the largest number of grants. Three of the projects were either directly supported by this agreement, or the non-federal NFWF dollars support is used as direct match. One additional project was supported with NOAA funds through the Coral Funds, but is directly related to the scope of work. Other projects, while important for the overall analysis of mitigation approaches, are either not in one of the three priority watersheds, or not focused on one of the ag-producing run-off types prioritized for this scope of work and therefore are not described further.

PI and Project Identifier: Paul Sturm, Ridge to Reefs, #44400

Title: Stormwater Planters to Treat Contaminated Runoff in Guánica (PR)

Purpose: To establish a community garden to address contaminated runoff that is currently pumped into the waterfront at Guánica Bay, Puerto Rico. This project will create a series of stormwater planters to mitigate contamination from the largest stormwater drainage area in the main town area of this priority watershed and prevent harmful pollutants from reaching the coral reef system that is in decline.

Abstract: The Ridge to Reefs, Inc will use a pump and treat approach to utilize effluent to provide water and nutrients to stormwater planters along the Guánica waterfront or Malecon area. Stormwater runoff and return flow from washwater discharges and sewage leaks combine to create a contaminated stew that is discharged to Guánica Bay several times daily. High concentrations of bacteria and nutrients that are discharged from this area have been highly documented. This project will mitigate contamination from the largest storm water drainage area in the main town area of this priority watershed and prevent harmfull pollutents from reaching the coral reef system that is in decline.

PI and Project Identifier: Roberto Viqueira, Protectores de Cuencas, #43561

Title: Acceleration of Watershed Restoration Efforts in Puerto Rico

Purpose: To accelerate restoration efforts in priority Puerto Rico watersheds, stabilize over 20 acres of drainage area and reforest over 10 acres of land by constructing a native and conservation plant nursery. This project will yield up to 10,000 native trees and 10,000 vetiver plants over two years, which will stabilize soils and prevent erosion and run-off to coral reef systems downstream.

Abstract: The Protectores de Cuencas, Inc. will accelerate restoration efforts in priority Puerto Rico watersheds, stabilize over 20 acres of drainage area and reforest over 10 acres of land. This will be

accomplished by decreasing restoration costs by constructing a native and conservation plant nursery that will yield up to 10,000 native trees and 10,000 vetiver plants in two years. All of these projects will stabilize soils and prevent erosion and run-off to coral reef systems downstream.

The nursery/greenhouse will support several on-going projects including: a) implementation of the Culebra Watershed Management Plan, b) reduction of sediment loads to coastal waters to improve and delimit public access at Bahia Mosquito in Vieques, and c) continue efforts associated with the Shade Coffee Round Table initiative in the Guánica and the central coffee farming region. Protectores de Cuencas, Inc. will also assist farms in completing the certification process and greatly improving soil conservation on the farms with our partners USDA-Natural Resource Conservation Service and US Fish and Wildlife Service.

PI and Project Identifier: Paul Sturm, Ridge to Reefs, #48615

Title: Application of Vegetative and Bioengineering Approaches in West Maui to Help Control Sediment Transport (HI) (other funding sources)

Purpose: To implement mitigation projects to reduce sediment runoff in West Maui, Hawaii. This project will use bioengineering practices that can act to re-stabilize these areas and help to mitigate the impacts from future land use changes as agriculture is reintroduced to the area.

Abstract: The Ridge to Reefs, Inc will implement mitigation projects to reduce sediment runoff in West Maui, HI. West Maui watersheds suffer from a number of stressors to the nearshore reefs including the impact of pollutants from legacy agriculture, increasing urban runoff and wastewater injection wells that connect to the ocean. As former agricultural lands begin to re-stabilize after abandonment, one of the major concerns and observations are the eroding legacy sediments in the channels or gulches which appear to be a significant source of sediment to downstream reefs. Fortunately, the headwater areas within the West Maui watershed have been protected and preserved and extensive efforts have occurred there to remove and keep out invasive and non-native animal species (wild pigs) as well as illegal recreational motor biking. The middle watershed however was intensively farmed until recently for pineapples, seed corn and sugarcane. The relatively erodible soils entrained within the streambeds and flanking terraces within the middle portion of the watershed continue to transport legacy sediments, which preliminary findings suggest, are mobilized by relatively small rain events. The project will work within these middle and lower watershed area to address sediment transport within the gulches.

American Samoa Faga'alu Quarry Design Implementation, #46512:

In Faga’alu, data collected identified a quarry as the major source of sediments smothering nearshore coral reefs. NFWF coordinated with the government of American Samoa, Horsley Witten Group, and Samoa Maritime to develop engineering plans and a mitigation strategy to reduce sedimentation loads from a quarry in the watershed. Funding supported the finalized plans and equipment purchase for implementation. Corrective action at the quarry began in September 2014 and included settlement ponds and other mitigative measures. While this is not an agricultural activity and no NRCS dollars were used to support the project directly, this project combined with the monitoring investments in Objective 3 is the single best opportunity to demonstrate a causal relationship with sedimentation reduction (one of the priority ag-threats) in the watershed to coral health.

Objective 6: *Disseminate the Toolkit to US Coral Reef Managers and Practitioners*

After the suite of tools has been developed and field tested then it needs to be brought to local managers in a forum in which they can be trained on the use and access to the resources and understand how they might use them. Several of the individual projects have elements of both stakeholder engagement to develop the tools and dissemination elements. NFWF intends to contract the generation of training materials for the more complex tools if necessary and then use the task force meetings as a platform for initial dissemination efforts so that stakeholders can discuss and ask questions about the tools in person.

While it is too early to disseminate the products of the toolkit, NFWF has hosted or co-hosted a number of workshops to foster collaboration across the various projects listed in the grants list and many more that are supported outside of NFWF. Some example efforts include:

- In March, 2014 NFWF staff hosted over 20 researchers and managers to discuss the work that is taking place in the two West Maui watersheds and identified opportunities to streamline and standardize methods and ways to collaborate for more comprehensive products.
- In early 2015 NFWF began structured interviews with subject matter experts regarding the assessment and prioritized threat mapping component of the tool-kit. Staff interviewed both agency, academic and for-profit researchers to explore available knowledge and resources and to gain insight in appropriate structure and purpose for tool development.
- NFWF used the US Coral Reef Task Force meeting in Fajardo, Puerto Rico in October 2015 to facilitate convening researchers and mitigation implementers in the Guanica watershed. The Guanica watershed coordinator, with the support of NFWF, convened lead investigators from monitoring projects in the watershed to ensure coordination of their activities. The researchers exchange information about the scope of their projects, including the point location where sampling is occurring.
- September 16, 2016 NFWF hosted eight external participants in a workshop to vet the principles and initial draft of the rapid watershed assessment tool. An agenda of this meeting can be found in Appendix C.

Discussion of Quality Assurance:

The most critical data quality issues are around the biomarker work both in the field and in the lab. The following is an example of some of the specific methods and sampling design for the West Maui sampling sites.

<u>Replicates in the Field - Toxicants</u>

Quantitative protein analyses were performed on the coral (*Porites lobata*) samples collected from the shallow and deep sites at Wahikuli and Honokowai, West Maui, using the liquid chromatography-tandem mass spectrometry (LC-MS/MS) technique. For each site, three biological replicates were used (3 different corals), and each biological replicate had three technical replicates (same coral, but 3 analyses).

The LC-MS/MS run with the Q-Exactive™ used in the analysis can identify thousands of proteins per run. Each run from the current analysis resulted in identification of over 1000 proteins. 'Spectral counting' is a relative quantification technique, which allows pairwise comparison of two conditions (e.g. Honokowai Deep vs Honokowai Shallow) to assess relative differences in the amount of particular proteins, and assigns statistical significance. The following pairs of samples were compared using the spectral counting method:

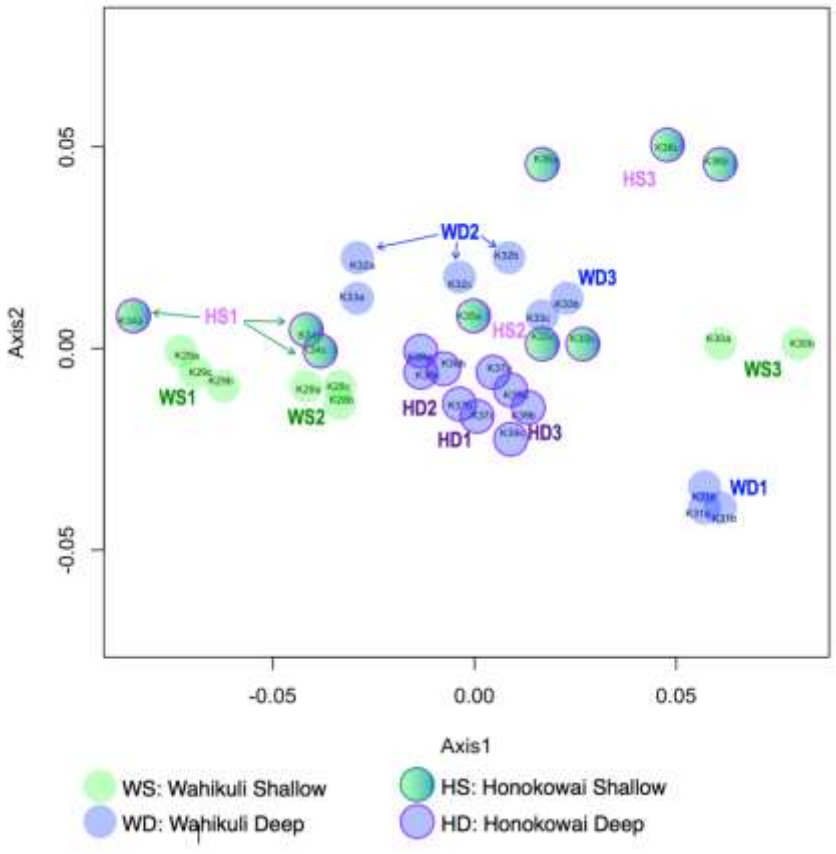
1. Wahikuli Deep vs. Wahikuli Shallow
2. Honokowai Deep vs. Honokowai Shallow

3. Wahikuli Deep vs. Honokowai Deep
4. Wahikuli Shallow vs. Honokowai Shallow

Figure 4 is a non-metric multidimensional scaling (NMDS) plot of the results of LC-MS/MS for all West Maui samples. NMDS is a technique that helps visualize the similarity/dissimilarity of the samples from a dataset. From Figure 1, we can see that the technical replicates (e.g. K29a, 29b, and K29c) for each of the biological samples plotted closely, indicating that sample preparation was good, and the instrument was functioning properly. Any outliers detected in this step were eliminated from the subsequent analysis (e.g. one of the technical replicates for Wahikuli Deep, K30c), and the rest of the technical replicates were pooled to produce one biological replicate result.

Figure 4 also shows roughly how similar the biological replicates were, as well as how different the samples from different sites were. For example, Wahikuli Shallow samples (WS1, WS2 and WS3) spread along the axis 1, while they positioned almost at the same spot on the axis 2, indicating the biological replicates shared similar protein expressions, while some variability existed. This indicates that while the samples from this site may be genetically different, their responses to their environment and stressors are similar. Wahikuli Deep samples (WD1, WD2 and WD3), on the other hand, spread slightly more along both axes 1 and 2, but there was no overlap between the shallow and deep samples, suggesting their protein expression patterns were, in fact, different, as would be expected. Two of the Honokowai Shallow samples plotted along the same position on the axis 2 as Wahikuli Shallow samples, indicating the similarity between the shallow samples from both sites. The biological replicates of Honokowai Deep samples (HD1, HD2, and HD3) grouped especially closely together, indicating protein contents/expressions were uniform and likely stable at this site.

