

**Monitoring Strategy and Preliminary Survey
Design for Guam/CNMI Coral Reef
Ecosystem Studies with a Focus on Apra
Harbor and Kilo Wharf¹**

based upon results from

**Guam/CNMI Marine Natural Resources
Monitoring Protocols Workshop
December 7-10, 2007
Honolulu, Hawaii**

**NOAA Pacific Islands Fisheries Science Center
Coral Reef Ecosystem Division**

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Introduction

This report has been prepared by the Coral Reef Ecosystem Division (CRED) of the Pacific Islands Fisheries Science Center (PIFSC) of the National Oceanic and Atmospheric Administration (NOAA) in response to a request from the Naval Facilities Engineering Command (NAVFAC) of the U.S. Navy to develop a monitoring plan to assess ecological impacts of proposed Navy activities in the Mariana Archipelago, with particular focus on planned construction at Kilo Wharf in Apra Harbor, Territory of Guam.

As background, NAVFAC is responsible for service to the U.S. Pacific Fleet, by serving as the Navy's facilities, installation, and contingency engineers in the Pacific Area of Responsibility (AOR). As part of this mission, NAVFAC is in charge of expansion of Kilo Wharf in Apra Harbor, which is scheduled to begin construction as early as March 2008 (permit pending), as well as numerous other potential projects in the U.S. Territory of Guam and the Commonwealth of the Northern Mariana Islands (CNMI). In preparation for this work, NAVFAC requested assistance from CRED to develop and implement a design for ecological monitoring of the benthic habitats, associated biological communities, and environmental and water quality conditions of Apra Harbor before, during, and after dredging and construction at Kilo Wharf. In those requests, NAVFAC indicated their desire for CRED to perform this work due to the similarity of the monitoring requirements to CRED's primary mission. Tasked by NOAA's Coral Reef Conservation Program, CRED leads an integrated, multi-disciplinary program of research, mapping, and long-term monitoring of coral reef ecosystems of the U.S.-affiliated Pacific Islands to promote conservation, management, and public awareness. In carrying out this mission, CRED scientists, in collaboration with local scientific institutions and resource management agencies, have been conducting biennial Pacific Reef Assessment and Monitoring Program (RAMP) research cruises to monitor the abundance and distribution of corals, other invertebrates, algae, and fish in the context of their benthic and oceanographic habitats around the 50 island and atoll ecosystems of the U.S.-affiliated Pacific Islands since 2000 using consistent, standardized methods. As part of Pacific RAMP, Mariana Archipelago RAMP cruises in 2003, 2005, and 2007 surveyed the coral reef ecosystems of the islands and a few submerged banks in the Mariana Archipelago, with the exception of Farallon de Medinilla.

Following the initial request from NAVFAC, Dr. Russell Brainard, Division Chief of CRED, initiated discussions with colleagues at the University of Guam Marine Laboratory (UoG), the University of Hawaii's Hawaii Institute of Marine Biology (HIMB), the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS), NOAA's Coral Reef Conservation Program, Office of Habitat Conservation, three branches of the Government of Guam (Environmental Protection Agency [GEPA], Division of Aquatic and Wildlife Resources [DAWR], and Bureau of Planning and Statistics [BPS]), and Sea Engineering Inc. Immediately after the initial contact from NAVFAC, a meeting to discuss potential monitoring and assessment work in Apra Harbor and the Mariana Archipelago was held with the NOAA Fisheries Pacific Islands Regional Office (PIRO), the U.S. Fish and Wildlife Service's Pacific Islands Office (USFWS), and the Environmental Protection Agency's Pacific Islands Office (EPA) on August 29, 2007.

In late October 2007, PIFSC received funds from NAVFAC for CRED to convene a focused workshop to discuss and develop a statistically rigorous survey design to address the monitoring requirements in Apra Harbor and elsewhere in the Mariana Archipelago. Due to the shortness of time prior to the planned initiation of dredging and construction at Kilo Wharf and limited availability of key personnel, a four-day workshop was convened at the East-West Center in Honolulu, Hawaii over the period December 7-10, 2007, bringing together key scientists and statisticians from CRED, UoG, RSMAS, HIMB, the Navy, Sea Engineering Inc., and Marine Research Consultants, and a few resource managers from NOAA, EPA, and the CNMI Division of Fish and Wildlife. Invitations to the workshop were sent to the key scientific and NMFS participants on November 7, 2007. After determining the venue for the workshop and how many participants from the Navy, various resource agencies, and contractors could be accommodated, a more general invitation was sent out on November 26, 2007. Due to the short notice, all invitees that would not be able to attend the Workshop were asked to provide input regarding their assessment and monitoring requirements by whatever means were most convenient, including separate meetings, conference calls, email, or PowerPoint files.

Participants from CRED included: Dr. Russell Brainard (oceanography and discussion leader), Dr. Bernardo Vargas-Angel (coral health), Dr. Jean Kenyon (corals), Dr. Peter Vroom (algae), Dr. Robert Schroeder (fish), Dr. Michael Parke (GIS), Dr. Kevin Wong (observing systems), Joyce Miller (project manager), Scott Ferguson (logistics), Seema Balwani (administration), Marie Ferguson (workshop organization), Jacob Asher (benthic), Jason Helyer (benthic), Amy Hall (invertebrates), Marc Nadon (fish), and Oliver Vetter (oceanography). Participants from UoG included the Director of the Marine Laboratory Dr. Alexander Kerr (invertebrates), Dr. Tom Schils (algae), and Dr. Andrew Halford (fish). Significant additional inputs were received from Dr. Laurie Raymundo (coral health) and Dr. Peter Schupp (invertebrates) prior to and after the workshop. Due to their familiarity with the marine organisms and environment around Guam, it is anticipated that UoG scientists will play a major role in any of the proposed CRED-led monitoring activities in Guam and the Mariana Archipelago. Dr. Jerry Ault (biostatistician and fish) and Dr. Steven G. Smith (biostatistician and fish) from RSMAS participated because of their specialized expertise in adaptive, statistically rigorous,

stratified-random-sampling designs for monitoring nearshore ecosystems. Though colleagues from HIMB were consulted prior to the workshop, including meetings with the Director of HIMB Dr. Jo-Ann Leong and Scott Godwin (invertebrates) and email exchanges with Dr. Paul Jokiel (corals) and Dr. Ku'ulei Rodgers (coral reef monitoring), scheduling conflicts limited their direct participation in the workshop to attendance of Friday December 7th by Scott Godwin. Stephen H. Smith, marine ecologist from NAVFAC, participated during all four days of the workshop and provided insights regarding the Navy's requirements.

In addition to the participants who attended all four days of the workshop, consultants from companies that have or are conducting on-going projects with the Navy in Guam and CNMI (Sea Engineering, Inc., Marine Research Consultants, and Helber, Hastert and Fee Planners Inc.), and resource managers from the U.S. EPA, USFWS, and PIRO were invited to participate in the introductory session of Friday and in the summary session on Monday afternoon. Lists of all invitees and participants at each session are provided in Appendix A along with contact information.

The agenda for the workshop (Appendix B) was developed by CRED to assist in addressing the Navy's goal of reaching agreement on protocols to be used for: (1) monitoring the impacts of the Kilo Wharf expansion project and other similar proposed future projects, and (2) assessing marine resources at discrete locations within the Mariana Archipelago which may be considered for activities such as pier/wharf construction or amphibious assault training. Further, to the maximum extent possible, the protocols for (1) and (2) should produce data which would be comparable with the integrated ecosystem observations collected by CRED as part of Pacific RAMP to allow statistically rigorous comparative analyses to be conducted. Although the goals of the workshop included general discussions regarding survey designs for the broader, though lesser-defined, activities proposed throughout the Mariana Archipelago, the primary focus of the discussions was to examine design options for monitoring Apra Harbor, with initial focus on assessing the impacts of the Kilo Wharf project. It was anticipated that the process for designing adaptive, statistically valid monitoring protocols that would be developed during the workshop could be applied to other areas in Guam and CNMI in the future. While specific details, including ecological focus, habitat maps, number of survey strata, sizes of sampling units, frequency of sampling, etc. may be different for other projects at different locations, the principles used to design an adaptive, statistically valid sampling protocol remain the same. It was agreed at the workshop that there would be adaptive survey design development as the project proceeded with full involvement of agency partners.

Following the workshop, CRED scientists, led by Dr. Brainard and Dr. Vargas-Ángel, incorporated the framework from the workshop into the proposed monitoring design. An advance copy of the report was sent to all participants for comment on Dec. 26, 2007; these comments were incorporated into a Jan. 11, 2008, draft. The Jan. 11, 2008 draft was circulated with a request for comments; comments were later received from PIRO and from USFWS. Original comments from external reviewers are included (as received in the final review cycle) in Appendix C.

From these reviews, the authors have tried to incorporate technical comments and correct errors. However, for a number of reasons, it has not been possible to incorporate or address all of the comments into this Feb. 11, 2008 final version of the report.

- At the time of publication, it is not clear whether any monitoring work will be done by the workshop participants for the Kilo Wharf project. Until this uncertainty is resolved, additional, extensive work to better define monitoring protocols for this specific location is unwarranted. If or when additional funding becomes available to plan surveys at Kilo Wharf or other specific locations, this report can be used as a starting point for survey design and detailed questions regarding appropriate protocols for a specific site can then be addressed.
- This report is a scientific document discussing monitoring protocols and survey design, and the primary authors do not find it appropriate to discuss several resource management issues, including the appropriate roles of various agencies and mitigation strategies, as has been requested by some reviewers.
- Some of the questions regarding statistical survey design and survey protocols, were discussed at length during the workshop. Dr. Ault's and Dr. Smith's papers on survey design are included in the references and copies of these papers or their Power Point presentation are available upon request.
- For detailed descriptions of CRED Standard Operating Procedures (SOP's), we refer readers to *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005* (http://ccma.nos.noaa.gov/ecosystems/coralreef/coral_report_2005), the draft *Coral Reef Ecosystem Monitoring Report for American Samoa: 2002-2006* (www.pifsc.noaa.gov), and the CRED website (www.pifsc.noaa.gov/cred). Where specific questions regarding methods have been asked by the reviewers, the specific protocols in question have been elaborated upon. Methods for data analysis and preparation are also thoroughly documented in the *Coral Reef Ecosystem Monitoring Report for American Samoa: 2002-2006*. If additional funding for specific monitoring projects is received, detailed SOP's based upon these methods will be the foundation of all field work and data collection.

Workshop

The first day of the workshop (Friday, Dec. 7, 2007) was designed to determine the requirements and design end points for ecological and environmental monitoring in the Mariana Archipelago generally, and in Apra Harbor specifically, from the perspectives of both Navy and the pertinent resource management agencies and to share with all participants a summary of what is known about the ecological and environmental conditions in Apra Harbor. Mr. Stephen H. Smith, NAVFAC's marine ecosystems expert, presented an overview and background regarding the Navy's needs and requirements for ecological monitoring in the region and outlined project parameters of the Kilo Wharf construction project. Mr. Smith asked that the following questions be considered at the workshop:

- What constitutes a sensitive habitat/resource?
- How can these be ranked?

- What are the most appropriate ways to assess various habitats/resources?
- How can we maximize comparability with other CRED data and studies?
- How can we assess changes & differentiate changes related to Navy actions vs. changes resulting from other factors?
- How can we most effectively reach a consensus with stakeholder agencies on methodology and interpretation of data?

Ms. Joyce Miller (CRED project manager) summarized pertinent information contained in the Environmental Impact Statement provided by NAVFAC and information already assimilated into an Apra Harbor Geographic Information System (GIS) by CRED to facilitate discussions during the workshop. Specific data layers that were pertinent to monitoring design were requested from NAVFAC, but not all data in the EIS were included. Copies of the GIS project were made available to interested partners.

Biological information was summarized by Mr. Stephen H. Smith from NAVFAC and Dr. Steven Dollar from Marine Resource Consultants. Mr. Marc Ericksen and Mr. Robert Rocheleau from Sea Engineering Inc. presented results of oceanographic surveys and plume modeling conducted for Kilo Wharf. Additionally, Wendy Wiltse provided EPA's perspective regarding monitoring needs in Apra Harbor during the Kilo Wharf expansion and more generally.

Dr. Brainard presented a summary of the CRED-led Pacific RAMP monitoring efforts, including limited discussion, with inputs by the various principal investigators, about the methods and protocols used during Pacific RAMP. Dr. Ault and Dr. Smith provided an overview of the use of a stratified random sampling design approach to obtain statistically valid estimates of ecosystem change in a cost-effective manner.

On Saturday, December 8, 2007, CRED, UoG, and RSMAS scientists discussed and loosely prioritized ecological and environmental parameters needing to be monitored and proposed methods for monitoring Apra Harbor under idealized circumstances unconstrained by funding or logistics. Discussions specific to coral, algae, fish, invertebrates other than coral, protected species, sedimentation, and oceanography were held in order to determine the most appropriate and effective techniques for collection and analysis for each ecosystem component.

On Sunday, December 9, 2007, the discussions shifted from the idealized unconstrained design parameters discussed on Saturday to a more realistic situation constrained by budget, staffing, and logistics. The scientific experts discussed the monitoring timeframe for the project with construction due to start in as little as three months, the level of effort needed, and what each institution might be able to contribute, given the construction schedule. A survey design was developed based upon Dr. Ault's and Dr. Smith's adaptive random stratified sampling approach, which was modified to include a subset of fixed sampling stations for monitoring purposes.

On Monday, December 10, 2007, project design parameters were reviewed and a summary of results was prepared during the closed morning session. Then the results

were presented to resource managers and key stakeholders who attended the meeting (see Appendix A) during the open afternoon discussions.

The workshop results as presented at the end of the conference are provided in Appendix D (extracted from the Microsoft PowerPoint presentation file).

Project Design Parameters

In order to design an effective monitoring protocol and program, a set of working assumptions and requirements were needed. Based upon the Final Environmental Impact Statement (EIS) Kilo Wharf – Milcon P-502 and Appendices and the background provided during presentations and discussions with resource managers on Friday, December 7, the following set of design parameters were formulated.

- Provide an adaptive, statistically sound and cost-effective design using stratified random sampling approach.
- Assume a monitoring period of 1 ½ to 3 or more years (pre-construction, construction, and post-construction). Duration of the post-construction time period should be determined once the impacts of the construction are better quantified and understood. It was discussed that the post-construction monitoring could require many years (10 or longer).
- Use methods that are compatible with CRED’s existing Pacific RAMP protocols, so that results are intercomparable and changes associated with causes other than Kilo Wharf construction can be quantitatively evaluated.
- Monitor the full range of hard-bottom habitats in Outer Apra Harbor.
- Conduct ecosystem surveys with a focus on benthic communities, coral health², fish, and species of concern (including turtles).
- Evaluate Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC) throughout Apra Harbor.
- Monitor water quality and oceanographic parameters. Specifically:
 - Monitor sediment plume dynamics
 - Targeted plume sampling to characterize suspended sediment released during the dredging

1 ² In this report, the term “coral health” means free of disease. Consequently the term disease is defined as “lack of normal function”. The elucidation of mortality or disease by source is not an easy task; however, not impossible as the reviewer suggests, particularly in light of a punctuated source of disturbance. Grossly, anticipated coral morphological and health changes due to increased sedimentation stress can include, but not limited to: tissue swelling, discolorations, bleaching, and partial mortality. It is expected that sedimentation stress will exacerbate the background levels of disease in areas moderate-to-severely affected by increased sedimentation. Histological examination of tissues will provide added insight, in terms of the severity of the impact. Appropriate training and inter-observer calibration are key to delivering a reliable product.

- Evaluate existing plume model using other modeling techniques and refine model with data collected during wharf construction.
- Provide ability to distinguish between turbidity associated with Kilo Wharf construction vs. other causes and sources.
- Monitor key nutrients to determine dynamic changes in ecosystem processes.
- Contaminants
- Monitor sediment deposition.
- Monitor environmental parameters, including:
 - Weather: wind, rain
 - Circulation: currents, waves, tides
 - Temperature, salinity

The above-listed parameters were used as the starting point for our discussions and cannot be considered to be a complete and exhaustive requirements statement. They did, however, provide a common framework for the workshop discussions. If development of a Kilo Wharf monitoring program proceeds, the first step will be to more thoroughly evaluate and define project requirements.

Survey Design

Survey strategy

The conceptual structure and strategy of the monitoring survey design discussed in the workshop were centered on the use of an adaptive, stratified-random-sampling approach in combination with fixed sites to monitor biological and physical parameters in the context of environmentally-mediated ecosystem change. This approach is congruent with CRED's Pacific RAMP and applicable to spatial scales ranging from archipelagic to site specific, and was formulated to provide the foundation for environmental monitoring as it pertains to US Navy projects in the Commonwealth of the Northern Mariana Islands (CNMI) as well as the US Territory of Guam, in particular Apra Harbor and Kilo Wharf. Because construction of the Kilo Wharf expansion is scheduled to be initiated as early as March or April 2008, many of the details pertaining to the survey design were aimed at monitoring for such construction projects in the context of the Apra Harbor. However, the workshop participants agreed that as additional projects in Apra Harbor or elsewhere in the Mariana Archipelago are proposed, similar workshops focusing on assessing the impacts of those specific projects are highly recommended in order to formulate specific survey designs to better meet the requirements of both the Navy and the pertinent resource management agencies. Those workshops would provide an opportunity to develop a sound understanding of the ecological and environmental setting and the most likely impacts to examine.

Definition of Survey Parameters

In order to define the number of sampling units needed for a statistically robust design, a number of survey parameters must first be established:

- Areal extent of surveys: definition of the Survey Domain.

