NATURAL RESOURCE DAMAGE ASSESSMENT
M/V MISS BEHOLDEN GROUNDING SITE
WESTERN SAMBO REEF, FKNMS
MARCH 13, 1993

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August 16, 1995

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1. INTRODUCTION

1.1 Description of the Incident

On March 13, 1993 the M/V MISS BEHOLDEN, a 147 foot freighter, ran aground on the eastern portion of Western Sambo Reef in the Florida Keys National Marine Sanctuary (FKNMS). The area injured by the grounding is a shallow (4-12 feet deep) coral spur and groove habitat[1] dominated by Porites asteroides (mustard hill coral), Millepora complanata (bladed fire coral) and Palythoa caribbea (golden seamat). Various species of soft corals and Porites asteroides found within the adjacent reef flat/sand channel community also were severely injured by the grounding. The combination of the size of the vessel (392 ton steel hull) and the shallow depth of the grounding area resulted in near to total destruction of all corals and associated sessile biota[2] within the 1,025.6 square meter area of impact.

Because the biological and ecological characteristics, and consequently the estimated recovery periods, of this area are not uniform throughout the total area of impact, this 1,025.6 square meter region will be treated as three distinct areas throughout the analysis described below. These three areas are: 1) the coral colonies on top of the injured spurs, which were sheared off by the grounded vessel (249.6 sq. m); 2) the structural framework on the inner edges of the spurs, including all attached colonies, which was crushed during the grounding (133.5 sq. m); and 3) the groove area separating the injured spurs (642.5 sq. m).

1.2 Summary of the Claim

As the principal Federal trustee for living and non-living resources in the marine environment, NOAA is responsible for assessing injuries to trust resources, recovering monetary damages for such injuries from responsible parties, and using the recovered damages to restore, replace, or acquire the equivalent of the injured resources.

Under Section 312 of the National Marine Sanctuaries Act, any person or vessel that destroys, causes the loss of, or injures any sanctuary resource is liable to the United States for an amount equal to the sum of response costs and damages associated with the injury, as well as interest on this amount. Damages are defined under Section 302 as the sum of:

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[1] "Spur and groove" is a term used to describe a specific reef morphology. Spurs are long, narrow aggregations of coral that extend seaward. They usually occur near abrupt changes in bottom slope, and exhibit coral species zonation by depth. Grooves are the channels between spurs characterized by a carbonate sand bottom.

[2] Sessile biota refers to those organisms permanently attached to or established on the coral colonies.

compensation for restoration costs[3], compensation for lost use of sanctuary resources pending restoration, damage assessment costs, and reasonable costs of monitoring.

Based on the calculations presented in this report, we have estimated total natural resource damages associated with this incident to be $1,873,741. Values for the individual claim components are presented in Table 1 below.

TABLE 1

SUMMARY OF NATURAL RESOURCE DAMAGE CLAIM

Damage Assessment and Response Costs[4]	$75,857
Restoration Costs[5]	$1,671,337
Monitoring Costs	$126,547
TOTAL CLAIM	**$1,873,741**

Our analyses of each of the components of the claim are provided in the following sections. The spreadsheets containing the supporting calculations are provided as Attachments A through G to this report.

2. CHOICE OF ASSESSMENT METHODOLOGY

In order to quantify the damages associated with the grounding of the M/V MISS BEHOLDEN, NOAA and the State of Florida have chosen to apply habitat equivalency analysis (HEA). HEA determines the quantity of equivalent habitat necessary to be restored and/or created, beyond the restoration of the injured resources to baseline, such that the total services provided by the compensatory habitat over its lifespan equals the total services lost due to the natural resource injuries. Services refer to functions that a resource performs for other resources or for humans.

There are three primary reasons why HEA is the most appropriate method for quantifying damages associated with this case. First, there is little on-site human use associated with the injured area. Thus, the primary category of lost on-site services pertains to the biological functions of the area. Such services include, but are not limited to, provision of:

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[3] The term restoration is used here to encompass restoration, replacement, and/or acquisition of the equivalent.

[4] This figure includes interest on damage assessment and response costs incurred as specified in Section 312 of the National Marine Sanctuaries Act.

[5] Includes costs of restoration planning and NEPA compliance (see Section 6.4).

substrate, habitat and food for associated animals; feeding, breeding and nursery ground for ecologically and economically important fisheries species; wave-breaks for inshore habitats and species; and larval recruits to populations in other sites. HEA represents one of the few methodologies that can be used to quantify interim resource losses where the on-site uses are primarily ecological/biological, and the off-site human uses are difficult to quantify.

A second criteria for use of HEA is the existence of feasible restoration/habitat creation projects that provide services of comparable types and quality to those that were lost due to the natural resource injury. The trustees recognize that coral reefs are extremely complex systems built up over decades or centuries and that their natural processes cannot be fully replicated. However, based on expert judgment and practical experience, the trustees have determined that artificial reefs sufficiently similar in function to natural reefs can be created using concrete modules to form the necessary three-dimensional structure[6], and then transplanting a combination of whole and partial coral colonies and coral cores onto this artificial substrate.

