3.0 INJURY

3.0 INJURY DETERMINATION AND QUANTIFICATION

3.1 SUMMARY OF PREASSESSMENT ACTIVITIES

Three threshold requirements identified in OPA must be met before Restoration Planning can proceed:

1. Injuries have resulted, or are likely to result, from the incident;
2. Response actions have not adequately addressed, or are not expected to address, the injuries resulting from the incident; and
3. Feasible primary and/or compensatory restoration actions exist to address the potential injuries.

All of the information collected during the Preassessment Phase for the Incident was collected by the Trustees and Chevron prior to August, 1996. This information satisfies the three criteria listed above and confirms the need for restoration planning to address spill impacts.

3.1.1 General Description of Impacts

Immediate public impacts from the discharged oil included:

- the closure of Pearl Harbor to vessel traffic.
- the partial closure of the City and County of Honolulu's bicycle/jogging path around East Loch in the vicinity of the Waiau Power Plant,
- suspension of ferry service to Ford Island,
- the closure of the Visitor Center and associated boat trips to the Memorial, and
- the closure of the Harbor to recreational and commercial fishing and boating.

Oiling of shorelines and intertidal areas affected freshwater and saltwater wetlands, mudflats, and sandy beaches. These oiled habitats contribute to many recreationally and commercially valuable fish and wildlife species. Other shoreline types, including riprap, seawalls and piers, were also oiled. Introduction of oil into the water column and sediments may have exacerbated the extant pollution problems in Pearl Harbor.

Cleanup of shorelines accelerated the destabilization of existing shoreline protection at the Visitor Center and may have impacted other habitats that required intensive and/or repeated aggressive cleanings. Removal of contaminated sediments from wetland areas may not only have adversely affected the overlying vegetation at the time of removal but also caused soil/sediment alterations that will prevent or substantially delay natural recovery by native vegetation.

A more detailed discussion is provided below on specific assessments undertaken for the following natural resource categories: air resources, surface waters, wildlife and marine/estuarine biota.

3.1.2 Air Resources

Samples taken and analyzed by Chevron and the NPS at the Visitor Center indicate that the air resource was not affected with respect to public health and/or natural resources (Chevron 1996, Robichaux 1996).

The NPS undertook an air sampling investigation at the Visitor Center for a period of three to six days after the Incident because of concerns about the health and welfare of NPS employees, volunteers and visitors, particularly the elderly, who might potentially be exposed to the volatile fractions evaporating from the spilled oil. NPS employees working at the Visitor Center on the morning of May 14, 1996 reported smelling strong petroleum odors and experienced nausea and vomiting after exposure to the fumes-laden ambient air (Billings pers. comm.).

Four outdoor, ambient air sampling stations were established at the Visitor Center: two along the Halawa Stream shoreline, one along the Pearl Harbor shoreline next to the former Ford Island ferry dock, and one on the sidewalk immediately outside the theater building. Air samples collected on May 17 and 18, 1996 were analyzed for total petroleum hydrocarbons (TPH) and benzene only. Samples collected on May 20, 1996 were analyzed only for hydrogen sulfide. No detectable concentrations of TPH, benzene or hydrogen sulfide were measured at the specified analytical detection limits during this limited air sampling at the Visitor Center during a period of three to six days after the oil spill. Table 1 details the results of this air sampling event.

Table 1. Ambient air sampling results for TPH, benzene and hydrogen sulfide at four outdoor monitoring stations established at the USS *Arizona* Memorial Visitor Center on May 17, 18 and 20, 1996 (Robichaux 1996).

analyte	date sample collected	number of air samples collected	analytical detection limit	analyses results
total petroleum hydrocarbons (TPH)	5/17/96 5/18/96	4 7	100 μg^1 100 μg^1	not detected[3] not detected[4]
benzene	5/17/96 5/18/96	4 7	1.0 μg^1 1.0 μg^1	not detected[5] not detected[6]
hydrogen sulfide	5/20/96	4	ppb[2] by volume	not detected

[1] measured as mass absorbed by sampling device at 1 liter of air per minute of sample time (in micrograms).
[2] ppb = parts per billion.
[3] sample time = 25 - 28 minutes.
[4] sample time = 16 - 23 minutes.
[5] sample time = 25 - 28 minutes.
[6] sample time = 16 - 23 minutes.

Warm ambient weather conditions during the day on May 14, 1996 acted to volatilize a fraction of the spilled oil creating a widely detected "odor problem" around Pearl Harbor especially within the Naval Complex and in Pearl City (Kakesako and Barayuga 1996). The Hawaii Department of

Health advised the public that the spilled oil did not present an immediate public health threat except for these odors (Kakesako *et al.* 1996).

3.1.3 Surface Waters

Two specific studies of surface water impacts resulting from the Incident were undertaken. The Trustees independently contracted an analysis of certain aerial photoimagery taken during the first day of the spill event and the Trustees, in cooperation with the Chevron, contracted for an investigation of the extent of oil coverage on the surface waters of Pearl Harbor during the first six days of the spill event.

The aerial imagery study of the surface waters of Pearl Harbor used multispectral imagery taken late in the afternoon on May 14, 1996, the first day of the spill. These images were taken with an airborne multispectral camera system that features four narrow spectral bands that can be selected for specific environmental applications. A total of 220 aerial, multispectral images along 12 different flight lines across Pearl Harbor were collected. Of these, five specific geographic areas of Harbor shoreline were selected for detailed analysis to demonstrate the extent of oil coverage and oil spill shoreline impacts. These five geographic areas included:

- Hospital Point to Waipio Point;
- the shoreline immediately to the north of Hospital Point;
- the shoreline at the Visitor Center, including the USS *Bowfin* and *Bowfin* Park (Photo 1);
- the USS *Arizona* Memorial, the sunken remains of the USS *Arizona* and the east coast of Ford Island; and
- the shoreline adjacent to the HECO Power Plant, including the source location of the oil spill.

The imagery was obtained in four narrow bands at wavelengths of 450, 550 , 650, and 770 nanometers (nm) at approximately 0.6 meters/pixel under cloud cover shadow in the later afternoon after 5:00 p.m. Hawaii Standard Time (HST) on the first day of the oil spill. Processing of these images distinctly shows regions of oil, oil sheen and coastal impacts (TerraSystems 1997). A summary of these selected images is provided in Table 2.

These images demonstrate the broad distribution of the spilled oil on the surface waters of East Loch of Pearl Harbor extending from the upper reaches of East Loch south to Waipio Point on the Waipio Peninsula at the Pearl Harbor entrance channel during the first day of the spill on May 14, 1996. These aerial images also demonstrate the limited success of protective booms which were deployed to provide protection from the spilled oil to the USS *Arizona* Memorial, the sunken remains of the USS *Arizona* and the mouth of Halawa Stream (TerraSystems 1997).

In the second surface water study the Trustees, in cooperation with Chevron, contracted an investigation of the areal extent oil coverage on the surface waters of Pearl Harbor based on analyses of aerial imagery and video overflights. This analysis used digital data entry regarding oil slick position into a Geographic Information System (GIS) application called "Spatial Analyst."