- Habitat types (i.e., reef flat, reef crest, reef slope) and impact zones (i.e. sediment plume) to be surveyed (strata).
- Areal extent of each stratum.
- Discipline-specific size of sampling units based on mapping information and monitoring methods.
- Number of sampling units to be surveyed (sites) in each stratum for desired level of statistical precision.
- Survey tiers based on level of capacity (personnel) and logistical constraints.
- Frequency of surveys during each survey stage based on processes and constraints.
- Construction project design specific to a project

Survey Domain:

Within the context of the Kilo Wharf expansion in Apra Harbor, the first element in the survey design was the compilation of the survey domain map, which was completed before the workshop and included a number of separate layers of information compiled into a GIS, including:

- Satellite imagery (Figure 1)
- Available bathymetric data, including LIDAR and multibeam bathymetry (Figure 2 and Figure 3)
- Derivatives of bathymetric data, e.g., slope and isobath contours (Figure 2 and Figure 3)
- Benthic habitat characterizations developed by the Biogeography Program of NOAA’s National Centers for Coastal Ocean Science (NCCOS) for all of Apra Harbor (Figure 4) and by NAVFAC and their contractors (Marine Research Consultants) near Kilo Wharf for the EIS (Figure 5). Note that the bathymetric data (Figures 2 and 3) show a much more complex seafloor in deeper water than the habitat characterization “unconsolidated” category in Figure 4. Because the habitat characterization in Figure 4 is based upon satellite imagery, which may not penetrate to the bottom in deeper areas of Apra Harbor, this “unconsolidated” category should be refined when more data become available.
- Locations of proposed dredging activity and barge anchoring areas as per the EIS (Figure 6)
- Extent of predicted average and extreme sediment plume areas as per the EIS (Figure 7)³

³ Reviewer suggests that the plume model is incorrect, the plume extends farther west in the harbor, and that monitoring for suspended and accumulated sediments should be extended west to Orote Island.

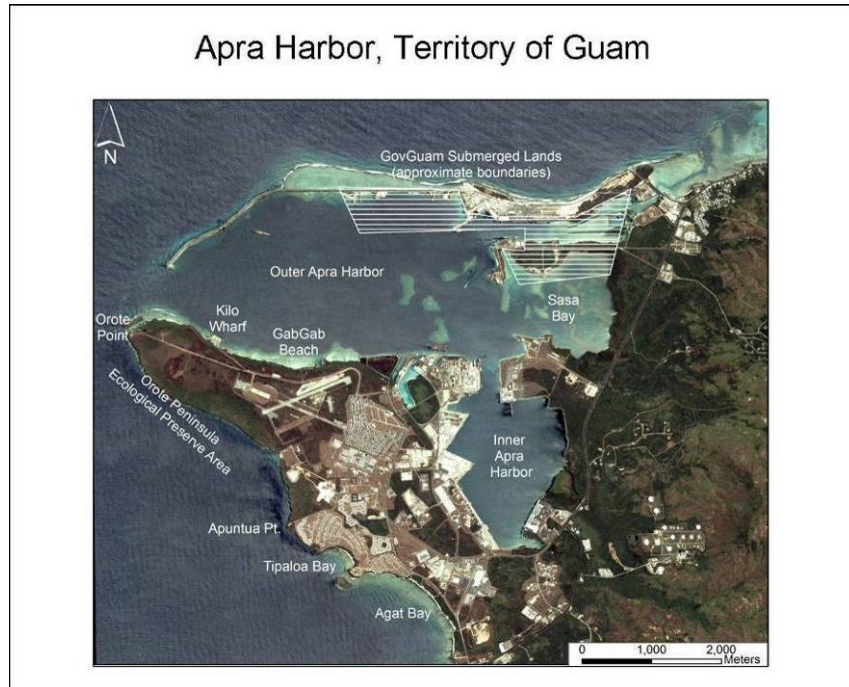


Figure 1: Apra Harbor, Territory of Guam, Location Map

As part of the on-going design process, the survey domain map will be refined using new and higher quality information as it becomes available. Several actions that could quickly enhance the baseline information were identified:

- A more detailed analysis of the shallow habitats of Apra Harbor is available from Dr. Steve Dollar of Marine Research Consultants and will be added to the existing GIS database.
- Validate current habitat maps and expand the extent of the habitat characterizations by conducting towed-diver benthic surveys.
- More accurate and closely-spaced LIDAR data are available from the Naval Oceanographic Office. In addition, Apra Harbor apparently will be re-surveyed using LIDAR in the near future. If access to these data can be gained, the ability to further characterize the benthic habitats would be enhanced.
- Refine the sediment plume model and evaluate the plume extent to adjust potential plume impact zones, which would require greater development of both the physical-transport and water-quality models.

Apra Harbor Bathymetry

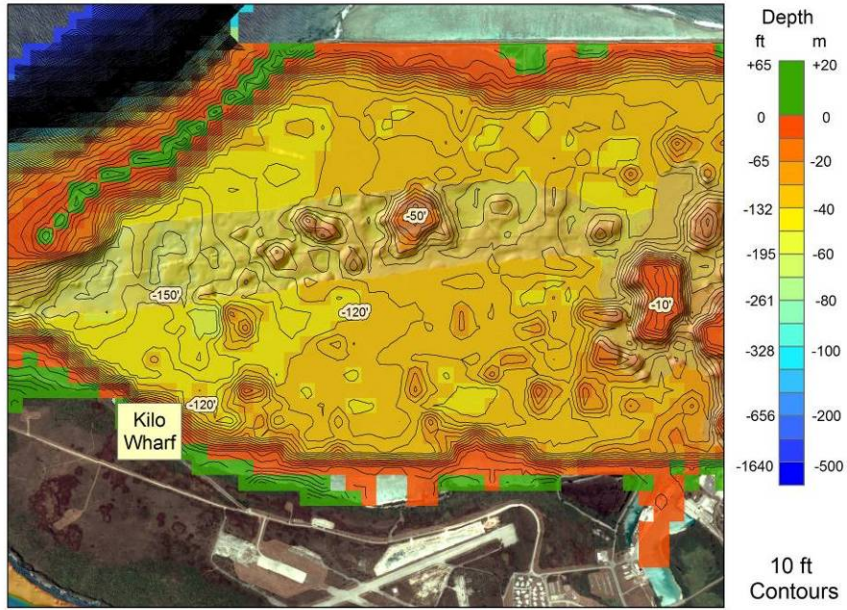


Figure 2: Apra Harbor Bathymetry.

Kilo Wharf Bathymetry

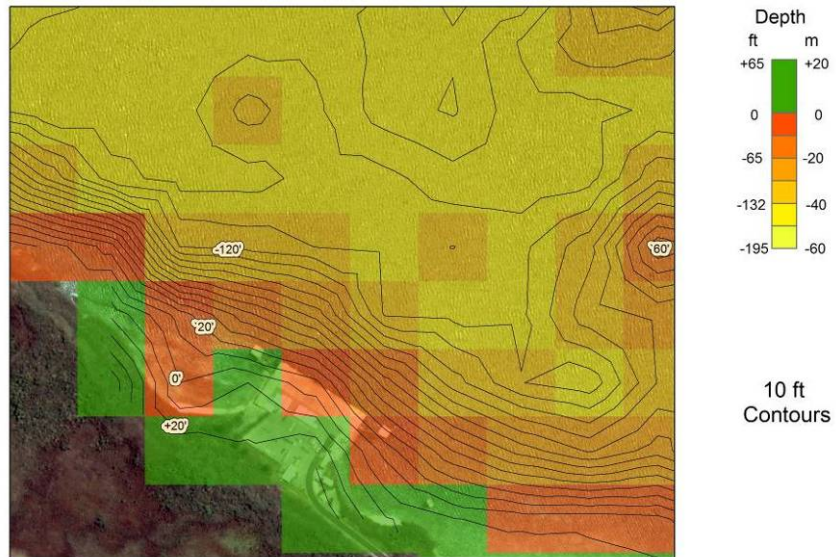


Figure 3: Kilo Wharf Bathymetry.

Apra Harbor Cover

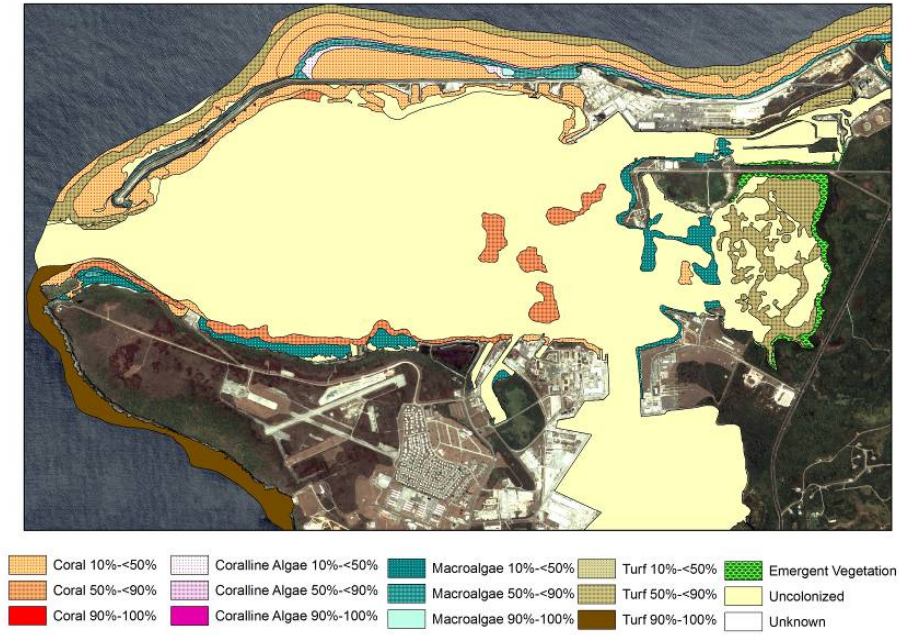


Figure 4: Apra Harbor benthic cover as determined by NOAA Biogeography Program.

Kilo Wharf Seafloor Characteristics

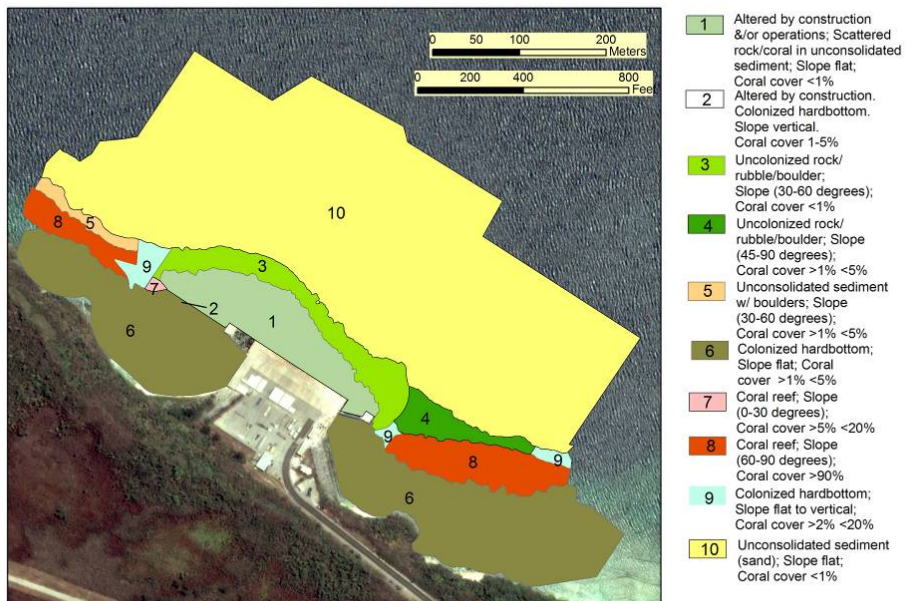


Figure 5: Kilo Wharf seafloor characteristics extracted from Kilo Wharf EIS.

Kilo Wharf Construction Footprint

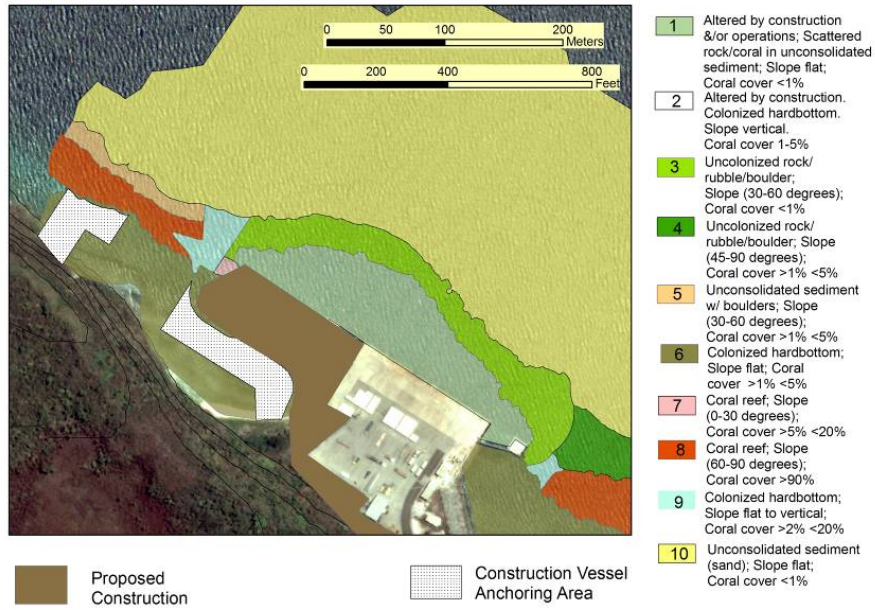


Figure 6: Kilo Wharf construction and anchoring areas extracted from Kilo Wharf EIS.

Kilo Wharf Predicted Sediment Plume Areas

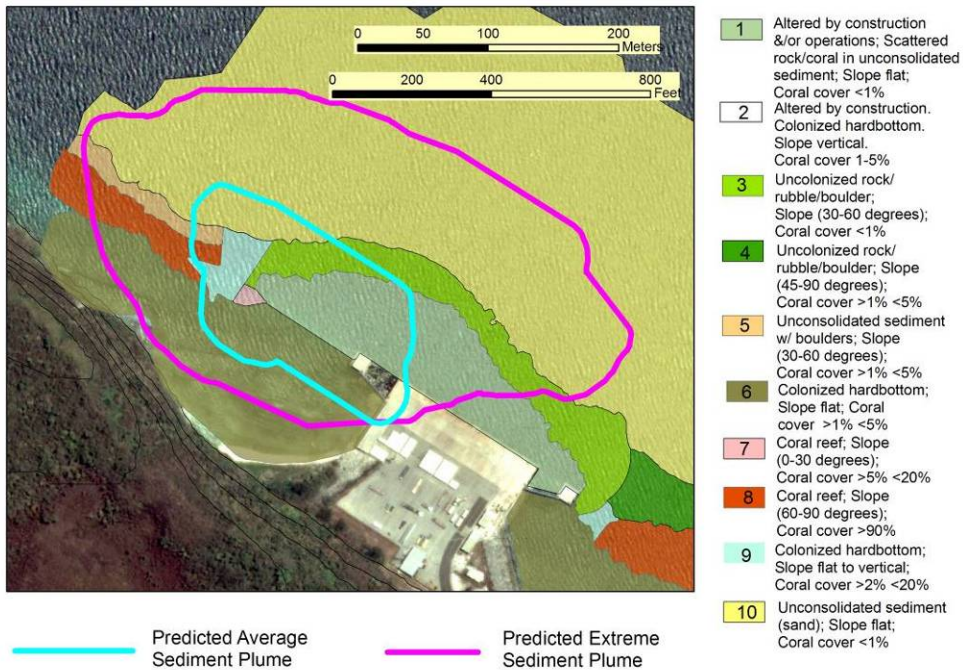


Figure 7: Predicted average and extreme sediment plumes from Kilo Wharf EIS.

The workshop participants also clearly established that due to current logistical and personnel constraints faced by CRED scientists and partners, the proposed monitoring activities within Apra Harbor would have to occur using a three-tiered approach based on expanding capacity of the respective institutions and the likelihood of impacts from Kilo Wharf construction. Tier 1 surveys would cover the Orote Peninsula from the harbor entrance to Gab Gab Beach, including the Kilo Wharf construction site and the most likely areas to be impacted. As added personnel and logistical resources become available, survey scope and efforts would expand into the outer Apra Harbor and Sasa Bay respectively (Figure 1). Within this context, three survey domains were delineated for each of three project tiers:

Survey Domain 1- Kilo Wharf construction site and Orote Peninsula which stretches approximately 4 km from the harbor entrance to the inlet east of Gab Gab Beach. This domain corresponds to Tier 1 and is the area that contains the habitats directly impacted and immediately adjacent to the Kilo Wharf construction site. Construction activities are scheduled to begin in spring, 2008 (Figure 8). Based on the critical need for pre-construction assessment and evaluation of construction and impacts, this would be the initial target Survey Domain. As personnel and logistic resources become available, the scope of environmental monitoring would expand to include the survey domains in Tiers 2 and 3, respectively.

Survey Domain 2- Outer Apra Harbor, excluding Sasa Bay. This domain corresponds to Tier 2, and is the area of interest in order to gain a better understanding of the impact of construction activities at Kilo Wharf in the context of the overall biological resources and circulation patterns in Apra Harbor (Figure 8). Survey domain 2 includes all of survey domain 1.

Survey Domain 3- Outer Apra Harbor including Sasa Bay: Corresponds to Tier 3 and is the survey area identified which provides the broader environmental and biological framework for current and future construction, including both Kilo Wharf expansion and the potential construction of an aircraft carrier pier. Survey domain 3 includes all of survey domains 1 and 2.

