LNG CARRIER *MATTHEW* PRELIMINARY SITE ASSESSMENT PLAN AND EMERGENCY RESTORATION PLAN

Photo credit: Sea Ventures, Inc.

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March 3, 2009

Introduction

The LNG carrier Matthew, a 920 foot tank vessel was reported to strike bottom on December 15, 2009 on the southern coast of Puerto Rico near the entrance to Guayanilla Bay at approximately 18° 2.781'N, 65° 48.268'W. The natural resource Trustees from the National Oceanic and Atmospheric Administration (NOAA) and the Puerto Rico Department of Natural and Environmental Resources (PRDNER) reported injury to benthic resources bounded by the following 4 locations (**Figure 1**):

1. 17 57.688 N, 66 45.442 W
2. 17 57.706 N, 66 45.461 W
3. 17 57.725 N, 66 45.410 W
4. 17 57.742 N, 66 45.425 W

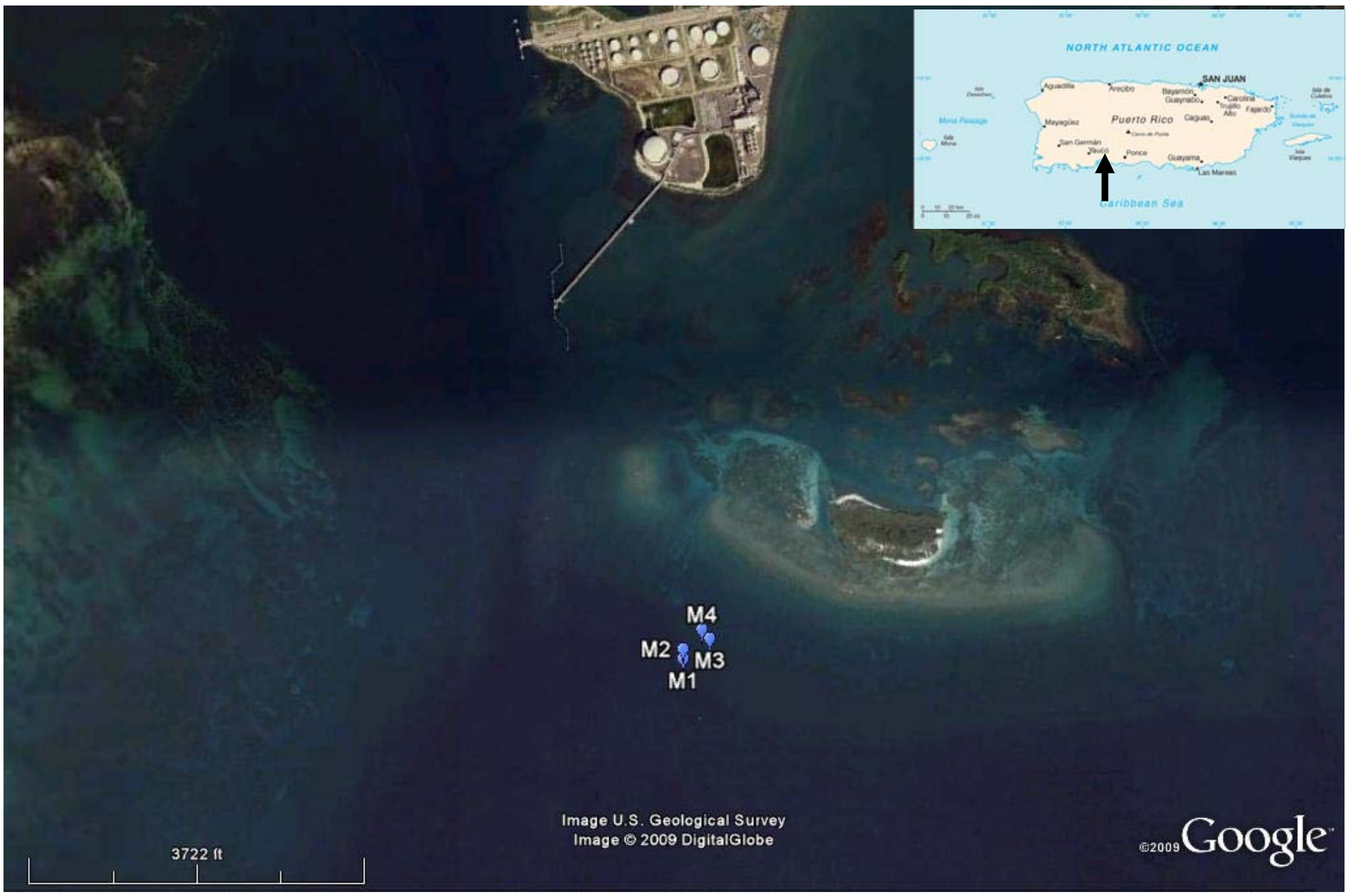

Figure 1. Reported grounding position.

Polaris Applied Sciences, Incorporated (Polaris) was retained to work cooperatively with natural resource Trustees from NOAA and the PRDNER to map the alleged injury areas, assess the degree of injury and develop an emergency restoration plan with CSA International, Inc. and Sea Ventures, Inc. This report presents preliminary injury information from site surveys conducted on December 18 through 20, 2009. This document also presents comprehensive emergency restoration recommendations for the affected area that are meant to address primary restoration to the extent practicable.

Pre-Assessment Surveys

A visual assessment with personnel from NOAA and PRDNER was conducted December 16 and 17, 2009. Work began to triage injured corals on December 17, 2009. The area was mapped and qualitative data were collected on December 18, 2009. Triage was completed on December 23, 2009 and an Emergency Restoration/Primary Restoration Plan was developed and is presented herein.