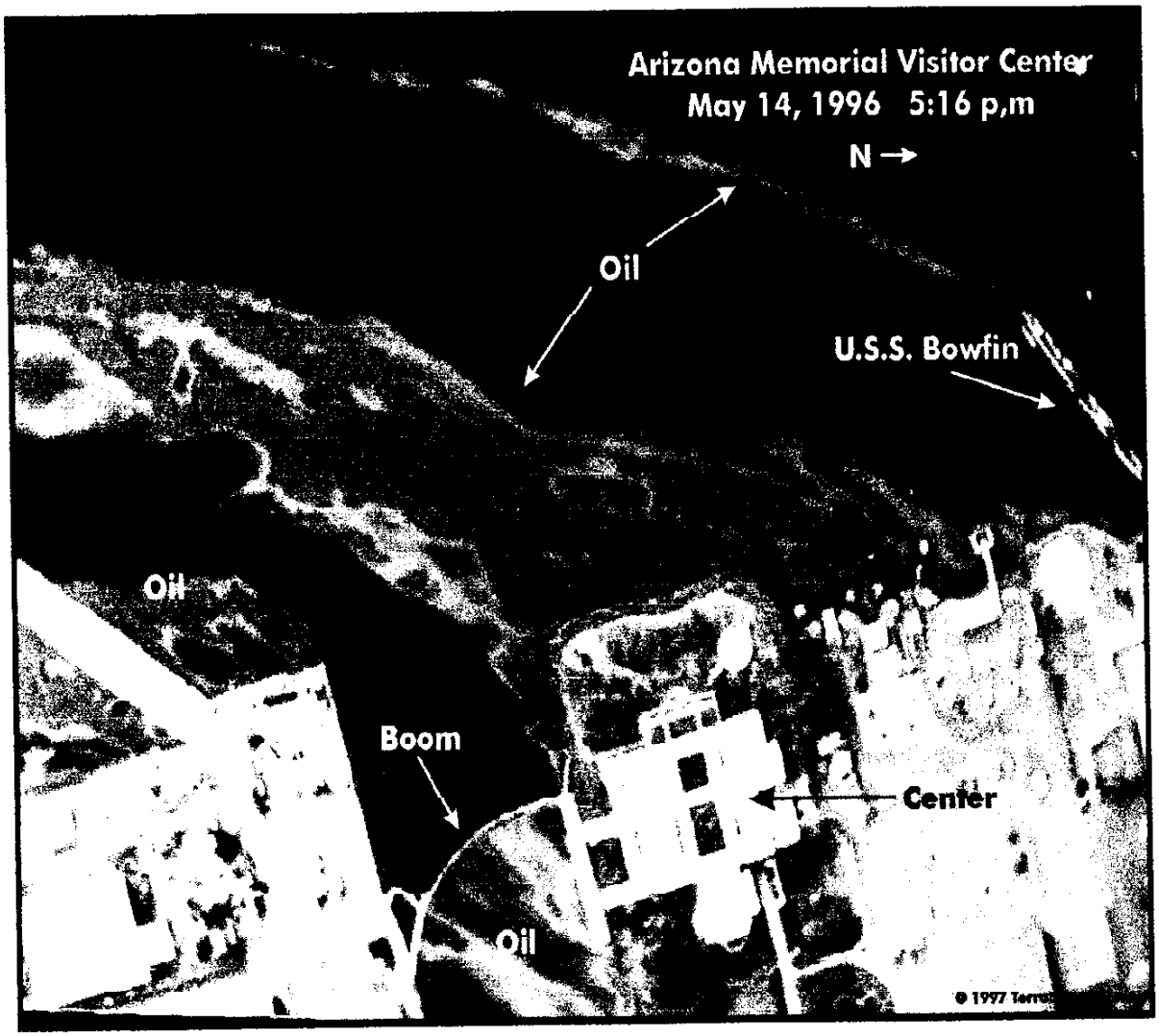

Photo 1. Aerial view of USS *Arizona* Memorial Visitor Center, on the shoreline of East Loch, Pearl Harbor, Oahu, Hawaii on May 14, 1996, 5:16 pm, showing oil on the surface water and shoreline of Pearl Harbor and in the mouth of Halawa Stream (see Section 3.1.3)(Photo courtesy of TerraSystems, Inc.).

Table 2. Summary of selected aerial spectral imagery of surface waters of Pearl Harbor taken on May 14, 1996 (TerraSystems 1997).

location of image	time of day (HST) on May 14, 1996	description of visible oil effects
Hospital Point to Waipio Point	17:04	long bands of oil stretching from Hospital Point to Waipio Point at Pearl Harbor entrance channel
shoreline north of Hospital Point	17:09	a broad band of oil stretching between Ford Island and Hospital Point and shoreline impacts on Ford Island and on the Naval Reservation
USS *Arizona* Memorial Visitor Center shoreline	17:16	a broad swath of oil hitting the entire length of the Visitor Center shoreline, the (now former) Ford Island ferry landing, the USS *Bowfin* and the *Bowfin* Park oil escaping behind a containment boom stretched across the mouth of Halawa Stream from the Visitor Center dock to the USN Pier and impacting the Visitor Center shoreline which the booming strategy intended to protect
USS *Arizona* Memorial and east coast of Ford Island	17:20	a band of oil stretching in a north-south orientation intersecting with the USS *Arizona* Memorial, the emergent turret of the sunken USS *Arizona* remains and the historic mooring quays oil on both sides of the boom deployed to protect the Memorial a band of oil impacting the eastern shoreline of Ford Island
HECO Waiau Power Plant and source of oil spill	~17:10	oil emerging from Waiau Stream, entering East Loch of Pearl Harbor and impacting mangrove-lined shorelines west of Waiau Stream and on the Pearl City Peninsula oil in freshwater marsh

This GIS was then used to calculate total areal coverage of visible oil on the surface waters of Pearl Harbor. The results of this analysis of areal extent of oil coverage of the surface waters of Pearl Harbor is provided in Table 3.

This investigation concluded that over the period of the first six days of the Incident, oil likely covered 2,289.9 acres (9,270,967 m^2) of the surface waters of Pearl Harbor. Oil sheen was directly observed during this period on 1,598.9 acres (6,473,154 m^2). Oil sheen likely affected

Table 3. Calculated areal extent of surface waters in Pearl Harbor demonstrating evidence of oil exposure following the incident, based on GIS Spatial Analyst analyses of multispectral images and video overflights from May 14 - 19, 1996 (Gundlach 1997).

date (1996)	photo or video data source	calculated areal extent (acres and m^2) of oil coverage of surface waters of Pearl Harbor			
		sheen[1]	probable sheen[2]	heavier[3]	probable heavier[4]
May 14	vertical multispectral images from TerraSystems	not calculated	-	16.4 acres 66,219 m^2	-
May 14	TerraSystems high-altitude video overflight taken at 17:00 - 17:30	259.6 acres 1,051,897 m^2	-	18.3 acres 74,083 m^2	-
May 15	unnamed video overflight taken at 12:34 - 12:52	not calculated	-	18.3 acres 74,087 m^2	5.6 acres 22,871 m^2
May 15	Chevron video overflight taken at 17:22 - 17:44	not calculated	not calculated	not calculated	-
May 16	Chevron low-altitude video over-flight taken in late afternoon	1,091.3 acres 4,418,027 m^2	not calculated	not calculated	-
May 17	Chevron video overflight, time of day not specified	363.6 acres 1,472,229 m^2	33.8 acres 136,711 m^2	3.9 acres 116,115 m^2	-
May 19	Chevron video overflight, time of day not specified	371.4 acres 1,503,601 m^2	39.1 acres 158,359 m^2	0.3 acres 1,077 m^2	-
May 14 -19	summary of all video overflights	1,598.9 acres 6,473,154 m^2	55.2 acres 223,283 m^2	64.1 acres 259,326 m^2	5.7 acres 22,871 m^2

[1] characterized as rainbow or silver in color
[2] assumed sheen coverage into/from the out-of-view portion of frame
[3] characterized by darker color
[4] assumed heavier coverage into/from the out-of-view portion of frame

another 690.3 acres (2,794,813 m^2) based on probable transport trajectories and observed shoreline oilings. According to Gundlach (1997), those geographic areas of Pearl Harbor which exhibited oiled surface waters during the first six days of the oil spill include:

- all of Southeast Loch,
- all of East Loch except the northeast reach along the Aiea shoreline,
- the mouth of Middle Loch,
- the mouth of West Loch, and
- the Pearl Harbor entrance channel.

These data, collected by both the Trustees and Chevron, indicate that surface waters were contaminated by the spilled oil. This contamination interrupted services such as navigation, tourism aesthetics, fishing, boating, and swimming. Additionally, surface waters served as a pathway of contamination to shorelines, wetland habitats, fish and wildlife resources, soils, and sediments.

3.1.4 Wildlife

Mostly anecdotal accounts of macrofaunal casualties associated with the Incident exist. One endangered Hawaiian stilt was reportedly found dead as a result of the oil spill (Devine 1996), however, this mortality was not verified by any of the Trustee representatives. The USCG reported that one unidentified bird was oiled and that "some crayfish and frogs" were oiled and killed in Waiau Stream (USCG 1996j). A "couple of dead crawfish and four pufferfish" were collected from Waiau Stream during oil spill response operations (IBRRC 1996).

Chevron developed an independent summary of wildlife reportedly affected by the Incident. Two species of exotic urban birds, two species of fish (including a marine species and a euryhaline species) and one species of aquatic macroinvertebrate were listed in Chevron's report entitled "Waiau Pipeline Spill, Summary of Affected Wildlife" (Chevron 1996). This summary is shown in Table 4.

Elliott (1996) offered the following explanations for the apparent "lack of noticeably impacted native birds" in the area impacted by the oil spill:

- the spill happened at the time of year when most of the migrant bird populations were gone,
- the spill happened at night when birds were not feeding in the area, and
- the human disturbance during the spill cleanup process essentially hazed the birds from the area.

Rapid predation of bird carcasses by feral dogs, feral cats and mongooses also could have contributed to the paucity of recovered oiled birds (Demarest and Elliott 1997).

3.1.5 Marine/Estuarine Biota (Finfish, Shellfish and Invertebrates)

The type of oil discharged on May 14, 1996 has the ability to adversely affect eggs, juveniles and adults of recreationally and commercially valuable finfish and shellfish that depend on the Pearl Harbor estuary for their existence. Additionally, Pearl Harbor serves as a major source of baitfish used by the recreational and commercial skipjack tuna fisheries (=*aku*) (Naughton pers. comm., Oishi pers. comm.).