Finally, HEA represents a cost-effective means for assessing damages. Rather than implementing costly, site-specific field studies, the trustees have relied upon existing information as the basis for the HEA input parameters. Trustees utilized the following data sources in implementing the HEA for the M/V MISS BEHOLDEN grounding site: data collected during the response and injury assessment phases; values from existing scientific literature; best professional judgment of qualified experts; information from similar projects conducted in the past; and readily available sources of information on labor, equipment and materials costs. These data sources were determined to be of sufficient quality and applicability to the M/V MISS BEHOLDEN grounding site to render site-specific studies unnecessary.

Given that all of the above criteria are met, HEA is the most appropriate methodology for estimating the level of compensation due as a result of this incident.

3. GENERAL DESCRIPTION OF HABITAT EQUIVALENCY ANALYSIS

HEA is an assessment approach developed to estimate natural resource damages for incidents primarily involving reductions in on-site ecological resource services. Ecological services refer to functions that one resource performs for another, as opposed to functions with a direct link to human uses. NOAA has successfully applied HEA to a wide variety of incidents affecting a range of different habitats.

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[6] Reef replacement modules are massive, precast concrete structures secured to the existing natural substrate that are designed to mimic natural reef formations. Creation of artificial reef substrate using reef replacement modules has been demonstrated to be effective on the Sunny Isles and Biscayne Bay reef creation projects in southern Florida.

The basic approach underlying HEA is to determine the extent of compensatory reef habitat to be created such that the total services provided by the created area over its functional lifespan is equal to the total services lost due to the grounding, from the period of the incident until recovery of the injured area has occurred. Given the extent and severity of the injury caused by the M/V MISS BEHOLDEN, the affected areas may never recover fully. However, for purposes of this analysis, successful recovery is characterized by the restoration of the primary services provided by the reef community.

Even assuming successful recovery of the resource, restoration of the injured areas alone is not sufficient to compensate for the total losses incurred due to the grounding. Because restoration did not occur immediately following the grounding and because the resource will take years to return to its baseline (pre-injury) level of service production following restoration, compensation for these interim lost services must be incorporated into the estimate of total damages in order to sufficiently compensate the public for the total losses incurred due to the grounding. HEA calculates this compensation in the form of additional reef habitat that must be created above the level of primary restoration, such that the value of the total services provided by the compensatory habitat over its lifespan equals the total interim lost services due to the grounding.

The concepts of interim lost services and habitat equivalency are described in greater detail and depicted graphically in the Technical Appendix at the end of this report.

4. CALCULATION OF NATURAL RESOURCE DAMAGES

Because of differences in the extent of injury to the spur tops, spur structure and groove area, as well as differences in the estimated recovery horizons, the injured area was treated as three distinct areas for purposes of estimating damages. Three separate habitat equivalency analyses were performed, and the results were added together to arrive at an estimate of total damages.

For each injured area, the following parameters were determined in order to implement HEA:[7]

- Nature and extent of injury:
- Recovery period for injured reef resources;
- Functional forms of the recovery and maturity curves;
- Relative levels of service provision for created and natural habitats;
- Time horizon of services provided by created habitats;
- Time elapsed between the grounding and the implementation of restoration/habitat creation projects; and
- Real discount rate.

The values chosen for these parameters for each area of injury are provided in the sections below.

4.1 Habitat Equivalency Parameters for Spur Tops

4.1.1 Extent and Nature of the Injury

Data on the extent and nature of the injuries caused by the grounding of the M/V MISS BEHOLDEN were collected during the injury assessment efforts. Nine days after the vessel was removed from the reef, scientists from NOAA and the Florida Marine Research Institute (FMRI) began their underwater site assessment. Using a combination of semi-permanent site markers, underwater quadrats, underwater video, aerial photography and Geographic Information Systems (GIS) equipment, the trustee injury assessment team calculated that the grounding had completely scarified 249.6 square meters of coral spurs. Due to the size of the vessel and the force with which it grounded, all of the injury was classified as total destruction, meaning that the injured coral colonies were crushed beyond the point where they could be righted and resecured to the existing framework.

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[7] Values for these parameters were provided through the use of the following sources: 1) information collected during the injury assessment phase of the case, 2) relevant scientific literature; 3) data from previous restoration projects; 4) publicly available cost data; and 5) the best professional judgment of the trustee experts involved in this case. These sources were used in lieu of detailed, site-specific studies for three reasons. First, given the slow rates associated with coral growth and recovery, the time required to conduct relevant studies would be prohibitively long within the context of a damage assessment case. Second, the time and complexity associated with such studies makes them costly to implement. Most importantly, existing data sources are appropriate for characterizing the service flows associated with the injured and created habitats, and for estimating the extent of compensatory habitat and damages required. Where uncertainties existed, the trustees sought to make conservative assumptions.

4.1.2 Recovery Period for Injured Reef Resources

While the portions of the reef system injured by the grounding are expected to recover at different rates (or not at all), the definition of recovery is constant across all injured areas. For purposes of this assessment, recovery is defined in terms of the three-dimensional habitat complexity, benthic community composition and structure, associated mobile taxa, and major ecological functions and interactions.