The December 16-18, 2009 surveys were conducted to gather qualitative data of biota presence, injury nature and extent, and general conditions of the surrounding to be used in preparation of an emergency restoration plan. The recommended emergency restoration plan is comprehensive and, if successful, will likely satisfy all primary restoration requirements at the site provided the overall site situation and stability do not change by unforeseeable acts. A paint sample was also collected from the seafloor under chain of custody for archival purposes.

Coral impact boundary assessments were performed using AquaMap™, a SONAR (Sound Navigation and Ranging) based survey system. The AquaMap™ system consists of three baseline transducers and a diver station. The three baseline transducers are stationary units and are moored to the bottom of the ocean floor around the dive site. The diver station is a mobile transducer and is moved around the dive site to areas of interest. The diver station transmits a brief sonar signal (or sonar code), which travels to all three baseline stations. Upon receipt of a signal, each baseline station transmits a reply back to the diver station. The diver station is then able to compute its distance from each of the baseline stations. A relative coordinate system is developed and precise positions (about 0.15 m) can be recorded within the dive site. A buoy was attached to one of the baseline stations and was geo-referenced with a Global Positioning System. This position, along with a bearing to another baseline stations, was used to produce a chart of the estimated injury. Photographs and video of each survey was recorded to document the outer edges. These data are being processed to produce an accurate map of the site and features.

Reference transect data will be collected such that they can be compared to the injury area to estimate the loss of hard and soft coral organisms. Reference sites will be chosen in the field and agreed to by both the Trustees and Responsible Party (RP) on-site representatives. The long diameter of encrusting and boulder hard corals will be recorded along with the maximum height of soft corals and branching hard corals in areas immediately adjacent to the injury. The meter-stick is moved along the tape until the ten meter section has been recorded. Other observations of sponges and encrusting zooanthids will also be recorded. The reference transects will be stratified to represent areas immediately adjacent the injury and in the same depth zone. These data will be analyzed and shared with all parties. These data will be used to estimate service loss in addition to structure.

Affected Area

The affected reef area is a hard bottom of underlying limestone formed by reef building organisms in the past and currently supports hard and soft corals as well as numerous other benthic invertebrates (**Figure 2**). The bathymetry varies from 24 feet near the bow to 38 feet with scattered deeper sand, coral and rubble depressions of greater depth at the southern end, where the water quickly drops to several hundred feet beyond the injury area. The reef may be described as a low-lying spur and groove formation with reef spurs projecting 2-6 feet above sand grooves (channels).

The hard bottom seafloor is estimated to have 25% to 35% cover of soft and hard corals among a variety of other benthic organisms (**Figure 2**). Reference data will be analyzed to provide more quantitative estimates of biota during the assessment. The hard corals are dominated by mountainous star coral (*Montastrea annularis*) cavernous star coral (*Montastrea cavernosa*), starlet coral (*Siderastrea* spp), smooth brain coral (*Diploria strigosa*), mustard hill coral (*Porites astreoides*), finger coral (*Porites* sp) and pillar coral (*Dendrogyra cylindricus*). Branching calcareous hydroids (*Millepora spp*) and other subdominant hard corals such as butterprint brain coral (*Meandrina* sp), fungus coral (*Mycetophyllia* sp), grooved brain coral (*Colpolphyllia natans*), elliptical star coral (*Dichocoenia stokesii*), starlet coral (*Isophyllia* sp) and sparse colonies of staghorn coral (*Acropora cervicornis*) a federally threatened species were observed in a few locations. There are also numerous branching soft corals at the site including the sea fan (*Gorgonia flabellum*), and several species of sea rods and sea plumes (*Pseudopterogorgia* sp, *Pterogorgia* sp, *Plexaura* sp, *Plexaurella* sp, *Muricea* sp, *Eunicia* sp).

Biota cover in addition to hard and soft corals includes encrusting and branching sponges and coralline and crustose algae. Numerous large barrel sponges (*Xestospongia muta*) among others are scattered throughout the coral community. Benthic invertebrates were also observed and include sea cucumbers, mollusks, brittle stars and small crustaceans.

Figure 2. Unaffected hard bottom area showing the community composition of soft corals and hard corals (upper left). Reef groove (upper right). Large *Montastrea annularis* colony (lower left), and finger coral *(Porites* sp) growing out of a barrel sponge (*Xestospongia muta*).

Preliminary Results

GPS boundary positions indicate the site lies within approximately 4,000 square meters (**Figure 3**). There are also isolated areas of injured reef on coral outcroppings to the west of the main.

The injured site is variable and includes flat scarring, toppled, broken and crushed rock and corals, scattered rubble, burial, broken or slumped ledge outcrops as well as substantial structural fracturing in the underlying substrata (**Figure 4**). There is also bottom paint in chips and embedded into cracks and crevices. Although there are no large deposits of paint, there is considerable large rubble created by crushing. There are no large berms of rubble though many of the grooves were infilled with rubble. Nonetheless, the large-sized rubble at the site is substantial and will likely constitute the majority of effort to stabilize and re-create structure during emergency/primary restoration. It appears the majority of injury occurred within one continuous area with some additional isolated injury along the periphery (primarily to the West and Southwest) as depicted in a schematic of the injury features (**Figure 5**). The areas of isolated injury, mostly of less than 5 square meters each, comprise an additional area of approximately 100-200 square meters (**Figure 6**). The main flattened area (100% loss of biota and structure) has been initially mapped by the RP representatives as approximately 1,325 square meters. Areas not flattened have been scarred, fractured, buried or otherwise partly affected.