Table 4. Summary of wildlife affected by the Incident as reported by Chevron (1996).			
affected species[1]	number affected	date reported or collected	comments
mynah bird	2	5/16-17/98	found on north shore of Ford Island floating in oil/water at tide line, disposed of as oily debris
tilapia	1	5/20/98	found on Pearl Harbor Naval Shipyard shoreline, some apparent oiling on dorsal and pectoral fins
pufferfish	4	5/23/98	found at Waiau Power Plant cooling water out-take, no apparent oiling on fish
freshwater prawns	2	5/23/98	found at Waiau Power Plant freshwater pond, oiling apparent
dove (juvenile)	1	5/23/98	found at Waipio Peninsula in shallow water, no apparent oiling
[1] No scientific or Hawaiian names were provided in this report.			

The commercial baitfish fishery within Pearl Harbor is controlled by the USN by permit. The State of Hawaii closed Pearl Harbor to fishing during the spill (Oishi pers. comm.).

The discharged product has been shown in other studies to adversely affect organisms of the type found in the Pearl Harbor estuary. These impacts range from population level disruptions to individual organism effects.

3.2 INJURED NATURAL RESOURCES AND RESOURCE SERVICES

Specific discussion is provided below on the following categories of natural resources and resource services injured as a result of the Incident: intertidal habitat, water column habitat, subtidal habitat, freshwater marsh habitat and human use services.

3.2.1 Intertidal Habitat

The intertidal habitat is defined as that shoreline area which is inundated by sea water during high tide cycles and which is then exposed to the air during low tide cycles. A gently sloping sandy beach or a mudflat will have a significantly wider band of intertidal habitat and, therefore, an increased area of oil exposure opportunity than vertical seawalls or steeply sloped riprapped shorelines. The typical tidal range for Pearl Harbor is about two feet (Grovhoug pers. comm.).

Chevron and the Trustees, each applying a "Habitat Equivalency Analysis" (HEA) to evaluate injury to the intertidal habitat in Pearl Harbor, reached divergent conclusions about the estimated injury to the intertidal habitat:

- the Trustees estimated that 25 acres of intertidal habitat were affected; Chevron estimated that 11.61 acres of intertidal habitat were affected;
- the Trustees considered presence or absence of oil in evaluating each of the four defined shoreline habitat types; Chevron considered three gradations ("heavy," "moderate" or "light") in the presence of oil in each of the four shoreline habitat types;
- the Trustees assumed an initial 80 percent lost services for oiled intertidal habitat; Chevron scaled initial lost services assumptions to the three gradations of oiling: 95 percent initial lost services for "heavy" oiling, 50 percent initial lost services for "moderate" oiling and 10 percent initial lost services for "light" oiling; and
- the Trustees assumed a 10-year recovery period for all 25 acres; Chevron scaled recovery period assumptions to the three gradations of oiling: 4 years for "heavy" oiling, 2 years for "moderate" oiling and 1 year for "light" oiling.

Table 5 describes the Trustees' estimate, in linear feet, of intertidal habitat of East Loch that was likely exposed to oil as a result of the Incident. The Trustees chose to classify intertidal habitat by the four shoreline habitat categories that are predominant in the East Loch: industrial shoreline, mangrove forest, rocky shoreline and mixed sediment shoreline. The Trustees estimated that 77,965 linear feet of intertidal habitat was oiled.

Table 5. Estimated intertidal habitat, by habitat type (industrial shoreline, mangrove forest, rocky shoreline and mixed sediment), oiled in East Loch, Pearl Harbor during the Incident.

oiled intertidal habitat	intertidal habitat type				total intertidal habitat oiled
	industrial shoreline[1]	mangrove forest[2]	rocky shoreline	mixed sediment	
linear feet (feet)	48,330	7,485	15,792	6,358	77,965
area (feet^2)	114,990	374,250	315,846	254,333	1,089,419
area (acres)	3.3	8.6	7.3	5.8	25.0

[1] includes riprap, seawalls and piers
[2] predominately red mangrove (*Rhizophora mangle*)

The Trustees used a multiplier to estimate the area of habitat types impacted. The multiplier considered areas that may have been exposed to oil based on the difference between the highest high tide and the lowest low tide for the period of exposure (*e.g.*, response phase of the spill). The Trustees estimated that 1,089,419 square feet or 25 acres of intertidal habitat were impacted by the oil spill.

The Trustees estimated that initial lost services for the general intertidal habitat of East Loch was about 80 percent. Lost services include many ecological functions such as the reproduction,

survival ability and feeding efficiency of many marine, estuarine and terrestrial species known to carry out one or more of these functions in East Loch. Flora and fauna that were potentially affected by the spill in this habitat include, but are not limited to, a variety of categories such as algae, invertebrates, fish, shorebirds, waterbirds and migratory birds.

Natural communities within the affected 25-acre area were directly and indirectly exposed to oil over time. Residual oil, not retrieved during the response phase, that may have accumulated on vegetation and in sediment could have served as a pathway of exposure to these organisms. The adverse effects of oil may have been realized through absorption and ingestion of oil or oiled prey species.

The Trustees estimate that the intertidal habitat of East Loch may recover to baseline conditions within approximately ten years from the onset of the spill. This estimated recovery period is based on literature that suggests a recovery period of comparable length for intertidal habitats in general (Albers 1991, Cubit *et al.* 1987, Cubit and Connor 1993a, Cubit and Connor 1993b, Jackson *et al.* 1989, Vandermeulen 1984).

3.2.1.1 Resources at Risk

The following three general categories of living intertidal resources in Pearl Harbor were at risk of oil exposure during this Incident: birds, vegetation and intertidal invertebrates.

Birds: A list of birds known to feed, loaf, roost, shelter and in certain cases, nest within the intertidal habitat areas within Pearl Harbor is provided in Table 6. These behaviors provide spilled oil exposure opportunities in the intertidal habitats in Pearl Harbor. Table 6 also provides information about the federal and state protection status of these birds, any reported observations of these birds during oil spill response activities, and a general determination of these species' relative oil spill exposure risk. These species were likely present in the intertidal areas during the general time frame of the Incident in Pearl Harbor and the subsequent cleanup period.

Vegetation: The red mangrove, an introduced species and the dominant intertidal vegetation in East Loch, along with other types of emergent halophytes (*e.g.*, bulrush), were directly exposed to oil during the spill. Mangroves are susceptible to the toxic effects of oil (Vandermeulen 1984). Mangrove forests provide shelter and a network of channels where certain estuarine species find refuge and food during certain life stages (*e.g.*, larvae and juveniles) when they are particularly vulnerable to predation. Consequently, oiling of mangroves and/or retention of oily water could adversely affect other fauna which depend on them for habitat.

Intertidal Invertebrates: Intertidal invertebrates, including crustaceans (*e.g.*, amphipods, isopods, decapods, barnacles), mollusks and polychaete worms, are at risk to shoreline oil exposure. Such intertidal species could be killed by the smothering effect of the oil, by direct toxic effect of the oil, or by invasive shoreline cleanup measures. These invertebrates are important food items for the endangered Hawaiian stilt.

Table 6. Bird species at risk of exposure to spilled oil in the intertidal habitat areas of Pearl Harbor, Oahu, Hawaii, for a time period of six months after the incident.

bird species name			Federal status[1]	State status[2]	reported observation in vicinity of oil spill	oil spill exposure risk[3]
common name	scientific name	Hawaiian name				
WATERBIRDS: coot, Hawaiian	*Fulica americana alai*	*`alae ke`oke`o*	M, E	E	-	high
duck, Hawaiian	*Anas wyvilliana*	*koloa maoli*	M, E	E	-	high
mallard	*Anas platyrhynchos*	-	M	-	-	high
night-heron, black-crowned	*Nycticorax nycticorax hoactli*	*`auku`u*	M	-	(IBRRC 1996) (Elliott 1996)	high
SHOREBIRDS: curlew, bristle-thighed	*Numenius tahitiensis*	*kioea*	M	-	-	high
golden plover, Pacific	*Pluvialis dominica fulva*	*kōlea*	M	-	(IBRRC 1996) (Elliott 1996)	medium
plover, black-bellied	*Pluvialis squatarola*	-	M	-	-	high
sanderling	*Calidris alba*	*hunakai*	M	-	-	high
stilt, Hawaiian	*Himantopus mexicanus knudseni*	*ae`o*	M, E	E	(IBRRC 1996) (Elliott 1996)	high
tattler, wandering	*Heteroscelus incanus*	*`ūlili*	M	-	(IBRRC 1996) (Elliott 1996)	high
turnstone, ruddy	*Arenaria interpres*	*`akekeke*	M	-	(IBRRC 1996) (Elliott 1996)	high
FIELD/URBAN BIRDS: cardinal, northern	*Cardinalis cardinalis*	*`ula`ula*	M	-	(IBRRC 1996) (Elliott 1996)	low
dove, barred	*Geopelia striata*	-	-	-	(IBRRC 1996) (Elliott 1996)	low
egret, cattle	*Bubulcus ibis*	-	M	-	(IBRRC 1996) (Elliott 1996)	low
mynah, common	*Acridotheres tristis*	-	-	-	(IBRRC 1996) (Elliott 1996)	low

[1] E = listed by the USFWS as "endangered" under the Endangered Species Act (ESA).
M = listed by the USFWS as "migratory" and protected under the Migratory Bird Treaty Act.
[2] E = listed by the State of Hawaii as "endangered" under the Conservation of Aquatic Life, Wildlife, and Land Plants Act.
[3] as determined in Demarest and Elliott (1997).

