Fishes

- The cyanobacteria bloom produced by the oil spill altered the fish community in the vicinity of the grounding site. Herbivorous species, such as surgeonfish (*Acanthurus triostegus*) and parrotfish (*Scarus frontalis*), increased in abundance, while those species associated with a healthy reef ecosystem such as butterflyfish (*Chaetodon* spp.) and damselfish (*Chromis acares*) decreased in abundance (USFWS 1997).

- Alterations in the fish community were still evident two years after the spill, and appeared to be maintained by the on-going bloom and altered physical habitat (USFWS 1997) .

3.3 Recent Field Surveys and Natural Recovery

The most recent field study revealed that the reef ecosystem remains severely altered both intertidally on the reef flats and subtidally along the ocean and lagoon-facing reef slopes (Burgett 1998). The following oil-related injuries were still apparent five years after the spill:

- Cyanobacteria and articulated corallines continue to dominate more than 800 m of the reef flat. Much of the normally abundant crustose coralline algae remains dead within this area, and shows no signs of recovery.

- The area of proliferating invasive speices and dead crustose coralline algae has continued to **expand** and now includes portions of the northwest arm and lagoon.

- Several pinnacles within the lagoon are now largely devoid of any living coral colonies and are dominated by large mats of cyanobacteria.

- The sea urchin population remains reduced within 1000 m of the grounding site.

- Sea cucumbers remain absent near the grounding site.

Detailed investigation of fish and giant clam populations were not conducted 1998 due to time and funding constraints. However, since neither the crustose coralline, sea urchin, or sea cucumber populations have recovered, and cyanobacteria and articulated coralline algae still dominate much of the reef area injured by the oil spill, there is no reason to assume the fish or giant clam populations have recovered from the effects of the oil.

In mid-1999, the zone of opportunistic invasive species still dominated most of the reef flats along the SW arm of the atoll, but there were some signs that the area of coverage had shrunk in size as a result of the removal of some of the vessel debris in that area. Nevertheless the 'weedy' species still dominate the reef flat near the grounding site (Maragos, in prep.). The Trustees believe the data clearly shows that natural recovery will NOT occur for many years, if at all, necessitating active restoration efforts.

3.4 Conclusions

The pristine nature of Rose Atoll National Wildlife Refuge was seriously impacted in October 1993 when the Taiwanese fishing vessel *Jin Shiang Fa* ran aground on the southwestern side of the atoll and spilled over 100,000 gallons of fuel and lube oil. Initial documented injuries due to the oil release included a massive die-off of crustose coralline algae, giant clams, boring sea urchins and other invertebrates in the vicinity of the spill site. Areas along the reef flat and reef slope where the coralline algae died were quickly colonized by opportunistic invasive species (primarily cyanobacteria and the articualted coralline *Jania* spp.). Conditions on the atoll over six years after the spill either show little improvement or have deteriorated. The crustose coralline algae have not recovered at the spill site and the 'weedy' invasive bloom have expanded into other areas of the reef and lagoon. Sea urchins and sea cucumber numbers near the spill zone remain depressed. Although giant clams appear to be slowly recolonizing the impacted area, clams within the lagoon continue to show signs of physiologic stress.

The die-off of crustose coralline algae is of particular concern for the future management of Rose Atoll NWR, since this algae is the primary reef-building plant on the atoll. In the absence of a healthy crustose coralline algal community, reef growth may fail to keep pace with storm erosion or rising sea levels. The structure of the reef also may become weakened in areas where crustose coralline algae are absent. Either scenario could lead to unpredictable changes in the water circulation patterns across the atoll, or possibly result in a breach of the southwest arm. Such an event would produce catastrophic changes in the lagoon's protected ecosystem, and would threaten critical nesting habitat for federally protected seabirds and sea turtles.

The bloom and expansion of opportunistic invasive species at the spill site is also of major concern. Although such blooms are common after an oil spill in the marine environment (Bellamy et al. 1967, Houghton et al. 1991, Jackson et al. 1989), they are usually ephemeral, lasting only several months to a year (Bellamy et al. 1967, Keller and Jackson 1993). The bloom at Rose is now in its sixth year, it has expanded, and it is most persistent in areas containing high levels of dissolved iron associated with vessel debris. Iron has been shown to be a limiting nutrient for algae in oceanic environments (Martin and Fitzwater 1988), and it seems likely that the algal bloom at Rose is being maintained or enhanced by the presence of this element above baseline levels. Initial emergency restoration activities begun in 1999 corroborate these data and evidence.