The upper surfaces on the sections of the reef spurs that suffered superficial structural injuries were dominated by gorgonians and hard corals (primarily Porites astreoides and Millepora complanata). Based on scientific literature and the best professional judgment of the trustee experts, this area is expected to recover naturally within 50-75 years given no active restoration efforts and within 30-50 years given transplanting of the scarified spur surface. Given the unique nature of the ecosystem and the wide range of services provided by the resource, the value of 20 years of interim lost services in the absence of active restoration efforts would be significant. In applying HEA, we conservatively have assumed that the spur top areas will recover fully in 30 years following transplanting.

4.1.3 Functional Form of the Recovery and Maturity Curves

The recovery curve depicts the cumulative percent of the injured resource that will have recovered as of each point in time over the full duration of the injury. Based on the best professional judgment of trustee experts, we have assumed that recovery of the spur top areas will proceed along a linear path until the point of full recovery is reached.

The same functional form and parameters were used to characterize the maturity functions as were used for the recovery functions. The maturity function refers to the level of services provided by the created habitat as of each point in time from the point of creation until the habitat reaches full maturity (i.e. maximum provision of services). Because of the totality of the destruction caused by the M/V MISS BEHOLDEN, we have assumed no difference between the on-site recovery function and the off-site maturity function.

In incorporating these assumptions for the recovery and maturity functions within the HEA, we averaged the square meter-years of services provided at the beginning and end of each period to calculate the total discounted square meter-years of services provided in each year. This procedure accounts for the fact that recovery/growth occurs over the course of a year, rather than instantaneously at the beginning or end.

4.1.4 *Relative Levels of Service Provision - Created vs Natural Habitats*

One of the factors influencing the extent of compensatory habitat required is differences in the level of ecological and other services provided by natural, relative to created habitats. Based on the best professional judgment of trustee experts, we assume a 1:1 productivity ratio. This is a conservative assumption, since it implies the created reef habitats will be as productive as the injured natural resource in terms of all associated services.

4.1.5 *Time Horizon of Services Provided by Restored/Created Habitat*

To properly characterize the total levels of services provided by the created habitat over time, any factors that would limit the lifespan of the created habitat need to be incorporated into the HEA. In this case, we conservatively have assumed that the created reef resources will provide services over an infinite time horizon.

4.1.6 *Time Elapsed Between Grounding and Implementation of Restoration/Habitat Creation Projects*

In quantifying the total services lost due to the grounding and the total services provided by the created habitat, the amount of time elapsed between the grounding incident and the performance of on-site restoration activities must be estimated. A similar estimate must be made regarding the amount of time between the grounding and the implementation of the off-site compensatory habitat creation projects. These periods represent the time necessary to: conduct emergency response activities; assess the injury; quantify the damages; reach settlement or judgment on damages; develop a detailed restoration plan; acquire any necessary permits; and secure the necessary materials and contract services required to implement the restoration plan. Given the current state of the case, the predicted performance periods associated with the restoration/habitat creation efforts, and the narrow time/weather window available to perform the restoration, it is unlikely that restoration could begin before Summer 1997. Thus, the trustees have estimated an elapsed time of four years from the date of the grounding for both of these duration parameters.

4.1.7 *Real Discount Rate*

Discounting is an economic procedure that transforms flows of services or monetary payments made over time to a single economically equivalent amount provided today. The concept of discounting is an important component of HEA because both the injured and created habitats provide service flows over long periods of time, while damages for injuries to these resources are paid at a specific point in time. Thus, a real discount rate of 3.0 percent is employed in order to place damages in present value terms. The choice of a 3.0 percent discount rate is based on an analysis of historical real after-tax rates of return on various assets.

4.1.8 Summary of Habitat Equivalency Results for Spur Tops

Attachment A provides the detailed HEA calculations for the spur tops, based on the parameter estimates discussed above. Based on the habitat equivalency calculations, 173.7 square meters of compensatory habitat need to be created in addition to the primary restoration activities undertaken at the injured site to compensate for the interim lost services associated with the injuries to the spur tops.

4.2 Habitat Equivalency Parameters for Spur Structure/Framework

4.2.1 Extent and Nature of the Injury

Using the same methods discussed in Section 4.1.1, trustee experts determined that 133.5 square meters of three-dimensional reef framework were crushed and displaced during the grounding event. For the reasons discussed in Section 4.1.1, this injury also was characterized as total destruction.

4.2.2 Recovery Period for Injured Reef Resources

The nature of the injuries to the inner portions of affected spurs was so severe that all living organisms (primarily hard corals, gorgonians and sponges) and the massive underlying reef structures that supported them were destroyed. The ecological and environmental conditions do not currently exist to permit regrowth of this structure within any reasonable timeframe.[8] Therefore, no significant recovery of these structures and the assemblages they supported are projected in the absence of active restoration efforts. However, if the rubble created by the grounding were removed, the structure of these injured spurs rebuilt using the concrete modules, and transplants attached to these modules, recovery would be expected within 30-50 years.[9] The basic techniques and underlying ecological processes associated with these techniques are generally well-established, and are

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[8] Endean and Stablum, 1973; Gittings, Bright, Choi and Barnett, 1988; Gittings, Bright, and Hagman, 1993; Gittings, Bright and Holland, 1993; Grigg and Maragos, 1974; Hudson and Diaz, 1988; Pearson, 1981; Rogers, Suchanek and Pecora, 1982; Rogers, 1993; Stoddart, 1974; Woodley, et al., 1981.