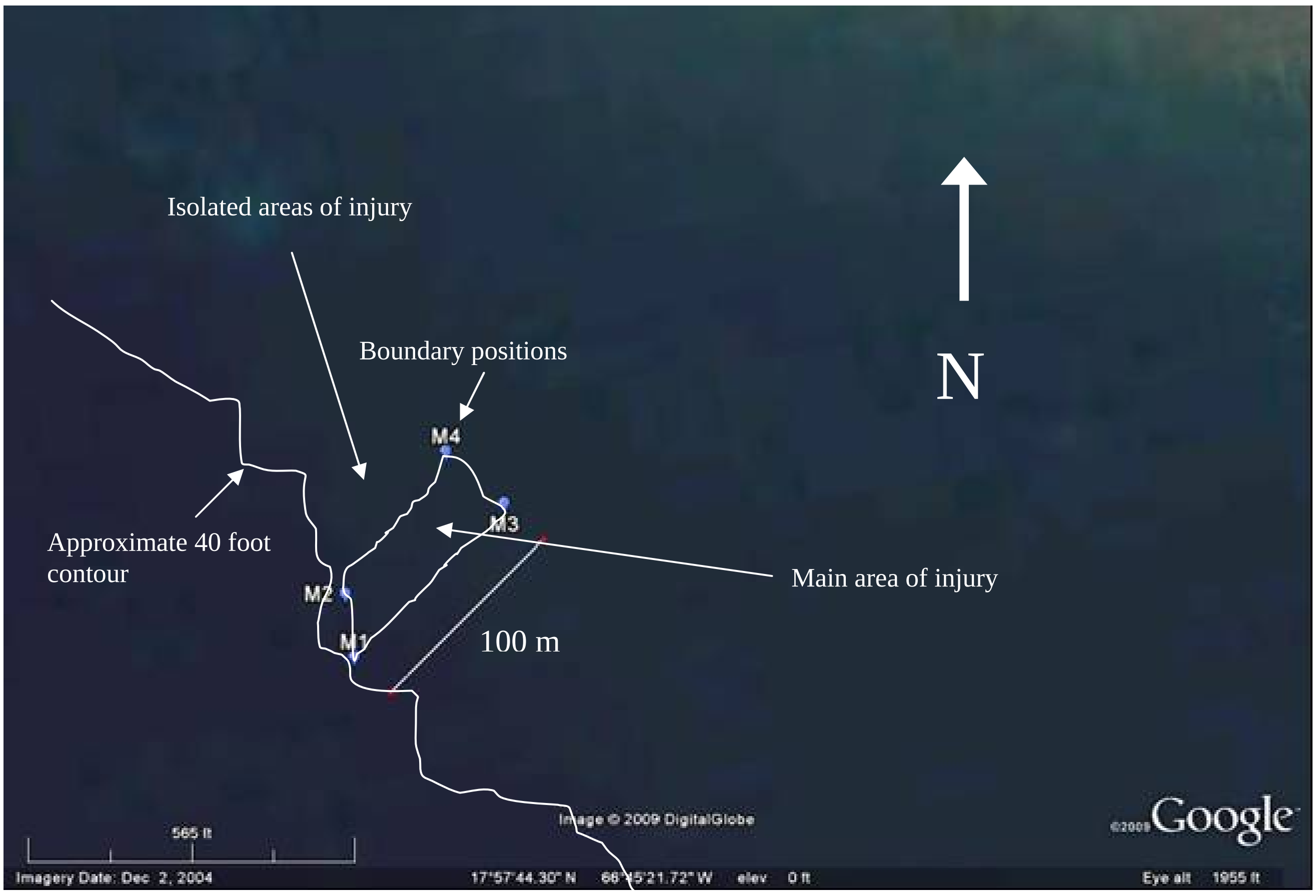

Figure 3. Boundary positions of the injury site.

Figure 4. Clockwise from upper left; 1) Large pieces of fractured rubble, 2 Large broken *Montastrea annularis* colony, 3) Flattened area with fine sediment, 4) fractured reef substrate, 5) Burial in reef groove with small rubble, and 6) Isolated injury area to the west of the main injury site.

