PRELIMINARY

ENVIRONMENTAL IMPACT ASSESSMENT
HOPE-X LANDING SITE FACILITIES
KIRITIMATI (CHRISTMAS) ISLAND
REPUBLIC OF KIRIBATI

Prepared for

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For Submittal to

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Betio, Tarawa
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1.0 INTRODUCTION

1.1 PROJECT CONCEPT

1.1.1 Japan's Space Program

Japanese development of space technologies is spearheaded by the National Space Development Agency of Japan (NASDA). Organized in 1969, NASDA conducts research in areas such as Earth observation systems, tracking and data acquisition, satellite systems, and launch vehicles, including the H-II launch vehicle. NASDA's mission is to develop new technologies to promote further productive uses of space. Additional information is available at NASDA's web site, www.nasda.go.jp/home/.

1.1.2 The HOPE Program

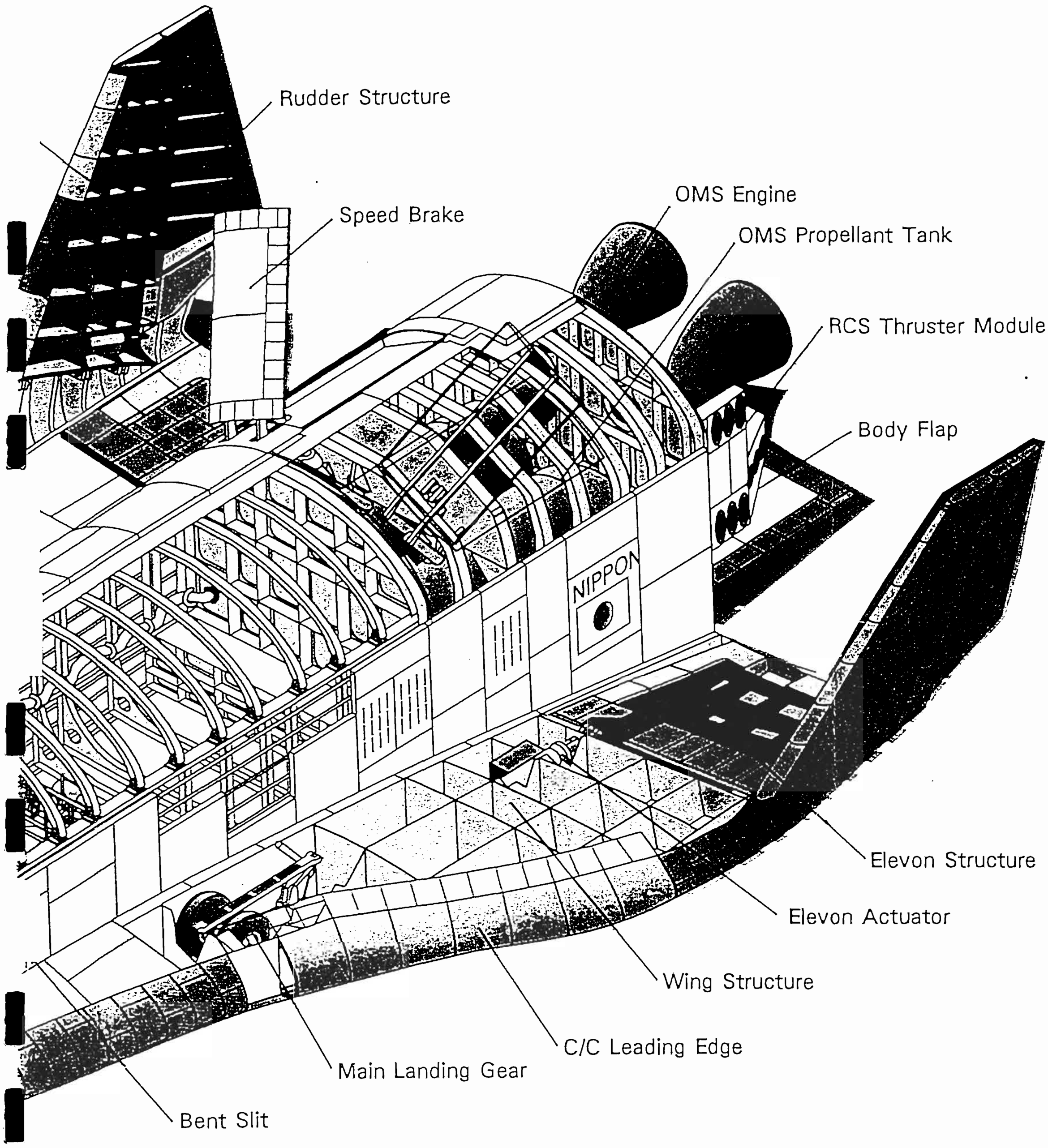
A major thrust of the Japanese space program is development of new space transportation systems. This requires development of appropriate launch vehicles and complexes, as well as development of a transporter vehicle itself. The latter requirement is the focus of the "H-II Orbiting Plane" (HOPE) program. The HOPE vehicle (Figure 1-1) is envisioned as a means of replenishing and retrieving materials from space stations and as an operational platform in orbit. It is an unmanned vehicle that will be capable of carrying out a variety of observations and experiments (science and engineering, communications, materials, biotechnology, life sciences, etc.).

The technology necessary to develop an operational HOPE vehicle is being developed in several sub-programs. Of primary interest to this Environmental Impact Assessment (EIA) is the HOPE-X program. The HOPE-X is a technology test vehicle being developed to establish the systems technology required for completing the HOPE. As this vehicle is a developmental stage of the HOPE, it will have no payload; it is itself an experimental vehicle. It is envisioned that the HOPE-X will be launched from the Tanegashima Space Center in Japan, and after reaching an altitude of about 110 kilometers, will separate from the launch vehicle, complete one revolution of the earth, and to reenter the atmosphere to land on Christmas Island (See Figure 2-7).

Several other sub-programs have been carried out to develop technologies to support the HOPE vehicle. The Automatic Landing Flight Experiment (ALFLEX) involved releasing a scale-model of the HOPE vehicle at high altitude and having it execute an automatic landing similar to what will be required of the HOPE. Objectives of the ALFLEX program included collection of navigation, guidance and control performance data during the low speed flight phase and further development of the automatic landing technology. The successful experiment took place in 1996 at the Woomera Airfield in South Australia.

The Hypersonic Flight Experiment (HYFLEX) was planned to acquire experience in design, manufacture and flight operation of a hypersonic lifting vehicle, and to obtain flight data in the hypersonic speed range. The surface of this test vehicle was covered with carbon/carbon, ceramic tiles and flexible insulation, which are also planned to be used on the HOPE. The test vehicle was launched in February 1996 by a J-1 launch vehicle and separated at an altitude of 110 kilometers before splashing down in the ocean near the Ogasawara Islands.

The Orbital Re-Entry Experiment (OREX) provided experience in design, production and operation of a re-entry vehicle. The OREX vehicle was launched and inserted into orbit in February 1994. It completed a single orbit, collected re-entry data, and splashed down in the Central Pacific Ocean. Critical technical issues addressed by the OREX experiment included aerodynamics and heating during re-entry, structural heat-resistance during re-entry, communications blackout during re-entry, and navigation, both during re-entry and while in orbit.



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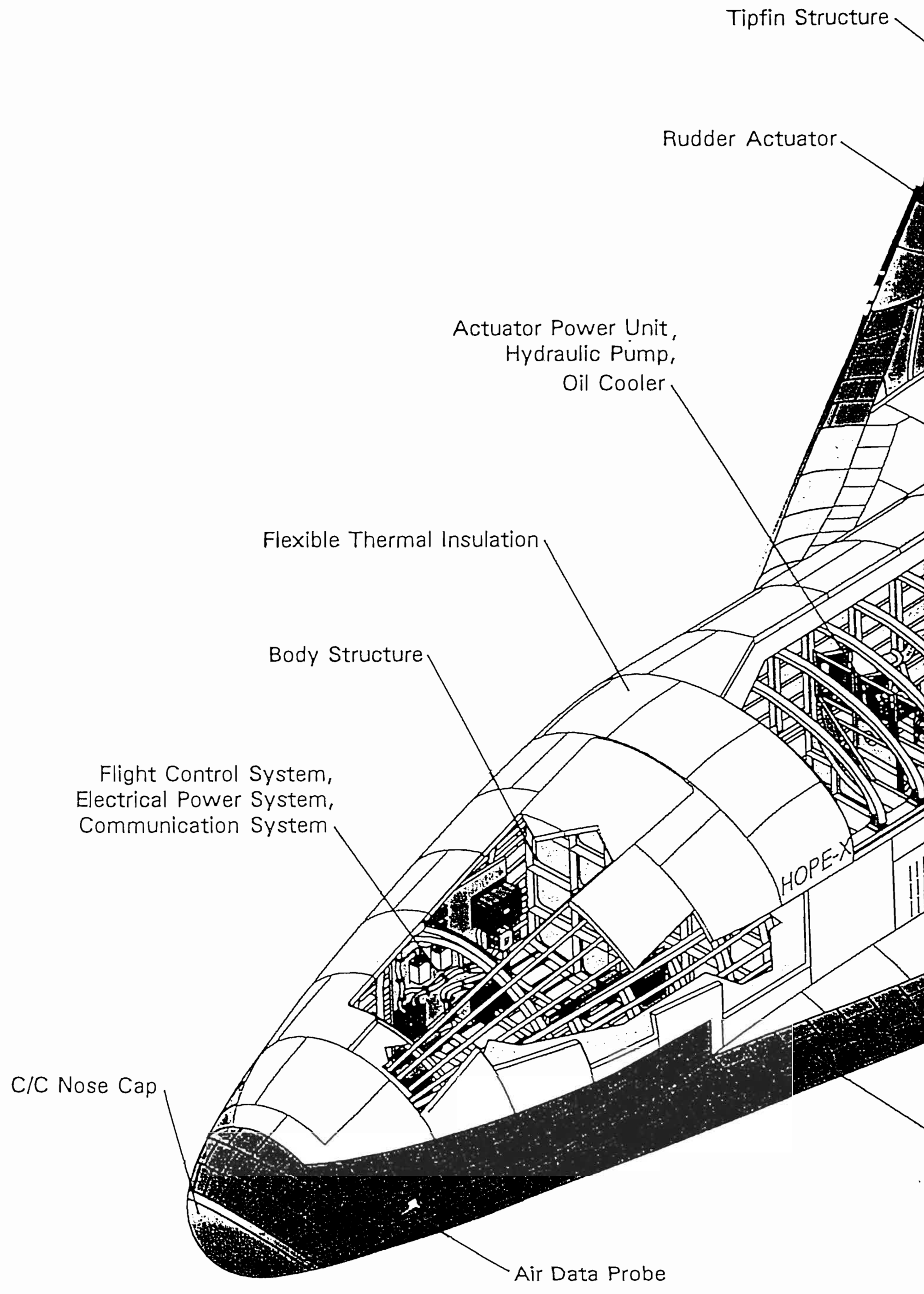

Source:
NASDA HOPE-Experiment Vechicles
Dated: June, 1996

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1.1.3 Christmas Island As The HOPE-X Landing Site

Christmas Island is favored for establishment of the HOPE-X landing facility for several reasons:

- Its equatorial location facilitates operation of the HOPE-X orbiter in the preferred low inclination orbit;
- Its dry, mild, sunny climate;
- The existence of an unused airfield in very good condition located in an unpopulated area surrounded by undeveloped lands (Aeon Field near the southeast tip of the island);
- The existence of the NASDA Christmas Island Downrange Tracking Station (XDRS) facility on the northern side of Christmas Island for tracking and telemetry data gathering; and
- An excellent long-term cooperative relationship between the governments of Kiribati and Japan.

The purpose of the HOPE-X facility on Christmas Island is threefold:

1. To provide a landing site for the HOPE-X unmanned space shuttle after launching from the Tanegashima Space Center in Japan;
2. To establish a communications and tracking link between the existing NASDA XDRS, the space vehicle and the Tanegashima Space Center; and
3. To prepare the vehicle for transport back to Japan.

1.1.4 Organization of the Project

NASDA is the project sponsor, with overall responsibility for development of the launch vehicle, the test vehicle and operations. Mitsubishi Corporation (MC), through their Space Systems Unit, is providing management assistance and project coordination. TRW Components International (TRWCI) is managing facilities development and providing operational support to the missiou. TRWCI operates the existing XDRS on Christmas Island. Dames & Moore (D&M) is providing the environmental impact assessment services.

By agreement of the various involved Ministries of the Government of Kiribati, the lead agency for this environmental review process is the Ministry of Information, Communication and Transport. Facilitation of scoping activities, field surveys, data gathering, and document review is being performed by the Environmental Unit of the Ministry of Environment and Social Development.

1.2 ENVIRONMENTAL COMPLIANCE

1.2.1 The Regulatory Framework

At present, the Republic of Kiribati is in the process of finalizing the enabling statute and the regulations establishing an environmental impact assessment (EIA) system for major developments. In 1996, under a consultancy from the Asian Development Bank, draft regulations for such a system were developed. It is likely that the regulations that will eventually be adopted will be very similar if not identical to these draft regulations. In considering establishment of a landing facility on Christmas Island for the HOPE-X vehicle, both NASDA and MC recognized the desirability of assessing the potential impacts of such a facility on the unique environment of Christmas Island. It was decided, therefore, to follow the procedures outlined in the draft EIA regulations under consideration by the Kiribati government, even though they do not yet have the force of law. Using these regulations to assess the project's impacts will facilitate evaluation by the government of the relative merits and impacts of the project, allow development of appropriate mitigation measures for potential negative impacts, and provide the opportunity to implement follow-on monitoring programs to assure the effectiveness of the mitigation measures. Monitoring during construction and operation of the project will be essential to provide early indications of possible adverse effects and allow modification of activities or procedures to minimize such effects, as well as provide a vehicle for training of local staff entrusted with protection of natural resources.

1.2.2 The Environmental Review Process

The environmental review process for this project will be somewhat unique in comparison to that envisioned as the standard in the draft EIA regulations for two reasons: first, the institutional infrastructure for EIA review is not yet fully in place and, second, the economic and environmental significance of this project to the Republic of Kiribati has resulted in formation of two coordinating committees, one each on Christmas Island and Tarawa, chartered to specifically examine the implications of the HOPE-X project to the resources of Christmas Island and the country in general. These HOPE-X Coordinating Committees have had and will continue to have a major role in identification of potential impacts, review of impact assessment, evaluation of suggested mitigation measures, and recommendation of monitoring activities.

The system of review developed and agreed to by NASDA and the government of Kiribati for this project is as follows. The preliminary EIA report (PEIAR) will be submitted to the Coordinating Committees for a one-month review. The document will be revised as per comments from the committees, and resubmitted as the final EIA report (FEIAR). The EIA will again be reviewed by the coordinating committees acting as representatives of the various Ministries from which the members are drawn. Following this, the EIA will be reviewed by the Ministry of Finance and the Development Coordinating Committee (DCC), comprised of the Secretaries of all Ministries. A final review will be done, and ultimately approval given, by the Cabinet. The draft EIA regulations provide that prior to approval of a development, the PEIAR shall be released by the Ministry of Environment and Social Development to relevant government Ministries, local government councils and other interested parties for written comments. In the present instance, representatives of the various interested parties have been assembled into the Coordinating Committees for efficiency of review.

To facilitate review by an international audience, Christmas Island place names used in this EIA are those specified on the 1:50,000 scale map published by the Government of the United Kingdom (Ordnance Survey) for the Government of Kiribati (Series X782 (DOS 436), edition 8-OS 1993).

2.0 PROJECT DESCRIPTION

2.1 SETTING

Christmas Island is located approximately 2° north of the equator, approximately half way between Hawaii (2,500 km to the north) and Tahiti (2,700 km to the south) (Figure 2-1). Christmas Island is one of thirty-three low-lying coral atolls comprising the Republic of Kiribati, formed in 1979 from the former British Gilbert Islands Colony. Its atolls are widely distributed over 5 million square kilometers in three archipelagos, namely the Gilbert, Phoenix, and Line Islands. Christmas Island is one of eleven islands or reefs in the Line Islands, eight of which are part of the Republic of Kiribati. Because it is within the equatorial dry zone, rainfall is low and unpredictable with periods of extended drought followed by periods of moderate to heavy rainfall. Easterly tradewinds prevail throughout most of the year. Air temperature is very stable, with lows around 24°C and highs around 30°C. Normally, water temperatures are also stable, but ocean warming sometimes occurs during periods of El Niño Southern Oscillations (ENSO), the periodic appearance of anomalous warm water in the eastern Pacific. Extreme ENSO events have greatly altered ocean temperatures, rainfall, and wind patterns in the short term, and an especially severe ENSO event in 1982-1983 caused the complete abandonment and subsequent failure of all seabird colonies on Christmas Island (Schreiber and Schreiber, 1984).

Christmas (Kiritimati) Island, at 321 km^2, has the largest contiguous land area of any coral atoll in the world. It measures some 32 km wide and 56 km long, and represents approximately one half of the total land area of Kiribati (Nippon Tetrapod, 1995; KVB, 1996). The highest point on the island, "Joe's Hill," is approximately 13 m above mean sea level (MSL), but on average the atoll is between 1.5 and 3.7 m above MSL (Bailey, 1977). Approximately 25 percent of the atoll's surface consists of more than five hundred lakes and lagoons that have formed east and southeast of the main lagoon (Helfrich, 1973)(Figure 2-2). Many of the lagoons contain small islands, over 700 in all. Many of these islands provide predator-free nesting sites for seabirds. Three islands in the main lagoon, Cook Island, Motu Upua, and Motu Tabu, have large seabird colonies and have been designated protected areas.

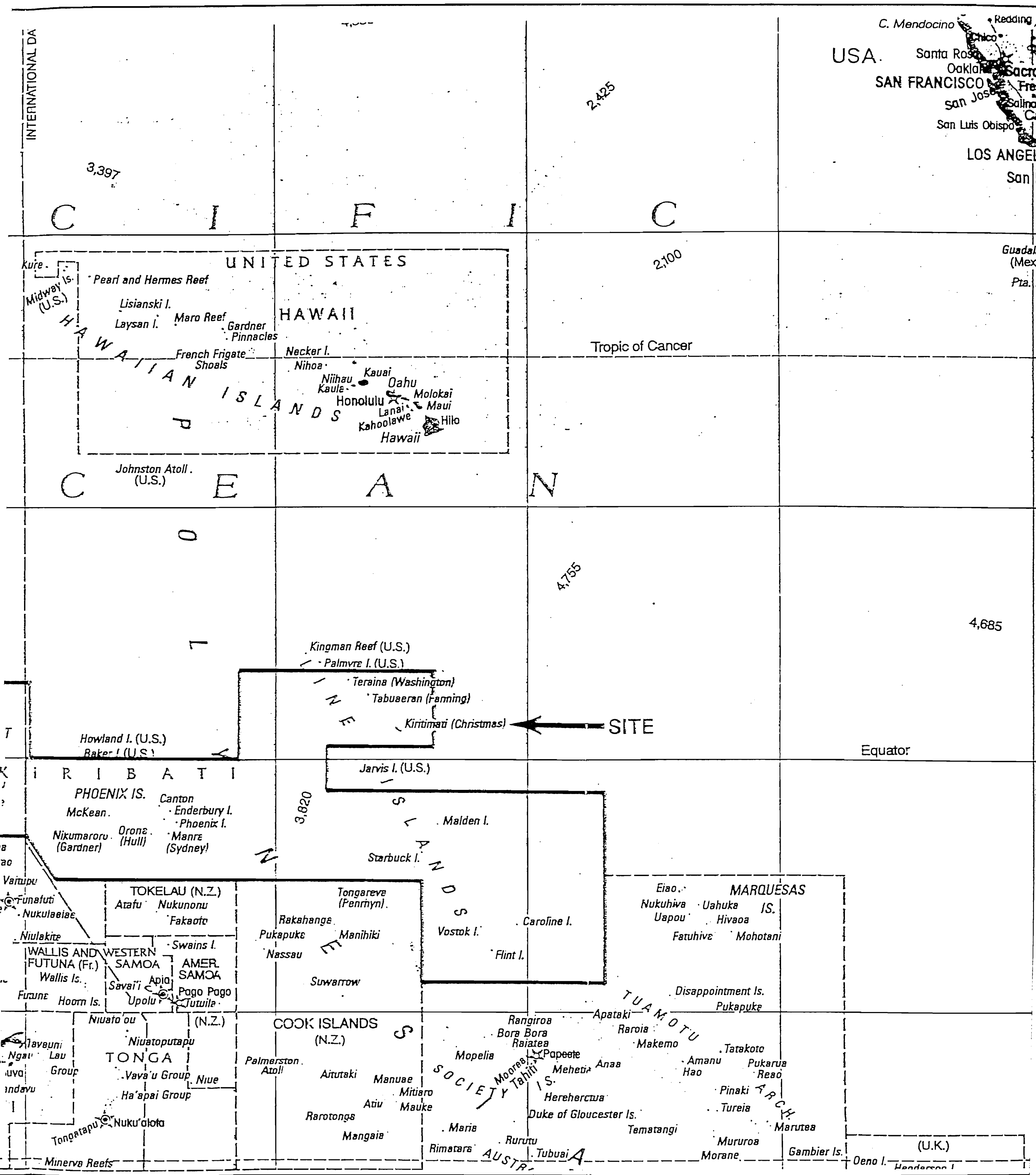
A population of about 3,200 people, essentially all relocated from Tarawa Atoll, occupy four villages situated about the main lagoon in the northern portion of the island. The southern portion of the island is unpopulated and undeveloped. It does, however, support the world's largest seabird colonies. Eighteen species of seabirds and one endemic land bird nest on the island, making it an environmental resource of international significance. The island is surrounded by spectacular coral reefs, supporting a semi-subsistence life style for the majority of residents. Economic opportunities and employment are provided by a copra plantation, exports of marine resources, a few small stores, a government-owned hotel and government service. In recent years, the atoll has become well known among sportfishing enthusiasts as providing light-tackle, world-record opportunities for several popular species (bonefish, trevally), and some residents have found employment as fishing guides.

During World War II, the island was occupied by British and American forces. Subsequently, the island was used by both the British and the Americans for conducting atmospheric testing of nuclear weapons. These efforts resulted in development of considerable infrastructure, including several airfields, a wharf and a paved roadway extending from London, the government center and largest village, to beyond South-east Point (Figure 2-2).

2.2 PROPOSED FACILITIES AND INFRASTRUCTURE IMPROVEMENTS

The Hope-X landing operations require the following new permanent facilities and improvements to existing infrastructure in various locations on Christmas Island, as shown on Figure 2-2:

- Aeon Field, the HOPE-X landing site, will have an extended runway, shelters for the Hope-X orbiter and personnel, and other support facilities,



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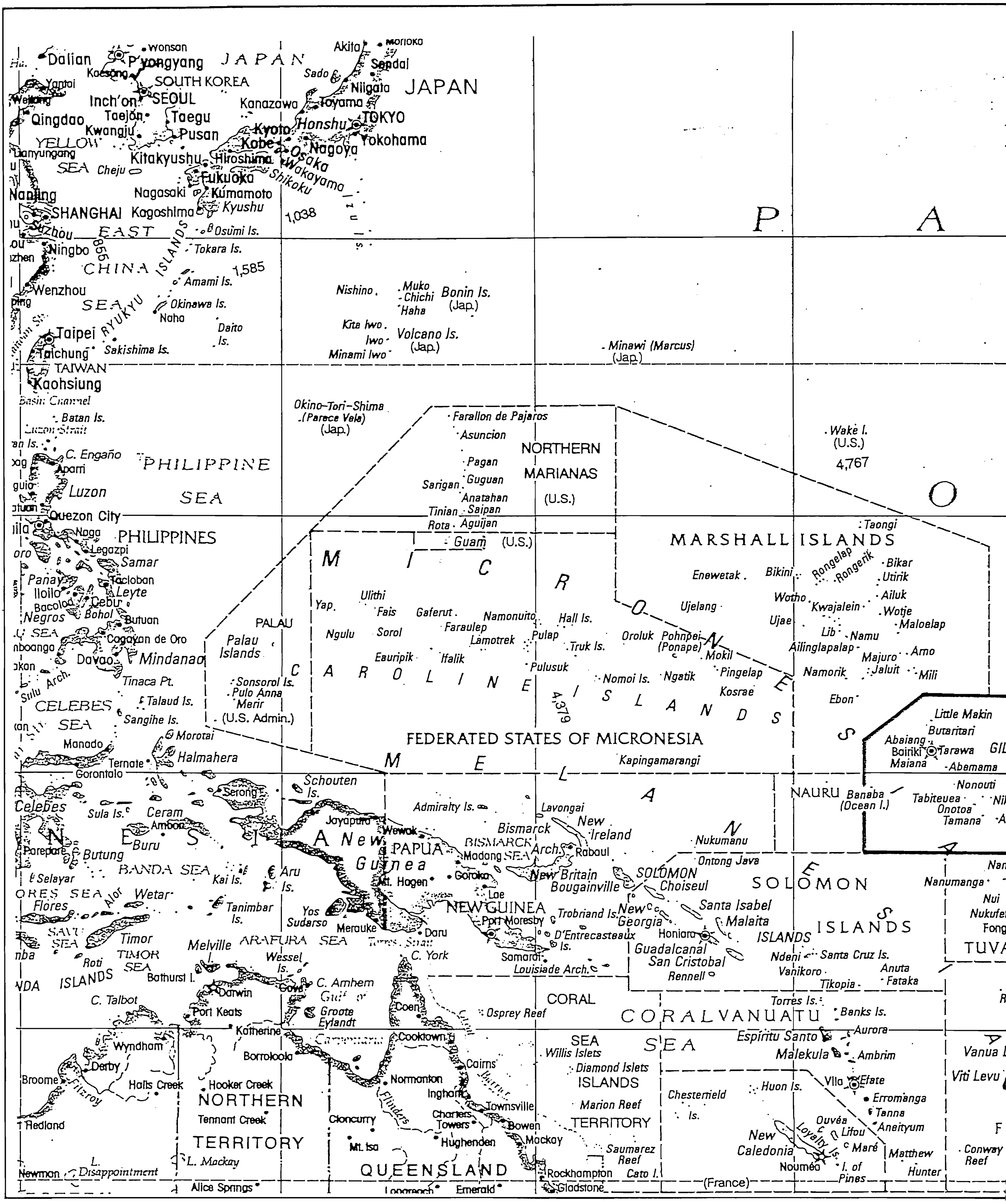


Source: Hammond Inc. World Map

- Carver Way and A-1 roadways will be improved to facilitate the transport of employees and equipment between the various project facility locations,
- The London wharf will be repaired and the harbor area dredged to facilitate cargo offloading and removal of the HOPE-X and other equipment to offshore ships, and
- NASDA employee lodging facilities will be built near Poland.

The following description of the proposed facilities and infrastructure improvements was provided by TRWCI (1997).

2.2.1 Aeon Field

Aeon Field is located in an uninhabited area near the southeast tip of Christmas Island. It is approximately 42.5 km from Cassidy International Airport and 67.3 kilometers from London Village. The existing runway, 1832 m in length, was constructed 1958-9 by British military forces for the Vickers Valiant Bomber Aircraft. Reportedly, the runway was used for only 60 cycles (one landing and one take-off), and it remains in excellent condition (Boeing Corp., 1994). The Aeon Field site plan and proposed improvements are shown on Figure 2-3. The runway is 30 m wide with 18 m shoulders, and is oriented east-west (090°-270°).

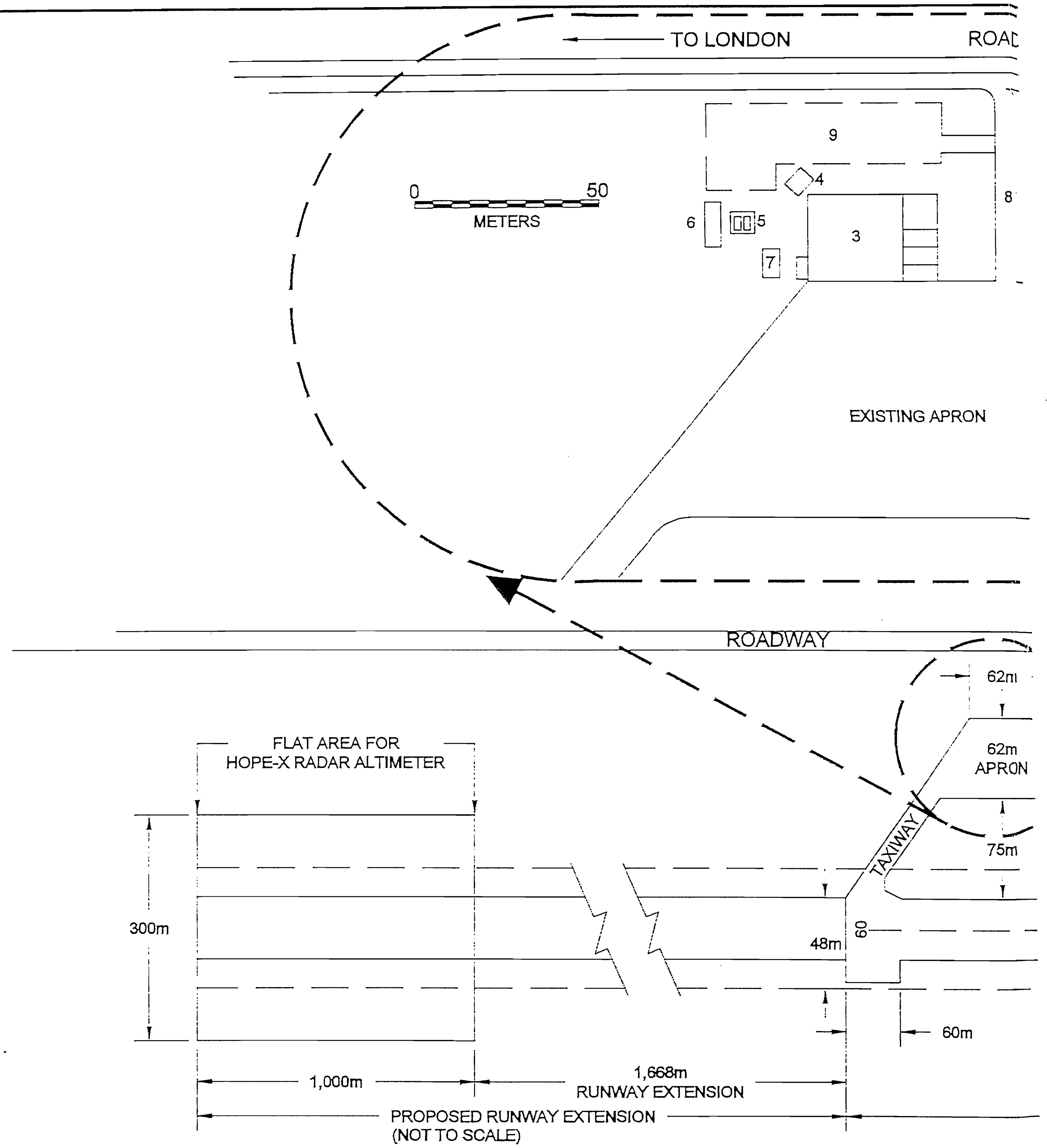
Based on recent geotechnical investigations, the runway is constructed of approximately 15 cm of base course materials taken from local sources and overlain with approximately 10 cm of asphalt. The shoulders are of the same compacted base course as the runway, but do not have an asphalt covering. The existing construction is capable of handling the proposed HOPE-X loads.

Proposed improvements to the runway include:

- extend the runway 1,668 m to the west,
- clear and level a 1,000 m by 300 m area off the extended west end of the runway for the radar altimeter,
- remove vegetation from the shoulders and ends of the runway,
- repair the shoulder base course,
- re-grade the south shoulder to improve surface drainage,
- harden 10 m of the shoulders with cold mix asphalt paving,
- repair holes and cracks along the runway edges,
- brush the runway surface to remove loose materials, and
- repaint runway markings.

The following support facilities are also required at Aeon Field, as shown on Figure 2-3:

- A HOPE-X shelter (25 m by 33 m by 8 m), which will also house a small chase aircraft and ground support equipment. The spacecraft will be stored at the airfield for approximately three weeks during deservicing and preparation for transport back to Japan. The structure will be built on the north edge of the existing pavement of painted, pre-engineered steel framing with corrugated aluminum roofing and siding (Figure 2-4). The office and storage rooms will be air-conditioned and insulated. The roof will also be insulated to maintain acceptable interior temperatures. Louvered windows will provide cross ventilation. Adjacent to the shelter, a parking lot will be constructed of 15 cm, level, compacted base course overlain with 2.5 cm of gravel. A single-lane access road from the HOPE-X shelter parking area to the main Road will be similar in construction to the parking lot. Small capacity (189 liters) flat skid-mounted fuel tanks will supply the small generators at the shelter.
- A generator building (3 m by 12 m) to house two 125 kw diesel-powered generators. The structure will be fabricated of pre-engineered steel framing with corrugated aluminum roofing and siding. No air conditioning is proposed, but there will be louvered windows for ventilation. Exhaust stacks with standard mufflers, exhaust vents, and fuel spill guards will be installed. Adjacent to the personnel structure will be a small structure housing two 50 kw generators to supply power to the



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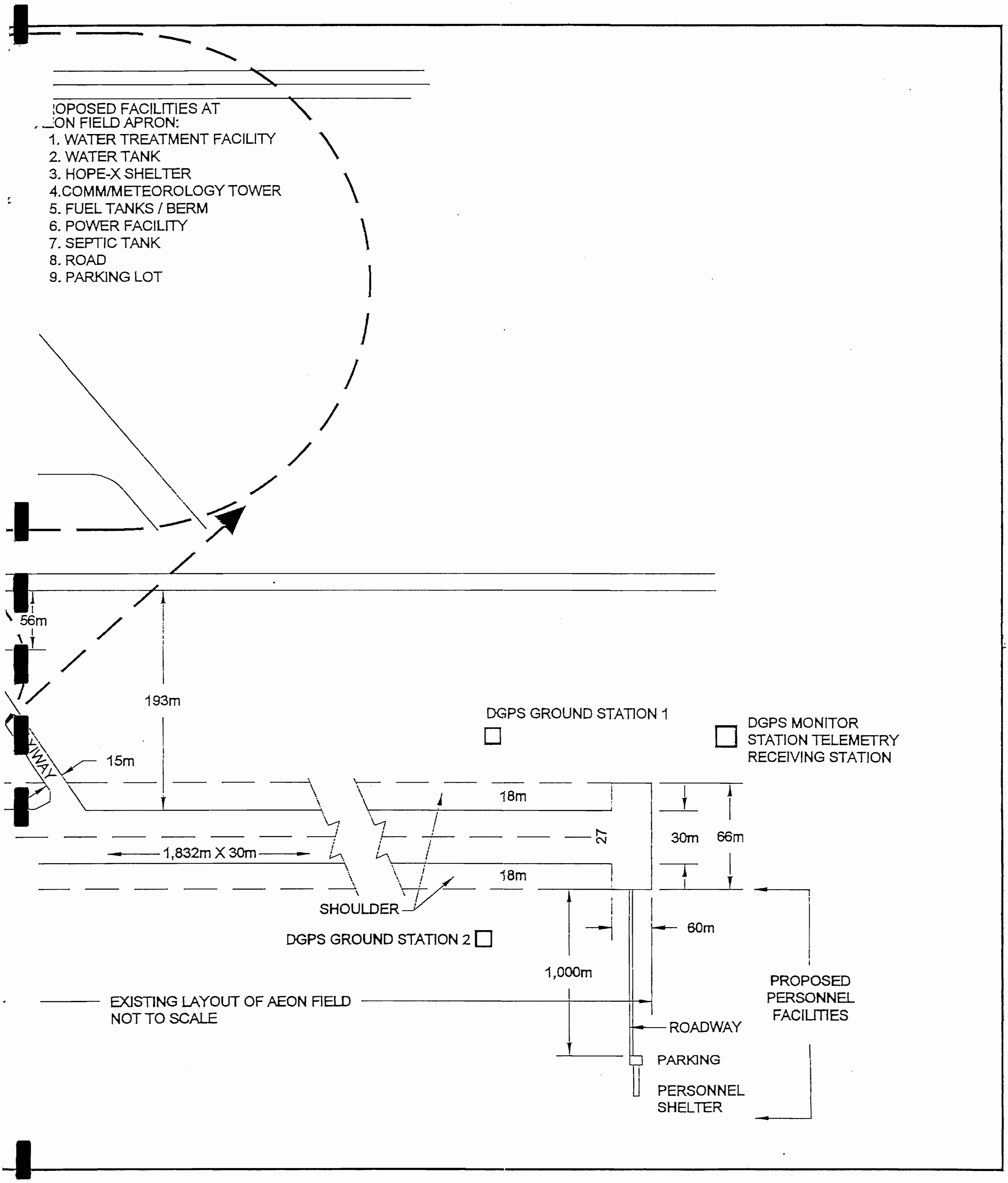


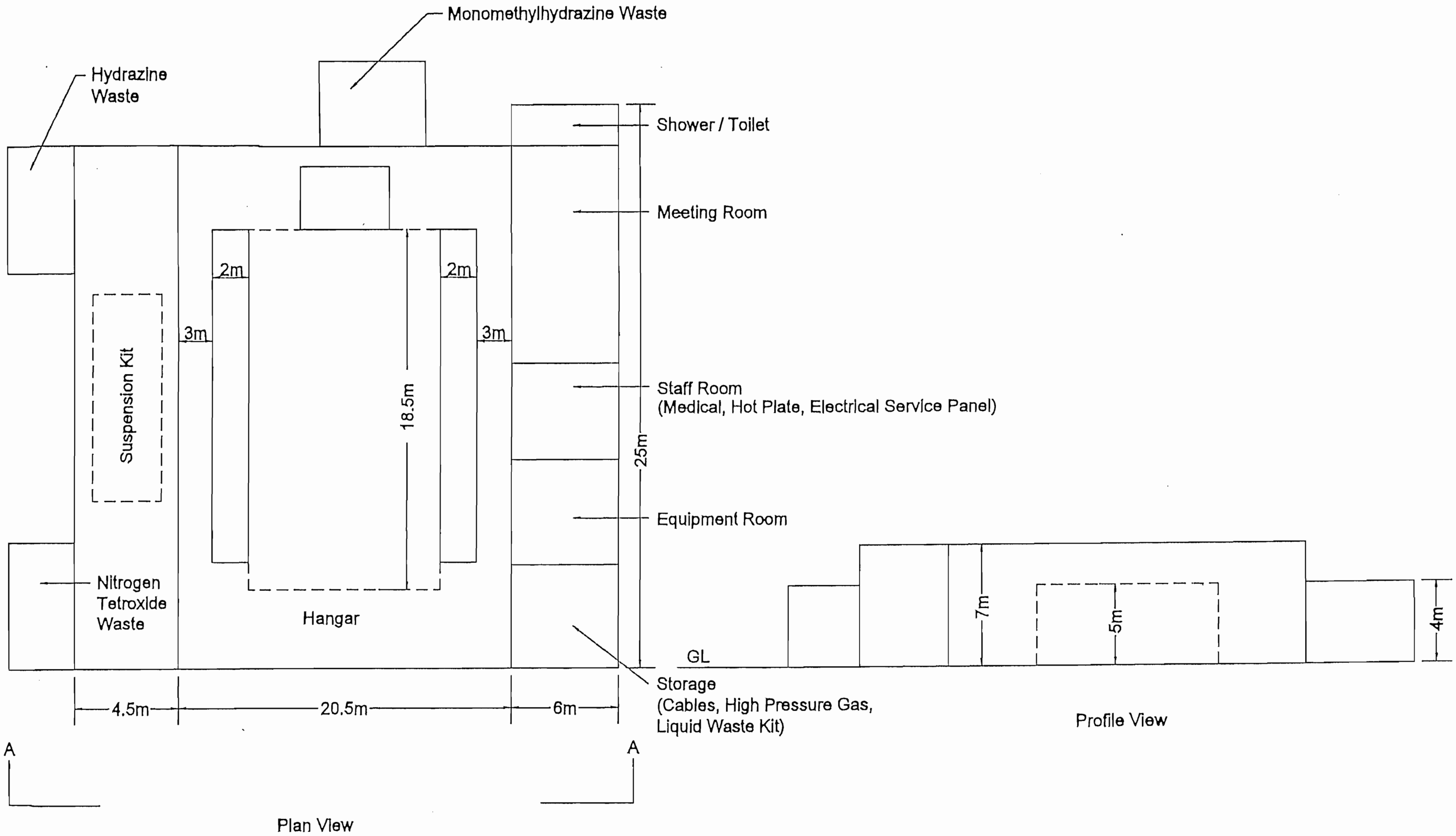
AEON FIELD SITE PLAN

HOPE–X LANDING SITE EIA
CHRISTMAS ISLAND, REPUBLIC OF KIRIBATI

FIGURE 2–3

instrumentation and the shelter.

- Two above-ground, diesel fuel storage tanks (11,355 liters total capacity) adjacent to the generator building. The tanks will be constructed of single-wall painted steel. Concrete masonry spill containment berms (1 m in height) will completely encircle the tanks. There will be sufficient fuel for two 50 kw generators operating twenty-four hours per day for two weeks.
- A potable water supply system employing a reverse osmosis (RO) unit comparable to other facilities world-wide where a natural fresh water supply is unavailable. The raw water supply for the RO system will be brackish groundwater, and the location of the supply wells is yet to be determined. The resultant brine will be injected into the ground at a depth below any freshwater lens in the area. A 23,000 liter above-ground water storage tank will have either UV or ozone disinfection technologies installed. The tank will be constructed of UV-stabilized, fiber-reinforced plastic. The treated water will be distributed through a water distribution network of PVC piping to point-of-use locations that have not yet been identified. The predicted potable water demand is 4,000 l per day, giving a minimum six-day storage capacity. A secondary water source will be developed to supply gray water applications. The gray water will be treated for bacteria only. The treatment facility will be constructed of pre-fabricated steel framing with corrugated aluminum roofing and siding. Louvers will be installed to facilitate ventilation.
- A standard septic tank and leaching field system, comparable to those currently utilized on the island or a self-contained sewage treatment plant. The preferred method of treatment and disposal of wastewater is being evaluated. The facilities are likely to be located west of the existing apron. The system will be adequate for the fifty personnel that will be present at the site for three months per year during landings, and the few maintenance personnel located at the site during non-operational months. The anticipated volume of wastewater is 3,785 liters per day during operations and 757 liters per day during non-operational periods.
- A meteorological facility consisting of a galvanized steel tower with sensors for measurement of wind direction and speed, temperature, barometric pressure, humidity, and rainfall. Currently, the plan is to install a single, triangular, non-guyed tower, approximately 25 m in height, to accommodate both the meteorological and communications equipment. The tower will be painted red and white per regulations and will have a red safety light mounted at the top.
- A microwave antenna installed on the meteorological tower. A portion of the HOPE-X shelter will be used to house the telecom and other communications equipment. The existing public telephone network operated by Telecom Services Kiribati Limited will be used for non-critical communications. A second system will be established to handle mission-critical communications. This backup system will consist of INMARSAT terminals at Aeon Field. During construction, HF radios and INMARSAT "Mini-M" portable satellite telephones will be utilized.
- A telemetry receiving system capable of receiving the UHF/VHF-Band radio frequencies transmitted by the HOPE-X. The system will include a quad helix antenna on a dual axis pedestal and will operate at 300 and 2600 Megahertz (Mhz).
- A differential global positioning system (DGPS) to be used as a navigational aid for the approach and landing of the HOPE-X.
- An air-conditioned personnel shelter to house operational equipment and serve as an emergency shelter for personnel should the HOPE-X veer off course. The structure will be located approximately 1,000 m from the southeast end of the runway (Figure 2-4). The structure (3m by 9m by 3m) will be built on a 30 cm thick reinforced concrete slab, with a minimum 1 m mound of sand on all sides. There will be two doorways for the shelter, one on the east and the other on the south side. Each of the doorways will have protective tunnel entrances and doors constructed to 2-hour fire safety rating specifications. Two 50 kw generators will supply primary and backup power to the shelter. It would be prohibitively expensive to extend the power grid from the HOPE-X shelter to the personnel shelter, and therefore independent systems are envisioned.
- A 1,000-m unpaved single-lane access road and parking area to service the personnel shelter. The 15 cm of compacted base course with gravel top will be constructed level to the centerline of the runway to prevent flooding. There will be no top seal coat.