[9] Recovery of the full range of services on the injured reef will require the restoration of preexisting three-dimensional habitat complexity. This structural feature of coral reefs is critical for the recruitment and survival of many important mobile animals such as fish and crustaceans (Alevizon and Gorham, 1989; Baynes and Szmant, 1989; Brock and Norris; 1989; Endean and Stablum, 1973; Endean, 1973; Gittings, Bright, Choi and Barnett, 1988; Gittings, Bright and Hagman, 1993; Gittings, Bright and Holland, 1993; Gladfelter, 1982; Gorham and Alevizon, 1989; Harriott and Fisk, 1988; Hixon and Beets, 1989; Hudson, Robbins, Tilmant and Wheaton, 1989; Hudson and Diaz, 1988; Maragos, 1992; Pearson, 1981; Roberts and Ormund, 1987; Rogers, Suchanek and Pecora, 1982; Rogers, 1990; Rogers, 1993; Sheehy and Vik, 1992).

expected to result in significantly faster recovery time, relative to no active restoration.[10] As was the case for the spur top areas, we conservatively have chosen 30 years, the lower bound of the recovery horizon assuming active restoration, for input into the HEA.

4.2.3 Functional Form of the Recovery and Maturity Curves

For the reasons stated in Section 4.1.3, we have assumed linear recovery and maturity functions.

4.2.4 Relative Levels of Service Provision - Created vs. Natural Habitats

We have assumed that there is no difference in productivity between transplanted coral colonies on restored spur structure and coral colonies transplanted on top of existing natural spurs. Thus, we make the same assumption of a 1:1 productivity ratio between created and natural habitats that was made in the analysis of injured spur tops.

4.2.5 Time Horizon of Services Provided by Restored/Created Habitat

The modules used in restoring the injured reef and creating the compensatory habitat areas should withstand even serious storm events. Thus, we have assumed that the restored and created reef resources will provide services over an infinite time horizon.

4.2.6 Time Elapsed Between Grounding and Implementation of Restoration/Habitat Creation Projects

We assume an elapsed time of four years for both the time period between the grounding incident and the performance of on-site restoration activities, and the time period between the grounding and the implementation of the off-site compensatory habitat creation projects. These are the same assumptions that were made in Section 4.1.6 for the spur tops area.

4.2.7 Real Discount Rate

For the reasons stated in Section 4.1.7, we have assumed a real discount rate of 3.0 percent.

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[10] Brock and Norris, 1989; Gittings, Bright and Hagman, 1993; Harriott and Fisk, 1988; Hudson, Robbins, Tilmant and Wheaton, 1989; Hudson and Diaz, 1988; Keller and Jackson eds, 1993; Maragos, 1992; Sheehy and Vik, 1992; Shinn, 1976; Wulff and Buss, 1979.

4.2.8 Summary of Habitat Equivalency Results for Spur Tops Area

Attachment B provides the detailed habitat equivalency calculations for the spur structure/framework, based on the parameter estimates discussed above. Based on the habitat equivalency calculations, 92.9 square meters of compensatory habitat need to be created in addition to the primary restoration activities undertaken at the injured site to compensate for the interim lost services associated with the injuries to the spur structure/framework.

4.3 Habitat Equivalency Parameters for Groove Area

4.3.1 Extent and Nature of the Injury

Using the same methods discussed in Section 4.1.1, trustee experts determined that groove areas between the coral spurs sustained 642.5 square meters of injury as a result of burial from grounding debris, as well as crushing and dislocation of corals and other reef organisms. For the reasons discussed in Section 4.1.1, this injury also was characterized as total destruction.

4.3.2 Recovery Period for Injured Reef Resources

The groove area was dominated by gorgonians and hard corals, which were crushed by the vessel and/or buried by the large volume of coral rubble generated by the grounding. These colonies would be expected to recover within 30-40 years given no active restoration measures, and within 15-25 years given removal of the rubble generated by the grounding. No transplanting of hard or soft corals is recommended within the groove area. Due to the extent to which organisms in this area are scarified by major storms, transplants likely would be killed before they could reach full maturity.

These estimates of recovery time for the groove area are partially based on observations made at similar reef restoration project sites in Florida, as well as on the scientific literature cited above and the best professional judgments of the trustee experts. Consistent with our previous parameter choices, we have chosen the lower bound of the recovery range assuming active restoration (15 years) for input into the HEA.

4.3.3 Functional Form of the Recovery and Maturity Curves

For the reasons stated in Section 4.1.3, we have assumed linear recovery and maturity functions.

4.3.4 *Relative Levels of Service Provision - Created vs. Natural Habitats*

For the reasons discussed in Section 4.1.4, we assume a 1:1 productivity ratio between created and natural habitats.

4.3.5 *Time Horizon of Services Provided by Restored/Created Habitat*

For the reasons stated in Section 4.1.4, we assume that the restored and created reef resources will provide services over an infinite time horizon.

4.3.6 *Time Elapsed Between Grounding and Implementation of Restoration/Habitat Creation Projects*

For the reasons discussed in Section 4.2.6, we have assumed an elapsed time of four years for both the time period between the grounding incident and the performance of on-site restoration activities, and the time period between the grounding and the implementation of the off-site compensatory habitat creation projects.

4.3.7 *Real Discount Rate*

For the reasons stated in Section 4.1.7, we have assumed a real discount rate of 3.0 percent.