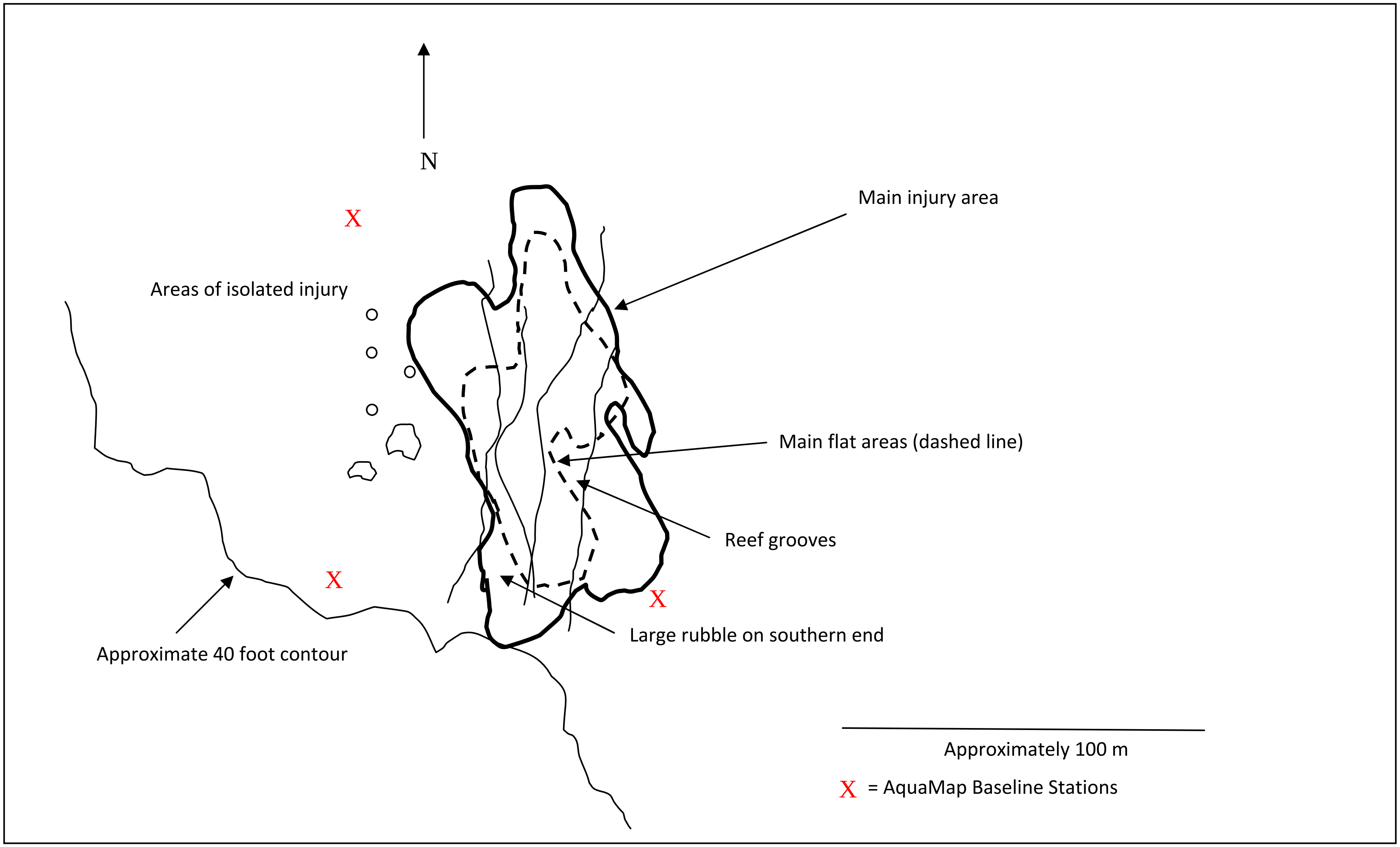

Figure 5. Schematic of injury features. Diagram not to scale and for planning purposes only. AquaMap will create an accurate diagram of the area for restoration planning purposes.