3.2.1.2 Oil: Pathway and Exposure

Response personnel observed oil moving out of the freshwater marsh into East Loch before and after booms were deployed around the tributaries exiting the marsh at the HECO power plant (USCG 1996). The natural environment in East Loch was likely exposed to oil via a number of direct pathways that include water-accommodated fractions (WAFs), oil droplets, oil slicks, oiled substrate, oiled sediment particles, oiled detritus, oil in food items (e.g., in plankton guts, bioaccumulated in bivalves), and oil on food items (*e.g.*, oiled intertidal organisms) (Cubit pers. comm.).

Typically, wildlife is exposed to oil through either direct surface contact, ingestion, absorption or indirect ingestion. Direct contact with oil can foul feathers, matt hair, irritate mucous membranes, and smother animals. Oil droplets on the feathers of adult federally-listed and state-listed endangered waterbirds (*i.e.*, Hawaiian stilts, Hawaiian ducks, Hawaiian coots, or Hawaiian moorhens) may have been transmitted to chicks or eggs. Embryos in the early stage of incubation are especially vulnerable to contact with oil and small quantities ranging from 1 μl to 20 μl may be sufficient to cause death (Parnell *et al.* 1984, Hoffman 1990, Albers 1991).

Inhalation or dermal absorption of the volatile components of oil can injure airways and cause internal toxicity. Organisms can also ingest oil by preening or cleaning their body surface or through direct consumption (*e.g.*, filter feeding or swallowing oil particles). In addition, indirect exposure can occur when oil-contaminated prey is consumed. Waterbirds can be adversely affected from residual surface sheen and oil or indirectly through bioaccumlation processes whereby they ingest tainted invertebrates or vegetation during forage activities (Albers 1995b, Baca *et al.* 1985, Vandermeulen 1984). The extent to which endangered Hawaiian waterbirds were exposed to spilled oil in Pearl Harbor remains uncertain.

3.2.1.3 Evidence of Injury

Table 6 lists the bird species expected to be present in the Pearl Harbor spill zone within six months after the spill. Of these species, the Hawaiian stilt, ruddy turnstone, wandering tattler, golden plover and black-crowned night-heron were observed feeding in the mudflats (colloquially called "Shopping Cart Flats") at the mouth of Waiau Stream (Elliott 1996), an area documented to be exposed to spilled oil (Entrix 1996). Resident and migratory birds could have been negatively impacted by the spill due to direct contact with the oil or diminished food resources and foraging habitat (USFWS 1997).

Direct injury due to the oil is evidenced by a number of factors. The prop roots of many mangroves, which typically provide attachment substrate for various intertidal invertebrate fauna (*e.g.*, crustaceans, mollusks, and bryozoans), were covered with oil (SCAT observations of Divisions A, E and X, July 1996)(USCG 1996). Oiled prop roots eventually become tacky and can result in the loss of viable habitat for these species. Approximately one-quarter of an acre of mangrove forest fronting the HECO power plant at the mouth of Waiau Stream was eventually removed because it was considered a trap for oil and created a risk of exposure to wildlife resources.

Several crab carcasses, four pufferfish (*Arothron* sp.) (= *o'opu hue*), and one pigeon carcass were collected during the spill (Chevron 1996, IBRRC 1996). Oiled sand on several pocket beaches within Pearl Harbor was removed and not replaced leaving a steeper profile to the beach. Sand typically contains small mollusks and crustaceans that are often important food to probing shorebirds and benthic feeding fishes.

In accordance with the Chevron/Trustees MOA, additional field studies concerning the assessment of injury to intertidal habitat and wildlife resources were not undertaken. Instead, Chevron and the Trustees agreed to focus their efforts on restoration.

3.2.1.4 Recovery Period

It is not unreasonable to postulate that the low energy intertidal habitat within Pearl Harbor will take as long as ten years to return to baseline conditions following this spill (Vandermeulen 1984, Albers 1991, Gundlach and Hayes 1978, Cubit *et al.* 1987, Cubit and Connor 1993a, Cubit and Connor 1993b).

3.2.2 Water Column Habitat

The water column habitat comprising the open marine waters of Pearl Harbor include the water's surface and the water column proper extending from the water's surface to the harbor bottom.

3.2.2.1 Resources at Risk

The biological resources of the water column habitat consist of all species living in or on this habitat, including phytoplankton, zooplankton, fish, birds, turtles and marine mammals. These biological resources in the water column also include spores, eggs, larvae, juvenile stages and other life history stages of species whose adult stages may occur primarily in other habitats. For example, eggs and larvae from many species of subtidal and intertidal benthic invertebrates are dispersed into and develop in the water column habitat. The water column habitat of Pearl Harbor supports various commercial, recreational and subsistence finfish as shown in Table 7.

Three species of birds -- the brown booby, the black noddy and the white tern -- sit on, swim in or feed from the water column habitat of Pearl Harbor. These behaviors provide spilled oil exposure opportunities in the open water habitat in Pearl Harbor. Table 8 provides information about the federal and state protection status of these birds and a general determination of these species' relative oil spill exposure risk. These species were likely present on the open water areas during the general timeframe of the incident.

The federally-listed and state-listed threatened Pacific green sea turtle, which feeds on sea grasses and algae in Mamala Bay, has been regularly reported in Pearl Harbor (Naughton pers. comm.). At least one Pacific green sea turtle has been regularly observed in and around the sunken remains of the USS *Arizona* and is thought to be resident in that location (Adams pers. comm.). On March 21, 1998, federally-listed endangered humpback whales, specifically an adult and a calf, were observed within Pearl Harbor. This use of Pearl Harbor by humpback whales is considered an unusual event.

Table 7. Fish species in Pearl Harbor, Oahu, Hawaii, with fisheries values at risk of exposure to spilled oil from the Incident.

fish species name			water column habitat usage			fishery value	
common name	scientific name	Hawaiian name	spawning	nursery	adult forage	commercial	recreational
surgeonfishes	*Acanthuridae* spp.	*manini*	✓	✓	✓	-	✓
eagle ray	*Aetobatus narinari*	*hihimanu*	✓	✓	✓	-	✓
bonefish	*Albula vulpes*	*`o`io*	✓	✓	✓	-	✓
cardinalfishes	*Apogonidae* spp.	*upapalu*	✓	✓	✓	-	✓
soft puffer	*Arothron hispidus*	-	✓	✓	✓	-	✓
sleeper goby	*Asterropteryx semipunctatus*	-	✓	✓	✓	-	✓
parrotfish	*Calotomus spinidens*	-	✓	✓	✓	-	✓
jacks	*Carangidae* spp.	*papio*[2] *ulua*[3]	✓	✓	✓	✓	✓
blacktip shark	*Carcharhinus limbatus*	*manō*	✓	✓	✓	-	✓
butterflyfishes	*Chaetodontidae* spp.	-	✓	✓	✓	-	✓
milkfish	*Chanos chanos*	*awa*	✓	✓	✓	✓	✓
conger eel	*Conger cinreus*	*puhi uha*	✓	✓	✓	-	✓
porcupine-fishes	*Diodontidae* spp.	-	✓	✓	✓	-	✓
Hawaiian tarpon	*Elops hawaiiensis*	*awa`aua*	✓	✓	✓		✓
Hawaiian anchovy	*Encrasicholina purpurea*	*nehu*	✓	✓	✓	✓	✓
gobies	*Gobiidae* spp.	*o`opu*	✓	✓	✓	-	✓
moray eel	*Gymnothorax undulatus*	*puhi*	✓	✓	✓	-	✓
halfbeak	*Hemiramphus depauperatus*	-	✓	✓	✓	-	✓
squirrelfishes	*Holocentridae* spp.	*u`u*	✓	✓	✓	-	✓
Hawaiian flagtail	*Kuhlia sandvicensis*	*āholehole*	✓	✓	✓	-	✓
blacktail snapper[1]	*Lutjanus fulvus*	*to`au*	✓	✓	✓	-	✓

Table 7 (continued).