Fig.4: NMDS Plot of LC-MS/MS results



The variability we saw among the biological replicates from this West Maui study appears to reflect inherent biological variation of field samples, which would be expected. In the LC-MS/MS results from our other experiments where genotypes and/or environmental conditions were more strictly controlled, we saw less variability among biological replicates.

Replicates and Treatment in the Lab - Nutrients

To evaluate how coral physiology (transcriptomics, respirometry and photophysiology) and microbial communities and metagenomes respond to a month-long chronic low nutrient exposure, corals (2 species, 7 colonies each) are steadily dosed with nutrients for 4 weeks using peristaltic pumps. Each of three replicate aquaria receives one of 5 levels of nutrients (ranging from 1-13 uM nitrate with phosphate 3:1).

The two biggest lab elements are to maintain the nutrient dosing regime while keeping other parameters as stable as possible. Both of these characteristics of the closed system are monitored throughout the research to make sure they stay within appropriate ranges and standards for error. Figure 5 presents some of the results to date on maintaining treatment protocols and a stable environment.

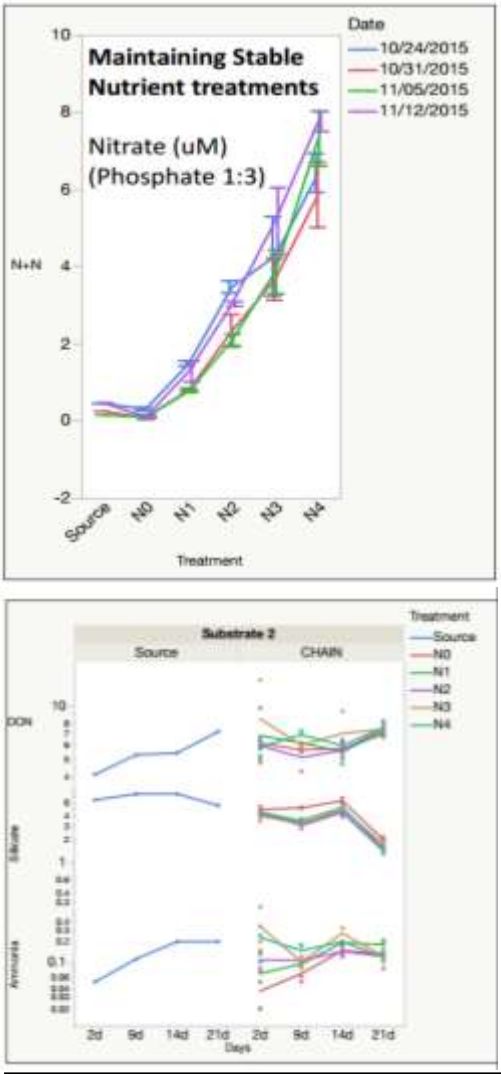


Fig. 5: Selections from a report-out from the Craig Nelson group on nutrients to demonstrate their lab set up (1) and protocols for dosing (2) and environment (3) data quality controls.

Findings

Biomarker and Threshold Research

All of the core grants under these objectives remain active. As is common with new and innovative research, unexpected delays have plagued these projects. Some of the delays experienced by this suite of research include: bleaching events that impacted samples, adaption to new methods that required re-analysis, backlogged labs due to such new and specialized processing requiring one location and huge volumes of data that take significant time to analyze. Still, each of the projects is showing promise for achieving the stated goals and therefore extensions have been granted to not lose the investments in the tool development.

Preliminary reports indicate that corals are responding to threat inputs at the genetic level faster than can be observed visually just as we had hoped. In fact, a large number of genes are responding and therefore the majority of the work that remains is in sorting through all of the responses to look for patterns and the best markers to develop further for field testing. The work on toxicants had already identified markers in the lab when work began for this proposal so their results are further along; still they also changed methods halfway through the process due to breakthroughs in transcriptomic science. Figure 6 is a representation of a gene map for

Fig. 6: Metabolic pathways map, highlighting significantly upregulated pathways at Wahikuli. Shows the annotated proteins that mapped to known metabolic pathways using the iPATH software to provide the diagnostics on the type and relative magnitude of the stressors. Green lines indicate the pathways upregulated in the shallow samples, and blue lines indicate the pathways upregulated in the deep samples at Wahikuli location. The metabolic pathways highlight that xenobiotic/drug metabolism was significantly upregulated (more active) in the shallow sites at both locations. This is the protein expression is a response to pollutants. Additional analyses of the classes of cytochromes P450 expressed can differentiate among classes of pollutants (e.g. organophosphate pesticides versus hydrocarbons).

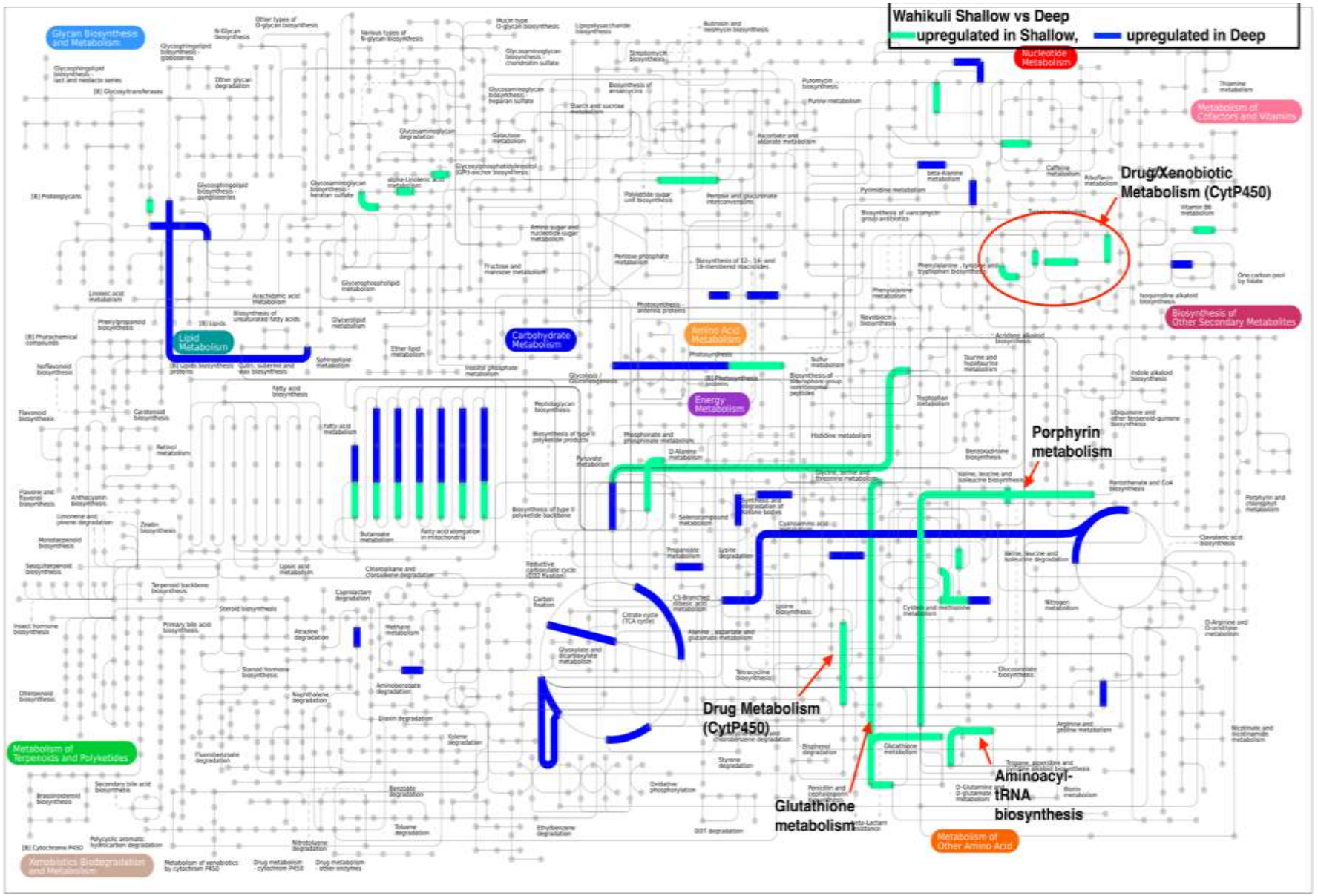
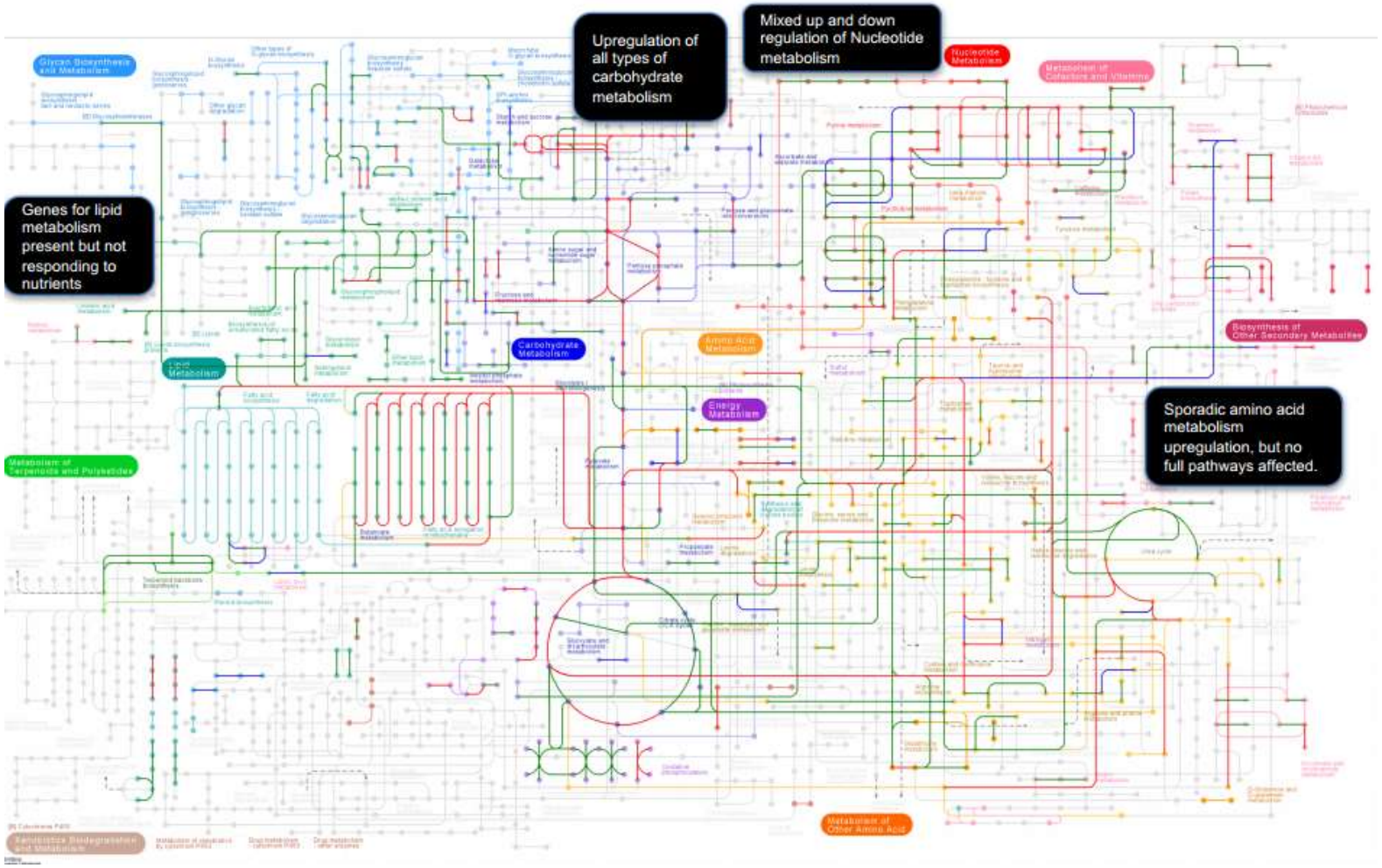


Fig. 7: Similar metabolic pathways map to the one found in Figure 6 from some of the nutrient samples shows a tremendous amount of response activity. While this is promising for eventually developing a biomarker tool for nutrients, it will require an extensive amount of analysis to isolate the patterns for further testing and refinement.



some of the toxicants they tested in the most recent run. Similar maps from the other two projects (such as the one for nutrients in Figure 7) have yet to find which genes they will focus in on and therefore have many more pathways that are showing responses and need to be further refined before the results are this clear.