The Trustees injury assessment data indicates that immediate action is necessary to address conditions that are preventing the resources injured by the oil spill from returning to their baseline condition. The remaining vessel debris must be removed before the reef will be able to recover from the adverse effects of the *Jin Shiang Fa* oil spill. The Trustees data also suggests that without intervention, this once pristine atoll will not only continue to degrade, but could undergo a catastrophic change if crustose coralline algae populations do not return to their pre-spill abundance and distribution. It is therefore necessary to begin restoration actions at Rose Atoll as soon as possible.

In accordance with the OPA regulations (CFR Section 990.54), the Trustees have developed and evaluated three primary restoration alternatives. Compensatory restoration alternatives were not evaluated, nor are any being considered at this time. In addition, the Trustees have carefully considered, but are not evaluating firther, a *No Action Alternative*. The Trustees believe the data collected on the oil spill injured natural resources at Rose Atoll during the past several years clearly show that these resources are not returning to their pre-spill conditions via natural recovery. Thus, the Trustees believe active primary restoration actions must be taken.

In selecting the preferred restoration alternative for the injuries at Rose Atoll NWR, the Trustees followed the guidance criteria provided by the NOAA OPA NRDA regulations and considered the following questions/criteria:

- The likelihood of success - will the alternative return the reef to its pre-spill conditions?
- Will the alternative prevent future injury or cause collateral injury?
- Will the alternative benefit multiple injured natural resources?
- Will the alternative cause a public health or safety problem?
- Can the Trustees establish meaningful performance criteria to evaluate the progress/success of the alternative?
- What are the projected costs and are they reasonable in relation to the expected benefits?

4.1 Removal of Vessel Debris (preferred alternative)

Removing the remaining vessel debris is the single most important action that can be taken to return the oil injured natural resources at Rose Atoll to their pre-spill conditions. Evidence from the Trustee's studies suggest that the injury and death of corals, fish, giant clams, sea cucumbers, sea urchins, and crustose coralline algae and the proliferation of invasive cyanobacteria and articulated coralline algae, began with, and was directly related to, the *Jin Shiang Fa* oil spill. In addition, studies indicate that the persistent, invasive cyanobacteria and articulated coralline algal bloom is being artificially maintained and enhanced by elevated iron levels in the water, the result of corrosion from the remaining vessel debris.

Significant recovery of the reef community injured by the oil spill will not occur until the remaining vessel debris is removed. Once removal operations are complete, the Trustees anticipate that natural recovery processes will return the atoll to its pre-spill conditions without additional intervention. No other potential restoration alternative is considered viable without the removal of the remaining vessel debris.

4.1.1 Project description

Debris removal operations have been separated into distinct reef flat, reef slope and lagoon components, as each has a different removal strategy and equipment requirements. Removal of debris from the reef flat and lagoon is conducted from the lagoon side of the reef, while the removal of debris from the reef slope is approached from the seaward side.

Removal of reef flat and lagoon debris requires the use of a small removal vessel capable of traversing the 3 m deep channel into the lagoon. Larger debris may be cut into a manageable size using acetylene cutting torches [or Caricable ®]. The reef flat debris is then moved to the edge of the lagoon, loaded into a skiff, and transferred to the removal vessel's hold using a combination of booms, davits, winches and cargo nets. Lagoon debris is stockpiled to or cut into a manageable size by divers before being lifted to the surface and onto the removal vessel using a combination of nets, cables, lift bags and hoists.

The removal of debris from the ocean-facing reef slope is more difficult due to the constant, heavy wave action in this area. An unanchored removal vessel must be stationed just outside the surf zone to support divers. Divers will gather and stockpile small debris, section larger debris using underwater cutting torches (if possible), place cargo netting around piles or pieces, and then attach cables and air lift bags. The debris then is lifted off the bottom and moved offshore, or dragged down the reef slope away from the surf zone, where it can be hoisted off the bottom. A removal tug likely will be needed to move or drag the largest items (i.e., the engine block and drive train assembly) which cannot be cut.