Apra Harbor
Study Tiers

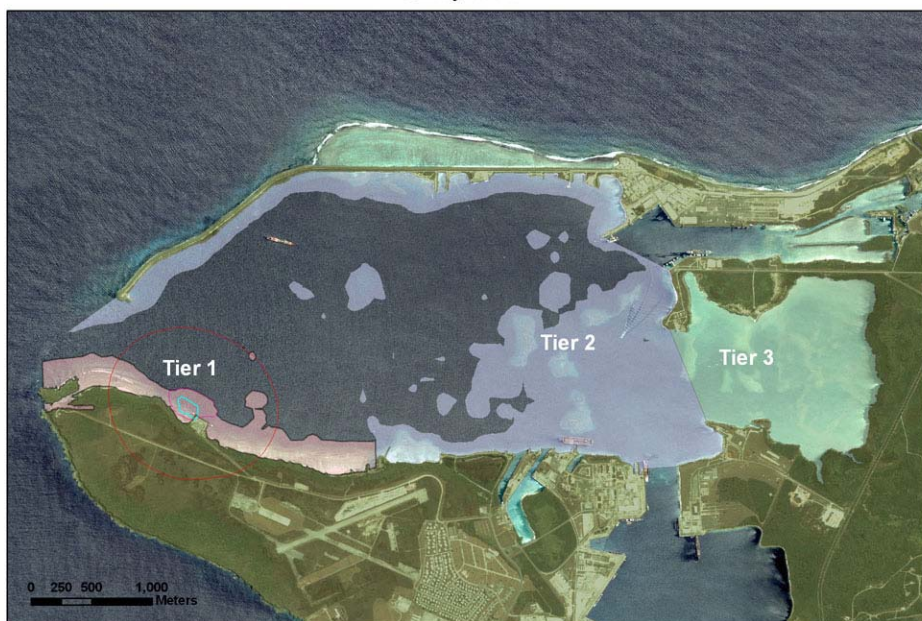


Figure 8: Survey domains for project Tiers 1–3 corresponding to hard-bottom < 30m for all the three tiers. Tier 2 includes Tier 1 and Tier 3 includes both Tiers 1 and 2.

Habitat Types to be surveyed:

- The next step was to define which portions of the survey domain could or would be monitored. It was agreed that for the purpose of this monitoring design, surveys should target the hard-bottom communities in diver accessible areas, that is, less than 30 m in depth. In addition, based on the NOAA Biogeography benthic habitat maps (Figure 4) it was also agreed that areas classified as uncolonized (occurring mostly in waters deeper than 30 m) would not be included in this monitoring design. Note that the bathymetric data (Figures 2 and 3) show a much more complex seafloor in deeper water than the habitat characterization “unconsolidated” category in Figure 4. Because the habitat characterization in Figure 4 is based upon satellite imagery, which may not penetrate to the bottom in deeper areas of Apra Harbor, some of this “unconsolidated” category might better be classified as “unknown”. Thus, as shown in Figure 8, portions of the Tier 2 area in depths less than 30m that are shown as “unconsolidated” in Figure 4 have been targeted for sampling. Although the possibility of sampling all non-hard-bottom areas was discussed, it was decided not to include areas deeper than 30 m (many of which would be included in the “unconsolidated” category) because of diving safety, cost, and time considerations.⁴

⁴ Reviewers suggest that uncolonized habitats also be surveyed.

Because Kilo Wharf and the Orote Peninsula would be the focal point for the initial tier 1 surveys, scientists agreed to stratify the area in three habitat type strata including: the reef flat (RF), Reef crest (RC), and reef slope (RS). Target habitat types for the Orote Peninsula were not specifically defined in the EIS (Figure 7), but were derived from the depth information and the NOAA Biogeography benthic habitat maps (Figure 4). Generally, the RF is the relatively shallow (0 – 3 m) macroalgal dominated habitats between the shoreline and the reef crest. The RC is the shallow coral covered rise between the reef flat and the reef slope. The RS generally has a steep slope in the depth range between 4 m and 30 m and typically has high live coral cover.

Sediment Impact Zones:

Three impact zones (as related to sedimentation stress) were also defined for the Kilo Wharf Construction. Kilo Wharf High Impact Zone (HIZ) corresponds to the predicted extreme sediment plume extent shown in Figure 7. This predicted extreme sediment plume map was developed by Sea Engineering Inc. based upon numerical circulation model computations for all of Apra Harbor given uniform wind stress across the harbor. It is recognized that this model does not include wave action and refinement of the model is recommended for future work; however, this is the information that was available at the time of the workshop. The Kilo Wharf Medium Impact Zone (MIZ) was defined as the area between the HIZ and an arc extending 500 m outside of the HIZ. The Kilo Wharf Low Impact Zone (LIZ) covers all other areas beyond the 500 m arc along the Orote Peninsula (Figure 9a). Therefore, the combination of the three main habitat zones and three sediment impact zones produces 9 strata to be sampled (Table 1). In addition, an area of the reef slope in the HIZ which was previously impacted by the original construction of Kilo Wharf in the early 1980’s is treated as an additional stratum bringing the total number of strata to be sampled to ten.

Table 1: Numbers and types of strata proposed for the Kilo Wharf construction monitoring.

		Habitat Types		
		Reef Flat (RF)	Reef Crest (RC)	Reef Slope (RS)
Kilo Wharf Sediment Impact Zones	High Impact (HIZ)	HIZRF	HIZRC	HIZRS
	Moderate Impact (MIZ)	MIZRF	MIZRC	MIZRS
	Low Impact (LIZ)	LIZRF	LIZRC	LIZRS

Based on Figure 7, the RF in the high impact zone (HIZ) is comparable to Habitat Type 6, the RC is comparable to Habitat Type 2, as well as shallow areas between Habitat Type 6 and Habitats 8 and 9; and RS is comparable to Habitat Types 5, 8, and 9. Because the EIS provides much more detailed information about the habitat within the HIZ immediately surrounding Kilo Wharf than is available for other areas of the harbor

(Figure 4), and because the HIZ is clearly the most critical area during the Kilo Wharf survey, CRED scientists suggest that Habitat Types 1 and 3 (Figure 7) should be considered as an added separate stratum. Although Habitat Types 1 and 3 are defined as areas that have been previously disturbed by construction and, according to the Navy's EIS, have little coral cover, CRED scientists consider it is important to address these high impact areas within the sampling plan. For this reason, they are not classified as Reef Flat, Crest or Slope habitat types, but instead defined as stratum 10, unconsolidated sediment and a construction-altered habitat within the 30 m depth contour (Figure 9b).

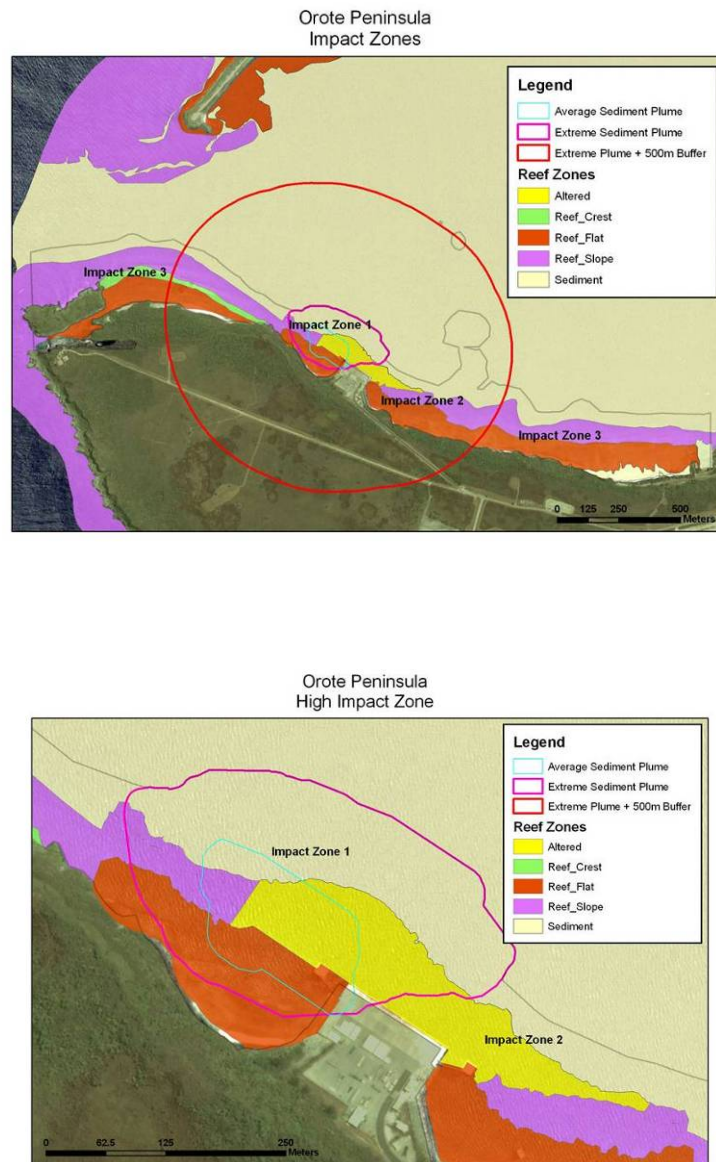


Figure 9: Kilo Wharf sediment impact zones; a. Orote Peninsula (top panel); b. enlarged view of the Kilo Wharf high impact zone (lower panel).

Number of sampling units (stations):

The stratified random design that is proposed here is similar to what has been developed for the Florida Keys (FK) and Northwestern Hawaiian Islands (NWHI), in which the “survey domain” (i.e., hard-bottom reef benthos < 30m depth) was divided into strata defined by habitat (e.g., in atoll systems, forereef, backreef, lagoon) and depth. With the use of benthic habitat maps, each stratum was delineated into 100m x 100m cells (NWHI) or 200 m x 200 m cells (FK) as primary units. Based on the benthic habitat characterizations developed by NOAA, in many parts of the outer Apra Harbor, the hard-bottom benthos < 30 m depth represents a narrow fringe. During the workshop, scientists proposed that the sampling unit for benthic surveys for Apra Harbor should be 10 m x 20 m and the sampling units for fish and turtle surveys should be 20 m x 50 m. This was indicated in order to include the different habitat types in the monitoring design. After additional consideration about desired consistency with CRED’s Pacific RAMP monitoring protocols, the benthic sampling unit was refined to be 10 m x 25 m.

During the workshop, a preliminary definition was used to develop a working number of sampling stations (benthic, fish, and turtle surveys) for the three survey domains in each of the three project Tiers. These were estimated as a percent of the total survey domain area (hard-bottom benthos < 30 m depth for each project Tier). For project Tiers 2 and 3, the total number of sampling stations was determined to be 1% of the total Survey Domain area (Table 2). For Tier 1 (Orote Peninsula and Kilo Wharf), the number of sampling stations was driven by the need to cost-effectively monitor the effects of Kilo Wharf construction within the 10 strata (Table 2). The computations above are based on comparable sampling designs developed for the FK and NWHI⁵. These preliminary calculations were carried out at the workshop to facilitate this preliminary design; more complete statistical analyses, including a power analysis and the level of change that can be detected, are planned for future stages of the project if they are funded.

For Tier 1, the Orote Peninsula, five stations would be located within each of the 10 strata. Therefore, of the 50 stations that would initially be selected using the random stratified sampling approach, it is proposed that 18 of the sites become permanent stations, six of which will occur within each Sediment Impact Zone. This is to allow following specific colonies/areal plots through time as well as provide replicate measurements.

Figure 10 illustrates the allocation of the sampling units within the survey domains.

⁵ Reviewers suggest that western Pacific habitats are much more diverse than FK and NWHI and that the sample size be estimated from the sample variances derived from previous survey work around Kilo Wharf.

Table 2: Number of Apra Harbor/Kilo Wharf sampling stations as determined by stratified random sampling design protocol

Area Description (Survey Domain)	Survey Domain Area (acres/Ha)	Benthic Stations (10 x 20 m)	Fish/Turtle Stations (20 x 50 m)
Outer Apra Harbor –Tier 3	670 / 271	135 (1% of SU)	80 (3% of SU)
Outer Apra Harbor excluding Sasa Bay – Tier 2	360 / 146	73 (1% of SU)	44 (3% of SU)
Orote Peninsula – Tier 1	130 / 56	50 (10 strata)	50 (10 strata)
Kilo Wharf plume – Tier 1	20 / 8	Included in Orote	Included in Orote

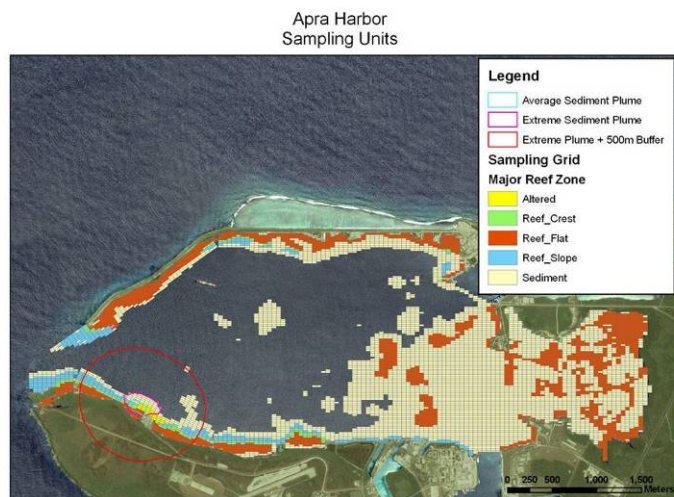
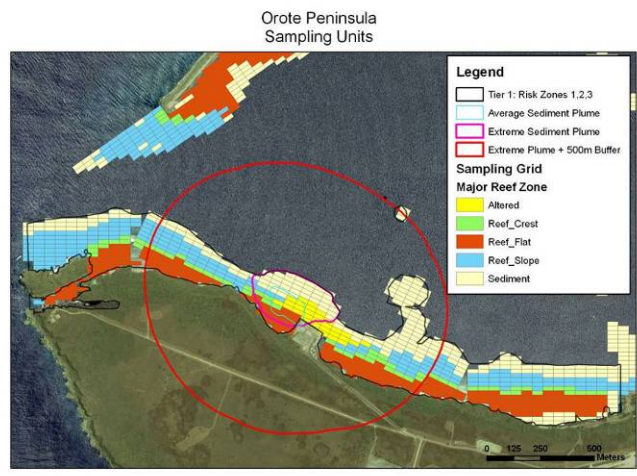


Figure 10: Allocation of the sampling units within the survey domains; a. Orote Peninsula (top panel); b. outer Apra Harbor including Sasa Bay (lower panel).

Survey Stages and Timing:

Tier 1 monitoring would begin at the 50 sites along Orote Peninsula, requiring approximately 8-11 days per survey period. Though it would be desirable to conduct more than one pre-construction survey, personnel limitations and timing will likely limit the pre-construction survey to one period, unless construction is delayed. Additionally, during the Construction Period, it is proposed that a Tier 1 survey be conducted at least every six to eight weeks.

Eighteen of the 50 Tier 1 stations would become fixed stations with permanent transect stakes installed and co-located Sediment Transport Stations (STS) deployed. In addition, a total of six Oceanographic Harbor Monitoring Stations (OHMS) (see Environmental Monitoring Methods section) would be installed. One OHMS would be located in each of the Kilo Wharf Impact Zones and the other three would be located at the monitoring sites in the Outer Apra Harbor. Of the total of 50 biological monitoring stations for Tier 1, thirty-two station locations would be re-randomized during each successive survey event.

Tier 2 of this design would involve the expansion of monitoring into Outer Apra Harbor excluding Sasa Bay, adding approximately 25 additional benthic monitoring stations and adding or re-randomizing the fish/turtle monitoring station locations. Of the additional 25 benthic stations selected by the random stratified sampling design, several may become fixed sites with permanent transects. Additional STS would be located at each permanent station, but no additional OHMS would be added in Tier 2. The team of scientists also suggested that it would be highly desirable that monitoring activities transition to Tier 2 surveys as soon as possible, perhaps during the Kilo Wharf Construction Phase. However, funding and personnel constraints will dictate the timeframe in which the monitoring efforts can expand from Tier 1 to Tier 2.

Tier 3 of this design would include monitoring in Sasa Bay. It is anticipated that this would be desirable at least one year in advance of any further construction (e.g., the planned pier that would accommodate aircraft carriers). During this Tier, impact zones would be developed for the proposed carrier pier design and a monitoring program similar to Tier 1 Kilo Wharf design would be developed. An additional two or three OHMS and a similar number of permanent monitoring stations with STS may be appropriate in Tier 3.

Monitoring Methods

The next step in the design process was to discuss and gain consensus on what protocols would be most appropriate for benthic communities, mobile fauna such as fish and turtles, and for the environmental parameters. The proposed monitoring methods described here are based upon the discussions that were held during the workshop, which have then been used as a framework for a more detailed monitoring and sampling plan.

Benthic Monitoring Methods

For the purpose of this study, the benthic reef community includes corals, algae, and other sessile and mobile invertebrates. Each biotic component was discussed separately during the workshop, but a common monitoring protocol for the benthic community was formulated with regards to location and frequency of surveys. Coral and algal surveys would be conducted simultaneously during daytime operations, but some surveys for invertebrates other than corals would need to be conducted at night.

Detailed biological surveys were proposed to quantitatively and qualitatively characterize the diversity, abundance, temporal variation and spatial distribution of corals, algae and other invertebrates. As expressed in the previous section, benthic monitoring sites would be selected to form a mix of random and permanent marked stations, in order to provide the statistical rigor of this adaptive, random-stratified-sampling approach as well as periodic monitoring of specific sites and taxa. Within each 10 m x 25 m station, the sampling unit will consist of a 25-m line transect, which will serve as the focal point for the coral, algal, and invertebrate surveys. CRED scientists suggest that a 10 x 25 primary unit be used, and thus a 25-m transect, to be more consistent with the protocols used in CRED's Pacific RAMP. The monitoring methods outlined below employ complementary and overlapping methods, collectively referred to as Rapid Ecological Assessment (REA), used by CRED during Pacific RAMP surveys at over 300 sites at over 50 Pacific islands/atolls in the Hawaiian Archipelago, American Samoa, U.S. Line and Phoenix Islands, Wake Atoll, Guam, and Commonwealth of the Northern Mariana Islands. All survey start and end points are located using Global Position System (GPS) sensors; this is CRED's SOP.

Scientists reiterated that the proposed monitoring for Kilo Warf and Apra Harbor consists of a three-tier process in which the survey domain and effort would gradually and progressively increase to eventually encompass the outer Apra Harbor and Sasa Bay as was discussed during the workshop. However within the context of the workshop, the benthic survey methods discussions focused on Tier 1. Tiers 2 and 3 would involve the selection of additional stratified random survey stations as well as other sites to be determined by further scientific discussions if additional construction projects are proposed within the survey domains.