Below is a brief summary of some of the results to date for the individual projects, the current status and the anticipated completion date (ACD) based on the most recent reports sent to NFWF.

PI and Project Identifier: Francois Seneca, University of Hawaii, #44399

Title: Threshold and Reduction Targets for Land-based Stressors to Coral Reefs (HI, AS)

Status: Active **ACD:** 12/30/16

Progress to Date:

- **Assessment of physiological sensitivity**: The timing of responses in corals experiencing various levels of total suspended sediment concentrations was determined using respirometry chambers fitted with an oxygen probe and Photo-physiological measurements (PAM).
    - *Progress*: An experiment using 400 mg/L Total Suspended Sediment (this concentration was guided by in situ measurements collected by USGS in West Maui – pers. comm. Curt Storlazzi) showed that coral respiration start to remarkably increase between 3 and 4 days of exposure, and reach a 36% increase after 5 days.
    - *Findings*: This finding indicates that coral metabolism is normal for a few days under sediment exposure, probably fueled by excess photosynthates (sugar) produced by their algae. However, in addition to an increased energy demand for maintenance of sediment-free surfaces, corals will also face limitations in their normal source of energy or photosynthates due to prolonged reduced light. These opposite factors are likely to force corals to use alternative energy source such as lipid reserves. This hypothesis may see some support in the genes and proteins that have been detected as significantly regulated in response to sediment stress.

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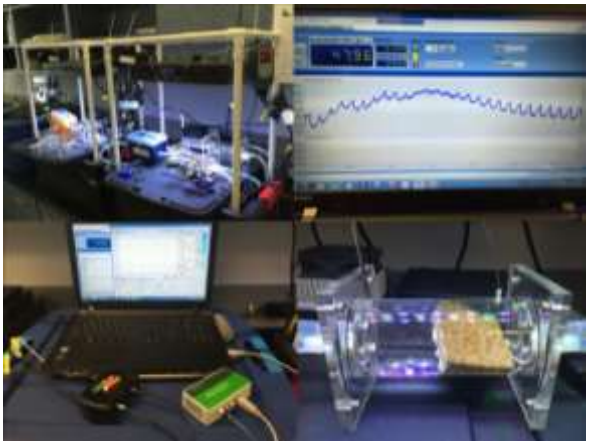
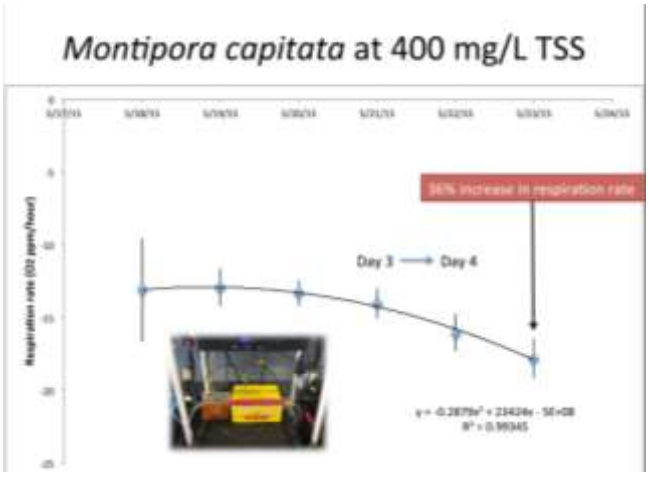




Testing apparatus and initial data for TSS experiments.
Photo: Francois Seneca

- **Total suspended sediment (TSS) experiments on Hawaiian and Caribbean corals**: TSS exposure experiments were conducted using Hawaiian red dirt and four common Hawaiian coral species and Florida Keys white silt and three Caribbean species.
    - *Progress*: A controlled experiment was conducted on four HI coral species (three genotypes per species) at the Hawaiian Institute of Marine Biology. Exposure consisted of two treatments a low brown water event TSS level - 40 mg/L - and a medium brown water event TSS level - 400 mg/L, each lasting for 4 and 7 days before samples were fixed for further molecular analyses. An additional controlled sediment exposure experiment was conducted at the Smithsonian Marine Station in Fort Pierce, Florida using three Caribbean species, Orbicella faveolata, Montastrea cavernosa, and Acropora cervicornis. Three different colonies were used per species and triplicate chunks were exposed to 0, 30, 100, 300, and 1,000 mg/L TSS for 5 days. Samples were collected at the end of the experiment for proteomics and transcriptomics analyses.
    - *Findings*: There was no significant change in the photosynthesis efficiency of the algal symbiont detected, which suggests that suspended sediment has no detrimental effects on the photosynthetic apparatus of the algae over 7 days. This can be explained by the fact that the tanks used for the experiment were much shallower (~ 30 cm deep) than the depth at which corals are found in the field. Although light was reduced to ~1-10 umol.m-2.sec-1 at the bottom of the tanks containing sediment, this PAR intensity is still enough for Symbiodinium to photosynthesize. On the other hand, the same concentrations of sediment in few meters of water, as it occurs in the field, would keep the corals in total darkness and can start to affect the algae around 4 days (DeSalvo et al. 2012).
- **Transcriptomics analyses for the detection of genes responsive to TSS exposure:** Gene expression analysis on corals exposed to TSS has been conducted using RNASeq sequencing.
    - *Progress*: Forty eight RNASeq libraries were prepared and sequenced using the Illumina platform, generating approximately 15 million reads per library. The transcriptomes of the four Hawaiian coral species were assembled and annotated for use to select candidates for the development of antibodies for biomarkers, but the Hawaiian mass bleaching event in 2015 destroyed all of the field colonies that had been acclimated in preparation for this work in West Maui, i.e. Honokowai and Wahikuli. In light of this set-back, the project moved to Florida, at the Smithsonian Marine Station in Fort Pierce to work on three common Caribbean species found in Florida and Puerto Rico. A replicate TSS exposure experiment was conducted in May and June 2016 and samples are now being processed for proteomics analyses.
    - *Findings*: No significant gene expression differences were detected in the controls over time, but significant gene expression differences were detected in response to both TSS treatments. The gene expression analysis has already produced lists of thousands of genes responsive to the sediment exposure treatments. These gene lists from the Pacific and Caribbean species are being compared to identify similarities and differences between treatments but also between species of a same location and across locations. Results will point to genes and proteins that can be best used as biomarker tools of sediment stress across species and geographical locations.
- A talk was given at the 2016 International Coral Reefs Symposium in Honolulu presenting the physiological and transcriptomics results from the experiment conducted on HI corals.

PI and Project Identifier: Craig Nelson, University of Hawaii, #44447

Title: Setting Nutrient Thresholds to Coral Reef Health (HI, AS)

Status: Active **ACD:** 1/30/17

- **Develop a coral/microbial nutrient response gene expression panel**: Conduct a series of mesocosm experiments to define how corals and their symbiotic microbial communities change the expression of genes associated with physiological responses to nutrients.
    - *Progress:* The experiments successfully dosed 300 individual coral nubbins from 7 colonies each of 2 species (Porites lobata and Pocillopora damicornis) continuously at five distinct ecologically-relevant nutrient levels (ambient, 3, 6, 9 and 12 uM nitrate and ambient 1, 2, 3, 4 uM phosphorus) in triplicate independent tanks for 5 weeks. Researchers processed coral nubbins for measurement of surface area, RNA and DNA extraction for gene expression and microbial community profiling, Symbiodinium densities (the zooxanthella symbiont), and other measures of tissue quantity and quality. Illumina RNA-Seq Libraries have been established with 35 Pocillopora RNA extracts representing 7 colonies treated at 5 different levels of nutrients in cooperation with Francois Seneca and sent to the lab for processing – large volumes of data are now being analyzed. Unfortunately coral sampling in Maui failed and therefore a new sampling expedition is planned for Summer, 2017.
    - *Findings:* There are lots of genes increasing and decreasing in multiple coral individuals in response to the nutrients, and there are lots of microbes that increase in percent abundance on the corals dosed with nutrients. The next step will be to narrow down to a few relevant genes and microbes, and look for patterns in the field that can be turned into a marker. Several hundred corals from Samoa and along groundwater gradients in Maunalua Bay on Oahu have been analyzed to test the tool once a marker is identified.
- **Document water quality and reef condition gradients in W. Maui and Faga‘alu**. Along the coast of West Maui there exist regions of high LBSP impact and nearby regions with lower impact (e.g. clearly impacted Kahekili, less impacted Hanaka‘ō‘ō). Water quality data exist from the Hawai‘i Department of Health and USGS and reef condition data exist from both state and federal sources (DAR/CRAMP and NOAA/CRED); this proposal will compile, analyze and supplement these with higher spatial and temporal resolution to help set thresholds for these locations.
    - *Progress*: Surveys of nutrient concentrations have been conducted in West Maui and Faga’alu, surveying 10 samples in each of two transects at each of 4 sites across several sampling events.
    - *Findings*: These results will drive site selection for the threshold gradients in the field (see below).
- **Establish coral and microbial response thresholds to varying levels of N and P from field gradients**. Collect colony fragments of Pocillopora damicornis and Porites lobata colonies from several positions and timpoints in the two study areas and assay the expression level of the 96 genes in the nutrient response panel using the rapid, cost-effective Fluidigm assay to ground truth the lab findings.
    - *Progress*: Had not initiated this aspect of the proposal in the Spring 2016 report although plans for sampling in Faga’alu were scheduled for August 2016.