Debris must be deposited into the ocean at a sufficient depth (>500 m) to prevent future storms and large waves from carrying the material back onto the reef slope. Therefore, debris will be transported 3 nautical miles north of the atoll and deposited at an open ocean disposal site already authorized by the Environmental Protection Agency. The depth and distance of this site from the atoll is sufficient to eliminate any further interference with the zone of living coral, and will permit the atoll's reef to return to baseline conditions.

4.1.2 Likelihood of success

The Trustees believe that once the vessel debris is removed, and iron levels in the water are reduced, the likelihood of continuing injury to the Rose Atoll reef ecosystem from the *Jin Shiang Fa* oil spill will be significantly reduced. Although there is limited direct evidence to explain exactly what factors are promoting the bacteria and articulated coralline algal bloom at Rose, marine chemists and ecologists contacted by the Trustees agreed that the additional iron present in the ecosystem may be the primary causative factor. Thus, removal of the vessel debris and thereby the additional iron, appears to be the most viable restoration option available to return this atoll to its pre-spill conditions. This explanation is bolstered by two on site observations. First, in a previously unimpacted area of the reef where an iron rebar stake was placed by scientists studying the effects of the spill, a swath of cyanobacteria grew on the down current side of the stake. Second, preliminary observational data recorded following recent emergency restoration activities involving removal of much of the debris on the reef flat, indicated an obvious reduction in the amount of cyanobacteria in the area cleared (J. Maragos, pers. obs.).

4.1.3 Benefits to multiple resources

The Trustees expect that the actions of the preferred restoration alternative will benefit multiple components of the impacted reef community at Rose Atoll. Marine scientists suggest that one of the reasons the crustose coralline algae, sea urchins, sea cucumbers and other marine invertebrates, and marine fish impacted by the oil spill have not returned to pre-spill levels is because the cyanobacteria and articulated coralline algal mats may be acting as a physical barrier on the reef substrate. Specifically, these invasive species may be preventing marine invertebrates from fully accessing protective cover or foraging habitat. Returning the cyanobacteria and articulated coralline algal community to its pre-spill conditions is expected to allow the injured invertebrate populations to fully recolonize Rose and return to their pre-spill levels.

4.1.4 Likelihood of preventing further injury and avoiding collateral injury

Removal operations have the potential to disturb or injure reef organisms in areas where removal operations are being conducted. The Trustees will minimize this potential injury by having the Trustee's Project Manager on site during removal operations.

4.1.5 Effects on public health and safety

Since the atoll is closed to all public access, restoration operations will have no impact on either public health or safety.

4.1.6 Performance criteria

Performance criteria will be used to determine whether restoration objectives are met and whether the injured marine resources have recovered to near pre-spill conditions. The Trustees have selected two performance criteria to evaluate restoration efforts at Rose Atoll. One criterion will be the return of crustose coralline and cyanobacteria and articulated coralline algae to very near their baseline percent cover levels. Data collected from reference sites at Rose Atoll show that crustose coralline algae typically cover from 50-80% percent of the reef substrate (J. Burgett, unpubl. data), while opportunistic species like cyanobacteria are usually absent or rare. Restoration will be considered satisfactory when greater than 80% of the monitoring sites in the impacted area return to these unimpacted reference site levels.

Oil-caused injury also was apparent in several marine invertebrate species including: corals, boring sea urchins, sea cucumbers and giant clams. The populations of these species will continue to be monitored at previously established sampling locations. Recovery will be considered successful when the density of these species at impacted sampling locations reaches more than 80% of the mean density found at unimpacted sampling locations.

Data from the reef community will be evaluated in detail on an annual basis for ten years following the debris removal actions. In the event that the performance criteria reviews provide little sign of significant improvement at the atoll, the Trustees will consider proposing modifications to the plan or reconsidering some of the presently rejected restoration alternatives.