Corals

At each survey site, one 25-m transect line would be laid out and videotaped to provide a permanent historical record of the benthos, which can later be used to extract independent estimates of coral percent cover, colony densities, and species composition if needed. Frequent videotaping of survey transects at fixed sites (possibly weekly), might be conducted by either the Navy or the UoG divers. Videography is intended as a back-up, rather than a primary procedure and the video record can be used to compute independent estimates of percent cover, colony density, and species composition for a comparative and complementary approach, as required. This procedure may become part of the standard protocol to create a durable record of ecosystem change; however data might not be routinely analyzed unless notable changes, which could include partial colony mortality and loss of live coral cover, are observed.

1. *Percent benthic cover*: The line point intercept method (LPI) was proposed for the assessment of relative abundance and percent cover of the different sessile benthic elements. As the scientist swims along the transect lines, he/she will inspect and record the benthic elements falling directly underneath each 50-cm interval mark on the metered transect tape, for a total of 50 points per transect. The number of both randomized and permanent sites selected was based on the best knowledge available at the time of the monitoring workshop and the Smith and Ault design protocols. Benthic elements would be tallied and recorded under the following scheme: live coral, recent dead coral, old dead coral pavement, coral rubble, sand, rock, macroalgae, turf algae, macroinvertebrate, and other. Scleractinian coral will also be identified to the species level and such information recorded. For the purpose of this survey, species of macroalgae would be grouped together in functional groups, including, but not limited to: turf, cyanophytes, branching coralline red algae, crustose coralline red algae, etc. More detailed algal surveys would deal with the benthic floral biodiversity and abundance (see below).

2. *Size class distribution and coral condition*: Scientists would collect size measurements (e.g., maximum length, width, and height) of coral colonies whose center fell within one half meter on either side of each transect. Collectively, these three measurements can be used to understand changes in % live coral cover, based on estimates of % total live coral tissue. Colony height also provides a gross indication for topographic complexity. Although changes in colony height may not be expected during the KW dredging project, colony height may provide an interesting correlation to the observed/measured sedimentation stress (increased partial mortality/disease) among the different strata, as well as within individual colonies. For most coral species, colonies would be measured (with a ruler to the nearest 0.5 mm), enumerated and identified to the species level. In addition to the size metrics acquired for each colony, the divers would also collect data pertaining to percentage of live/dead tissue per coral colony, as well as health condition, including, but not limited to: bleaching, recent/old mortality, disease, and *Acanthaster/Drupella* predation. Also, sediment accumulation and related tissue loss will be documented, particularly for plating corals such as *Porites rus*. The above data would be used to compile species richness, colony density (no. corals per m²), relative abundance (percent colonies per taxon), and to plot the size distribution of corals at each site. In addition, estimates of overall disease prevalence and prevalence by taxon/disease state could be computed. In areas of very high colony density, size metrics and health condition parameters can be collected with selected sub-sections of the best transect if it is not practical to evaluate all colonies along a 25-m transect.

Scientists also discussed that because *Porites rus* is the dominant coral species found around Kilo Wharf and given its indeterminate growth habit, it would be difficult to determine the extent of a single colony for this species. Panel scientists were aware that stands of *Porites rus* are rarely mono-specific. However, according to the more experienced researchers in that particular

environment, the fore-reef slope habitat exhibits a much greater diversity than the stands dominated by *Porites rus*. While it is possible to record the species diversity in stands dominated by *Porites rus*, colony three-dimensional metrics will be predominantly collected along the fore-reef slope. Based upon experience with multiple coral species across the Pacific Islands, CRED scientists have noted elevated inter-observer error in population size class-distribution-assessments for species with indeterminate growth habits. In order to calibrate inter-observer variability and provide for a durable, historical record, digital photography of the permanent 1.0 m plots is included in the protocols. The scientists present at the monitoring workshop considered that the collection of colony size metrics for species like *Porites rus* is prone to high levels of interpretation as it relates to colony size and boundaries. As such, estimations of community composition and structure for areas dominated by *Porites rus* will be based on estimates of percent cover collected using the Line-point intercept method. Visual estimates of percent cover will be conducted periodically only for those permanent transects exhibiting dominance by *Porites rus*; and, within those transects, measurements of percent cover will be limited to four-evenly spaced 1.0 m² sections along the 25m transect. This course of action was decided based on the difficulty to collect reliable, three-dimensional size metrics on stands dominated by *Porites rus*, and the need to document the occurrence of lesions and relate those to the larger healthy tissue. Therefore, population dynamics for *Porites rus* in the study area will be assessed primarily based on percent live cover metrics, rather than the traditional size-class distribution measurement. Health condition assessment for mono-specific stands of *Porites rus* would be attained based on visual estimates of percent cover and lesions within one half meter on either side of each transect.

3. *Permanent stations:* Along the Orote Peninsula, a total of 18 stations would be selected and permanent transect markers installed. Six fixed stations would fall within each sediment impact zone (high, medium, low). Six stations were chosen as part of the preliminary strategy with insufficient pilot data for more rigorous analyses; sampling probabilities proportional to area are the best way to get sufficient data that will provide meaningful variance estimates. It was proposed that permanent stations be visited every two months to follow individual colonies within selected areal reef plots. Within each permanent station, a 25-m permanent transect would be established, along which coral health condition would be evaluated for all colonies whose center fell within one half meter on either side of four, evenly spaced, 1.0-m sections along the 25-m transect (0–1.0 m, 7.0–8.0 m, 14.0–15.0 m, 21.0–22.0 m, respectively). Coral size metrics would be collected at the time of permanent transect deployment as well as at the end of the construction period. In the case of plots containing *Porites rus*, assessments would be based on visual estimates of percent cover, health condition, and number of lesions. Digital photography of the permanent plots would also provide a durable record of each areal plot periodically monitored, which can later be used to extract an independent estimate of coral percent cover as well as coral health condition.

4. *Functional and cellular responses to sedimentation stress:* Assessment of tissue and cellular reactions was proposed by the panel of scientists as a means to evaluate the coral's susceptibilities and responses to sedimentation stress at Kilo Wharf. Histopathology provides a visual means by which to survey coral cellular reactions to physical injuries, contaminants, and toxicants, as well as the mechanisms of damage and repair in target cells and tissues. Histopathological processing and examination of coral tissues was indicated to evaluate sublethal cellular responses to the range of sedimentation impact regimes before, during, and after construction of the Kilo Wharf expansion project. Coral tissue samples would be procured at a subset of the fixed stations within each of the sediment impact zones. The suite of species selected need to be available in all three impact zones in order to allow for comparisons in responses among the different impact zones. Selected genera need to be common due to the number of samples that will be collected. Collecting and analyzing different suite of species at each impact zone would provide greater bias and would not allow between-sites comparisons.

Steve Smith–RSMAS and B. Vargas-Ángel–CRED suggest a maximum of two species: *Porites rus*; due to its abundance, and another massive coral, perhaps a faviid. Corals selected for the functional and cellular responses to sedimentation stress were chosen based on the following criteria: growth morphology (massive vs. platy/branching); susceptibility to sedimentation stress; ecological and structural importance at the study areas; and relative abundance at the study sites. *Porites rus* was selected as one of the target species due to its importance as an ecological and structural component at the study area. The second target coral genus (faviid) was selected to serve as a counterpoint to the platy growth morphology of *Porites rus*, and because it's higher susceptibility to sedimentation stress compare to *Porites rus*. A total of 60 samples per species, 20 within each impact zone (high, medium, and low), would be collected at each of the following times: before construction; 2 weeks-1 month after initiation of construction; 2 months, 6 months, and 9 months into construction; and after the end of construction. Although selecting three target species would be ideal, only two coral species were selected for this part of the project, to ensure thorough and timely examination of all samples (~600 samples) by the dedicated coral histopathologist. Tissue samples would be procured using hammer and chisel and fixed in a zinc-formaldehyde solution, decalcified, and processed to produce paraffin blocks. Representative sections of each block would be obtained and stained using Harris hematoxylin and eosin (H&E) and modified Movat's Pentachrome method (see Peters et al., 2005). These histological techniques were developed by a CRED scientist, Dr. Bernardo Vargas-Ángel, during previous coral monitoring work in Southeast Florida (Vargas-Ángel et al., 2006a) and have been successfully implemented in the past to determine tolerance to contaminants and toxicants including increased levels of sedimentation not only in corals but other sessile invertebrates as well.

Scientists also proposed the collection of additional tissue samples for the assessment of reproductive capacity and fecundity of corals immediately preceding the spawning season. Tissue samples for these techniques would also be collected at a sub-set of the permanent stations within each impact zone. Between 20 and 30 coral tissue samples per species would be procured at each of the three impact zones. Samples would be collected using hammer and chisel and fixed in a formaldehyde solution. In dissected, decalcified tissues, reproductive condition (fertile/infertile) would be ascertained based on the presence or absence of gonads, and for reproductive colonies, fecundity estimates could be derived from counts of late stage III/IV oocytes per surface area of tissue examined (Vargas-Ángel et al., 2006b). Tissue samples for these analyses would be collected a few weeks before spawning. This approach was proposed as an additional, independent methodology to appraise and evaluate coral responses to sedimentation stress. Although the methodology proposed is fairly standard for reproductive studies, some panel scientists feel that this approach may have the potential for inconclusive results. To clearly assess reproductive potential and fecundity, multi-year studies are desirable to allow for the elucidation of spatial and temporal variability. This would imply sampling during the upcoming spawning season and establishing a baseline for fecundity estimates prior to the construction, then sampling for at least a couple of years afterward, during and post construction, in order to determine the severity and extent of the impacts.

It may not be possible to implement all of the above techniques in the monitoring program and trade-off analyses will be necessary in the future to determine the suite of techniques that will be used for specific monitoring sites, given time and funding constraints.

Algae

Algal population surveys would be aimed at assessing the percent cover, relative abundance, and species diversity of the macroflora.

Percent cover, relative abundance and diversity: Macroalgae would be monitored along the established transects for corals and other invertebrates at each of the monitoring stations (both randomly selected and fixed sites). Six 0.25m² quadrats would be placed at 5 m intervals along the 25 m transect (Preskitt et al. 2004, Vroom et al. 2005). As was discussed with regards to determining the ideal number of sites for coral analyses, six stations were chosen as part of the preliminary strategy with insufficient pilot data for more rigorous analyses; sampling probabilities proportional to area are the best way to get sufficient data that will provide meaningful variance estimates. For each quadrat, the percent cover of the different algal species would be obtained based on visual estimates. Voucher specimens of small and enigmatic algae will be collected for further identification in the laboratory. In addition, a durable photographic record of the 0.25 m² quadrats will be obtained to provide the basis for quantitative data for further in-depth, species-level algal percent cover analyses as needed. Frequent Tier 1 surveys (every six to eight weeks) to collect species-level data would allow distinguishing seasonal dynamics from disturbances due to construction activities. Obviously, the ability to successfully incorporate this

seasonal component is entirely dependent upon the still-uncertain construction project's timeline and the feasibility of performing Tier 1 surveys over a sufficient period of time. Ecological comparisons of algal assemblages in the impacted area during and after construction activities with assemblages of the pre-construction phase and control sites could reveal dominance shifts in benthic biota. Based on habitat and physiological characteristics of algal taxa, such changes in community structure could be ascribed to stressors like sedimentation and the release of nutrients from the sediment. In addition, sudden changes in algal cover could be correlated with environmental parameters to identify indicator species of specific stressors. Quantitative population thresholds of such indicator species could be set as the program evolves and would benefit future environmental impact assessments in Apra Harbor and in Micronesia at large.

Invertebrates

Invertebrates serve important functional roles in the coral-reef ecosystem of Apra Harbor. These groups, composed of over 30 phyla, include herbivores, sediment processors, corallivores, or prey for other reef organisms. Voucher specimens of undescribed, poorly known or taxonomically refractory species, as well as representatives of otherwise interesting taxa will be collected, photographed and preserved using standard methods and, if necessary, sent to specialists for determination, before being deposited in the National Museum of Natural History (Washington DC), Florida Museum of Natural History (Gainesville FL) or the University of Guam Invertebrate Collection.

1. *Abundance and species diversity of cryptic taxa:* Cryptic taxa are among the most diverse components of metazoan heterogeneity on coral reefs. However, they are notoriously difficult to sample without destroying reef framework to access the inhabited crypts. We will deploy arrays of CRED-developed Autonomous Reef Monitoring Structures (ARMS) for systematically assessing and monitoring cryptic invertebrate diversity. ARMS are small, long-term collecting devices designed to mimic, to some degree, the structural complexity of a coral reef, thus attracting colonizing sessile and mobile invertebrates over the period during which they are deployed (www.hawaiiantolls.org/research/CoML/collection/arms.php). Massive parallel DNA sequencing of ARMS collections will be used to systematically provide indices of invertebrate diversity that would be comparable spatially and temporally. All sequences would be deposited in the Barcode of Life and GenBank.
2. *Percent cover and species diversity of sessile taxa:* Quantitative counts and size measurement of major groups of the sessile fauna will be performed within 0.5 m on either side of each 25-m transects at the permanent transect sites selected for corals (see Corals above). Measurements of major and minor axes of the circumferences of selected colonies of target taxa will be recorded to calculate colony area. These measurements will be recorded over the course of the monitoring period to detect population-level trends in size-class distributions.

Likely target taxa known from Apra Harbor will include the demosponges *Stylissa*, *Rhabdastrella*, *Xestospongia*, *Meloplus*, *Cibrochalina*; didemnid ascideans; and octacorallian alcyonaceans *Lobophytum*, *Sarcophyton* and *Sinularia*; the hexacorallian stichodactyllariid *Heteractis*, the zoanthid *Palythoa* and corallimorpharians.⁶

3. *Abundance and species diversity of motile taxa*: The majority of coral-reef invertebrates are diurnally cryptic, presumably to minimize predation by visually oriented diurnal predators, such as fishes. Further, diurnally active invertebrates remain exposed at night⁷. Therefore, transects will be performed nocturnally to better estimate abundances of the invertebrate fauna. Quantitative counts and size measurement of selected, mostly large (> 3 cm total length) invertebrates will be performed within 0.5 m on either side of each 25-m transect at each site to document the abundance and diversity of vagile taxa. We will target several groups of speciose and abundant taxa, including echinoderms (e.g., ophiasterid asteroids and aspidochirote holothuroids), molluscs (e.g., *Cypraea*, *Conus*, corallivorous muricids and bivalves, such as *Tridacna*), crustaceans (e.g., xanthids, dardanid and pagurid hermits, *Panilurus* and symbiotic palaemonids), as well as polychaete annelids (e.g., serpulids, spirorbids, sabellids and terrebellids).
4. *Size-class structure of echinometrid echinoids*: Despite their seemingly rigid test, echinoids respond to changes in nutritional state by changes in test diameter. Therefore, this measurement is a rapid and sensitive indicator of echinoid fitness. The test diameter along the major axis of the most abundant species of echinoids encountered on the nocturnal transects of motile fauna will be measured with vernier calipers. These measurements will be recorded over the course of the monitoring period to detect population-level trends in size-class distributions. Abundant species in Apra Harbor include several medium-sized (to 7 cm width) species in the family Echinometridae: *Echinometra mathaeii*, *Echinometra* sp. A and *Paraselenia gratiosa*.

Microbial communities⁸

1. *Assessment of diversity and ecological dynamics in target habitats*: Microbial communities play a critical role in the recycling of organic material in the marine environment; thus, spatial and temporal changes in community diversity and composition can be used as an indicator of their ecology and function. In addition, this study would enable the development of functional fingerprints of microbial communities for selected habitats and their variation as a function of sedimentation stress forcing, because disturbances such as excessive sediment

⁶ Reviewer suggests collecting quantitative data (i.e., density per square meter for key functional groups (e.g., echinoderms, mollusks, crustaceans), in addition to species diversity data.

⁷ Reviewer suggests that SOP for how nocturnal and diurnal surveys will be conducted. Since nocturnal surveys are not a part of CRED's normal suite of activities, at such time as funding would be provided, more detailed SOP's would be developed for the project.

⁸ Reviewers request references to support the usefulness of microbial surveys for monitoring, since this is still a relatively experimental technique for this type of work.

loading affect the total environmental system. Together with the other proposed monitoring studies the results of this study could have a vital role in identifying if possible disease onsets or outbreaks in marine invertebrates and algae are correlated with changes in microbial communities (occurrence or increase in abundance of potential pathogens e.g. *Vibrio coralliilyticus*).

Monitoring will consist of taking swabs and tissue samples from the selected macroinvertebrates, as well as collecting sediments and seawater samples at the different monitoring sites. Samples will be frozen, freeze dried and stored until analyzed. Bacterial DNA will be extracted and amplified using polymerase chain reaction (PCR). The amplified bacterial DNA will be compared using denaturing gradient gel electrophoresis (DGGE; Taylor *et al.*, 2004; Taylor *et al.*, 2005). DGGE is used because it is: 1) rapid, allowing analysis of many samples; 2) 'universal', i.e. targets as many taxa as possible (including non-culturable species) with a non-specific primer, and; 3) allows putative identification of detected organisms via sequencing of excised bands. This molecular approach has proven particularly useful for the characterization and comparison of invertebrate-associated microbial communities before and after changes in environmental conditions. This method allows detecting qualitative differences (changes in bacterial species composition) between different organisms, sediments and seawater, as well as between different habitats and temporal changes. However, it is not suitable for detecting changes in the abundance of certain key species unless techniques such as real time PCR are used during amplification of the bacterial DNA. By applying real-time PCR we will ensure the reliable quantification of target microorganisms within a complex sample. Specific PCR primers will be used for the organisms of interest, and the amplification of these sequences will be compared with amplification of known quantities of reference DNA. From the resulting data one can infer the abundance of specific sequence types or the bacteria of interest.