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HOPE-X SHELTER

HOPE–X LANDING SITE EIA

CHRISTMAS ISLAND, REPUBLIC OF KIRIBATI

- Exterior lighting for the facility consisting of low-intensity sodium-vapor lamps mounted facing down on poles and buildings. Fluorescent lighting will be used indoors. There are no requirements for high-intensity lighting or runway landing lights, but some exterior lighting will remain illuminated during the night for security purposes.

2.2.2 Roadways

2.2.2.1 Artemia Corner to Poland Village (Carver Way)

The existing 30 km unpaved Carver Way between Artemia Corner and Poland Village (Figure 2-2) will be improved as part of this project. It will require surveying and geotechnical analysis for road integrity. Currently, extensive flooding occurs during rainy periods, and the road may require filling of as much as 30 cm in some areas. Culverts will be constructed where appropriate so as not to interfere with the flow of water between ponds. Vegetation will be cleared from both sides of the roadway. Approximately 7.5 cm of processed base course will be added, and compacted. A seal coat of emulsified asphalt to preserve surface conditions is being considered.

2.2.2.2 Cassidy Airfield to Aeon Field (A1)

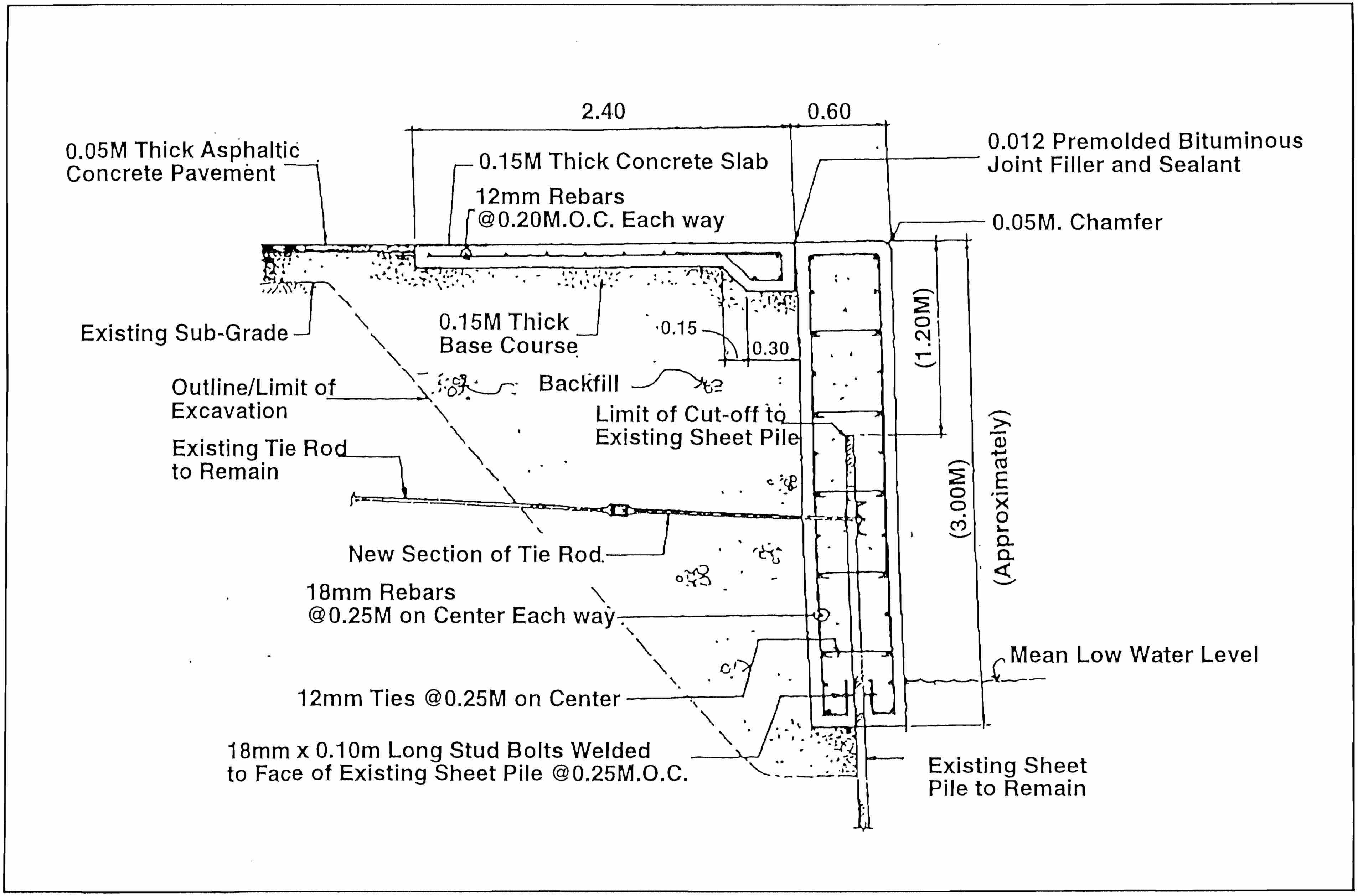
The double-lane sealed road that extends from London Village to Cassidy Airfield (Figure 2-2) was originally intended to traverse the entire east side of the atoll past Aeon Field to South-east Point and beyond. The entire route (A1) was graded and compacted, but south of Cassidy Airfield, only one lane was paved. The existing 42.5 km asphalt single-lane portion of A1 will be expanded to two usable lanes. The project will require the removal of vegetation, repair, leveling and re-compacting the existing base course, and application of an emulsified seal coat over the entire length. This portion of the HOPE-X project constitutes a significant portion of the construction budget and schedule.

2.2.3 London Port Improvements

2.2.3.1 Wharf Repairs

The wharf was constructed by the Americans during 1942-1943. It was constructed of sheet pilings with steel tie-back rods holding the pilings. The top 0.9 m to 1.5 m of sheet piles were filled with concrete, and then backfilled to form the dock loading area. The final length was 112 m with 15.2 m wing walls.
The existing wharf at London Port has deteriorated. Extreme corrosion has occurred in the sheet piles resulting in large holes. The horizontal structural members appear to have completely corroded away. The wharf loading area and road approach to the wharf area are rough but stable. Sand has drifted into the front of the wharf and formed a small beach visible at low tide.

The following modifications are proposed to restore and upgrade the wharf (Figure 2-5):
- The wharf landing area will be repaired with new base course, as required, and leveled and smoothed.
- The wharf repair will consist of the following tasks: replace the steel whalers to restrain the piles from outward movement (20m length); demolish the existing cap and construct a new concrete cap for the sheet piles; level, smooth and recompact the wharf area with base course material in an area of about 4,500 m^2. A 2-m retaining wall will be constructed on both sides of the renovation to eliminate foundation bleeding and maintain the integrity of the repairs. Cathodic protection (sacrificial anodic zinc) will be installed to inhibit corrosion of the repaired sheetpiles.



DAMES & MOORE

PROPOSED LONDON WHARF REPAIRS
HOPE–X LANDING SITE EIA
CHRISTMAS ISLAND, REPUBLIC OF KIRIBATI

2.2.3.2 Harbor and Channel Dredging

Sand accumulated in front of the wharf will be dredged to secure a sea approach. A clamshell dredge will likely be used. The dredged coral sand will be disposed of on land in the vicinity of the harbor where fill is needed. It is estimated that maintenance dredging will be required approximately every five years.

The Cook Island Passage and Recommended Track 050 will be utilized for ship passage. A channel will be dredged to a depth of 3 fathoms (5.5 m) at mean low low tide. Further soundings are required to determine the actual magnitude of the dredging and equipment needed. Materials dredged from the channel will be disposed of at sea in deep water. Approximately 240,000 m^3 of dredged materials will be generated from the harbor and channel dredging.

Twenty buoy markers will be re-established to mark the passageway. They will be 0.76 m diameter cell foam core with a hard plastic outer casing. A galvanized steel chain attached to a 90 kg anchor will secure each buoy.

2.2.4 Christmas Island Down-Range Station (XDRS)

The existing receiver on the northern shore of Christmas Island (Figure 2-2) will be modified for the HOPE-X UHF/VHF telemetry systems. In addition, 5.6 GHz radar and 450 Hz command systems will be installed for range safety operations.

2.2.5 NASDA Accommodations

As many as 200 project-related individuals are expected to arrive on Christmas Island for the landing events. Lodging and dining facilities for approximately forty to fifty NASDA employees will be constructed between Paris and Poland on the leeward side of the Island (Figure 2-2). The NASDA lodging facility is designed for potential expansion to accommodate the anticipated 200 people, if accommodations are not available elsewhere. Initially, the two single-story concrete masonry unit (CMU) structures will each have ten double occupancy dormitory units and one service room for informal dining, recreation and office activities (Figure 2-6). Each of the dormitory rooms will have an air conditioning unit and complete shower and lavatory facilities. The two lodging structures will be arranged in parallel and connected by a concrete path. A large common dining and recreation facility (15 m by 24 m) will be located between the two dormitory buildings.

Power supply for the NASDA quarters will initially consist of two 150 kw diesel generators, however, the generation facility will be built to accommodate the anticipated future installation of three 750 kw generators. The structure will be fabricated of structural steel framing and aluminum siding and roofing. Sturdy construction methods will be required to support the bridge crane and hoists that will be used for placement and repair of generators. An air-conditioned room in the facility will house the power grid access and switch gear. Fuel for the generators will be stored in above-ground tanks with approximately 11,355 liters total capacity. The reserve capacity will be adequate for one 150 kw generator operating for twenty-four hours a day for two weeks. Alternative power supply technologies are being evaluated.

The water supply RO system and water storage system will be similar to that described above for Aeon Field, except the system will be expandable to accommodate up to 200 persons. There is a nearby freshwater lens that is being evaluated as a potential source of feed water. Conservation measures, such as the development of a secondary source of water for gray-water applications (e.g. flushing toilets, irrigation) are being planned. The water treatment system will be housed in a building constructed of concrete/structural steel framing with aluminum siding and roofing including louvers and lighting as necessary. The potable water will be stored in UV-stabilized, fiber-reinforced plastic tanks with an approximate total storage capacity of 76,000 liters, which equates to approximately ten days of demand. Distribution systems will be similar to those described for Aeon Field.

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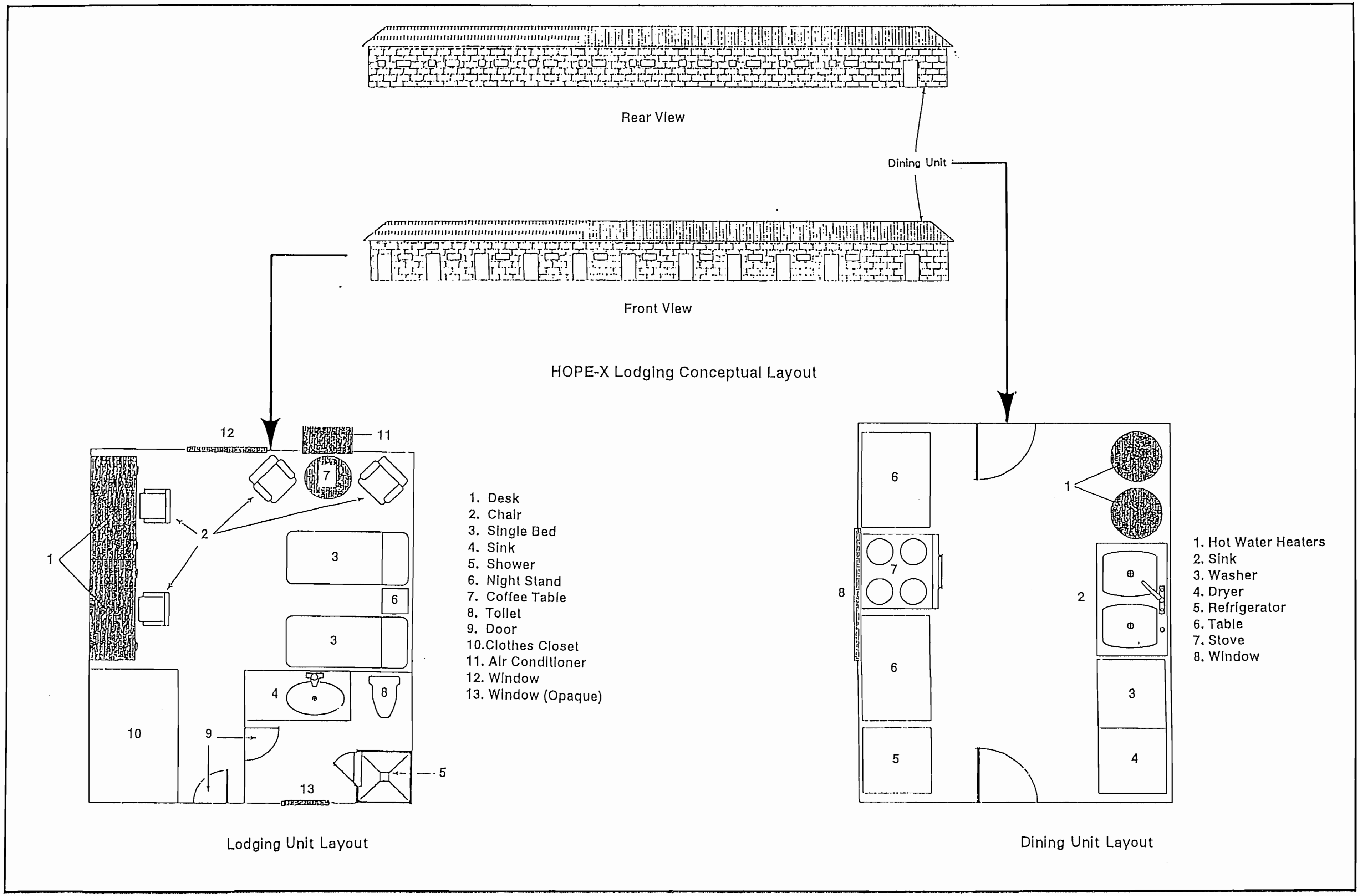


DAMES & MOORE

PROPOSED NASDA LODGING AND DINING FACILITIES

HOPE–X LANDING SITE EIA
CHRISTMAS ISLAND, REPUBLIC OF KIRIBATI

The sewage treatment facilities at the Poland quarters will be designed for a planned future expansion to 200 personnel. Initial demands on the system will be based on 40 personnel and approximately 7,600 liter of waste per day. The small sewage treatment plant will consist of a combination of aeration and activated sludge technologies, and will initially have a 40,000 liter per day capacity.

2.3 SPECIALIZED EQUIPMENT

2.3.1 The H-II Launch Vehicle

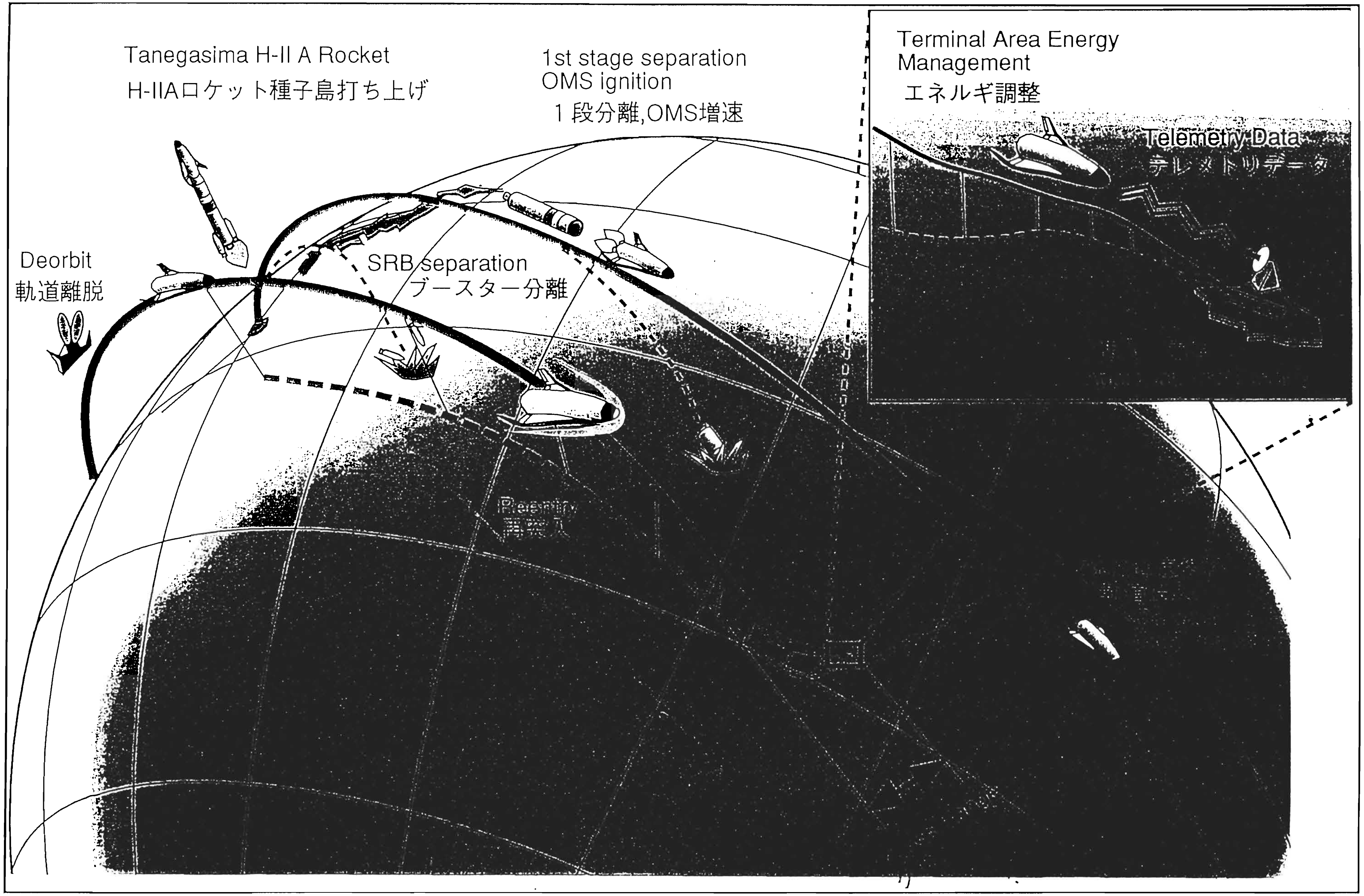
The HOPE-X will be launched from the Tanegashima Space Center in Japan using the H-II A launch vehicle. The mission profile is shown on Figure 2-7. While earlier Japanese satellite launch vehicles were developed using licensed technology from the United States, the H-II A is entirely Japanese in design. Launch vehicles are broadly categorized as small, medium, or heavy according to their size and ability to place various categories of payloads into orbit. They are also classified as expendable or non-expendable. Most launch vehicles are expendable, their stages and components jettisoned during flight. In the Hope-X missions, the H-II A launch vehicle employs two solid rocket boosters (SRB)(1 set) and four solid strap-on rocket boosters (SSB)(2 sets:A and B) capable of launching a large satellite into geostationary orbit (Figure 2-8). The Hope-X/H-II A launch sequence is shown in Table 2-1.

TABLE 2-1
Launch Sequence

Seconds	Event
	LE-7A (main engine) ignition
	SRB ignition
0	lift off
40	SSB (set A) ignition
101	SSB (set B) ignition
109	SRB, SSB (set A) separation
172	SSB (set B) separation
415	H-II A separation
418	OMS (Second Stage) ignition

Once the exhausted components of the launch vehicle separate, the HOPE-X is free to complete its revolution around the earth before beginning its re-entry and landing.

The approximate splashdown locations of jettisoned components in the western Pacific Ocean are summarized in Table 2-2 and shown on Figure 2-9. The solid rocket boosters and set A of the strap-on boosters will splashdown within as area of about 25 km by 50 km about 300 km west of the Ryukyu Islands. Set B of the strap-on boosters will splashdown slightly west of set A. Wake Island is the closest land mass to the approximate splashdown location of the H-II A.. It is 400 km southeast of the closest anticipated splashdown of the first stage and its fragments. The exact splashdown locations will vary depending on meteorological conditions.



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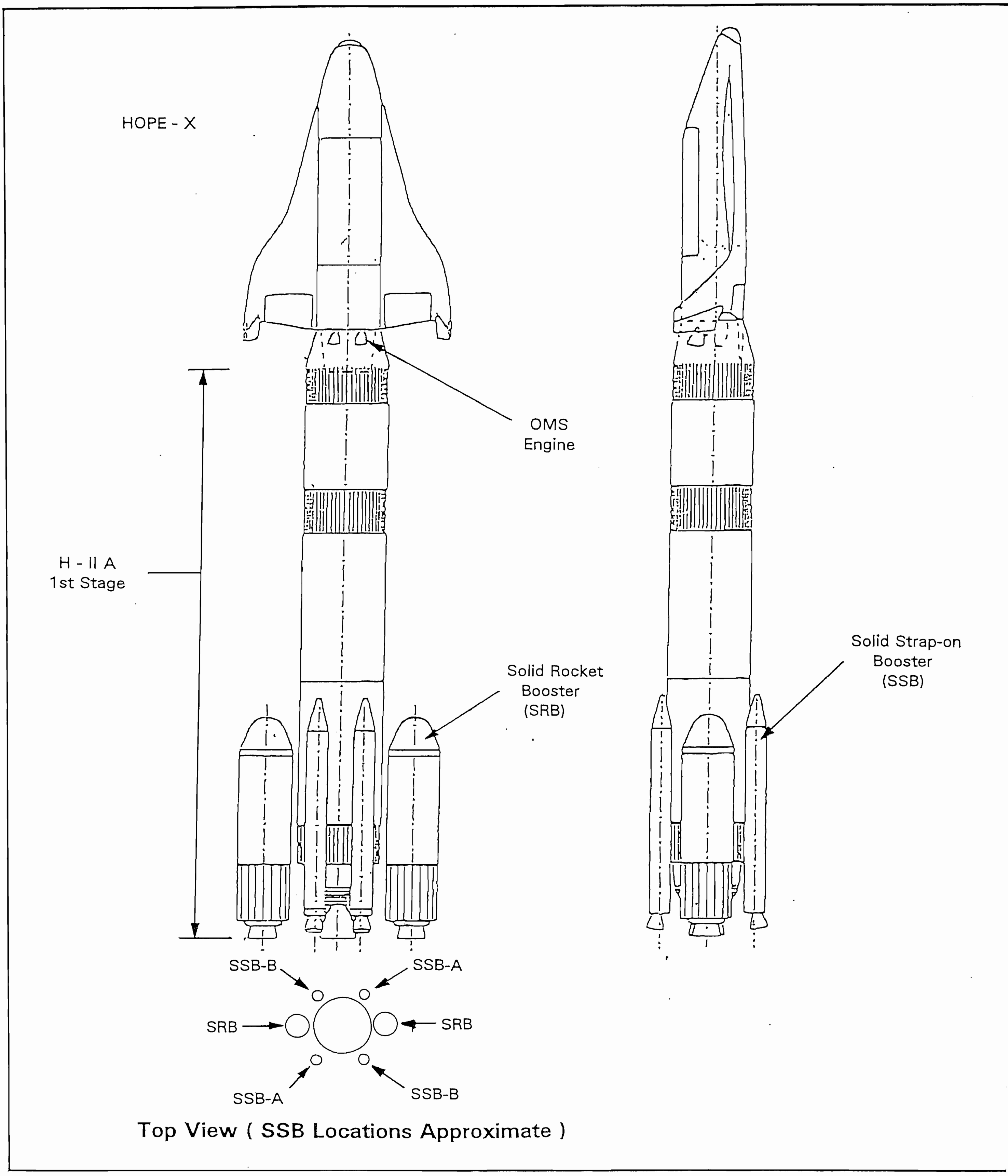
HOPE-X MISSION PROFILE

HOPE-X LANDING SITE EIA
CHRISTMAS ISLAND, REPUBLIC OF KIRIBATI



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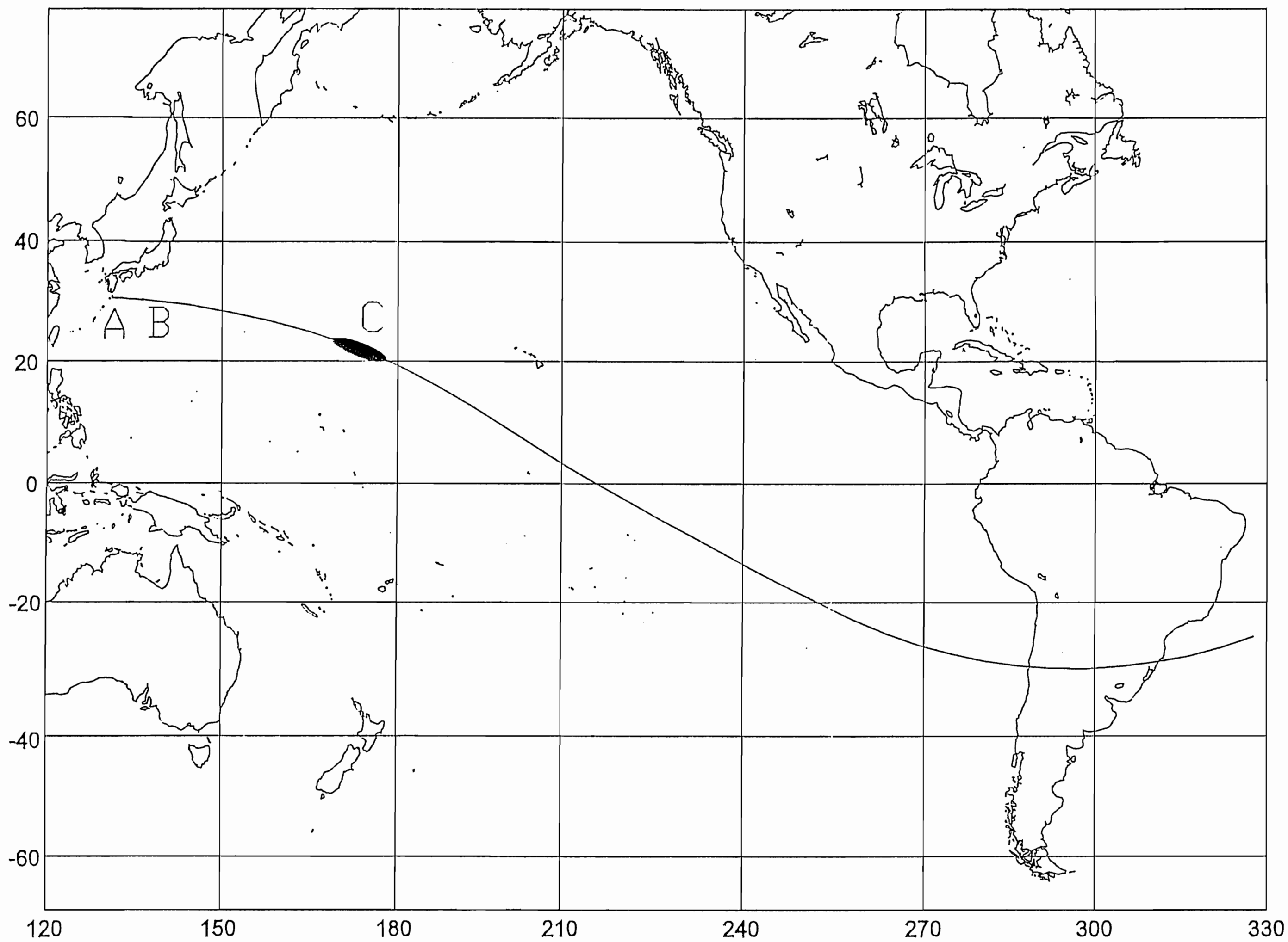
HOPE-X / H-II
HOPE-X LANDING SITE E
CHRISTMAS ISLAND, REPUBLIC OF KIRIBA
FIGURE 2-



LEGEND:
A = SRB AND SSB SPLASH DOWN
B = SSB SPLASH DOWN
C = FIRST STAGE SPLASH DOWN

APPROXIMATE SPLASHDOWN LOCATIONS OF BURNED-OUT STAGES

HOPE-X LANDING SITE EIA
CHRISTMAS ISLAND, REPUBLIC OF KIRIBATI

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FIGURE 2-9

TABLE 2-2
Splashdown Locations of Launch Vehicle Components

Component	Latitude (°N)	± (km)	Longitude (°E)	± (km)	Nearest Land Mass
SRB	30.368	12.7	133.150	25.3	Ryukyu Is.
SSB (A)	30.368	12.7	133.150	25.3	Ryukyu Is.
SSB (B)	30.212	12.7	136.713	25.3	Ryukyu Is.
H-II A	21.671	130.2	174.222	524.2	Wake Is.

2.3.2 The HOPE-X Vehicle

The HOPE-X unmanned vehicle is illustrated in Figure 1-1. Its length is approximately 16 m and its width approximately 10 m. Its gross weight is approximately 11 tons at launch. It is composed of aluminum alloy with heat resistant surfaces of carbon fiber composite, ceramic tiles and flexible adiabatic materials. On-board are guidance, navigation and control equipment. Control surfaces on the wings provide aerodynamic stability. To perform its ultimate functions, it has both OMS (orbital maneuvering system) and RCS (reaction control system) rocket motors. Although early flights of the HOPE-X will be suborbital to test equipment systems, the eventual missions of the vehicle will require insertion into orbit. Re-entry will be accompanied by extreme heating and a temporary communications black-out. About 30 minutes after re-entry, the vehicle will land at a speed of about 350 km/hr using a microwave landing system. The entire mission, from lift-off to landing will take place within a little more than two hours.

2.3.3 Flight and Landing Control Support Equipment

A number of improvements will be made to the NASDA XDRS facility to support the HOPE-X missions, including:

- construction of new facilities for tracking the HOPE-X flight (to house equipment for measuring the orbit using C-band radar transponder and telemetry data, equipment for establishing safe flight line, and flight safety command and control equipment),
- improvements to the current VHF and UHF telemeter receivers,
- installation of a new 3.2 meter diameter parabolic antenna, a new transmitter and new receiver for the C-band radar transponder,
- installation of a fifteen-element cross Yagi antenna and a new transmitter for the command transmitter,
- installation of a portable VHF radio for communicating with Aeon Field and the chase plane, and
- upgrading of existing equipment for communications with the launch facility.

At Aeon Field the following improvements will be completed:

- a new DGPSR ground station will be built,
- a five-element cross Yagi antenna and a new receiver will be installed for the VHF and UHF telemeter receiver facility,
- a new optical tracking facility will be built, and
- a 5.6G Hz radar and 450 Hz command system will be installed for range safety.

2.3.4 The Overland Transporter

The HOPE-X transporter is expected to be similar to a flatbed truck with special harnesses and fixtures to restrain the vehicle from movement during delivery from Aeon Field to the port in London. It's likely that the vehicle will be transported inside a specially fabricated container.

2.3.5 Ocean Transport Vessels

The HOPE-X vehicle, with its container perhaps still attached to its transporter vehicle, will be put onto a barge dockside at London. The barge will ferry the vehicle to a freighter moored in deeper water outside the lagoon for transport back to Japan.

2.4 CONSTRUCTION

2.4.1 Construction Facilities, Equipment and Materials

Lodging and dining facilities for the construction crew will be constructed at Artemia Corner, and near Tabwakea Village (Figure 2-2). A construction baseyard for the storage of supplies and equipment will be developed in the area of Joe's Hill (Figure 2-2). The Artemia Corner facilities (Figure 2-10) will include lodging for workers, supervisors and guests, a kitchen and dining area, a power plant (150 kw diesel generator), a septic tank and leaching field, a primary water supply well and RO system, and a brine disposal well. Brackish water will be drawn from wells developed in the vicinity, and RO filtered to meet the potable water demand. The resultant brine will be injected into the ground at a depth below the fresh water lens. Locations of the supply and injection wells will be finalized following further study of the freshwater lens at Artemia Corner. As an alternative to the septic tank and leaching field, a self-contained sewage treatment plant that could be relocated to Aeon Field after construction is completed is being considered. Approximately 17,032 liters per day of sewage will require treatment and disposal.

Telecommunications during construction will consist of HF radios and portable INMARSAT "Mini-M" telephones. The combination of systems will provide both intra-island and international communications. The Artemia Corner facility will be used during landing events by observation personnel.

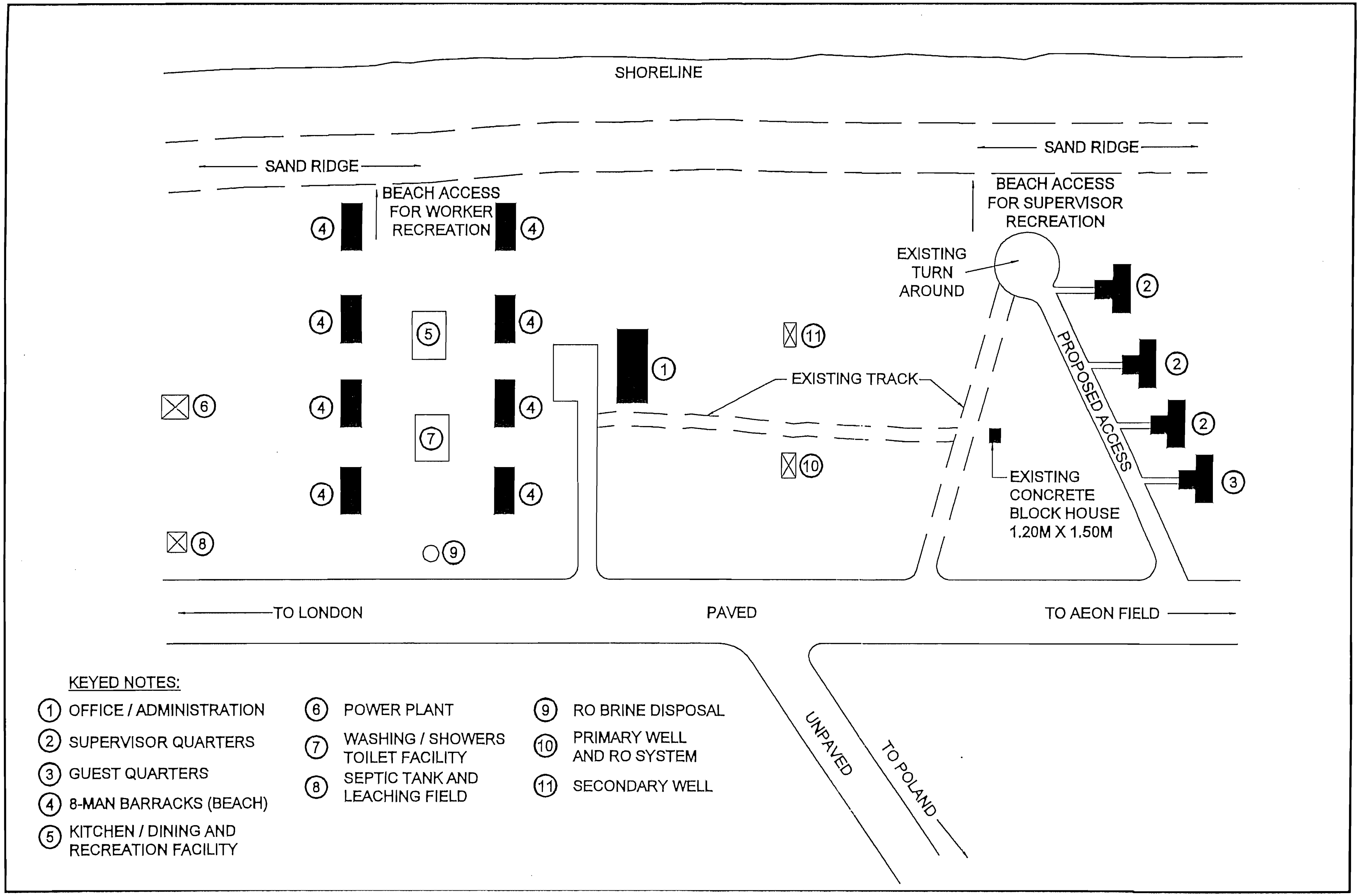
An additional temporary construction camp will be constructed near Tabwakea Village in support of the proposed wharf repairs. Approximately twelve wharf repair workers will be housed at the camp for approximately three months.

The majority of construction materials required for the HOPE-X facilities are not readily available on Christmas Island. The materials that are available are sand for base course, and coral to be crushed for use as construction aggregate. Base course production processing will be at Joe's Hill (Figure 2-11). Coral borrow pits will result from the excavations. The areas designated for borrow pits, crushing and screening, and stockpiling are shown on Figure 2-11. Other activities proposed for the service area include a 75 kw generator, a warehouse/storage area, toilet facility with a holding tank, a concrete batch plant and a motor pool/shop. An area between the borrow area and the existing road may be suitable as a solid waste landfill site.

Building and wharf construction materials and equipment will be imported from the U.S. Imported material for constructing the shelters and buildings will include cinder block, cement, mortar, weatherized steel and sheet metal (galvanized, corrugated), corrugated aluminum alloy sheeting, fiberglass, and wood. Ocean freighter is the most cost-effective means of delivery, but will require that the harbor and wharf improvements be completed as a prerequisite, so alternative means, such as a C-130 cargo aircraft, will be needed for delivery of initial materials.

2.4.2 Scheduling and Personnel

The HOPE-X Landing Site improvements will be performed in phases. This EIA and ongoing design engineering will be completed in 1997. In 1998, dredging and other port repairs will be completed and road repairs will be initiated. Much of 1999 will be devoted to Aeon Field and Poland infrastructure construction. In the year 2000 all facilities will be completed, and the first HOPE-X landing is scheduled in 2001.



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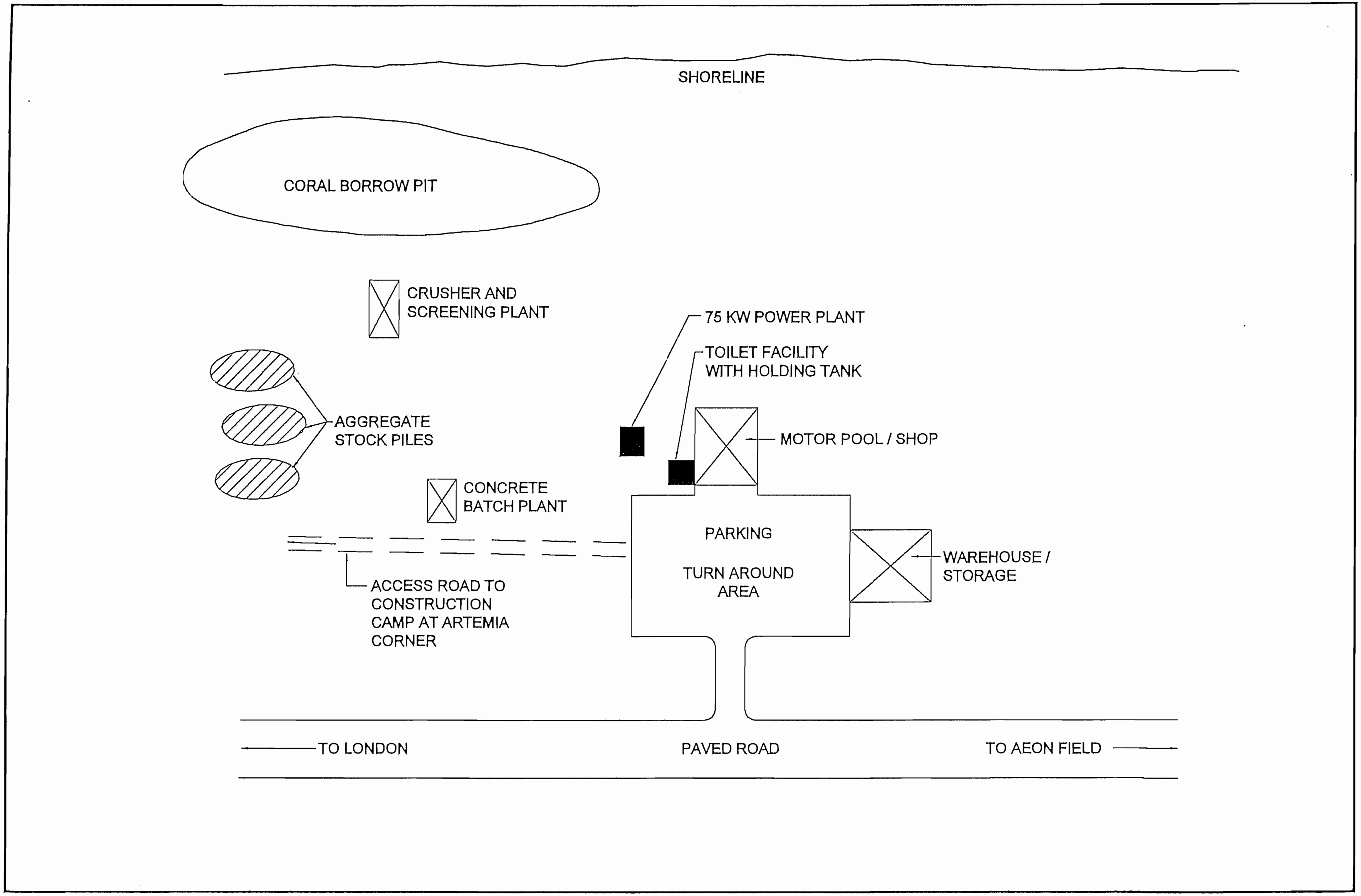
ARTEMIA CORNER SITE PLAN

HOPE-X LANDING SITE EIA
HRISTMAS [redacted] ISLAND, [redacted] BLIC OF KIRIBATI [redacted]
FIGURE 2-10



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JOE'S HILL SITE PLAN

HOPE–X LANDING SITE EIA

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Construction of the HOPE-X facilities will require approximately 75 laborers plus engineering and supervisory personnel. Local construction labor will be utilized to the extent possible, primarily as unskilled labor. A local apprenticeship program will be developed to train and introduce local workers to commonly-accepted building practices and procedures. Non-construction job opportunities for the local population include kitchen support, camp operations, security, and maintenance.

2.4.3 Costs

Capital costs for all of the Christmas Island facilities associated with the HOPE-X program are estimated at US $30 million.

2.5 HOPE-X OPERATIONS

2.5.1 Mobilization

Prior to a landing event, ten ground crew members will be stationed within the personnel shelter at Aeon Field. Another ten ground crew members will be stationed at Artemia Corner, outside of the precautionary area, until after landing. All VIPs and press will be stationed at a site near Poland. Flight control operations will be done from the XDRS. Ten technicians will be involved there. Optical observation equipment will be set up outside the precautionary area. Four operators will be required. Six security guards will patrol the precautionary area. Of the estimated 200 people that will be housed on Christmas Island during the landing event, approximately forty are considered essential to operations.

2.5.2 Typical Landing Event

Upon landing, the safety of the HOPE-X will be confirmed using the portable telemeter equipment in the shelter, and the air conditioning vehicle will be mobilized. A safety check will be made of the following: the pressure, temperature and condition of the shut-off valves of chambers filled with helium gas, nitrogen tetroxide (NTO), monomethyl hydrazine (MMH), and hydrazine; and the temperature of critical equipment. Within fifteen minutes after landing, the air conditioning unit will be connected by technicians wearing Chemturion™ encapsulating chemical protective suits with supplied air. The operation and monitoring of air flow to the Chemturion suits and the operation and monitoring of the air conditioning unit will be conducted from the air conditioning vehicle and monitored on the craft monitors. Cooling of the vehicle will proceed for one hour, after which time the ground crew from Artemia will join the operation, and the vehicle will be towed into the hangar. Observations with visual and internal monitors will proceed. Excess propellants (NTO, MMH, and hydrazine) will be removed and safely stored. Data recorders and the OMS will be removed. The RCS and APU pipes will be sealed.

2.5.3 Demobilization

The test craft will be packed into a container without dismantling and transported to London for shipment to Nagoya. Waste propellants will be stored apart from one another according to a Hazardous Materials Handling Plan, and transported back to Japan with the HOPE-X.