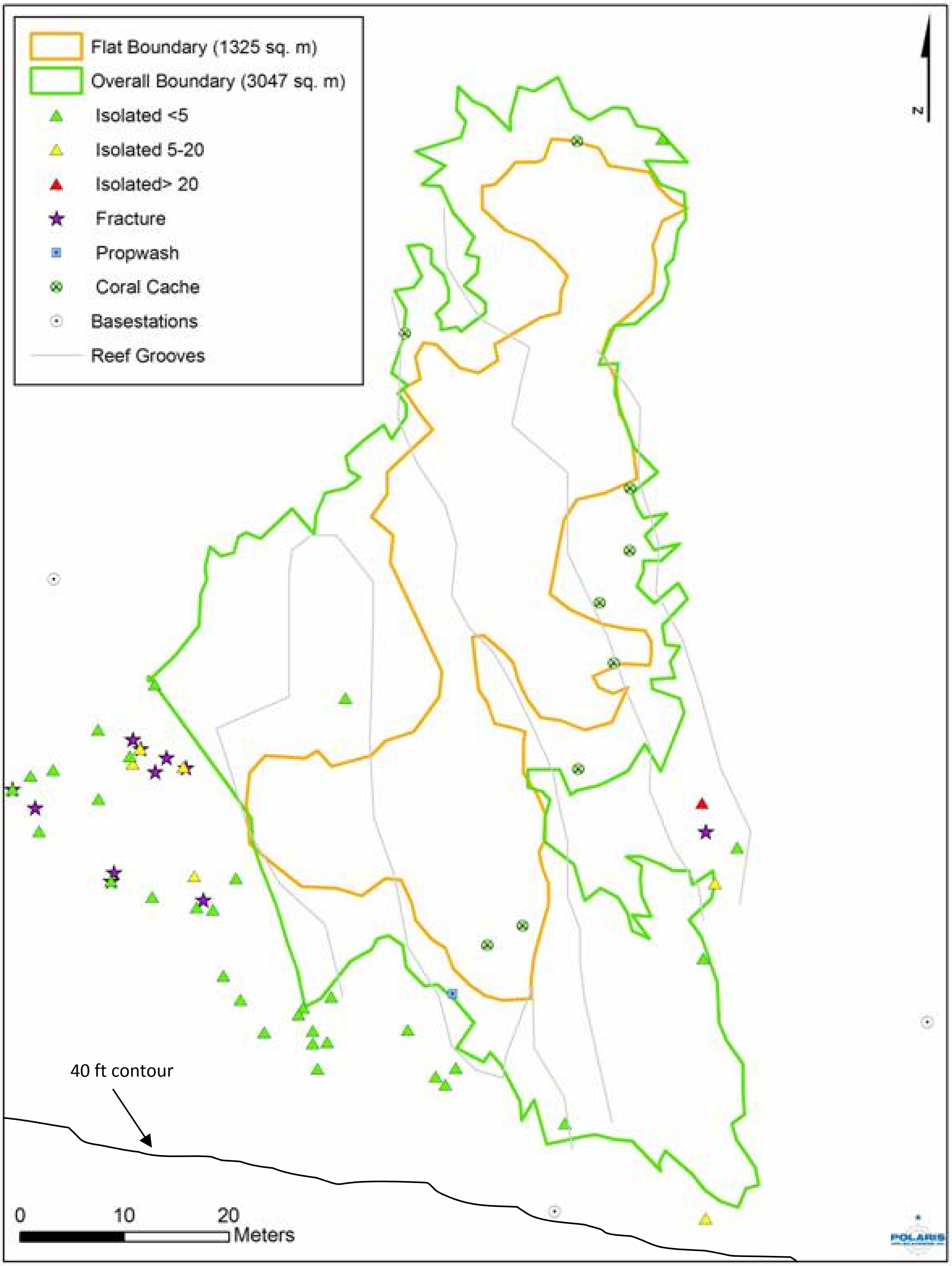

Figure 6. AquaMap of injury areas.

Emergency Restoration

In the aftermath of incidents such as the grounding of the LNG Carrier *Matthew*, there are two main phases of restoration as part of Natural Resource Damage Assessment under the Commonwealth of Puerto Rico Law for the Protection, Conservation and Management of Puerto Rico Coastal Reefs, (also known as Law #147) and the Oil Pollution Act of 1990 (OPA): primary and compensatory restoration. Primary restoration includes actions necessary to help the site recover to its former condition. Compensatory restoration includes actions to compensate for lost ecological services until the site recovers to its former condition. Emergency restoration is a form of primary restoration often undertaken in the immediate aftermath of an incident to minimize or prevent ongoing losses and harm to the reef. It is our goal to present and implement a comprehensive emergency restoration strategy. If successful, this strategy is likely to eliminate the need for additional primary restoration at the site. Compensatory restoration will subsequently be developed to address outstanding service losses.

The objectives of the Emergency Restoration are as follows:

1. Stabilize large rubble to the maximum extent possible while minimizing the use of foreign materials such as cement, iron and non-native rock.
2. Re-create the lost structure (rugosity).
3. Stabilize reef fractures.
4. Rescue and re-attach as much live biota as practicable.

The following are specifications for emergency restoration. These actions are proposed to prevent ongoing harm to the reef habitat, in particular to prevent ongoing loss of established corals. These actions are also proposed to reduce the magnitude and duration of injury at the site and to promote natural recovery.

<u>Emergency Restoration Tasks</u>

1. Rescuing detached hard and soft corals.

   Collect and store as many re-attachable coral fragments as can be located (**Figure 7**). This is defined as corals or coral tissue of a size that can be easily manipulated by divers and is in good condition. This is generally a size of greater than 10 centimeters. Smaller corals will be re-attached if in good condition. Small fragments in less than good condition generally have a very low survival rate. Good condition refers to dislodged coral with a large portion of the tissue intact, and sponges and soft corals dislodged with basal structures intact.

   Status: Complete December 22, 2009

Figure7. Small and large corals temporarily re-located on top of flattened areas for pending restoration.

2. Site Mapping, Restoration Site Designation, and Restoration.

Initial site mapping utilizing the Aquamap system was completed in December.

The Trustees have made arrangements with partners at the University of Puerto Rico and University of Miami to have an Autonomous Underwater Vehicle (AUV) collect multi-beam bathymetry of the site, as well as to collect still photographs that will be mosaiced into a single overall site image. This data is being collected the week of February 22nd and will be available within two weeks of collection.

The impact site will be divided into manageable working areas or sub-units which will be mapped and identifiable on the bottom. At the initiation of restoration operations, the conditions of each unit will be described and photos will be captured. For each unit, a plan of action for restoration work and a prioritization scheme will be jointly developed by RP/Trustee Representatives. The status of activities in each work unit should be updated daily and included in a master tracking and unit completion checklist.

Status: Underway

3. Remove Bottom Paint.

   Remove and dispose of gross bottom paint contamination. Manually remove large deposits by hand with scraping tools. Small paint fleck accumulations will be either removed by a modified SCUBA Epibenthic Sampler (small handheld suction device with collection bag) or will be capped under cement and rubble. Opportunistic removal of bottom paint will occur during all activities.

   Status: Not initiated

   Performance: Paint is variable in its form and difficulty in extraction. It exists as dust, fragments, chips and clumps and is found in the open, in crevices, and wedged intermittently in skeletal coral polyps and is not easily definable by quantitative means. Remaining paint residues will be removed to the extent practicable, as long as the return on the effort produces a waste stream.

4. Prepare Individual Sites for Restoration

   In specific restoration areas where structure will be re-established, substantial accumulations of fine sediment will be cleared to enable a better cement purchase as necessary. To the extent possible, re-attachment areas will be selected in places where the cement has the best opportunity to hold. Specifically, this will be accomplished using the following methodology:

   1. The site will be divided into manageable units that are mapped and easily delineated on the bottom.
   2. Prior to placement or reattachment of any reef material and/or coral within the restoration unit the following activities must take place:
      a. The majority of re-attachable (> 10cm) reef rubble and all coral within the zone shall be temporary placed in an adjacent area, or otherwise temporarily moved, so that the zone can be adequately assessed for loose material and necessary material removal can occur.
      b. The bulk of loose small material in the reattachment area shall be removed by hand or mechanically.
         i. Material should be disposed of in an area approved by the Trustees
         ii. The RP's contractors may select and implement the technique for rubble removal that they think is best; however, techniques that result in the re-dispersal of small material into adjacent reef habitat or cached materials will not be permitted. On-site Trustee representatives may shut down operations if removal technique is causing excess turbidity and/or possible reef impacts.