fish species name			water column habitat usage			fishery value	
common name	scientific name	Hawaiian name	spawning	nursery	adult forage	commercial	recreational
striped mullet	*Mugil cephalus*	*`ama`ama*[2] *anae*[3]	✓	✓	✓	✓	✓
goatfishes	*Mullidae* spp.	*weke*	✓	✓	✓	-	✓
blenny	*Omobranchus elongatus*	-	✓	✓	✓	-	✓
boxfish	*Ostracion meleagris camurum*	-	✓	✓	✓	-	✓
threadfin	*Polydactylus sexfilis*	*moi*	✓	✓	✓	-	✓
damselfishes	*Pomacentridae* spp.	*mamo*	✓	✓	✓	-	✓
lizardfish	*Saurida gracilis*	*ulae*	✓	✓	✓	-	✓
hammerhead shark	*Sphyrna lewini*	*manô kihikihi*	✓	✓	✓	-	✓
barracuda	*Sphyraena barracuda*	*kaku*	✓	✓	✓	-	✓
wrasse	*Stethojulis balteata*	*hinalea*	✓	✓	✓	-	✓
silvery tilapia[1]	*Tilapia melanotheron*	-	✓	✓	✓	-	✓
Mozambique tilapia[1]	*Tilapia mossambica*	-	✓	✓	✓	-	✓
needlefish	*Tylosurus crocodilus*	*aha`aha*	✓	✓	✓	-	✓

[1] an introduced species in Hawaii now considered naturalized.
[2] name used for juveniles.
[3] name used for adults.
(Data from Chevron 1996).

3.2.2.2 Oil: Pathway and Exposure

Gundlach (1997) determined the total geographical surface of Pearl Harbor waters that were exposed to oil from the Chevron spill. As an expert, chosen by the Trustees and agreed to by Chevron, he compiled available records of oil on the shoreline and surface waters of Pearl Harbor during the spill. This included aerial photographs, aerial videos, and shoreline oiling records. He calculated that 2,289.9 acres of surface waters in Pearl Harbor, mostly within East Loch, were exposed to oil during the first three days of the spill.

Table 8. Bird species at risk of exposure to spilled oil on the open, marine water areas of Pearl Harbor, Oahu, Hawaii, as a result of the Incident.

bird species name			Federal status[1]	State status[2]	reported observation in vicinity of oil spill	oil spill exposure risk[3]
common name	scientific name	Hawaiian name				
booby, brown	*Sula leucogaster plotus*	*`ā*	M	-	(Elliott 1996)	high
noddy, black	*Anous minutus melanogenys*	*noio, `eki`eki*	M	-	-	high
tern, white	*Gygis alba rothschildi*	*manu o kū*	M	T	-	high

[1] M = listed by the USFWS as "migratory" and protected under the Migratory Bird Treaty Act.
[2] T = listed by the State of Hawaii as "threatened" under the Conservation of Aquatic Life, Wildlife, and Land Plants Act.
[3] as determined in Demarest and Elliott (1997).

The specific gravity of the spilled oil was between 1.0097 and 1.0052, as determined from samples taken adjacent to the ruptured pipeline (Roberts 1996). The oil sank in the fresh water of Waiau Marsh and was slightly buoyant in the sea water of Pearl Harbor. This relatively dense oil is susceptible to being moved downward in the water column by the following mechanisms (NRC 1985):

- when sorbed onto sediments and other particles in the water column,
- in turbulent conditions (*e.g.*, wave mixing), and
- in zones where currents are downward moving (*e.g.*, convergence portions of Langmuir circulations and in other convergence zones where currents meet).

The last conditions are of note because oil, plankton, neuston and fish also collect in such convergence zones. Consequently, convergence zones concentrate oil and biota in the same locations, exposing water column biota to higher concentrations of oil than would be estimated from average surface area coverage.

Response personnel observed submerged globules of oil being transported under oil booms and out of Waiau Stream. At least some of this oil floated to the water surface when it reached the denser sea water of East Loch (USCG 1996j). Chevron's contractor reported that "[i]n numerous cases, particularly in the immediate vicinity of the spill, oil was observed to be 'suspended' in the water column. This effect was observed in areas of noticeable current flow and/or surface turbulence (waves)" (Entrix 1996).

Water samples were taken by Chevron (AECOS 1996), analyzed by Arthur D. Little (1996), and represented as measures of oil concentrations during the spill (Chevron 1996). However, the incident occurred on May 14, 1996 and the water samples were taken on May 28, 1996, two weeks later. The samples were taken by AECOS, Inc. at three oil-exposed locations in Waiau Bay of East Loch and one "control" location (AECOS 1996). Chevron reported low concentrations of oil in these samples. However, because of the two-week period between spill and sampling, these measurements have little meaning with regard to the concentrations that were in the water column of Pearl Harbor during the May 14-16, 1996 period when most of the oil slicks were moving through the area assessed by Gundlach's (1997) study (see above).

Examples of potential mechanisms through which water column biota can be exposed to spilled oil are the following:

- exposure to components of oil dissolved in water,
- direct contact with free oil in the water column,
- ingestion of particulate oil in the water, and
- feeding on food items contaminated with oil.

As examples of the third mechanism above, filter feeders and particulate feeders, such as zooplankton and Hawaiian anchovy, probably ingested oil particles from the water column (as described in NRC 1985). As examples of the fourth mechanism above, Hawaiian anchovy probably fed on zooplankton containing ingested oil. In addition, scavenger and predatory fish probably fed on subtidal and intertidal fauna contaminated with oil.

3.2.2.3 Evidence of Injury

Evidence of injury to water column biota consists of inferential evidence and a study based on photo documentation (Gundlach 1997). As noted above, according to the Chevron/Trustee MOA, the Trustees did not conduct detailed formal studies to determine and quantify injury. Inferential evidence of injury to water column biota is based on preliminary estimates of oil exposure and its potential adverse effects as determined from published field and laboratory studies relative to the estimated exposure to the same or similar oil.

The University of California at Santa Cruz (UCSC) laboratory studies of toxicity of the spilled Chevron oil to mysid shrimp (UCSC 1996) do not apply here because:

- the laboratory mysids were only exposed to the dissolved portion of this low-solubility oil, without exposure by direct contact with the oil or ingestion of oil particles as would have occurred in Pearl Harbor.
- the mysids were only exposed to oil for a few hours, whereas the biota of Pearl Harbor would have been exposed for much longer periods of time, especially during the first three days of the spill.
- the laboratory exposure of mysids was conducted at a water temperature of 14.3°C which is much colder than the average water temperature of 26°C in Pearl Harbor (Evans and Morris 1974). For a given concentration of oil in water, toxicity increases with temperature (for review, see Mayer and Ellersieck 1986).

- the laboratory mysids were not exposed to photo-oxidative products of the oil which include chemicals that are more soluble and more toxic than the original oil (Payne and McNabb 1983). Exposure of oil to sunlight in Pearl Harbor could have produced such compounds; and
- the laboratory mysids were only examined for acute (short-term) lethal or narcotic effects of the oil. The laboratory mysids were not examined for longer term survival or adverse effects of the oil on factors such as predator avoidance, swimming ability, feeding ability or reproductive success.

In accordance with the Chevron/Trustee MOA, additional field studies concerning the assessment of injury to fish and other water column biota were not undertaken. The spilled oil had a low acute toxicity, and therefore, adverse effects resulting from exposure to the spilled oil were not likely to have produced immediate mass mortality of most species. Consequently, lack of evidence for mass mortality is not evidence that the spill caused no adverse effects. Adverse effects of the oil, if any, were more likely to have been manifested in slow (not acute) rates of mortality or in adverse effects that were sublethal. Because the number of predatory and scavenging fish present in Pearl Harbor, edible biota that died or that were behaviorally impaired were likely to have been eaten by scavengers or predators before they could be found by personnel present during the spill (Grovhoug pers. comm.). Therefore. actual observed evidence of injury should be considered to represent a small proportion of total injury and be extrapolated accordingly.

During the spill, personnel collected four dead pufferfish (Chevron 1996, IBRRC 1996). These have been stored in a DLNR freezer and the cause of death has not been determined. In addition, one dead spiny balloonfish (*Diodon holocanthus*) (= *kokala*) was found near the spill release site (Cubit pers. comm.), and dead tilapia were found near the USN docks (Chevron 1996).

Inferred injury to water column biota includes reduced primary production, reduced secondary production and adverse effects of oil on fish reproduction and early fish development (as reviewed and described in Weis and Weis 1989). The oil may have had other adverse effects on fish, for example, by impairing avoidance of predators and reducing rates of feeding growth and long-term survival. Oil has been reported to reduce plankton populations (NRC 1985).