2.5.4 Scheduling and Personnel

Landing missions or *operations* are proposed on a schedule of one per year for approximately five years, beginning in the year 2001. The specific dates and times for these landings have not been determined, but winter months are preferred. The facilities will be fully operational, requiring forty to fifty essential personnel, for three months in support of each operation. After landing, the HOPE-X will be stored in the Aeon Field shelter for up to three weeks before transport back to Japan.

2.5.5 Costs

Operating costs have not yet been determined.

2.6 FACILITY MAINTENANCE OPERATIONS

Only one to five maintenance personnel will be required during the annual nine-month non-operational period. During this time, the power, telecommunications, water and waste systems will be periodically serviced and tested.

2.6.1 Security

During landing operations the local police force and private security personnel will be employed. The size of the security force has not yet been determined. Entry into the "Precaution Area" shown on Figure 2-2 will be restricted to essential operations personnel. Security posts will be established at key locations to prevent entry of unauthorized personnel.

During non-operational periods, there will be 24-hour per day, seven days per week security monitoring, in addition to security personnel posted at the facility entrance. Security fencing is being considered at the entrance to Aeon Field, but the extent of the fencing has not been determined. Once per week a TRWCI representative will check the overall condition of the facility. No automatic alarm systems have been proposed.

2.6.2 Solid Waste Disposal

A refuse disposal site to accommodate the needs of the entire project has not been identified. A fully-lined solid waste landfill (approximately 70 m by 70 m by 2 m deep) is currently proposed, subject to the recommendations of the local Ministries and the environmental baseline studies. The proposed landfill would be adequate for eight years of use.

2.6.3 Hazardous Waste Disposal

Hazardous waste generated during construction will include used motor oil, and approximately 100 used batteries. The used oil from diesel and unleaded gasoline engines and hydraulic oil will be incinerated using special equipment that will be brought in during the construction phase. The characteristics of the emissions will be available after discussions with the selected incinerator manufacturer. The batteries will be collected, stored and removed from the island at the end of the construction phase.

The HOPE-X vehicle will land with small quantities of propellants (NTO, MMH, and hydrazine) on board. Three small mobile carts, one for each propellant, will hold tanks, equipment, reagents, nitrogen gas and an operations console. The HOPE-X tanks will be purged with nitrogen gas into scrubber systems on the respective cart. The propellants will be stored in tanks until returned to Japan with the HOPE-X vehicle.

Each of the RO water treatment units will produce a brine effluent. The effluent will likely be injected into the ground at a depth below any freshwater lens in the area. Alternatively, discharge of effluent into nearby lagoons of similar salinity is being considered where practical.

3.0 ALTERNATIVES TO THE PROPOSED ACTION

3.1 OTHER REASONABLY FORESEEABLE AND TECHNICALLY APPROPRIATE ALTERNATIVES

3.1.1 Alternatives to Christmas Island as a Landing Site

Conceivably, the HOPE-X vehicle could be programmed to land at any number of locations. Within Kiribati, however, no other atoll offers the combination of favorable attributes of Christmas Island. Even elsewhere in the Pacific, the combination of unused infrastructure on remote, undeveloped and unpopulated land may not exist. Additionally, Christmas Island is far enough east that the post-re-entry operations will occur over the very sparsely populated Pacific Ocean, rather than over Asia, minimizing public safety risks. Politically, the cordial relationship between the governments of Japan and Kiribati that has been developed over the past 20 years of cooperation on the XDRS facilitates the project. Other locations would not have this advantage.

3.1.2 Alternatives to Project Components

The only foreseeable alternative to Aeon Field as a Christmas Island landing site is Cassidy Airfield (Figure 2-2). This alternative, however, has several serious drawbacks. First, Banana Village, with a population of 905 people, is only 1 km away, compromising public safety and site security. Second, Cassidy is the island's International Airport, and disruptions of either aircraft flight schedules or HOPE-X operational schedules could result from mixed use. This alternative would, however, have a few advantages. Any potential disruption of sooty tern colonies which might occur at Aeon would be avoided at Cassidy. The improvement of the roadway from Artemia Corner to Aeon Field would not be necessary. Creation of a focal point of activity and employment at the south of the island would not occur, avoiding secondary impacts associated with an increased human presence in this remote area. In the interests of public safety, however, Aeon field is a better alternative.

To develop the HOPE-X landing site on Christmas Island and support the operations, sea access must be improved. The proposed solution is to repair the London wharf, and dredge the area fronting the wharf and an entrance channel. An alternative which has been suggested is to build a pier or jetty across the reef near the fuel farm just north of London Village. This alternative would avoid the impacts associated with both the initial and the recurrent maintenance dredging. It would, on the other hand, physically remove a sizable section of a living tropical coral reef. Such a facility, open to North Pacific swells, would sometimes be unusable. An accident involving a vessel carrying petroleum products or even a load of fish could kill a large reef area. Failure of the structure itself is also possible, bringing both ecological and economic impacts. The proposed alternative offers a safer facility in an already environmentally degraded area, albeit at the expense of a long term commitment to maintenance dredging.

Presumably, once the port facilities are available, mobilization of a construction camp and baseyard at Artemia Corner would begin. This will consolidate and centralize operations for all of the work in the southern portion of the island and minimize disruption of existing villages. Alternatives would include a *facility closer* to Aeon Field, or closer to either Poland or Banana. A facility slightly closer to Aeon would offer less disruption to Poland-London traffic, although the normal level of traffic will be dwarfed by the numbers of construction-related vehicles, and both roads will be undergoing improvements. A location closer to either Poland or Banana would be less centralized, causing unnecessary traffic, and increasing the intrusion on one or the other of the villages. The Artemia Corner site appears to be the best overall site for the construction facilities, for all activities except the wharf repair.

Construction of housing facilities near Poland for the technical staff associated with the landing operations is proposed. New facilities, similar in design to the Captain Cook Hotel, would be built at a previously undeveloped site. Alternatives are lodging at the NASDA XDRS, the Captain Cook Hotel, Artemia Corner, or Aeon Field. Lodging at XDRS would overload that facility's capacity and maximize daily travel distances. The size of the technical staff and number of expected visitors would also exceed the capacity of the Captain Cook Hotel, but the hotel could be expanded and renovated to provide quarters quite similar to those proposed for Poland. This alternative would preserve the natural environment at the Poland site and eliminate the necessity for the improved road from Artemia to Poland. The construction camp will be removed before operations begin. If, however, those facilities supporting worker lodging were retained and improved, this location would be convenient to Aeon Field and outside of the Precaution Area during a landing event. Lodging at Aeon Field itself would increase facilities and population within the Precaution Area. Given that the lodging will only be utilized for three months a year, it might be a better use of resources to improve the hotel which could be operated year-round. The Poland facility, however, brings with it a number of improvements to the basic infrastructure and public health conditions of the Poland villagers. In addition to the road, the village would benefit from improved water supply and waste treatment. It would also distribute the economic benefits, including employment opportunities of the project, to Poland in addition to the other villages.

The tracking capabilities of the existing XDRS are scheduled to be upgraded to support the HOPE-X operations. Other facilities will be located at Aeon Field. The alternative would be to co-locate the facilities. Location of all facilities at XDRS is not operationally viable, so co-location could only occur at Aeon. Technically, this is feasible, and perhaps in the long-term, consolidation is desirable, but in the short-term the expense would be great and support of other operations could be compromised, if only temporarily.

3.2 THE NO-ACTION ALTERNATIVE

The No-Action Alternative is the default scenario if the project is not implemented. None of the impacts of the proposed project, positive or negative, would occur. This is not to say, however, that conditions on Christmas Island would not change in the absence of the project. Other specific developments and the continuation of existing trends can be anticipated. Most important of the on-going trends is the relocation of families from South Tarawa to Christmas Island. Many such immigrants are unskilled and unemployed, increasing the pressure on the natural resources of Christmas Island, particularly marine resources and bird populations, to support additional residents in a semi-subsistence life style. Implementation of the HOPE-X project would stimulate in-migration, although it can be expected that skilled workers would predominate as better employment opportunities become available. The HOPE-X project would reinforce and accelerate a long-term trend to a monetary economy on the island. On the other hand, it would provide improved access to several parts of the island, thereby also increasing pressure on natural resources by those still practicing a subsistence life style. To counteract this, various mitigation measures involving resource management, pest control and enforcement of regulations, are proposed in the following sections.

4.0 DESCRIPTION OF THE ENVIRONMENT, POTENTIAL IMPACTS, AND PROPOSED MITIGATION

The purpose of this Chapter is to describe the environmental setting in terms of its component resource categories, and disclose the reasonably foreseeable impacts to those resources resulting from implementation of the proposed project or any of the potential alternative actions, including the No-Action Alternative. Where resources may be negatively affected, mitigation measures are suggested, as appropriate and practicable. Components of a program to monitor resource status during construction and operation of the proposed project are also described.

4.1 THE REGULATORY AND ADMINISTRATIVE ENVIRONMENT

4.1.1 The Republic of Kiribati

Throughout the nineteenth century, the village chiefs were the governing authority in the island groups now comprising Kiribati. The traditional authority was replaced by Great Britain's colonial rule until the Republic of Kiribati was established in 1979. The constitution establishes an elected forty-one member House of Assembly (Maneaba ni Maungatabu) as the legislative authority; the president (Beretitenti), elected by popular vote from among candidates recommended by the House of Assembly; and the eight-member cabinet, appointed by the President, as executive authority. The administrative structure of the government is illustrated in Figure 4-1.

4.1.2 Christmas Island

Each of the populated islands in the Republic of Kiribati, including Christmas Island, has a local council to preside over island issues. In addition, a separate Ministry (Ministry of Line and Phoenix Development) has been established to oversee growth in the Phoenix and Line Islands.

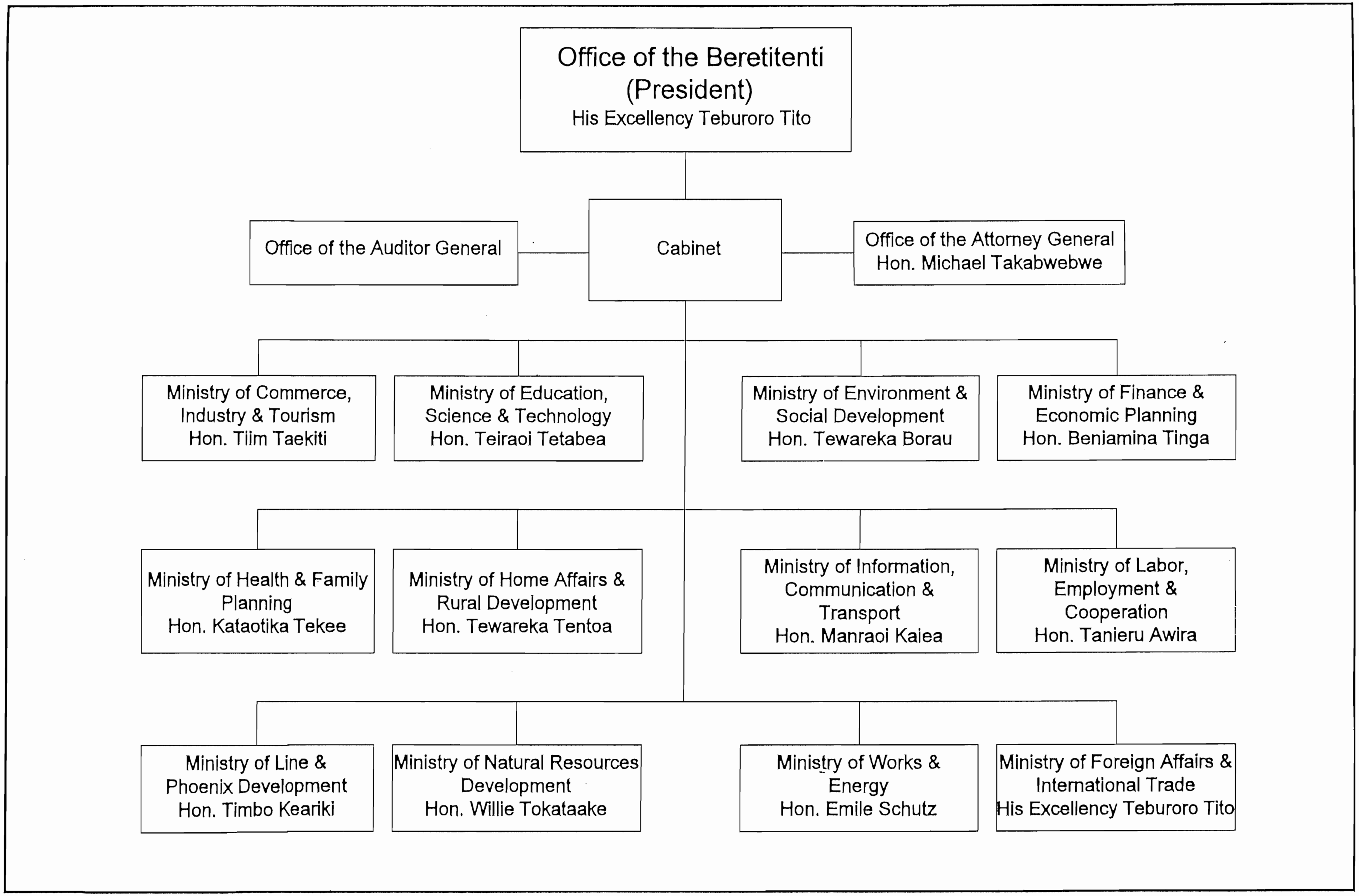
Christmas Island is government-owned. London is the seat of local government. Figure 4-2 illustrates the existing land use designations for Christmas Island, and provides an indication of the land use compatibility of the project components. Aeon field and the lands seaward to the shore are in a "water reserve." Protection of the aquifer will be a consideration in siting wells to provide feed water for the reverse osmosis unit. Outside the water reserve, most of the coastal lands are in the "government reserved area." The bulk of the interior of the southern tip of the island is in a "wildlife sanctuary" created to protect nesting seabirds. It is not anticipated that facilities or construction activities would intrude into the sanctuary. The existing borrow area which served during the original construction of Aeon Field will be reactivated for the facilities expansion. It is located between the water reserve and the wildlife sanctuary.

The road between Aeon Field and Banana Village passes through mostly government reserved lands, but also two small water reserves, and near North-east Point, a special use zone and tourism area. Artemia Corner is also designated a tourism area.

Carver Way, connecting Artemia Corner to Poland, begins in the Artemia Corner tourism area and passes through mostly government reserved areas. The central lagoon area, however, is a major wildlife sanctuary. Towards Poland, the road passes through additional government lands, coconut plantation, a water reserve and the Poland residential area.

The London Wharf is within a "residential/commercial zone."

In general, the proposed facilities are in accord with the land use designations. Development at Aeon Field, however, will occur over a designated water reserve. Measures to protect this aquifer may be required, although the most recent study of water reserves on the island indicates a complete lack of



DAMES & MOORE

ADMINISTRATIVE ORGANIZATION OF THE REPUBLIC OF KIRIBATI GOVERNMENT

HOPE–X LANDING SITE EIA
CHRISTMAS ISLAND, REPUBLIC OF KIRIBATI

developable reserves beneath the entire southeast peninsula of the island (Falkland 1983; 1992). The water reserve land use designation appears to be a result of earlier studies which suggested potable reserves might be present. The construction camp is proposed to be developed within a tourism area. Currently, only the remains (foundations) of various buildings and facilities remain from the Artemia (brine shrimp) project headquarters which formerly occupied the site. The Poland lodging area is within a government reserved area, with water reserve to the south and a tourism area to the north.

It is NASDA's intention to negotiate a lease for use of the southern portion of the island from approximately Carver Way south. This lease would preclude other development in the area, creating a de facto wildlife sanctuary. The area, however, is currently used by residents to access fishing grounds, and for other recreation and picnics. It is not expected that these uses would be curtailed, except in the immediate vicinity of the Aeon Field facilities and during landing events when the Precaution Area would be cleared of all non-essential personnel. Certainly the officers of the Wildlife Unit will require access for management and enforcement purposes.

4.2 THE SOCIAL, CULTURAL AND ECONOMIC ENVIRONMENT

4.2.1 Historical Setting

Christmas Island was discovered by Captain James Cook in 1777, at which time the atoll was uninhabited. Archaeological research provides no evidence of permanent settlements by the early Polynesians, but coconut groves and a few artifacts, simple structures and burials indicate temporary occupation, probably from several sources at quite different times.

The island remained unoccupied until 1881, when a New Zealand firm developed a copra plantation and a pearl shell fishery. Prior to the British purchase of the rights to the island after World War II, various companies held rights there. Americans occupied Christmas Island during World War II, but British administration was restored thereafter. Permanent residents first arrived from various islands in the Gilbert group in 1941. Nearly all inhabitants of Christmas Island have come from other atolls through government resettlement programs, therefore they do not have strong historical ties to Christmas Island. Traditional Micronesian songs, dances and other customs continue to be practiced.

In 1892, Great Britain established a protectorate over the Gilbert and Ellis Islands. The protectorate became a British colony in 1916, which was expanded to include Christmas Island in 1919. In the early twentieth century, the British Gilbert and Ellice Islands Colony administration planted coconut trees and built homes to encourage settlement and economic development.

The first major impacts to the atoll were during World War II, when British and American forces constructed roads and improved the London port. Large ships were able to dock inside the main lagoon. The military abandoned the atoll during the later stages of the war, but small populations of Gilbertese settlers remained.

Between 1957 and 1963, Christmas Island was used by the British and later the Americans for nuclear weapons testing. An extensive infrastructure of roads, buildings and airfields was constructed or improved in support of the testing. After the ban of nuclear testing in 1963, the British colonial administration encouraged more settlers to the atoll and promoted agricultural and maricultural development. The remains of the British and American military installations have been recycled into other structures and uses. No historically significant sites have been designated on Christmas Island (UH, 1997).

Self-government of Kiribati began with the British appointment of islanders to government positions in 1963. Full internal self-government was granted in 1977, and complete independence for the Republic of Kiribati was granted in 1979.

4.2.2 Current Conditions

The Kiribati population in 1995 was approximately 72,000, 40 percent of whom lived on Tarawa Atoll, the seat of government. The Line Islands and Phoenix Islands together comprised only 7 percent of the Kiribati population. The population of Christmas Island, however, continues to steadily increase through the Republic's resettlement programs. A resettlement plan is ongoing and involves the relocation of 6,000 people from the Gilbert Islands to the northern Line Islands, which include Christmas. The progress of the resettlement has not been fully implemented due to the delay in providing adequate infrastructure (Nippon Tetrapod, 1995).

According to the official 1997 census report (Table 4-1), 3,271 people reside on Christmas Island. Forty-three percent of the population is less than 15 years of age, forty-four percent are between the ages of 15 and 44, and the average life expectancy is 53 years. In general, males and females are equally represented in the population. The villages of London, Tabwakea, Banana, and Poland represent 36.5, 29.5, 27.6 and 6.2 percent, respectively, of the total Christmas Island population (Census, 1997).

TABLE 4-1
Christmas Island Census - 1997

Village	House -holds	0-12 mo		1-6 yr		7-14 yr		15-44 yr		45-65 yr		66+ yr		Totals		Grand Totals
		m	f	m	f	m	f	m	f	m	f	m	f	m	f	
London	191	20	19	98	93	138	131	286	272	54	61	4	18	600	594	1194
Tabwakea	128	13	19	74	63	122	123	22	202	55	51	13	0	500	468	968
Banana	115	11	17	87	84	110	108	206	181	43	45	5	8	462	443	905
Poland	36	4	4	20	16	26	20	50	42	13	9	0	0	113	91	204
Totals	470	48	59	279	256	396	382	756	697	165	166	22	36	1675	1586	3271

In 1980, the Kiribati government instituted compulsory and free education for children. The population is universally educated through the first five primary grades. Secondary education is limited, for lack of openings, to 19 percent of the population, and six percent obtain tertiary education (Ikeda, 1990). I Kiribati is the primary language, but English is used for official purposes and is taught as a second language. Education is valued by parents, who recognize that future employment is dependent on educational achievement.

The predominantly rural society is largely dependent on subsistence agriculture and fishing. Agriculture is severely hampered by the lack of rainfall and nutrient-poor soil with poor water retention properties. Slow economic development of The Republic of Kiribati is attributed to a lack of enterprises and skilled labor, lack of capital, the geographic distances among islands, lack of adequate port facilities, and infertile soil. Historically, the principal export was phosphate, but the resource was depleted in 1979. In 1980, the export earnings dropped by 80 percent. Current exports are limited to copra and fish, which account for only 10 to 15 percent of the Gross Domestic Product (GDP). Imports account for 80 percent of the GDP, but the trade deficit is partially offset by remittances from other nations for use of Kiribati's Exclusive Economic Zone (Nippon Tetrapod, 1995).

The Australian Dollar is the legal currency (Kiribati Travel Fact File, 1996-1997, undated). The government, which accounts for approximately 75 percent of the cash-based employment in Kiribati, employs approximately 17 percent of the population (Ikeda, 1990). Most of the government positions are located in South Tarawa. The few existing private sector businesses are compelled to offer higher wages than the government to attract employees away from the more popular government positions. The Kiribati values of equality and conformity interfere with the development of individualistic enterprises, and therefore cooperatives dominate the retail trade sector. Some of the young men find employment on foreign ships, however, the demand for sailors is static. Increased opportunity for employment is an objective described in the National Development Plan.

Tourism is a viable sector for future economic growth in Kiribati, specifically Christmas Island. Although East Asia and Pacific Regional tourism has increased steadily over the past fifteen years, the South and Central Islands account for less than 5 percent of the total travel in the region. Christmas Island demonstrated a 147 percent increase in arrivals between 1980 to 1987, but there was a steady decline in arrivals between 1987 and 1991. The number of arrivals in 1995 indicated a recovery to approximately the 1987 level. In 1995 there were 1,098 arrivals at Christmas Island and 92 percent of the arrivals were traveling for pleasure (UH, 1997). Tourism to Christmas Island is nearly completely dependent on air service to the island, which has been very irregular since independence. The principal recreational activities attracting visitors are sportfishing, diving, and bird watching.

Government support for developing a tourist industry is the key to tourism growth, since there is little private sector funding. The Kiribati National Development Plan and a detailed tourism development plan describe short-and long-term tourism strategies. The government objectives include: improve the frequency and reliability of air transportation service; expand, upgrade or develop new accommodations; and upgrade water supplies, electrical supplies, sewerage facilities, and trash disposal activities.

The Kiribati Government has been conservative in initiating new ventures that may prove difficult to sustain and may require future subsidy. Foreign aid rather than loans has been the focus for financing specific projects. The "leakage" of revenue outside of Kiribati and minimal local employment resulting from the use of expatriate labor, could seriously impact the net benefit of any new project. The goods and services purchased by tourists or employees of other ventures are likely to be wholly or partially imported, because the economy is not diversified. Other leakages anticipated include the profits taken out of the country by foreign operators, expenditures to promote tourism in Kiribati and to train personnel on foreign land, and the purchase of imported goods by local personnel. No definitive studies have been conducted to date on the economic benefits of tourism to Christmas Island (UH, 1997). The Seventh Economic Development Plan objectives include five percent annual economic growth, improved economic production diversity, and greater self-reliance.

4.2.3 Potential Impacts and Proposed Mitigation

Infrastructure and facilities construction will require three years, during which time there will be approximately 75 continuously resident expatriate workers. Clearly, there will be significant social, cultural and economic impacts related to construction of the project. During construction, both direct and indirect jobs will be available to local workers. Additional employment will bring more money into the economy. Interaction with expatriates will provide exposure to more modern culture and values. Movement away from the traditional communal village values and subsistence lifestyle is likely for at least some residents, especially the young males most likely to interact with the construction workers in occupation and recreation.

Once facilities are constructed, operations will take place for only three months a year, during which time as many as 200 people will be living temporarily on Christmas Island. The essential technical personnel (40 to 50 individuals) will be housed at the NASDA lodging facility in Poland, the other visitors will either be accommodated in the existing tourist accommodations or the NASDA lodging facility will be expanded. The *HOPE-X* facilities and operations will, therefore, provide few direct long-term jobs, but there will be programs to train islanders in construction skills, landscaping, housekeeping, and maintenance jobs. The proposed apprenticeship programs have been discussed with the school principals. The training and experience received during construction will prepare individuals for any future development opportunities in the Republic.

Construction and operation of the project will require more skilled labor than is currently resident on Christmas Island. Logically, some of this demand will be met by immigrants from Tarawa, furthering the government's resettlement plans. This in itself will contribute to secondary impacts on all environmental resources. As the resident population grows, pressure will mount on the renewable environmental resources, specifically those resources critical to maintenance of the subsistence or semi-subsistence life style practiced by many of the residents. Clearly, additional constraints will be required to ensure resource sustainability, thereby providing a de facto promotion of a more modern, money-based economy. This will inevitably result in further erosion of traditional customs and values. Change to the culture is inevitable and already there is a movement toward modernization.

The secondary impacts of population growth on the resources of Christmas Island will occur regardless of the alternative implemented, including No-Action. In the latter case, however, the impacts would occur over a longer time period, reflecting the gradual resettlement program. It is possible that the impacts of the No-Action alternative would be more severe because the immigrants generally might be less skilled overall, thereby placing more pressure on the subsistence resources.

Within government and the populace, the proposed project is not particularly controversial. While it is acknowledged that aspects of the project place significant environmental resources at some risk, and may restrict access to certain areas of the island, the positive economic benefits of the project including infrastructure improvements, jobs creation, growth in personal income, and increased government revenues, are perceived to justify its implementation.

4.3 INFRASTRUCTURE AND SERVICES

4.3.1 Port and Airport

Beneficial impacts of the project would include improved infrastructure on Christmas Island, especially in the vicinity of Poland Village and at the London Wharf. The wharf improvements will provide for more efficient ocean access for cargo and passengers. If sufficient draft clearance is provided dockside, the improved wharf may serve to initiate other ventures such as fish transshipping. A potential negative impact of the improved access to the wharf is the introduction of alien species, especially species of rats not now present on the island. Means to minimize this are described in the terrestrial biota section below.

While improvements at Cassidy Airfield are not part of the present project, the proposed development provides the impetus for resumption of reliable long-term air service to the island. This would have impacts throughout the population, economy and environment. In fact, reliable, regular air service is the single most necessary thing for economic development on the island. Paradoxically, such service brings with it the potential to inflict serious harm to natural resources resulting from increased levels of use for commercial and recreational purposes. Additional resource monitoring and more rigorous enforcement of wildlife regulations will help mitigate these impacts.

4.3.2 Roads and Traffic

A paved road (A1) extends from London through Banana to Aeon Point and beyond. In addition, a network of unpaved roads, constructed of lagoon mud and sand, radiates across the island, and numerous jeep trails traverse the countryside. Most of the unpaved roads are in poor condition, with passibility often depending on the volume of recent rainfall. This is especially true for Carver Way, leading to Poland and the Paris Peninsula (Figure 2-2). Extended reaches of this road flood after heavy rainfall, and sometimes remain flooded for weeks afterwards. The improvements proposed for this road will be a significant benefit to the residents of Poland, but will not come without the risk of negative impacts to natural resources. Both direct and indirect impacts are possible. Direct impacts to the ecosystems of the ponds inland of the road may result if normal replenishment of water from the main lagoon is retarded or prohibited. To avoid this possibility, installation of culverts is recommended to permit water flow beneath the roadway. Indirect impacts to natural resources may result as a consequence of the improved access to fishing areas or bird colonies. Improved enforcement of wildlife regulations will be necessary to mitigate this impact.

Improvement of the existing paved road by providing an additional lane between Cassidy Airfield and Aeon Field will little affect local traffic, for which the present road is adequate. Given the increased traffic to the southern portion of the island coincident with the development of Aeon Field, however, the two lanes will provide a much safer route.

Existing traffic on Christmas Island is very light, with the heaviest concentrations of vehicles in London and Banana villages and on the road between them. Elsewhere, traffic on the major roadways can be measured in minutes elapsing between passage of vehicles. Towards the southern portion of the island, the measure would more appropriately be hours between vehicles. Clearly, the HOPE-X project will increase traffic to all parts of the island, although different parts of the island will be affected to greater or lesser degrees as work progresses. For example, wharf improvement construction will induce additional traffic primarily in London. If these construction workers are housed near London, there may be little necessity for them to travel extensively to other parts of the island. Once the wharf work is complete, the focus of work will shift southward. Workers will be housed at Artemia Corner, so commuting through villages will not be necessary. While roadway improvements are underway, some traffic delays may be expected, but in most cases one lane will remain open at all times. The only exception to this might be during installation of culverts along Carver Way.

4.3.3 Waste Treatment

There is no centralized sewage collection, treatment and disposal system on the island. Septic tanks and leach fields are used exclusively. Banana Village is being considered for relocation to protect the fresh water lens in the area from wastewater contamination. This type of system or a self-contained sewage treatment plant is being considered for Aeon Field. Even though the facility will be operational for only three months of the year and occupied by no more than 50 personnel, this area is within a designated water reserve. Precautions will be necessary to insure that the groundwater aquifer is protected. Secondary treatment systems are proposed for the Poland accommodations and the construction camp at Artemia Corners. It has not yet been specified where the effluents of these treatment systems will be disposed of, but groundwater aquifers, lagoon waters used for recreation and subsistence, and coastal waters supporting vibrant coral reefs could all be at risk.

4.3.4 Power and Fuel

There is no island-wide distribution system for electrical power. Diesel generators provide electricity for the villages of London, Banana and Poland, and the Captain Cook Hotel. The lack of back-up power supply and spare parts cause frequent blackouts. Although Christmas Island would be an ideal candidate for solar power, the costs are prohibitively expensive for the average resident. The Captain Cook Hotel does use solar water heaters. Wind pumps have been employed on the island for years, and wind generators could someday provide non-baseload power. Ocean thermal energy conversion (OTEC) power is a viable option for the island, but would require a much larger, centralized demand to be economical to install.

Fuel and other petroleum products are supplied solely by The Kiribati Oil Company (KOIL). There is a fuel storage tank farm near London. The storage capacity for the various fuels is as follows: 381,364 l of gasoline, 596,919 l of diesel oil, 53,426 l of kerosene, and 1,101,888 l of Jet A-1 fuel. Delivery by oil tanker is dependent on demand. There were three shipments in 1996.

The HOPE-X project is designed to be generally self-sufficient for its power needs. The only exception to this may be for the wharf improvements and wharf worker lodging, each of which may *depend on island* resources for power. The additional fuel demands created by the project may require more frequent tanker deliveries to the London fuel farm, increasing the possibility of spills or releases. The present pipeline offshore from the fuel farm is inadequately designed and deteriorating. Reportedly, recent repairs to the fuel line effectively prevent the influx of ocean water when the facility is not in use.

4.3.5 Communications

Local and international telephone and fax services are provided by Telecom Services Kiribati Limited (TSKL), which is owned by the government (51%) and Telestra of Australia (49%). Telestra provides all dial tone services, and all regulatory functions are the government's responsibility. The government is responsible for control and allocation of radio frequency assignments. On Christmas Island a council of local residents has been established for the operation and security of the telecommunications equipment. The TSKL antenna system is located in London.

These services are generally adequate, but sometimes outages occur. The project will use these services for some routine communications, but will establish its own systems for mission critical communications and data transmission. It is not expected that the additional levels of use will overload the local capacity, but if this happens, additional circuits will have to be installed, presumably at the expense of the project.

4.3.6 Government Services

Most of the government services available on the island would be unaffected by the project. Family members would not accompany expatriate workers; local schools or other social services would not be used. In case of medical emergency during operational periods, a small triage team will be assembled and available to handle such incidents. Injuries requiring further diagnosis, testing and/or continued medical care will be coordinated by the U.S. Coast Guard and/or medical facilities in Hawaii.

Several areas of government service will require upgrading and augmentation due to changing conditions brought about by the project. Additional agricultural inspectors should be employed at the port and airport to reduce the possibility of alien species imports. Several additional positions in wildlife management and enforcement will also be needed.

4.4 THE NATURAL ENVIRONMENT

The primary reason for Christmas Island being a tourist destination is the pristine natural environment and abundant natural resources. In particular, the seabird colonies and marine fisheries resources are renown worldwide. Christmas Island is home to eighteen species of marine birds. The most numerous are the Sooty Terns, Frigatebirds, Shearwaters, and Petrels. In recent years, Christmas Island has become known as one of the best light tackle fishing locations in the world, with world-record bonefish and trevally being caught. Even with a relatively small population resident on the island and limited tourism, however, noticeable depletion of these resources has occurred. Poaching of birds and eggs is common. Enforcement of prohibitions on this activity is inadequate. Subsistence fishing has affected lagoon stocks of milkfish, bonefish and other resources. Commercial fishing efforts by local residents and foreign interests have targeted species of interest to consumers in Hawaii and elsewhere, including at various times mullet, reef fish, and pelagic species such as tuna. There have also been intense "pulse" fisheries for specialty products including lobsters, shark fins, beche de mer (sea cucumber), and currently, aquarium fish. These types of efforts rapidly deplete targeted resources to non-economic levels.

Numerous regulations exist to protect the environmental resources of Christmas Island. The island is a wildlife sanctuary with all species of birds and other animals protected by law. Specific areas, as shown on Figure 4-2, are restricted to the public, and require escort by the warden of the wildlife conservation unit. It is illegal to hunt, capture, kill, or willfully destroy any bird on Christmas Island. To preserve the fish supply, numerous other regulations are imposed on fishing in the waters of Christmas Island. For example, the area in the southeast corner of the main lagoon is a conservation-no kill zone, where only catch-and-release fishing is permitted. Nevertheless, the best intentioned and crafted regulations are ineffectual without adequate enforcement. For the remarkable and unique natural resources of Christmas Island to remain viable assets will require an increasingly concerted enforcement effort as the resident and visitor populations continue to grow. There is a complementary need for education of the population, perhaps beginning in the schools, about natural resource sustainability and its importance to the life style and economy of the residents of the island.

4.4.1 Geology, Topography and Soils

Christmas Island lies atop the southeasternmost portion of a northwest-southeast trending volcanic ridge. The volcanic basement is covered by from 30 to more than 120 m of coral (Northrup, 1962; Jenkin and Foale, 1968). The basic shape of the island likely reflects the distribution of its volcanic basement, but the surficial detail is controlled by sea-level fluctuations and further climatic and tectonic influences. The irregular shape of Christmas Atoll is probably due to the arrangement of volcanic peaks. The development of the distinctive geomorphologic features (the interior lagoons or ponds) is a result of linear patch reef growth, and a progressive westward and northward infilling of the main lagoon, perhaps aided by simultaneous gradual northwestward tilting of the entire atoll (Helfrich, 1973).

On the basis of morphology and sediment type, the island can be classified into nine subaerial and two submarine landform units (Jenkin and Foale, 1968). The maximum elevation is 10.7 meters in the coastal dune unit along the Bay of Wrecks, although masses of reef rock distributed throughout the island's interior exhibit a rather uniform surface not exceeding four meters above present sea level (Wentworth, 1931).

Soil development is very slow and generally uniform on dry atolls due to the scarceness of organic matter and the common chemical nature of the parent mixed calcareous debris. Thus, lateral soil differences result mainly from variations in the size and depositional mode of shell and coral fragments, whereas incipient soil profiles develop only as a response to increased compaction and a decrease of organics with depth.

Construction of the HOPE-X facilities and improvements to the island's infrastructure will require a considerable amount of site work including grading, grubbing and compacting. Insignificant changes to the already flat topography will result. Of concern, however, is the source of fill needed for the wharf repairs and road improvements. It will be important to ensure that seabird nesting areas and productive marine habitats are not disrupted by borrow or fill activities. The possibility of isolating inland ponds by the elevation of Carver Way is discussed above.

Dredging associated with the wharf and channel improvements will require movement of the greatest volume of sediment, and have the greatest potential impacts on natural resources and habitats. The dredging plan calls for on-land disposal of the materials dredged from the harbor. There are numerous low lying areas near the wharf which could be productively reclaimed with no loss of important wildlife habitat. Mitigation measures will be required, however, for containment of the plume of disturbed sediments during dredging and from any disposal area adjacent to the ocean. Materials dredged from the entrance channel will be barged offshore and dumped in deep water. A plume of silty water will result from this activity and dewatering of the sediments in the barge. this activity should be closely monitored to determine if viable coral reefs and being affected. If so, dredging operations should be suspended until more favorable wind, tide and current conditions prevail.

4.4.2 Water Resources

Christmas Island lies within the Equatorial Dry Zone. The average annual rainfall is 840 mm, but annual volumes can vary from a fraction of to many times that amount. There is little surface runoff because the topography is relatively flat and the ground surface highly porous. The only freshwater sources are rainwater and groundwater in the form of a lenses floating on underlying denser sea water. There are major lenses located at Decca, Four Wells, Main Camp, Banana, and New Zealand Airfield. The

- Ozone concentrations should be near zero given the small quantities of volatile organic carbon (VOCs) emitted from stationary and mobile sources and the small size of the atoll which does not provide adequate time for significant photochemical transformation of VOCs and buildup of ozone.
- Nitrogen dioxide concentrations will be limited by the quantity of ozone available for the transformation of nitrogen oxide (NO), the primary pollutant from mobile and stationary combustion engines, to nitrogen dioxide.
- Lead concentrations from anthropogenic activities will be immeasurable since there are no sources of lead on Christmas Island with the exception of the trace amounts in fuel burned.
- Carbon monoxide sources include the main stationary sources (village generators) and mobile sources; however, there are few stationary and mobile sources on the atoll, so background levels are expected to be low.
- Stationary sources and mobile sources will emit low levels of particulates; however, most mobile sources on the atoll burn gasoline, rather than diesel fuel, minimizing particulate emissions from motor vehicles.

The only industrial source of emissions is the aircraft at Cassidy Airport, but there are no more that one to two flights per week.

Construction activities will result in short-term negative impacts on localized air quality. These will result from tail pipe emissions from construction equipment and fugitive dust from grading activities. These impacts will be localized and transient.

In the absence of Republic of Kiribati air quality regulations, the State of Hawaii Ambient Air Quality Standards will be applied (HRS, 1993). These standards are the maximum allowable concentrations of pollutants in the ambient air necessary to protect human health and welfare. The pollutants for which Hawaii standards have been established are carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter less than 10 microns in size (PM-10), ozone (O_3), sulfur dioxide (SO_2), lead, and hydrogen sulfide (H_2S).

No information is presently available on the specific construction equipment to be used for the project; however, it is likely that a variety of types of equipment will be required. In general, diesel-powered equipment will emit more NO_x, SO_x, and particulate matter per unit of fuel consumption, compared with gasoline powered equipment. The latter, however, emit more hydrocarbons and CO.

Fugitive dust generation from grading and heavy construction equipment is usually estimated at 1.2 tons per acre per month of activity (USEPA, 1985). The total land area to be disturbed by the project has not been determined, but the potential for significant dust generation exists. These impacts would be localized, transient and temporary, and can be held below significance by employing appropriate mitigation measures. Watering and other soil stabilization techniques are routinely employed to substantially reduce the dust generated by construction.

Mitigation measures intended to minimize construction impacts on air quality include the following:
- Minimize the number of concurrent construction/grading or equipment-intensive projects;
- Minimize the simultaneous operations of multiple fuel-burning construction equipment units;
- Use catalytic reduction for gasoline-powered equipment;
- Apply injection timing to retard diesel-powered equipment; and
- Water construction areas to minimize fugitive dust.

Long term pollutant impacts associated with the landing site and associated facilities include the effects of increased vehicular road traffic between facilities, stationary sources such as generators and fuel storage tanks, refueling operations, and any open burning of waste materials.

4.4.4 Terrestrial Biota

4.4.4.1 Introduction

Native vegetation on Christmas Island is comprised of 18 native species and about 50 non-native species, the latter of which are confined mostly to villages and abandoned military sites. Most plants are low-growing shrubs and annuals, with only one prevalent species reaching small tree size. The introduced coconut palm, however, because of its height, dominates the landscape in and near inhabited areas where it has been planted.

Terrestrial fauna on the island is dominated by seabirds, which comprise the largest collection of seabirds in the world. Only one resident landbird occurs on Christmas Island, and several species of migrant shorebirds spend their non-breeding season here. One formerly resident shorebird is now extinct. Other than birds, the only native terrestrial vertebrates are three species of lizards.

Christmas Island has been designated a wildlife sanctuary under Section 8 (1) of the country's Wildlife Conservation Ordnance, 1975, as amended in 1979 and 1989. Designated as closed areas within the wildlife sanctuary under Section 8 (3) of the ordinance are Cook Island, Motu Upua, Motu Tabu, North-west Point, and Ngaon te Taake (an area between the main lagoon and Central Lagoons)(see Figure 4-2). While wildlife sanctuaries and closed areas protect birds (in theory), they have no provision for protecting habitat. Recommendations have been made (MBA International, 1997) to designate Christmas Island a Conservation Area, which does protect habitat, and expand the scope of closed areas to include Paris Peninsula, South-east Point, Frigatebird Island, and all Sooty Tern colonies during the duration of the nesting season (see Garnett, 1983).

4.4.4.2 Vascular Plants

Because of its isolation in the central Pacific Ocean, Christmas Island has very few native plant species. All 18 native species present on the island are common and widespread in the Pacific and have excellent dispersal capabilities and colonizing potential. No plants are endemic. Most of the native species and at least one non-native are common and widespread, and are frequently dominants or subdominants in areas with appropriate soil and microclimatic conditions.

Within the five general areas surveyed, 14 of the 18 native species found on Christmas Island were recorded. Three of the four species that were not recorded do not occur in the areas surveyed, and the fourth, the grass *Digitaria pacifica*, is a fairly widespread but generally uncommon (at this season?) annual that was found in only one location (not a survey area) on this visit. In survey areas, only seven non-native species were recorded. Other than *Tribulus cistoides*, which may be native, and *Cocos nucifera*, which is widely cultivated, all introduced species recorded were in the immediate vicinity of Aeon Field, Dakota Strip, Poland, and the old South Pacific Airways Hotel site, an indication that few introduced plant species have yet become widespread on the island.

The most abundant and widespread species on the island are the grass *Lepturus repens*, the shrub *Scaevola taccada*, its associated parasite *Cassytha filiformis*, and in saline soil on the lagoon side of the island, the shrub *Suriana maritima*. Other species, notably the prostrate or semi-prostrate *Boerhavia repens, Sesuvium portulacastrum*, *Tribulus cistoides*, and *Heliotropium anomalum*, and the prostrate to (usually) erect subshrub *Sida fallax* are locally common but generally not dominant. The only native trees on Christmas Island are *Pisonia grandis*, found only in one cluster near the east end of Dakota Strip at South-east Point and the widespread *Messerschmidia* [or *Tournefortia*] *argentea*, which is more often than not a large shrub. The widely cultivated, non-native coconut palm dominates the landscape in and near inhabited areas. Detailed descriptions of the flora found in each of the survey areas (see Table 4-2) are provided in Appendix A.

4.4.4.3 Seabirds

Because they play such an important role on Christmas Island, and because they are probably the most vulnerable to human disturbance, an emphasis was placed on seabirds throughout this study. Christmas Island is reported to have the largest seabird colony in the world, both in terms of numbers of birds and number of species. Its inner lagoon is a mosaic of islets that provide predator-free nesting sites for many birds. Eighteen species of seabirds and one endemic land bird nest on Christmas Island. Based on estimates from the early 1980s (Perry 1980, Garnett 1983, Schreiber and Schreiber 1984), Christmas Island has the largest known colonies of at least four species, with populations of several other species among the world's largest. No other island can claim as many numbers of so many different species, and few, if any, can boast more species. It is not surprising, then, that the seabirds of Christmas Island are of international importance.

By most accounts, the numbers of seabirds nesting on Christmas Island have dropped precipitously in the past fifteen to twenty years. Some attribute the drop to the actions of rats and feral cats, others to illegal poaching of birds and Sooty Tern eggs (see Ongoing Impacts, below). It is clear that all have played a significant role in their demise. With the island's rapidly expanding human population, increased access to motorized vehicles and boats, inadequate regulations and virtually no enforcement of these regulations, poaching of birds and harvesting of Sooty Tern eggs have played a major role in population declines. Cats and rats are also a serious problem.