iii. The removal of material is likely to expose more complex habitat structure and rugosity that was buried following the grounding. This structure may allow the RP to minimize the amount of augmentation material that needs to be brought into the site.

c. The majority of the work unit area must have presence of firm underlying substrata prior to the initiation of cementation and reattachment.
   i. The goal of this requirement is to ensure that reattached material has a lasting and secure attachment.
   ii. If unstable sections of the site are found, and it is not practical to achieve the required amount of hard substrate, some or all of the following actions may be necessary:
      1. Secure any eroding edges.
      2. Removal of surface layer fine material.
      3. Restoration structures that are placed on unstable substrata must be of a sufficient weight—minimum of two tons (~10 sq. m +)—to ensure that they will not roll or flip during storms even if further site erosion takes place and they are unable to be tied into hard substrate. These structures should be built around a minimum of one large (> 1m) piece of limestone to further enhance stability or sufficiently cemented together to encompass one large piece of limestone/cement conglomerate.

d. Trustee approval of site preparation within each restoration zone will occur prior to initiating the restoration of structure.

Status: Not initiated

5. Repair large underlying reef fractures.

Within each restoration zone, any large fractures will be identified. If determined appropriate by on-site personal, some of these large fractures may have to be grouted with cement and rebar. In some situations, it may be appropriate to leave the fracture in place or to only utilize a minimum amount of cement, if the reef fracture is not likely in jeopardy of expanding. There is no performance in this task, although monitoring for ancillary injury addresses the risk.

Status: Not initiated.

6. Restore Site Structure and Rugosity.

Multiple enhancement structures with areal coverage ranging from 2 to 20 m^2, with weights ranging from .5 to 10 tons will be built to restore site rugosity, improve coral recruitment and recovery, and minimize the chance of future site expansion and injury. These structures will provide substrate heterogeneity that mimics natural conditions and facilitates the natural processes that shape the nearby reef system. Proper application of structural enhancement will help restore and promote structural complexity of the habitat and subsequently restore associated biological assemblages. This structural enhancement could include use of both material generated from the grounding and augmentation material brought in from offsite.

Natural substrates are preferred and include on-site rubble/boulders/framework within and adjacent to the impact area. Loose limestone rubble from the site with limited attached soft or hard coral growth will be gathered and used to re-establish the general site topography and stability and to reduce the potential for additional injury (**Figure 8**). Large pieces of limestone rubble (> ~10 cm) and occasionally a meter across will be used to enhance site complexity in the flattened areas. Concentrations of smaller (<10 cm) dead coral and limestone rubble will be incorporated into reef structures when possible or removed from the site. In instances where reef grooves have been buried or partially filled by rubble, this material will be removed from the groove and incorporated into the structure or removed from the site.

Because during the grounding some structure was completely crushed, augmentation with quarried limestone boulders may also be necessary. Limestone boulders will be locally acquired in Puerto Rico. The majority of boulders will have an estimated diameter of > 0.5 m (1.5 ft) and a correlative weight that can be safely maneuvered by a single diver with a lift bag.

Areas of re-attachment will be the main flat areas (**Figure 4**). Concrete placement will avoid covering existing live biota. The structures will be arranged to present a variety of sizes and shapes (**Figure 9**) with special consideration of the following:

- Where practical, structures should be close to the existing edges at some point since it will help decrease chances of site erosion and/or expansion and may aid recruitment and recovery (edge effect).
- In areas with sufficient hard structure exposed, a minimum structure size of ~2 square meters will ensure structures are resistant to movement in swells. Increased sheer force resistance will be accomplished by placing cut-nails or rebar into the subsurface prior to cementation.
- In areas of the site where significant structural damage has occurred and it is not feasible or possible to expose sufficient hard stable substrate, the minimum structure size will be increased to a minimum of ~14 square meters and a minimum weight of 2 tons. These structures should be built around a minimum of one large (> 1m) piece of limestone to further enhance stability. The larger structures will ensure that even if further site erosion takes place, the structures will have sufficient weight to remain on their own, absent being structurally tied to the bottom. Increased sheer force resistance will be accomplished by driving rebar to resistance into the subsurface prior to cementation.
- Structures built should attempt to maximize habitat complexity by varying vertical reef, creating overhangs, and insuring areas of refuge.

Material used to restore structure at the site will be secured with Marine Portland (Type II if available) cement with a 50% mix of clean silica sand. The concrete will be mixed in a cement mixer or drill on the vessel to a thick consistency to avoid dissolution and sedimentation underwater. While small material can and should be placed directly into cement, larger material will require that rebar is driven into a void space and cement is poured between boulders. When building the foundation of larger limestone structures, divers will work to ensure, to the maximum extent practical, that cement is poured prior to directly adjacent concrete becoming dry. If it is not practical to pour all cement within a structure's foundation at the same time, horizontal rebar shall be placed sticking out of the poured cement into the area remaining to be poured.

Status: Incomplete

Performance

In order to evaluate the successful restoration of reef structure following emergency restoration, data will be collected to compare reef structure in the restored impact with reference areas adjacent to the impacted site. Data collection will consist of a minimum of 5 – 10 transects in both the restored impact area and adjacent reference areas. Transects of approximately 50m will be used to record traditional rugosity measurements (chain method) as well as the highest structure and lowest depth from the seafloor within a belt transect as described below. It is expected that the data will be collected within each work unit as emergency restoration work is nearing completion within a work unit or comprehensively over the entire site near the completion of all site work.