4.3.8 *Summary of Habitat Equivalency Results for Groove Area*

Attachment C provides the detailed habitat equivalency calculations for the spur structure/framework, based on the parameter estimates discussed above. Based on the habitat equivalency calculations, 252.0 square meters of compensatory habitat need to be created in addition to the primary restoration activities undertaken at the injured site to compensate for the interim lost services associated with the injuries to the groove area.

4.4 *Summary of Habitat Equivalency Results for All Injured Areas*

Based on the sum of the HEA calculations for the three areas discussed above, a total of 518.6 square meters of compensatory habitat needs to be created in addition to the primary restoration activities undertaken at the injured sites (1,025.6 square meters) in order to compensate for the interim lost services associated with this grounding. The following section discusses the specific activities that will be undertaken to restore the injured habitat and provide compensation for interim lost resource services.

5. GENERAL DESCRIPTION OF THE CHOSEN RESTORATION AND HABITAT CREATION PROJECTS

NOAA's and Florida's restoration goals for this grounding are to conduct feasible, cost-effective, in-kind restoration using the best available techniques to accelerate recovery of the injured resources to pre-grounding service levels, and to prevent additional injury from the rubble remaining at the grounding site.

Six criteria developed by NOAA sanctuary managers and technical staff were used to evaluate the extent to which different restoration alternatives met the overall restoration goals. The evaluation criteria used in selecting restoration and compensatory habitat creation projects are presented below in Table 2.

TABLE 2

CRITERIA FOR EVALUATING RESTORATION ALTERNATIVES

Criteria	Definition
1 Reduce Potential for Additional Injury	Reduce the potential for an increase in the nature or extent of the existing injury.
2 Technical Feasibility	Likelihood that a given restoration action will work at the site and that the technology and management skills exist to implement the restoration action.
3 Reduce Recovery Time	Measures that accelerate or sustain the long-term natural processes important to recovery of the affected resources and/or services injured or lost in the incident.
4 Reduce Potential for Collateral Injury	Likelihood that the requirements, materials, or implementation of a restoration action minimizes the potential for collateral injury.
5 Consistent with Restoration Objectives	Maintain a consistency with Sanctuary restoration objectives at all injured sites.
6 Aesthetic Acceptability	Restoration alternatives that create substrates and topography that most closely resemble the surrounding habitat and minimize visual degradation.

Based on evaluation of these criteria, a three-part restoration approach was selected by NOAA and the State of Florida for implementation at the grounding site. The three components of this approach are: 1) removal of rubble from the groove area; 2) fabrication, transportation and placement of reef replacement modules; and 3) collection and attachment of coral transplants to the existing substrate and reef modules. With the exception of rubble removal, which was determined not to be relevant for the off-site areas, these same components comprise the compensatory habitat creation effort.

Removal of rubble created by the grounding from the groove area is necessary to prevent coral rubble from scouring the nearby reef area during storms. In the absence of rubble removal efforts, this scouring may prevent successful coral recruitment or may eliminate coral recruits that do manage to become established.

Use of reef replacement modules is necessary to reconstruct the reef substrate destroyed by the grounding. Natural recovery of this structure would be expected to take hundreds of years (if at all), during which period no significant recovery of the organisms supported by these structures would be expected to occur. However, the use of concrete reef replacement modules to mimic this natural structure, and thus significantly accelerate recovery, has been demonstrated to be effective at a number of similar sites in southern Florida and the Florida Keys. Use of reef replacement modules also is supported by the scientific literature cited in Section 4 above, as well as by the best professional judgments of trustee experts.

Given a stable substrate, transplanting coral colonies is a viable, proven method of more rapidly restoring species composition, colony abundance, and habitat complexity, relative to natural recovery. Transplanting of corals will be done on both the tops of the injured spurs to restore those colonies that were sheared off by the grounded vessel, and on the tops of the reef replacement modules, to replace those colonies that had existing on the natural structural framework prior to its destruction from the grounding.

6. COSTS ASSOCIATED WITH RESTORATION AND HABITAT CREATION

The sections below discuss the processes for estimating the total costs associated with the restoration activities described in Section 5.[11]

6.1 Rubble Removal Costs

The first step in restoring the injured areas is removal of the 441.5 square meters of rubble created by the grounding from the groove area.[12] This is required to prevent secondary injury to the surrounding areas in the event of storm activity, and also to clear the area to

[11] Because of agency staff constraints, restoration costs are estimated under the assumption that the majority of restoration activities will be performed by outside contractors. Thus, the costs presented represent our best estimates of the actual costs of procuring these contract services.

[12] The total rubble area was calculated using a computerized Geographic Information System (GIS), based on a mylar tracing of an aerial photograph of the grounding site. While the extent of the rubble is expressed using a two-dimensional measure (sq. meters), the depth of the rubble within a given square meter area may be up to .5 meters.

allow recolonization of soft corals and other organisms within the groove area. Removal of every piece of rubble is not feasible nor cost effective, so removal efforts will be focused on all pieces 25 centimeters or greater on a side.