TABLE 4-2
Terrestrial Biota Surveys

Date	Locality	Purpose
3 May	Aeon Field, Dakota Strip	general assessment
4 May	Carver Way (mainland only)	general assessment
7 May	Poland to Benson Point	general assessment
9 May	Lagoon 10 (Islands 1-3)	seabirds, plants
10 May	Bathing Lagoon Island	seabirds, plants
12 May	Isles Lagoon (Islands 6-8, 11, 14, 15)	seabirds, plants
13 May	Isles Lagoon (Islands 18-22, 29, 31-33)	seabirds, plants
14 May	Isles Lagoon (Islands 16, 17, 34-40)	seabirds, plants
15 May	Aeon Field, Dakota Strip Carver Way, Boating Lagoon, Bathing Lagoons (mainland)	Sooty Tern, plants plants
16 May	Isles Lagoon (Islands 4,5,9,10,12,13); Lagoon 7 (Islands 1-8)	seabirds, plants
17 May	Cook Island	Sooty Tern
18 May	Boating and Bathing Lagoon Islands Poland to South Pacific Airways Hotel ruins	seabirds, plants plants
19 May	Lagoon 1 (Islands 1-3); Lagoon 2 (Islands 1-6)	seabirds, plants
20 May	Lagoon 3 (Islands 1-3), Lagoon 4 (Islands 1-5)	seabirds, plants

The only breeding seabird not recorded on this visit was the Polynesian Storm-Petrel (*Nesofregetta fuliginosa*). It has been recorded breeding only from July to January (Figure 4-3), and may not be present at this season.

It should be kept in mind that the mid-May surveys conducted for this EIA represent only a snapshot of a very dynamic and complex breeding bird population. For some species, mid-May is the "off" season with very few or no birds breeding. For others, it may be the height of the breeding season. For still others, the breeding season varies seasonally from year to year, enough to make it nearly impossible to determine if mid-May 1997 was a relatively productive or non-productive year, depending upon what stage each is in during its breeding cycle in this particular year. For example, no evidence was found that Blue-gray Noddies were nesting; yet most previous studies had at least some breeding at this time of year. What this lack of breeding evidence means cannot be determined in such a brief period. The same can be said for the Masked Booby.

Another variable that could not be detected in this relatively brief survey conducted on only part of the island is the possibility that the centers of abundance of some species may have shifted since Garnett's thorough surveys in 1979-1981. For example, are the relatively low numbers of Phoenix Petrels representative of an actual decline, an off-peak period in their breeding cycle, or an indication that many of the birds have shifted to another part of the island since 1980; or is it a combination of these?

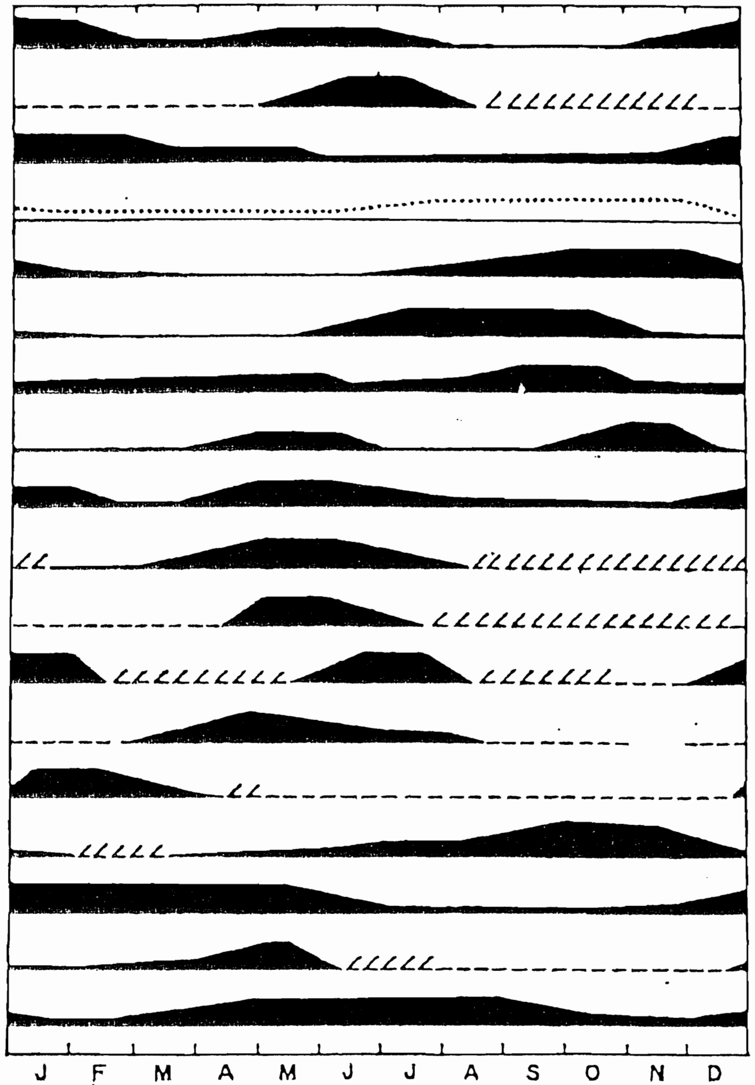
Therefore, it would be speculative to attempt to extrapolate the condition of seabird populations on Christmas Island as a whole from sampling only a small portion of the island over a two-week period in May.

SEABIRD DISTRIBUTIONS

Carver Way Lagoons

Immediately adjacent to Carver Way along the 12 km stretch where it bisects the island are a number of land-locked lagoons. Ten of these have islands (Figure 4-4), but four of these (Lagoons 5, 6, 8, and 9) appeared to have few breeding seabirds and were not visited. In each of the six lagoons visited, all significant islands (or, in a few instances, island clusters) are numbered. Survey results are tabulated in Appendix A and described below. A summary of the survey, showing the seabird species observed in each of the Carver Way lagoons is provided in Table 4-3.

I-Kiribati	English	Scientific
te ruru	Phoenix Petrel	*Pterodroma alba*
te tangiuoua	Wedge-tailed Shearwater	*Puffinus pacificus*
te tinebu	Christmas Shearwater	*Puffinus nativitatis*
te nna	Audubon's Shearwater	*Puffinus lherminieri*
te bwebwe ni marawa	Polynesian Storm-Petrel	*Nesofregetta fuliginosa*
te taake	Red-tailed Tropicbird	*Phaethon rubricauda*
te mouakena	Masked Booby	*Sula dactylatra*
te kibui	Brown Booby	*Sula leucogaster*
te kota	Red-footed Booby	*Sula sula*
te eitei	Great Frigatebird	*Fregata minor*
te eitei	Lesser Frigatebird	Fregata ariel
te keeu	Sooty Tern	*Sterna fuscata*
te tarangongo	Gray-backed Tern	*Sterna lunata*
te karakara*	Great Crested Tern*	*Thalasseus bergii**
te raurau	Blue-gray Noddy	*Procelsterna cerulea*
te io	Brown Noddy	*Anous stolidus*
te mangkiri	Black Noddy	*Anous minutus*
te matawa	Common Fairy-Tern	*Gygis alba*



* Not found in study area of 1997 investigation

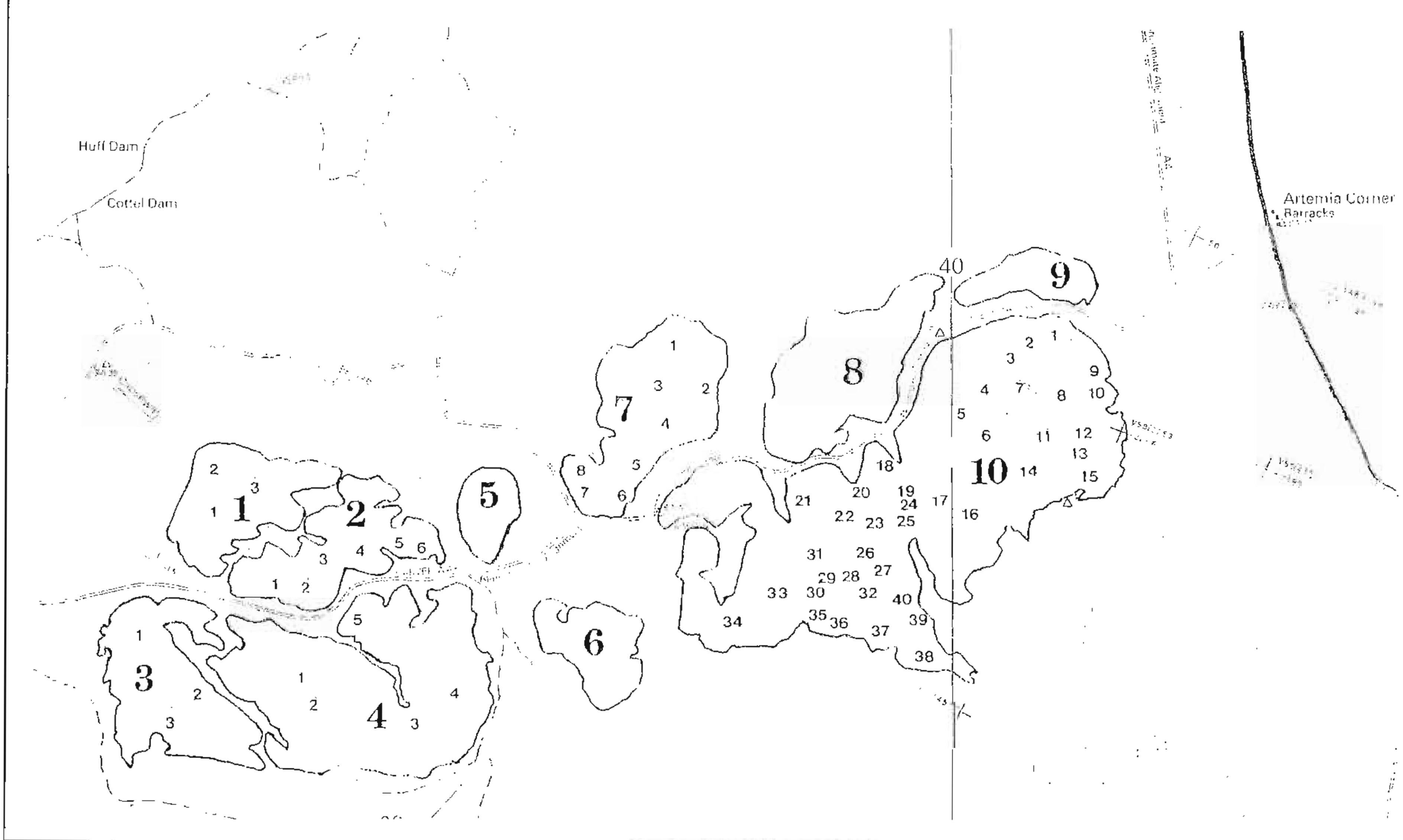
Source: Schreiber and Schreiber, 1970

The Figure shows an idealized year for each species based on information gathered by Ashmole, Gallagher, and Schreiber. Data for some species are more accurate than for others. The presence of eggs is shown in black, the presence of chicks but not eggs by slanted lines, and the presence of adults only by dashes.

DAMES & MOORE

SEABIRD BREEDING SEASONS
HOPE–X LANDING SITE EIA
CHRISTMAS ISLAND, REPUBLIC OF KIRIBATI

Lagoons with islands adjacent to Carver Way are highlighted and numbered. Each island surveyed is represented with a smaller-sized number.



Source: Jones, 1997, Appendix A

DAMES & MOORE

VICINITY MAP OF LAGOONS NEAR CARVER WAY

HOPE-X LANDING SITE EIA
CHRISTMAS ISLAND, REPUBLIC OF KIRIBATI

TABLE 4-3
Seabird Distribution by Lagoon Along Carver Way

Species	Lagoon: 1	2	3	4	7	10	TOTAL
Christmas Shearwater	70 (67)	4 (4)	-	20 (19)	8 (8)	2 (2)	104
Phoenix Petrel	60 (55)	10 (9)	-	7 (6)	8 (7)	25 (23)	110
Red-tailed Tropicbird	110 (39)	8 (3)	-	33 (12)	59 (21)	71 (25)	281
Brown Booby	1 (11)	-	-	-	7 (78)	1 (11)	9
Red-footed Booby	38 (14)	11 (4)	-	33 (12)	80 (30)	105 (39)	267
Great Frigatebird	50 (4)	7 (<1)	32 (3)	15 (1)	124 (10)	1,019 (82)	1,247
Gray-backed Tern	20 (3)	313 (55)	-	160 (28)	33 (6)	46 (8)	572
Brown Noddy	208 (31)	90 (13)	3 (<1)	54 (8)	105 (16)	216 (32)	676
Black Noddy	305 (35)	90 (10)	-	319 (37)	140 (16)	15 (2)	869
Common Fairy-Tern	7 (19)	-	-	9 (25)	20 (56)	-	36
TOTAL	869 (21)	533 (13)	35 (<1)	650 (16)	584 (14)	1,500 (36)	4,171

Lagoon 1

Lagoon 1 has two large islands and one small island (Figure 4-4). The two large islands are among the most productive visited. Island 3 had the largest Brown Noddy colony by far and the second largest Black Noddy colony. Among the 58 islands visited, it ranked first in number of species (12) and estimated number of nests (603, not counting the two burrowing shearwater species). Island 1 ranked third with 10 species and sixth with an estimated 255 nests, not counting the burrowing shearwaters (Table 4-3).

Lagoon 1 had the largest colonies of Christmas Shearwater, Phoenix Petrel, and Red-tailed Tropicbird, and the second largest colonies of both Brown and Black noddies. In all, Lagoon 1 may be one of the most productive lagoons on Christmas Island, despite its small size and the presence of only 3 islands.

Lagoon 2

Lagoon 2 has six small to medium-sized islands (Figure 4-4). Island 2, the largest, is clearly the most productive with 10 species and approximately 448 nests, excluding the two burrowing shearwaters. Island 2 had the largest Gray-backed Tern colony with an estimated 300 active nests at the time of the visit. It also had perhaps the largest Wedge-tailed Shearwater colony of any of the islands visited. An abandoned Gray-backed Tern colony (old, addled eggs) was present on Island 5 (Table 4-3).

Lagoon 3

Even though Lagoon 3 is about the same size as Lagoons 1 and 2, its two small and one medium-sized islands had only two breeding species between them — Great Frigatebird (Island 3) and Brown Noddy (Island 1). Island 2 had no breeding birds.

Lagoon 4

This is a very shallow lagoon, and the number of islands comes and goes with fluctuating water levels in the lagoon. At the time of the survey, there were only five islands large enough to support breeding seabirds. Islands two and four, the two largest and each supporting trees, also had the most birds. Each had nine species, with Island 4 having slightly more active nests. Lagoon 4 had the largest colony of Black Noddies and the second largest colonies of Christmas Shearwaters and Gray-backed Terns.

Lagoons 5 & 6

These lagoons were not visited, as they are small with only a few small, treeless islands that, from the mainland, appeared to have few if any seabirds.

Lagoon 7

Lagoon 7, with eight islands, was nearly as productive as Lagoon 1. Island 3, the largest, had 11 species and about 85% of the nests in this lagoon. Islands 5, 6, and 8 had no nesting seabirds, and Island 4 had only a few Brown Noddies. This lagoon had the largest population of Common Fairy-Terns and the second largest of Red-footed Boobies and Great Frigatebirds (although barely a tenth of the collective population of frigatebirds in Isles Lagoon).

Lagoon 10 (Isles Lagoon)

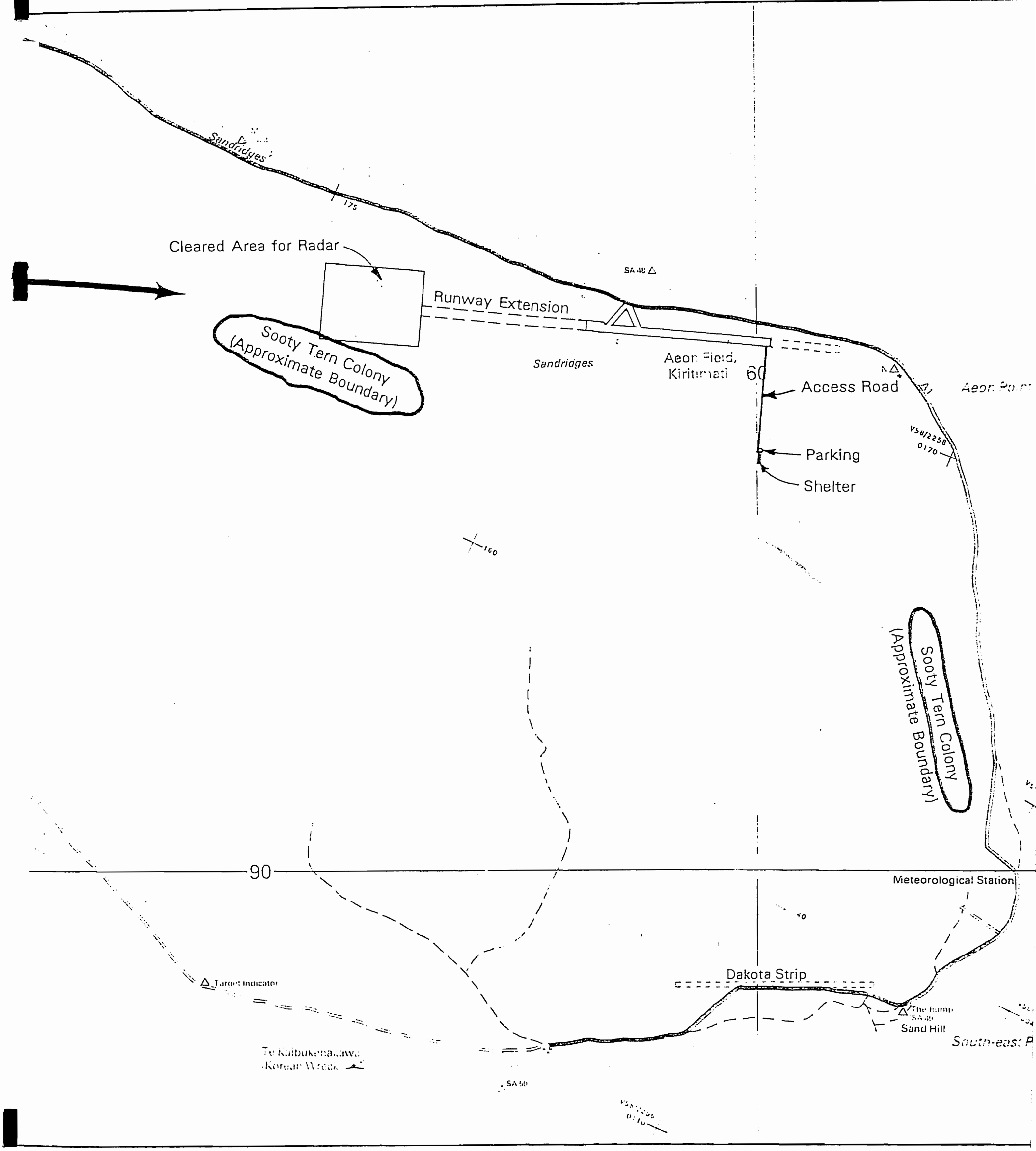
This large lagoon, the second largest enclosed lagoon on Christmas Island, has over 60 islands, about 50 of which are large enough to support breeding birds. Of these, all but a few in the southwestern part of the lagoon were visited. Some of the numbered "islands" are actually clusters of small islands. "Island" 34, for example is actually 15 closely associated small islets. Islands 29 and 33 are also small clusters of islands. Isles Lagoon had more than 1,000 Great Frigatebird nests at the time of our visit, by far the largest colony in the Carver Way lagoons. It also had the largest numbers of Red-footed Boobies and Brown Noddies collectively, even though no one island had a particularly large colony of either species and no one island had more than seven breeding species.

A detailed account of each of the seabird species encountered in the Carver Way lagoons is provided in Appendix A.

Aeon Field to Dakota Strip

There are two large Sooty Tern (*Sterna fuscata*) breeding colonies in the general area of Aeon Field and Dakota Strip (Figure 4-5). At the time of the survey in May, birds were just beginning to lay eggs, so an accurate estimate of numbers could not be obtained. It is believed that both colonies, however, contained in excess of 100,000 pairs based on observations of flying birds in the vicinity of each. In the beginning of May, only the Dakota Strip colony was present, and it expanded greatly over the next 2-3 weeks. The colony west of Aeon Field did not materialize until the second week of May, with egg laying reported by 18 May (A. Teem, personal communication). The closest approach of these two colonies to Aeon and Dakota fields was approximately 1.5 km in both cases.

The Sooty Tern is by far the most abundant seabird on Christmas Island, and is perhaps still the largest in the world despite its considerable reduction in the past two to three decades. Traditionally, it has had breeding colonies on Cook Island, between North-west Point and the Captain Cook Hotel, at the tip of the Paris Peninsula, near South-east Point and variously along portions of the South-east Peninsula. Except for Paris Peninsula (K. Teebaki personal communication), two sets of Sooty Terns nest in each locality, one incubating eggs in December and January and the other in May and June after the first group has fledged young and left the island. In June 1967, R. Schreiber estimated 3.5 million eggs in six colonies. Since studies on other islands have shown that at least four birds use the breeding island for every egg that is laid



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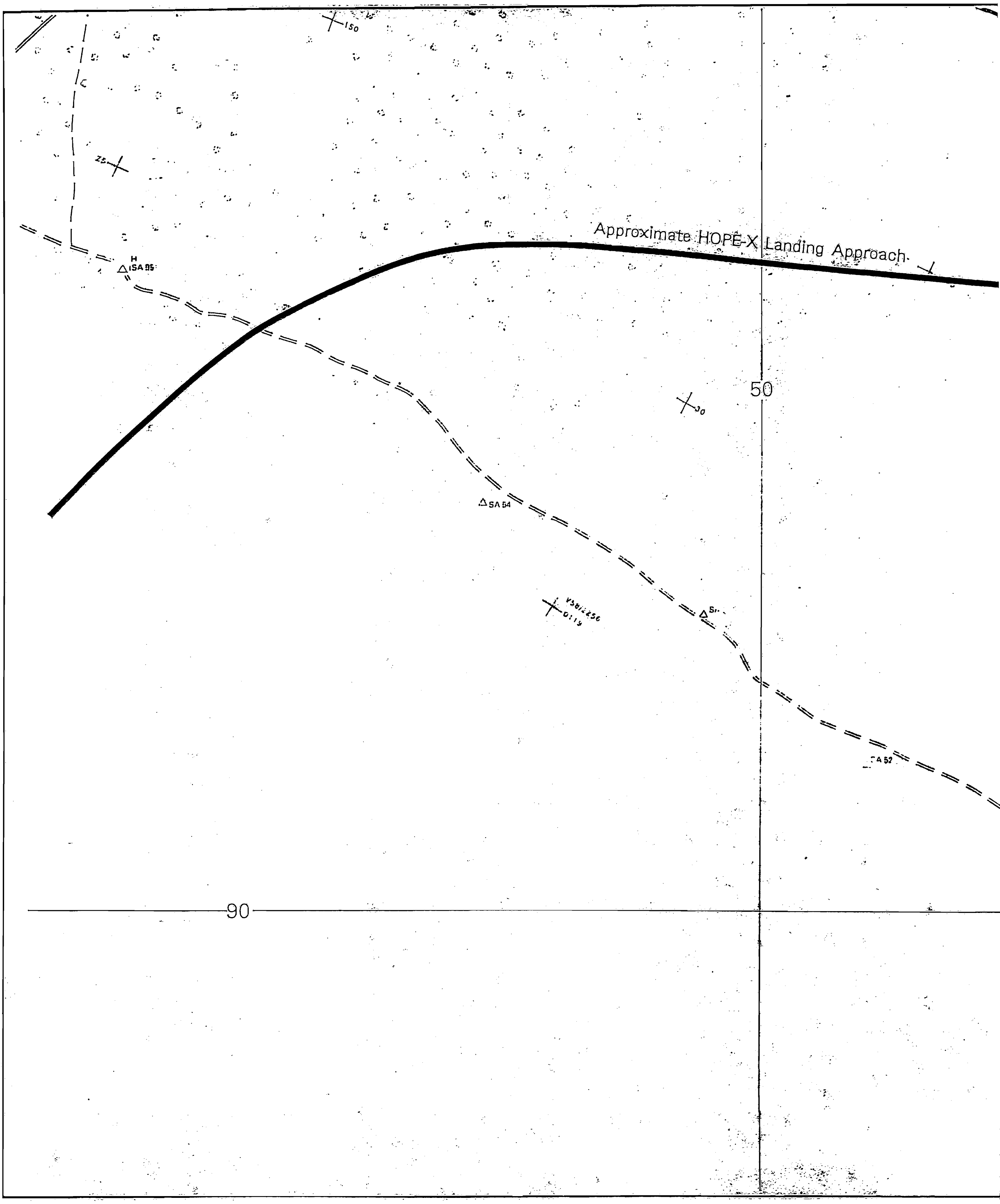

Source:
A. Government of the United Kingdom Ordnance Survey (1"=50,000), 1993.
B. Colony Boundaries: June, 1997 (Appendix A)
C. NASDA, 1997.

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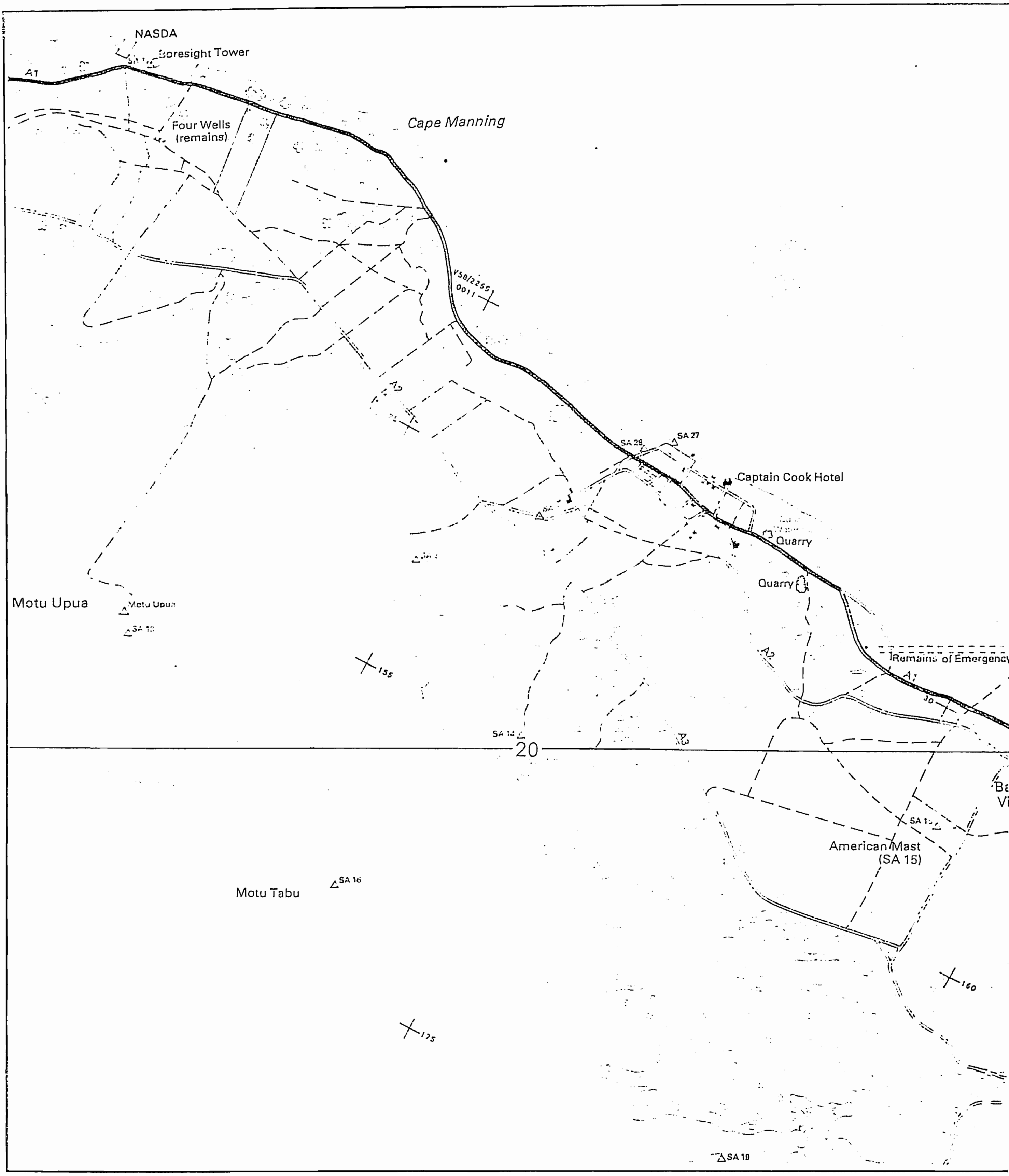

Source:
Government of the United Kingdom.
Ordnance Survey (1"=50,000), 1993.

VICINITY MAP OF THE
BOATING AND BATHING LAGOONS
HOPE-X LANDING SITE EI
CHRISTMAS ISLAND, REPUBLIC OF KIRIBA
FIGURE 4-

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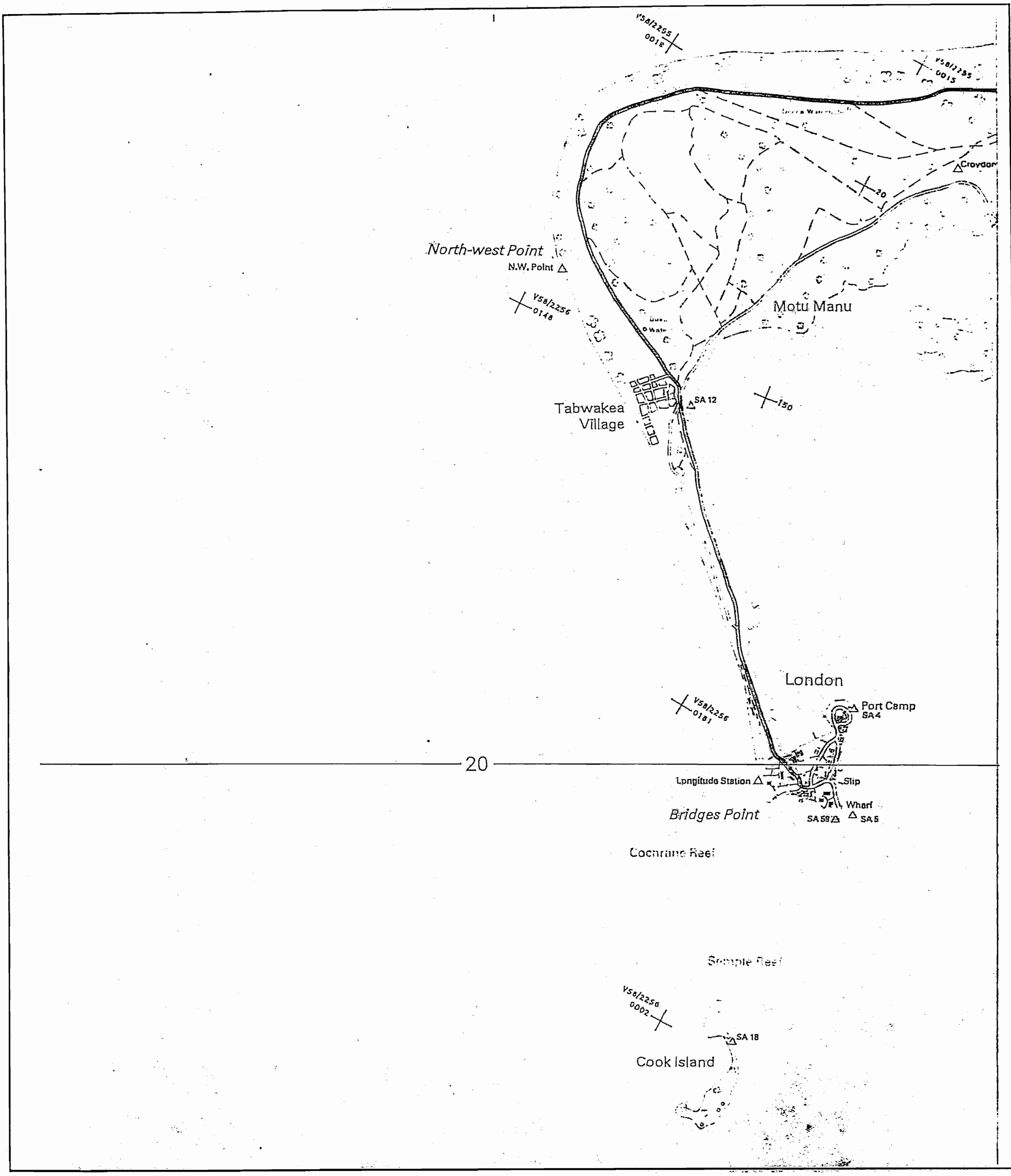

Source:
Government of the United Kingdom
Ordnance Survey (1"=50,000), 1993.

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VICINITY MAP OF
LONDON AND COOK ISLAND
HOPE-X LANDING SITE EI
CHRISTMAS ISLAND, REPUBLIC OF KIRIBAT

FIGURE 4-

(the breeding pair and two non-breeders), Schreiber and Ashmole (1970) estimated 14 million birds to be present in June 1967. Since two separate sets of birds breed on the island (assuming both sets of birds occupied all six sites), the total number of adult birds using the island in a year would be approximately 28 million.

Such large numbers are certainly not the case today. Schreiber and Ashmole describe the almost complete failure of the colony near the present NASDA site in 1967. Egg gathering by residents was the principal reason, with an estimated 250,000 eggs collected of the approximately 600,000 laid. Great Frigatebirds also destroyed a number of chicks, and feral cats killed large numbers of adults. They found 50-75 fresh cat-eaten carcasses each morning. In all, only 25 chicks survived to fledge.

Garnett commented on this species' apparent decline since 1967. He estimated a population of 4-6 million birds per season (= 8-12 million/year) during the 1979-1981 period, a decline of 65% in just over a decade. Although he did not give figures for each colony, he especially noticed a decline in the colony near the NASDA site, which he also attributed primarily to the illegal gathering of eggs. In addition to egg collecting, feral cats and frigatebirds, he identified feral pigs as yet another problem.

Because of the time of year of the current survey, population estimates were impossible to obtain. However, on Cook Island where the birds bred nearly a month earlier than elsewhere this year, a rapid, but presumably accurate, survey conducted on 17 May 1997 revealed approximately 94,000 eggs, which compares favorably with Schreiber's estimate of 100,000 eggs in June 1967. However, Cook Island is considered the most productive site now because of its isolation and its protected status as a closed area.

Approximately 30 pairs of Masked Booby (*Sula dactylatra*) were estimated to be scattered throughout the Aeon Field to Dakota Strip area, within 1 km of each airstrip. None seen appeared to be nesting; all birds observed were standing, and none were sitting — an indication of incubation. Although a few immature birds were observed, especially in the Central Lagoons area, the ratio of immatures to adults was much lower than for Red-footed Boobies, suggesting relatively poor breeding success over at least the past year or two (immatures take two years to attain adult plumage).

Bathing and Boating Lagoons

The large island just offshore of the Bathing Lagoon and two smaller islands closer to the Boating Lagoon were surveyed on 10 and 18 May (Figure 4-6). Compared with those in the Central Lagoons region, few birds nest on these islands. Despite the size of the Bathing Lagoon Island, only about 10 Red-tailed Tropicbird nests, 5 Red-footed Booby nests, 10-20 Brown Noddy nests, and 5 Common Fairy-Tern nests were estimated in the survey period. Other species such as the Christmas Shearwater and Phoenix Petrel may also nest in small numbers, but none were detected.

Between this island and the Boating Lagoon are two smaller islands (Figure 4-6). The larger of the two was the only one with nesting seabirds, and it had only 1-2 Red-footed Booby nests, an estimated 10 Brown Noddy nests, and 5 Black Noddy nests.

Vicinity of Poland

No seabirds nest in the vicinity of Poland other than, perhaps, Masked Booby. Near Benson Point is a large Sooty Tern colony, but it is only active in December through March according to warden Teebaki. A few birds were observed at Paris, but no indication of a breeding colony was evident.

London

No seabirds breed in the immediate vicinity of London; however, nearby Cook Island (2 km to the south) is a major seabird breeding colony (Figure 4-7), as is Motu Upua, 2 km to the northeast, and Motu Tabu, 4.5 km to the east. All of these colonies are readily accessible by boat from London, the largest village on the island, and Motu Upua can be reached by wading during the lowest tides. Each of these three islands has been designated a closed area, but enforcement is nil.

4.4.4.4 Other Fauna

REPTILES

Three species of terrestrial reptiles occur on Christmas Island, and each is widespread in the Pacific. However, only one was seen in the study sites during the surveys.

Snake-eyed Skink *Ablepharus boutonii*. This small skink was seen frequently in all mainland study areas, as well as on one island in the Central Lagoons region.

Mourning Gecko *Lepidodactylus lugubris*. None were observed in the study areas, although this species is supposed to be widespread and common (Garnett 1983).

Stump-toed Gecko *Gehyra mutilata*. This species may be found only in villages and other inhabited areas. None were observed in the study areas.

LAND BIRDS AND MIGRANTS

Only one resident land bird occurs on Christmas Island, and it is endemic to the northern Line Islands. In addition, several species of shorebirds and waterfowl, all known for their long-distance migrations, may be found on Christmas Island at various times of the year. All the shorebirds (Charadriidae; Scolopacidae) that visit Christmas Island breed in the Arctic. One of these is discussed below because of its limited world range and its vulnerability.

Line Islands Warbler or **Bokikokiko** *Acrocephalus aequinoctialis*. This small, drab warbler is found only on Christmas, Washington, and Fanning islands (Pratt, Bruner and Berrett, 1987) but apparently has been exterminated from Fanning (Garnett 1983). It is still common on Washington and Christmas. Garnett shows this species occurring throughout both peninsulas in the northern and southwestern portions of the island and at the base of the South-east Peninsula, but not in the Central Lagoons area. The current survey found them still widespread in all areas shown by Garnett (except the base of the South-east Peninsula, which was not visited), but also in the Central Lagoons area. Garnett's failure to map them from this area may have been an oversight, as warden Teebaki recalls them being present in this region at least since the mid-1970s when he arrived on the island. No quantitative surveys were conducted for this species; however, individuals were routinely heard and occasionally seen flying across the highway during this visit, suggesting that they remain fairly common.

Bristle-thighed Curlew *Numenius tahitiensis*. This species has one of the most restricted breeding ranges of any shorebird, being confined to a small area of western Alaska. It winters exclusively on islands in the central tropical Pacific from the western Hawaiian Islands and the Line Islands west to the Marshall Islands and Fiji. It has traditionally been hunted on many islands, resulting in significant declines in many areas of its wintering range.

Christmas Island may be one of the few islands where this species is still plentiful because it has not been persecuted here. A few of this species were seen almost daily during the current visit, and a few individuals may be present at any time of the year; those in late May to early July probably being non-breeding birds (perhaps in their first year) that failed to migrate north.

Mammals

No terrestrial mammals are native to Christmas Island with the possible exception of the Polynesian Rat

(*Rattus exulans*). It is generally presumed, however, that this species was brought to Christmas Island and many other islands by aboriginal explorers. Dogs, cats, and pigs have all been introduced more recently. Because of a strict law that permits only male dogs to be brought onto the island, they have not spread and no feral population exists. Feral cats, on the other hand, are a major problem for seabirds (see, for example, Flint in press, as well as discussion below) and can now be found over most of the island (see map in Garnett 1983). Feral pigs, to lesser extent, can also present problems for nesting seabirds near villages.

4.4.4.5 Endemic, Rare, And Endangered Species

Christmas Island has no endemic or especially rare vascular plants, and special searches were not required. Among the terrestrial fauna, two bird species, the Phoenix Petrel and Polynesian Storm-Petrel, are considered rare worldwide, although neither is yet afforded any special designation under international treaties (see Flint, in press, for discussion of their present status and vulnerability). One additional species, the Line Islands Warbler, is endemic to the northern Line Islands. Any island endemic or near endemic, no matter how abundant, must be considered potentially imperiled because of its vulnerability to disease, introduced vectors, feral animals, and other man-caused threats such as widespread habitat alteration and water, air or soil pollution.

4.4.4.6 Impacts

Impacts that may result from implementation of the HOPE-X Landing Site project are best evaluated in the context of ongoing impacts on the terrestrial fauna and flora. Ongoing, man-caused impacts have the potential to be exacerbated as the population increases and activities expand to other parts of the island through implementation of this project.

ONGOING IMPACTS

<u>Poaching of Seabirds</u>

Present impacts on the seabird colonies are several in nature, all man-caused. Residents have been poaching hundreds, if not thousands, of birds for food and sport probably since the island was first settled more than a hundred years ago, but the extent of poaching has increased dramatically with the rapidly expanding human population and the proliferation of motor vehicles and motor boats which allow access to areas previously considered secure. There is some indication that poaching activities have declined significantly in the recent past (2-3 years) as a result of a more stringent prohibition against poaching and educational programs in the schools.

According to local residents, there is no preference for poaching one species over another. When asked if the recent lifting of the government ban on importing chickens for consumption has alleviated the need to poach birds, the answers were as varied as the number of people asked. One person said people now raise chickens for food and there is no need to poach. Another said the government does not allow them to raise chickens for food, and the chickens they have are for special occasions. When asked if they are eating fewer wild birds because they can now buy chicken in the market, some said they still catch birds because chickens are too expensive. Others said chickens are inexpensive and most people buy them. Obviously, there are various explanations depending upon the family's income, customary practice, and understanding of government policy. When asked if most people are aware that it is prohibited to kill the birds, most invariably said they are, but they do not understand why it is prohibited. Everyone agreed that the prohibition against killing birds is not being enforced.

Everyone interviewed also agreed that there are many fewer birds on the island now than in the past; although one person pointed out that at least some species were increasing again. This same person said that when he first came to the island in 1976, many birds nested on the main island but that people had scared them away to the harder-to-reach islets [while this may be true, cats may be the main culprit in the exodus from the main island].

Harvesting Eggs of the Sooty Tern

In a separate category because of its severity, is the poaching of Sooty Tern eggs for food. This practice continues and has devastated one of the largest single-species populations of any bird in the world in only three decades. In addition to the hundreds of thousands of eggs reportedly taken each breeding season, entire colonies are disrupted by the presence of humans in the colony (especially at night) and during critical periods in the nesting cycle. People continue to engage in this activity, although apparently to a lesser extent than previously, and freely admit it, despite their awareness of the laws against poaching and the severe penalties (in principle, at least) if convicted. People interviewed admit to poaching when they know no wardens are around. Some say they cannot afford to buy eggs in the store. Others say that people do not eat the eggs that their own chickens lay, either for cultural reasons or because the Sooty Tern eggs taste better. Still others say they do not think much about the prohibition because it has been customary to harvest tern eggs ever since they can remember. One person said they will collect enough eggs for three days when wardens are not around, but that they do not collect more than they can eat.

Rats and Feral Cats

Another serious problem is the destruction of seabirds by feral cats and Polynesian Rats. Destruction of entire island faunas by cats has been well documented. Polynesian Rats, although much smaller than cats, and significantly smaller than Norway and Black Rats (*Rattus norvegicus* and *rattus*, respectively), have also decimated populations of burrow- and ground-nesting shearwaters and petrels (Procellariidae; Hydrobatidae) in the Pacific (Flint in press and pers. comm.). Because of cats and rats, all four species of shearwaters, the Polynesian Storm-Petrel, and six of seven species of terns that breed at Christmas Island are now restricted to offshore islands in the lagoons. However, rats, which are excellent short-distance swimmers, have invaded several major seabird islands, including Motu Upua (personal observation) in recent years.

The near destruction and ultimate relocation of the island's only Lesser Frigatebird colony from the main island to a lagoon island was also attributed to cats, even though frigatebirds are among the largest flighted birds in the world and have dangerously sharp, hooked bills. Nevertheless, their young are vulnerable, especially at night when vision and orientation in these diurnal birds is severely limited.

The tiny Line Islands Warbler seems not to have suffered, perhaps because it builds its nest in the uppermost branches of *Messerschmidia* trees and *Scaevola* bushes.