2. *Sampling design:*

The sampling design will include the sites proposed by the other monitoring studies and as such will consist of heavily as well as less impacted reef sites⁹. Spatial and temporal sample collection will be closely coordinated with the other monitoring studies. Samples will be taken from selected invertebrates (e.g. sponges and corals) at each 25 m monitoring transect. Swabs and/or tissue samples will be collected in triplicate from each selected invertebrate following methods described by Taylor and colleagues (2004). Sampled invertebrates will be permanently marked for repeated sampling over time. Adjacent to each sampled invertebrate 3 sediment and seawater samples will be collected as well. This sampling design would enable the development of functional fingerprints of microbial communities for selected habitats and assessment of their variation as a function of sedimentation stress. Furthermore, comparison of seawater and sediment bacteria with invertebrate associated bacteria should allow discerning if

⁹ Reviewer notes that it may be difficult or impossible to locate sites within the harbor that are significantly "less impacted reef sites" because of repeated construction and dredging in the harbor for the past 50 years.

possible changes in the microbial community of the target invertebrates correlate with changes in sediment and/or seawater bacteria. If such comparisons are made between samples from affected (construction site) and control sites (non/less disturbed sites), it could possibly reveal if changes in invertebrate bacterial composition (including possible occurrence/increase in pathogens) are due to exposure to sediment plumes or affected seawater.

Fish and Turtle Monitoring Methods

CRED, UoG, and RSMAS scientists readily agreed that monitoring all fish species and all sizes using a Stationary Point Count (SPC) method would be the most effective technique for this work and consistent with CRED's methods throughout the Pacific. The SPC method records fish of all size classes in a 7.5m radius cylinder. To avoid being overwhelmed by fish diversity and numbers, fish are recorded underwater using a set of simple rules:

- Two divers drop down on randomly generated latitude/longitude positions within the habitats defined in the random stratified design and move to the center of the circle at the base of their SPC cylinder
- During the first 5 minutes of the SPC, divers create a list of fish species observed in their cylinder. No counts or sizes are recorded. An exception to this rule is for rare mobile species that are likely not to be seen again during the replicate (e.g., sharks, jacks), which are immediately sized and enumerated. Divers rely on memory to recall the original sighting.
- After the first 5 minutes, the divers go through their list one species at a time, counting and sizing individuals currently present in their cylinder. If no individual from a species is present, the diver simply writes down what the original sighting was (e.g., two 10 cm *A. triostegus*). For better efficiency, it is possible to count individuals from 3 or more species at a time, if the densities are low and the divers are not overwhelmed.
- Important: Any additional species observed after the first 5 minutes are not recorded. However, the divers can take all the time they need to go through their fish list and complete their counts following the first 5 minutes. This should take an additional 5 to 10 minutes.
- Once the first replicate is completed, the team moves the transect line to another location nearby and repeats this procedure.
- Bumphead parrotfish and humphead wrasse are fisheries species of concern and will be routinely noted as part of fisheries surveys.

Because green sea turtles are the principal protected species that has been observed in Apra Harbor, turtle presence would be monitored by all fish and benthic divers using a set of parameters consistent with guidelines from protected species managers. Don Hubner (NOAA, PIRO, Protected Resources Division) suggested a series of target monitoring parameters for protected species including:

- Presence and distribution of animals
- Habitat types (when and where animals were observed)

- Behavior and behavioral effects (what where the individuals doing; any observable behavioral changes resulting from the construction?)
- Acoustic monitoring (applicable to marine mammals)
- Health conditions (e.g., Fibropapillomatosis in green turtles). Discussions with George Balazs (NOAA, PIFSC, Protected Species Division) indicated that monitoring for presence of tumors would be extremely useful.
- Estimate of carapace length (applicable to turtles).

Additional protected species to be noted and monitored include Hawksbill turtles and spinner dolphins.

In addition, CRED scientists indicated that a limited number of towed-diver surveys may be conducted to evaluate turtle abundance and distribution and overall benthic habitats in Apra Harbor.

Environmental Monitoring Methods

NAVFAC has suggested that CRED and Sea Engineering Inc. might work cooperatively to implement the environmental monitoring recommendations provided here. A suite of oceanographic monitoring methods has been developed and is used by CRED scientists as part of Pacific RAMP. For information on CRED's Pacific-wide oceanographic monitoring program, see <http://www.pifsc.noaa.gov/cred/oceanography.php>. Sea Engineering Inc. has previously conducted specific oceanographic surveys in Apra Harbor, primarily using in situ deployed Acoustic Doppler Current Profilers (ADCP), to characterize and to aid in the development of a circulation model for the harbor. The extent of potential sedimentation plumes was simulated using the Environmental Fluid Dynamics Code (EFDC) model developed by the EPA. The results of the analysis were provided as part of the EIS and also presented at the December 2007 workshop.

As outlined below, oceanographic data acquisition to support the ecological monitoring effort in Apra Harbor will consist of periodic surveys (ADCP and water quality transects) and positioning seafloor monitoring stations to collect continuous time series datasets. Two types of seafloor monitoring stations are proposed:

- Oceanographic Harbor Monitoring Stations (OHMS), which include an Environmental Acoustic Recorder (EAR), a salinity and temperature recorder (SBE37), a sediment trap array, a turbidity sensor, a UV sensor and an ADCP.¹⁰
- Sediment and Turbidity Stations (STS): A more economical and smaller package consisting of an array of three sediment traps and an archiving turbidity sensor.

A number of methods are recommended in order to assess and document oceanographic conditions in Apra Harbor before, during, and after construction at Kilo Wharf.

¹⁰ Reviewer suggests that wave pressure sensors might also be considered for inclusion on the OHMS.

1. *Assess the direction and distribution (temporal and spatial) of turbidity events in the vicinity of the construction site.*

Large quantities of particulate material, generated by the construction activity, runoff, or other events, typically manifest themselves as turbidity (reduced water clarity). Data acquisition should capture the extent and persistence of any turbidity events in the vicinity of the construction site.

Proposed method: Turbidity sensors (transmissometers) will be incorporated into the OHMS instrument stations and profiles will be conducted with the CTD casts (see #6 below). Transmissometers will be moored on the harbor floor and may, in addition, include a string array of turbidity sensors through the water column (Figure 11 and Figure 12). These stations will be serviced every two weeks, including inspection of the optical sensor and connectors and removal of bio-fouling and other material that may inhibit sensor function. If required, data can be uploaded as part of the servicing to allow for more frequent review of the developing time series dataset. Frequent review of these data will allow enhancement of the sampling plan, if warranted. In addition to the permanent stations, a transmissometer will be attached to the hand held CTD to give vertical profiles of turbidity in the water column. Turbidity will be measured at each CTD cast location (Figure 13).



Figure 11: Distribution of OHMS at Apra Harbor.

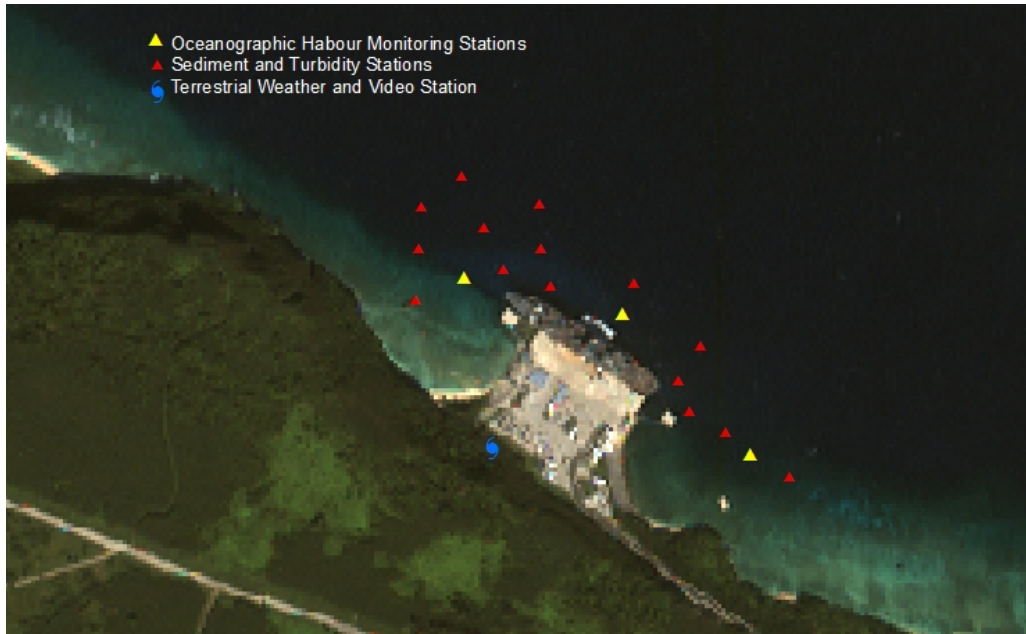


Figure 12: Distribution of STS and OHMS near Kilo Wharf, Inner Apra Harbor¹¹.

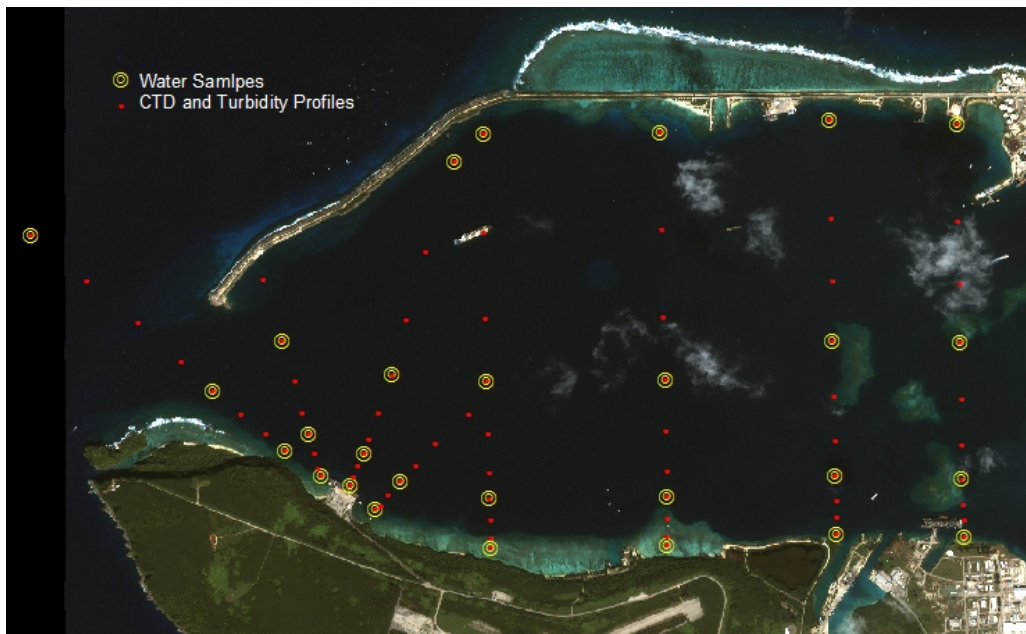


Figure 13: CTD and Turbidity profile locations, Apra Harbor.

2. *Assess potential affects from Kilo Wharf construction on light propagation to the benthos in the vicinity of the construction site.*

The amount of photosynthetically available radiation (PAR) influences coral reef communities. Particulate material generated by the construction activity, runoff, or other events can reduce water clarity and could affect the amount of solar energy reaching the coral. Vessels moored for long periods of time, such as construction

¹¹ Reviewer notes absence of sensors in shallow water.

barges, and other craft can also affect the amount of solar radiation reaching the benthic community.

Proposed method: UV sensors placed on OHMS mooring stations will be deployed at instrument mooring sites (Figure 11 and Figure 12). An above-water UV sensor will be located at the proposed ground station (see #4 below) to account for changes in solar radiation due to cloud cover and other atmospheric events. These sensors will be serviced every 10-14 days, including inspection of the optical sensor and connectors, and removal of bio-fouling and other material that may inhibit sensor function. If required, data can be uploaded as part of the servicing to allow for more frequent review of the developing time series dataset.

3. *Document the underwater sound levels, including vessel traffic, construction noises, and ambient reef sounds before, during, and after construction.*

Many animals associated with coral reefs, including various fish and invertebrate species are soniferous - that is, they produce sound. Tracking the acoustic activity of these animals with passive monitoring instruments enables one to assess patterns of change, stability, and seasonality in biological processes over time. Passive acoustic methods are also well suited for monitoring human activities on the reef, because the noise produced by boat engines, anchor chains, construction, dredging, and other anthropogenic sources are readily detectible.

Proposed method: Ecological Acoustic Recorder (EAR) units will be included as part of the OHMS package to obtain a time-indexed dataset of ambient noise levels and anomalous acoustic events in the vicinity of the construction site and at control sites within and outside the harbor (Figure 11 and Figure 12). The EAR is a passive acoustic device developed by NOAA CRED and the Hawaii Institute of Marine Biology specifically for monitoring fish, invertebrates, and human activity in marine habitats. EAR units are self-contained systems that can be deployed on the seafloor to sample and record the sound field on a given duty cycle. The units can also be programmed to detect and record acoustic events. EAR units can be left in place unattended for months at a time, because they are not compromised by bio-fouling.

4. *Provide a time-indexed photo record of the construction site to document weather, ocean, and construction related events.*

Ocean and weather conditions are significant factors influencing the conditions near and around the construction site. Meteorological data (wind vectors, rain, solar radiation, barometric pressure, air temperature) coupled with a time-indexed visual log of construction developments will provide important information when trying to establish correlations between construction events and oceanographic/ecological observations. Image data may also be used as a visual aid for assessing persistence of any visible turbidity events, their sources, and any time-delay between the production of the turbidity event and the measurement of the change in turbidity by other instruments.

Proposed method: An enhanced meteorological monitoring station located on the bluff behind the construction site or on an elevated platform on the wharf (such as a utility pole) will be equipped with a digital imaging system to acquire video or still images of the construction site and surrounding waters (Figure 12). Wireless communication (cellular or satellite telemetry) with the monitoring station will allow data to be accessible in near real-time via the internet on a password protected site. Note: Situating the cameras and obtaining permission to place instruments in the proposed location so that security concerns are properly addressed still need to be worked out. In addition, we need to ensure that personnel assigned to the upkeep and maintenance of this station have access to the site.

5. *Determine physical oceanographic parameters including waves, tides and currents within Apra Harbor*

Waves and tides influence the coral reef ecosystems which have developed within Apra Harbor. Coastline alterations and structures can result in modifications to established current regimes, potentially causing changes in recruitment, feeding, reproduction patterns, and other biological activity. Detailed information on waves, tides and currents within the harbor will assist in predicting and tracking the extent and movement of particulate and other potential construction inputs.

Proposed methods: Waves, tides and currents will be measured using Acoustic Doppler Current Profilers (ADCPs) fixed to the OHMS moorings (Figure 11 and Figure 12). These measurements will be used to support and verify EIS findings, as well as measure any alterations to the current regime in the vicinity of the construction site. ADCPs can also be deployed such that they scan the water column horizontally, allowing some information about the plume extent to be inferred from the ADCP backscatter data. Deployment of high frequency surface radar can be used to map winds and surface currents in the harbor and vicinity.

6. *Assess the natural variability and any anthropogenic signal in water column turbidity, salinity, and temperature.*

Anthropogenic influences can often be measured as changes in salinity, temperature, and turbidity throughout a water column. Even small changes in one or more of these parameters can have significant impacts on coral reef ecosystems. Sedimentation (the settling of particulate matter from the water column) on coral communities can cause severe damage through reduction of photosynthesis and physical damage to coral tissue. Vertical profiles of these parameters will provide information on sediment plumes, fresh water run-off, phytoplankton blooms and temperature variability. Profiles taken on a high-frequency and spatially dense sampling scheme can provide information on the timescale of an event, the depth variability in any particular parameter, and the spatial distribution of a specific event.

Proposed method: Conduct shallow water (< 40 m depth) CTD (conductivity, temperature, depth) surveys at predetermined locations around the harbor (Figure 11). The frequency of sampling will depend on construction activity. A weekly

sampling interval is anticipated for before and after construction. A sampling interval of every other day is preferable during construction activity. The CTD profiles should also include turbidity and fluorescence measurements. Fluorescence measurements will help to distinguish between organic and inorganic material. These data will track changes in salinity, temperature and particulate concentration as well as vertical and horizontal distribution of potential sediment plumes. See Table 3 for Guam EPA water quality standards and limits.

7. *Assess the natural variability and any anthropogenic signal in water column chemistry and chemical toxicity.*

Corals rely on numerous and complex chemical exchanges for tissue growth and repair, feeding and reproduction. Data from water samples will show if chemicals, both naturally occurring and anthropogenic, are being introduced, removed or their concentrations altered during the course of construction and dredging. Chlorophyll and nutrient analysis will be performed on water samples, in accordance with established CRED sampling protocols. GEPA classifies the water in Apra Harbor as ‘M2’ or ‘good’ quality water and has set acceptable limits for water quality based on the M2 criteria:

Table 3: Guam Environmental Protection Agency water quality standards for ‘M2’ waters.

Constituent Measured by EIS Water Sampling	Abbreviation	Criteria / Limits from Guam Water Quality Standard for M2
Orthanophosphate phosphorous	PO ₄ ⁻³	50 µg L ⁻¹
Nitrate	NO ₃ ⁻	200 µg L ⁻¹
Nitrite	NO ₂ ⁻	
	NH ₄ ⁺	
Total Nitrogen	TN	
Total Phosphorus	TP	
Total Organic Nitrogen	TON	
Total Petroleum Hydrocarbon	TPH	
Chlorophyll a	Chl <i>a</i>	
Turbidity		1.0 nephelometric turbidity units (ntu)
Total Suspended Solids	TSS	20 mg L ⁻¹
pH	PH	6.5- 8.5
Dissolved Oxygen	DO ₂	>75% saturation
Salinity	S	Change < 10% ambient ppt
Temperature	T	Change < 1 ⁰ C ambient

Proposed method: During designated CTD surveys (at least once per week), a Niskin bottle array will be used to take samples at 3 depths per station at designated water sampling sites (Figure 13). Samples will be analyzed for each of the constituents listed in Table 3. The EIS provides an initial data point in this important time series. However, all water samples analysed for the EIS were taken

from a single sampling session (between the hours of 0700 and 1030 on December 9th 2004.)

8. *Determine sediment accumulation rates at various distances from Kilo Wharf before, during and after construction.*

Sediment accumulation onto a coral ecosystem can significantly disrupt biological processes. Accumulation rates that exceed certain levels have been shown to be harmful to corals, from restricting growth rates to total coral mortality.