PI and Project Identifier: Robert Richmond, University of Hawaii, #34413 (funding from other sources)

Title: Effectiveness of Watershed Mitigation Activities on Corals (HI)

Status: Active **ACD:** 12/30/17

- **Collection of baseline biomarker data from the corals along the discharge gradient**
  As biomarkers have already been identified for several toxicants, this portion of the thresholds and biomarker work was able to start with field testing and charectorization of two of the West Maui watershed locations.
    - *Progress*: Sampling has been completed at both the shallow and deep site locations as Wahikuli and Honokowai as well as a control site.
    - *Findings*: The comparison of deep and shallow samples resulted in a significantly more abundant proteins in the shallow locations at both locations. The higher numbers of upregulated proteins in the shallow sites at both locations show that the corals at the shallow sites had enhanced cellular activities in response to reduced water quality. The proteins were filtered to those that matched to the existing UniProt (Universal Protein Resource, which is a catalog of information on proteins [uniprot.org].) IDs. This process identified 285 total annotated proteins in Wahikuli samples, and 484 total proteins in Honokowai samples, which were significantly upregulated at either Shallow or Deep sites.
    - Glutathione, xenobiotic and porphyrin metabolism were also significantly upregulated in the shallow sites at both locations, suggesting higher environmental stress, including exposure to pollutants, at both locations and even a shift away from normal cellular and metabolic function, another indicator of environmentally induced stress. Other highlighted pathways included general amino acid/fatty-acid metabolism and degradation. Since these proteins/pathways are associated with numerous cellular functions, it will require further analysis to fully comprehend what cellular activities were affected in the shallow or deep samples and hence, the diagnosis of specific stressors at this site.
- **Reciprocal transplants of corals along the gradient of discharge to determine the timing and reversibility of protein upregulation and down regulation**
  As biomarkers are being fine-tuned to denote stress from specific threats, the project also is evaluating these biomarkers across a graident to determine sensitivity to levels of stress and to evaluate use in tracking recovery in coral health.
    - *Process*: The initial regulatory pathways analysis using iPATH revealed that transcription, translation and proteasome activities were highly enhanced in the shallow samples at both locations. This suggests that more cellular activities/actions were taking place in the shallow samples. These data are now being assessed in light of the specific stressors and the levels of responses over the gradients of watershed discharges.
- **Controlled laboratory exposure experiments to determine the response times and thresholds for protein upregulation**
    - *Progress*: Had not initiated this aspect of the proposal in the June 2016 report although plans for additional sampling in Maui and these controlled exposure experiments were part of a recent extension request through December of 2017.

Rapid Watershed Assessment

Watershed dynamics are complex, characterized by climate, geology, topography, land use, and other factors. Selecting AND implementing the most appropriate management or restoration strategies is challenging. On top of that, the vulnerability of coral ecosystems to pollutants washed off of the land (land based sources of pollution) also depends on a number of factors related to the coral itself, the currents within the lagoon, and concentrations of key pollutants. Even realizing that the systems were extremely complex, and that each location had its own unique set of conditions, NFWF and its partners were underwhelmed with the WMPs that were being generated as part of the increased USCRTF emphasis. Much of the lack of specificity and ability to measure success seemed to be from an absence of information or current data about the watershed itself and the potential threats to reefs within the system. This stems from a long-standing debate between gathering

more data to increase confidence but 'monitoring corals to death' or implementing obvious problems with what little resources are available while not knowing if you will have enough resources to make a difference or if you are even targeting the critical sources or threats. NFWF worked with contractor Anne Kitchell to try to identify a happy medium that would allow for more informed action without expensive multi-year studies.

To begin, NFWF requested that Anne survey managers and practitioners from all of the US coral jurisdictions to test our assumptions about the tool being created for them. One of the key themes from the survey of island watershed managers was the need for guidance to PRIORITIZE threats, pollution sources, and management strategies. Given limited budgets and staff resources, it is important to know that funds and staff resources are being utilized in a way that will meet desired outcomes for coral reef and watershed protection and restoration. The survey rejected our assumption that the current guidance was too complex and therefore the new tool does not need to 'dumb it down' for local managers, but rather the translation of current guidance to island geographies was seen as a significant need. Practitioners also acknowledged more in-water and on-land monitoring considerations needed to be made at the time of plan development than is currently being done, but that multiple options were needed based on available capacity.

After the survey was complete, the contractor team developed a draft tool based on a decision-tree format which would walk the user through the assessment through a series of yes/no questions (see Appendix C). This process decision-tree was then supported with reference 'profile' sheets for each step for step by step instructions (see example in Appendix D).

This draft tool was presented to a group of practioners in the watershed assessment field and several managers that have been tasked with writing WMPs for coral watersheds at a workshop in September, 2016. An agenda of the working session discussion can be found in Appendix E, including a list of participants.

Other elements identified in the survey for inclusion in the tool:

- Prioritization of threats, pollution sources, and management strategies
- Components of a plan/ checklist with tools
- Elements of a model watershed plan scope of work
- "Formal" risk assessment method
- Modeling and understanding pollution budgets
- Implementation project ideas by pollutant type, ranging from $ to $$$.
- Assessing aggregate impacts: land use, boating, tourism, etc.
- Ways to connect land to coral in monitoring / evaluation strategies
- Focus on community involvement/stakeholders
- Approaches for monitoring: simple to complex; Range of values for water quality to compare monitoring results; ID source & measure impact

Findings: While the need for a tool to assist island jurisdictions was confirmed, the debate continues on how much data is enough for planning and implementation. There are significant concerns about the ability to monitor threat reduction at the scale of watersheds (>5 sq mi) that the USCRTF is supporting and an even greater concern in local manager's ability to link any measurable threat reduction with a change in the coral resource with currently available tools. While this causal relationship is the ultimate goal and making this linkage may result in further resources being available for restoration, the local focus for most jurisdictions is on community engagement and empowerment to gain a groundswell of support for efforts rather than proof that efforts are having the desired effect. The tool will need to balance these somewhat conflicting goals of coral conservation.

Implementation in the Focal Watersheds

When NFWF realized that the standardized metrics created by the USCRTF would not cover on-land monitoring and that the new assessment and evaluation tools would not be ready before implementation projects were underway, the implementation strategy was adapted to focus on filling the gaps in LBSP monitoring and baseline assessment for each of the three geographies and to establish a basis for evaluation for specific threats and implementation projects at the site level were possible. This resulted in three separate approaches to both establishing monitoring programs at each of the locations and in selecting implementation projects.

Guanica, Puerto Rico

As the lead watershed in the USCRTF Watershed Partnership Initiative, Guanica has had the most coordinated investment into threat reduction projects. However, only recently has the emphasis turned to increasing investments in monitoring and fine-tuning the priorities called for in the current WMP with an updated plan.

Restoration site in Guanica uses Vetiver grass to slow down water and reduce erosion. Photo: Roberto Viqueira

While this has greatly increased the investments in research at a variety of scales, coordination of sampling sites and analysis continues to be a problem at this location. NFWF has approached this watershed with a block-grant to a relatively new player to the scene that could bring fresh eyes and was not biased by any of the pre-existing priorities listed in the plan. This comprehensive monitoring program involves a number of tools and techniques including core samples and historical data to establish locally based thresholds.

Implementation projects selected under this award specifically targeted engagement of newly emerging community groups to build capacity for implementation projects and building capacity for restoration projects throughout Puerto Rico and support and engineering at the municipal level which appears to be an opportunity for growth in conservation partnership at this location. This watershed also supported a 'far from reef' 'small scale' project in the form of restoration and BMPs on mountain farms in the upper reaches of the watershed and a 'mid-watershed' 'medium scale' project in an urban area to provide a diversity of case studies.

Current progress, status and ACD are provided for each of these projects below.

PI and Project Identifier: Lisa Rodrigues, Villanova University, #46613 (funding from other sources)

Title: A Toolkit for Managing River Inputs to Coral Reefs (PR)

Status: Active **ACD:** 4/30/2017

Progress: Three sampling trips have been completed focusing on predominantly dry and wet season sampling. In 1.5 years of this study, two of the proposed activities are nearing completion: (1) quantifying watershed pollutant concentrations to discern the threshold for acute stress on coral health and (2) identifying point source impacts and mitigation success of existing riparian buffers. The remaining 6 months of the project will be devoted to completing laboratory and statistical analyses, model development, model ground-truthing, and dissemination with a workshop and/or webinar.

Findings: Worked to date has revealed four knowledge gaps that may continue to limit successful implementation and management of Guánica's Watershed Management Plan (WMP): (1) Current water quality monitoring lacks the spatial and temporal scale required to accurately delineate the relative contribution, timing, and delivery of solute and sediment fluxes to the Guánica watershed. (2) Downstream of the LDC-Rio Loco confluence and towards Guánica Bay, the channel near ID4BB acts as a sediment sink during low discharge periods. The amount of sediment perennially stored there, the amount remobilized during high discharge events, and contaminant content and concentration (e.g., heavy metals, organic compounds) are unknown. (3) Initial findings from metal contamination in oysters from Guánica, suggest a contribution of heavy metals to the near shore bay from land-based activities (both present-day and historical). (4) There is a lack of systematic coral health and coral cover surveys in the Bay. A decision needs to be made by funding partners where they want to be on the 'monitor vs implement' spectrum for this watershed given how large it is. Getting to these significant knowledge gaps will take significant investments in time and money.

PI and Project Identifier: Paul Sturm, Ridge to Reefs, #44400

Title: Stormwater Planters to Treat Contaminated Runoff in Guánica (PR)

Status: Active **ACD:** 12/30/2016

Progress: Initial meetings with the Town of Guánica Public Works and Mayor's Office helped to establish a restoration strategy and approach with Ridge to Reefs, Protectores de Cuencas and the Landscape Architects for the project. Stormwater planters will be constructed adjacent to the vault which collects stormwater and wastewater from the town. Work with city architect to allow for initial treatment to reduce odors and contaminants before reuse for watering within Malecón. Project is working to secure permits for construction.

Findings: The presentation the of the design concepts to the Mayor of Guánica and his staff allowed it to be integrated into a much larger $1.2M redevelopment project for the malecón area. As a result of this effort, the Mayor made it a priority to integrate these water quality and treatment objectives into the project to improve the ecological and economic conditions in the area and to help jumpstart the revitalization of the area. Coordination with Architect Juan Berdasco on folding this project into the larger project will also increase the impact of the project beyond what was initially planned.

PI and Project Identifier: Roberto Viqueira, Protectores de Cuencas (PDC), #43561

Title: Acceleration of Watershed Restoration Efforts in Puerto Rico

Status: Submitting Reports **ACD:** 8/30/2016

Progress: Protectores de Cuencas (PDC) completed 100% of the nursery/greenhouse with a total of three structures built. A three-day Open House for high school and faculty, their parents and the community in general was held reaching approximately, 700 High School students (Grades 9-12) and 30 teachers. PDC identified and enrolled 10 farmers interested in obtaining the shade coffee certification. PDC nursery trees have been used in several restoration projects, including: 1) Culebra: Pta Soldado, Fulladoza, Tamarindo, with additional restoration efforts projected for the next 3-4 years in Culebra; 2) Guánica: Tamarindo, Atolladora and the restoration in several farms. Completed projects as part of the Culebra's Watershed Management Plan implementation are utilizing vetiver grass and native trees.

Findings: The Environmental Education Program Activities were a success. Public involvement exceeded the anticipated participation. This unexpected result was primarily due to the fact that local schools and community in general, have limited exposure to environmental education programs. Furthermore, these activities provided the opportunity for high school students to gain volunteer experience while learning unique skills in the nursery. Hands-on activities have proven to be most effective while educating the community of conservation efforts specific to our area. Completing the nursery/green house has been a great asset to the organization as it has provided the means to produce the vegetative materials used in the continuous restoration efforts at a significantly reduced cost, allowing PDC to undertake additional restoration projects that otherwise would have been postponed due to budget restrictions. The Shaded Coffee Certification process, however, continues to be an increasing challenge. PDC is working with the Certification Board to fine tune the process and start a greater certification process that can push other farmers to move to more sustainable practices.