One person said the ongoing cat-trapping program was effective in that there are a lot fewer cats now. Others said cats were still a big problem. One person pointed out that the controversial introduction of the feline distemper virus to the island around 1990 was ineffective.

DIRECT IMPACTS RESULTING FROM PROJECT DEVELOPMENT

Direct impacts associated with project development may include direct removal of vegetation and destruction of bird nesting sites, dredging of fill material for road construction and building pads, deepening and ongoing maintenance dredging of channels leading from either the Boating Lagoon or Bathing Lagoon, contamination of soil and lagoon water from chemical, hazardous, and toxic spills, sewage, and garbage, and bird collisions with both stationary and non-stationary objects.

Construction of building pads and roads will result in the direct removal of vegetation; however, this loss of vegetation should be minimal and is not seen as significant. No plant species or plant associations (communities) are locally or regionally rare or endemic.

The only bird nesting sites or habitats likely to be destroyed by project development are those of the Masked Booby near Aeon and Dakota strips and the Line Islands Warbler along Carver Way and in the vicinity of Poland Village. But these impacts, too, are seen as minimal, as boobies are very sparsely distributed in the vicinity of Aeon and Dakota strips and vegetation removal in these areas should also be minimal. The same is true of the Line Islands Warbler. Habitat destruction along Carver Way for road improvements will be minimal with respect to the wide distribution of the warbler on the island, and the proposed lodging site near Poland is in an area where little warbler habitat exists.

It is anticipated that fill material will be needed for elevating Carver Way, and perhaps as fill for building pads at the lodging site near Poland. If this material is dredged from the lagoons, the potential exists for disturbance of seabird feeding areas and disruption of nearby breeding colonies, especially near Carver Way. The impact from dredging sand from the lagoon side of Paris Peninsula is seen as minimal, and may even be beneficial if properly conducted, as this area has filled in following construction of a jetty several decades ago. Dredging material from the lagoons adjacent to Carver Way, however, has the potential to become a significant impact if it is extensive or is conducted in such a way that water circulation patterns are significantly altered, bottom sediments are suspended and spread over large areas, or nearby seabird nesting colonies are disrupted.

Perhaps of greatest concern is the spillage or runoff into the lagoons of asphalt or other petroleum-based material used to resurface Carver Way. Petroleum residues can contaminate the water surface and oil birds' feathers, causing them to lose their water repellency and insulating properties. Seabirds that feed on or beneath the surface of oil-contaminated lagoons (all three booby species are especially vulnerable) are readily killed when their feathers become oiled. An uncontained surface film of oil or accumulated tar in the lagoons near Carver Way would be considered a significant impact. Because of these potential impacts, it is likely that Carver Way will not be paved.

The potential for birds to collide with towers, guy wires, or even the landing space shuttle itself must be considered; however, it is very unlikely that birds would collide with the approaching space shuttle. Only the Sooty Tern flies high enough and in large enough numbers for a collision to be feasible. However, observations of Sooty Terns in the large colony west of Aeon Field indicated that the vast majority of birds were flying at or below the crowns of coconut palms in a nearby plantation. Also, Sooty Terns are highly maneuverable, strong fliers that can easily avoid a large object such as a space shuttle or other landing aircraft approaching at relatively slow speed. Frigatebirds, a much larger species, also fly high, but few occur in this area, and despite their large size, they are also quite agile fliers.

Many species of birds are attracted to lights at night, presumably because migratory species use the stars and other celestial bodies for orientation during migration and may confuse lights with stars. Resident species should not be attracted to lights and, if they are, they are likely to adapt readily to their presence. Large numbers of night-migrating landbirds, under certain weather conditions, can collide with tall towers that have a light or beacon at the top. Often, they collide with unseen guy wires rather than the tower itself. This phenomenon is well documented for continental areas; however, very few migrant landbirds ever reach islands as remote as Christmas Island, and none have been recorded on Christmas. Thus, this potential impact is not seen as significant. Nevertheless, it should be closely monitored in case large numbers of resident birds or migrant shorebirds do become attracted to the lights.

INDIRECT AND LONG-TERM IMPACTS

Indirect and long-term impacts resulting from project implementation pose a greater threat to terrestrial biotic resources than direct impacts. Existing impacts resulting from poaching and feral animal predation are very serious and if not curtailed will ultimately destroy most, or even all, seabird colonies on the island. Construction of a space shuttle landing site and ancillary facilities will result in an increase in both the resident and transient human population. Frequent arrivals of passenger and cargo planes and ships will increase the chance of unwanted pests and disease vectors being inadvertently introduced to the island. The potential for a significant increase in the number of pets, especially cats, and the resultant increase in feral animals also exists.

An increase in the number of and access to motor vehicles and motor boats, along with improved roads and people employed in areas now considered remote, such as at Aeon Field and the Paris Peninsula, will greatly increase the opportunities for poaching over a much wider area than currently practiced.

These potential impacts are significant if not carefully monitored and controlled and, ideally, eliminated.

4.4.4.7 Mitigation

In summary, potentially significant adverse impacts resulting from the preferred alternative that should be avoided or mitigated are:

- Bird poaching opportunities will increase with an increase in the human population and easier access to breeding colonies.
- The feral cat population may increase.
- The likelihood of undesirable pests and disease vectors inadvertently being brought to and becoming established on the island is greatly increased.
- Lagoons near Carver Way may become polluted from seepage or spillage of petroleum-based materials.
- Dredging activities in the lagoons near Carver Way may suspend sediments in the lagoons, destroying benthic food items, and otherwise disrupt the lagoon ecology and decrease visibility for foraging seabirds.

AVOIDANCE

Many otherwise significant impacts can be avoided by prudent project design. If improvements to Carver Way do not include paving or treating with a petroleum-based substance to suppress dust, and do not include dredging in the adjacent lagoons for fill material, then these potentially significant impacts will be avoided.

If extensive improvements to Carver Way are to occur, fill material should be taken from on-shore areas near the road, not from the lagoons. Care must be taken to contain all petroleum-based (and other) pollutants so that they do not enter the lagoons. All garbage and trash should also be contained and transported to designated disposal sites. Even seemingly harmless litter can cause serious impacts on seabirds. Birds frequently become entangled in plastic "six-pack" rings and discarded monofilament fishing line left lying around. Small pieces of plastic and paper products floating on the water are often mistaken for food. These are picked up and eaten or fed to young in place of legitimate food.

ELIMINATION OF POACHING

Increased employment opportunities created by project implementation should eliminate or greatly reduce the need for subsistence-level harvesting of birds, eggs, and other organisms as long as local residents are preferentially hired for jobs for which they are qualified and trained for jobs in which they are not presently qualified. The Government of Kiribati must assure that the I-Kiribati people are maximally employed for jobs created by this project, and that non-citizens/non-residents are employed only for the jobs that cannot be filled locally, and for purposes of training the local people to ultimately fill these positions.

However, jobs alone will not necessarily result in the elimination of bird poaching and harvesting of Sooty Tern eggs. The people inhabiting the island, as well as I-Kiribati visitors from Tarawa and elsewhere, must be educated in the importance of protecting their valuable seabird resource, both for its intrinsic value as a major component of a complex ecosystem that could be severely disrupted if the bird populations are lost or greatly diminished, and for its economic potential in attracting tourists from around the world. They must learn that seabirds play an important role in supporting fish, coral, and other marine animal and plant communities (as well as vice versa). They must learn that most tourists will not come to the island once the large numbers and variety of birds are gone, or the birds become so wary that they cannot be approached easily.

Educational and environmental awareness programs can be sponsored and financed by project developers at minimal expense as mitigation to offset ongoing impacts as well as those associated with project implementation. Programs should be established in the schools and churches to teach children the value of their seabird resources, and how non-sustainable levels of seabird and egg harvesting will quickly cause the extirpation of these birds from the island, and why birds will not come from elsewhere to fill the void (see Schreiber and Schreiber 1988). School textbooks are seriously deficient in matters of environmental science and need to be revised and updated to reflect the atoll environment. Various environmental awareness programs should be established that include important lessons in seabird ecology as well as marine ecology. Suggested programs are discussed in detail in the recent 3-volume *Republic of Kiribati Institutional Strengthening of the Environment Unit TA No. 2199-KIR* (MBA International 1997).

ERADICATION OF POLYNESIAN RATS AND FERAL CATS

The problem with Polynesian Rats and feral cats is already serious. Not only should it not become worse, it can and should be effectively eliminated. Feral cats have already forced most breeding seabird species off the main island, and Polynesian Rats have now reached several key offshore seabird colonies. The birds most at risk are shearwaters, petrels, and storm-petrels, including the very rare Phoenix Petrel and Polynesian Storm-Petrel.

As mitigation for project implementation, the present feral cat eradication program should be expanded by increasing the number of traps and trapping locations and the intensity of trapping effort. The possibility of using poisoned bait and bait laced with the recently developed oral feline sterilization vaccine should also be explored. If feasible, these programs should be introduced as soon as possible to augment the trapping effort.

Rats should be removed from the islands as soon as possible, especially Motu Upua and any other major seabird nesting islands where they may have become established. Poisoning and trapping are the most effective means of eradicating the rats.

Associated with many lagoons are many peninsulas, some with constricted bases making them "near islands." Some of these have already been separated from the main island by cutting channels across their base. As a result, cats have either been eliminated from these newly created islands through trapping or have been prevented from reaching them. Additional "near islands" should be identified and turned into islands, with appropriate care being taken not to cut channels between two separate lagoons and not to disrupt the marine ecology through undue spreading of suspended sediments during excavation operations.

PEST AND VECTOR CONTROL

As on other islands throughout the Pacific such as Guam and Hawaii, the Republic of Kiribati should *rigorously* enforce inspections at all ports of entry, especially on Christmas Island with its internationally-important bird resource. The Brown Tree Snake (*Boiga irregularis*) is of particular concern because of its remarkable reproductive capacity, its voracious appetite for birds and lizards, and its highly aggressive behavior. All cargo that could contain a hidden snake, even a small one, must be carefully inspected before release for distribution on the island.

The potential introduction of Norway Rats (*Rattus norvegicus*) or Black Rats (*Rattus rattus*) is another serious concern associated with an increase in traffic from the mainland and other islands. All precautions should be taken to prevent their introduction, which is especially likely from cargo vessels and barges that may dock at London Wharf. All containers destined for Christmas Island should be closely inspected for rodents before they are off-loaded, and effective rat barriers between ship and dock must be maintained to prevent rats from moving directly from ship to shore. Inspections of shoreline facilities in London should be conducted routinely, and people should be strongly encouraged to report any sighting of a rat larger than the small Polynesian Rat. These inspections should also include searches for and reports of snakes.

The potential for introducing various agricultural insect pests and both plant and animal disease vectors increases directly with the increase in number of boat and plane arrivals. Importation of all fruits, vegetables, meats, and other organic products should be closely regulated and monitored.

PROTECTION OF SOOTY TERN NESTING COLONIES

Sooty Tern populations can rapidly return to previous numbers of three decades ago if their colonies are protected to ensure maximum breeding success. Ideally, no egg harvesting should be allowed. However, if for cultural or economic reasons, some harvesting is found to be necessary, it should be conducted only by wardens trained in the proper times and locations for harvesting; for example, early in the egg-laying phase, in the daytime, and around the periphery of the colony only. A moratorium on all egg collecting should remain in effect for at least three full years; and only after this period should any harvesting occur, and only then if it is deemed absolutely necessary.

The proposed lodging site near Poland is close to one of the island's largest Sooty Tern colonies on the Paris Peninsula. Even though this is a designated tourism area, access to the tip of the peninsula should be by permit only when terns are present.

MONITORING PROGRAMS

In order to assure the effectiveness of the programs discussed above, ongoing monitoring programs are necessary. It is especially important that monitoring of seabird populations take place throughout the construction phase of the project. If any mitigation efforts are found not to be effective and significant impacts result or have the potential to result, then these mitigation programs must be modified or abandoned in favor of a program that is effective. If, for example, lights atop communications towers are found to attract large numbers of Sooty Terns which, in turn, are killed or injured in collisions with the towers and guy wires, then some modification of the lighting may be necessary, such as lower intensity lights, shielding so that the lights cannot be seen from above, use of a different or more intense color, or creating a flashing pattern with longer "off" time and shorter "on" time.

Baseline surveys of seabirds should be initiated prior to commencement of construction in seasons other than May when the current survey was conducted in order to obtain a reasonably complete picture of seabird population levels at all times of the year. Only then, once a baseline condition is determined, can monitoring programs meaningfully assess the effectiveness of mitigation efforts.

Monitoring programs are also an opportunity for training and should serve as a vehicle for institutional strengthening of the government's Wildlife Conservation Unit. Ultimately, it will be the responsibility of the local I-Kiribati population to manage and protect Christmas Island's valuable natural resources while participating in the country's economic growth well into the next century.

4.4.5 Coral Reefs

4.4.5.1 Introduction

Appendix B contains the results of a detailed survey of coral reefs at Christmas Island, and a discussion of potential project-related impacts to these resources. Survey results and potential impacts are summarized below based on the information presented in Appendix B.

Coral reef habitats are abundant and diverse at Christmas Island, and can be grouped into several categories (site numbers are explained in Table 4-4):

- exposed ocean reefs (e.g. sites 1,2,3)
- protected ocean reefs (e.g. sites 7,8,9,14,15)
- passes (e.g. sites 4,9,12,16)
- outer lagoon (e.g. 5,6,9,10)
- inner lagoon (e.g. 11,13)

Water circulation and exposure to ocean waves appear to be the most important natural factors influencing development of coral reef communities in these habitats. For example, stony and soft corals achieve their greatest abundance and diversity on ocean reef slopes off the protected west and southwest sides of the atoll and at sheltered habitats in the outer southern pass and adjacent lagoon. Here stony corals range from 30 to 46 species per site and display live coral coverage of about 50 to 90% per site. In contrast, the innermost lagoon habitats show no live coral coverage or species of coral present. Water circulation is sluggish, temperatures warmer, salinities probably higher, (see Schoonmaker et al. 1985), and bottom habitats covered with sediments - factors all unfavorable to coral growth.

Coral reef communities are present at several northern lagoon stations (sites 5,6,10; Table 4-4) and two exposed ocean reef stations (sites 2,3), but the level of coral development was poor, averaging less than 12% live coral cover and less than 20 species of corals per site. In the case of the two ocean reef sites, exposure to heavy wave action and scour from suspended sediments probably limits greater coral development. Also, huge expanses of dead standing coral (staghorn *Acropora* spp) were reported at site 3, the result of a recent coral kill, possibly from lethal or sublethal temperatures from a recent El Nino, excessive predation from a crown-of-thorns starfish infestation (*Acanthaster*) or some other undetermined cause. Large waves can also generate considerable scour, suspending sediments and abrading living corals during heavy surge and wave action.

TABLE 4-4
Synopsis Of The Marine Sites Surveyed During The May 1997 Visit To Christmas Island

Site No:	Site Name	Location	Type of Survey	Relevance to proposed development
1	Aeon	SE point	ocean shoreline survey	closest marine area to shuttle landing site
2	Bay of Wrecks	E Coast	ocean scuba survey and transects	closest accessible "reference" site to Aeon field
3	Navy/ N. London	NW Coast	ocean scuba survey	close to proposed alternative ocean dock site and fuel transfer facilities
4	Outer Cochran Pass	W Coast	scuba drift dive in pass (begin)	existing navigation channel between lagoon and ocean for main port
5	Inner Cochran Pass	W Lagoon	scuba drift dive in pass (end)	close to access channel from navigation channel to main port
6	Wilkes Lagoon	NW Lagoon	lagoon scuba survey and transect	shallow reef areas that may need to be dredged to improve access to main port
7, 14	Poland Caves	SW Coast	ocean scuba drift dives (two)	most important recreational sport dive site on atoll and reference site for survey
8	View Finder	SW Coast	ocean scuba survey and transects	most important recreational dive site nearest to proposed Poland NASDA lodging facilities
9	Cook Pass	W Coast	scuba survey and drift dive in pass	only other pass into lagoon; reference site and two sport diving sites
10	London Dock	NW Lagoon	lagoon snorkel survey	existing main port and seaweed culture sites
11	South Pacific Airways Hotel-wharf site (ruins)	SW Lagoon	lagoon snorkel survey	possible lagoon access from NASDA lodging facility
12	Inner Cook Pass	W Lagoon	lagoon scuba survey and transect	excellent shallow reference reef inside the South Pass
13	Boating Lagoon	NW Lagoon	lagoon snorkel survey	potential dock and water taxi landing for existing Captain Cook Hotel and Banana Village
15	Ocean Pinnacles/ Grapple Reef	W Coast	ocean scuba survey	ocean reef closest to protected area of Cook Island
16	Cook Lagoon Reef	W Lagoon	lagoon scuba drift dive	lagoon reef closest to Cook Island protected area

Depressed coral abundance in the northern outer lagoon appears to be related to anthropogenic stress (sites 5,6,10). Urban populations are close by at Banana, Tabwakea and London, and a prior history of dredging, navigation traffic and fuel spills are likely, especially at sites 5 and 10. At site 6, the reef has deteriorated to piles of loose sediment and rubble, indicative of several decades of chronic stress and the lack of coral recovery. It is possible that natural factors may also be contributing to the decline of reef communities in the northern lagoon, possibly from temperature stress and/or crown-of-thorns starfish (*Acanthaster*) infestations. Yet, comparable pass and lagoon habitats nearby and just south of Cook islet show very healthy and diverse coral reef communities despite water circulation and depth regimes comparable to those of the degraded lagoon and pass habitats just north of Cook Islet. Also, ocean reef habitats just offshore and west of Cook Islet (site 15) appear unaffected suggesting the following:

a) the regular strong ebb and flow of water out of the two passes serves as a barrier against adverse environmental/ecological conditions spreading to coral reefs south of Cook islet
b) coral community abundance and diversity is very high on pass and adjacent lagoon reef habitats near the south pass (Benson Pass), and
c) coral community development is degraded on pass and adjacent lagoon reef habitats north of Cochran Pass.

It appears that the history of port development and urban development over the past half century, particularly during the World War II and nuclear weapons testing epochs, are partially responsible for degraded lagoon reef conditions in the northern (Wilkes) lagoon and Cochran pass region. Chronic sewage pollution, boat traffic, fuel spills, and sedimentation from urban activities may be preventing or impeding natural recovery of coral reef communities.

CORAL BIODIVERSITY

A total of 87 species belonging to 33 genera of stony corals were reported from Christmas Atoll during the May 1997 surveys. Of these, 30 genera belong to the order Scleractinia while the remaining three are hydrozoan corals. These numbers compare to 72 species belonging to 31 genera reported during more detailed surveys at Fanning (Tabuaeran) Atoll, the next atoll up the chain from Christmas (Maragos, 1974), 30 genera and 94 species reported at Palmyra which is two atolls up the chain (Maragos 1988), 14 genera and 32 species at Johnston Atoll 1300 km southwest of Honolulu (Maragos and Jokiel 1986), 16 genera and 50 species from Hawaii which is about 1900 km north of Christmas (Maragos 1995), and 35 genera and 84 species from Kanton in the Phoenix Islands which is about 1500 km southwest of Christmas (Maragos and Jokiel 1978). The 1997 surveys include many new coral species and 3 new genera records for the Line Islands (*Plerogyra, Oxypora* and *Barabattoia)* two of which are new records for both the Phoenix and Line Islands region (except *Plerogyra*). The coral fauna for Christmas compares closely with the other well-surveyed atolls of the northern Line Islands, which average about 32 genera and 80 species. The only exception is Johnston Atoll with much lower totals for both genera and species and which compares more closely to Hawaii.

Some interesting aspects of the coral biota are evident: 1) there is good representation by several genera including *Acropora, Astreopora, Favia, Favites, Fungia, Montipora, Pavona, Porites, Platygyra* and *Pocillopora,* and 2) these same genera are also well represented in the other island groups nearby except for three braincorals *(Favia, Favites, Platygyra)* and one acroporid *(Astreopora)* which are absent from Hawaii and Johnston. One very peculiar observation was the scarcity of the normally common genus *Acropora* at Christmas. Nowhere was *Acropora* abundant, and large dead stands of staghorn *Acropora* were observed at two exposed ocean sites (2 & 3). The 10 species of *Acropora* at Christmas Island is comparable to those of nearby Fanning and Kanton but is much lower than the 29 species reported at Palmyra.

OTHER INVERTEBRATES AND ALGAE

In general, green algae are more common in the lagoon and on ocean facing reef flats along the shores of southeast point. The most common alga, *Ulva,* is thought to be an indicator of high nutrient outflow. Brown algae are most common on the reef flats in the lagoon. The cyanobacteria (formerly blue-green algae) occur most commonly in the inner lagoon, which experiences sluggish circulation and high temperatures and salinities. Red algae is most common on exposed ocean facing reef slopes, especially crustose coralline algae which form butresses and ridges on the outer reef margins facing the prevailing wave action. The one exception is the abundance of the fleshy red alga *Eucheuma,* a species intentionally introduced and released on Christmas Island's reefs a few decades ago to promote future mariculture (Maxwell Doty, personal communication, 1975). In fact this alga is now successfully cultured in several reef flat and shallow lagoon plots near London and Benson Points near the passes. The alga grows quickly, and after drying is sold to commercial interests in Denmark which processes the algae for several cosmetic and industrial purposes. Some fishermen feel the *Eucheuma* seaweed mariculture plots may be disrupting bonefish runs between the lagoon and ocean reefs. Escaped patches of the alien species were seen in several places in the lagoon.

Several macro-invertebrates are very common and a few are now surprisingly rare. The small giant clams (*Tridacna maxima*) are still very common in the vicinity of shallow reefs near the south (Poland) pass, and the starfish *Linckia* are widespread on many ocean and pass environments. The crown-of-thorns starfish is exceedingly abundant on reefs, fringing the south pass, and is also common on other ocean reef sites. The preferred prey corals include *Acropora* and *Favia,* which may help to explain the present rarity of *Acropora* at Christmas. The sea cucumber population is surprisingly sparce in the outer lagoon and pass environments but more conspicuous at inner lagoon reef sites. Fishermen reported that large quantities of the sea-cucumbers were previously collected and sold to commercial interests as beche-de-mer, a delicacy in many Asian areas. Lobsters also used to be very common at Christmas, but were only rarely seen diving the surveys. Also, ornamental mollusks (cowries, cones, spider conches, etc) are not common. It may be that these species are depleted because of their commercial value. Fisherman also reported that sea turtle abundance, both at nesting beaches and swimming in nearshore waters, is also declining. Overharvesting of sea turtles, especially at nesting beaches may be responsible. Although the beaches of Cook Islet are protected, apparently only a few turtles now nest there.

4.4.5.2 Impacts

EFFECTS OF THE PROPOSED ACTIONS ON CORAL REEF HABITATS

Several aspects of the proposed project could have adverse effects on marine resources at Christmas Island:
(1) improvements to existing port facilities or construction of a new port
(2) improvements to fuel transfer facilities and operation of the facilities
(3) dredging of the navigation channel
(4) any dredging, blasting, filling, or discharge of dredged or fill material to create land or obtain materials
(5) disposal of rubbish, solid waste, sewage, thermal effluents and waste fuels near the coast or in marine waters resulting in pollution
(6) improvements to road causeways across lagoon habitats
(7) stormwater discharge into marine waters from the new facilities (dock, airfield, lodging facilities, etc.)
(8) loss of sandy beach habitat if buildings are constructed too close to the shoreline.

Indirect or secondary effects could result in the following adverse impacts:
(9) increased population growth with consequent increased exploitation of marine resources and local extinction of rare species (e.g. sea turtles, giant clams)
(10) increased demand on sportfishing and sportdiving sites due to increased visitor use, and
(11) conflicts between commercial, sportfishing, and subsistence use of edible marine resources.

Each of these are discussed at greater length in Appendix B and are summarized below.

Principal sources of potential impact would stem from construction or renovation of the main London port and associated dredging. Dredging, filling, blasting, or shore protection associated with the harbor and entrance channel, or acquisition of construction materials from marine environments also pose serious threats to marine ecosystems. Improvement to existing fuel transfer, waste management, and fish and wildlife conservation measures are also needed to reduce impacts from future space shuttle and lodging facilities and operations. Road improvements will need to accommodate improved drainage and installation of culverts or small bridges to restore circulation in some of the inner lagoon ponds. Stormwater runoff and shoreline setbacks for structures near beaches must be carefully planned. Of major concern will be the need to control future population growth and urban sprawl attributed to immigrants seeking jobs and a more "modern" lifestyle that would be stimulated by the project. Protection of important coral reef, fish, and wildlife resources as well as improved management of existing protected areas is needed.

CIGUATERA FISH POISONING

In addition to its direct effects, dredging in tropical waters has sometimes been associated with an increase in occurrences of ciguatera fish poisoning. Ciguatera fish poisoning is caused by a toxin produced by a microscopic marine organism, a dinoflagellate called *Gambierdiscus toxicus*. These organisms, which grow on the surface of marine algae, are eaten by herbivorous fish. Since the toxin accumulates in fish, any fish up the food chain can become toxic. Surgeon fish, parrotfish, and others that feed directly on the algae or coral reefs upon which the algae grows may become toxic. Fish that prey on these herbivores, trevally, snappers and eels for example, may become even more toxic because of the cumulative effect. None of the pelagic fish, tunas, marlin, dolphin fish or wahoo, have been found to be ciguatoxic to date.

Unfortunately, there is no way of detecting a ciguatoxic fish from its appearance, smell or taste. The fish seem to be unaffected by ciguatoxin. The freshness of a fish has no relationship to its toxicity. Furthermore, the toxin is not altered by cooking, drying, salting or freezing the fish.

To minimize the risk of being poisoned, consumers should not eat the roe (eggs), liver or guts of any reef fish. The toxin is concentrated up to 100 times more in these parts of the fish. In Hawaii, several deaths have resulted from eating the viscera of toxic fish. Common symptoms of illness may include general weakness, diarrhea, muscle pain, joint aches, numbness and tingling around the mouth, hands and feet, reversal of temperature sensations, where cold objects feel hot and hot objects feel cold, and others, such as nausea, vomiting, chills, itching, headache, sweating and dizziness (Hawaii Dept. of Health, 1991).

The best treatment for ciguatera poisoning during the early phase of poisoning (1-3 days after eating a toxic fish) has been a mannitol (a low molecular weight alcohol sugar or carbohydrate) infusion. This is not a cure or antidote for ciguatoxin, but relieves many of the severe symptoms of poisoning (Shirai, et al., 1991). A supply of mannitol should be procured and stocked in the London clinic for this purpose.

4.4.5.3 Mitigation Measures

Improved management of fish and wildlife seasons, beaches, and existing protected areas is needed to withstand more intensive impacts when the proposed space shuttle port and support facilities are operational. In particular, long-range plans are needed to reduce urban encroachment (including water reserves). Enhanced monitoring and enforcement activities are both needed. These actions would also help to defuse the expanding level of conflict between subsistence, sport and commercial fishers.

Mitigation measures will be needed to reduce the effects of waste disposal, sewage discharges, and other pollutants. Recycling, burning, compaction, and consolidation of solid waste should be planned. The land use plan should be finalized, implemented, and enforced to prevent urban encroachment into valuable fish and wildlife areas. Measures may also be needed to minimize the effects of dredging, filling, and blasting including:

1) use of silt curtains or other barriers to contain resuspended sediments,
2) use of sedimentation basins or enclosed discharge basin for pipeline slurry, if any
3) preconstruction of shore protection and then backfilling behind the structures to limit sedimentation of fill operations,
4) selecting dredging and quarrying sites away from coral reef and beach sites,
5) use of drilling and shooting for explosive excavation and fracturing of rock,
6) establishing turbidity monitoring during construction and a water quality performance

standard,

7) institute a long range monitoring program before, during and after construction or operational phases, including the training of local government staff to implement the monitoring
8) stockpiling dredged or fill materials on land or within enclosed basins
9) establishing a ciguatera monitoring program

The ciguatera monitoring program could have several components including directly monitoring the toxin producing dinoflagellate or its substrata, but the most direct method would be to test individual fish for the presence and concentration of the toxin. A new test kit for this purpose is being marketed in Honolulu. IT should be noted, however, that the kit measures the level of toxin only, not the susceptibility of an individual to the toxin. Individuals vary widely in their susceptibility to the toxin based on prior exposure, amount consumed, and other dietary and general health-related factors.

Finally an island-wide public involvement program is needed to solicit the views of residents on their concerns, opinions, and suggestions. This will be especially important in promoting jobs and business opportunities, but without haphazard urban sprawl and unmanaged waste disposal. These meetings might also help to diffuse existing conflicts between fishers and identify other useful measures and ideas to reduce the effects of the proposals on the environment.

4.4.6 Marine Fisheries

4.4.6.1 Introduction

Five aspects of Christmas Island's historical and current marine fisheries were investigated during field studies on the island in May, 1997.

1. Data were obtained from the Fisheries Division of the Government of Kiribati, which conducted household interviews in the villages of Banana, Tabwakea, and London in January and February of 1995. Information was obtained on fishing effort, gear types, catch, and major fishing locations for each household. The raw data from this survey were obtained from the Fisheries Division and analyzed to document the extent of subsistence fishing activities conducted in each village.
2. Records of food fish exports were obtained from Kiritimati Marine Export Ltd., a government sponsored buyer and exporter of marine fisheries products from Kiritimati Island, to assess the varieties, value and destination of seafood products exported for commercial purposes.
3. Interviews with Fisheries Division staff, fishing guides, and other individuals involved in marine resource use provided valuable information on fishing practices throughout the atoll. These individuals provided information on major fishing gear types, fishing locations, major species sought, and changes that have been observed in any of these fisheries over time. These results are summarized on Figure 4-8.
4. Large-scale visual fish assessments were conducted to directly assess species numbers and abundance for all visually observable fishes.
5. Quantitative visual transects (50 x 5 m) were conducted at five locations to determine total number of species, total number of individuals, species diversity and evenness and sites potentially affected by project components. The methodologies and results of these investigations are presented in Appendix C, and summarized below.

4.4.6.2 Results

SPORTFISHING

Light tackle sportfishing for bonefish and giant trevally is one of the most important industries on Christmas Island. During periods of regular air service, tourists engaging in light tackle sportfishing occupy a number of rooms in the Captain Cook Hotel, employ local fishing guides, and support a number of ancillary industries that provide employment and revenue to the island. There are currently concerns over conflicts between subsistence fishers and the sportfishing industry. Gillnets set on productive fishing flats do not allow access to recreational anglers. The number and size of bonefish have also reported to have declined over time, possibly partially as a result of intensive subsistence harvest. Paris Flats is a major spawning area for bonefish; *Eucheuma* culture in this location may potentially inhibit reproductive movement patterns and reduce spawning success. Increased population pressure resulting from construction and operation of the space shuttle landing site and support facilities may exacerbate any existing problems with the fishery. Any channel dredging could also adversely effect bonefish habitat. Improved roads and a jetty near Poland would obviously assist fishermen in that area but could potentially affect light tackle sportfishing for bonefish and giant trevallys.

SUBSISTENCE GILLNETTING

Gillnetting, primarily for milkfish, is the major subsistence fishing activity on Kiritimati. Fishermen have reported declines in numbers and sizes of catch, particularly near population centers. Conflicts with sportfishing interests and overfishing will only increase with increased population pressures and declining resources.

EXPORT FISHERIES

Kiritimati Marine Export Ltd. is the only buyer and exporter of marine products from the island. Pelagic species such as wahoo and tunas as well as snappers and groupers are the major species exported. These stocks are currently in good condition, particularly the pelagic resources. Proper management along with reliable air service and stable markets could result in a sustainable and profitable industry. Mullet and milkfish have been exported in large numbers in the past and these stocks may be reaching maximum levels of exploitation.

AQUARIUM FISH FISHERY

This fishery has grown substantially in the past five years and now appears to be overcapitalized. Fishers report declines in certain valuable species and divers must fish deeper and longer to obtain profitable catches. Poor conservation practices have resulted in a more aggressive approach to harvest. A number of recent fatalities and injuries has raised concerns about the safety and training of participants in this fishery.

OFFSHORE SPORTFISHNG AND RECREATIONAL DIVING

These industries currently are limited by facilities and the tourist market. Pelagic fisheries and coral reef resources are currently very healthy, and the associated industries have the potential to expand with reasonable management.

4.4.6.3 Impacts

Major impacts from this proposed project could result from renovation of the London dock, dredging of channels, and construction of new docks in various areas. Minor dredging and renovations to the current dock would probably have short-term impacts to the marine fauna and not significantly modify the long-term dynamics of these systems. Dredging to allow deep draft vessels access to the dock would constitute a major dredging operation that would most likely disrupt the nearshore and lagoonal marine environment for some time. Channel dredging in the Paris area has the potential to disrupt movement and spawning of bonefish as well as potentially damaging the healthy shallow coral reef system associated with Cook Pass.

Increased population as a result of the construction and operation of the space shuttle landing site and support facilities could potentially have an impact on the marine resources of the island. As a result of population growth, Tarawa lagoon has suffered severe overfishing with a notably skewed sex ratio and decline in the size of bonefish (Beets 1994). Overfishing of bonefish has been suggested in areas close to London, Tabwakea, and Banana villages. Laborers have been imported in a number of Pacific Islands to supplement the need for workers at various levels of expertise. Many imported laborers come from locations that often have severely overexploited resources and no history of resource tenure. These laborers often can change the dynamics of the local fishery from one of selective and sustainable harvest to complete ecosystem harvest. Maintenance of traditional harvest methods and improvements to the current fisheries management system should be encouraged.

4.4.6.4 Mitigation Measures

RECOMMENDATIONS ASSOCIATED WITH POTENTIAL PROJECT IMPACTS

Minimize Dredging Activities

Improvements to the existing dock and a tug and barge system appear to be the option that will provide the least amount of environmental impact to the island while still serving the purposes of the project. The area adjacent to the existing dock lacks significant marine life and dredging in this area would have minimal impact. Cochran Channel is currently about 15 feet deep. Dredging to allow deep-draft vessels (>30 feet) access to the wharf does not seem feasible and would require substantial dredging that would likely have a major negative impact on the associated marine community.

Shallow Draft Docks In The Lagoon

Areas offshore of the old boating lagoon site, London wharf, and the ruins of the wharf at the South Pacific Airways hotel site near Poland were surveyed. These sites are all associated with soft bottom marine communities that are low in diversity and abundance. Any dredging or dock construction at these sites would not adversely impact the local environment and would possibly be beneficial to small boat operations involved in sportfishing, diving, and subsistence fishing. Channel construction for these routes should attempt to follow natural channels and limit the amount of dredging. There are highly diverse fish and coral communities associated with the shallow lagoon inshore from Cook Pass. Dredging operations in this area should attempt to minimize coral damage and disruption to this habitat.

Environmental Monitoring Program

An environmental monitoring program should be conducted prior to, during, and after any construction activities. This should include assessment of marine fauna and flora as well as water quality monitoring. Local environmental personnel should be trained to carry out all aspects of this monitoring. Potential impact sites, as well as reference control sites, should be identified prior to the construction phase of the project. Permanent transects should be established in a number of locations at these sites to determine abundances of important resources during all phases of the project. A stratified random sampling design should be developed to conduct these surveys. Sample size optimization should be conducted to determine the proper number of samples needed for the statistical power to detect changes in abundance of target resources. A coordinating scientist could train local environmental personnel and periodic assist in monitoring.

Focus Groups And Scoping Meetings

Meetings and workshops with all stakeholders should be continued to air concerns and suggestions that may be associated with the project as it is implemented. This will allow island-wide participation in the project and help to establish an interactive management strategy that will benefit all members of the community.

RECOMMENDATIONS FOR SUSTAINABLE MARINE RESOURCE USE

Improve Current Fisheries Management Regulations

The subsistence gillnet fishery for milkfish and other species has declined in recent years, particularly near population centers. Efforts should be made to resolve user conflicts between subsistence fishers and recreational sportfishers. This could involve closed areas or limited entry to either or both fisheries. Sportfishing guides have already set a voluntary limit of 30 anglers per day. Spawning areas and seasons for important resource species should be identified and possibly closed to improve reproductive success. Increased harvest and canning of milkfish for sale to Tarawa has recently been proposed. In order for this harvest to be sustainable, a better understanding of the population structure of the species and fisheries yields will be necessary.

Recommended Closed Areas

Cook Island is currently a wildlife reserve and possesses large colonies of nesting seabirds (Jones 1997). It has been proposed that the adjacent marine habitat around Cook Island also be included as a reserve or sanctuary. The shallow reefs around Cook Island along with the unique offshore ocean pinnacles offer healthy reef environments with valuable marine resources. Any effort to establish a reserve area or restrict access to this area should be made with community involvement and recommendations to ensure proper siting and compliance to any potential refuge.

Some fishing guides have advocated the closure of the area of Paris Flats and Texas Flats to protect bonefish spawning sites. Suggestions from these individuals include prohibition of seaweed culture, diving and snorkeling activities and restrictions on speed and access of boats.

Live Fish Fishery

In recent years, a live reef food fish trade has developed for the "ultimate in fresh fish," those selected from restaurant aquaria only minutes before eating (Erdmann and Pet-Soede, 1996). These fish are highly prized in Hong Kong, Singapore, Taiwan, mainland China, and other Chinese population centers. The target species include groupers and humphead wrasse. These fish often receive prices 400-800% higher than identical dead fish in Hong Kong (Johannes and Riepen, 1995). The huge economic rewards associated with this fishery are attracting fishers and business persons in rapidly increasing numbers throughout the world. The fishery has already caused the decline in stocks of these prized species in the Philippines and Indonesia. Once stocks are exhausted, the industry continually moves on to new "virgin" locations. The fishing practices usually include the use of sodium cyanide to stun large fish and the use of crow bars to break open reefs to capture these species. Collateral destruction of reefs as well as mortality of other reef species due to cyanide poisoning is a large problem in addition to the loss of target species. This fishery should not be allowed to become established in Kiritimati and the use of poisons should be banned from use for any type of harvest.

Ornamental Fish Trade

The number of aquarium fish export companies should be limited or even reduced to avoid additional overcapitalization and depletion of these resources. Divers should be SCUBA-certified and trained to properly handle fish. Proper education and training will reduce diver accidents and help to establish a better conservation ethic. Offshore holding facilities can be destroyed during storms and result in high mortality of the catch as well as injuries to surviving fish. Efforts should be made to encourage shore-based holding facilities that will reduce fish mortality and improve the quality of the product. To avoid conflicts with recreational divers and to reduce anchor damage to coral reefs, permanent moorings could be established at popular dive sites. The use of moorings by ornamental fish collected could concentrate fishing effort at these locations and exacerbate local depletion of target species. Regulation of these moorings needs to be considered. Fish collectors and dive operators should work jointly to try to utilize different areas to reduce conflicts.

Offshore Sport Fishing

Efforts should be made to expand and market the recreational sportfish fishery. These resources provide the opportunity for light tackle, catch-and-release, and trophy "big game" fishing. These resources are currently underutilized and if regulated properly, the recreational impact should allow for sustainable resource use.

Offshore Fisheries Resources

The pelagic and deepwater fisheries resources are currently harvested at modest levels. The major impediment to expansion is currently the availability of a stable market and reliable air transport. The deepwater bottomfish fishery should be regulated by limited entry since these types of fisheries have been known to have limited resource potential and have been overexploited in a number of Pacific islands in a relatively short period of time.

4.4.7 Ambient Noise

4.4.7.1 Existing Conditions

Ambient noise results primarily from surf, birds and wind. Traffic noise is intermittent and generally quite moderate due to the very light traffic conditions. Intrusive noises are generally restricted to the occasional vehicle with a defective muffler and infrequent aircraft operations. There are no industrial facilities on the island, the four diesel generating stations probably representing the greatest sustained level of industrial-type noise present.

Currently, there are no local regulations or guidelines for noise. The State of Hawaii Department of Health Administrative Rules governing noise control for Oahu will be used for discussion purposes in the absence of noise regulations for the Republic of Kiribati. Noise is defined as any sound that may produce adverse physiological or psychological effects or interfere with individual or group activities, including but not limited to communication, work, rest, recreation, or sleep (HAR, 1981). Sound levels are measured in units called bels, and most often the measurement are in tenths of bels referred to as decibels (dB). "A"-weighted sound levels (dBA) are measured using an electronic "A" filter incorporated into sound level meters. The "A" filter has a similar frequency response to the human ear which is most sensitive to sounds in the range 1,000 to 4,000 Hertz frequency, and less sensitive to lower and higher frequencies. The A-weighted sound pressure levels are much lower than the unweighted "flat" values. The subject's perception of sound loudness is dependent on the frequency of the sound. The level of sound dBA is a good measure of loudness of that sound and different sounds of the same dBA sound equally loud. As sound waves move through the atmosphere, the energy of the waves is weakened (attenuated) as the distance from the source increases.

Excessive noise is further defined as any sound to which an individual is exposed and which exceeds the allowable noise level more than 10 percent of the time in any twenty-minute period. Allowable daytime noise levels are slightly greater for agricultural and industrial areas (70 dBA) versus residential and preservation areas (55 dBA). The nightime allowable noise level for residential and preservation areas is more restrictive than that for daytime at a level of 45 dBA.

4.4.7.2 Impacts

Development of the project will involve excavation, clearing, paving and other construction activities, all of which require heavy noise-generating construction equipment. No blasting is anticipated. Short-term impacts of construction noise would be experienced by the construction crew and nearby wildlife populations only, except for the noise generated in the vicinity of the London wharf. This could affect nearby residents and commercial and government workers. Minimal noise will be generated during the facility's non-operational period, but during the operational phase there will be increased vehicular and generator noise.

4.4.7.3 Mitigation

To minimize noise impacts during construction, the work will be limited to the hours of 7:00 am to 4:00 pm, Monday through Friday. Guidelines for construction crew health and safety will be adhered to, including the provision for hearing protection when necessary.

No other mitigation is proposed for the construction phase or the non-operational periods. During the operational periods, the generators will be operated within their structures, limiting ambient noise. Other equipment and vehicular noise will be moderate. During a landing operation, little noise will be heard from the HOPE-X, as it will approach from the prevailing downwind direction. On-site technical personnel will be inside the protective shelter.

4.4.7.4 Sonic Boom

INTRODUCTION

Supersonic refers to travel that exceeds the speed of sound. A sonic boom effect would result from the acoustical energy that is generated when the HOPE-X is supersonic. A body moving through the atmosphere generates pressure disturbances about it. These disturbances move at the speed of sound, although the air molecules through which the wave travels move only a small distance. The wave itself, rather than the individual molecules, travels from the moving body to the ground. At subsonic speeds the disturbance is generally too gentle to be noticed at ground level; however, at supersonic speeds a shock wave develops. The shock wave forms a continuous surface that travels along with the vehicle in supersonic flight. The primary components of the sonic boom generated by an aircraft are the compression shock formed at the bow of the aircraft and a collapse shock generated by the tail. Intermediate features of the aircraft generate secondary systems of shock waves (DBEDT, 1993).

Acoustic waves (noise, sonic booms) propagate through the atmosphere as wavefronts along ray paths determined by the local sonic velocity. One can plot the ray paths for various acoustic source positions and directions toward sensitive sites (villages, wildlife habitats) away from the HOPE-X landing trajectory. Estimates of relative attenuation or enhancement of blast overpressure or acoustic energy are based on the divergence or convergence of these ray paths at each affected site. The predicted overpressure or sound level provides a measure of the potential noise hazard or annoyance level (DBEDT, 1993).

The shape and footprint of the acoustical energy associated with any particular landing will be affected by the trajectory as well as meteorological conditions during the landing. Meteorological conditions may alter the peak pressures, shift the focal region up or down range, and distort the shape of the landing path. Four atmospheric parameters play major roles in acoustic wave propagation: temperature, wind, dew point, and pressure.

IMPACTS

The HOPE-X supersonic reentry through the atmosphere will generate ground level sonic booms. As a consequence of the reentry flight path most of the sonic boom footprint lies over open ocean; however, the sonic boom produced by the final supersonic portion of the trajectory does impact Christmas Island and its coastal waters. The potential environmental impacts of the sonic boom on Christmas Island were analyzed by ACTA, Inc., and their report is included in its entirety as Appendix D.