Proposed method: A suite of 21 sediment stations and turbidity sensors will be deployed in the vicinity of Kilo Wharf and around Apra Harbor. OHMS stations will all include a sediment trap array and a turbidity sensor. Additional Sediment and Turbidity Stations (STS) will be deployed at each of the 18 benthic permanent monitoring transects in the impact zone, as well as the 3 control transects around Outer Apra Harbor. The use of time-series photography to record the deposition and resuspension of sediment, as pioneered by the USGS¹², is also being investigated. Analysis of the size distribution of plume sediment will improve the modelling of plume dynamics and extents.¹³

9. *Determine if any changes in sediment toxicity can be detected before/after construction.*

Over time, toxic elements from anthropogenic inputs settle to the ocean floor and accumulate in the sediment layers. Dredging can disrupt these layers of sediment and re-suspend these constituents into the water column. When soft sediments are present, measurement of changes in toxicity levels in the sediment are important to determine the effect of dredging on water quality. Based upon the EIS, it does not appear likely that much of the Kilo Wharf dredge material will consist of soft, unconsolidated sediment. However, when soft sediment is to be dredged, sediment toxicity would need to be monitored. It would also be advisable to perform targeted plume sampling near the dredge head in order to characterize suspended sediment released during dredging.

Proposed method: To be determined. CRED Oceanographic group currently does not have in-house expertise to determine changes in sediment toxicity, if such studies are required.

¹² Reviewer suggests adoption of USGS methods. CRED had already been in contact with Curt Storlazzi of USGS regarding possible collaborative work.

¹³ Reviewer suggests that more information be provided regarding sediment trap arrays.

10. Validate Apra Harbor circulation model and perform sensitivity analysis.

Estimating sediment plume extents, predicting larval distribution, efficient response to fuel spills, and forecasts of the impacts of future construction can all benefit from a robust and validated general circulation model of Apra Harbor.

Proposed method: The existing EFDC model developed by Sea Engineering can be improved with additional development and validation, in particular more realistic forcing and boundary conditions and a sensitivity analysis to these various inputs. Development of a Deflt 3D model of the harbor by an independent team can further validate simulation results.¹⁴

Data Management and Access

One of the conditions under which CRED has agreed to manage this project is that we must assure the Navy and the resource management agencies timely access to scientifically defensible information and achieve transparency among all involved in the effort. All information collected will be made available both to the Navy and to the pertinent resource managers as soon as possible.

A critical element of a project with collaborating groups in Guam, Hawaii, and Florida is provision of a data management structure that allows access for all involved groups. CRED has developed a Pacific-wide database for its RAMP data and distributes data to partners both via shared access to the database and web download for base-level mapping data such as bathymetric maps (www.soest.hawaii.edu/pibhmc). The Microsoft Access and Oracle database structures that CRED uses for its biological and oceanographic data allow rapid turn-around of data (often the same day as the data are collected). These tools can easily be expanded or modified for Apra Harbor monitoring. A dedicated data manager would be hired for the project. Rigorous quality assurance and control (QA/QC) methods for checking data entry to the database have been implemented at CRED in the course of seven years of data collection and production of the Coral Reef Ecosystem Monitoring Report for American Samoa: 2002-2006. The QA/QC methods will be routinely applied to all data collected for this project.

It is planned that a project website would be established which would facilitate data exchange. Password protected portions of the website are envisioned in order to allow both Navy and resource management agencies access to any near-real-time data streams (e.g. video, photographs) and to summaries of scientific data.

Meetings and Reporting

It is not anticipated that it will be possible to provide a pre-construction survey report due to the short time frame before construction begins. However, the EIS contains a thorough review of currently available information. A report regarding the pre-construction and

¹⁴ Reviewers note that collection of reef flat and surface oceanographic samples and addition of wave impacts should be incorporated into validation of the circulation model.

construction phases of the project would be prepared four months after construction ends and post-construction updates or briefings would be provided eight months and fourteen months after construction ends.

Briefings for scientists and resource managers at intervals of six to eight weeks are planned during the pre-construction and construction phases of the project. These will be separate from scientific exchanges that are likely to occur during survey operations. NAVFAC has suggested that the management briefings be held alternately in Honolulu and Guam and that phone and/or video conferencing would be available for those not able to attend.

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A complete list of algal references for Apra Harbor and Guam is available upon request.

Appendix A: Invitee, Participant, and Contact List

**Guam/CNMI Marine Natural Resources Monitoring Protocols
Workshop
Imin Conference Center, East-West Center, Honolulu, Hawaii
December 7 – 10, 2007**

Invitees

1. Dr. Rusty Brainard – NOAA-PIFSC-CRED
2. Scott Ferguson – NOAA-PIFSC-CRED
3. Dr. Kevin Wong – NOAA-PIFSC-CRED
4. Dr. Michael Parke – NOAA-PIFSC-CRED
5. Seema Balwani – NOAA-PIFSC-CRED
6. Joyce Miller – NOAA-PIFSC-CRED-JIMAR
7. Dr. Bernardo Vargas-Angel – NOAA-PIFSC-CRED-JIMAR
8. Dr. Jean Kenyon – NOAA-PIFSC-CRED-JIMAR
9. Dr. Peter Vroom – NOAA-PIFSC-CRED-JIMAR
10. Dr. Bob Schroeder – NOAA-PIFSC-CRED-JIMAR
11. Marie Ferguson – NOAA-PIFSC-CRED-JIMAR
12. Jacob Asher – NOAA-PIFSC-CRED-JIMAR
13. Jason Helyer – NOAA-PIFSC-CRED-JIMAR
14. Marc Nadon – NOAA-PIFSC-CRED-JIMAR
15. Oliver Vetter – NOAA-PIFSC-CRED-JIMAR
16. Dr. Jo-Ann Leong – UH - Hawaii Institute of Marine Biology
17. Scott Godwin – UH - Hawaii Institute of Marine Biology
18. Dr. Ku'ulei Rodgers – UH - Hawaii Institute of Marine Biology
19. Dr. Paul Jokiel – UH - Hawaii Institute of Marine Biology
20. Stephen H. Smith – Navy – NAVFAC – Kilo Wharf Overview
21. Vanessa Pepi – Navy - NAVFAC
22. Leighton Wong – Navy - NAVFAC PAC Environ'l Business Line Mgr – (Fri & Mon)
23. Karen Sumida – Navy – NAVFAC PAC – (Fri & Mon)
24. Dr. Steve Dollar – Marine Research Consultants (Fri & Mon)
25. Dr. Robert Rocheleau – Sea Engineering (Fri & Mon)
26. Marc Ericksen – Sea Engineering (Fri & Mon)
27. Dr. Richard Brock – Environmental Assessment LLC – (Fri & Mon)
28. Gerry Davis – NOAA-NMFS-PIRO – (Fri & Mon)
29. Dr. Steve Kolinski – NOAA-NMFS-PIRO (Fri & Mon)
30. Wendy Wiltse - EPA (Fri & Mon)
31. Dr. Kevin Foster - FWS – (Fri & Mon)
32. Michael Molina – FWS – (Fri & Mon)
33. Dr. Jerry Ault – Univ. of Miami RSMAS
34. Dr. Steve Smith – Univ. of Miami RSMAS
35. Dr. Alexander Kerr – Univ. of Guam Marine Lab
36. Dr. Andrew Halford – Univ. of Guam Marine Lab
37. Dr. Tom Schils – Univ. of Guam Marine Lab
38. Mike Trianni – CNMI
39. Tom Fee - Helber, Hastert and Fee Planners, Inc. – (Fri & Mon)

Guam/CNMI Marine Natural Resources Monitoring Protocols Workshop
Imin Conference Center, East-West Center, Honolulu, Hawaii
December 7 – 10, 2007

Participant List by Date

December 7, 2007

1. Dr. Rusty Brainard – NOAA-PIFSC-CRED
2. Scott Ferguson – NOAA-PIFSC-CRED
3. Dr. Kevin Wong – NOAA-PIFSC-CRED
4. Dr. Michael Parke – NOAA-PIFSC-CRED
5. Seema Balwani – NOAA-PIFSC-CRED
6. Joyce Miller – NOAA-PIFSC-CRED-JIMAR
7. Dr. Bernardo Vargas-Angel – NOAA-PIFSC-CRED-JIMAR
8. Dr. Jean Kenyon – NOAA-PIFSC-CRED-JIMAR
9. Dr. Peter Vroom – NOAA-PIFSC-CRED-JIMAR
10. Dr. Bob Schroeder – NOAA-PIFSC-CRED-JIMAR
11. Marie Ferguson – NOAA-PIFSC-CRED-JIMAR
12. Jacob Asher – NOAA-PIFSC-CRED-JIMAR
13. Jason Helyer – NOAA-PIFSC-CRED-JIMAR
14. Marc Nadon – NOAA-PIFSC-CRED-JIMAR
15. Oliver Vetter – NOAA-PIFSC-CRED-JIMAR
16. Amy Hall – NOAA-PIFSC-CRED-JIMAR
17. Stephen H. Smith – Navy – NAVFAC – Kilo Wharf Overview
18. Dr. Steve Dollar – Marine Research Consultants
19. Dr. Robert Rocheleau – Sea Engineering
20. Marc Ericksen – Sea Engineering
21. Wendy Wiltse - EPA
22. Dr. Jerry Ault – Univ. of Miami RSMAS
23. Dr. Steve Smith – Univ. of Miami RSMAS
24. Dr. Alexander Kerr – Univ. of Guam Marine Lab
25. Dr. Andrew Halford – Univ. of Guam Marine Lab
26. Dr. Tom Schils – Univ. of Guam Marine Lab
27. Mike Trianni – CNMI
28. Tom Fee - Helber, Hastert and Fee Planners, Inc.

December 8, 2007

1. Dr. Rusty Brainard – NOAA-PIFSC-CRED
2. Scott Ferguson – NOAA-PIFSC-CRED
3. Dr. Kevin Wong – NOAA-PIFSC-CRED
4. Dr. Michael Parke – NOAA-PIFSC-CRED
5. Joyce Miller – NOAA-PIFSC-CRED-JIMAR
6. Dr. Bernardo Vargas-Angel – NOAA-PIFSC-CRED-JIMAR
7. Dr. Jean Kenyon – NOAA-PIFSC-CRED-JIMAR

8. Dr. Peter Vroom – NOAA-PIFSC-CRED-JIMAR
9. Dr. Bob Schroeder – NOAA-PIFSC-CRED-JIMAR
10. Marie Ferguson – NOAA-PIFSC-CRED-JIMAR
11. Jacob Asher – NOAA-PIFSC-CRED-JIMAR
12. Jason Helyer – NOAA-PIFSC-CRED-JIMAR
13. Marc Nadon – NOAA-PIFSC-CRED-JIMAR
14. Amy Hall – NOAA-PIFSC-CRED-JIMAR
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16. Dr. Jerry Ault – Univ. of Miami RSMAS
17. Dr. Steve Smith – Univ. of Miami RSMAS
18. Dr. Alexander Kerr – Univ. of Guam Marine Lab
19. Dr. Andrew Halford – Univ. of Guam Marine Lab
20. Dr. Tom Schils – Univ. of Guam Marine Lab
21. Mike Trianni – CNMI

December 9, 2007

1. Dr. Rusty Brainard – NOAA-PIFSC-CRED
2. Scott Ferguson – NOAA-PIFSC-CRED
3. Dr. Kevin Wong – NOAA-PIFSC-CRED
4. Dr. Michael Parke – NOAA-PIFSC-CRED
5. Joyce Miller – NOAA-PIFSC-CRED-JIMAR
6. Dr. Bernardo Vargas-Angel – NOAA-PIFSC-CRED-JIMAR
7. Dr. Jean Kenyon – NOAA-PIFSC-CRED-JIMAR
8. Dr. Peter Vroom – NOAA-PIFSC-CRED-JIMAR
9. Dr. Bob Schroeder – NOAA-PIFSC-CRED-JIMAR
10. Marie Ferguson – NOAA-PIFSC-CRED-JIMAR
11. Jacob Asher – NOAA-PIFSC-CRED-JIMAR
12. Jason Helyer – NOAA-PIFSC-CRED-JIMAR
13. Marc Nadon – NOAA-PIFSC-CRED-JIMAR
14. Oliver Vetter – NOAA-PIFSC-CRED-JIMAR
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17. Dr. Steve Smith – Univ. of Miami RSMAS
18. Dr. Alexander Kerr – Univ. of Guam Marine Lab
19. Dr. Andrew Halford – Univ. of Guam Marine Lab
20. Dr. Tom Schils – Univ. of Guam Marine Lab

December 10, 2007

8 am - noon

1. Dr. Rusty Brainard – NOAA-PIFSC-CRED
2. Scott Ferguson – NOAA-PIFSC-CRED
3. Dr. Kevin Wong – NOAA-PIFSC-CRED
4. Joyce Miller – NOAA-PIFSC-CRED-JIMAR
5. Dr. Bernardo Vargas-Angel – NOAA-PIFSC-CRED-JIMAR

6. Seema Balwani – NOAA-PIFSC-CRED-JIMAR
7. Marie Ferguson – NOAA-PIFSC-CRED-JIMAR
8. Oliver Vetter – NOAA-PIFSC-CRED-JIMAR
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10. Dr. Jerry Ault – Univ. of Miami RSMAS
11. Dr. Steve Smith – Univ. of Miami RSMAS
12. Dr. Alexander Kerr – Univ. of Guam Marine Lab
13. Dr. Andrew Halford – Univ. of Guam Marine Lab
14. Dr. Tom Schils – Univ. of Guam Marine Lab
15. Mike Trianni – CNMI

December 10, 2007

Noon – 4pm

1. Dr. Rusty Brainard – NOAA-PIFSC-CRED
2. Scott Ferguson – NOAA-PIFSC-CRED
3. Dr. Kevin Wong – NOAA-PIFSC-CRED
4. Seema Balwani – NOAA-PIFSC-CRED
5. Joyce Miller – NOAA-PIFSC-CRED-JIMAR
6. Dr. Bernardo Vargas-Angel – NOAA-PIFSC-CRED-JIMAR
7. Marie Ferguson – NOAA-PIFSC-CRED-JIMAR
8. Oliver Vetter – NOAA-PIFSC-CRED-JIMAR
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11. Dr. Robert Rocheleau – Sea Engineering
12. Wendy Wiltse - EPA
13. Dr. Jerry Ault – Univ. of Miami RSMAS
14. Dr. Steve Smith – Univ. of Miami RSMAS
15. Dr. Alexander Kerr – Univ. of Guam Marine Lab
16. Mike Trianni – CNMI
17. Tom Fee - Helber, Hastert and Fee Planners, Inc.
18. Don Hubner – NOAA/PIRO/PRD

Workshop Contact info

<i>Project</i>	Guam/CNMI Marine Natural Resources Monitoring Protocols Workshop	<i>Meeting Date:</i>	December 7-10, 2007
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Workshop Contact info

Project Guam/CNMI Marine Natural Resources
Monitoring Protocols Workshop

Meeting Date: December 7-10, 2007

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Appendix B: Planned Meeting Agenda

**Guam/CNMI Marine Natural Resources Monitoring Protocols
Workshop
Imin Conference Center, East-West Center, Honolulu, Hawaii
Dec. 7-10, 2007**

DRAFT Agenda

Friday, Dec. 7 Asia Room (Scientists and Resource Managers)

Welcoming

- 08:00 – 08:20 Coffee, tea, and pastries
- 08:20 – 08:50 Welcoming remarks and introductions – Dr. Rusty Brainard, NOAA-CRED
- 08:50 – 09:00 Opening remarks - Leighton Wong, Navy-NAVFAC

Project Considerations

- 09:00 – 09:20 Overview of proposed DoD activities and supporting natural resource surveys
Steve Smith, Navy-NAVFAC
- 09:20 – 09:50 EIS and GIS overview – Joyce Miller, NOAA-CRED
- 09:50 – 10:00 Discussion

- 10:00 – 10:20 Break

Ecological and Environmental Background – What do we know? What don't we know?

- 10:20 – 10:35 Biological surveys – Dr. Steve Dollar – Marine Research Consultants
- 10:35 – 10:50 Biological surveys – Dr. Kevin Foster - USFWS
- 10:50 – 11:05 Biological surveys – Steve Kolinski?- NOAA,
- 11:05 – 11:15 Environmental surveys - Wendy Wiltse?-EPA
- 11:15 – 11:30 Oceanographic surveys – Dr. Bob Rocheleau/M. Ericksen – Sea Engineering
- 11:30 – 12:00 Additional inputs and discussion

Lunch

- 12:00 – 13:00 Lunch

Monitoring Goals and Design End-points – What are expectations of monitoring?

- 13:00 – 13:20 Navy requirements
- 13:20 – 13:50 Resource management agency requirements – NOAA, USFWS, EPA, Guam
- 13:50 – 14:20 Pacific RAMP and CRED considerations – Dr. Rusty Brainard
- 14:20 – 14:45 Other considerations and discussion – Univ. of Guam, HIMB, RSMAS

- 14:45 – 15:00 Break

Survey Designs Considerations – What's needed for statistical rigor?