Future plants for restoration.
Photo: Roberto Viqueria

West Maui, Hawaii

In the two Hawaii watersheds the situation is different from that in Guanica in threats, capacity of local groups, engagement by government, data and size. From the beginning, there was a greater emphasis in data collection and prioritization of threats for implementation. In fact, there has been over 30 documented research projects happening concurrently along the reefs of these two watersheds alone! NFWF's approach to West Maui has been to work with the watershed coordinator to bring these data collection efforts into a unified monitoring plan for the two watersheds and to fill any gaps identified.

NFWF has also hosted an initial meeting of researchers to help them network and collaborate in sampling which resulted in increased on-site project coordination within the same sampling year. The platform was considered so successful that it was repeated by NOAA a year later, using the NFWF model, in which roughly 40 researchers and management partners met to discuss their current projects and those just getting underway. Three PIs which have received NRCS funds under this agreement were present.

New funding from NFWF through the Coral Fund focused on water quality monitoring that could be sustainable for this area. There were concerns with shrinking state budgets and yet there was a concern that 'citizen science' may not be used by managers. The Hawaii location is establishing a citizen monitoring program that will

not only meet EPA quality control guidelines, but will also be specifically approved by the agency as part of the process. This process will also be documented for transferability to other jurisdictions. This general water quality monitoring program for major waterways and bays is supplemented by an urban run-off monitoring program that will help provide a more complete picture of LBSP.

Implementation projects have only recently started in earnest as the focus has been more on establishing the highest priority projects and building a partnership and community base. Many of the projects are extremely large in scale, such as dam retrofits and retention and piping for reclaimed water – and identifying mid-scale projects that will still have impact to show progress has been a challenge. NFWF selected a project that uses a BMP commonly used in the Caribbean but is relatively new to Hawaii to provide a mid-watershed test of a medium scale project to reduce sediment run-off form historical agricultural roads that are no longer being maintained.

Brown water event in West Maui focal geography, agricultural roads and stream erosion have been identified as potential sediment sources. Photo: Tova Calendar

Current progress, status and ACD are provided for each of these projects below.

PI and Project Identifier: Dan DeLany, The Nature Conservancy, #46650 (funding from other sources)

Title: Quality-Assured Community Water Quality Monitoring (HI)

Status: Active **ACD:** 9/30/2017

Progress: The Nature Conservancy (TNC) has engaged federal, state and community partners to develop a quality-assured community-based water quality monitoring program, which we are piloting in the watersheds of Wahikuli-Honokowai, West Maui. The training materials and quality assurance program documentation has been developed and volunteers have been recruited and trained. The first five designated sites are being sampled bi-weekly since June 10, 2016 and work is underway with partners to add an additional twelve sites to the program. TNC and partners submitted a draft Quality Assurance Project Plan (QAPP) to the State of Hawai'i's Department of Health, Clean Water Branch (DOH) in June 2015, resubmitted to the DOH after revisions in February 2016, and again in September 2016. TNC continues to respond to the comments in order to align our program with the DOH program, with the intention of having our data merged into the DOH annual Integrated Report.

Finding: While it is too soon for data findings, TNC has shared the process that they have engaged in with EPA and the state of Hawaii as well as shared manuals and protocols with other watershed coordinators and managers at both ICRIS and the 2016 USCRTF meetings.

PI and Project Identifier: Paul Sturm, Ridge to Reefs, #48615

Title: Application of Vegetative and Bioengineering Approaches in West Maui to Help Control Sediment Transport (HI) (other funding sources)

Status: Active **ACD:** 4/30/2017

Progress: Held an Expert Roundtable (included participants from included the West Maui Coordinator, NRCS, Coral Reef Alliance, Maui Cultural Lands and West Maui Ridge to Reef partnership) and conducted field visits to refine restoration strategies in April/May 2016. Project design is complete and methods have been adapted to West Maui including the use of native plant species and cultural practices as part of the restoration approach. Implementation efforts are being planned for October/November and we are finalizing logistics for the restoration practices as well as the engagement of volunteers etc. A series of techniques and designs for channel and gulch stabilization for use in other Maui watersheds has been created with input from the expert roundtable and coordination is in place with the West Maui Partnership to address treatment (fenced) and control (unfenced) restoration practices to determine the need for fencing for ungulates in future projects.

Faga'alu, American Samoa

Perhaps because of the small scale of the Faga'alu watershed (<2 sq mi) and the size and low complexity of the key threat (one land owner/quarry) – this watershed is the only one in which a causal link between reduction of a threat (sediments) appears to have been measured in the watershed and the baseline and monitoring is in place to monitoring reef response over time. In Faga'alu, baseline data has been collected by researchers from NOAA, San Diego State University, American Samoa Department of Wildlife Resources, and American Samoa Community College to determine stream turbidity, sedimentation rates on reef, and flushing rates of Faga'alu Bay. While San Diego State University has been NFWF's primary grantee, efforts have been made to provide small grants to other local institutions to build their capacity and by the end of 2017, monitoring efforts should be managed locally.

High volume of sedimentation on an otherwise healthy reef system off Faga'alu.
Photo Tent Biggs

Simultaneously, the project team has been coordinating with the government of American Samoa, Horsley Witten Group, and Samoa Maritime to develop engineering plans and a mitigation strategy to reduce sedimentation loads from a quarry in the watershed. Initial data collected identified the quarry as the major source of sediments smothering nearshore coral reefs. Staff from NFWF, NOAA, EPA and NRCS were engaged in the identification of a project to bring the quarry into compliance and significantly reduce sedimentation run-off.

New BMPs in place at Faga'alu quarry.
Photo: Trent Biggs

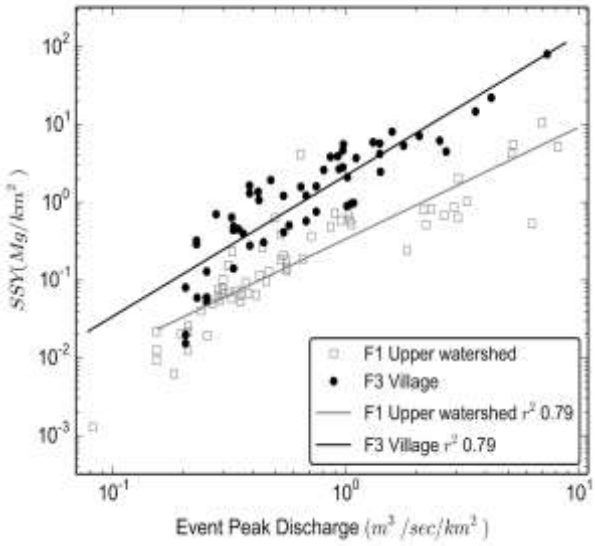


Fig. 8*:* Relationship between event peak discharge during a storm (x-axis) and the storm-total suspended sediment yield (SSY, Mg (tons) per km^2) in Faga'alu watershed, based on storms monitored prior to mitigation activities at the quarry (2011-2013). FG3 shows the SSY at the site in the Village, and the open squares are from site FG1 in the upper, forested watershed. Messina and Biggs, unpublished data.

Several mitigation structures were put in place, including settlement ponds, and post implementation monitoring continues. Figure 8 shows initial monitoring prior to mitigation efforts. The data collected to date will provide the baseline for assessing the effectiveness of mitigation activities. The percent reduction in SSY for a given storm size will be calculated from the newly collected data. Mitigation will be deemed successful if the points below the quarry are within the 95% confidence limits of the relationship for the upper, forested watershed.

Conclusions and Recommendations:

While we are hopeful that these investments will result in a tool box that will significantly change our ability to assess and manage LBSP to the benefit of coral reefs, most of what we have supported is pushing the envelope in current science and management practices. Our initial timeline and budget for these activities and products were not realistic given the exploratory and developmental nature of the products and the number of partners that need to be engaged to build them correctly. While we are not where we had hoped to be at the close of this agreement with finished products and tested tools, this grant from CIG has been an instrumental catalyst in a very large body of work that is producing excellent results and this work WILL continue through its completion. As tools are tested and become ready for up-take by managers, NFWF will work to engage the NRCS USCRTF liaison and credit NRCS and CIG as appropriate for their support.

As these projects are coming to a close we are hearing very promising developments in both scientific breakthroughs and continued support from other sources. As NFWF continues to work in this arena we are also exploring new partnerships that may change the way we invest in watersheds based on the tools that are developed in this agreement. Over the course of this coming year, NFWF is working with its Board of Directors and partners from USGS, NOAA, EPA and NRCS on ways that we can apply some of the preliminary results from this body of work to chart a new course for our coral conservation investments.

NFWF remains committed to furthering support for these efforts to improve management of our watershed and reef systems and we believe the tools started under this agreement are a huge step forward in making that happen and we thank NRCS for their support.

Appendices

Appendix A. Grants List: List of projects supported through NFWF and its partners targeting the objectives and scope of work of this proposal. The projects that received direct support from this agreement or are specifically allocated as match to this agreement are in bold. Not only does this list demonstrate the extensive body of work beyond this specific agreement and investment from NRCS, but it also demonstrates the NOAA partner commitment (funds through NFWF partnership) to the monitoring portion that was pledged in our initial proposal. While some of these projects have completed their activities, many are continuing to work towards shared objectives.