6.1.1 Dive Labor Costs for Rubble Removal

Dive labor costs for rubble removal are based on an assumption that clearing one square meter of rubble area will take three diver hours. This estimate is based on the experience of the trustee experts. Dozens of large boulders created by the grounding in the groove area can only be moved by air lift bags; thousands more will have to be hand loaded into metal baskets for removal. Total dive labor costs for the rubble removal phase of the restoration were calculated by multiplying the total square meters of rubble by the number of hours required to clear a square meter, to determine the total dive labor hours required to complete this phase of the restoration. This figure was then multiplied by the hourly cost per diver to arrive at an estimate of total dive labor costs. Hourly diver costs were based on an average of price quotes provided by dive companies with expertise in these types of underwater restoration activities. A more detailed discussion of dive labor costs is provided in the following section on coral transplantation costs. Based on these assumptions, total dive labor costs associated with the rubble removal effort are estimated to be $51,380.

6.1.2 Equipment Costs for Rubble Removal

Based on trustee restoration experience, the following equipment will be needed to remove the rubble from the groove area: 1) a scow tug and barge combination used to transport the rubble from the grounding site to a disposal site; 2) a dive platform used to serve as a base of operations and to house divers at the site; 3) iron baskets used to collect rubble below the surface; 4) lift bags used to float the baskets full of rubble to the surface where they can then be loaded onto the barge; and 5) a crane for bringing baskets of rubble onto the barge. Assuming an 8 hour dive day, it will take three teams of three divers 18.4 days to complete this work, resulting in total equipment costs of $61,470.[13] The sum of labor and equipment costs is $112,849. The detailed cost calculations associated with the rubble removal effort can be found in Attachment D.

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[13] A detailed discussion of the structure and number of the dive teams, and the length of the diving day can be found in the section on transplantation costs.

Cost estimates for the tug/barge, crane and metal baskets were based on costs incurred during previous coral restoration projects. Costs associated with the offshore diving platform are discussed in detail in the section on transplantation costs under "Boat-Related Costs".

6.2 Reef Module Fabrication, Transportation and Placement Costs

Restoration of the injured spurs and creation of the compensatory reef habitat is to be accomplished using prefabricated concrete modules, bolted together and joined with underwater cement to the adjacent natural areas. Based on previous restoration project experience, the unit price per reef replacement module is estimated to be $7,000.[14]

Based on the extent of the injury to the spur framework and the size of the reef replacement modules, 45 modules will be needed to restore the spur framework/structural area injured by the grounding. At a cost of $7,000 per module, restoration of the injured reef framework/structure is estimated to cost $315,000.

In calculating the cost of reef modules for the compensatory habitat area, the trustees assumed that 25 percent of the total compensatory habitat area would be comprised of modules, while the other 75 percent would be open space, similar to the groove area in the injured habitat. This ratio of elevated to open area is approximately equivalent to the ratio used on other reef creation projects and also reflects the approximate ratio of spur to groove habitat in the area of the grounding. Given these assumptions, the compensatory habitat creation project requires 44 reef modules at a total cost of $308,000. Added to the cost of the modules needed for the restoration of the injured spurs, the total reef replacement module cost is estimated to be $623,000 (see Attachment D).

6.3 Coral Transplantation Costs

Following removal of rubble from the groove area and deployment of reef replacement modules at the site of the grounding and the site chosen for creation of the compensatory reef habitat, the final step in implementing restoration is to transplant coral on top of the injured spurs and reef replacement modules. Costs associated with transplantation were estimated in a manner very similar to the approach used to estimate rubble removal costs. Labor, vessel and materials costs were estimated individually and then added to arrive at a total costs estimate for the transplanting efforts. The components of this calculation are discussed below in detail.

6.3.1 Number of Transplants Required

In calculating the total costs associated with transplanting coral onto the injured spur tops and spur structure, as well as the created modular reef habitat, the first step was to estimate the total number of transplants required. This calculation was done by multiplying the average per square meter densities of Porites asteroides and Millepora complanata in the unaffected reef areas adjacent to the grounding

[14] The dimension of the modules to be used for both the spur restoration effort and the offsite habitat creation project are 1.2 meters wide by 1.2 meters high by 2.4 meters long. One end of the module would be beveled at an angle to mimic the structure of the reef spur. Modules would be cast with plywood forms, using sand to create void spaces within the module structure.

site by the total number of square meters of habitat to be restored/created as determined by the injury assessment and the HEA calculations. Species densities in the unaffected areas adjacent to the grounding site were determined using standard underwater survey techniques conducted by trustee coral reef biologists. In calculating the appropriate number of transplants, trustees conservatively assumed that restoration efforts would involve transplantation of Porites asteroides and Millepora complanata only, despite the presence of up to ten other species in the area of the injury. These other species were omitted from the analysis for a number of reasons including: low likelihood of successful transplantation; insufficient availability of suitable donor colonies; or very low projected abundance at the injured site. Under these assumptions, 2,742 transplants are necessary to perform the primary restoration of the injured areas, while 928 transplants are needed for the compensatory habitat creation effort.