Replicate rugosity measurements for each transect will be recorded at three random starting locations along each 50 meter transect using a 10 meter chain by laying the chain along the natural contours of the seafloor. The three replicates will be averaged and then combined with the other transects for an overall average rugosity. Transect locations will follow depth contours and not include any reef sand depressions as they did not occur in the impacted area. Locations will be chosen jointly by the Trustees and RP. Average structure differential or distance between the lowest and highest part of seafloor (including stony corals) will also be recorded along the transect in the following manner. The transect will be broken up into 5-meter increments. The belt transect will consist of 1 m on either side of the transect tape, thereby creating ten 2m x 5m blocks along the length of the transect. Measurements will be taken in each increment along the transect. The target values for rugosity and structure differential will be established after the data for reference areas has been established. The goal of the restoration is to establish structure with rugosity and structure differentials similar to that of the reference. Target rugosity and structure differentials are likely to be established within 10% - 20% of the average reference value.

While emergency restoration work is ongoing, preliminary rugosity and structure differential measurements will be taken at the site to determine if the completed work is likely to meet target rugosity and structure differential targets. These measurements can be done on a work area by work area basis or comprehensively over the entire site. If measurements are to be taken within a work unit, transect lengths can be adjusted as appropriate for the size of the work area. If targets are unlikely to be met with the current amount of material and both parties agree that additional limerock is necessary, the additional material will be brought in and incorporated into the emergency restoration. At the completion of the placement of on-site rubble and limerock, the Trustees and RP will perform a final site inspection and collect final transect data to ensure that the emergency restoration has met the established rugosity and structural differential targets, demonstrating the sufficiency of the emergency restoration work in reestablishing reef structure.

To evaluate the continued success of the emergency restoration actions on restoring site structure, follow-up monitoring will occur. Structures are expected to remain intact and corrective action will be necessary if substantial loss of reattached material (approximately 10% or more) occurs or if dislodged or failing structures are likely to cause ancillary damage to the restored area or to adjacent reef.

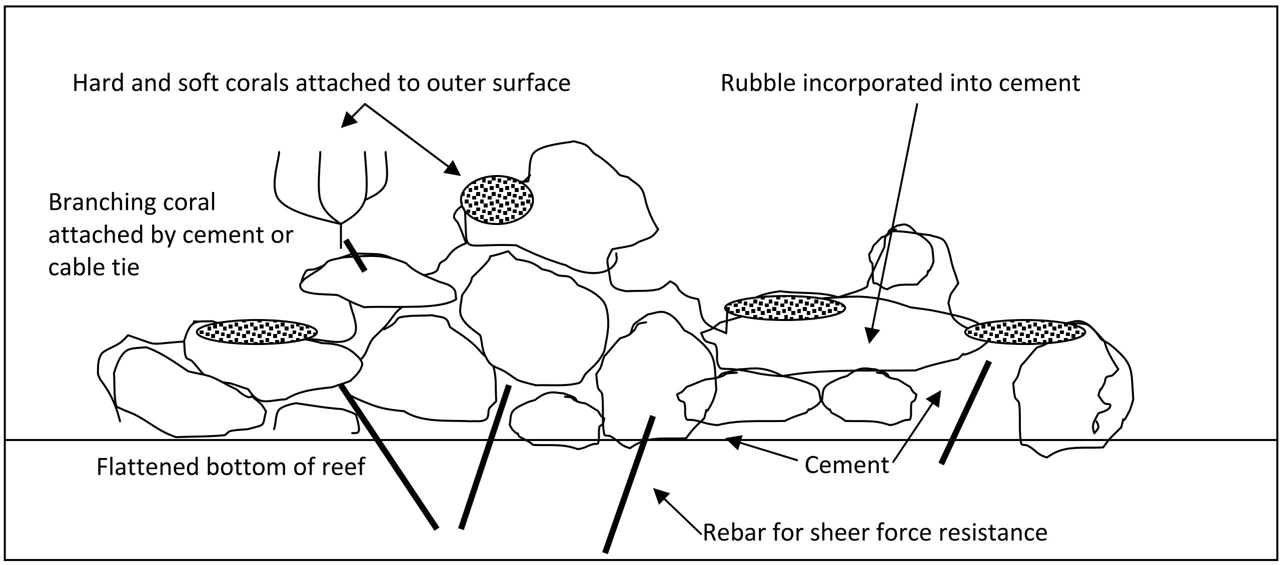

Figure 8. Schematic of rubble/concrete and coral structure.

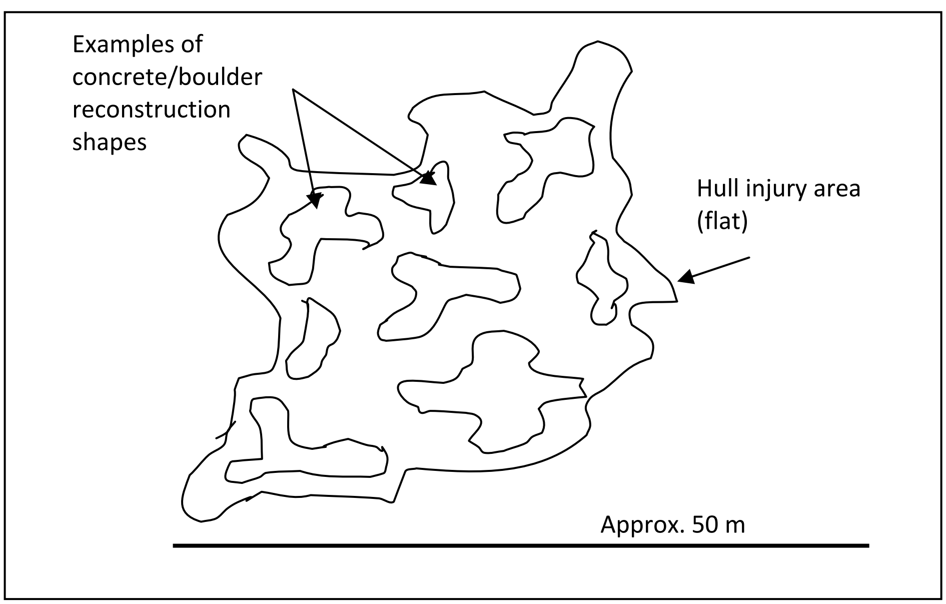

Figure 9. Example schematic overview of proposed primary restoration area.