4.1.7 Monitoring reef recovery and return to baseline conditions

Reef flat communities often take years to recover following an oiling event (Cubit and Conner 1993, Suchanek 1993, USFWS 1997). For example, coral reefs killed by response actions at Pago Pago Harbor are expected to take approximately ten years to fully recover (NOAA 1999). The types of long term injuries documented to corals following oil spills include death, reduced growth and reduced reproduction (Loya and Rinkevich 1980, Jackson et al. 1989).

Based on this information, it is likely that the reef at Rose Atoll also will take many years to fully recover. Long term monitoring is therefore necessary to determine whether additional restoration actions will be necessary to return the reef community to its baseline condition. Sampling locations established during the injury assessment phase of this incident, as well as additional monitoring sites recently established in the lagoon and on the ocean reef slopes, will be monitored in the field biennially to determine changes in the percent cover of crustose coralline algae, other benthic algae, corals, and abundance of other marine invertebrates and fishes. These data will allow Trustees to accurately assess reef recovery and evaluate the effectiveness of the selected restoration alternative. Monitoring studies will begin following the completion of removal operations (2000) and will be conducted annually for ten years.

Newly available imagery from the IKONOS 1 satellite may provide a cost-effective means of monitoring the return of the coralline algae community to the reef flat in the years between field monitoring surveys. Previous satellite images revealed that portions of the reef flat covered with invasive algae appeared darkly colored compared to areas covered with a healthy crustose coralline community. However, there is little information available on using satellite imagery to monitor the recovery of a remote coralline algal reef. Thus, the Trustees expect this technique will require significant field monitoring to ensure that the interpretation of the satellite images is providing accurate data on recovery.

4.1.8 Expected costs

The cost to implement the preferred restoration alternative and monitor recovery is expected to be $1,174,775 (Appendix A). The Trustees believe these costs are reasonable considering the amount of debris that must be removed (estimated to be in excess of 100 tons), the challenging work conditions (constant high energy wave action), and the atoll's extremely remote location (nearly 2,500 miles SSW of Honolulu, HI). The Trustees estimated total cost ($625,378) for removing the vessel debris is less than half the cost of the response actions, which insurers reported at over $1,100,000 (USFWS 1997). The estimated costs are also considerably less than the $2,000,000 estimate provided by Mobile Diving Salvage Unit of the U.S. Navy, for removal of the remaining debris (letter to Secretary Berry from Admiral Archie Clemins dated January 25, 1999). Finally, the estimated removal costs are less than the costs estimated by a private salvage firm for removing individual vessels grounded in Pago Pago Harbor ($232,053 - $696,159; NOAA, 1999), a much more easily accessible, less challenging work environment.

The expected costs for monitoring ($549,397) are also reasonable considering the remoteness of Rose, its open ocean exposure and the uncertainty faced by the Trustees. In addition, the Trustees are attempting to reduce monitoring costs by using ground verified satellite imagery on alternate years to monitor recovery. The satellite imagery provides a considerable cost savings compared with annual on site visits.

Although the Trustees are making every effort to conduct the most cost effective restoration program, there remains a considerable amount of uncertainty. This uncertainty includes not only the challenging work conditions and remoteness of the site, but the uncertainty regarding how quickly the reef killing algae will persist after the iron is removed. Since these many uncertainties make it likely that mid-course corrections will be necessary in the proposed restoration effort, eight percent of the total cost has been added to the budget for project management. This project management cost is expected to allow the Federal and American Samoan Trustees to make the logistical and administrative adjustments necessary to achieve a fully successful restoration effort.

4.2 Manual Removal of Invasive Species / Transplantation of Crustose Coralline Algae

(rejected alternative)

Manual removal of invasive algae would entail using knives or similar tools to scrape off the 'weedy' algae adhering to the reef substrate, and would be a prerequisite to the transplantation of crustose coralline fragments. Attempting to transplant crustose coralline fragments without first removing the 'weedy' species likely would result in the cyanobacteria and articulated coralline algae over-growing and killing the transplants. In addition, cementing coralline transplants to the reef substrate requires that the surface be relatively clean and free of growth such as cyanobacteria.