6.3.2 Time Required to Accomplish Transplantation

After calculating the total number of transplants required to complete the restoration and compensatory habitat creation projects, the total dive hours, days and weeks required to perform this transplantation was estimated. These estimates were necessary for calculating both labor and boat-related costs. Total dive hours required to perform the specified level of transplanting were calculated by multiplying the total number of transplants by the number of hours per transplant. Based on past coral transplantation projects, the trustee experts conservatively assumed that it would take one dive team, consisting of a primary diver, a secondary diver and a materials handler, 1.5 dive hours to perform each transplant. Included in this estimate is the time necessary to: identify an appropriate donor colony; travel to the donor colony site; collect the coral colony, core or piece to be transplanted; travel back to the restoration/creation site; and secure the transplanted coral to the appropriate substrate. Assuming 1.5 dive hours per transplant per team and three teams of divers, a total of 2.0 transplants can be completed each hour. Given 3,670 total transplants required, transplantation efforts are estimated to require a total of 1,835 hours to complete. Trustee experts estimate that transplanting efforts will take three dive teams operating eight dive hours per day, six days a week, a total of 38 weeks to complete. This estimate is based on the physical site characteristics, the number of daylight hours per day, expected wind speeds, and projections of total workable hours per day.

6.3.3 Dive Labor Costs

Total dive labor cost estimates are based solely on hourly costs per dive team. A total of three teams was determined by the trustee restoration experts to be the maximum number that could operate safely and effectively within the same area.

Each dive team will be composed of three people - a primary diver, a secondary diver and a materials handler.[15]

Hourly costs per diver were calculated using the average of the hourly price quotes provided by five companies with sufficient capabilities and experience to perform the types of underwater restoration activities required by this project. The average hourly dive cost per diver was calculated to be $38.79. Total dive labor costs associated with the transplanting effort, assuming three three-person dive teams, are estimated to be $640,582 (see Attachment D).

6.3.4 Boat-Related Costs

For purposes of estimating boat-related costs, we have assumed that divers would stay six days a week on a 55-foot off-shore work vessel moored near the restoration site. A smaller 25 foot outboard vessel would be used as a supply vessel for shuttling dive equipment and restoration materials from shore to the primary work platform. This arrangement is both more efficient and cost effective than stationing divers on shore and transporting them to and from the work site each day. Analysis of the costs of these two options shows an estimated cost savings of $1,295/day associated with the offshore option. These cost savings are attributable to decreased travel time, lower lodging and meal costs and reduced fuel consumption.

Trustees estimated boat-related costs based on price quotes from Florida operators providing comparable vessels to those that would be needed to implement the specified restoration. Trustees estimated a cost of $800/day for the offshore work platform, including the cost of a captain plus living accommodations for nine, three meals a day and fuel. A weekly rental rate of $810 was assumed for the 25 foot supply vessel, not including crew or fuel. Factoring in fuel costs and the costs of a mate required to operate the supply vessel and assist in crewing the offshore work boat, total boat-related costs are estimated to be $1,037/day. Given 38 weeks to complete the restoration and compensatory habitat creation projects, total boat-related costs are estimated to be $237,773.

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[15] The primary diver's duties include selection of donor colonies, removal of transplant colonies or blades, stabilization of the transplant base and attachment of the transplant. The secondary diver is primarily responsible for transporting the transplants from the donor site to the materials handler, and also assists in selection of donor colonies and stabilization/attachment of transplants. The materials handler is responsible for mixing and preparing the underwater cement and handling of transplants while they are being transported from the donor to transplant site.

6.3.5 Materials Costs

Molding plaster and type II Portland underwater cement are needed to secure transplants to the natural and modular substrates. Based on previous restoration projects, trustee restoration experts estimate that one-twentieth of a bag of molding plaster and one-quarter of a bag of type II cement are required for each transplant. At current prices for molding plaster and type II cement, the materials cost per transplant is $2.63. Total materials costs for the entire project is $9,633 (see Attachment D).

6.4 Environmental Review, Permitting and Supervision Costs

In addition to the labor and materials costs associated with the primary restoration and compensatory habitat creation projects, a number of tasks must be undertaken to ensure proper implementation of the restoration activities. These tasks include the preparation of an environmental assessment, obtaining required environmental permits and supervision of contractor activities. The costs associated with each of these tasks are discussed below in detail.

6.4.1 Costs Associated with Preparation of an Environmental Assessment

Restoration projects are subject to Federal statutes and regulations which require project review and issuance of appropriate environmental permits. In order to meet National Environmental Policy Act (NEPA) requirements, an Environmental Assessment (EA) must be conducted for major Federal actions that may significantly affect the human environment. In this case, the Federal action is the environmental restoration of an injured habitat being restored under the auspices of the National Marine Sanctuary Act. The required EA will: discuss NOAA's review of alternative actions and their applicability and environmental consequences; summarize the proposed restoration actions at the site; summarize the existing environmental setting; identify coordination required with other Federal, State, and Local agencies; and provide all relevant references and supporting documentation. The cost associated with preparing an EA for the restoration projects discussed above is estimated to be $25,000. This figure is based on recent NOAA experience in preparing EAs for similar restoration projects in the Florida Keys.

6.4.2 Environmental Permitting Costs

Implementation of restoration projects requires environmental permitting. The Department of the Army's permit program, within the Army Corps of Engineers (COE), under Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act, is the relevant permitting agency for this project. These laws require permits authorizing activities in or affecting navigable waters of the United States, the discharge of dredged or fill material into waters of the United States, and the transportation of material for the purpose of disposing it into ocean waters. Information on activities related to the above must be submitted to the COE in a permit application for evaluation. Costs associated with preparation, response to comments and modification of a permit for the present restoration project are estimated to be $7,500. This estimate is based on costs incurred on similar projects and the best professional judgment of trustee experts.