- 15:00 – 16:00 Survey design considerations 101 – Drs. Jerry Ault/Steve Smith, RSMAS
- 16:00 – 16:30 Discussion
- 16:30 – 16:45 Final guidance from resource managers and stakeholders
- 16:45 Adjourn

Days 2 and 3
East-West Center, Imin Conference Center, Tagore Room
Scientists and Statisticians

Saturday, Dec. 8 **Optimal Survey Design - What would we monitor, where, how often, and using what methods if unconstrained by funding, personnel, and logistics?**

- 08:00 – 08:20 Coffee, tea, and pastries
08:20 – 08:40 Review of day 1 requirements – Dr. Rusty Brainard, NOAA-CRED
08:40 – 10:10 What components of the ecosystem need to be monitored? Generally for Guam / CNMI and specifically for Apra Harbor?
 a) Biological
 b) Environmental
 c) Anthropogenic
10:10 – 10:30 Break
10:30 – 12:00 What are the time and space scales for optimal survey design?
 a) Kilo Wharf and Apra Harbor
 b) Generic locations and projects (eg. Pagan, Tinian, and Aguijan)
12:00 – 13:00 Lunch
13:00 – 14:40 What are preferred survey methods?
 a) Benthic composition – corals, other invertebrates, algae
 b) Fish and mobile fauna
 c) Oceanography and water quality
14: 40– 15:00 Break
15:00 – 16:30 Discussion
16:30 Adjourn

Sunday, Dec. 9 **Realistic Survey Design - What can we monitor given realities of funding, personnel, scheduling, and logistics?**

- 08:00 – 08:20 Coffee, tea, and pastries
08:20 – 08:40 Review of day 2 requirements
08:40 – 10:00 What are constraints and limitations?
 a) personnel and scheduling (i.e. who's available and when?)
 b) logistical, scheduling, and funding constraints?
10:00 – 10:20 Break
10:20 – 12:00 Given constraints, what/how/who/when conduct Apra Harbor baseline assessment?
12:00 – 13:00 Lunch
13:00 – 14:00 Given constraints, what/how/who/when conduct Apra Harbor monitoring during and post-construction?
14: 00– 14:45 Discussion
14:45 – 15:00 Break
15:00 – 16:30 Data management, processing, analysis, and reporting
16:30 Adjourn

Day 4
East-West Center, Imin Conference Center, Tagore Room
Scientists and Resource Managers (afternoon session)

Monday Dec. 10

Morning – Final discussions and concensus among scientists and statisticians

08:00 – 08:20 Coffee, tea, and pastries

08:20 – 12:00 Discussion and preparation of talking points for afternoon debriefing with resource manager.

12:00 – 13:00 Lunch

Afternoon – Overview of Workshop Outcomes for Navy and Resource Managers

13:00 – 13:30 Overview of Apra Harbor and general monitoring designs

13:30 – 15:00 Discussion

15:00 – 15:20 Break

15:20 – 16:00 Discussion and closing comments

a) Navy

b) Resource Management Agencies

c) CRED

16:00 Adjourn

Appendix C: Reviewers' Comments

1. Marc Ericksen – SEA Engineering – 28 January, 2008

Joyce:

The report is thorough and clear.

I have only 1 minor change to the intro paragraph in the/Environmental Monitoring Methods /section. I suggest changing the sentence to read as follows:

Sea Engineering Inc. has previously conducted specific oceanographic surveys in Apra Harbor, primarily using in-situ deployed Acoustic Doppler Current Profilers (ADCP) to characterize currents and to aid in the development of a circulation model of the harbor.

Also, one item that I think is missing from the data collection program is targeted plume sampling to characterize suspended sediment released during the dredging. This would focus on measurements near the dredge head to determine what is being released.

Thanks

Marc.

2. Dr. Tom Schils – University of Guam – January 28, 2008

). Six 0.25 m² quadrats would be placed at 5 m intervals along the 25 m transect and a second set of six quadrates would run parallel with the first set with an offset of 3 m toward shallower water (Preskitt et al. 2004, Vroom et al. 2005). For each quadrat, the percent cover of the different algal species would be obtained based on visual estimates.

Dr. Schils requested that we delete “and a second set of six quadrates would run parallel with the first set with an offset of 3 m toward shallower water.”

3. Dr. Michael Trianni (Dept. of Fish and Wildlife, CNMI) – January 28, 2008

Joyce,

Just some comments on the proposed Fish method.

Fish and Turtle Monitoring Methods

- Two divers move to the center of the circle at the base of their SPC cylinder **THIS IS PRESUMABLY A PRE-DETERMINED LAT/LONG POSITION?**
- During the first 5 minutes of the SPC, divers create a list of fish species observed in their cylinder. No counts or sizes are recorded. An exception to this rule is for rare mobile species that are likely not to be seen again during the replicate (e.g., sharks, jacks).

- After the first 5 minutes, the divers go through their list one species at a time, counting and sizing individuals currently present in their cylinder. If no individual from a species is present, the diver simply writes down what the original sighting was (e.g., two 10 cm *A. triostegus*). For better efficiency, it is possible to count individuals from 3 or more species at a time, if the densities are low and the divers are not overwhelmed. IF NO COUNTS OR SIZE ESTIMATES ARE MADE DURING THE FIRST FIVE MINUTES, THEN HOW WOULD THE RECORDER KNOW THE SIZE(S) OF THE ORIGINAL OBSERVATION? THIS WOULD SEEM TO IMPART BIAS AS IT WOULD RELY ON THE ACCURACY OF THE INDIVIDUAL OBSERVER?
- Important: Any additional species observed after the first 5 minutes are not recorded. However, the divers can take all the time they need to go through their fish list and complete their counts following the first 5 minutes. This should take an additional 5 to 10 minutes.
- Once the first replicate is completed, the team moves the transect line to another location nearby and repeats this procedure. IS THERE A TRANSECT TO BE USED FOR THE SPC, OR WOULD IT SIMPLY BE RANDOMLY GENERATED POSITIONS THAT THE OBSERVERS WOULD MOVE TO? WHAT WOULD BE THE PURPOSE OF THE TRANSECT? IT WOULD SEEM TO BE UNNECESSARY.

Thanks for the opportunity to comment.

Mike

4. Dr. Gerry Davis – Pacific Islands Regional Office – January 29, 2008

The National Marine Fisheries Service, Pacific Islands Regional Office (PIRO), Habitat Conservation Division (HCD) has reviewed the PIFSC Internal Report IR-08-001 and has the following comments:

The effort to better define the information essential to evaluate the impacts of KILO wharf and approaching consensus on the applied methodology is supported by PIRO, HCD. There are two critical perspectives that need to be recognized in the regulatory context. The US Fish and Wildlife Service, US Environmental Protection Agency, Government of Guam Regulatory Agencies and HCD maintain their mandated authorities and ability to manage these authorities throughout this process. In this case, that consideration requires that each maintain the flexibility to define data needs and methodologies to best fit their responsibilities.

At first contact in pursuing this issue, HCD emphasized the importance of maintaining the regulatory management of overseeing and participating in the pre-construction site specific data collection in support of effective project management. It is critical to maintain this role and therefore essential to ensure this effort maintains focus on monitoring.

Additionally, efforts have been made to engage HCD in developing this workshop but these efforts have been limited by lack of involvement in the planning process and adequate advance notice of the workshop dates. While management agency participation was intended, the limited management perspective significantly impacted the product. If future such efforts are going to be initiated, the management agencies should be equal priority as part of the planning process from the beginning.

Document specific Comments:

- 1 There is a general presentation blurring when trying to understand the primary objective. The development of the concept in the beginning stages of this effort were characterized as focusing on KILO Wharf. Throughout the document a larger application is implied. Given the uncertainty of the other work at this point, it needs to be clearly stated that this products purpose is to serve the KILO monitoring requirement and that application of the methodology will be considered for future work. Based on this, the title may more appropriately be: Proposed KILO Wharf Coral Reef Monitoring Strategy, Considerations for Guam/CNMI Coral Reef Monitoring Strategies.
- 2 Page 2: It is stated that the workshop was established to discuss and develop a statistically rigorous survey design to address monitoring requirements, which falls directly under regulatory agency purview. The management agency participation descriptions needs better clarification. Those that participated, should be listed similarly to the others participating. The limited participation needs to represent the late invitation and the late shifting the meeting time over a weekend as significant logistical reasons for the lack of involvement.
- 3 Page 3, Para 2: The goals of the workshop are defined here in much broader terms than originally discussed. Again while applying what is developed to future monitoring may make sense, there is not sufficient knowledge of these activities to make such a commitment. Recommend removing statements like, “to the maximum extent possible, the protocols ... should produce data which would be comparable ... [with] RAMP”. While RAMP is a great resource, matching RAMP is not the goal. The goal should be defining the desired data set and gathering this information in the best way. Yes, having comparable data sets is essential but not to the point of potentially gathering the wrong information for the intended purpose.
- 4 Page 3, Para 4: If the first day of the workshop was “designed” to gain the perspectives of the Navy and pertinent resource management agencies. While some valuable management agency input was received, again better explanation of the lack of involvement by USFWS and HCD needs to be included to characterize the lack of input.
- 5 Page 4, Para 1: It is not clear that the regulatory agency surveys are included in this data set.
- 6 Page 4 Para 5: It is not clear if the timeframe discussion was a science discussion or a management discussion. If it was intended to be a management discussion,

- this should include the managers and reference to the laws that drive many of the timeframes.
- 7 Page 4: Para 7, line 3: Change to “Then the results were presented to attending resource managers and list them
 - 8 Page 5: Compatibility with RAMP protocols for evaluating change associated with causes other than construction. It appears change associated with causes other than construction related activities would more suitably be addressed by adequate monitoring appropriate and multiple site specific reference sites. Does CRED apply all of it’s RAMP protocols specifically in Apra Harbor in a manner that would allow for adequately evaluating what may be very localized changes, or lack of? It was not clear in the document how this issue is being addressed.
 - 9 Page 5: In the parameters under “water quality”, contaminants should be added. This is especially true in the Harbor area.
 - 10 Coral “health” is used repeatedly in the document. How is it defined? This is further complicated by indications to assess impact of mortality, disease by source. This is difficult if not impossible and may be at further risk due to surveyor variance. The desire to gather this information is easy to justify but the scientific methodology is not well enough defined to ensure a viable product.
 - 11 Page 8, 2nd bullet: The refining of the sediment plume is not well defined. The hydrology study used in the EIS does not accurately represent surface water movement, reef flat water circulation or incorporate wave impacts on circulation patterns. These are seen a significant flaws in the presented model.
 - 12 Page 9, Figure 4: This figure is very misleading as it defines the majority of the harbor as lacking coral reef complexity. Clearly the sampling data is insufficient to define the majority of the habitat in the harbor. This needs to be reflected in the figure descriptors.
 - 13 Page 11: The tiered survey approach provides no guarantee that an adequate number of appropriate reference sites will be monitored in a manner that allows some level of reasonable inference regarding causes of potential change associated with Wharf development. Unless we missed something, this is problematic.
 - 14 Page 12, para 2: As presently presented, the carrier berthing will all be captured in Tier 2.
 - 15 Page 12: There needs to be additional focus on sampling in non-hard bottom habitat. This is especially important to foraging and invertebrate populations. Further clarification is also needed in understanding how mixed soft and hard-bottom habitats are assessed. Definitions and justifications need to be provided for appropriate evaluation.
 - 16 Page 13, para 2: This model does not include wave action and this is a significant variable to exclude from this prediction. The data used to build this model does not represent surface water movement and the sampling areas were all in deep water beyond the reef slope. This means the most critical reef flat and reef margin areas were not sampled.
 - 17 Page 15, number of sampling units: Data do exist for many of the habitats at the site. While it’s nice to do 5 samples in each habitat (along with subsamples, 50 samples total), what level of change will be detected by this protocol? Four days

- of work, lots of scientists, two biostatisticians..., was a power analysis completed or even considered for the KILO project, and if not, why? Given these computations are based on comparable sampling designs developed for FK and NWHI, please at least report the level of change such methods can detect in these regions (assuming it has been determined) to provide some sense of what might be expected for Kilo if transference applies. Also, how are “permanent” sites actually defined in terms of an undefined but anticipated level of methodological error in positioning and surveying 25 m swaths of reef repeated over time? What are the statistics to be used to assure independence and where are appropriate references? If the intent is to follow specific colonies, why aren’t individual coral colonies going to be labeled in a manner that allows for accurate identification and multiple measurements over time (addressed to some extent, although not clearly, later in the document)? Is there a listing of the types of changes anticipated that will specifically and purposefully be monitored? Both the limitations and ability to detect change with these methods at this site should be fully disclosed.
- 18 Page 17, Para 2: What do the “Oceanographic Harbor Monitoring Stations” actually measure?
 - 19 Page 17: If resources are not available for tier 2 or 3 activities, how will appropriate reference sites be selected and surveyed? Is the assumption that absent measurements in reference areas all change will be associated specifically to Kilo Wharf construction activities? Is the Navy providing written agreement to such? Or is it portended that biannual RAMP surveys throughout the archipelago that may or may not include Apra Harbor will serve to clarify all sources of change? If the later, please fully explain where and how.
 - 20 Page 18, Corals: the videotape will allow for estimating “planar” percent cover. This should be stated. Also, colony density determinations from videotape are erroneous at best. Why suggest this as an assessment methodology when other means will provide greater accuracy? How good is the videotape resolution for determining species composition? How many fixed sites are there in a habitat (2, 3)? Again, what are the intended statistics?
 - 21 Page 18: Percent benthic cover: What type of variance is anticipated and how does this relate to appropriate sample size and any ability to detect change?
 - 22 Page 19, Size class distribution and coral condition: How much time is anticipated for making three measurements on every single coral colony along a 25 m transect? It’s going to take a long while especially on some of the reef flat areas where diversity and colony densities are fairly high to measure and account for everything listed. For instance, assume 300 colonies within a 25 m² transect and 20 to 60 seconds to identify, measure and record all parameters of interest for each coral. We are then either talking about some very long dives (1.7 to 5 hrs per 25 m² transect) and extended surveys, or inaccurate/low quality results. What instruments will be used to measure corals? How is it envisioned the three parameters (length, width, and height) will be used to assess change? Are the parameters going to be combined in some fashion that grossly enhances error? Is “plating” corals meant as opposed to “platy”? Will size measurements still be attempted in *Porites rus* habitats? What is the inter-observer error associated with

- “visual estimates of percent coral cover”? Note, *Porites rus* stands are rarely mono-specific. It’s important to evaluate the colony interstices for other corals. Additionally, the methodology described indicates notable changes will be documented. These terms need definition to have functional use. It is also critical to realize if any of this information is going to be used in restoration analysis that size characterization is critical to this modeling process.
- 23 Permanent stations: How is it determined that six replicates (24 sub-samples) will be enough to detect change within each sediment impact zone? Isn’t there likely to be a gradient moving away from the actual dredging, thus enhancing variability in levels of change and ability to statistically detect it? Are four subsamples enough to detect change adequately if particular subsections of impact zones need evaluation? If a “quadrat” happens to have limited numbers or no corals present, how will it be used as downward change may be disproportionate or completely unachievable? Please provide the statistical basis for the numbers of subsamples and replicates proposed in association with all potential outcomes. How permanent will these 1m² subsamples be (will they be demarcated on each corner as permanent quadrats)? Where are adequate references located for comparison?
- 24 Page 20: Functional and cellular responses to sedimentation stress: Wouldn’t limiting tissue collection to genera common to sediment impacted areas create a potential for bias in determining stress? Why only two, apparently hardy genera are considered, as opposed to other, more ephemeral and susceptible genera? Three species known to be present and relatively abundant should be selected based on existing information that may allow for covering a range (high, medium, low) of susceptibilities to sediment. However, given this work is fairly experimental and apparently not well established in terms of being conclusive from a management or ecological implications perspective, is this just being seen as an opportunity to collect samples to do science? Overall, what’s it going to mean? Please define. Wouldn’t the time and money be better utilized in increasing sample sizes and adding reference sites to enhance the ability to estimate more determinable project impacts such as associated mortalities and changes in underlying community foundations and dynamics?
- 25 Page 20: Assessing health condition and linkage to causes is not well defined from an assessment approach and lacks definition statistically. There is also concern for parity between surveyors.
- 26 Page 21: Algae: Are sub-sample and replicate numbers enough? How can one determine impact associated changes absent measurements from an adequate number of appropriate reference sites?
- 27 Page 21: Invertebrates: What is an ARM? How does it work, and what’s the uncertainty in what it tells you? Fully agree with and recommend nocturnal surveys for motile taxa.
- 28 age 23-24, Microbial communities: While interesting, the time and money devoted to determining “*potential*” pathways of impact via microbial community changes might be better invested in ensuring actual impacts are adequately determined.
- 29 Page 24, Turtles: It’s “Don Hubner”, not “Dan”.

- 30 Page 25: Under Turtles and Species of Concern, bumphead parrotfish and humphead wrasse should be added to the list of target species. This is especially important because the Orote Peninsula historically had a large bumphead parrotfish population.
- 31 Page 26, para 1: This text needs correction as Hawksbill Turtles have been routinely observed in the Harbor, especially foraging in the Sasa Bay area. Additionally, Spinner Dolphins have been infrequently observed inside the Harbor as far in as Gab Gab Reef.
- 32 Page 27, para 1: Some consideration should be given to placing wave pressure wave sensors.
- 33 Page 28, Figure 12: It again should be noted the lack of sensors in shallow water.
- 34 Page 33, Validate Apra Harbor Circulation Model....: Reef flat samples, surface samples and wave impacts need to be built into this effort.
- 35 Page 3, Para 1 and Appendix A. Correct references to Dr. Kolinski, Ph.D. in Zoology specializing in coral reef ecology.

Thank you for the opportunity to comment on this and please feel free to contact me to further discuss any of the information presented. We look forward to continuing to work through this effort together.

Gerry

5. Michael Molina – U.S. Fish and Wildlife Service – January 31, 2008

Pacific Islands Fish and Wildlife Service (PIFWO) Comments on “Monitoring Strategy and Preliminary Survey Design for Guam/CNMI Coral Reef Ecosystem Studies with a Focus on Apra Harbor and Kilo Wharf”

The PIFWO Coastal Conservation Program is grateful for the opportunity to review the document. We support the use of scientifically credible methods to assess construction-related impacts to coral reef resources during construction associated with the Kilo Wharf Extension Project. Overall, we believe full cooperation among the Navy and other federal, state, and territorial resource agencies is essential to ensure better planning, design, implementation, and management of projects that have the potential to adversely affect coral reef resources in the Pacific. We have several general and specific concerns associated with the document.