This project would, at least in the short term, reduce the amount of cyanobacteria and articulated coralline algae on the reef and potentially promote the return of the crustose coralline algae to areas injured by the oil spill. However, for the reasons described below the Trustees have concluded that this restoration alternative is not the most practical and appropriate option for Rose Atoll at this time:

- This approach would likely have little or no long lasting effect if water iron levels remain elevated. Before either project could be initiated, iron concentrations in the water would need to be lowered to pre-spill levels to inhibit the return of the cyanobacteria and articulated coralline algae and promote the growth of the crustose corallines. This project could therefore only be attempted after all vessel debris had been removed.

- The very widespread occurrence of the cyanobacteria and articulated coralline algae following six years of growth, combined with the rough open ocean conditions at Rose would make the manual removal of the algae a very difficult and costly task.

- At present the area of the reef covered by the invasive species is too large to be the focus of a transplant operation and without some certainty that the 'weedy' invasives will not again proliferate, transplanted corals likely would be rapidly overgrown.

4.3 Reintroduction of Marine Invertebrates (rejected alternative)

Injury studies demonstrated that a significant number of boring sea urchins, sea cucumbers, and giant clams were killed by the spill. Restoration efforts for these species could include the reintroduction of individuals of each species into impacted areas. These reintroduced individuals could be either raised in aquaria at a facility specifically constructed for the purpose, or they could be collected from areas on the atoll unaffected by the oil spill and translocated to impacted areas.

This direct facilitated recolonization effort likely would enhance the recovery of specific marine invertebrate populations affected by the oil spill. However, this alternative was rejected at the present time for the following reasons:

- Releasing propagated or collected marine invertebrates into areas where invasive species are still abundant likely would reduce their chances of survival as the cyanobacteria mats may act as a physical barrier to settling juveniles and prevent them from accessing the reef substrate for cover or foraging habitat. Also field observational data suggest that the presence of the cyanobacteria seems to be causing a stress reaction in giant clams. Thus, this project could only proceed after these mats are removed.

- Sea urchins and sea cucumbers can have very high fecundity and they are relatively mobile. Therefore, the Trustees are hopeful that they will naturally recolonize impacted areas once the mats of invasive algae are eliminated. The Trustees are less certain about the recovery rates of the giant clam. However, at present we do not have the technical and logistical expertise to artificially propagate this species and have decided our best option is to monitor recovery after the invasive species are significantly reduced. If any of the impacted marine invertebrate populations fail to grow back towards baseline levels following the significant reduction in the cyanobacteria mats, the Trustees may reconsider the option of artificially propagating and releasing larvae of the still impacted species.

4.4 Restoration Summary

The Trustees have selected the removal of the remaining vessel debris as the preferred restoration alternative. This action will remove the source of iron believed to be maintaining the bloom of invasive species that began following the *Jin Shiang Fa* oil spill. The removal of the proliferating invasive species should, in turn, facilitate the recolonization of the crustose coralline algae, as well as benefit populations of marine invertebrates injured by the oil spill. While each of the rejected restoration alternatives could potentially provide additional benefits to affected species, we believe that the natural recolonization of impacted areas may make such efforts largely unnecessary once the vessel debris is removed. A summary of project costs is presented below.

Summary of Estimated Costs for Emergency Restoration of Rose Atoll, NWR	
Project Element	**Total Cost**
Removal Operations	$625,378
Recovery Monitoring	$549,397
Administrative Record	$8,000
Project Management (10%)	$118,278
Total Project Costs	**$1,301,053**

4.5 Project Management

The U.S. Fish and Wildlife Service (Service) will serve as the Lead Administrative Trustee. These duties will include: responsibility for programmatic oversight, review, and management, financial management and cost documentation, public notification and outreach. . The Department of Marine and Wildlife Resources is co-trustee for the refuge, and will offer assistance to the Service and the contractor as necessary.

In accordance with OPA regulations (CFR Section 990.45), an Administrative Record (Record) was established by the Trustees. The Record will provide the public with a repository of documents relied upon by the Trustees in making determinations regarding injuries to the atoll and the selected restoration alternative. In addition, the Record may facilitate administrative and judicial review of the Trustees' actions and determinations. The Record will be available for public review at the following locations during normal business hours:

U.S. Fish and Wildlife Service
300 Ala Moana Blvd.