3.2.2.4 Recovery Period

The dimensions of the water column injury are spatial extent, severity and duration of injury. The analysis by Gundlach (1997) indicates approximately 2,300 acres of East Loch and adjoining areas were exposed to oil slicks from the Incident. Multiple pathways exist to expose zooplankton and fish to this oil. The Trustees estimate that adverse effects of oil on plankton, fish, and other water column biota would have resulted in approximately 10 percent lost services over this 2,300 acres. While a sigmoid recovery time-path may be technically appropriate, the linear time-path used by the Trustees in their HEA was considered to be a reasonable approximation over the recovery period considered.

3.2.3 Subtidal Habitat

The subtidal habitat in Pearl Harbor includes those harbor bottom areas which are perpetually submerged by water.

3.2.3.1 Resources at Risk

Subtidal habitats in Pearl Harbor include hard substrata such as submerged natural rock, riprap, cement and sheet metal piling walls and pier pilings; and soft substrata, such as sand and mud bottom.

A variety of recreationally important invertebrate species, including bivalves and crustaceans, use the subtidal, benthic habitats in Pearl Harbor. These invertebrates, both native and exotic species, occupy this subtidal habitat for spawning, nursery areas and as adult forage area. Table 9 provides a summary of those invertebrate species with fishery value that use the subtidal habitat of Pearl Harbor. Numerous other species of invertebrates (*e.g.*, gastropods, polychaetes, ascidians) are also found on the hard and soft substrata of Pearl Harbor (Coles *et al.* 1997).

Shellfish and other aquatic invertebrates generally have less efficient metabolic systems than do finfish for breaking down petroleum products. Shellfish can take in hydrocarbons directly from seawater or by ingesting oil droplets, tainted food or contaminated sediments. Crustaceans, such as crabs, are able to transform petroleum hydrocarbons to polar metabolites that may be excreted or bound to tissues. Bivalve mollusks, including clams and oysters, lack efficient enzyme systems to metabolize petroleum compounds (Chevron 1996).

3.2.3.2 Oil: Pathway and Exposure

Biota in subtidal habitats would be exposed to the heavy spilled oil through the same mechanisms as described above for the Water Column Habitat. In addition, the Oil in the Sea report (NRC 1985) lists the following as the "most important" mechanisms by which oil can reach subtidal sediments:

- sorption of oil to particles including mineral sediments, detritus and plankton;
- ingestion of oil by zooplankton and incorporation into fecal pellets;
- weathering of oil by physical and chemical processes; and
- direct mixing of oil and sediments.

Regarding sorption of oil to particles, this dense oil (specific gravity 1.0097 to 1.0052) (Roberts 1996) would readily sink if it incorporated sand or other mineral sediment. SCAT team members observed tar mats in the subtidal zone. Sorbent pad sampling near the release site adjacent to the Waiau Power Plant did not find visible amounts of oil on sediments in this location (USCG 1996, Naughton pers. comm., Chevron 1996). Shortly after the spill, however, independent sampling of surficial bottom sediments for an NPL investigation found visible free oil of undetermined origin in subtidal bottom sediments in Pearl Harbor (Grovhoug pers. comm.).

Table 9. Subtidal invertebrate species, including bivalves and crustaceans, in Pearl Harbor, Oahu, Hawaii, with fishery value at risk of exposure to spilled oil from the incident

invertebrate species name			subtidal habitat usage			fisheries value	
common name	scientific name	Hawaiian name	spawning ground	nursery ground	adult forage	com-mercial	recrea-tion
Bivalves: Japanese oyster[1]	*Crassostrea gigas*	-	✓	✓	✓	-	✓
Eastern oyster[1]	*Crassostrea virginica*	-	✓	✓	✓	-	✓
common littleneck clam[1]	*Protothaca staminea*	-	✓	✓	✓	-	✓
Crustaceans: Hawaiian crab	*Podophthalmus vigil*	-	✓	✓	✓	-	✓
white crab	*Portunus sanguinolentus*	*kuahonu*	✓	✓	✓	-	✓
mangrove crab (or Samoan crab)[1]	*Scylla serrata*	-	✓	✓	✓	-	✓
slipper lobster	*Scyllarides squammosus*	*ula papapa*	✓	✓	✓	-	✓
stone crab	*Thalamita crenata*	-	✓	✓	✓	-	✓
glass shrimp (or Hawaiian prawn)	*Macrobrachium grandimanus*	*opae*	✓	✓	✓	-	✓

[1] These species are not native to Hawaii but are now considered naturalized.
(Data provided in Chevron 1996, Oishi pers. comm.)

The most likely contamination of subtidal sediments would be adjacent to heavily oiled beaches where the oil could pick up sediment and sink into the subtidal zone (Entrix 1996). Oiled sediment and oiled debris could also be transported from these beaches into the subtidal zone (Cubit pers. comm.). Lengths of shoreline were oiled by this spill which, in turn, could have contributed oil to the adjacent subtidal habitats. However, subtidal locations adjacent to oiled shorelines were not sampled as part of the oil spill investigations during this incident. Further, pocket sand beaches along the eastern shoreline of the Waipio Peninsula continued to be oiled even after daily cleaning until at least early July 1996, approximately seven to eight weeks following the spill (Oishi pers. comm.), suggesting that all oil sources had not been located and removed. Oil from these sites could have subsequently migrated into subtidal habitats.

3.2.3.3 Evidence of Injury

In accordance with the Chevron/Trustee MOA, additional field studies concerning the assessment of injury to the subtidal habitat and associated living resources were not undertaken. Scientists from the Bernice P. Bishop Museum made some incidental observations in a few partially oiled locations as part of another study and reported that nothing seemed to be injured some weeks after the spill (Coles *et al.* 1997). However, the Bishop Museum observations, at best, would have only detected obvious injury that would have persisted from the time of the spill to the time the Museum investigators visited their sites (*e.g.*, lasting discoloration or necrosis of sessile organisms such sponges and ascidians). The Bishop Museum observations were not designed to specifically investigate effects of this spill and did not include the following:

- sites of heaviest oiling;
- biota that would have decomposed, washed away, sank, been scavenged or otherwise disappeared if killed by oil;
- systematic observations for effects of oil; and
- sublethal effects that would not have been obvious to the casual observer, such as long-term decreased survivorship or reduced reproduction.

All evidence of injury to subtidal benthic biota is inferred from preliminary estimates of oil exposure and its potential adverse effects as determined from published field and laboratory studies demonstrating adverse effects relative to the estimated exposure to same or similar oil. The UCSC studies (UCSC 1996) of toxicity of the Chevron oil do not apply here for the same reasons explained in the prior section on Water Column Habitat.

Injury to subtidal biota is inferred from exposure of the biota through probable direct contact with and ingestion of oil. Adverse effects of such exposure on subtidal biota would include decreased rates of growth, reduced long-term survivorship and decreased rates of reproduction. For example, these effects could be the consequences of oil causing reduced feeding, reduced avoidance of predators, and interference with endocrine functions.

3.2.3.4 Recovery Period

Total injury to subtidal biota is measured in terms of spatial extent, severity, and duration of injury. The Trustee estimates of total injury are based on preliminary estimates of exposure to oil and the consequent adverse effects on subtidal biota. Duration of injury is estimated from estimates of spatial extent and severity of injury in combination with life history information. Examples of factors that affect duration of injury include:

- life stages of subtidal bottom fauna and flora that were adversely affected by the spill (*e.g.*, production of eggs and larvae, survival of juveniles and adults),
- abundance of individuals surviving the spill,
- reproductive rate of surviving individuals,
- immigration of individuals from other areas, and
- life span of individuals belonging to the adversely affected species.

As an initial estimate of injury to subtidal biota, the Trustees considered that most injury probably occurred adjacent to heavily oiled beaches. Accordingly, they estimated that 5 acres of subtidal habitat suffered 30 percent lost services. While a sigmoid recovery time-path may be technically appropriate, the linear time path used by the Trustees in their HEA was considered to be a reasonable approximation over the recovery period considered.

3.2.4 Freshwater Marsh Habitat

The Trustees estimated that about two acres of freshwater marsh on the HECO power plant property near the mouth of Waiau Stream were affected by the spill. This estimate was later confirmed by the property owners and used by Chevron in their HEA (Entrix 1996, Foster pers. comm.).

The oil spill resulted in approximately 982 bbls. (41,244 gals.) of No. 6 fuel oil spilling into the stream (Chevron 1996). The petroleum product flowed downstream into the two-acre freshwater marsh on HECO power plant property. The warm oil initially floated into the marsh and permeated the emergent vegetation, predominately California grass (*Brachiaria mutica*). As the oil cooled, it sank to the bottom of the marsh creating subpools and then became incorporated into sediments (Entrix 1996).

Approximately two acres of oiled California grass was removed by Chevron as part of the response effort (Entrix 1996). Therefore, it is reasonable to assume that the volume of oil that infiltrated the marsh negatively impacted all flora and fauna found within this habitat. Sessile organisms [*e.g.*, Asiatic clams (*Corbicula fluminea*)] were smothered by the settling of the oil on the marsh sediment. Birds, fish and invertebrates that frequent the marsh were at risk of exposure with the oil in the marsh. Therefore, the Trustees believe that 100 percent of the freshwater marsh's ecological services were lost as a result of the spill.