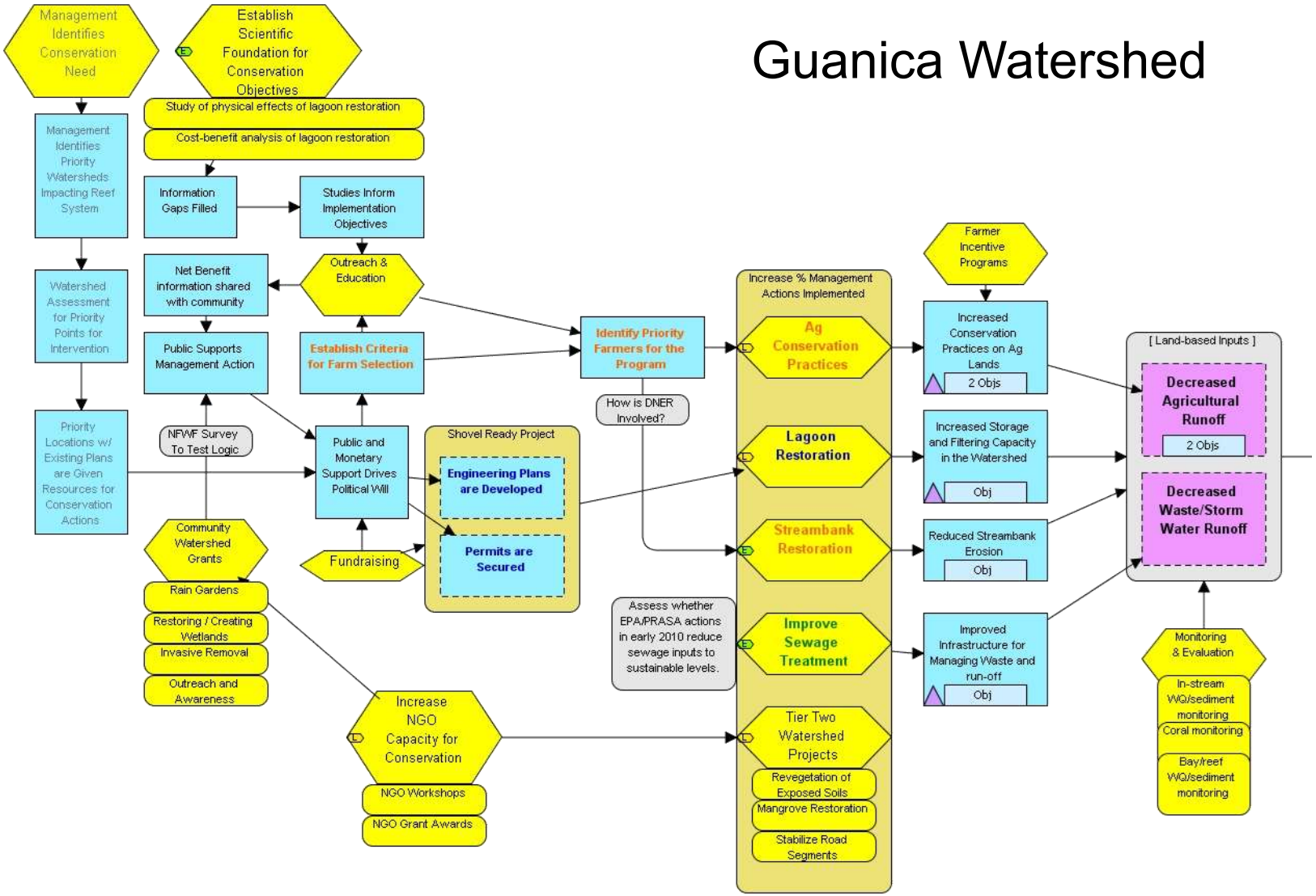
ID	Project	Organization	Project Description	NRCS CIG	NOAA	Other NFWF	Grantee Matching Funds
Threshold Matrix and Biomarker Tool for Health and Mitigation Response Analysis							
44399	**Threshold and Reduction Targets for Land-based Stressors to Coral Reefs (HI, AS)**	**University of Hawaii - Manoa**	**Establish minimum response thresholds and threat reduction targets for sedimentation and turbidity in the main reef-building corals of Hawaii and American Samoa. Project will couple these targets with other tools in development which will allow managers to assess threats to coral reefs and monitor their recovery at a finer scale and in a shorter timeframe.**	**$43,825**	**$45,183**		**$89,492**
44447	**Setting Nutrient Thresholds to Coral Reef Health (HI, AS)**	**University of Hawaii**	**Develop and apply a Nutrient Response Assay for two species of corals and their associated microbial communities in the West Maui and Faga'alu priority watersheds. Project will link water quality thresholds (nitrogen, phosphorus) to microbial and coral physiological responses to create a tool for management to assess impacts to reef systems before coral mortality.**	**$41,000**	**$50,000**		**$91,000**
34491	Toxicity Testing on Coral and Sea Urchins in Hawaii	Haereticus Environmental Laboratory	Conduct toxicity tests to sample areas suspected of contamination from shallow-well sewage injections in West Maui. Project will establish biological effect concentrations.		$15,300		$10,000
34413	Effectiveness of Watershed Mitigation Activities on Corals (HI)	University of Hawaii	Develop evaluation tools and metrics to measure the effectiveness of watershed-based mitigation activities on coral reefs in Hawaii.		$24,005	$60,000	$0
Rapid Watershed Assessment for Threat Prioritization							
51456	**Watershed Threat Assessment Tool Development**	**Horsley Witten Group, Inc.**	**Develop a simplified decision support tool for improving the link between watershed management priorities and coral health.**	**$46,228**	**$3,522**	**$31,150**	**$0**
34562	Coastal Use Mapping for Management-Decision Making in American Samoa	San Diego State University Research Foundation	Support participatory digital mapping of coastal uses in American Samoa.		$59,385		$0
Tools for Monitoring and Evaluation to Determine Causal Relationships							

46613	A Toolkit for Managing River Inputs to Coral Reefs (PR)	Villanova University	Create a cost effective, transferrable, and easy-to-use toolkit consisting of models and a management guide that will support watershed management. Project will use a multi-tiered sequential approach combining analyses of instantaneous water quality and coral health, riparian buffer efficacy, and the record of historic land use in coral and sediment cores to identify land-based sources of pollution and to reduce specific acute and/or chronic stressors on coral reefs in the Guánica watershed.			$125,454	$161,465
46650	Quality-Assured Community Water Quality Monitoring (HI)	The Nature Conservancy	Implement a community-based, quality-assured water quality monitoring program for the reefs of Wahikuli-Honokowai. Project will produce a quality assurance plan, standardized methods, training modules and baseline data.			$108,395	$109,475
41502	Nutrient and Sediment Contributions from Urban Storm Water (HI)	University of Hawaii	Gather data in two West Maui priority watersheds to allow management measures to target areas contributing the greatest sources of pollutants to marine waters. Project will characterize water quality at various points throughout the urban portion of the watershed.			$66,525	$66,692
48808	Capacity Building for On-Island Impact Assessment of Sediment Load Reduction in Faga'alu Watershed, American Samoa	San Diego State University Research Foundation	Build capacity for sediment load reduction monitoring in the Faga'alu watershed, American Samoa. Project will provide an assessment of the impact of mitigation activities recently completed to address run-off from an active quarry.		$41,261	$4,000	$45,261
34806	Monitoring Sediment Impacts to Coral in Faga'alu Bay, American Samoa	American Samoa Community College	Study flow dynamics and sedimentation effects on coral colonies in Faga'alu Bay, American Samoa. Project will collect photo-quadrats to monitor long term impacts of sediment.		$2,400		$0
34883	Develop Sediment Budget for Coral Health in American Samoa	Alex Messina	Continue monitoring of sediment flux to a priority coral reef during and after a watershed and coral reef restoration project.		$4,000		$0
35657	Survey of sedimented shallow reefs in American Samoa	AS-DMWR	Track temporal changes in coral reef benthic cover in selected sites in Fagaalu reefs, Tutuila Island by photo-quadrat method. These changes will be related to the dynamics in sedimentation.		$4,840		$0
34503	Talakhaya Watershed Soil Loss Assessment, CNMI	University of Guam	Design and carry out a study to assess and quantify the change in soil loss from Talakhaya watershed badlands as a result of the revegetation efforts being conducted by Rota DLNR-Forestry staff.		$123,600		$23,000
45591	Pilot Coral Reef Ecosystem Status and Trends Report	University of Maryland Center for Environmental Science	Develop a status and trends assessment framework and report card process that synthesizes biological, physical, and socio-economic data from two jurisdictions of the National Oceanic and Atmospheric Administration's Ocean and Coastal Resource Management Program.		$60,000		$0
Support the Testing of Innovative Approaches to Addressing Common LBSP							
46512	**American Samoa Faga'alu Quarry Design Implemention**	**National Fish and Wildlife Foundation**	**To fill in any gaps in funding for implementing the engineering plans for the Faga'alu Quarry.**	**$0**	**$0**	**$113,896**	**$0**
43561	**Acceleration of Watershed Restoration Efforts in Puerto Rico**	**Protectores de Cuencas, Inc.**	**Accelerate restoration efforts in priority Puerto Rico watersheds, stabilize over 20 acres of drainage area and reforest over 10 acres of land by constructing a native and conservation plant nursery. Project will yield up to 10,000 native trees and 10,000 vetiver plants over two years, which will stabilize soils and prevent erosion and run-off to coral reef systems downstream.**	**$10,500**	**$60,000**	**$4,500**	**$75,000**

44400	**Stormwater Planters to Treat Contaminated Runoff in Guánica (PR)**	**Ridge to Reefs, Inc**	**Establish a community garden to address contaminated runoff that is currently pumped into the waterfront at Guánica Bay, Puerto Rico. Project will create a series of stormwater planters to mitigate contamination from the largest stormwater drainage area in the main town area of this priority watershed and prevent harmful pollutants from reaching the coral reef system that is in decline.**	**$17,883**	**$57,117**		**$85,000**
48615	Application of Vegetative and Bioengineering Approaches in West Maui to Help Control Sediment Transport (HI)	Ridge to Reefs, Inc	Implement mitigation projects to reduce sediment runoff in West Maui, Hawaii. Project will use bioengineering practices that can act to re-stabilize these areas and help to mitigate the impacts from future land use changes as agriculture is reintroduced to the area.		$74,225		$74,494
30936	Stabilizing Streambanks and Reducing Erosion in South Kohala to Benefit Coral Reefs (HI)	The Kohala Center	Reduce sediment inputs into Pelekane Bay coral reef system by reducing land-based run-off. Project will engage volunteers to capture overland flow of sediment with erosion-control structures, and will restore stream banks in key drainages.		$60,000		$69,500
31007	Engage West Maui Hotels in Watershed Management Planning	The Coral Reef Alliance	Perform targeted outreach to assess the demand for reclaimed water by West Maui Hotels and to engage this industry in watershed management planning.		$55,524		$69,000
38245	Storm Runoff Remediation in Napili Bay (HI) - II	Napili Bay and Beach Foundation, Inc.	Finalize streambed remediation to complete planned flora restoration, and expand Napili Bay health monitoring efforts to include assessment of nutrient pollutants in runoff.		$28,000		$28,000
39345	Quantifying Watershed Erosion Control Impacts on Coral Reefs in the U.S. Virgin Islands	University of San Diego	Assess the effectiveness of watershed erosion control best management practices through marine and terrestrial monitoring in Coral Bay, U.S. Virgin Islands.		$18,055		$18,102
43499	Sediment Run-off Reduction in Coral Bay St. John (U.S. Virgin Islands)	Coral Bay Community Council, Inc.	Install sedimentation reduction practices in two drainage basins and make recommendations in other areas to continue sediment reduction efforts in Coral Bay. While this project targets two drainage basins within Coral Bay, the techniques used are designed to be replicable throughout the U.S. Virgin Islands and elsewhere.		$67,010		$67,146
48288	Advancing Reef Sustainability to Reduce Land-Based Pollution in the West Maui Watershed (HI)	The Coral Reef Alliance	Advance watershed conservation that complements the Wahikuli-Honokowai Watershed Management Plan in Hawaii by targeting shoreline properties in reducing land-based sources of pollution. Project will spread knowledge about low impact development (LID) alternatives and engage 10 property owners in implementing 10 new sustainability measures, of which at least three will be LID related.		$50,000		$173,000
48638	Rain Garden Installations for the Priority Watersheds of American Samoa	American Samoa Department of Marine and Wildlife Resources	The Department of Marine and Wildlife Resources and the Coral Reef Advisory Group of American Samoa will engage local communities to install rain gardens in four priority watersheds on the islands of Tutuila and Aunu'u. The villages of Faga'alu, Vatia, Nu'uuli and Aunu'u will each be represented by a community group to organize volunteers.		$43,310		$40,000
41171	Implementation of Priority Watershed Projects in Guam	Marianas Resource Conservation & Development Council	Enable improved availability of native plants for stream bank stabilization and targeted erosion control projects to include mini-grants to growers. Support Community Coral Reef Monitoring Program.		$22,500		$4,800