American Samoa Government
Department of Marine and Water Resources

Honolulu, HI 96850

P.O. Box 3730
Pago Pago, American Samoa 96799

References

Amerson, A.B., W.A. Whistler, and T.D. Schwaner 1982. Wildlife and wildlife habitat of American Samoa. II. Accounts of flora and fauna. U.S. Dept. of the Interior, Fish and Wildlife Service Report. 151 pp.

Balazs, G., P. Craig, B. Winton, and R. Miya 1994. Satellite telemetry of green turtles nesting at French Frigate Shoals, Hawaii and Rose Atoll, American Samoa. Proc. 14th Annual Symp. on Sea Turtle Biology and Conservation. 4 pp.

Barclay, S. 1993. Trip Report: Rose Atoll, November 28 - December 9, 1993. Administrative Report, U.S. Fish and Wildlife Service, Honolulu, Hawaii. 13 pp.

Bellamy, D.J., P.H. Clarke, D.M. John, D. Jones, and A. Whittlick 1967. Effects of pollution from the Torrey Canyon on littoral and sublittoral ecosystems. Nature 216: 1170-1172.

Burgett, J. 1998. Memorandum to Don Palawski. Update on conditions of Rose Atoll, August 1998. U.S. Fish and Wildlife Service, Honolulu, Hawaii.

Cubit, J. and J.L. Connor. 1993. Effects of the 1986 Bahia las Minas oil spill on reef flat communities. Proceedings of the 1993 Oil Spill Conference: 329-334.

Ford, G.R. 1975. Needs of the United States Territories of Guam, American Samoa, and the Virgin Islands, a proclamation by the President of the United States of America. February 1, 1975. 2pp.

Green, A.L. 1996. Status of the coral reefs of the Samoan Archipelago. Department of Marine and Wildlife Resources Biological Report Series, Pago Pago, American Samoa. 125 pp.

Green, A.L., and P. Craig 1996. Rose Atoll: a refuge for giant clams in American Samoa? Department of Marine and Wildlife Resources Biological Report Series, Pago Pago, American Samoa. 55 pp.

Greenwalt, L.A. 1974. Notice of Establishment, Rose Atoll National Wildlife Refuge, American Samoa. Federal Register 39(71), Thursday, April 11, 1974. 16 pp.

Houghton, J.P., D.C. Lees, W.B. Driskell, and A.J. Mearns. 1991. Impacts of the Exxon Valdez spill and subsequent cleanup on intertidal biota--1 year later. In: Proc. of the 1991 Oil Spill Conference. American Petroleum Institute, Washington, D.C., pp. 467-475.

Jackson, J.B.C., J.D. Cubit, B.D. Keller, V. Batista, K. Burns, H.M. Caffery, R.L. Caldwell, S.D.

Garrity, C.D. Getter, C. Gonzalez, H.M. Guzman, K.W. Kaufmann, A.H. Knap, S.C. Levings, M.J. Marshall, R.Steger, R.C. Thompson, and E. Weil. 1989. Ecological effects of a major oil spill on Panamanian coastal marine communities. Science 243: 37-44.

Keller, B.D., and J.B.C. Jackson, eds. 1993. Long-term assessment of the oil spill at Bahia Las Minas, Panama. Synthesis Report, Volume II: Technical Report. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans. 1017 pp.

Loya, Y. and B. Rinkevich. 1980. Effects of oil pollution on coral reef communities. Marine Ecology Progress Series 1:77-80.

Maragos, J.E. 1994. Review Draft: Reef and coral observations on the impact of the grounding of the longliner *Jin Shiang Fa* at Rose Atoll, American Samoa. Program on Environment, East-West Center, Honolulu, Hawaii, 21pp. + 4 tbs. + 1 fig.

Maragos, J.E. 1999. Observations of the reefs, corals and giant clams at Rose Atoll during initial operations to remove ship debris from the reef flats and lagoon (May-Aug. 1999). U.S. Fish and Wildlife Service Report, in preparation.

Martin, J.H., and S.E. Fitzwater. 1988. Iron deficiency limits phytoplankton growth in the northeast Pacific subarctic. Nature 331: 341-343

Mayor, A. 1921. Rose Atoll, American Samoa. Proc. Amer. Philos. Soc. 60: 62-70.