7. Reattach (i.e., cement to substratum) corals following site stabilization and re-attachment of structural features discussed below.

   Biota will be re-attached to the bottom in areas that are stable and in such a way that re-attachment does not disturb other biota. For live corals, we propose the majority of re-attachment within the main scar area following stabilization of other rubble and creation of structural relief. Corals will be re-attached in groupings on structures but sufficiently apart from one another to allow growth and minimize competition.

   Surface preparation will include "cleaning" algae from the limestone substratum and underside of object being re-attached such that cement re-attachment will not fail (**Figure 10**). Wire brushes could be used to clear the surface of algae. All reef surfaces for re-attachment will include previously injured areas with clear and stable surfaces

   Corals and other biota will be re-attached with Marine Portland (Type II if available) cement with a 50% mix of clean silica sand. The cement will be mixed on the vessel to a thick consistency to avoid dissolution and sedimentation underwater. Cement will be placed in 5-gallon buckets with lids and lowered carefully to the bottom directly over the work site. Smaller corals may be also attached utilizing a two part underwater epoxy. No adhesive material other than the minimum amount of cement or epoxy to secure a fast position will be deposited on-site.

   Performance: A subset of re-attached corals (approximately 10%) will be marked for monitoring in consultation with the trustees.

   Status: Not Initiated

Figure 10. 1) Collecting corals. 2) Preparing the surface. 3) Pouring cement. 4) Re-attached group of corals.

8. Minimizing additional harm to the habitat

All work will be done in a manner to minimize collateral impacts to the surviving biota and habitat structure. This includes care in placement of anchors or mooring points, vessel operations, diver operations, and placement of materials during removal and disposal. Trustee supervisors may change any activities that they determine to be posing unacceptable risks to the environment in the operations area.

In particular, within one-week of beginning site operations, temporary mooring buoys will be installed in the vicinity of the grounding site to secure work vessels during restoration operations and significantly reduce the potential for further habitat impact due to vessel anchor deployment and recovery. Vessel moorings will be anchored to the seafloor at selected locations at the grounding site that are hard bottom substrate, relatively devoid of epibiota, and with spatial distribution around the grounding site to facilitate versatile positioning of work vessel(s). Vessel moorings will be marked with surface buoys.

9. Trustee/Biologist supervision

   Due to the complexity of the work, the size of the site, and the number of field decision points expected, the Trustees will have a representative of NOAA, PRDNER or Trustee Contract personnel onboard during the majority of restoration activities. Trustee personnel will augment the contractor supplied work crew and, when appropriate, work as part of the diving rotation.

   Field changes and decisions as authorized in this plan may be made in the field with consultation with the RP Representative and the Trustee Project Manager as necessary. Decisions that can not be mutually resolved in the field or changes to plan as approved will be discussed between the RP representatives and the Trustee Project Manager before engaging contractors to conduct the changes. However, the Trustees may require the RP's contractor to stop a particular activity at any time until agreement can be reached. Agreed upon changes will be incorporated into the work plan with contractors in an expeditious manner. Possible changes that are not discussed in this plan will be first discussed and approved by the RPs and Trustees' designated representatives.

Post-Restoration Credit and Assessment

The assessment of service loss and gains will be based on the assumption that both structure and biota provide similar levels of the overall reef service. Measures of structural relief performance will be completed as discussed above in item 6 under Emergency Restoration Tasks. Provided the goal of structure (i.e., impact area is returned to levels similar to reference rugosity) is met by the Emergency Restoration, the injury to the structure component of overall reef service will be considered fully restored. The biota component of overall reef service will be estimated by using reference transect data from mutually selected (i.e., on-site Trustee and RP representatives) adjacent areas to estimate the abundance and size distribution of biota that were impacted. After taking into account survival of reattached biota in the injury area, the total surviving reattached corals will be subtracted from the estimates of total impacted corals to quantify the remaining loss of biological resources. Overall reef service recovery rates will be determined at a later date and will be based on the estimated return of the site to similar biota cover based on growth estimates and other relevant data.

Schedule

Initiate Coral Triage – Complete, December 20, 2009
Establish Restoration Units and Develop Unit Plans - February/March 2010
Remove Bottom Paint – Initiate February/March 2010
Prepare Individual Sites for Restoration – March 2010
Clear large rubble and place on flat areas –Initiate March 2010
Cement coral and rubble – March-May 2010
Re-Attach Coral –March-May 2010
Baseline Monitoring- June 2010
Restoration Assessment and Credit – June-July 2010

Reference

Wilson, S. K., Graham, N. A. J. & Polunin, N. V. C. 2007. Appraisal of visual assessments of habitat complexity and benthic composition on coral reefs. Mar. Biol. 151, 1069–1076. (doi:10.1007/s00227-006-0538-3)