A predictive model was used in the analysis, which assumed average weather conditions and no wind. For impact analyses, if the no-wind footprints provide a sufficient safety margin, then no further analyses are required. The HOPE-X descent sonic boom is not expected to cause a wind-sensitive operational constraint.

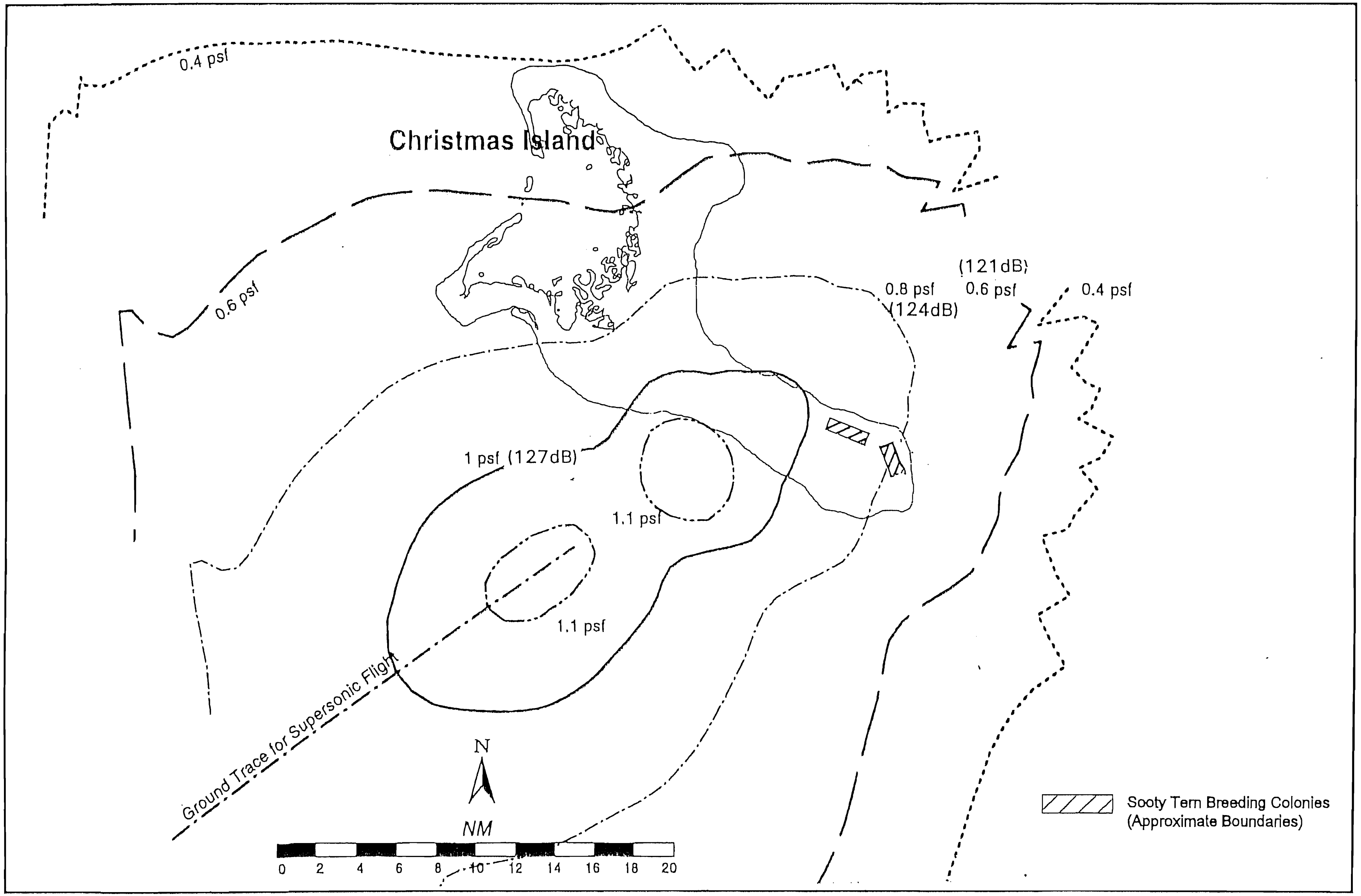
In addition to meteorological conditions, the model was based on the magnitude of the sonic boom source. The magnitude is a function of the geometry of the spacecraft. The HOPE-X is similar to the U.S. Space Shuttle orbiter, only significantly smaller. The sonic boom characteristics of the U.S. Space Shuttle have been extensively studied, and the results of these studies were used to derive the HOPE-X sonic boom source magnitude by scaling the U.S. Space Shuttle weight down to the landing weight of the HOPE-X (9,900kg).

The estimated overpressure contours and ground trace for the northeasterly supersonic no-wind landing are shown on Figure 4-9. This figure shows sonic footprint boundaries and indicates which areas of Christmas Island may be subjected to sonic booms. Estimated HOPE-X landing peak overpressures will occur southwest and south of Christmas Island over water at approximately 1.2 pounds per square foot (psf) (129.6 dB), and attenuate across the island at sound pressures to 0.4 psf at the limit of the region affected by any sonic boom. The entire island is expected to be impacted by the HOPE-X landing sonic boom, with the greatest pressures over the unpopulated "neck" of the island, south of Artemia Corner and north of the landing site. Overpressures in the populated areas will be less than 1 psf (127 dB), well below the levels expected to cause structural damage, window breakage or human physiological impairment. The levels, however, will be audible and may startle some people. The duration of the sonic boom along the flight track between peaks is estimated to be 275 milliseconds; while, off-track sonic booms may last as long as 400 milliseconds.

Startle responses in marine birds and mammals are known to occur at impulses of as low as 90 dB flat; but, controlled experiments with sonic boom levels up to 150 dB flat have failed to elicit panics, or cause physiological damage. The impact on birds and mammals remains an issue because there have been circumstantial accounts of catastrophic damages, notably the "Sooty Tern Incident." This incident occurred in 1969 on the Dry Tortugas off the coast of Florida. This area is a region subject to frequent sonic booms. Prior to the breeding season, the investigators performed a census of the Sooty Terns in the area. Several months after the end of the season a second census was performed. The investigators did not visit the area during the intervening period. Only approximately 400 chicks were present at the post-breeding count versus the anticipated 40,000. In their attempt to explain the breeding failure, the investigators discovered that in mid-season, persons in buildings in Fort Jefferson National Monument, some miles away, had reported exceptionally loud sonic booms. No timely follow up to these reports had occurred. The investigators attributed the breeding failure to sonic boom exposure.

Since that time, however, it has been conclusively demonstrated that the eggs could not have been damaged by the sonic booms. A typical response to a sonic boom is for the birds to rise, fly about briefly and return to their eggs. It has, however, been argued that the birds may have been disturbed sufficiently so they lost interest in breeding and the eggs were allowed to cool to the point to cause a massive breeding failure. No substantiation has been found for this argument.

There are two Sooty Tern breeding colonies in the vicinity of Aeon Airfield. The precise boundaries of these colonies are not known, but they appear to be located within the 1.0 psf to 0.8 psf (127 dB to 124 dB)



Source:
ACTA, Inc., 1997, Appendix D.

TYPICAL SONIC BOOM FOOTPRINT FOR HOPE-X APPROACH

HOPE–X LANDING SITE EIA
CHRISTMAS ISLAND, REPUBLIC OF KIRIBATI

DAMES & MOORE
GROUP | A DAMES & MOORE GROUP COMPANY

36125–001–5005–011 job 5005c.dwg 8/97 DRAFT

FIGURE 4–9

sonic boom footprint range. Sonic booms at these levels of short duration are not expected to elicit panic responses, physiological damage, or disruption of long-term behavior.

MITIGATION MEASURES

The HOPE-X personnel will be protected from noise impacts by the shelter at Aeon Field. Non-essential personnel would be kept away from the landing area. Island residents and visitors will be given advance notice of the landing event, and be informed of potential "startle" effects. Hearing protection for the general population will not be necessary .

The sonic boom impacts on Sooty Tern colonies and other bird populations could be mitigated by scheduling the landings during non-breeding times of the year. It is also recommended that a biologist be present to monitor and document the impacts of the first landing and prescribe further mitigation, if necessary.

4.4.8 Light Emissions

4.4.8.1 Existing Conditions

Light emissions on the atoll are limited to nighttime residential lighting in London, Banana, and Poland villages and at the Captain Cook Hotel, and occasional vehicle lights along the roadways.

4.4.8.2 Impacts and Proposed Mitigation

No high intensity sky lighting will be required at any of the project facilities, nor will any runway landing lights be required. The only exterior lighting will be low-intensity sodium vapor fixtures mounted on poles or the buildings to illuminate the ground surface. There will also be a red safety light mounted at the top of the telecom/meteorological tower. Effects of this light will be monitored for potential impacts on nearby bird populations. Fluorescent lighting will be utilized inside the buildings.

4.5 PROJECT HAZARDS

4.5.1 Range Safety

Two portions of the flight are pertinent to a discussion of range safety and may place the inhabitants of the Republic of Kiribati at risk. The initial reentry maneuver and late in flight during landing. Malfunctions during either stage of reentry are of interest because of the possibility of significantly altering the impact point of the HOPE-X. The HOPE-X contains quantities of potentially hazardous materials including hypergolic fuels. An accident causing HOPE-X to impact and breakup on Christmas Island has the potential for releasing some of this hazardous material to the environment, in addition to the physical impacts of debris and intact structural components.

4.5.1.1 Re-entry Control Procedures

The purpose of the range safety system is to maintain positive control over a launch vehicle during the flight to ensure that it does not endanger the public. Radar, optical devices, and telemetry track the vehicle and send their data to computers to determine the exact location of the spacecraft during flight. If the vehicle deviates dangerously from its intended course, then a radio command is sent to initiate the vehicle destruct system. At least two adequate and independent sources of vehicle position and velocity are operated during powered flight to ensure that no single-point failure will result. Redundant computers and command/control systems are also required.

Range instrumentation normally includes radars, command transmitters, telemetry receiving stations, computers for processing in "real-time," communications equipment, and optical instrumentation. The telemetry system transmits information from the HOPE-X to the ground-based facilities. It sends inertial guidance data as well as data on performance of engines, pumps, and steering systems. Guidance data is routed to the range safety computer and used along with radar and optical information to track the vehicle's position.

The deorbit burn of the HOPE-X Orbital Maneuvering System (OMS) is designed to impart a velocity component in the orbital plane sufficient to initiate reentry and a velocity component out of the trajectory plane to deplete the OMS fuel tank. The reentry trajectory controls employ a combination of vehicle aerodynamic surfaces and a Reaction Control System (RCS). Like the STS Orbiter, the HOPE-X uses the RCS for control at high speeds, relying on the aerodynamic surfaces for control at lower speeds and lower altitudes. The three on-board guidance computers employ a hybrid Inertial Measurement Unit (IMU) - Global Positioning System (GPS) navigation scheme. Beginning in the Terminal Area Energy Management (TAEM) Phase, navigation may be refined using the Differential GPS system based on Christmas Island.

The IMU/GPS system is responsible for establishing state vector information upon which the guidance computers initiation of the deorbit maneuver is based. The reentry trajectory consists of a combination of straight segments and controlled turns. The turns are used to maneuver to avoid overflight of populated areas, for energy management, and alignment with the approach path.

The flow chart below is an event tree showing the sequences of events following a deorbiting maneuver as reflected in the information provided by NASDA.

RANGE SAFETY RECOMMENDATIONS

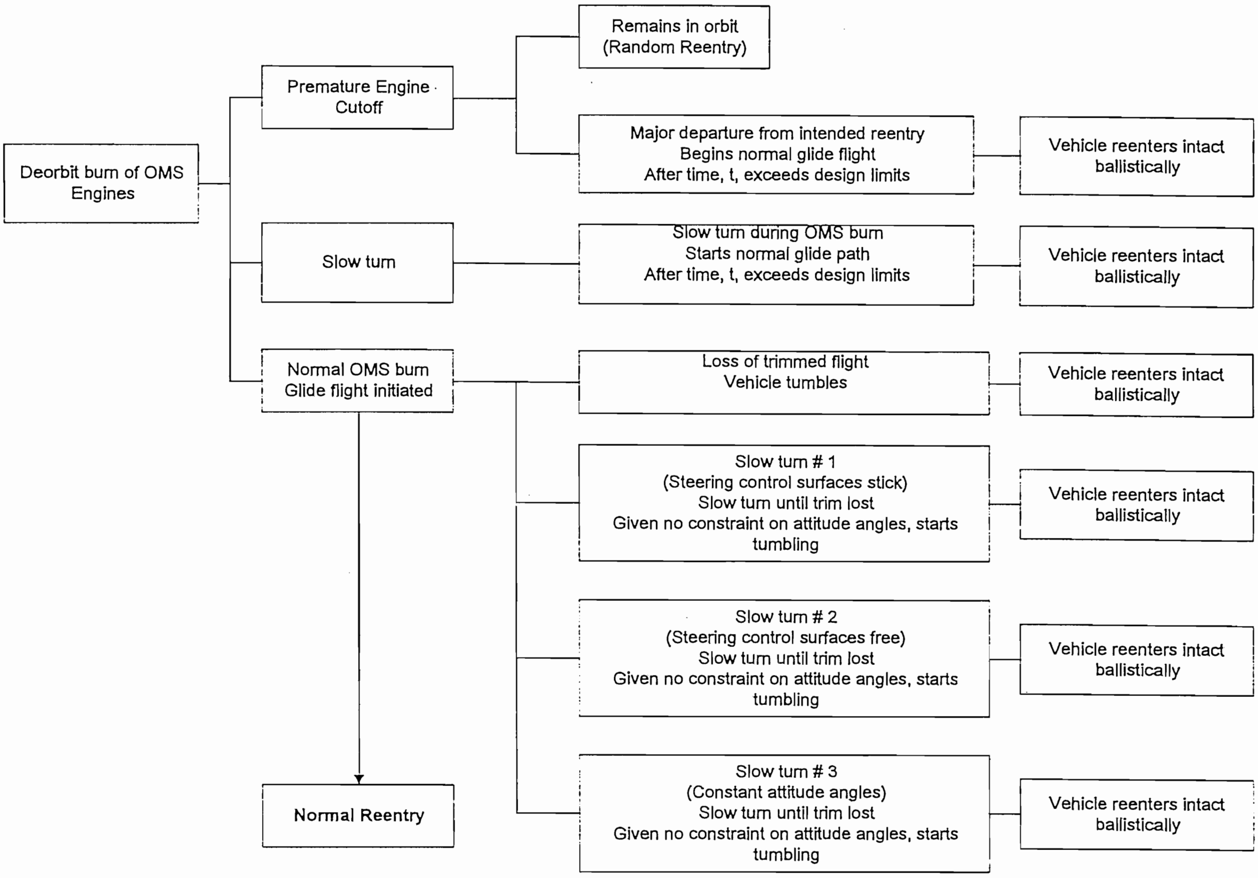
An evaluation of the range safety probability study that was provided by NASDA was conducted to assess the environmental impacts of the HOPE-X landing events. The methodology and recommendations of the reviewers is provided in Appendix D. The following is a brief list of recommendations to minimize the impacts associated with a landing event:

Deorbit Burn Phase - Although the Autonomous Flight Controller includes three redundant computers to enhance system reliability, there remains the possibility of common cause failures. Complex computer software systems are particularly difficult to prove to be free from common cause failures. It would be prudent to make provisions for validation of the HOPE-X position, velocity and attitude prior to allowing the initiation of the OMS burn. This should address such issues as 1) assuring that HOPE-X can achieve the desired state vector within the tolerances required for a successful reentry after the OMS burn, and 2) contingency plan if HOPE-X cannot achieve the "window" required for a safe OMS reentry.

The Range Safety System - HOPE-X has been designed not to breakup when the Flight Termination Command is issued at altitudes below 40 kilometers; this is a crucial design feature in controlling the hazards to Christmas Island and its immediate vicinity. The impact probability study provided by NASDA employs the assumption that the HOPE-X does not breakup. Breakup of the vehicle would increase the number of reentering fragments and alter their aerodynamic characteristics. For such a debris cloud to reach Christmas Island one of two conditions must be satisfied:

- The HOPE-X design to assure that breakup does not occur below 40 kilometers must fail.
- Some failure must occur while HOPE-X is still above 40 kilometers that elevates the velocity vector sufficiently to increase the impact range to Christmas Island and alters the velocity vector in a northerly direction so that the debris does not pass safely to the south of Christmas Island. The Range Safety System designed should be reviewed to rule out the possibility of a vehicle failure disabling the range safety system before the vehicle can be placed in the "range safety mode."

Landing Phase - A malfunctioning spacecraft poses a potential hazard as a massive impacting object. In addition, a malfunctioning spacecraft may breakup on impact releasing quantities of toxic substances. A malfunctioning intact HOPE-X would be expected to impact with a high level of kinetic energy. Thus, it poses a potentially significant hazard to property, protective structures and their occupants. In particular, it is recommended that the HOPE-X personnel shelter located a little more than a kilometer to the side of the HOPE-X runway be evaluated to assess whether it is adequate to protect the ten ground crew members stationed within it. In addition, emergency evacuation procedures may be desirable to protect against an incoming malfunctioning HOPE-X.



Event Tree for Reentry of HOPE-X

RISK ANALYSIS AND RISK CONTROL

Risk estimates of casualty expectations to the general public and personnel outside the precaution area are listed in the following table:

TABLE 4-5
Estimated Risks to Populations Outside the Precaution Area

Location: Island	Location: Town	Population	Impact Probability	Casualty Expectation (Upper Bound)	Casualty Expectation (Lower Bound)
Kiritimati	London	1194	8.3×10^{-12}	4.4×10^{-12}	9.2×10^{-13}
Kiritimati	Tabwakea	968	9.3×10^{-12}	3.5×10^{-12}	7.4×10^{-13}
Kiritimati	Banana	905	4.2×10^{-11}	3.3×10^{-12}	7.0×10^{-13}
Kiritimati	Poland	204	7.1×10^{-11}	7.5×10^{-12}	1.6×10^{-13}
Taraina		1123	1.1×10^{-7}	1.1×10^{-8}	2.4×10^{-9}
Tabuaeran		1833	4.5×10^{-7}	2.2×10^{-8}	4.6×10^{-9}
Total Outside Precaution Area		6217	5.6×10^{-7}	3.3×10^{-8}	7.0×10^{-9}

These calculations indicate that the risk levels to the people of the Republic of Kiribati are well within the acceptable risk standards.

A rough estimate of the risk to the ten members of the ground crew inside the HOPE-X shelter is between 2 x 10^{-9} and 8 x 10^{-9}. The probability that the shelter will be struck is estimated at 2.5 x 10^{-11}. These estimates are extremely low and may underestimate the probability of impact to the shelter. On the other hand, a failed intact 9,900 kg vehicle landing out of control may penetrate even a substantial structure. Impact probabilities for ships underneath the flight track were estimated to range from 2 x 10^{-9} to 8 x 10^{-9}. Acceptable levels of risk have not been established by NASDA for the HOPE-X landing missions; however, they have been established and are imposed by NASDA for launches. The fatality expectation is less than or equal to 1.5 x 10^{-7} per foreign country, and for essential mission personnel less than or equal to 1.0 x 10^{-4}. The estimated levels of risk are within the acceptable range of criteria established for launches.

4.5.1.2 Mitigation

The adequacy of the HOPE-X personnel shelter is a concern. It should be analyzed to determine its vulnerability to direct impact by the HOPE-X. Additional protective berms to absorb kinetic energy may provide an adequate safety margin. Emergency procedures should be developed for the ground crew to respond to a malfunctioning HOPE-X expected to land on Christmas Island. These should include crew actions during final descent and safety precautions for the clean-up crew to detect and remove all hazardous materials released. Notices to Airmen and Mariners should be published specifying the higher hazard regions along the approach.

4.5.2 Solid Waste

There is no central sewage treatment and disposal system on the island. Septic tanks are used for initial containment but disposal will need to be addressed as the population increases. As part of the project, a solid waste disposal site will be identified with government approval. Non-hazardous and non-toxic solid waste will be disposed of at this site. When meteorological conditions permit, burning will be used to reduce the volume of waste.

During construction, a small, portable incinerator will be operated to dispose of waste products such as motor oil.

4.5.3 Hope-X Hazardous Materials

4.5.3.1 Introduction

Range safety and hazardous materials associated with the HOPE-X are discussed in Appendix D. The following paragraphs summarize those analyses. Hazardous materials onboard the HOPE-X at landing are summarized in Table 4-5.

The HOPE-X will employ a liquid propulsion system using two liquids for fuel and an oxidizer. These liquids are stored in separate tanks and moved into the combustion chamber by pumps or pressure. Some propellants are hypergolic, which means that they ignite upon contact with one another. Hypergolic propellants are used in spacecraft attitude control systems and during vehicle launch.

TABLE 4-6
Hazardous Materials Onboard HOPE-X at Landing

Source	Materials	Maximum Quantity (kg)
Structure	Carbon Phenolics	508.9
Heat resistant coating	Carbon fiber	125.8
Propellant System		
OMS	Nitrogen Tetroxide	22
RCS		66
OMS	Monomethyl Hydrazine	93
RCS		109
APU	Hydrazine	24
Electrical Power System	Cobaltous lithium	32.4
	Dimethyl carbonate	21.6
Actuators	Hydraulic oil	78

Liquid propellants are pumped or transferred by gas pressure from storage tanks to the combustion chamber. The HOPE-X propulsion system will use the following hypergolics: nitrogen tetroxide (N_2O_4), as the oxidizer; hydrazine (N_2H_4) and monomethylhydrazine (MMH), for fuels. On landing, there will be residual chemicals to be properly unloaded, stored, and transported back to the launch site. These three chemicals are considered to be hazardous materials, meaning they may pose a risk to human health or the environment. The storage, handling and disposal of liquid propellants is regulated by government agencies. The United Nations Organization (UN) has developed a hazard classification system, and the U.S. Department of Defense (DOD) has developed standards for the storage, handling and disposal of propellants and explosives, based on the UN classification. NASDA follows the standards described in the USAF Eastern and Western Range 127-1 Range Safety Requirements; USAF 30th and 45th Space Wings.

By their nature, the transport and storage of the hazardous materials will require both engineering controls and personal protective equipment that provide both respiratory and full body protection from toxic and corrosive substances. The engineering controls will include spill containment, point source emission controls, and standardized work practices and controls. Calcium hypochlorite would be used to neutralize spills of hydrazine or monomethylhydrazine, and sodium hydroxide would be used to neutralize the oxides of nitrogen. Point source emission control could be achieved by using vacuum lines to capture propellant vapors directly at any suspected release points such as equipment connections.

The following is a brief discussion of the characteristics and potential hazards associated with the three chemicals.

HYDRAZINE

Propellant grade hydrazine contains a minimum of 97.5 percent basic hydrazine and the remainder is water. Hydrazine, in addition to being a high-energy rocket fuel, is used in the production of pesticides, pharmaceuticals, textile dyes and serves as an oxygen scavenger for boiler waters.

At room temperature, hydrazine is a colorless and oily liquid with an ammonia-like odor. It presents a severe explosion hazard when exposed to heat or allowed to react with oxidizing materials. The fumes are extremely irritating, hygroscopic and tend to condense onto surfaces. Care should be taken to avoid contact with oxidizers, strong acids, nitric acid and porous materials. When heated to decomposition, this substance emits toxic fumes of nitrogen oxides.

The environmental fate and transport of hydrazine is not well understood. It is very soluble in water and releases could pose a threat to drinking water sources if not properly contained. Hydrazine undergoes rapid degradation by hydroxyl radicals, ozone, and nitrogen dioxides present in the atmosphere.

Toxic effects due to acute exposure in animals involve damage to the lungs, liver and kidneys. The central nervous system is also affected by exposure. Routes of exposure are through inhalation, skin contact, and ingestion. Inhalation causes irritation to nose and throat, dizziness, nausea, temporary blindness. It is readily absorbed through the skin. Hydrazine is classified by the U.S. EPA as a probable human carcinogen based on animal experiments.

Handling

All personnel should wear full protective clothing and approved amine/ammonia type respiratory protection. All sources of ignition should be removed from the area. Spills should be covered with sand or vermiculite and carefully transferred to a well marked container for disposal. Fires may be extinguished with water, carbon dioxide or sand.

MONOMETHYLHYDRAZINE

Propellant-grade monomethylhydrazine (MMH) contains a minimum of 98 percent basic MMH and the remainder is water. At room temperature it is a clear colorless liquid with a fishy odor. It mixes readily with water, alcohol and hydrocarbons and is stable in extreme temperatures. It is stable to friction and shock, except when exposed to catalysts such as iron oxide.

It is extremely volatile, and high temperatures, direct sunlight, heat, sparks, and other ignition sources should be avoided. It is considered a chronic and acute health hazard. Possible routes of exposure include inhalation, skin absorption and ingestion resulting in upper respiratory irritation, pulmonary edema, organ damage, and permanent corneal damage. Symptoms of overexposure include inflammation, vomiting, nausea, dizziness, convulsions, and abdominal pain. It is a suspected carcinogen.

Handling

In the event of a spill the area should be evacuated and ignition sources removed. Vapors should be suppressed in a water fog, and all liquid should be contained for dilution by water to 5 percent and neutralized with a 5 percent hypochorite solution. Personnel should wear a full-faced positive pressure supplied air respirator and butyl rubber boots, gloves and apron or suit.

NITROGEN TETROXIDE

Nitrogen tetroxide is a mixture of nitrogen tetroxide and nitrogen dioxide, and is used as an oxidizing agent in rocket fuel. It is a reddish brown liquid with an acidic odor. Mixture with water produces nitrous acid and nitric acid. It is very stable at room temperature. To maintain its stability, contact with moisture, bases, most metals and organics must be avoided.

Liquid nitrogen tetroxide will not burn but will support combustion. It is hypergolic with the hydrazines, but not with all combustible materials. Non-hypergolic mixtures present an explosion hazard especially in high temperatures or pressures. It reacts violently with organic chemicals.

As a gas, nitrogen tetroxide is highly toxic with corrosive fumes. When released to the atmosphere it undergoes rapid photochemical degradation with a half-life of about two minutes. The byproducts are nitric acid rain, or ozone and hydroxyl radicals.

As either a vapor or liquid it is considered to be highly corrosive to tissues and may be fatal. It causes serious burns and permanent pulmonary damage.

Handling

Personnel should be equipped with full-face respirators, acid resistant gloves and protective clothing. Spills should be neutralized with sodium carbonate before disposal.

4.5.3.2 Impacts and Mitigation Measures

When the HOPE-X Orbiter lands it will be carrying small quantities of toxic materials that may be released in an accident. This includes approximately 509 kg of carbon phenolic as part of structural members, approximately 126 kg of carbon fiber as part of the heat resistant coating, approximately 66 kg of nitrogen tetroxide (NTO) and 109 kg of monomethyl hydrazine (MMH) from the OMS/RCS systems; and approximately 24 kg of hydrazine from the auxiliary power unit. The electrical power subsystem includes approximately 32 kg of cobaltous lithium in the battery and 22 kg of dimethyl carbonate. The actuators contain approximately 78 kg of hydraulic oil. Landing of a failed intact or nearly intact vehicle on Christmas Island may create toxic risks to personnel or natural resources from the release of hazardous substances and may be expected to create special clean up problems. Nevertheless, the relatively small quantities involved suggests that the risks may be minimal.

The estimated maximum quantities of residual chemicals to be unloaded from the HOPE-X are nitrogen tetroxide, 59.06 liters; monomethylhydrazine, 232.18 liters; and hydrazine, 23.74 liters. A risk assessment analysis was not conducted for the HOPE-X landing operations, but the risks can be discussed in qualitative terms. It is assumed there will be no intentional releases of the hazardous materials to the environment, and all exposures will be accidental. Accidents may be associated either with a successful landing or an unsuccessful landing. In either case, weather conditions at the time of incident will affect the severity of the toxic diffusion and debris dispersal.

The landing path of the HOPE-X will be carefully monitored for correct positioning. In the event of a HOPE-X crash at land or sea, the intermixing of propellant fuels with the oxidizers on impact may cause an explosion, which is likely to consume the hazardous materials, but present a fire hazard. The mechanical energy produced during the uncontrolled combustion could produce damaging winds. In addition to the chemical and wind hazards, are the vehicle fragments that may include burning propellants that could explode upon landing. NASDA will employ their standard emergency procedures for protecting personnel. The impacts on marine biota are difficult to assess because of the unknown nature of the materials involved, the dilution and advection rates, and the toxicity of these chemicals to marine organisms.

The more likely scenario for a spill is human error in the handling or transport of the hazardous materials following a successful landing. Human error rather than poor packaging or container design causes the majority of accidental releases.

Accidents could occur at any of the following phases:
1) transfer of residual fuel from HOPE-X to canisters
2) transporting canisters to the storage area at Aeon Field
3) temporary storage of canisters at Aeon Field
4) loading canisters onto surface transport vehicles
5) surface transport of fuels from Aeon Field to a ship for transport back to Japan
6) loading onto the Japan transport
7) ocean transport to Japan

Typically, only one chemical is involved in an accidental spill, thereby minimizing the potential for an explosive reaction. Under these conditions the spill is characterized as an evaporating liquid, or a gaseous cloud that is naturally buoyant.

Hydrazine fuels are extremely flammable liquids and a large spill or leak would likely result in a fire. The most likely sources of ignition are:

- electrical equipment that is not powered down
- contamination in the drainage system that reacts with the fuel and creates autoignition temperatures
- electrostatic discharge caused by uncontrolled fluid flow.

Nitrogen tetroxide does not undergo decomposition reactions that produce rapid heat release in the atmosphere. Combustion type reactions are possible only in the unlikely event that the released oxidizer comes into contact with a fuel source. Combustible materials such as paper, cloth, and wood should not be allowed near the oxidizer storage canister. Any spills or leaks from the canister will enter a containment system and be diverted to a holding tank for dilution and neutralization. The major result of a large nitrogen tetroxide spill will be high concentrations of nitrogen dioxide in the area of the spill.

Spills at the landing site will be easier to contain because a specially trained team will be readily available and the spill containment engineering controls will be in place. Speed in containing the spill is critical to minimizing the health risks. Wildlife is potentially at risk for exposure to contaminated air if the spill is not contained rapidly. Aeon Field personnel will be protected from exposure by the use of positive pressure air supplied chemical protective suits.

Since the hazardous materials will not be transferred to other containers, the likelihood for a spill is low. It is more likely that a fuel canister would be dropped. Chemicals will be stored and transported in containers specifically designed to prevent inadvertent ignition, and spills on impact. An emergency response unit should accompany the vehicles to contain, collect and remove any spilled fuel. Active response will reduce exposure and reduce risk significantly. Public use of the roads will be restricted during transport of the chemicals, and the public should be informed when transport is scheduled. A police escort will accompany the transport. In the event of an accident, a safety zone will have to be established to protect the public. A warning program should be developed to inform the community of a release.

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Nitrogen tetroxide does not undergo decomposition reactions that produce rapid heat release in the atmosphere. Combustion type reactions are possible only in the unlikely event that the released oxidizer comes into contact with a fuel source. Combustible materials such as paper, cloth, and wood should not be allowed near the oxidizer storage canister. Any spills or leaks from the canister will enter a containment system and be diverted to a holding tank for dilution and neutralization. The major result of a large nitrogen tetroxide spill will be high concentrations of nitrogen dioxide in the area of the spill.

Spills at the landing site will be easier to contain because a specially trained team will be readily available and the spill containment engineering controls will be in place. Speed in containing the spill is critical to minimizing the health risks. Wildlife is potentially at risk for exposure to contaminated air if the spill is not contained rapidly. Aeon Field personnel will be protected from exposure by the use of positive pressure air supplied chemical protective suits.

Since the hazardous materials will not be transferred to other containers, the likelihood for a spill is low. It is more likely that a fuel canister would be dropped. Chemicals will be stored and transported in containers specifically designed to prevent inadvertent ignition, and spills on impact. An emergency response unit should accompany the vehicles to contain, collect and remove any spilled fuel. Active response will reduce exposure and reduce risk significantly. Public use of the roads will be restricted during transport of the chemicals, and the public should be informed when transport is scheduled. A police escort will accompany the transport. In the event of an accident, a safety zone will have to be established to protect the public. A warning program should be developed to inform the community of a release.

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1. INTRODUCTION AND SUMMARY

This report characterizes the sonic boom and range safety considerations associated with the reentry and landing of the HOPE-X Orbiter. These evaluations focus on the risks to the Republic of Kiribati with an emphasis on the Island of Kiritimati (Christmas Island).

The HOPE-X Orbiter is, unlike an aircraft, generally similar in its blunt shape to the United States Space Shuttle Orbiter. It is, however, a significantly smaller vehicle. Table 1-1 lists key parameters for the reentering HOPE-X Orbiter.

Table 1-1. Key Dimensions of HOPE-X Orbiter

Parameter	Value
Total Weight Prior to Deorbit Maneuvers (kg)	11,132
Total Weight After Deorbit Maneuvers (kg)	9,900
Length (m)	18.3
Width (m)	10.2
Fuselage Width (m)	3.1
Height (m)	3.2
Wing Area (m^2)	65

The deorbit burn of the Orbital Maneuvering System (OMS) is designed to impart a velocity component in the orbital plane sufficient to initiate reentry and a velocity component out of the trajectory plane to deplete the OMS fuel tank. The reentry trajectory controls employ a combination of vehicle aerodynamic surfaces and a Reaction Control System (RCS). Like the STS Orbiter, the HOPE-X Orbiter uses the RCS for control at high speeds, relying on the aerodynamic surfaces for control at lower speeds and lower altitudes. The three on-board guidance computers employ a hybrid Inertial Measurement Unit (IMU) - Global Positioning System (GPS) navigation scheme. Beginning in the Terminal Area Energy Management (TAEM) Phase, navigation may be refined using the Differential GPS system based on Christmas Island.

The IMU/GPS system is responsible for establishing state vector information upon which the guidance computers initiation of the deorbit maneuver is based. The reentry trajectory consists of a combination of straight segments and controlled turns. The turns are used to maneuver in order to avoid overflight of populated areas, for energy management, and alignment with the approach path.

Two portions of the flight are of greatest interest to this review: (1) the initial reentry maneuver, and (2) later in flight when a malfunctioning vehicle can hazard the Kiribati Republic or sonic booms can reach Christmas Island. In Chapter 3, it is noted that malfunctions during the initial reentry maneuver are of interest because of the possibility of significantly altering the impact point of the HOPE-X. Such malfunctions could hazard areas considerably beyond the scope of this study. Late in flight, supersonic flight subjects Christmas Island to low level sonic booms; overpressure levels are well below damaging levels (See Chapter 2). Also, late in flight failures may place the inhabitants of the Republic of Kiribati at risk. Chapter 3 shows that the range safety submittal supports the conclusion that the impact risks are nominal. In addition, the HOPE-X Orbiter contains quantities of potentially hazardous materials. These are summarized in Table 1-2. An accident causing HOPE-X to impact and breakup on Christmas Island has the potential for releasing some of this material to the environment.

Table 1-2. Hazardous Materials Onboard HOPE-X at Landing

Source	Materials	Maximum Quantity (kg)
Structure	Carbon Phenolics	508.9
Heat resistant coating	Carbon fiber	125.8
Propellant System OMS RCS	Nitrogen Tetroxide	 22 66
OMS RCS	Monomethyl Hydrazine	93 109
APU	Hydrazine	24
Electrical Power System	Cobaltous lithium	32.4
	Dimethyl carbonate	21.6
Actuators	Hydraulic oil	78

2. HOPE-X DESCENT SONIC BOOM

The supersonic reentry flight of the HOPE-X Orbiter through the atmosphere will generate ground level sonic booms. As a consequence of the reentry flight path most of the sonic boom footprint lies over open ocean. The sonic boom produced by the final supersonic portion of the trajectory does, however, affect Christmas Island (Kiritimati) and its coastal waters. The following material characterizes this sonic boom footprint and the methods employed in its calculation.

2.1 Method of Calculation

Four types of information are required to evaluate the environmental impact of the sonic boom produced by the HOPE-X:

1. The planned trajectory,
2. representative meteorological profile,
3. the source term (sonic boom near the HOPE-X Orbiter), and
4. definition of the region at risk and a characterization of the sensitive objects or species.

The analysis is based upon a nominal descent trajectory. The trajectory data is used in the analysis as follows:

Present position defines the point of origin of the shock waves at each trajectory time point.

Velocity and vehicle attitude define the geometry of the Mach cone at the point of origin.

Acceleration is used to define maneuver induced sonic boom focusing regions.

A meteorological profile is used to calculate an effective speed of sound profile in the direction of sonic boom wave propagation. The effective speed of sound is a combination of the local speed of sound (driven by atmospheric density) and local winds. The effect of the atmospheric density profile on the sonic boom footprint is, typically, a higher order effect. Although the density profiles vary with location and time, relatively significant changes are required in the overall density profile to make a significant impact on the sonic boom footprint. The current analysis was performed using a typical tropical density profile.

The wind velocity profile can significantly alter the sonic boom footprint, changing both its shape and overpressures. Winds can cause the incident sonic boom wave to refract so that a region is in a "shadow" zone and is not affected by the incoming sonic boom wave. The winds can also focus in wave producing higher overpressures. Typically, sonic boom footprints for environmental impact analyses are initially calculated without regard to winds. If the no-wind footprints provide a sufficient safety margin, no further analyses are required. When this is not the case, analyses may be required of the sensitivity of the sonic boom footprint to winds and, in some instances, analyses may be required on the day of the operation to verify that conditions are acceptable. The HOPE-X descent sonic boom is not expected to cause wind-sensitive operational constraints.

The magnitude of the sonic boom source term is a function of the geometry of the Orbiter. The U.S. Space Shuttle Orbiter sonic boom characteristics have been extensively studied using theoretical calculations supported by wind-tunnel measurements. The HOPE-X Orbiter is similar in shape to the U.S. Space Shuttle Orbiter, only significantly smaller. The HOPE-X Orbiter sonic boom source term was developed by scaling the U.S. Space Shuttle Orbiter to the landing weight of the HOPE-X (9900 kg). This produces a representative, but conservative estimate of the HOPE-X sonic boom source term.

A top level view of the geography of Christmas Island was developed by using the United States Geological Survey's (USGS) version of the United States Defense Mapping Agency (DMA) World Vector Shoreline. This database does not include all of the detailed interior features such as lakes, etc. that DMA has in their full data set. It is, however, designed to provide shoreline data based on the Mean High Water mark suitable for scales close to 1:250,000. At this scale, the USGS represents that shoreline features will have no more than a 2 mm error.

The body of the Environmental Impact Statement characterizes the animal and bird species of Christmas Island. The section on Range Safety provides estimates of the human population distribution on Christmas Island. The results section of this discussion interprets the sonic boom levels in terms of the potential for adverse consequences.

2.2 Results of Analysis

The Orbiter sonic boom waveforms are symmetrical "N-waves." (See Figure 2-1.) The no-wind analysis produced a maximum calculated overpressure of 1.2 psf (129.6 dB flat). A typical "N-wave" along the flight track will have a peak to peak duration of approximately 275 milliseconds. Off-track sonic booms will be of longer duration, possibly as long as 400 milliseconds.

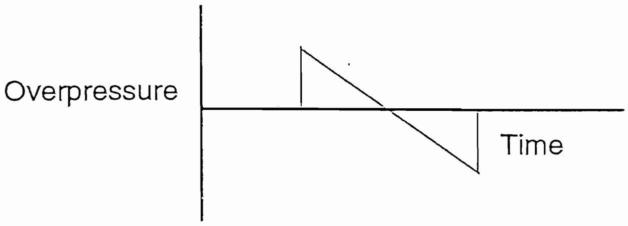

Figure 2-1. Typical HOPE-X Sonic Boom Signature

Figure 2-2 depicts peak overpressure isopleths for the no-wind case. The 0.4 psf contour corresponds very closely to the limit of the region affected by any sonic boom. The figure shows that the entire island is expected to be affected by the HOPE-X landing sonic boom with the greatest overpressures being along the "neck" of the island, south of Artemia Corner but north of the landing site.

Overpressures in the populated regions are less than 1 psf, well below the levels expected to cause structural damage or window breakage or human physiological impairment. These levels are well above the threshold of audibility and may, under the right conditions, startle some people.

Startle responses in marine birds and mammals are known to occur at impulses of as little as 80 to 90 dB flat SPL. Mammals and birds will generally run or fly in response to sonic booms and loud overflights. Controlled experimental studies with booms at levels up to 150 dB (peak flat SPL) have failed to elicit panics. Nevertheless, widespread concern continues because there are circumstantial accounts of catastrophic damages, notably the "Sooty Tern Incident."

This incident occurred in 1969 on the Dry Tortugas off the coast of Florida. This area is a region subject to frequent sonic booms. Prior to the breeding season, the investigators performed a census of the Sooty Terns in the area. Several months after the end of the season a second census was performed. The investigators did not visit the area during the intervening period.

Only approximately 400 chicks were present at the post-breeding count versus the anticipated 40,000. In their attempt to explain the breeding failure, the investigators discovered that persons in buildings in Fort Jefferson National Monument, some miles away had reported exceptionally loud sonic booms mid-season. No timely follow up to these reports had occurred. The investigators attributed the breeding failure to sonic boom exposure.

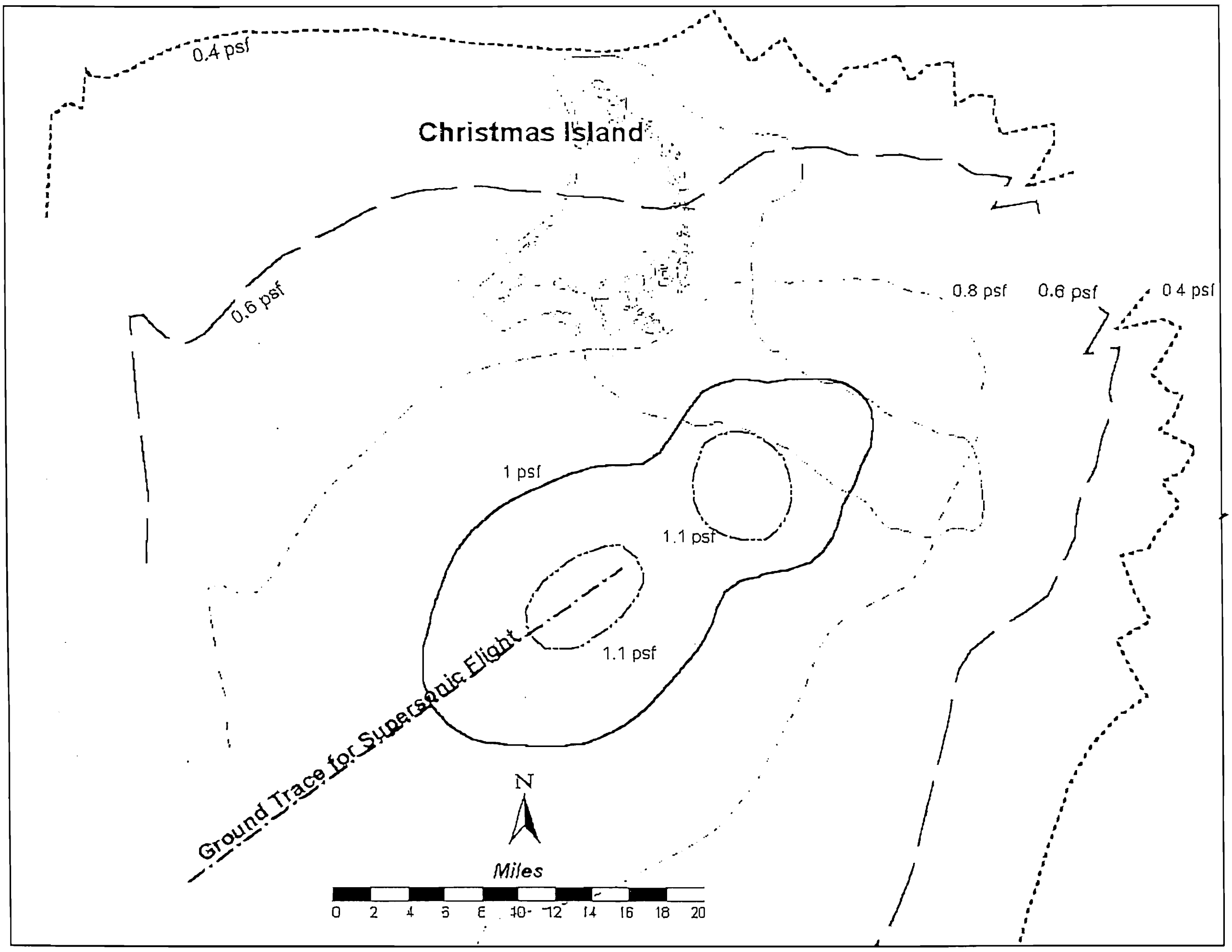

Figure 2-2. Typical Sonic Boom Footprint for HOPE-X Approach to Christmas Island

Since that time, it has been conclusively demonstrated that the eggs could not have been damaged by the sonic booms. A typical response to a sonic boom is for the birds to rise, fly about briefly and return to their eggs. It has, however, been argued that the birds may have been disturbed sufficiently so they lost interest in breeding and the eggs were allowed to cool to the point to cause a massive breeding failure. No substantiation has been found for this argument.