Molina, M. 1994. Trip report: Rose Atoll National Wildlife Refuge, American Samoa: October 31 to November 8, 1993. Administrative Report, U.S. Fish and Wildlife Service, Honolulu, Hawaii. 13 pp. + appendices.

National Oceanic and Atmospheric Administration. 1999. Emergency Restoration Plan and Environmental Assessment. Pago Pago Harbor, American Samoa. 92p.

Radtke, R. 1985. Population dynamics of the giant clam, *Tridacna maxima*, at Rose Atoll. Hawaii Institute of Marine Biology, University of Hawaii. 24 pp.

Rodgers, K.A., I.A.W. McAllan, C. Cantrell, and B.J. Ponwith 1993. Rose Atoll: an annotated bibliography. Technical Reports of the Australian Museum 9: 1-37

Suchanek, T.H. 1993. Oil impacts on marine invertebrate populations and communities. Amer. Zool. 33:510-523.

UNEP/IUCN. 1988. Coral reefs of the World Volume 3: Central and Western Pacific. UNEP Regional Seas Directories and Bibliographies. IUCN, Gland, Switzerland and Cambridge, U.K./UNEP, Nairobi, Kenya. xlix + 329 pp., 30 maps.

U.S. Fish and Wildlife Service. 1996a. Pre-assessment screen for physical injuries caused by the

F/V *Jin Shiang Fa* grounding at Rose Atoll National Wildlife Refuge, American Samoa. Report prepared by the U.S. Fish and Wildlife Service, Pacific Islands Office, Honolulu, Hawaii.

U. S. Fish and Wildlife Service. 1996b. Pre-assessment screen for spill-related injuries caused by the F/V *Jin Shiang Fa* oil spill at Rose Atoll National Wildlife Refuge, American Samoa. Report prepared by the U.S. Fish and Wildlife Service, Pacific Islands Office, Honolulu, Hawaii.

U.S. Fish and Wildlife Service. 1997. The impact of a ship grounding and associated fuel spill at Rose Atoll National Wildlife Refuge, American Samoa. Report prepared by the U.S. Fish and Wildlife Service, Pacific Islands Office, Honolulu, Hawaii.

Wass, R. 1981a. The fishes of Rose Atoll. Department of Marine and Wildlife Resources Biological Report Series. 10 pp.

Wass, R. 1981b. The *Tridacna* clams of Rose Atoll. Department of Marine and Wildlife Resources Biological Report Series, Pago Pago, American Samoa. 9 pp.

Appendix A: Restoration and Monitoring Costs

Removal Operations[1]

Initial reef flat cleanup

Removal vessel	15 days @ $2,000/day	$30,000
Removal skiff	15 days @ $400/day	$6,000
Removal equipment (cutting torches, ropes and cables)		$4,750
Removal personnel (6)	15 days @ $300/day (x6)	$27,000
FWS personnel (2)	17 days @ $600/day (x2)	$20,400
FWS airfare	$1,000 (x2)	$2,000
FWS lodging and per diem	2 days @ $200/day (x2)	$800
DMWR personnel (2)	15 days @ $300/day (x2)	$9,000
FWS/DMWR support vessel	15 days @ $2,000/day	$30,000
Food and fuel		$3,000
Project Development and Field Oversight and Management		$13,295
Total estimated cost of initial reef flat cleanup:		**$146,245**

Reef slope cleanup of deep debris (>6m depth)

Removal vessel	15 days @ $2,000/day	$30,000
Removal skiff	15 days @ $400/day	$6,000
Removal equipment (cutting torches, cables, air compressors, air tanks)		$15,375
Removal personnel		
Divers (3)	15 days @ $600/day (x3)	$27,000
Deck hands (2)	15 days @ $150/day (x2)	$4,500
FWS personnel (2)	17 days @ $600/day (x2)	$20,400
FWS airfare	$1,000 (x2)	$2,000
FWS lodging and per diem	2 days @ $200/day (x2)	$800
DMWR personnel (2)	15 days @ $300/day (x2)	$9,000
FWS/DMWR support vessel	15 days @ $2,000/day	$30,000
Food and fuel		$3,000
Project Development and Field Oversight and Management		$14,808
Total estimated cost of deep reef slope cleanup:		**$162,883**

Reef slope cleanup of shallow debris (<6m depth)

Removal vessel (tugboat)	10 days @ $2,000/day	$20,000
Removal skiff	10 days @$400/day	$4,000

---

[1]February 2000: Using funding provided through the U.S. Fish and Wildlife Service national refuge cleanup fund, a contractor has successfully removed much of the debris from the reef flat and begun the removal operation on the reef slope and lagoon areas. This source of funding is expected to be insufficient to complete these operations.