The Trustees estimate, based on a literature review, that recovery of the freshwater marsh will take at least ten years (Albers 1995a, Baca *et al.* 1985, Gundlach and Hayes 1978, Foght and Westlake 1984) and perhaps as many as 15 to 20 years (API 1991) before the marsh is fully recovered. Biodegradation of the residual oil may be mitigated due to the penetration of the oil in the sediment and vegetation of the marsh (Foght and Westlake 1984). The nature of this low energy environment also reduced the effectiveness of weathering processes that degrade surface oil and sheen. As residual sheen and oil become mobilized, fish, invertebrates, algae and vegetation will continue to be exposed to oil and its photo-oxidized byproducts thereby posing a direct and indirect exposure threat to federally-listed and state-listed endangered waterbirds that feed opportunistically in this area of Pearl Harbor (USFWS 1997).

3.2.4.1 Resources at Risk

The following three general categories of living freshwater marsh resources in the vicinity of Waiau Stream were at risk of oil exposure during this Incident: birds, aquatic fauna and vegetation.

Birds: A list of birds known to feed, forage, loaf or nest in the freshwater marsh habitat within East Loch, Pearl Harbor is provided in Table 10. These behaviors provide spilled oil exposure opportunities in the Waiau Stream freshwater marsh habitat in Pearl Harbor. Table 10

Table 10. Bird species at risk of exposure to spilled oil in the freshwater marsh habitat area of East Loch, Pearl Harbor, Oahu, Hawaii, as a result of the incident.

bird species name			Federal status[1]	State status[2]	reported observation in vicinity of oil spill	oil spill exposure risk[3]
common name	scientific name	Hawaiian name				
WATERBIRDS: coot, Hawaiian	*Fulica americana alai*	*`alae ke`oke`o*	M, E	E	-	high
duck, Hawaiian	*Anas wyvilliana*	*koloa maoli*	M, E	E	-	high
mallard	*Anas platyrhynchos*	-	M	-	-	high
moorhen, Hawaiian	*Gallinula chloropus sandvicensis*	*`alae `ula*	M, E	E	-	high
night-heron, black-crowned	*Nycticorax nycticorax hoactli*	*`auku`u*	M	-	(IBRRC 1996) (Elliott 1996)	high
pintail, northern	*Anas acuta*	*koloa māpu*	M	-	-	high
shoveler, northern	*Anas clypeata*	*koloa mohā*	M	-	-	high
SHOREBIRDS: golden plover, Pacific	*Pluvialis dominica fulva*	*kōlea*	M	-	(IBRRC 1996) (Elliott 1996)	medium
stilt, Hawaiian	*Himantopus mexicanus knudseni*	*ae`o*	M, E	E	(IBRRC 1996) (Elliott 1996)	high
tattler, wandering	*Heteroscelus incanus*	*`ūlili*	M	-	(IBRRC 1996) (Elliott 1996)	high
turnstone, ruddy	*Arenaria interpres*	*`akekeke*	M	-	(IBRRC 1996) (Elliott 1996)	high
FIELD AND URBAN BIRDS: cardinal, northern	*Cardinalis cardinalis*	*`ula`ula*	M	-	(IBRRC 1996) (Elliott 1996)	low
dove, barred	*Geopelia striata*	-	-	-	(IBRRC 1996) (Elliott 1996)	low
egret, cattle	*Bubulcus ibis*	-	M	-	(IBRRC 1996) (Elliott 1996)	low
mynah, common	*Acridotheres tristis*	-	-	-	(IBRRC 1996) (Elliott 1996)	low

[1] E = listed by the USFWS as "endangered" under the Endangered Species Act.
M = listed by the USFWS as "migratory" and protected under the Migratory Bird Treaty Act.
[2] E = a species listed by the State of Hawaii as "endangered" under the Conservation of Aquatic Life, Wildlife, and Land Plants Act.
[3] as determined in Demarest and Elliott (1997).

also provides information about the federal and state protection status of these birds and a general determination of these species' relative oil spill exposure risk. These species were likely present in the freshwater marsh during the general timeframe of the Incident and the extended period afterwards when oil still remained in the marsh.

Aquatic Fauna: The aquatic fauna of the freshwater marsh near the mouth of Waiau Stream is predominately exotic. Table 11 provides a list of common or conspicuous aquatic fauna found in freshwater marsh areas of Pearl Harbor including information about the economic use value of these species.

Table 11. Common aquatic fauna in freshwater marsh areas around Pearl Harbor, Oahu, Hawaii, including information about economic use value (Foster pers. comm.)

aquatic species name		native (N) or exotic (E)	economic use value	
common name or *Hawaiian name*	scientific name		subsistence	recreational
MOLLUSKS: Asiatic clam	*Corbicula fluminea*	E	✔	-
[no common name]	*Vivaparious chinensis*	E	-	-
CRUSTACEANS: freshwater shrimp	*Atyoida bisulcata*	N	-	-
Tahitian prawn	*Macrobrachium lar*	E	✔	✔
Malaysian giant prawn	*Macrobrachium rosenbergii*	E	✔	✔
crayfish	*Procambarus clarkii*	E	✔	✔
FISHES: North American ciclid	*Cichlasoma citinellum*	E	-	-
goby or *o opu a kupa*	*Eleotris sandwicensis*	N	-	-
mosquitofish	*Gambusia affinis*	E	-	-
goby	*Mugilgobius cavifrons*	E	-	-
tilapia	*Tilapia macrochir*	E	✔	✔
tilapia	*Tilapia melanopleura*	E	✔	✔
silvery tilapia	*Tilapia melanotheron*	E	✔	✔
Mozambique tilapia	*Tilapia mossambica*	E	✔	✔
red-bellied tilapia	*Tilapia zilli*	E	✔	✔
AMPHIBIANS: marine toad	*Buffo marinus*	E	-	-
bullfrog	*Rana catesbiana*	E	✔	✔

Vegetation: The dominant vegetation in the freshwater marsh near the mouth of Waiau Stream is California grass. Water lettuce (*Pistia stratiotes*) and parrot's-feather (*Myriophyllum brasiliense*) are common vegetation in the marsh. Water lettuce and parrot's-feather are particularly important to the federally-listed and state-listed endangered Hawaiian moorhen for forage and for shelter.

3.2.4.2 Oil: Pathway and Exposure

This section identifies the presence of oil in the marsh, its general path from the spill site through the marsh and into Pearl Harbor, and extent of exposure. Approximately two acres of freshwater marsh were impacted by oil at the time of the spill.

Response personnel observed an oil leak from the Chevron pipeline into Waiau Stream. The oil flowed through the freshwater marsh at the HECO power plant facility near the mouth of Waiau Stream and emptied into Pearl Harbor. This observation is documented in USCG SCAT reports (USCG 1996). Also, oil in the freshwater marsh was documented by TerraSystems (1997) during an overflight event and by Entrix (1996).

Typically, wildlife is exposed to oil through either direct contact or ingestion or through indirect ingestion. Direct contact with oil can foul feathers, matt hair, irritate mucous membranes, and smother animals. Smothering, due to the volume of oil in the marsh, is likely to have impacted slow moving or sessile organisms that inhabited the marsh. Inhalation or dermal absorption of the volatile components of oil can injure airways and cause internal toxicity. Organisms can also ingest oil by preening or cleaning their body surface or through direct consumption (*e.g.*, filter feeding or swallowing oil particles). In addition, indirect exposure can occur when oil contaminated prey is consumed.

Vegetation is typically impacted by direct contact that coats the plant. There is some evidence that root hairs are also negatively impacted by oil penetrating the sediment.

3.2.4.3 Evidence of Injury

Approximately two acres of California grass, including roots and emergent vegetation, were dug up manually by Chevron employees and removed (Entrix 1996). California grass continues to be impacted as a result of the initial oil recovery efforts (Foster pers. comm.). Aquatic vegetation in the marsh continues to be oiled by residual oil that is remobilized from the marsh sediments. This oiling diminishes its value as wildlife habitat.

Certain invertebrate species inhabiting the freshwater marsh could have been affected by the oil. A possible die-off of Asiatic clams, as evidenced by large numbers of empty shells littering the muddy bottom, was observed in this vicinity two months after the spill and again ten months after the spill (Oishi pers. comm.). Crayfish (*Procambarus clarkii*) were reported oiled and killed in Waiau Stream (USCG 1996j).

Residual oiling of parrot's-feather and water lettuce was observed in the freshwater marsh (Foster pers. comm.). These plant species are important shelter vegetation for the Hawaiian moorhen.

Also, the Hawaiian moorhen is known to forage for arthropods found on this vegetation (Foster pers. comm.).