6.4.3 Costs Associated with Supervision of Restoration Activities

NOAA will incur costs associated with implementation of the restoration activities specified above. Construction activities by the selected contractor will require on-site supervision by NOAA field staff and headquarters personnel. Supervision of the present restoration project is estimated to cost $15,000, based on the best professional judgment of trustee experts.

Total planning, permitting and supervisory costs associated with implementation of the restoration and habitat creation activities are estimated to be $47,500. Table 3 below summarizes the total costs required to restore the injured spur and groove area and to create the compensatory habitat.

TABLE 3

TOTAL RESTORATION/HABITAT CREATION COSTS

Restoration Activity	Estimated Cost
Rubble Removal from Groove Area	$112,849
Reef Replacement Module Design, Fabrication and Deployment	$623,000
Transplantation on Injured Spurs and Reef Replacement Modules	$887,988
Environmental Review, Permitting and Supervision	$47,500
TOTAL RESTORATION COSTS	**$1,671,337**

7. MONITORING COSTS

Monitoring both the on-site restoration projects and the off-site compensatory habitat creation project provides information to NOAA biologists as to whether these projects are functioning and providing services in a manner consistent with restoration goals. Monitoring data also is utilized to determine if mid-course corrections to the restoration project are necessary.

The monitoring plan developed by the trustees for this site assumes that a principal investigator and assistant biologist each make four field trips in the first year following restoration, three trips in years two through five, and two trips in years six through ten. One of these trips each year is dedicated to surveying the potential impacts to the resource caused by storms, while the other trips are oriented towards regular data collection tasks. A higher number of trips is proposed for the first year of the plan because more changes are expected to occur during this period than during any other stage. The number of trips is reduced by one for the following year and remains constant through year five, the period when transplanted corals are most vulnerable. Any transplanted corals that survive beyond this stage are likely to survive the same natural perturbations as adjacent, non-transplanted colonies. However, if some transplants do not survive, replacement transplants can be cemented in their place. Monitoring during the last stage of the plan will focus primarily on coral colonization and succession, rather than on coral mortality. After year ten, the coral communities should be stable and further monitoring should not be necessary.

Total costs for this monitoring effort were estimated by multiplying the number of field and analysis hours by the hourly costs for the principal investigator and assistant biologist. Hourly costs were drawn from actual hourly rates for NOAA personnel in positions comparable to the principal investigator and assistant biologist. Costs per field day were calculated based on an eight hour day for both positions.

Based on the above assumptions, total monitoring costs are estimated to be $126,547.[16] Details of this calculation can be found in Attachment E.

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[16] This figure represents the undiscounted sum of annual monitoring costs over the full monitoring period, adjusted for expected inflation. A zero discount rate was assumed because this represents the rate of return available on the accounts into which recovered damages can be placed. An average expected inflation rate of 3.17% was used, based on projections made by the Congressional Budget Office of the annual percentage change in Federal salaries over the period of the monitoring effort. (Source: personal communication with Susan Strandberg, Budget Analysis Division, Congressional Budget Office, January 18, 1995).

8. DAMAGE ASSESSMENT AND RESPONSE COSTS

Federal damage assessment costs associated with the response, injury assessment and damage determination phases of the M/V MISS BEHOLDEN damage assessment currently total $67,213.[17] Assessment costs incurred by the state represent an additional $4,750. Documentation of these costs is presented in Attachment F.

Federal costs are calculated in two parts: labor and other charges. Labor charges represent the hourly cost of NOAA employees' work on this assessment, plus overhead. The other category includes all costs directly attributable to this particular incident including, but not limited to, travel, equipment, contract labor, and shipment costs.

State costs are calculated as the sum of raw direct labor costs and travel costs incurred by case team members.

In addition to actual response and assessment costs incurred, Section 312 of the National Marine Sanctuaries Act also allows trustees to claim for interest on these costs. Using an interest rate of 4.1 percent, which represents the 1993 historical nominal rate on 2-year U.S. Treasury bills, interest on Federal response and assessment costs totals $3,895[18] (see Attachment G).

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[17] These figures represent only costs incurred through June 24, 1995.

[18] 1993 historical rates are used because 1993 was the first year in which costs were incurred. A 2-year rate is used because this represents the period over which costs to date have been incurred. Calculations assume that the costs for a given fiscal year occurred at the midpoint of that fiscal year.

9. CONCLUSION

Based on the above analyses, total damages for the M/V MISS BEHOLDEN grounding incident are estimated to be $1,873,741. Table 4 below provides a breakdown of these costs by category.

TABLE 4

TOTAL NATURAL RESOURCE DAMAGES ATTRIBUTABLE TO THE M/V MISS BEHOLDEN GROUNDING INCIDENT

Category of Damages	Total Dollars
Restoration of Injured Area and Creation of Compensatory Habitat, Including Planning and Permitting	$1,671,337
Monitoring Costs	$126,547
Damage Assessment and Response Costs:	
Federal	$67,213
State	$4,750
Interest on Costs Incurred	$3,895
TOTAL NATURAL RESOURCE DAMAGES	**$1,873,741**

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