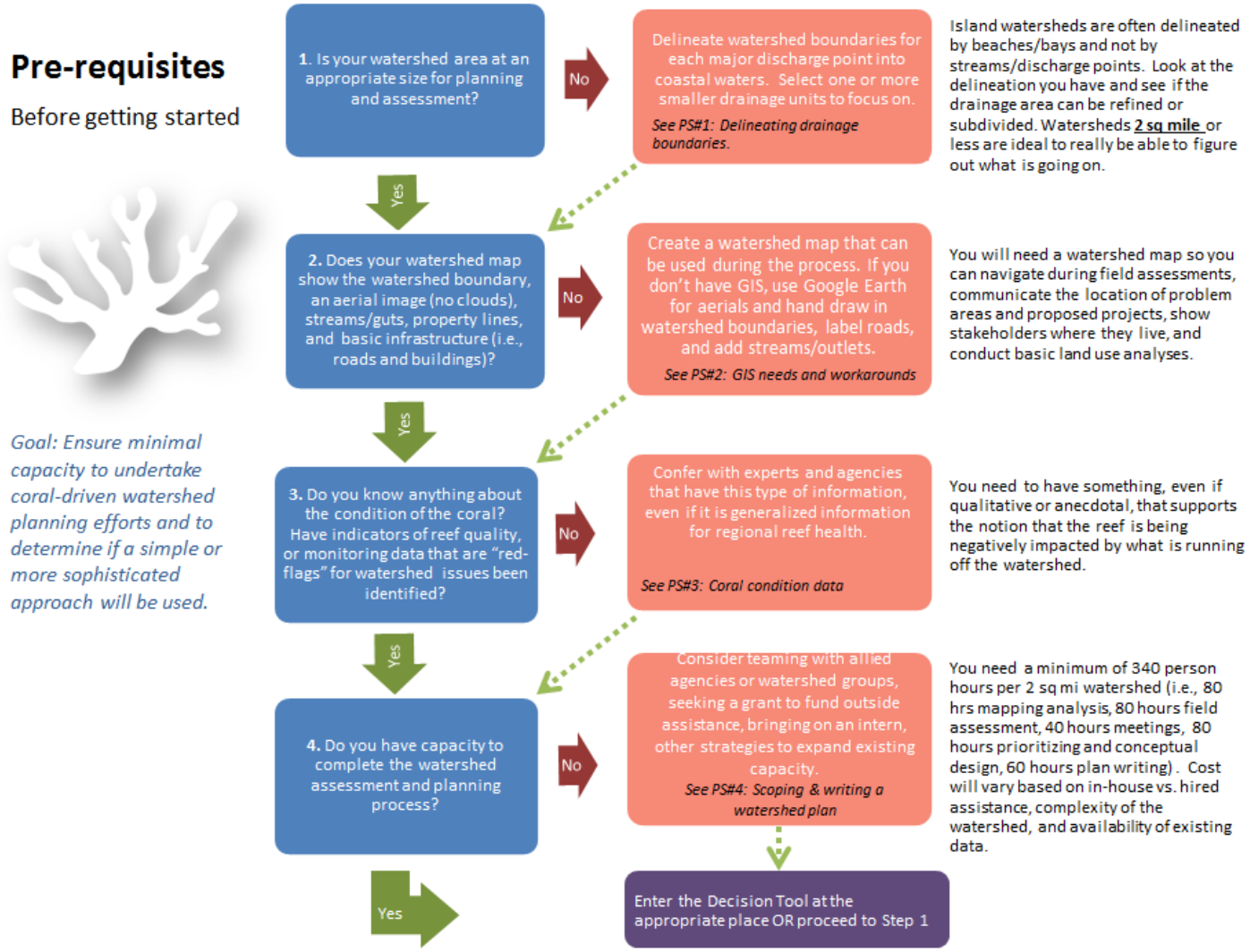
46248	Stabilization of Green Cay gut to significantly reduce sediment loadings to St. Croix East End Marine Park and Chenay Bay	Horsley Witten	This project is a multi-agency effort to implement a stream restoration project to stabilization an actively eroding headcut on the East End of St. Croix that was identified as a significant contributor of sediment to the East End Marine Park. This project involves obtaining the necessary permits, securing additional funding, and overseeing construction activities.		$131,400		$55,000

Appendix B. Theory of Change for Guanica Watershed Investments: Significant effort was made at the beginning of the USCRTF Watershed Partnership Initiative to lay out the theories of change in the watershed and which agencies would take the lead on each of the main elements prioritized in the WMP (NRCS-orange, NOAA-blue, EPA-green). While monitoring and evaluation was discussed, a comprehensive monitoring plan was never implemented to track progress through the framework. Quantitative targets were also not a part of the initial scoping.



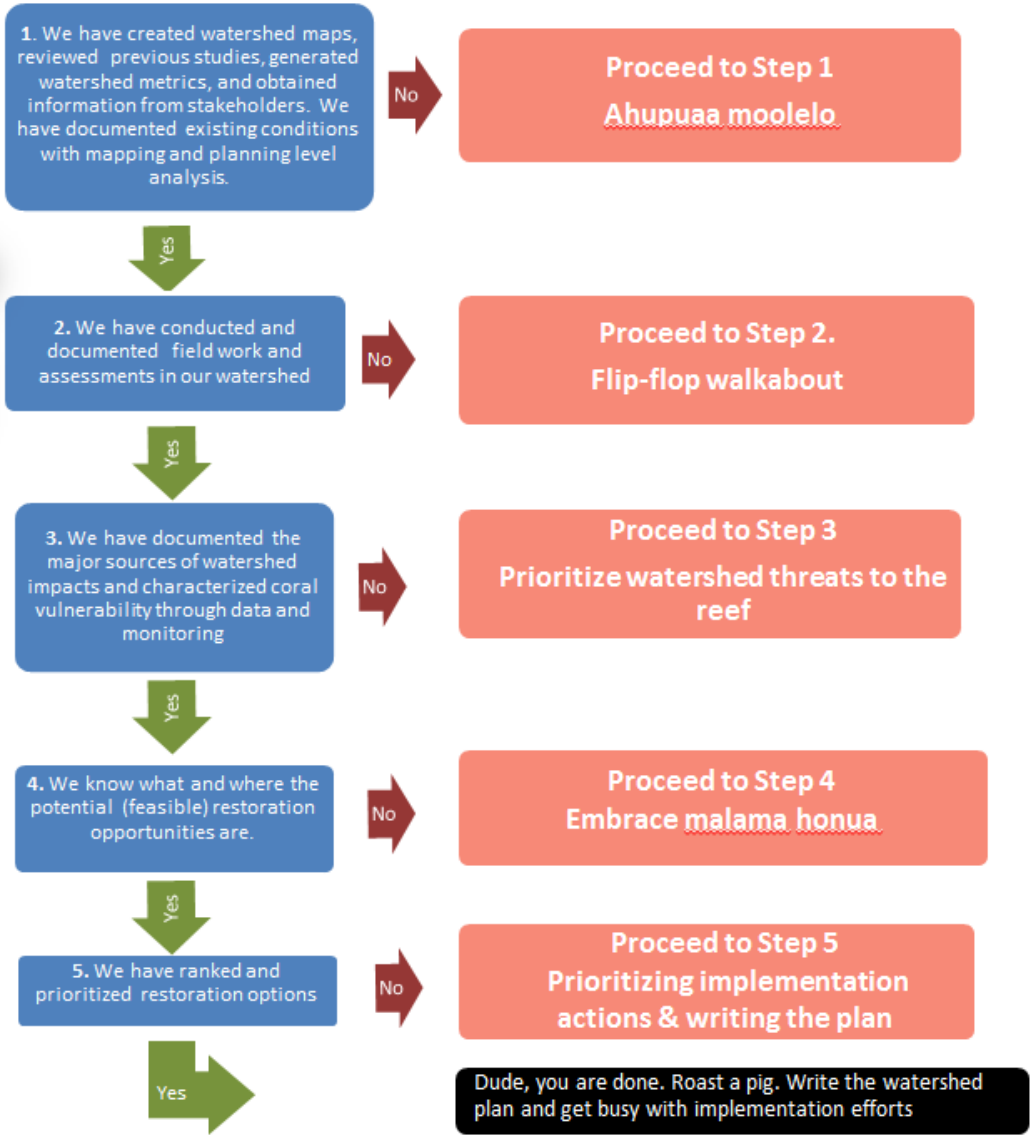
Appendix C. Draft Watershed Assessment Tool

The following screen captures are example elements of the tool from the version presented to the working group at the September 2016 meeting. Provided are the pre-requisites for using the tool effectively, a decision-tree for understanding where to enter the tool based on work done to date at the location and an example of one of the five steps in the tool. An updated version is being developed for a report out in January 2017 and then testing in at least two watersheds.



Enter the decision tool

Goal: Make the best use of this tool by acknowledging work that has been done and work yet to do to have a successful plan.



STEP 2
Flip-flop walkabout

Goal: Adding to the watershed story through field investigations to identify watershed problems, verify existing conditions, ID potential locations for restoration actions, and filling gaps in watershed mapping. Note: Wear close-toed shoes.

1. Have you pre-identified locations to visit based on what you know about the watershed, accessibility, and level of effort you can dedicate to the field?

No → Develop a field plan that identifies teams and schedules, locations to visit, and who should join you on-site to provide more information or access.
See PS#2: GIS needs and workarounds
See PS#8 Field Plan

Island watersheds can have steep, inhospitable terrain; no public easements on stream corridors; impassible roads; aggressive feral cats; and places were you could get into trouble. Know your limitations, call ahead, don't go alone, respect private property, and take a phone and a first aid kit.

Yes ↓

2. Have you observed both wet and dry weather conditions at key coastal discharge locations?

No → Conduct synoptic or more systematic surveys. Note If there is a beach berm.
See PS#9: Discharge observations

Go to each stream/gut opening or outfall pipe to observe conditions when it is raining and to see if there is flow even if it hasn't been raining (outfall pipes and non-perennial streams)

Yes ↓

3. Have you explored streams/guts/wetlands and mapped drainage infrastructure (piped conveyance systems)?

No → Streams and wetlands are watershed resiliency features. Walk the stream network where feasible. Evidence of problems in stream can be followed uphill to potential sources.
See PS#10. Stream walks & Discharge observations

You could burn all your field effort on stream walks. Consider popping in and out at strategic locations and reserving sweaty hikes to known problem locations. Key things to look for include overall habitat quality, concrete walls, culverts, discharge pipes, channel erosion, trash locations, and buffer quality. For ponds and wetlands, get a sense of depth and habitat quality. Lots of guidance out there. Could be complex or simple.

Yes ↓

4. Have you driven or walked upland areas (outside of the immediate stream corridor)?

No → Explore. Get sense of pollution sources, landuse hotspots and upland drainage patterns (along roads, piped network, etc) to each key discharge locations
See PS#11: Upland assessments

When driving around uplands, you are looking for things that could be problematic when it rains. Hotels, farms, auto repair, dumps, piggeries, quarries, etc. Check out "neighborhoods" for maintenance practices and evidence of organized community groups.

Yes ↓

5. Have you updated watershed mapping and communicated field findings

No → Transfer field findings to maps. Let stakeholders know what you saw.
See PS#1: Delineating drainage boundaries
See PS#2: GIS needs and workarounds
See PS#5: Stakeholder input

Update maps to show problem locations, existing infrastructure, flow paths, etc. Post for easy viewing, Google webmaps, etc.