Potential or probable injury likely occurred during the general time period of the spill. Some of the benthic invertebrates in the freshwater marsh, such as freshwater prawn (*Macrobrachium lar)* were likely impacted by either ingestion of oil or by smothering. The reduction of aquatic plants may impact birds *(e.g.*, Hawaiian ducks, Hawaiian moorhens, and Hawaiian coots) by reducing forage, predator protection, and nesting areas. It is likely that freshwater gobies (*Mugilgobius cavifrons*) were impacted either by ingestion of oil or smothering. It is also likely that waterbirds have been impacted by the initial and residual oil and sheen in the water column and along the waterline of the vegetation. Waterbirds are naturally attracted to open water spaces. With the loss of open water habitat in the Pearl Harbor area, it is likely that waterbirds have been attracted to the freshwater marsh, especially during periods when human activity in the marsh was low to none.

The probable die off of freshwater fish (*e.g.*, tilapia, mosquitofish) and invertebrate fauna likely resulted from ingestion of oil or smothering during the release of oil into the marsh. The normal behavior of birds within the vicinity of the marsh was likely disrupted by response crews during protracted cleanup.

In accordance with the Chevron/Trustee MOA, additional field studies concerning the assessment of injury to the freshwater marsh habitat and wildlife resources were not undertaken. However, the DOH and the USEPA are working with Chevron to further examine the risk to human health and the environment posed by the residual oil. Chevron has since contracted with Dames and Moore consultants to evaluate the ongoing risk of oil in the freshwater marsh. The final outcome of this evaluation has not yet been made available (Dames and Moore 1997).

3.2.4.4 Recovery Period

The Trustees used a recovery period of ten years in their HEA. However, based on a more thorough review of literature, the Trustees now estimate that full recovery may not be realized for 15 to 20 years in the freshwater marsh (Albers 1995a; API 1991).

3.2.5 Human Use Services

3.2.5.1 Tourism

Lost visitor use at the USS *Arizona* Memorial represents a disruption of services provided by the marine environment and thereby constitutes an injury in accordance with the OPA regulations (15 CFR Part 990.30). Lost visitor use at the Memorial includes:

- lost visits due to the closure of the Memorial immediately after the oil spill,
- lost public donations to the Memorial during the closure, and
- diminished number or quality of visits due to response actions that interfered with visitor experiences after the Memorial re-opened.

The causal link between the oil spill and this lost visitor use was established by the presence and duration of spilled oil at the Memorial and by the response actions conducted at the Visitor Center to remove the spilled oil.

The NPS closed the Memorial for four days immediately following the oil spill to assure public safety during extensive response actions at the Visitor Center. As a result of this closure, the public was denied the use and enjoyment of the Memorial contrary to the intent of Congress and the management objectives of the NPS (NPS 1983). The Memorial is one of the most popular tourist sites in Hawaii, drawing more than 1.5 million visitors a year. These visitors generally travel substantial distances (from the continental United States and from foreign countries) and likely incur substantial travel costs to see the Memorial. The NPS estimated approximated 16,200 visits were lost during the closure. Additionally, an estimated $2,843 in public donations to the Memorial were lost during the closure (Billings pers. comm.).

After the Memorial re-opened on May 18, 1996, the quality of visitor experiences was diminished by ongoing response actions at the Visitor Center. These response actions were required to remove spilled oil from the Visitor Center shoreline. To accommodate these actions, the entire back lawn of the Visitor Center was roped off, excluding the public from approximately 25 percent of the Visitor Center area that is normally open for public use, not including the parking lot. This landscaped area is oriented toward Pearl Harbor and includes the popular Remembrance Exhibit and an interpretive walk-path. A special Memorial Day observance in 1996, in which 34 new plaques at the Remembrance Exhibit were to be dedicated, had to be postponed because of these response actions. These response actions also obstructed visitors' views of the final resting place of the USS *Arizona* and the historic landscape of Pearl Harbor. Additionally, 50 percent of the parking lot that is normally open for public use was occupied as a staging area for the ongoing response actions. The NPS estimated that the quality of approximately 24,220 visits were diminished by these response actions (Billings pers. comm.).

3.2.5.2 Recreation

A portion of the public bicycle/jogging path, owned and operated by the City and County of Honolulu's Department of Public Works and which runs around the margin of East Loch was closed to the public for cleanup operations from May 14 to June 1, 1996 (see Appendix A.2).

3.2.5.3 Fisheries

A commercial baitfish fishery for Hawaiian anchovy exists in Pearl Harbor. Commercial skipjack tuna boats, under permit to the USN, are allowed to fish in certain regions of Pearl Harbor. The DOH closed Pearl Harbor to commercial and recreational fishing during an unspecified period following the May 14, 1996 release of oil into Pearl Harbor. This fishing closure was accomplished by the posting of signs at prominent shoreline access points around Pearl Harbor. An unknown number of commercial baitfish fishing opportunities in Pearl Harbor were lost following the oil spill.

3.2.5.4 Naval Operations

Injuries to Naval operations, construction projects, studies and other Navy activities are outside the scope of this Final RP/EA. The United States reserves its rights with respect to any and all such matters.

3.3 ASSESSMENT APPROACH

The goal of injury assessment under OPA is to determine the nature and extent of injuries to natural resources and services, thus providing a technical basis for evaluating the need for, type, and scale of restoration actions. The assessment process occurs in two stages: (1) injury determination, and then (2) injury quantification.

Injury determination begins with the identification and selection of potential injuries to investigate. In accordance with the OPA regulations, the Trustees considered several factors when making this determination, including but not limited to the following:

- the natural resources and services of concern;
- the evidence indicating exposure, pathway, and injury;
- the mechanism by which injury occurred;
- the type, degree, and spatial and temporal extent of injury;
- the adverse change or impairment that constitutes injury;
- available assessment procedures and their time and cost requirements;
- the potential natural recovery period; and
- the kinds of restoration actions that are feasible.

The list of potential injuries investigated for the Incident is provided in Table 12. As indicated in this Table, the Trustees evaluated possible injuries to nine categories of ecological and human use loss. These categories were selected based on input from the Preassessment Phase activities: local, state, and federal government officials; Chevron; and academic and other experts knowledgeable about the affected environment.

For each potentially injured resource category, the Trustees determined:

- whether it was likely that an injury had occurred,
- the nature of the potential injury, and
- a causal link between the potential injury and the oil spill.

Injury is defined by the OPA regulations as "an observable or measurable adverse change in a natural resource or impairment of a natural resource service. Injury may occur directly or indirectly to a natural resource and/or service" (15 CFR 990.30). The assessment methodologies used for the Incident are described in Table 12.

Where feasible, the Trustees used simplified, cost-effective procedures and methods to document injuries to natural resources and services.

Table 12. Potentially Injured Resources and Associated NRDA Assessment Methods used for the Incident.		
Potentially Injured Resources	Assessment Methods:	
	Ecological Services	*Human Use Services*
1. Air Resources	Use site investigations, *e.g.*, ambient air sampling	Use site investigations, *e.g.*, ambient air sampling.
2. Federal Lands	Compare affected area conditions with historic and reference data.	Compare affected use data with historic use data.
3. State/Local Lands	Compare affected area conditions with historic and reference data.	Compare affected use data with historic use data.
4. Surface Water	Use site investigations, relevant scientific literature, and best professional judgment of experts.	Compare affected use data with historic use data.
5. Groundwater	Compare affected aquifer conditions with historic and reference data.	Compare affected use data with historic use data.
6. Water Column	Use computer models or site investigations, primary productivity data, relevant scientific literature, and best professional judgment of experts.	--
7. Bottom Sediments	Use computer models or site investigations, relevant scientific literature, and best professional judgment of experts.	--
8. Wetlands	Use site investigations, relevant scientific literature, and best professional judgment of experts.	--
9. Wildlife	Estimate impacts to species/populations using site investigations, relevant scientific literature, and best professional judgment of experts.	
10. Marine/Estuarine Biota	Use site investigations, relevant scientific literature, and best professional judgment of experts.	--

In selecting appropriate assessment procedures, the Trustees considered:

- the range of procedures available under section 990.27(b) of the OPA regulations;
- the time and cost required to implement the procedures;
- the potential nature, degree, and spatial and temporal extent of the injury;
- the potential restoration actions considered for the injury;
- the relevance and adequacy of information generated by the procedures to meet information requirements of restoration planning; and
- the input/suggestions of Chevron.

Accordingly, depending on the injury category, the Trustees generally relied on site investigations, relevant scientific literature, literature-based calculations, and best professional judgment of experts.

Following these procedures, the Trustees determined, as described above, that injury likely occurred in the following five categories:

- freshwater marsh habitat in Waiau Stream,
- intertidal habitat in Pearl Harbor,
- subtidal habitat in Pearl Harbor,
- water column habitat in Pearl Harbor, and
- human use services related to the USS *Arizona* Memorial.