3. HOPE-X REENTRY RANGE SAFETY CONSIDERATIONS

Range safety considerations for the reentry and descent of the HOPE-X span a range of concerns beyond those that affect the people of the Kiribati Republic, its surrounding waters and airspace. It is useful to briefly review the treatment of reentry range safety by various other programs to set the stage.

3.1 Precedents

Space Shuttle

The most obviously similar program is the United States Space Shuttle Orbiter reentry. According to NASA sources there have been no analyses performed to assess the risks to people on the ground for the reentry and landing of the Orbiter. Key risk related controls are clearing the air space and using restricted areas to keep the public out of an area around the landing runway. The Orbiter is controlled during reentry by a combination of the Reaction Control System (RCS) thrusters and aerodynamic control surfaces. At low speeds (below about Mach 1) only the aerodynamic surfaces are used to provide control. Significant quantities of hypergolic fluids remain on board the vehicle after it has landed.

METEOR

A second program of interest was a commercial United States venture called METEOR. Regulation of the risks associated with the reentry and landing of the METEOR was under the U.S. Department of Transportation, Office of the Associate Administrator for Commercial Space Transportation (DOT/AST). This office imposed risk acceptability criteria and specified operational procedures that would be required to be implemented before they granted a license. Risk acceptability criteria were:

1. The probability of landing within the intended area must be 0.997 or greater.

2. The probability of a casualty within a 100 mile radius of the intended landing area must be no greater than 1×10^{-6}.

3. The probability of a casualty outside the 100 mile radius, or of damage to public property, or of damage to property on orbit must be no greater than 1×10^{-6}.

DOT/AST performed an extensive review of the training, operational organization, operational procedures, data sources, and decision making procedures before granting a license. Among the requirements they imposed was that the orbital parameters and vehicle attitude be within specified tolerances before a deorbit command could be issued.

DOT/AST limited their regulation to the particular orbital cycle from which reentry was planned. Random reentry risks in the event the intended deorbit was not possible were not addressed.

X-33

The X-33 is a prototype Reusable Launch Vehicle (RLV) sponsored by NASA and being developed by Lockheed Martin Corporation. Risk analyses have been required for both the ascent and reentry phases of X-33 operations.

Clearly, despite NASA's approach to the STS Orbiter risks, risk analyses and risk control, procedures for the reentry of a spacecraft are measures which should be required.

3.2 Acceptable Risk Criteria

There are several possible criteria that might be considered for acceptable levels of risk for this mission:

1. The National Space Development Agency of Japan (NASDA) current risk acceptability standards for any single launch include the following:

    - Fatality Expectation (E_F) $\leq 1.5 \times 10^{-7}$ per foreign country

    - Casualty Expectation (E_C) for mission essential workers $\leq 1.0 \times 10^{-4}$

While these criteria have so far only been applied to the launch phase of a mission, it would be logical to impose the criteria for the entire mission.

2. The DOT/AST risk criteria for the reentry of the METEOR spacecraft, as noted above, were:

    - Probability of missing the intended landing site ≤ 0.003.

- Probability of a casualty within 100 miles of the landing site $\leq 1\text{x}10^{-6}$.

- Probability of property damage to public property, of damage to property on orbit, or of a casualty outside of the 100 mile radius about the landing site $\leq 1\text{x}10^{-6}$.

3. A recent U.S. panel on range safety risk acceptability recommended the following standards for risks from inert debris for each mission:

   - Maximum fatality probability for any individual (general public) $\leq 1 \times 10^{-7}$

   - Expected number of fatalities (general public) $\leq 3 \times 10^{-5}$

   - Maximum fatality probability for any mission-essential individual $\leq 3 \times 10^{-6}$

   - Expected number of fatalities to mission-essential personnel $\leq 3 \times 10^{-4}$

   - Probability of impact by debris capable of causing a fatal accident on all aircraft $\leq 1 \times 10^{-9}$

   - Probability of impact by debris capable of causing a catastrophic accident on all ships $\leq 1 \times 10^{-6}$

This panel's recommendations include individual risk criteria as well as criteria for protecting ships and aircraft, not explicitly addressed in the first two sets of criteria presented.

It is recommended that the responsible regulatory agency adopt the pertinent NASDA regulations and augment them, as appropriate, with the recommendations cited above by the recent U.S. panel.

3.3 Operational Considerations

As noted in the introductory remarks, the U.S. DOT/AST determined that a considerable amount of detail is required for an adequate range safety review for licensing including

- training procedures
- operational organization
- operational procedures
- data sources
- decision making procedures.

In the context of an environmental assessment this level of review is not possible. Figure 3-1 presents an event tree showing the sequences of events following a deorbiting maneuver as reflected in the range safety probability study submittal. The event tree does not address the possibility of aerodynamic breakup of the HOPE-X vehicle resulting from a range safety action while the vehicle is above 40 kilometers (See comments under the Range Safety System heading below).

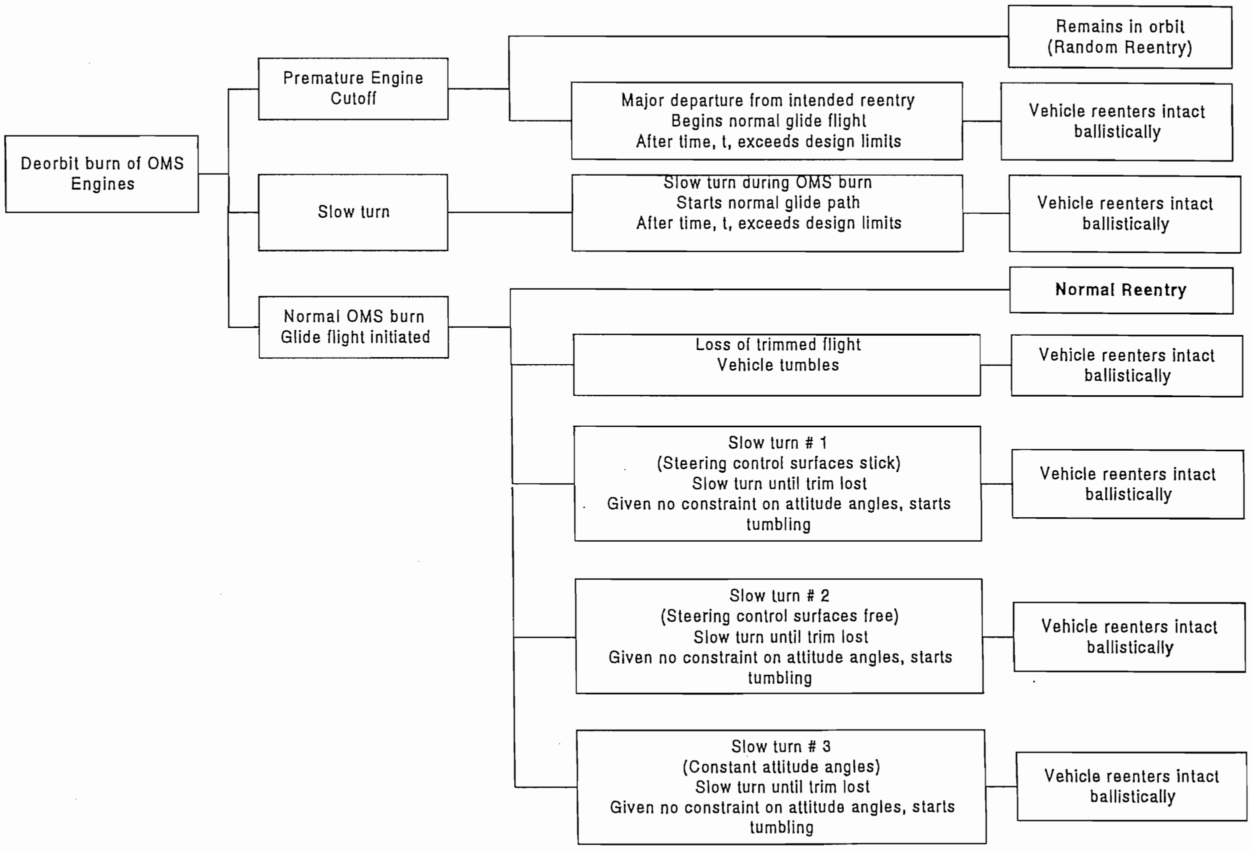

Figure 3-1. Event Tree for Reentry of HOPE-X Orbiter

The following comments address concerns raised by reviewing the range safety submittals:

1. *Deorbit burn*

This is described as being composed of three sub-maneuvers:

(a) De-orbit1 maneuver at t=5686 seconds,
(b) De-orbit2 maneuver at t=5729, and
(c) OMS burn at t=5784.

Variations in the orbital parameters from nominal should affect the required maneuvers at each point. Moreover, the duration of each maneuver, required rates, *etc.* are probably dependent on the actual achieved state vector at each reference point. Although the Autonomous Flight Controller includes three redundant computers to enhance system reliability, there remains the possibility of common cause failures. Complex computer software systems are particularly difficult to prove to be free from common cause failures.

It would be prudent to make provisions for validation of the HOPE-X orbiter's position, velocity and attitude prior to allowing the initiation of the OMS burn. This should address such issues as (1) assuring that HOPE-X can achieve the desired state vector within the tolerances required for a successful reentry after the OMS burn, and (2) contingency plan if HOPE-X cannot achieve the "window" required for a safe OMS reentry.

2. *The Range Safety System*

HOPE-X has been designed not to breakup when the Flight Termination Command is issued at altitudes below 40 kilometers; this is a crucial design feature in controlling the hazards to Christmas Island and its immediate vicinity.

The impact probability study provided by NASDA employs the assumption that the HOPE-X does not breakup. Break up of the vehicle will increase the number of reentering fragments and alter their aerodynamic characteristics. For such a debris cloud to reach Christmas Island one of two conditions must be satisfied:

- The HOPE-X design to assure that breakup does not occur below 40 kilometers must fail.

- Some failure must occur while HOPE-X is still above 40 kilometers that elevates the velocity vector sufficiently to increase the impact range to the range to Christmas Island and alters the velocity vector in a northerly direction so that the debris does not pass safely to the south of Christmas Island.

The Range Safety System design should be reviewed to rule out the possibility of a vehicle failure disabling the range safety system before the vehicle can be place in the "range safety mode".

3. *Landing Phase*

A malfunctioning Orbiter poses a potential hazard as a massive impacting object. In addition, a malfunctioning Orbiter may breakup on impact releasing quantities of toxic substances.

A malfunctioning intact Orbiter is expected to impact with a high level of kinetic energy. Thus, it poses a potentially significant hazard to property, protective structures and their occupants. In particular, it is recommended that the HOPE-X personnel shelter located a little more than a kilometer to the side of the HOPE-X runway be evaluated to assess whether it is adequate to protect the ten ground crew members stationed within it. In addition, emergency evacuation procedures may be desirable to protect against an incoming malfunctioning Orbiter.

When the HOPE-X Orbiter lands it will be carrying small quantities of toxic materials that may be released in an accident. This includes approximately 509 kg of carbon phenolic as part of structural members, approximately 126 kg of carbon fiber as part of the heat resistant coating, approximately 66 kg of nitrogen tetroxide (NTO) and 109 kg of monomethyl hydrazine (MMH) from the OMS/RCS systems; and approximately 24 kg of hydrazine from the auxiliary power unit.

The electrical power subsystem includes approximately 32 kg of cobaltous lithium in the battery and 22 kg of dimethyl carbonate. The actuators contain approximately 78 kg of hydraulic oil..

Landing of a failed intact or nearly intact vehicle on Christmas Island may create toxic risks to personnel or natural resources from these substances and may be expected to create special clean up problems from such an accident. Nevertheless, the relatively small quantities involved suggests that the risk may be minimal.

4. *Calculated risks*

While the failure modes and responses shown in the HOPE-X reentry event tree address the issues that would normally be considered, comments on the risk analysis are limited by the level of detail reviewed. In particular, experience in the United States has shown that launch vehicle designers tend to be overly optimistic regarding the reliability of their designs.

For consistency with essentially all criteria, risks need to be expressed as total collective risk (casualty or fatality expectations). Risk estimates have been developed based on the impact probabilities in the impact probability submittal. Table 3-1 lists estimates of casualty expectations to the general public and personnel outside the precaution area. Casualty expectation, E_C, was estimated using the equation

$$E_C = \frac{N_{pop} P_I A_L}{A_{pop}}$$

Table 3-1 Estimated Risks to Populations Outside the Precaution Area

Location		Population	Impact Probability	Casualty Expectation (Upper Bound)	Casualty Expectation (Lower Bound)
Island	Town				
Kiritimati	London	1194	8.3×10^{-12}	4.4×10^{-12}	9.2×10^{-13}
Kiritimati	Tabwakea	968	9.3×10^{-12}	3.5×10^{-12}	7.4×10^{-13}
Kiritimati	Banana	905	4.2×10^{-11}	3.3×10^{-12}	7.0×10^{-13}
Kiritimati	Poland	204	7.1×10^{-11}	7.5×10^{-12}	1.6×10^{-13}
Taraina		1123	1.1×10^{-7}	1.1×10^{-8}	2.4×10^{-9}
Tabuaeran		1833	4.5×10^{-7}	2.2×10^{-8}	4.6×10^{-9}
Total Outside Precaution Area		6217	5.6×10^{-7}	3.3×10^{-8}	7.0×10^{-9}

area of approximately 40,000 square feet, the impact probability for a freighter directly underneath the flight track will be on the order of $1x10^{-11}$ to $1x10^{-10}$. These impact probabilities are well within the normally acceptable levels. Nevertheless, specific mitigation measures are noted below:

- As noted above, there are concerns about the adequacy of a shelter for the ground crew members inside the precautionary area. A failed intact vehicle (9900 kg) landing out of control may penetrate even a very substantial structure. The shelter should be analyzed to determine its vulnerability to a direct impact by the HOPE-X. As needed, impact kinetic energy may be absorbed by one or more protective berms or additional layers of sandbags to provide an adequate margin of safety.

- Emergency procedures should be developed for the ground crew to respond to a malfunctioning HOPE-X Orbiter expected to land on Christmas Island. These should include crew actions during final descent and safety precautions for the clean-up crew to detect and remove all hazardous materials released.

- Notices to Airmen and Mariners should be published specifying the higher hazard regions along the approach.

Survey of the Fisheries Resources at Kiritimati Atoll for the Proposed Hope-X Unmanned Space Shuttle Landing Site Project

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4. Offer recommendations for the project to minimize environmental impacts and avoid user conflicts.

5. Offer recommendations on environmental monitoring during the project and management strategies for sustainable use of the marine resources.

3. METHODS

3.1. Underwater assessment techniques

Fish were visually assessed underwater using a variety of methods depending on the habitat and area to be covered. 1) **Snorkel surveys** were conducted in shallow water habitats where visibility was restricted. 2) **Qualitative SCUBA surveys** were conducted during drift dives of ca. one hour in duration to maximize the area covered during the survey. All species observed were noted and at the conclusion of the dive, species were placed in abundance categories based on the estimated number of individuals observed during the dive: 1 = < 5, 2 = 5-20, 3 = 20-50, 4 = 50-100, 5 = > 100. 3). **Quantitative visual transects** were conducted at five locations using standard underwater visual belt transect survey methods (Brock, 1954; Brock, 1982). A 50 m fiberglass measuring tape was laid out parallel to the reef edge. A SCUBA diver swam each transect at a constant speed (~ 15 min/transect), identifying to the lowest possible taxon all fishes visible within 2.5 m of either side of the centerline (250 m^2 transect area).

3.2. Personal interviews

Interviews were conducted with individuals from government, the dive industry, aquarium fish collectors, sportfishing guides, subsistence fishermen, and others involved in marine resource use. Based on these interviews, details were obtained on the type of fishing gear, locations, status of the fishery, and other information that could be useful in obtaining a baseline on marine resource use and potential impacts that could result from the proposed project.

3.3. Fisheries databases

The Fisheries Division of the Government of Kiribati conducted household interviews in the villages of Banana, Tabakea, and London in January and February of 1995. Raw data from this survey was analyzed to obtained information on fishing effort, gear types, catch, and major fishing locations for each household. Kiritimati Marine Export Ltd. provided receipts for fisheries products exported from Kiritimati from 1989 to 1996. Major gaps in these records resulted from changes in various importers during this time, periods without air service to the island, loss or unavailability of records, and periods of nonoperation. Despite these shortcomings, valuable information on export species composition was obtained.

4. RESULTS

4.1. Artisanal fisheries survey

Survey of the Fisheries Resources at Kiritimati Atoll for the Proposed Hope-X Unmanned Space Shuttle Landing Site Project

1. INTRODUCTION

Kiritimati (Christmas) Island was discovered by Captain Cook on December 24, 1777 and is the administration center of the Line and Phoenix Groups of the Republic of Kiribati (Kamatie et al. 1995). It is one of the largest coral atolls in the world with a land area of ca. 360 sq. km, about 25% of this area is occupied by several hundred ponds with a wide range of salinities (Schoonmaker et al. 1985). This large shallow lagoon area harbors abundant bonefish and giant trevally jack resources making Kiritimati Island one of the world's premier fly and light tackle fishing destinations.

American and British military personnel inhabited the island during World War II and established a network of roads and airfields to support the war effort. From 1957 to 1963, the British conducted above ground nuclear testing on Kiritimati Island and neighboring Malden Island. Extensive improvements to roads and infrastructure were performed during this time. Following the period of nuclear testing, the population of the atoll grew rapidly with individuals relocated from the overcrowded Gilbert group of Kiribati.

The Japanese space agency (NASDA) established a satellite tracking facility near the village of Tabakea in the 1970's. NASDA is presently proposing to construct an unmanned space shuttle landing port and support facilities on Kiritimati Atoll. The author and Dr. James Maragos conducted nearshore marine surveys and interviews with stakeholders on the atoll during a 1-8 May 1997 assessment of the potential environmental impact of this proposed project. This report presents the findings from this study and offers recommendations to reduce environmental impacts and stakeholder conflicts as a result of the proposed unmanned space shuttle landing project.

2. GOALS AND OBJECTIVES

The goals and objectives of this study are as follows:

1. Assess the current status of the coral reef resources of Kiritimati with particular emphasis on fishes.

2. Characterize the commercial, subsistence, and recreational fishing activities on the atoll.

3. Assess the impact of the proposed project on the fisheries resources and identify potential conflicts between the project and existing fishing and marine use activities.

The Fisheries Division of the Government of Kiribati conducted household interviews in the villages of Banana, Tabakea, and London in January and February of 1995. Information was obtained on fishing effort, gear types, catch, and major fishing locations for each household. The raw data from this survey were obtained from the Fisheries Division and analyzed to document the extent of fishing activities conducted in each village.

4.1.1. Fishing effort by location - Each household surveyed was asked to list the number of fishing trips per week in each of four general fishing locations: 1) lagoon, 2) open ocean, 3) fish ponds, and 4) reef. Much of the fishing effort appeared to be concentrated inside the reef, with the lagoon (53%) and the fish ponds (12%) together accounting for 65% of the total fishing effort (Table 1). The three villages had distinctly different fishing locations. Fishers from Banana primarily fished in the lagoon and fish ponds. No fishers from the other two villages reported any fishing activities in fish ponds. The lagoon (79%) was the primary fishing location for London fishers with 21% of the weekly fishing trips conducted on the outside reef areas. Fishers from Tabakea distributed their fishing effort fairly evenly among the lagoon (38%), open ocean (32%), and reef (30%) areas.

Table 1. Number of fishing trips per week by location for each village surveyed.

Location	Banana	London	Tabakea	Percent
Lagoon	50	37	42	53
Open ocean	1	9	36	19
Fish ponds	28	0	0	12
Reef	5	1	33	16

4.1.2. Gear type - Each household was asked to list the total number of each fishing gear possessed (Table 2). Gillnets were the dominant gear type accounting for 67% of all fishing gear, followed by handlines (24%), trolling gear (6%), and longlines (2%). Again, there were clear distinctions between villages for the types of fishing gear used. Gillnets were by far the dominant gear used by Banana fishers (89%). Fishers in London used primarily gillnets (70%) followed by handlines (21%). In Tabakea, gillnets (46%) and handlines (42%) were the two most common gear types.

Table 2. Numbers of fishing gear possessed in each village surveyed.

	Banana	London	Tabakea	Percent
Gillnet	66	33	38	67
Handline	4	10	35	24
Trolling	2	2	9	06
Longline	2	2	1	02

4.1.3. Gillnet mesh size - Gillnets were typically 100 m long with mesh sizes varying from 1.5" to 5" (Table 3). The most commonly owned gillnet had 3" mesh (55%), followed by 2" (15%), and 2.5" (13%).

Table 3. Gillnet mesh sizes recorded during village artisanal survey.

Mesh size	1.5"	2"	2.25"	2.5"	3"	3.5"	4"	4.5"	5"	Total
N	3	25	4	22	93	4	7	1	9	168
Percent	02	15	02	13	55	02	04	01	05	

4.1.4. Boat ownership - A total of 43% of all households responding to the survey said that they owned a boat of some type (Table 4.). A small number of fishers in Banana claimed boat ownership (3%) while at the other extreme, 90% of the respondents in Tabakea said that they owned boats. Fishers in London reported 39% boat ownership.

Table 4. Boat ownership by village.

	Own boat	No boat	Total	Percent
Banana	2	65	67	03
London	14	22	36	39
Tabakea	53	6	59	90
Total	69	93	162	43

4.1.5. Boat type and size - Three boat types were reported: 1) paddle canoes, 2) motorized skiffs, 3) Fisheries designed sailing canoes (10 m). Canoes accounted for 80% of all vessels reported (Table 5). Most canoes were small with the most common canoe length being 4.5 m length (45%) followed by 5 m (17%) and 6 m (15%) types. Motorized skiffs were powered by outboards ranging in size from 15 to 40 hp.

Table 5. Boat length and type from village survey.

Length (m)	Canoe	Skiff	Fisheries Canoe
4	4	2	0
4.5	24	1	0
5	9	8	0
5.5	2	0	0
6	8	0	0
6.5	1	0	0
7	2	0	0
7.5	1	0	0
8	2	0	0
9	0	1	0
10	0	0	1
Total	53	12	1
Percent	80	18	02

4.1.6. Sale of catch - Overall, 19% of the households interviewed reported selling all or a portion of their catch (Table 6). The Captain Cook Hotel and Kiritimati Marine Exports Ltd. were the major purchasers of fish on the island. Tabakea had the highest percentage of respondents who said they sold their catch (45%) while only 6% of the respondents in Banana reported selling their catch.

Table 6. Disposition of catch by village.

Village	No sale	Sale	Percent sold
Banana	64	4	06
London	33	4	11
Tabakea	24	20	45
Total	121	28	19

4.1.7. Catch composition - Each household surveyed reported their total catch for the seven day period prior to the interview and gave information on species caught, location and, gear types used (Table 7). Numbers reflect the total numbers for each species since weights were usually not reported. Milkfish (*Chanos chanos*) was clearly the dominant species caught (76%). Catches of the next most common species (bonefish - *Albula* spp. 7%) were an order of magnitude lower than the catch of milkfish. Over 90% of the catch was taken using gillnets with milkfish accounting for 84% of the gillnet catch followed by bonefish (8%). Handlines took 5% of the total catch with 35% of the catch consisting of tunas (Scombridae) followed by blacktipped groupers (*Epinephelus fasciatus*) (20%) and honeycomb grouper (*E. merra*) (17%). Trolling caught mainly skipjack tuna (*Katsuwonus pelamis*) (41%), other tunas (28%), and wahoo (*Acanthocybium solandri*) (21%).

Table 7. Catch composition by gear type.

Catch	Gillnet	Handline	Trolling	Bottom fishing	Total	Percent
Milkfish *Chanos chanos*	6665	0	0	0	6665	76
Bonefish *Albula* spp.	619	36	0	0	655	07
Tunas Scombridae	0	156	82	0	238	03
Red goatfish *Parupeneus* spp.	191	0	0	0	191	02
Convict tang *Acanthurus triostegus*	185	0	0	0	185	02
Blacktipped grouper *Epinephelus fasciatus*	0	90	0	50	140	02
Mullet Mugilidae	121	0	0	0	121	01
Skipjack tuna *Katsuwonus pelamis*	0	0	119	0	119	01
Honeycomb grouper *E. merra*	0	75	0	0	75	01
Wahoo *Acanthocybium solandri*	0	0	60	0	60	01
Yellowfin surgeonfish *A. xanthopterus*	53	0	0	0	53	01
Goatfish Mullidae	53	0	0	0	53	01
Redtailed snapper *Lutjanus fulvus*	16	5	0	25	46	01
Paddletail snapper *L. gibbus*	0	26	0	0	26	<01
Trevally *Caranx ignobilis*	16	9	0	0	25	<01
Other (15)	17	43	30	15	105	01
Total	7936	440	291	90	8757	
Percent	91	05	03	01		

4.2. Food fish exports

Kiritimati Marine Export Ltd. is a government sponsored buyer and exporter of marine fisheries products from Kiritimati Island. The company operates two 10 m motorized sailing canoes and three 20 foot fiberglass skiffs with 40 hp outboards. Composition of export catch varies depending on the particular import dealer and consists of pelagic species such as wahoo and tunas as well as deep water groupers and snappers. Records from 1989 to 1991 showed that the top five species exported by Kiritimati Marine Export Ltd. were tunas, wahoo, milkfish, paddletail snapper, and mullet (Table 8). Records from July 1995 to May 1996 from Kiritimati

Marine Export Ltd. to First Pacific Dealers in Honolulu showed mullet, blacktipped grouper, paddletail snapper, milkfish, and parrotfish to comprise the five top export species, respectively (Table 9). United Fishing Agency in Honolulu, Hawaii imported 15,481 lbs. of fish and lobster from Kiritimati from November 1996 to February 1997. Of that total, 14,418 lbs. (93%) consisted of wahoo. These figures indicate that the market for export fish from Kiritimati is highly variable and dependent on the particular dealer. Some dealers prefer groupers and snappers while others, worried about the possibility of ciguatera poisoning, will only buy pelagic species.

Table 9. Top five species exported by Kiritimati Marine Export Ltd. from 1989 to 1990. Weight is in pounds.

Species	1989	1990	1991	total
Tunas Scombridae	37252	28137	5336	70725
Wahoo *Acanthocybium solandri*	41372	22193	6215	69780
Milkfish *Chanos chanos*	60368	3000	5754	69122
Paddletail snapper *Lutjanus gibbus*	24674	3289	4038	32001
Mullet Mugilidae	16923	1711	5539	24173

Table 9. Top five species exported by Kiritimati Marine Export Ltd. to First Pacific Dealers, Honolulu, Hawaii from July 95 to May 96. Weight is in pounds.

Species	1995- 96
Mullet Mugilidae	11888
Blacktipped grouper *Epinephelus fasciatus*	2550
Paddletail snapper *Lutjanus gibbus*	1866
Milkfish *Chanos chanos*	1353
Parrotfish Scaridae	994

4.3. Fishing Gear Types and Locations

Interviews with Fisheries Division staff, fishing guides, and other individuals involved in marine resource use provided valuable information on fishing practices throughout the atoll. These individuals provided information on major fishing gear types, fishing locations, major species sought, and changes that have been observed in any of these fisheries over time. Maragos (1997) conducted interviews with these individuals to map the distribution of important marine resources and harvest methods. Appendix I of this report is a reproduction of the results of this mapping exercise.

4.3.1. Gillnets - This is the primary gear type used throughout Kiritimati and targets mainly milkfish. Bonefish, giant trevally, and other lagoon fish are also caught using this gear type. Fishing activity is fairly consistent year-round but tends to increase when ships arrive from Tarawa providing an outlet to export the catch. Gillnetting occurs throughout the lagoon, fishponds, and shallow reef flats around the atoll. Much of the fishing effort is concentrated in the lagoon area adjacent to the villages of London and Tabakea. Gillnets are set using small canoes or by wading out in shallow water. Gillnets are mostly laid on the slope in 10 to 15 feet of water to catch large milkfish as they are coming off the bottom. Villagers primarily from Banana, but also from London and Tabakea, often drive to the hyper-saline fish ponds in the back of the lagoon to harvest milkfish with gillnets. Milkfish in these ponds are reported to be oilier and therefore preferred by fishermen. There does not appear to be any type of village or individual marine tenure system. All fishers have access to all marine resources regardless of location. A number of fish ponds are used as milkfish rearing areas by the Fisheries Division and are off limits to gillnetting.

4.3.2. Light tackle sportfishery - The large lagoon, with extensive grassless sand flats, good year-round weather, and an abundance of bonefish has made Kiritimati one of the world's top light tackle angling destinations. The majority of the fishing is conducted using fly rods and in addition to bonefish, giant trevally are also caught with several International Game Fishing Association world records being established for this species on Kiritimati. The fishery started in the 1980s and now provid an important source of revenue to the island (Table 10) (Kamatie et al 1995). There are currently 30 independent and 5 government hotel guides involved in this fishery. There are usually 2 anglers per guide and groups consist of 2 guides and 4 anglers. A voluntary limit of 30 anglers per day has been established by the fishing guides. This practice is designed to reduce the interaction among anglers rather than as a conservation measure. The majority of the fishing occurs in the lagoon and along the leeward reef flats.

Bonefish are reported to spawn monthly during the full moon with Paris Flats being one of the major spawning locations. Most of the bonefish are released after capture and the government has established "no-kill" areas on a number of popular sand flats. Some of the fish ponds have been designated conservation areas where all fishing except catch-and-release recreational fishing is prohibited. Despite these conservation measures, a survey conducted by the Fisheries Division found a highly skewed sex ratio (15 males: 1 female) in one closed area and no females were observed from bonefish taken adjacent to Tabakea Village. Female bonefish are larger and therefore selectively removed by the fishery first. These results suggest overfishing of this resource and efforts should be made to develop additional conservation areas as well as other management strategies. Due to intensive fishing pressure, bonefish in Tarawa Lagoon were found to have a strongly skewed male to female sex ratio with declining size of individuals over a 15 year period (Beets 1994). These results suggest a low spawning stock of females and the potential for reproductive collapse of the species locally. It was also reported that during El Nino years fishing tends to be poorer on Kiritimati. The closure of the bridge from Little Plantation to Te Baura in 1986-87 is said to have made the ponds hypersaline in this area and has reduced the number of bonefish found in this location. Milkfish and tilapia are now reported to dominate this area.

Table 10. Annual number of anglers visiting Kiritimati (Kamatie et al. 1995)

Year	Number of anglers	Mean number per month	Fishing permits (Value AU$)
1988	666	56	23,310
1989	657	55	22,995
1990	617	51	21,595
1991	389	32	15,470
1992	379	31	19,145
1993	684	57	23,940
1994	813	68	28,455
1995	828	75	28,980

4.3.3. Offshore sportfishing - Dive Kiribati operates a 10 m motorized sailing outrigger canoe as a charter fishing boat. Wahoo, yellowfin tuna, and skipjack tuna are normally caught on light tackle (< 30 lb test) using standup rigs. Anglers participate in the offshore sportfishery as a secondary activity to the light tackle lagoon fishery for bonefish and giant trevally, which is the primary focus for these anglers. This fishery is tourist, and therefore, airline dependent. The abundance of the resources and close proximity to shore could make this industry profitable with proper marketing and more charter vessels.

4.3.4. Handlines - Handlines are used by subsistence fishers to catch bonefish, giant trevally and other lagoon and nearshore species. Much of the fishing effort is concentrated around the lagoons and ocean reef flats of the main villages of London, Tabakea, and Banana.

4.3.5. Dropline - This fishing practice involves multiple hooks on a weighted deep rig that is usually fished on the ocean side of the reef in water depths > 50 m but sometimes shallower. The major target species are snappers and groupers that are often exported, usually to Honolulu, through Kiritimati Marine Export Limited. Participants in this fishery and the trolling fishery use three different type vessels: 1) traditional paddle dugout canoes, 2) motorized skiffs, and 3) Tarawa Fisheries Designed motorized sailing canoes (10 m). Fishing activities are concentrated around the major population centers and off Cook Island. Fishing occurs around the entire atoll and is reported to improve the further one gets from the main villages.

A zone of no ciguatera poisoning is reported to occur from Benson Point (off Paris) to just past Vaskees Bay on the southwest end of the atoll. Dredging, filling, and other physical changes to habitats have been implicated as causes for some increases in ciguatera poisoning in a number of tropical areas (Carpenter and Maragos 1989). The channel entrance to London was dredged during WW II and the British Nuclear testing period in the late 1950's to a depth of ca. 15 feet. The reefs on the northern side of the channel, offshore from London and Tabakea, appear in poorer condition than those on the southern side past Paris. Dredging, and subsequent reef damage may partially explain the distribution of ciguatoxic fish around Kiritimati Island.

4.3.6. Trolling - Wahoo and tunas (yellowfin and skipjack) are the species taken primarily by trolling. Vessels are the same as described for the handline fishery. Trolling occurs around the entire atoll but is weather dependent. The southeast peninsula from Bay of Wrecks to Vaskess Bay is reported to have good fishing but is inaccessible at times due to swell and winds. Wahoo and tunas are some of the most important species sold to Kiritimati Marine Export Ltd.

4.3.7. Aquarium fish collecting - The aquarium fish fishery started in Tarawa in the early 1980s and moved to Kiritimati Island a few years later to take advantage of the air service to Honolulu and US mainland markets (Kamatie et al. 1995). In 1995 there were four companies exporting aquarium fish from Kiritimati: Tarawa Tropics, Willie Divers, Aveteba Marine, and Marine Beauties. Two additional companies have started operations within the past two years. Aquarium fish collecting occurs around the entire atoll but most of the effort occurs close to London, on the leeward side from the northwest point to the southwest point of the atoll. This area provided the quickest access and best conditions for collectors to operate. Collecting is also reported to occur in Vaskess Bay and off the village of Banana. We observed 3 to 5 boats with anywhere from 4 to 6 aquarium fish divers onboard during every day of our trip. Due to intensive harvest pressure divers now report having to go deeper and farther from port to collect.

Table 11 shows the top aquarium fish exports from Kiritimati Island by group for the four island exporters combined for the years 1994 and 1995. Clearly, angelfishes were the dominant group of export aquarium fish in 1994 and 1995. The most commonly collected angelfishes were: flame angelfishes (*Centropyge loriculus*), lemonpeel angelfishes (*C. flavissimus*), Goldflake angelfishes (*Apolemichthys xanthopunctatus*), Griffis angelfish (*A. griffisi*) and emperor angelfish (*Pomacanthus imperator*) (P. Wilder, pers. com.). Tangs were the second most common group in 1994 and third in 1995. This group of surgeonfishes included blue tangs (*Paracanthurus hepatus*) and brown tang (*Zebrasoma scopas*). The blue tang is now reported to be less frequently observed in intensely fished sites. One species of special interest is the endemic deep water butterflyfish (*Chaetodon declivis wilderi*). This is a subspecies of *C. declivis* found in other areas of the Indo-Pacific and is a highly value aquarium species due to its unique color pattern.

Table 11. Summary of aquarium fish exports (number of individuals) from Kiritimati Island (adapted from Kamatie et al. 1995). Groups are ordered by 1994 totals.

Group name	1994	1995
Angelfishes	68709	48275
Tangs	7028	5636
Damselfishes	3914	3424
Wrasses	1210	1770
Misc.	1059	7533
Butterflyfishes	507	409
Surgeonfishes	425	158
Triggerfishes	372	80
Groupers	298	169
Pufferfishes	161	194
Total	83683	67648
Value AU$	417796	325973

Kiritimati Island is one of the major aquarium fish importers into Hawaii. In 1991 Kiribati, exclusively Kiritimati Island, accounted for < 5% of all imported aquarium fish into Hawaii (H.R. 257 1995). By 1994 this number had climbed to 79% (Table 12).

Table 12. Total aquarium fish imports to Hawaii from 1991 to 1994. Percentage of imports originating from Kiribati.

Year	Total imports	Percent of imports from Kiribati
1991	566,746	< 5
1992	525,443	45
1993	564,735	69
1994	639,595	79

Within the past few years at least two divers have died and a number have been permanently injured due to aquarium fish collecting dive related accidents. Many of the highly valued angelfishes and butterflyfishes are found in deeper water or have become scarce in shallower depths. This has forced collectors to conduct repetitive dives at unsafe depths with few safety precautions, resulting in these dive related injuries.

Tarawa Tropicals has a shore-based holding facility with adequate capacity to hold fish for several weeks and uses proper biological filtration. All other exporters maintain their catch in offshore holding areas. Individual fish are placed in perforated plastic margarine-sized containers. These containers are placed in a gunny sack or five gallon plastic bucket and attached to a buoy. These fishes are in less than optimal condition if held in this manner for several weeks. Additionally, storms cause damage to the holding structures that lead to excessive fish mortality. This results in a waste of resources as well as the labor involved in collecting more fish.

4.3.8 Eel traps - These are small woven traps made of plant material and are used to collect eels on a limited use basis. The traps were usually deployed on shallow reefs flats from Southwest Point north to London. The area just to the north of Cook Island was identified as an area were eel traps were also used. Eels are often collected for special occasions and are used for subsistence only.

4.3.9 Cast nets - Cast nets are used on shallow reefs flats around the island with the heaviest concentration of effort occurring near the three main villages. The primary target species are mullet, surgeonfishes, and other reef fishes. Small mullet are often targeted as bait and used in the trolling and handline fisheries. It was estimated that ca. 25% of the fishermen own and use castnets on a somewhat regular basis.

4.3.10. Spearfishing - This appears to be a minor fishing practice that is concentrated on the reefs fronting London, Tabakea, Banana, and Poland. Parrotfishes, surgeonfishes, and groupers are the major target species in what is mostly a subsistence fishery.

4.3.11. Beche-de-Mer - Gleaning the shallow sand flats for Beche-de-Mer or sea cucumbers (Holothuridae) was previously an important commercial fishing activity on Kiritimati for export to China. The fishery was initially centered in the lagoon, close to the villages, but soon spread throughout the lagoon as fishing pressure increased and sea cucumbers became more scarce. The shallow reef flats around the island were also harvested once stocks in the lagoon became depleted. At present, stocks are probably too low to support a sustainable export fishery.

4.3.12. Shark fishery - At one time sharks were harvested intensely throughout the island. Blacktip reef sharks (*Carcharhinus melanopterus*) were caught in gill nets and on handlines in the lagoon and shallow reef flats. Whitetips (*Triaenodon obesus*), grey reefs (*C. amblyrhynchos*), and others were harvested using heavy shark rigs and chum off the reef edge around the island. Shark finning was a common practice with dead sharks without fins reported to have washed up on shore in a number of places. The market appeared to have peaked 3 to 5 years ago with most of the fins being exported to China. No market was established for the meat and little was consumed locally. The southeast point of the island is currently reported to have a number of large sharks due to its inaccessibility and limited fishing pressure.

4.3.13. *Eucheuma* - The seaweed *Eucheuma* is grown in shallow water (< 3 m) in the lagoon adjacent to London and near Paris, off Benson Point. Villagers harvest the algae, and after drying, the product is exported to Denmark where it is processed for various commercial uses.

4.3.14. Blacklip pearl oyster fishery - A South Pacific Commission study conducted in 1989 found that pearl oysters were in low natural abundance and there was no commercial potential for harvest from wild stocks (Sime et al. 1990). As a result of these findings, a five year ban on harvest was enacted and an agreement was made with Black Pearl Inc., a Kona, Hawaii based hatchery research facility, to provide spat for growout. The current status of this fishery remains unknown.

4.3.15. Lobsters - Lobsters, mainly spiny (*Panulirus* spp.) but also slippers (Scyllaridae) are reported to occur around the island except in the lagoon. They are normally taken while free diving but SCUBA is also used off the reef edge. The abundance of lobsters has declined around the main villages and nearby offshore waters but are still reportedly common along the southeast portion of the island. A processing plant was previously in existence in Banana but Kiritimati Marine Export Ltd. now handles all lobsters for export. This fishery is dependent on reliable air transport to export markets.

4.3.16. Coconut crabs - Coconut crabs (ca. 30) were reportedly brought from Fannning Island in 1989-90. A few in the 1/2 pound range have been caught near Banana Village. It is not know to what extent these crabs have established reproductive populations on the island.

4.4. Large-Scale Visual Fish Assessments

Random swims were conducted at each dive site to obtain information on species numbers and abundance for all visually observable fishes. Each dive was approximately one hour in duration and was limited to 100 ft maximum depth, with the majority of the dives spent shallower than 60 feet. Species identification was facilitated by published literature (Randall et al. 1990, Myers 1991, Kuiter 1992) and unpublished records from the Bishop Museum, Honolulu (Pyle, unpublished data). The latter show a total of 413 species of marine fishes recorded from Kiritimati Island. There are a number of reasons to account for the smaller number of species observed during this investigation (235) including limited sample size, depth of sampling, time of day, and the cryptic nature of some species. Several previous studies have used ichtyocides to collect small, cryptic fishes that reside within the reef framework as well as a number of dives to depths > 50 m.

4.4.1. **Dive site surveys and associated fish fauna:**

Site 1 - Aeon Field (2 May) - This wave exposed shallow reef flat (< 2 m) extends out ca. 50 m to the reef crest. It was not possible to swim past the reef crest due to high surf on this day but numerous small (1-2 m) blacktip sharks were observed cruising the reef flat. Schools of small surgeonfishes were conspicuous members of the fish assemblage at this site.

Site 2 - Bay of Wrecks (2 May) - This ocean reef slope had large fields of dead standing *Acropora*. The shallow surge channels harbored parrotfish, red snapper (*L. bohar*) and small surgeonfishes as well as the ubiquitous damselfishes and wrasses. The deep slope was dominated by large schools of planktivores, mainly fusiliers, anthias, and chromis. Large black jacks (*Caranx lugubris*), red snappers, parrotfish, and milkfish were observed along the reef edge down to 100.'

Site 3 - Navy Dump/ North London (3 May) - This shallow (10 to 25 feet) spur and groove habitat was heavily scoured by wave action and contained large sandy areas. This low relief habitat was numerically dominated by small wrasses and damselfishes, while surgeonfishes were the dominant group by biomass.

Sites 4 & 5 - Cochran Pass (3 May) - A shallow (20') reef pass between Cochran Reef and Bridges Point consisted of a disturbed or degraded coral reef community, most likely as a result of previous dredging activities. Large schools of surgeonfishes and individual parrotfish roamed extensively over this rubble and algae habitat. Schools of juvenile snappers (*Lutjanus kasmira, L. gibbus*, and *L. fulvus*) and juvenile parrotfishes were also observed in abundance. Large Titan triggerfish (*Balistoides viridescens*) and yellowmargin triggerfish (*Pseudobalistes flavimarginatus*) 50-75 cm in length were observed building nests on the channel floor. Nest-guarding females were vary aggressive towards the presence of divers. A manta ray was observed being cleaned on the outgoing tide.

Site 6 - Wilkes Lagoon (3 May) - A deteriorated coral reef in shallow water (11') near the access channel to London Village. Low fish numbers and diversity were observed at this site with small wrasses and damselfishes being the dominant groups present.