Yes ↓

Proceed to Step 3.

Appendix D. Example Profile Sheet from Watershed Tool

Throughout the tool are references to profile sheets that explain more about the step, why it is important, steps to achieve the step at different levels (based on capacity and resources) and references for further information.

PS#15 Stormwater Retrofits

What Is It?

Stormwater retrofits are permanent, structural BMPs used to address existing stormwater runoff problems (e.g., flooding, water quality, channel erosion). Retrofits are added to infrastructure (e.g., stormwater systems, roads, parking lots, rooftops) as an attempt to rectify the "sins of the past" by managing runoff where there currently is no treatment, or where treatment is ineffective. Retrofits include BMPs, such as cisterns, ponding basins, bioretention facilities, infiltration systems, porous pavement, impervious cover disconnection, and similar practices. In the context of this profile sheet, stormwater retrofits do not include temporary construction site controls (see PSx) or measures to stabilize unpaved roads (see PSx).

Why Is It Important?

Where stormwater impacts exist, development has already occurred, impervious cover has been built, and natural drainage paths have been altered. Regulations that control runoff from new/future development will do nothing to address existing stormwater issues. Retrofits are one way to improve conditions (albeit an expensive remedy) while achieving other related objectives, such as community greening, public outreach and watershed education, design demonstrations, and green jobs.

Getting Started

You don't need to be an engineer to identify stormwater retrofit opportunities, although you may need an engineer to design and permit retrofits for implementation, depending on their level of complexity.

- Clearly define the objectives of retrofitting by identifying the pollutant of concern and removal targets (some BMPs are better than others for certain pollutants), flood control goals (are you looking for storage, reuse, and recharge options), and other goals for your watershed.
- Review guidance documents to get a sense of the process for conducting a retrofit inventory and developing retrofit options. Two references we recommend for island practitioners are:
  - *Urban Stormwater Retrofit Practices* (CWP, 2007) – this guide contains detailed information on both the process of conducting a retrofit inventory, BMPs for urban retrofits, and methods for estimating retrofit costs.
  - *Stormwater Management in Pacific and Caribbean Islands: A Practitioner's Guide to Implementing LID* (HW and CWP, 2014)) – guidance on how to envision retrofits of existing BMPs and

WATERSHED ASSESSMENT LEVELS

	*Baseline Level* *Visit handful of promising sites, look for most feasible, highly visible opportunities; goal is to start the process and generate support through demonstration projects*
	*Good Practice Level* *More systematic inventory of known problem sites and ranking process; goal is to implement multiple projects across the watershed to begin to achieve load reductions*
	*Best Practice Level* *More extensive look at unmanaged portions of watershed; goal to meet specific management targets*

PS15-1

how hardscapes and landscapes can be integrated with stormwater management in the islands.

- Consult with NOAA representatives and island environmental agencies and public works about retrofit/drainage projects that are planned or have been installed in your jurisdiction or neighboring islands. What are the lessons learned?

Baseline Level

The least complicated approach to retrofitting is an opportunistic one that focuses efforts on identifying low-cost, low-effort practices in public, highly visible locations (e.g., "demonstration" projects). Simple BMPs such as enhancing riparian vegetation, rain gardens and small cisterns, don't require complicated engineering design, lengthy permitting process, and can be installed (and replicated) by community volunteers. While the ultimate goal is to improve conditions, the idea here is to identify early action projects that can generate restoration enthusiasm and build your retrofit capacity.

1. Look at your watershed map and identify candidate locations for retrofitting (usually schools, parks, town hall buildings, and popular sites, such as tourist/recreation parking areas).
2. Make a site visit to each candidate site; bring along your public works staff person and, if possible, your NOAA representative. Do a quick evaluation of whether the site looks promising for a retrofit. Evaluation the impervious area that drains to your proposed location. Be certain to check for site constraints, such as utility lines.
3. Make a simple sketch plan for the most promising sites. Consult state or territorial rain garden guidance, or stormwater manual to help size your BMP and identify needed materials.
4. Prioritize your sites based on simple factors, such as visibility to the public and the opportunity to treat runoff from areas that are not currently treated.
5. The implementation stage will require partnerships, funding, community outreach, and perhaps some technical design support. However, you will find that the planning work mentioned above will help generate support and enthusiasm.

Figure PF15-1. Relatively simple rain garden installation in Guam.

Good Practice Level

The baseline level is a great way to generate interest and enthusiasm for watershed restoration. However, a more systematic approach that implements multiple retrofits across the watershed is needed to begin to achieve actual pollutant load reductions.

This approach can built on the work done at the baseline level by adding a more extensive GIS analysis and field identification of opportunities on both public and private sites. In order to score, rank, and prioritize potential projects, more information should be collected (in the field and through additional research) at the

concept stage. A general procedure would be to:

1. Conduct a more extensive GIS analysis of candidate retrofit sites on public and private land. To the extent possible, include watershed drainage infrastructure (pipes, BMPs, drain inlets, outfalls) in areas where retrofits are planned.
2. Allocate the time and resources (with professional assistance as needed) to conduct a field reconnaissance of candidate sites, filling out field forms at each sites, such as CWP's "Retrofit Reconnaissance Inventory" (RRI, see CWP, 2007 or island-specific versions used in various jurisdictions).
3. For the best candidate sites, develop relatively simple concept plans: these are not full engineering plans, but have enough detail to identify the approximate size of the practice as well as planning-level excavation, grading, and materials.
4. Use simple, available BMP pollutant reduction and cost data to project estimated pollutant load reductions and planning-level costs for each project.
5. Score, rank, and prioritize candidate projects based on pollutant load reduction and cost/benefit, as well as other selected "screening factors," community support, feasibility, maintenance requirements, and site constraints (e.g., utilities). (see **Step 5** in the watershed planning process).

CWP (2007) provides more detail on the retrofit identification and screening process.

Implementation for this type of project will likely require engineering and construction plans, permits, and a good deal of coordination and project management. Outside expertise and inter-departmental collaboration are necessary elements.

Figure PF15-2. A more complex permeable parking lot retrofit on Oahu.

Best Practice Level

This approach will integrate the GIS analysis and field work described above for Good Practice with modeling of resource protection and watershed goals. These goals may address flooding or drainage issues, climate change adaptation, pollutant load reductions, enhancement of community infrastructure, and/or other objectives.

The Best Practice Level can focus on understanding how much area in your watershed is unmanaged and how much of this land needs to be managed to meet your objectives. The approach includes embracing more complicated designs, larger practices integrated with other infrastructure (e.g., roads, parking lots, large rooftops, drainage systems), a more sophisticated strategy for cost/benefit analysis, and implementation plans that encompass multiple projects on public and private land.

For both the Good and Best practice levels, retrofits can include: island bioretention, permeable parking, rainwater harvesting, and converting ponding basins into multi-cell wetland systems, among others.

PS15-3

In addition to the steps outlined for the Good Practice level, the following can be completed (each step is a suggested practice, but your exact steps will be prescribed by the goals and objectives of your watershed planning process):

1. Involve an engineering professional.
2. Research and select an appropriate model that can assist with the project. It is important to pick a model that is sophisticated enough for project needs, but not too sophisticated such that it is difficult to run and keep updated through time (see *PF#7, Watershed Pollutant Budget* for more guidance).
3. Delineate watershed areas that are currently managed and unmanaged by existing stormwater BMPs (treated prior to discharge off-site). You may need to review design plans for existing facilities, or conduct more detailed field assessments to delineate drainage areas or map flow paths.
4. Estimate total watershed impervious cover that needs to be managed to meet in-water restoration goals.
5. Quantify additional watershed area that could be managed with potential retrofits and quantify potential volume, flow, and load reduction benefits of each retrofit.
6. Develop design plans in enough detail to provide planning level cost estimates based on volume managed and other site factors. Include cost of advanced design, permitting, and construction.

As with many practices, it is best to have an overall retrofit plan for your watershed. This retrofit plan can be an important component of the watershed plan. The retrofits themselves require a fairly extensive planning, design, and installation process, and long-term maintenance requirements should always be considered early in the process.

References & Resources

Center for Watershed Protection (CWP). 2007. Urban Stormwater Retrofit Practices: Urban Subwatershed Manual Restoration Manual 3. http://owl.cwp.org/mdocs-posts/urban-subwatershed-restoration-manual-series-manual-3/

Horsley Witten Group and CWP. 2014. Stormwater Management in Pacific and Caribbean Islands: A Practitioner's Guide to Implementing LID. Prepared for: NOAA Coral Reef Conservation Program. http://www.coris.noaa.gov/activities/stormwater_lid/

HOK, 2012. Hawaii Rain Garden Manual

Hawaii Rain Garden App

Hawaii LID for Hotels

CNMI Rain Garden Guide

AS Rain Garden Guide

Guam Coastal Management Program. 2012. Rain Garden Installation Training Guide, Santos Memorial Park, Piti, Guam. http://www.coris.noaa.gov/geoportal/catalog/search/resource/details.page?uuid=%7BDE12F8CD-720C-4AD1-ADC1-65BC04F5AE65%7D

CNMI/Guam stormwater manual

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Appendix E. Work Session Agenda

WORK SESSION

PROJECT: NFWF Coral Watershed Assessment Tool
DATE/TIME: Friday, September 16, 2016 @ 8:30 AM -4:30 PM
LOCATION: National Fish and Wildlife Foundation
1133 Fifteenth Street, NW, Suite 1100
Washington, DC 20005
Phone 202-857-0166
ATTENDEES*: Michelle Pico and Courtney McGeachy (NFWF); Craig Goodwin (NRCS); Paul Sturm (RTR); Lisa Vandiver (NOAA); Carlos Ramos-Scharron (UT); Patricia Reed (former CBCC); Kaity Mattos (former CNMI BECQ); Dave Hirschman (HWE); and Anne Kitchell (HW)

** in-person. Cheryl Woodley (NOAA) may potentially call in*

Agenda

8:30-9:00 **Project background and survey of island watershed managers**
Purpose of the tool and what island watershed practioners think they need to do a better job with watershed assessment, planning, and prioritization of restoration activities

9:00-10:00 **Review other decision support tools (brief) & "strawman" framework**
Example decision tools provided by NFWF; walk through the draft 5-step tool and the profile sheet template(s)

11:00-12:00 **Expert insights into overall process**
Does the process make sense to you? Is this doable and does it offer anything new to island managers? What is missing? How can it be simplified?

12:00-1:00 **Lunch**

1:00-2:00 **Profile sheets: Land Use Loading Budget & Modeling**
What is the simplest method of estimating watershed loads? Can we assign default island loading coefficients? What are more sophisticated models you could recommend and what inputs are required? Do you have guidance on how to select a particular modeling approach?

2:00-3:00 **Profile sheets: Coral indicators/vulnerability to LBSP & monitoring protocols**
What is the minimum information needed to characterize reef health? What methods should be referenced for managers to determine susceptibility to LBSP? How do we direct managers down the path of baseline and long-term monitoring?

3:00-4:00 **Profile sheets: Watershed metrics/stressors (threats matrix) & linking threats to restoration opportunities**
How do you determine which watershed impacts have the most influence on reef? Do we have the right restoration options linked to watershed threats?

4:00-4:30 **Wrap-up**
Are there any follow-up items you can provide? What is our revision and roll-out schedule?