Removal equipment (shackles, cables, air compressors, lift bags)		$3,000
Removal personnel		
Divers (3)	10 days @ $600/day (x3)	$18,000
Deck hands	10 days @ $150/day (x2)	$3,000
Reef workers	5 days @ $150/day (x2)	$1,500
FWS personnel (2)	14 days @ $600/day (x2)	$16,800
FWS airfare	$1,000 (x2)	$2,000
FWS lodging and per diem	2 days @ $200/day (x2)	$800
DMWR personnel (2)	10 days @ $300/day (x2)	$6,000
FWS/DMWR support vessel	10 days @ $2,000/day	$20,000
Food and fuel		$2,000
Project Development and Field Oversight and Management		$9,710
Total estimated cost of shallow reef slope cleanup:		**$106, 810**

Final Reef Flat Cleanup

Removal vessel	10 days @ $2,000/day	$20,000
Removal skiff	10 days @ $400/day	$4,000
Removal equipment (raft, chain hoist, cutting torches, davits)		$5,000
Removal personnel (6)	10 days @ $300/day (x6)	$18,000
FWS personnel (2)	14 days @ $600/day (x2)	$16,800
FWS airfare	$1,000 (x2)	$2,000
FWS lodging and per diem	2 days @ 200/day (x2)	$400
DMWR personnel (2)	10 days @ $300/day (x2)	$6,000
FWS/DMWR support vessel	10 days @ $2,000/day	$20,000
Food and fuel		$2,000
Project Development and Field Oversight and Management		$9,420
Total estimated cost of final reef flat cleanup		**$103,620**

Lagoon Cleanup

Removal vessel	10 days @ $2,000/day	$20,000
Removal skiff	10 days @ $400/day	$4,000
Removal equipment (cargo nets, cables, air compressors, air tanks, davits)		$5,500
Removal personnel		
Divers (6)	10 days @ $600/day (x6)	$36,000
Deck hands (3)	10 days @ $150/day (x3)	$4,500
FWS personnel (2)	12 days @ $600/day (x2)	$14,400
FWS airfare	$1,000 (x2)	$2,000
FWS lodging and per diem	2 days @ $200/day (x2)	$800
DMWR personnel (2)	10 days @ $300/day (x2)	$6,000
Food and fuel		$3,000
Project Development and Field Oversight and Management		$9,620

Total estimated cost of lagoon cleanup:		**$105,820**
Total Cost of Removal Operations		**$625,378**

Recovery Monitoring[2] (6 biennial trips over 10 years)

FWS/DMWR support vessel	7 days @ $2,000/day (x6 trips)	$97,877
FWS personnel (4)	9 days @ $600/day (x4 personnel) (x6 trips)	$151,008
FWS airfare	$1,000 (x4 personnel) (x6 trips)	$27,965
FWS lodging and per diem	2 days @ $200/day (x4 personnel) (x6 trips)	$11,185
DMWR personnel (2)	7 days @ $300/day (x2 personnel) (x6 trips)	$29,362
Field equipment, maintenance, and supplies		
Small boat and motor		$20,000
Diving gear		$8,000
Gear maintenance	5 years @ $500/year	$3,495
Underwater photography gear		$3,000
Laptop computer and printer		$2,500
Scientific supplies	5 years @ $500/year	$3,495
Chemical Analysis of Water Samples for Iron	6 years @ $7,000/year	$4,200
Remote sensing	6 years @ $8,000/year	$55,928
Annual report printing, graphics, and web site maintenance $9,000 (x10)		$90,000
Project Development and Field Oversight and Management		$41,382
Total cost of monitoring:		**$549,397**
Total Cost of Restoration and Monitoring:		**$1,174,775**

[2]All the multi year costs were adjusted for inflation using a 3% per year inflation rate.