General Comments

We are concerned with the very limited involvement by resource agencies with regulatory authority pertinent to this project, and we believe that the lack of participation from us has not been adequately portrayed. Our office was marginally involved in planning efforts for this workshop and received notification of it late, after staff had already committed to other responsibilities. We recommend that this be reflected in the document and that the involvement of the various regulatory agencies be clarified. We request that future workshops involve us earlier in the planning process so that we can ensure our attendance and contribution. Finally, it must be clear that the U.S. Fish and Wildlife Service will always maintain its mandated authorities and the discretion to apply these authorities in the best way to incorporate fish and wildlife conservation into federal projects. The ability to identify our

data needs and the methods we employ to fulfill these needs cannot be compromised in order for us to implement our authorities in the most efficient way.

The document suggests that methods and designs discussed within it are to be employed beyond the scope and aerial extent of the Kilo Wharf project. We have significant concerns with this. Effective monitoring efforts must have specific goals and objectives in order to be successful. This document has been developed to assess sediment and other construction impacts associated with the Kilo Wharf project, and while aspects of the proposed plan may be applicable to other areas and for other projects, wholesale adoption of these methods and this design for other projects in other areas may be inappropriate. We recommend that the title of the document be changed to reflect the more narrow nature of the described work and that it be clarified that the design and methodologies included within are intended to assess construction-related impacts specifically at Kilo Wharf and without reference to other projects.

It is unclear if the focus of the project is on monitoring for regulatory/management reasons or to test new scientific methods that may have future management application or both. It is unclear from the discussion if the molecular and microbial work has attained “accepted” status as a monitoring tool. While not being against use of new methods to answer important management questions, we are concerned that some of the proposed methodologies are still in the “development” phase and may, thus, be inappropriate for use as monitoring tools for management and regulatory purposes. We commend NOAA-CRED and the Navy’s willingness to further develop new methods, but caution their use directly in this project. We recommend that these issues be clarified in subsequent versions.

As a monitoring plan, this document lacks needed detail on objectives, study design, methodology, data analysis and management, operating procedures, and budget. Without additional detail, it is difficult to assess, and thus endorse this plan. We recommend that you consider adopting the guidelines recommended by Oakley et al. (2003) for the development of monitoring plans/protocols for this document. These guidelines are currently used by the National Park Service, which implements the nation’s largest long-term monitoring effort. Specifically, we recommend that additional detail be added to address the following issues:

Objectives. The objectives of the monitoring effort are unclear. While it is stated that NOAA-CRED has been asked to develop a monitoring program for “...ecological monitoring of the benthic habitats, associated biological communities, and environmental water quality conditions of Apra Harbor before, during, and after dredging and construction at Kilo Wharf...” (page 1), the underlying purpose for this effort is not clear. If this monitoring program is intended to assist with impact determination for mitigation purposes, it is unclear how the data collected from this program will relate to previous surveys to measure impact at Kilo Wharf or how it would be used to scale or assess mitigation associated with the Kilo Wharf project. There is no discussion of previous impact assessments, mitigation site assessments, or performance criteria developed as part of the EIS process for the Kilo Wharf Project. It is unclear how the data collected from this project would inform the mitigation process associated Kilo Wharf. Furthermore, it is unclear if this project is intended to collect data to be used for future Navy projects in Apra Harbor or elsewhere (see our earlier comment). We recommend that the objectives of this work be clearly defined.

Survey Design. It appears that a split-panel design with a selection of fixed and random panels has been proposed. This design is effective and a scientifically sound choice. While we support this use of this design, it is unclear how specific parameters were determined and assessed, and we are concerned about its statistical rigor. The selection of the

number of sites appears to be based on sampling a percentage of the bottom, but no rationale for the appropriateness of this approach is provided. Ultimately, statistical power will be determined by variability in the sample and the number of samples taken, and while data are available for the Kilo Wharf area with which to derive variability estimates and, thus, calculate statistical power and appropriate sample size, this does not appear to have been done. Additionally, there are established methodologies for determining the proportion of fixed vs. random panels in a split-panel design. Using available data, it should be possible to determine this proportion to maximize the power of the sampling design. Finally, the timing of samples and the number of repeated samples is unclear. Monitoring efforts almost always gain their statistical power through a combination of sample size and repeated sampling. It is unclear what number of panel rotations are intended to be used as part of this monitoring program and no estimate of statistical power associated with additional sampling efforts have been provided. We recommend that the data available for the Kilo Wharf site be used to develop the specific parameters of the proposed split-panel design.

Methodology. The survey discusses several proposed data collection methodologies, but specific details are lacking. Without specific details in the monitoring plan, there is a risk of methodologies “drifting” over time. We recommend that each methodology presented in the document either be accompanied by a specific Standard Operation Procedure (SOP) on how to implement the method or a reference to an appropriate publication that contains a specific methodology. Guidance for SOPs can be found in Oakley et al. (2003).

Data Analysis. No information has been presented on the intended methods to analyze the collected data. It is unclear if a standard method for analyzing a split-plot design will be used where appropriate. It is unclear how data will be classified for analysis (*e.g.* species, genera, functional group, morphological form etc.) and what biological parameters will be examined. Data analysis should be structured to meet the objectives of the monitoring program. Additionally, statistical methods to be used on data collected using other designs (*e.g.* oceanographic and water quality data) are not clear. We recommend that the additional information on data analysis be provided.

Data Management. We are concerned that data management protocols are not well established. Monitoring programs often collect large volumes of data and effective data management is an absolute necessity. Effective data management needs to include methods to ensure quality assurance and control (QA/QC). No information has been provided on QA/QC protocols to ensure data is entered accurately into the described databases. No information is provided on responsibilities for data entry or management, routine data back-ups, nor anticipated archival processes for field notebooks/data sheets. We recommended that additional information and SOPs (as appropriate) be included to clarify QA/QC measures and other aspects of data entry and management.

Operating Procedures. We are concerned that the document lacks detailed SOPs that can be used by field and laboratory personnel to conduct the work. SOPs ensure that repeated samplings efforts and data analysis are conducted in a rigorous and consistent manner. We recommend that SOPs for all tasks be developed or cited (as appropriate) following the guidelines presented by Oakley et al. (2003).

Budget. No information has been provided on estimated costs to conduct the proposed monitoring effort. No consideration has been provided in the event that funding is not sufficient to conduct all aspects of the proposed work. As currently written, it is unclear what the ramifications of inadequate funding would be on the integrity of the data and the ability of the program to meet its stated objective. We recommend that a cost be estimated for the work or that the work be modularized and prioritized in the event that some components of it cannot be implemented. If a modular approach is taken, we recommend inclusion of a discussion of the pros and cons of each module be provided to clarify its importance to meeting the stated objectives or the monitoring program.

Specific Comments

Project Design Parameters (page 5). We feel the monitoring period is insufficient and recommend that it be expanded to at least 10 years, post-construction.

Project Design Parameters (page 5). We recommend that parameters for monitoring include: (1) Size and functional group structure of coral; (2) Coral recruitment; (3) Recovery of partially dead coral; (4) Survival of juvenile coral; (5) Benthic algae functional groups; and (6) Occurrence of sediment tolerant and sediment intolerant benthic organisms.

Survey strategies (page 6). The suggestion of holding additional workshops to assess future project impacts of coral reef resources within Apra Harbor is not consistent with existing federal regulations, such as the Clean Water Act, which identifies an existing process for federal review of planned projects. While we are always open to cooperating with our federal, state, and territorial partners, we will maintain our mandated authorities and ability to manage these authorities throughout this process; we will maintain the flexibility to define data needs and methodologies to best fit our responsibilities. We recommend that these authorities be acknowledged in the document.

Definition of survey parameters (page 6). We recommend that the following parameters be added to the list of considerations for survey parameters: the specific construction project design, which will ultimately define the survey domain and historical records of the area.

Survey Domain (page 9). The Kilo Wharf Predicted Sediment Plume Areas (Figure 7) is inconsistent with historical records (USN 1986) for dredge plumes at the Kilo Wharf site, which observed sediment plumes extending farther west in the harbor. We recommend that monitoring for suspended and accumulated sediments extend west to Orote Island.

Habitat types to be surveyed (Page 10). The document states that habitat types classified as uncolonized will not be included in the monitoring design. Uncolonized habitat in the marine environment is exceedingly rare. The benthic maps employed for this document, while the best available for the area, assess habitat from the perspective of coral. Uncolonized habitats are defined as containing <1% coral cover, but these areas most likely contain rich sponge, tunicate, and algae communities. These communities provide important ecological function to the area, and we recommend that they be included in the monitoring program.

Number of sampling units (page 14). The number of sampling units was derived from "...comparable sampling designs from FK [Florida Keys] and NWHI [Northwestern Hawaiian Islands]." We are concerned that these ecosystems are sufficiently different from those present in Guam that such a comparison is invalid. The benthic fauna in Guam is highly diverse, containing over 5,500 identified species (Paulay 2003, and contributions therein). This is considerably greater than that of the Hawaiian Islands and the Caribbean. We anticipate that biological variability (spatially and possibly temporally) is higher. Appropriate sample size determination should ideally be estimated from the variability of the parameters under investigation. We recommend that the sample size be estimated from the sample variances derived from previous survey work conducted in the Kilo Wharf.

Monitoring Methods (page 16-17). We recommend that start and end points of all survey stations be recorded using GPS instruments.

Coral (page 17). Nearly 400 species scleractinians (hard corals) have been identified from the Mariana Islands (Randall 2003). This number vastly exceeds those of both Hawaii and Florida. Many of these species are morphological similar and difficult to identify without a microscope. Depending on the desired taxonomic resolution, we are concerned that using photographs will be ineffective for collecting biological data. We recommend that these data collection methods be clarified to reflect the difficulties associated with coral identification from photographs.

Coral, 4. Functional and Cellular responses to sedimentation stress (page 19). The proposed technique is intriguing and we commend its inclusion. Because only two species of coral can be selected for this analysis, we recommended more information on the selection criteria used to determine which two species would be included in the analysis.

Algae (page 20). We commend the inclusion of a seasonal component in this work. However, we are concerned that the stated objective to separate seasonal changes and project related impacts will not be successful. Without an established pre-construction baseline at the site and/or a relevant reference location, these two factors cannot be easily separated. Under the current proposed plan, insufficient seasonally relevant pre-construction data will be collected and it is unclear if an appropriate reference site will be surveyed. We recommend that the objective and/or the project design of this section be clarified so that they are consistent and achievable.

Invertebrates, 2. Percent cover and species diversity of sessile taxa (page 21). We recommend collecting quantitative data (*i.e.*, density per square meter) for key functional groups (*e.g.*, echinoderms, mollusks, crustaceans), in addition to species diversity data.

Invertebrates, 3. Abundance and species diversity of motile taxa (page 21). Inclusion of night time surveys is necessary to obtain the stated data, and we commend NOAA-CRED for proposing surveys of this nature, which are often difficult to conduct. It is unclear, however, how these nocturnal surveys will be conducted relative to daytime surveys. It is unclear, for example, if the same transect lines will be surveyed and how this will be handled logistically (*e.g.*, will transects be left in the water, will only permanent sites be surveyed, etc.). We recommend that additional detail, ideally via an SOP, be provided on the logistics of how nocturnal and diurnal surveys will be conducted and integrated.

Microbial Communities, 1. Assessment of diversity and ecological dynamics in target habitats (page 22). No references have been provided to support statements about the usefulness of the proposed molecular approaches. We recommend that literature be cited where appropriate.

Microbial Communities, 2. Sampling Design (page 22). It is unclear what is meant by “other monitoring studies” and by “less impacted reef sites.” Nearly all of Apra Harbor has been repeatedly impacted by dredging and construction for the past 50 years, and it may be difficult or impossible to locate sites within the harbor that are significantly “less impacted reef sites.” We recommend that the terms “other monitoring studies” and “less impacted reef sites” be clarified and the discussion in this section adjusted as appropriate.

Environmental Monitoring Methods (page 24). We recommend that additional information on the sediment trap arrays be provided; specifically are the trap arrays passive tube collectors that integrate over time or are they automated collectors that will sample discrete, pre-defined time periods, allowing for a greater temporal resolution.

Environmental Monitoring Methods (page 24). We recommend that NOAA-CRED investigate adopting the USGS method that photographs plates affixed to the bottom to assess

sediment accumulation as part of its sediment monitoring protocol. This method employs photographing a white plate with a grid (which makes estimating percent cover of sediment easier) with a camera attached to an automated timer. Drs. Michael Fields or Curt Storlazzi of the USGS should be contacted for additional details.

Environmental Monitoring Methods (page 24-29). Without the accompanying figures, it is difficult to assess this portion of the monitoring plan. The text refers to figures for sample number and the spatial orientation of sampling sites. We understand the need to delete some figures to facilitate electronic mailing, but we recommend that future drafts of this document either contain or be accompanied by a second mailing containing all figures.

Oakley, K.L., L.P. Thomas, and S.G. Fancy (2003). Guidelines for long-term monitoring protocols. *Wildlife Society Bulletin*, 31 (4): 1000-1003.

Paulay, G. 2003. Marine biodiversity of Guam and the Marianas: overview. *Micronesica* 35-36: 3-25

Randall, R. H. 2003. An annotated checklist of hydrozoan and scleractinian corals collected from Guam and other Mariana Islands. *Micronesica* 35-36: 121-37.

Appendix D: Workshop Summary

Guam/CNMI Marine Natural Resources Monitoring Protocols Workshop
Imin Conference Center, East-West Center, Honolulu, Hawaii
Dec. 7-10, 2007

Workshop Summary

(Reformatted in outline form from PowerPoint Presentation)

- A. Kilo Wharf Monitoring Design Parameters
 - 1. Statistically sound and cost effective design using stratified random sampling
 - 2. Monitoring period -- 1 ½ to 3+ years (pre-construction, construction, and post).
 - 3. Full range of hard-bottom habitats in Outer Apra Harbor
 - 4. Ecosystem surveys with a focus on benthic communities, coral health, fish, and species of concern (including turtles)
 - 5. Evaluate Essential Fish Habitat and Habitats of Particular Concern
 - 6. Methods shall be consistent with existing CRED methods around Pacific
 - 7. Water Quality
 - a) Monitor sediment plume dynamics
 - b) Compare and refine plume models
 - c) Ability to distinguish between turbidity associated with project vs. other sources
 - d) Nutrients to monitor ecosystem dynamic changes
 - 8. Sediment deposition
 - 9. Environmental parameters
 - a) Weather: wind, rain
 - b) Circulation: currents, waves, tides
 - c) Temperature, salinity

- B. Benthic Monitoring Methods
 - 1. Includes corals, algae and other invertebrates
 - 2. Mix of random and fixed sites with permanent transects. Periodic monitoring of specific sites and taxa.
 - 3. Frequent video transects for permanent record
 - 4. Relative abundance, including percent cover
 - a) Photo-quadrat for algae
 - b) Line Intercept for corals and other sessile inverts.
 - 5. Measure biodiversity including use of ARMS for cryptic fauna
 - 6. Survey times as appropriate
 - a) Possible night surveys for invertebrates
 - b) Make sure access to survey sites is assured
 - 7. Size-class distribution method
 - a) Main method for most coral species and selected invertebrates

- b) Difficult to make accurate estimate of coral colony size for *Porites rus*. Therefore use percent cover rather than size class measurements
 - 8. Assess coral health
 - a) Look at individual colonies
 - b) Disease
 - c) Evaluate coral condition
 - d) Photographic records
 - 9. Histology to assess sedimentation stress
 - 10. Assess reproductive capacity and fecundity preceding spawning season
- C. Fish and Turtle Monitoring Methods
 - 1. Monitor all species, all sizes
 - 2. Use Stationary Point Count (SPC) method
 - 3. Turtle surveys may be complemented by towed surveys
- D. Environmental Monitoring Methods
 - 1. CTD Profiles
 - a) Salinity
 - b) Temperature
 - c) Turbidity
 - 2. Water Sampling
 - a) Nutrients
 - b) Chlorophyll
 - c) total suspended solids
 - 3. ADCPs
 - a) Currents, waves and backscatter
 - 4. Surface Radar
 - 5. Ecological Acoustic Recorder
 - a) Ambient noise
 - 6. Turbidity Sensors / Sediment Traps
 - a) Sediment deposition rates
 - 7. Terrestrial Meteorological Station
 - a) Wind
 - b) Precipitation
 - c) Relative Humidity
 - d) Video Acquisition of construction site
- E. Survey Design
 - 1. Refinement of survey domain map
 - a) Existing layers of depth and habitat zones
 - b) Access to LIDAR data, if possible
 - c) Validate habitat zones with towed diver surveys
 - d) Evaluate plume extent to adjust potential impact zones
 - 2. Sampling Domain
 - a) Depths less than 30 m

- b) Everything except unconsolidated
- 3. Sampling Domain Size
 - a) Outer Apra Harbor = 670 acres
 - b) Outer Apra Harbor excluding Sasa Bay = 360 acres
 - c) Orote Peninsula = 130 acres
 - d) Impact Zone (extreme plume) = 20 acres
- 4. Base Sampling Units
 - a) Corals 10 x 20 m
 - b) Fish 20 x 50 m
- 5. Pilot Survey Sampling Stations
 - a) Outer Apra Harbor
 - (1) Corals – 135 at 1%
 - (2) Fish – 80 at 3%
 - b) Outer Apra Harbor less Sasa Bay
 - (1) Corals – 73 at 1%
 - (2) Fish – 44 at 3%
 - c) Orote Peninsula Including Impact Zone
 - (1) Corals – 45 covering 9 strata
 - (2) Fish – 45 covering 9 strata
- 6. Frequency
 - a) Pre-construction baseline
 - (1) At least one
 - (2) Two if possible
 - b) Construction Phase Monitoring
 - (1) Benthic every 1-2 months
 - (2) Fish every 3 months
 - c) Oceanography
 - (1) Subweekly to quarterly

F. Data Management and Access

1. Use existing CRED database structures for all disciplines
2. Project website for data access (password protected)
3. Establish short timelines for observational data turnaround
4. Video or still photographic records for reference (not all would be processed)

G. Meetings and Reporting

1. Data and results available for all scientists and stakeholders via websites
2. Scientific meetings associated with survey periods
3. Regular briefings at 6-8 week intervals in Guam and Honolulu, alternately
4. May not be possible to do detailed pre-construction report due to short time-frame
5. Major report after construction period
6. Six month to one year updates post-construction