Sites 7 & 14 - Poland Caves (4 May & 7 May) - An ocean reef slope with high coral and fish abundance and diversity. Several large schools (>100 individuals per school) of the paddletail snapper (*Lutjanus gibbus*) were observed along the deep reef slope (60 - 90 feet) sometimes mixed with the bigeye emperor (*Monotaxis grandoculus*). Along this dropoff were also found a school of ca. 30 large (50 to 75 cm) black jacks (*Caranx lugubris*). Marbled groupers (*Epinephelus polyphekadion*) up to 75 cm and humphead wrasses (*Chelinus undulatus*) as large as 1 m appeared very curious and had obviously not previously been targeted by spearfishermen. The shallow (ca. 30 feet) spur and groove habitat was dominated numerically by small damselfishes and in biomass by surgeonfishes. Several pelagic species were observed along the reef sand interface at ca. 100 ft. A small school of yellowfin tuna (*Thunnus albacares*) (35-50 lb. each) and several dogtooth tuna (*Gymnosarda unicolor*) were observed at this location.

Site 8 - Viewfinder Reef (4 May) - A well-developed ocean reef with high coral cover but low structural complexity. Small planktivores, mainly damselfishes and anthias, were the most conspicuous members of the fish assemblage here. Small groupers (*Epinephelus fasciatus, E. urodeta*, and *E. argus*) were abundant within the framework of the reef.

Site 9 - Cook Pass (4 May) - Rich coral and fish assemblages along the outside and edge of the southern pass between Cook Island and Benson Point. At the deeper dropoff (~ 90') various species of anthias, redtooth triggerfish (*Odonus niger*), and other planktivores were common. A large school of ca. 50 barracuda (*Sphyraena genie*) were observed and reported to be resident at this site. Several large humphead wrasses were also observed along the edge. Along the reef slope schools of paddletail snappers and surgeonfishes were common. Towards the eastern end of the channel in ca. 30 feet of water several species of groupers were observed aggregating in fairly large numbers. The two dominant species observed were *Epinephelus polyphekadion* and *E. macrospilos*.

Site 10 - London Dock (4 May) - Disturbed dock and basin environment consisting of sandy bottom and seaweed. The small puffer (*Arthron hispidus*) was the only fish observed in this habitat.

Site 11 - South Pacific Airways Hotel-wharf site (ruins) (5 May) - Old rock jetty with associated shallow sand flats. Bluegreen algal mats floating and on attached to the bottom were dominant components of the biota. The pufferfish (*A. hispidus*) and small (4-6 cm) convict tang (*Acanthurus triostegus*) were common fishes seen along the jetty. Numerous schools (20-50 individuals) of small mullet (10-15 cm) and needlefish (*Platybelone argalus platyura*) were observed throughout the lagoon. Bonefish (20-40 cm) were observed in small schools just offshore from the jetty.

Site 12 - Inner Cook Pass (5 May) - This shallow pass terminated in a dead end channel with a rich coral community present. Small damselfishes, wrasses, and anthias were the dominant member of this fish assemblage. A number of groupers were observed exhibiting mating behavior and several were observed with distended stomachs. The dominant species observed were *Epinephelus polyphekadion* and *E. macrospilos*. Two *E. polyphekadion* were speared and upon macroscopic inspection, one female was observed to have developing gonads.

Site 13 - Boating Lagoon (5 May) - A disturbed inner lagoon sand flat with some rubble. Asphalt present may be the remains of an old causeway. Sea cucumbers dominated the limited fauna present at this site. Several small blacktip sharks were observed in the shallows (< 1 m).

Site 15 - Ocean Pinnacles/Grapple Reef (7 May) - A series of pinnacles offshore from Cook Island. The tops of the seaward pinnacles began at 60' and extended down a tallas slope to ca. 100' with rich coral cover on the tops of the pinnacles. This reef was extremely rich in planktivorous fishes, probably due to its proximity to the channel that receives nutrients from the lagoon on outgoing tides, an increased plankton abundance from eddies formed on the lee side of Cook Island, and localized upwelling in this area. Damselfishes (*Chromis acares* and *C. margaritifer*); surgeonfishes (*Acanthurus xanthopterus* and *A. thompsoni*); blue fusilier (*Caesio teres*); red tooth triggerfish (*Odonus niger*), and soldierfishes (*Myripristis* spp.) were dominant members of the planktivorous fish assemblage. Schools of snappers (*Lutjanus kasmira* and *L. gibbus*) and emperors (*Gnathodentex aurolineatus*) were abundant along the reef edge.

Site 16 - Cook Lagoon Reef (7 May) - Well-developed coral communities on the shallow lagoon flat provided good habitat for many small reef fishes. Wrasses, damselfishes, and butterflyfishes made up the most conspicuous members of the adult fish assemblage. This shallow, low relief area provided excellent habitat for juvenile parrotfishes and small groupers. As was the case in Cochran Pass, large Titan triggerfish (*Balistoides viridescens*) and yellowmargin triggerfish (*Pseudobalistes flavimarginatus*) 50-75 cm in length were observed building nests on the channel floor. Nest-guarding females were very aggressive towards the presence of divers.

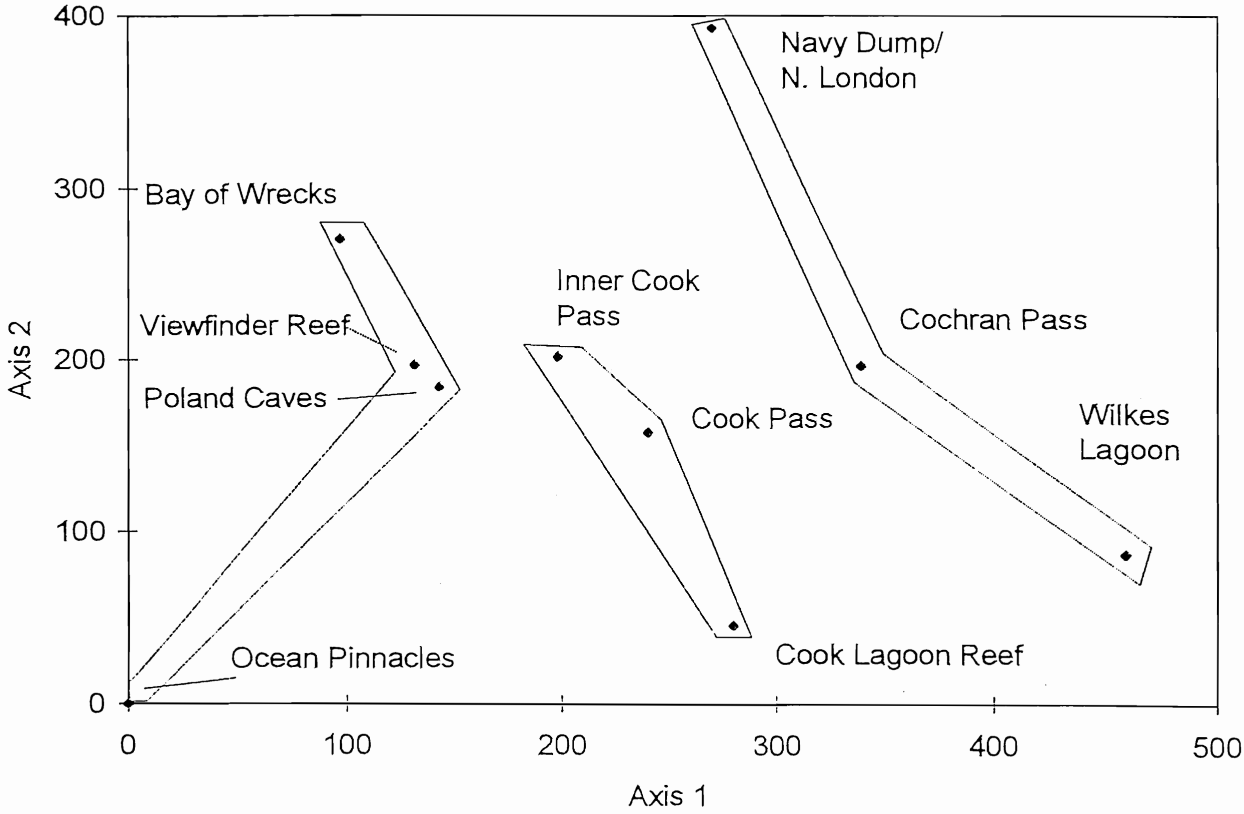
The greatest number of species was found at the ocean reefs with deep reef slopes and high habitat structural complexity (Table 13). These sites included Poland Caves (sites 7/14), Cook Pass (site 9), and Bay of Wrecks (site 2). Wilkes Lagoon (site 6) was a degraded reef with low coral cover and habitat complexity and had the lowest number of species observed at any site, excluding London Wharf.

Table 13. Total number of families and species observed during visual fish surveys. Site numbers in parentheses.

Location	Number of families	Number of species
Poland Caves (7/14)	25	129
Cook Pass (9)	21	122
Bay of Wrecks (2)	20	111
Cook Lagoon Reef (16)	17	97
Ocean Pinnacles/ Grapple Reef (15)	23	92
Viewfinder Reef (8)	19	84
Cochran Pass (4/5)	23	80
Navy Dump/N. London (3)	18	78
Inner Cook Pass (12)	13	71
Wilkes Lagoon (6)	13	27
Total	37	230

4.4.2. **DCA analysis of large-scale visual fish surveys** - Detrended correspondence analysis (DCA) of fish census data was used to identify clusters of similar sites in ordination space. This type of ordination results in an arrangement of samples of species in a low-dimensional space so that similar samples are in close proximity to one another (Gauch 1982). In DCA, habitat variables do not influence the ordination; rather, clusters of stations are created based strictly on similarity of assemblages of species (Greenfield and Johnson 1990). Sites clustered into three distinct groups based on DCA. Bay of Wrecks, Viewfinder Reef, Poland Caves, and Ocean Pinnacles were all ocean sites with deep reef slopes, high coral cover, high fish species richness, and an abundance of planktivorous fishes. These sites formed a cluster on the left hand side of Figure 1 and represent the most "pristine" sites surveyed. The three sites associated with Cook Pass had similar fish assemblages and formed another cluster in the center of the figure. These sites were shallower, with no or a poorly defined reef slope, and had intermediate levels of fish abundance and diversity. The cluster on the right hand side of Figure 1 consisted of Wilkes Lagoon, Cochran Pass, and the Navy Dump/N. London sites. These sites were typified by being shallow, with low coral cover and a low number of fish species. These sites had the poorest habitat and fish fauna of all sites surveyed, excluding London Wharf.

Figure 1. Detrended correspondence analysis of sites surveyed around Kiritimati Island. Axes 1 and 2 represent linear combinations of species based on correlated patterns of abundance. The distance between sites is proportional to the dissimilarity of fish species composition and relative abundance.



4.4.3. Species composition for large-scale visual fish surveys - A total of 235 species from 42 families was observed during all surveys at Kiritimati Island (Appendix II). Wrasses were the most well represented family with 37 species occurring, followed by surgeonfishes, 25 species, and damselfishes, 20 species (Table 14). The three most abundant species observed during the survey were all small damselfishes (Table 15). These species were dominant in almost all locations and occurred in 90% of all areas surveyed. Of the 10 most commonly observed species, larger fisheries-related species included the paddletail snapper, flagtail grouper, peacock grouper, and banded goatfish, respectively.

Table 14. Number of species by family for the twenty most abundant families observed during reef fish surveys.

Family	Common name	Number of species
Labridae	Wrasses	37
Acanthuridae	Surgeonfishes	25
Pomacentridae	Damselfishes	20
Chaetodontidae	Butterflyfishes	19
Serranidae	Groupers	19
Scaridae	Parrotfishes	14
Balistidae	Triggerfishes	9
Holocentridae	Squirrelfishes	9
Carangidae	Jacks	8
Mullidae	Goatfishes	8
Tetraodontidae	Pufferfishes	7
Lutjanidae	Snappers	6
Cirrhitidae	Hawkfishes	5
Caesionidae	Fusiliers	4
Lethrinidae	Emperorfishes	4
Pomacanthidae	Angelfishes	4
Carcharhinidae	Requiem sharks	3
Microdesmidae	Dartfishes	3
Apogonidae	Cardinalfishes	2
Blenniidae	Blennies	2

Table 15. The twenty most abundant species observed during dives. Numbers represent abundance estimates per dive: 1 = < 5, 2 = 5-20, 3 = 20-50, 4 = 50-100, 5 = > 100. Freq. = percentage of sites (n = 10) in which species was observed. IRD = index of relative dominance (mean x freq.). Species are ordered by IRD.

Species	Bay of Wrecks	Ocean Pinnacles/ Grapple Reef	Inner Cook Pass	View-finder Reef	Navy Dump/ N. London	Wilkes Lagoon	Cochran Pass	Poland Caves	Cook Pass	Cook Lagoon Reef	Mean	Freq. %	IRD
Chromis margaritifer Bicolor chromis	5	4	5	5	5	0	5	5	5	5	4.4	90	3.96
Chromis vanderbilti Vanderbilt's chromis	5	3	5	5	5	0	5	5	5	5	4.3	90	3.87
Plectroglyphidodon dickii Dick's damsel	4	4	4	4	4	0	5	4	4	4	3.7	90	3.33
Lutjanus gibbus Paddletail snapper	4	4	3	4	0	3	5	5	5	2	3.5	90	3.15
Thalassoma amblycephalus Twotone wrasse	5	0	5	5	4	0	5	5	3	5	3.7	80	2.96
Cephalopholis urodeta Flagtail grouper	3	3	3	3	3	0	3	3	3	3	2.7	90	2.43
Cephalopholis argus Peacock grouper	3	3	3	3	2	0	3	3	3	3	2.6	90	2.34
Cirrhitichthys oxycephalus Pixy hawkfish	4	0	1	3	3	4	4	2	3	2	2.6	90	2.34
Pseudanthias spp. Fairy basslets	0	4	5	5	4	0	4	4	5	0	3.1	70	2.17
Parupeneus multifasciatus Banded goatfish	0	3	3	2	3	2	3	3	2	3	2.4	90	2.16
Ctenochaetus striatus Striped bristletooth	4	2	3	3	5	0	0	4	3	3	2.7	80	2.16
Chlorurus sordidus Bullethead parrotfish	3	3	2	3	1	0	3	3	2	3	2.3	90	2.07
Stethojulis bandanensis Red-shoulder wrasse	4	0	3	2	4	0	4	2	2	4	2.5	80	2.00
Ctenochaetus marginatus Blue-spotted bristletooth	4	2	4	3	4	0	0	3	3	2	2.5	80	2.00
Paracirrhites arcatus Arc-eyed hawkfish	2	3	2	3	2	0	2	3	3	2	2.2	90	1.98
Lutjanus bohar Red snapper	3	4	2	2	0	0	3	3	3	4	2.4	80	1.92
Halichoeres hortulanus Checkerboard wrasse	3	2	1	2	4	0	2	2	2	3	2.1	90	1.89
Chaetodon ephippium Saddled butterflyfish	3	2	1	0	3	2	3	2	1	2	1.9	90	1.71
Centropyge flavissimus Lemonpeel angelfish	3	0	3	2	1	2	2	2	1	3	1.9	90	1.71
Paracirrhites forsteri Freckled hawkfish	2	3	3	3	2	0	0	3	2	3	2.1	80	1.68

4.5. Quantitative Visual Transects

4.5.1. Transect fish assemblage characteristics - Quantitative visual transects (50 x 5 m) were conducted at five locations with a total of 124 species observed on these transects. Fish ensemble characteristics from the transects included total number of species, total number of individuals, species diversity and evenness. Diversity measures take into account two factors: the number of species, and evenness, that is how equally abundant the species are (Magurran 1988). High evenness, occurs when species are evenly abundant, and is equated with high diversity. Habitat degradation can lead to declines in diversity and evenness over time. The Bay of Wrecks, Inner Cook Pass, and Viewfinder Reef had the highest numbers of species present while Wilkes Lagoon had the lowest (Table 16). The Bay of Wrecks site was dominated by a few species of planktivores (bluestreak and yellowback fusiliers, bicolor chromis, and anthias). This assemblage structure resulted in a large number of individuals (2258) but low diversity and evenness. The Navy Dump/N. London site had high diversity and evenness with no species being dominant.

Table 16. Ensemble characteristics for quantitative visual fish transects conducted at five sites on Kiritimati Island.

	Number of species	Number of individuals	Diversity	Evenness
Bay of Wrecks	53	2258	1.968	0.496
Inner Cook Pass	53	543	2.798	0.705
Viewfinder Reef	52	782	2.501	0.633
Navy Dump/ N. London	42	550	3.056	0.818
Wilkes Lagoon	30	338	2.369	0.697

4.5.2. Species composition - The frequency of occurrence, relative abundance, and index of relative dominance (frequency of occurrence x relative abundance) for the 20 most common fish species are shown in Table 17. Five of the ten most common species were damselfishes, followed by groupers (anthias) with two, and fusiliers with two, also. Most of these species were planktivorous and numerically dominant at most sites.

Table 17. Number of individuals for the 20 most common species observed on visual fish transects (50 x 5 m). Freq. = the percent occurrence of each species at all locations (N = 5). IRD = index of relative dominance (number of individuals x frequency of occurrence). Species are ordered by IRD.

Location	Bay of Wrecks (2)	Viewfinder Reef (8)	Navy Dump/N. London (3)	Wilkes Lagoon (6)	Inner Cook Pass (12)	Total	Freq. %	IRD
Chromis margaritifer Bicolor chromis	500	85	23	0	140	748	80	2992
Chromis vanderbilti Vanderbilt's chromis	0	250	68	0	90	408	60	1224
Pseudanthias bartellorum Bartlett's fairy basslet	300	10	0	0	30	340	60	1020
Chromis acares Midget chromis	170	10	0	0	60	240	60	720
Caesio teres Yellowback fusilier	600	0	0	0	0	600	20	600
Pterocaesio tile Bluestreak fusilier	500	0	0	0	0	500	20	500
Stegastes aureus Golden damsel	8	18	71	0	8	105	80	420
Anthias spp. Fairy basslets	0	180	0	0	20	200	40	400
Plectroglyphidodon dickii Dick's damsel	7	22	14	0	20	63	80	252
Thalassoma amblycephalus Twotone wrasse	0	21	26	0	26	73	60	219
Halichoeres ornatissimus Ornate wrasse	1	18	30	0	4	53	80	212
Cirrhitichthys oxycephalus Pixy hawkfish	0	7	20	29	0	56	60	168
Stethojulis bandanensis Red-shoulder wrasse	0	1	12	15	4	32	80	128
Ctenochaetus marginatus Blue-spotted bristletooth	1	3	15	0	10	29	80	116
Thalassoma quinquevittatum Five-stripe surge wrasse	0	0	50	0	4	54	40	108
Halichoeres hortulanus Checkerboard wrasse	0	3	30	0	1	34	60	102
Acanthurus nigricans Whitecheek surgeonfish	14	3	0	0	12	29	60	87
Ctenochaetus striatus Striped bristletooth	3	0	10	0	15	28	60	84
Cephalopholis urodeta Flagtail grouper	0	15	6	0	6	27	60	81
Pomacentrus coelestis Neon damsel	0	0	0	80	0	80	20	80

5. Discussion

5.1. Sportfishing

Light tackle sportfishing for bonefish and giant trevally is one of the most important industries on Kiritimati Island. During periods of regular air service, tourists engaging in light tackle sportfishing occupy a number of rooms in the Captain Cook Hotel, employ local fishing guides, and support a number of ancillary industries that provide employment and revenue to the island. There are currently concerns over conflicts between subsistence fishers and the sportfishing industry. Gillnets set on productive fishing flats do not allow access to recreational anglers. The number and size of bonefish have also reported to have declined over time, possibly partially as a result of intensive subsistence harvest. Paris Flats is a major spawning area for bonefish; *Eucheuma* culture in this location may potentially inhibit reproductive movement patterns and reduce spawning success. Increased population pressure resulting from construction and operation of the space shuttle landing site project will undoubtedly exacerbate any existing problems with the fishery. Any channel dredging could also adversely effect bonefish habitat. Improved roads and a jetty near Poland would obviously assist fishermen in that area but could potentially affect light tackle sportfishing for bonefish and giant trevallys.

5.2. Subsistence gillnetting

Gillnetting, primarily for milkfish, is the major subsistence fishing activity on Kiritimati. Fishermen have reported declines in numbers and sizes of catch, particularly near population centers. Conflicts with sportfishing interests and overfishing will only increase with increased population pressures and declining resources.

5.3. Export fisheries

Kiritimati Marine Export Ltd. is the only buyer and exporter of marine products from the island. Pelagic species such as wahoo and tunas as well as snappers and groupers are the major species exported. These stocks are currently in good condition, particularly the pelagic resources. Proper management along with reliable air service and stable markets could result in a sustainable and profitable industry. Mullet and milkfish have been exported in large numbers in the past and these stocks may be reaching maximum levels of exploitation.

5.4. Aquarium fish fishery

This fishery has grown substantially in the past five years and now appears to be overcapitalized. Fishers report declines in certain valuable species and divers must fish deeper and longer to obtain profitable catches. Poor conservation practices have resulted in a more aggressive approach to harvest. A number of recent fatalities and injuries has raised concerns about the safety and training of participants in this fishery.

5.5. Offshore sportfishng and recreational diving

These industries currently are limited by facilities and the tourist market. Pelagic fisheries and coral reef resources are currently very healthy and the associated industries have the potential to expand with reasonable management.

6. CONCLUSIONS

Major impacts from this proposed project would be the renovation of the London dock, dredging of channels, and construction of new docks in various areas. Minor dredging and renovations to the current dock would probably have short-term impacts to the marine fauna and not significantly modify the long-term dynamics of these systems. Dredging to allow deep draft vessels access to the dock would constitute a major dredging operation that would most likely disrupt the nearshore and lagoonal marine environment for some time. Channel dredging in the Paris area has the potential to disrupt movement and spawning of bonefish as well as potentially damaging the healthy shallow coral reef system associated with Cook Pass.

Increased population as a result of the construction and operation of the space shuttle landing site and associated facilites could potentially have an impact on the marine resources of the atoll. As a result of population growth, Tarawa lagoon has suffered severe overfishing with a notably skewed sex ratio and decline in the size of bonefish (Beets 1994). Overfishing of bonefish has been suggested in areas close to London, Tabakea, and Banana villages. Laborers have been imported in a number of Pacific Islands to supplement the need for workers at various levels of expertise. Many imported laborers come from locations that often have severely overexploited resources and no history of resource tenure. These laborers often can change the dynamics of the local fishery from one of selective and sustainable harvest to complete ecosystem harvest. Maintenance of traditional harvest methods and improvements to the current fisheries management system should be encouraged.

7. RECOMMENDATIONS

7.1. Recommendations associated with potential project impacts

7.1.1. **Minimize dredging activities** - Improvements to the existing dock and a tug and barge system appear to be the option that will provide the least amount of environmental impact to the island while still serving the purposes of the project. The area adjacent to the existing dock lacks significant marine life and dredging in this area would have minimal impact. Cochran Channel is currently ca. 15 feet deep. Dredging to allow deep-draft vessels (>30 feet) access to the wharf does not seem feasible and would require substantial dredging that would likely have a major negative impact on the associated marine community.

7.1.2. **Shallow draft docks in the lagoon** - Small boats would most likely shuttle passengers between Cassidy Airport (old boating lagoon site), London wharf, and the ruins of the wharf at the South Pacific Airways hotel site near Poland. These sites are all associated with soft bottom marine communities that are low in diversity and abundance. Any dock construction at these sites would not adversely impact the local environment and would possibly be beneficial to small boat operations involved in sportfishing, diving, and subsistence fishing. Channel construction for these routes should attempt to follow natural channels and limit the amount of dredging. There are highly diverse fish and coral communities associated with the shallow lagoon inshore from Cook Pass. Dredging operations in this area should attempt to minimize coral damage and disruption to this habitat.

7.1.3. **Environmental monitoring program** - An environmental monitoring program should be conducted prior to, during, and after any construction activities. This should include assessment of marine fauna and flora as well as water quality monitoring. Local environmental personnel should be trained to carry out all aspects of this monitoring. Potential impact sites, as well as reference control sites, should be identified prior to the construction phase of the project.. Permanent transects should be established in a number of locations at these sites to determine abundances of important resources during all phases of the project. A stratified random sampling design should be developed to conduct these surveys. Sample size optimization should be conducted to determine the proper number of samples needed for the statistical power to detect changes in abundance of target resources. A coordinating scientist could train local environmental personnel and periodic assist in monitoring.

7.1.4. **Focus groups and scoping meetings** - Meetings and workshops with all stakeholders should be continued to air concerns and suggestions that may be associated with the project as it is implemented. This will allow island-wide participation in the project and help to establish an interactive management strategy that will benefit all members of the community

7.2. Recommendations for sustainable marine resource use

7.2.1. **Improve current fisheries management regulations** - The subsistence gillnet fishery for milkfish and other species has declined in recent years, particularly near population centers. Efforts should be made to resolve user conflicts between subsistence fishers and recreational sportfishers. This could involve closed areas or limited entry to either or both fisheries. Sportfishing guides have already set a voluntary limit of 30 anglers per day. Spawning areas and seasons for important resource species should be identified and possibly closed to improve reproductive success. Increased harvest and canning of milkfish for sale to Tarawa has recently been proposed. In order for this harvest to be sustainable, a better understanding of the population structure of the species and fisheries yields will be necessary.

7.2.1. **Recommended closed areas** - Cook Island is currently a wildlife reserve and possesses large colonies of nesting seabirds (Jones 1997). It has been proposed that the adjacent marine habitat around Cook Island also be included as a reserve or sanctuary. The shallow reefs around Cook Island along with the unique offshore ocean pinnacles offer healthy reef environments with valuable marine resources. Any effort to establish a reserve area or restrict access to this area should be made with community involvement and recommendations to ensure proper siting and compliance to any potential refuge.

Some fishing guides have advocated the closure of the area of Paris Flats and Texas Flats to protect bonefish spawning sites. Suggestions from these individuals include prohibition of seaweed culture, diving and snorkeling activities and restrictions on speed and access of boats.

7.2.2. **Live fish fishery** - In recent years, a live reef food fish trade has developed for the "ultimate in fresh fish": those selected from restaurant aquaria only minutes before eating (Erdmann and Pet-Soede 1996). These fish are highly prized in Hong Kong, Singapore, Taiwan, mainland China, and other Chinese population centers. The target species include groupers and humphead wrasse. These fish often receive prices 400-800% higher than identical dead fish in Hong Kong (Johannes and Riepen 1995). The huge economic rewards associated with this fishery are attracting fishers and business persons in rapidly increasing numbers throughout the world. The fishery has already caused the decline in stocks of these prized species in the Philippines and Indonesia. Once stocks are exhausted, the industry continually moves on to new "virgin" locations. The fishing practices usually include the use of sodium cyanide to stun large fish and the use of crow bars to break open reefs to capture these species. Collateral destruction of reefs as well as mortality of other reef species due to cyanide poisoning is a large problem in addition to the loss of target species. This fishery should not be allowed to become established in Kiritimati and the use of poisons should be banned from use for any type of harvest.

7.2.3. **Ornamental fish trade** - The number of aquarium fish export companies should be limited or even reduced to avoid additional overcapitalization and depletion of these resources. Divers should be SCUBA certified and trained to properly handle fish. Proper education and training will reduce diver accidents and help to establish a better conservation ethic. Offshore holding facilities can be destroyed during storms and result in high mortality of the catch as well as injuries to surviving fish. Efforts should be made to encourage shore-based holding facilities that will reduce fish mortality and improve the quality of the product. To avoid conflicts with recreational divers and to reduce anchor damage to coral reefs, permanent moorings could be established at popular dive sites. The use of moorings by ornamental fish collected could concentrate fishing effort at these locations and exacerbate local depletion of target species. Regulation of these moorings needs to be considered. Fish collectors and dive operators should work jointly to try to utilize different areas to reduce conflicts.

7.2.4. **Offshore sport fishing** - Effort should be made to expand and market the recreational sportfish fishery. These resources provide the opportunity for light tackle, catch-and-release, and trophy "big game" fishing. These resources are currently underutilized and if regulated properly, the recreational impact should allow for sustainable resource use.

7.2.5. **Offshore fisheries resources** - The pelagic and deepwater fisheries resources are currently harvested at modest levels. The major impediment to expansion is currently the availability of a stable market and reliable air transport. The deepwater bottomfish fishery should be regulated by limited entry since these types of fisheries have been known to have limited resource potential and have been overexploited in a number of Pacific islands in a relatively short period of time.

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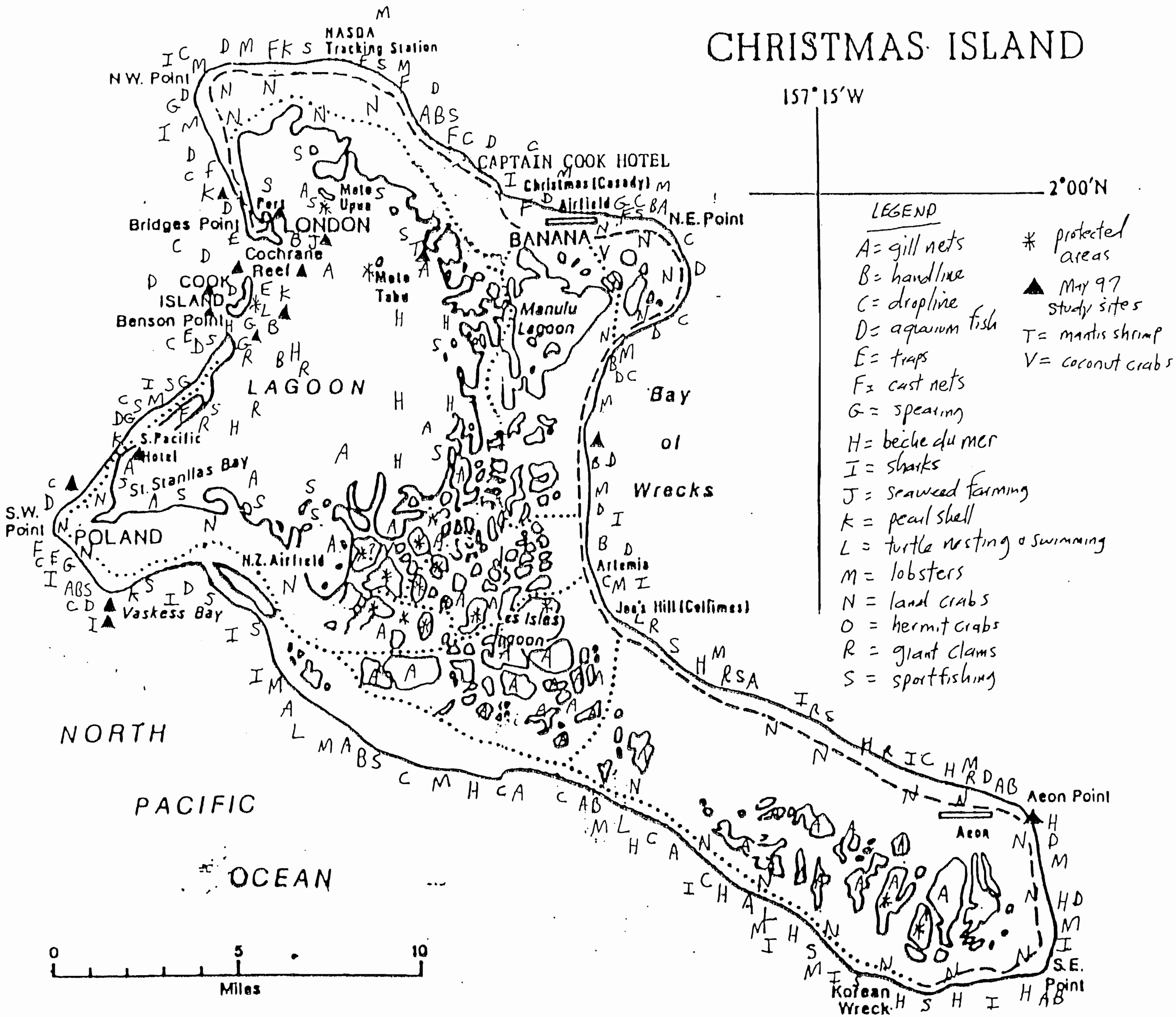

Appendix I. Map of Kiritimati Atoll showing major fishing locations by gear type and distribution of important marine resources (Maragos 1997).

Appendix II. Checklist of fish species observed at Kiritimati Island.

Family	Species
Carcharhinidae	*Carcharhinus amblyrhynchos*
	Carcharhinus melanopterus
	Triaenodon obesus
Myliobatidae	*Aetobatus narinari*
Mobulidae	*Manta birostris*
Albulidae	*Albula* spp.
Muraenidae	*Gymnothorax javanicus*
	Gymnothorax meleagris
Chanidae	*Chanos chanos*
Mugilidae	*Mullet spp.*
Belonidae	*Platybelone argalus platyura*
Hemiramphidae	*Hyporhamphus sp.*
Holocentridae	*Myripristis adusta*
	Myripristis amaena
	Myripristis berndti
	Myripristis kuntee
	Myripristis violacea
	Myripristis woodsi
	Sargocentron caudimaculatum
	Sargocentron spiniferum
	Sargocentron tiere
Aulostomidae	*Aulostomus chinensis*
Fistularidae	*Fistularia commersonii*
Scorpaenidae	*Pterois antennata*
	Sebastapistes cyanostigma
Caracanthidae	*Caracanthus unipinna*
Serranidae	*Cephalopholis argus*
	Cephalopholis miniata
	Cephalopholis sonnerati
	Cephalopholis urodeta
	Epinephelus fasciatus
	Epinephelus hexagonatus
	Epinephelus macrospilos
	Epinephelus melanostigma
	Epinephelus merra
	Epinephelus polyphekadion
	Epinephelus spilotoceps
	Gracila albomarginata
	Luzonichthys waitei
	Pseudanthias bartlettorum
	Pseudanthias cooperi
	Pseudanthias dispar
	Pseudanthias spp.

Appendix II. continued.

Family (cont.)	Species (cont.)
Serranidae	*Variola albimarginata*
	Variola louti
Priacanthidae	*Heteropriacanthus cruentatus*
	Priacanthus hanrur
Apogonidae	*Apogon angustatus*
	Apogon spp.
Malacanthidae	*Malacanthus brevirostris*
	Malacanthus latovittatus
Carangidae	*Caranx ferdau*
	Caranx ignobilis
	Caranx lugubris
	Caranx melampygus
	Caranx sexfasciatus
	Decapterus spp.
	Elagatis bipinnulata
	Scomberoides lysan
Lutjanidae	*Aphareus furcatus*
	Lutjanus bohar
	Lutjanus fulvus
	Lutjanus gibbus
	Lutjanus kasmira
	Lutjanus monostigma
Caesionidae	*Caesio teres*
	Pterocaesio lativittata
	Pterocaesio marri
	Pterocaesio tile
Lethrinidae	*Gnathodentex aurolineatus*
	Lethrinus olivaceus
	Lethrinus xanthochilus
	Monotaxis grandoculis
Mullidae	*Mulloidichthys flavolineatus*
	Mulloidichthys mimicus
	Mulloidichthys vanicolensis
	Parupeneus barberinus
	Parupeneus bifasciatus
	Parupeneus cyclostomus
	Parupeneus multifasciatus
	Parupeneus pleurostigma
Chaetodontidae	*Chaetodon auriga*
	Chaetodon bennetti
	Chaetodon ephippium
	Chaetodon kleinii
	Chaetodon lineolatus

Appendix II. Continued.

Family (cont.)	Species (cont.)
Chaetodontidae	*Chaetodon lunula*
	Chaetodon meyeri
	Chaetodon ornatissimus
	Chaetodon punctatofasciatus
	Chaetodon quadrimaculatus
	Chaetodon reticulatus
	Chaetodon trifascialis
	Chaetodon trifasciatus
	Chaetodon ulietensis
	Chaetodon unimaculatus
	Chaetodon vagabundus
	Forcipiger flavissimus
	Forcipiger longirostris
	Heniochus acuminatus
Pomacanthidae	*Apolemichthys xanthopunctatus*
	Centropyge flavissimus
	Centropyge loriculus
	Pomacanthus imperator
Cirrhitidae	*Cirrhitichthys oxycephalus*
	Cirrhitus pinnulatus
	Paracirrhites arcatus
	Paracirrhites forsteri
	Paracirrhites hemistictus
Pomacentridae	*Abudefduf sordidus*
	Chromis acares
	Chromis lepidolepis
	Chromis margaritifer
	Chromis vanderbilti
	Chromis viridis
	Chromis xanthura
	Dascyllus flavicaudus
	Dascyllus trimaculatus
	Lepidozygus tapeinosoma
	Plectroglyphidodon dickii
	Plectroglyphidodon imparipennis
	Plectroglyphidodon johnstonianus
	Plectroglyphidodon leucozona
	Plectroglyphidodon phoenixensis
	Pomacentrus coelestis
	Stegastes albifasciatus
	Stegastes aureus
	Stegastes fasciolatus
	Stegastes nigricans

Appendix II. Continued.

Family (cont.)	Species (cont.)
Labridae	*Anampses caeruleopunctatus*
	Anampses meleagrides
	Bodianus axillaris
	Bodianus loxozonus
	Cheilinus oxycephalus
	Cheilinus trilobatus
	Cheilinus undulatus
	Cheilinus unifasciatus
	Coris aygula
	Coris gaimard
	Epibulus insidiator
	Gomphosus varius
	Halichoeres hartzfeldi
	Halichoeres hortulanus
	Halichoeres margaritaceus
	Halichoeres melasmapomus
	Halichoeres ornatissimus
	Halichoeres trimaculatus
	Hemigymnus fasciatus
	Hologymnosus doliatus
	Labroides bicolor
	Labroides dimidiatus
	Labroides rubrolabiatus
	Labropsis xanthonota
	Macropharyngodon meleagris
	Novaculichthys taeniourus
	Pseudocheilinus hexataenia
	Pseudocheilinus octotaenia
	Pseudocoris sp.
	Pseudodax moluccanus
	Stethojulis bandanensis
	Thalassoma amblycephalus
	Thalassoma lunare
	Thalassoma lutescens
	Thalassoma purpureum
	Thalassoma quinquevittatum
	Thalassoma trilobatum
Scaridae	*Bolbometopon muricatum*
	Calotomus carolinus
	Chlorurus microrhinos
	Chlorurus sordidus
	Hipposcarus longiceps
	Scarus altipinnis

Appendix II. Continued.

Family (cont.)	Species (cont.)
	Scarus frenatus
Scaridae	*Scarus ghobban*
	Scarus globiceps
	Scarus niger
	Scarus oviceps
	Scarus psittacus
	Scarus rubroviolaceus
	Scarus tricolor
Pinguipedidae	*Parapercis sp.*
Blenniidae	*Cirripectes variolosus*
	Plagiotremus tapeinosoma
Gobiidae	*Gnatholepis scapulostigma*
	Valenciennea strigatus
Microdesmidae	*Ptereleotris evides*
	Ptereleotris heteroptera
	Ptereleotris zebra
Zanclidae	*Zanclus cornutus*
Acanthuridae	*Acanthurus achilles*
	Acanthurus blochii
	Acanthurus dussimieri
	Acanthurus guttatus
	Acanthurus leucocheilus
	Acanthurus lineatus
	Acanthurus maculiceps
	Acanthurus nigricauda
	Acanthurus nigrofuscus
	Acanthurus nigroris
	Acanthurus olivaceus
	Acanthurus pyroferus
	Acanthurus thompsoni
	Acanthurus triostegus
	Acanthurus xanthopterus
	Ctenochaetus binotatus
	Ctenochaetus hawaiiensis
	Ctenochaetus marginatus
	Ctenochaetus striatus
	Ctenochaetus strigosus
	Naso brevirostris
	Naso vlamingi
	Paracanthurus hepatus
	Zebrasoma scopas
	Zebrasoma veliferum
Sphyraenidae	*Sphyraena genie*

Appendix II. Continued.

Family (cont.)	Species (cont.)
Scombridae	*Gymnosarda unicolor*
	Thunnus albacares
Balistidae	*Balistapus undulatus*
	Balistoides viridescens
	Melichthys niger
	Melichthys vidua
	Odonus niger
	Pseudobalistes flavimarginatus
	Rhinecanthus aculeatus
	Sufflamen bursa
	Sufflamen chrysopterus
Monacanthidae	*Cantherhines dumerili*
Tetraodontidae	*Arothron hispidus*
	Arothron meleagris
	Arothron nigropunctatus
	Arothron stellatus
	Canthigaster amboinensis
	Canthigaster janthinoptera
	Canthigaster solandri
Diodontidae	*Diodon hystrix*

I-KIRIBATI NAMES AND SCIENTIFIC NAMES USED IN THE DOCUMENT

I-Kiribati Name	English Name	Scientific Name
PLANTS		
te arora	none	*Suriana maritima*
te boi	purslane	*Portulaca lutea*
te buka	Puka Tea	*Pisonia grandis*
te kaura	mallow	*Sida fallax*
te mao	Half-flower	*Scaevola taccada*
te maukinikin	Puncture Vine	*Tribulus cistoides*
te ni	Coconut Palm	*Cocos nucifera*
te ntanini	Beach Dodder	*Cassytha filiformis*
te ren	Beach Heliotrope	*Messerschmidia [Tournefortia] argentea*
te tarai	spurge	*Euphorbia hirta*
te uteute	grasses	*Cenchrus, Eleusine, Eragrostis, Lepturus*
te wao	spiderling	*Boerhavia repens*
none	Beggar-Ticks, Spanish Needles	*Bidens pilosa*
none	dodder	*Cuscuta campestris*
none	sedge	*Fimbristylis cymosa*
none	heliotrope	*Heliotropium anomalum*
none	Salt Marsh Fleabane	*Pluchea odorata*
none	Sea-Purslane	*Sesuvium portulacastrum*
BIRDS		
te bokikokiko	Line Islands Warbler	*Acrocephalus aequinoctialis*
te bwebwe ni marawa	Polynesian Storm-Petrel	*Nesofregetta fuliginosa*
te eitei	Great Frigatebird	*Fregata minor*
te eitei	Lesser Frigatebird	*Fregata ariel*
te io	Brown Noddy	*Anous stolidus*
te keeu	Sooty Tern	*Sterna fuscata*
te kibui	Brown Booby	*Sula leucogaster*
te kota	Red-footed Booby	*Sula sula*
te mangkiri	Black Noddy	*Anous minutus*
te matawa	Common Fairy-Tern	*Gygis alba*
te mouakena	Masked Booby	*Sula dactylatra*
te nna	Audubon's Shearwater	*Puffinus lherminieri*
te raurau	Blue-gray Noddy	*Procelsterna cerulea*
te ruru	Phoenix Petrel	*Pterodroma alba*
te taake	Red-tailed Tropicbird	*Phaethon rubricauda*
te tangiuoua	Wedge-tailed Shearwater	*Puffinus pacificus*
te tarangongo	Gray-backed Tern	*Sterna lunata*
te tinebu	Christmas [Island] Shearwater	*Puffinus nativitatis*

HOPE-X LANDING SITE
IMPACT ASSESSMENT FOR TERRESTRIAL BIOTA

ENVIRONMENTAL SETTING

Christmas Island is located 2° north of the equator, and is approximately half way between Hawaii (2,500 km to the north) and Tahiti (2,700 km to the south). It is one of eleven islands or reefs in the Line Islands, eight of which, including Christmas, are part of the Republic of Kiribati. Except for a few sand hills, all of Christmas Island lies below 3-4 m elevation. Because it is within the equatorial dry zone, rainfall is low and unpredictable with periods of extended drought followed by periods of moderate to heavy rainfall. Easterly tradewinds prevail throughout most of the year. Air temperature is very stable, with lows around 24° and highs around 30°. Normally water temperatures are also stable, but ocean warming sometimes occurs during periods of El Niño Southern Oscillations (ENSO), the periodic appearance of anomalous warm water in the eastern Pacific. Extreme ENSO events have greatly altered ocean temperatures, rainfall, and wind patterns in the short term, and an especially severe ENSO event in 1982-1983 caused the complete abandonment and subsequent failure of all seabird colonies on the island (Schreiber and Schreiber 1984).

Christmas (Kiritimati) Island, at 321 km^2, has the largest land area of any coral atoll in the world. Its interior is composed of lagoons roughly equal in size to its land area. The main, tidal lagoon comprises about half of the lagoon area. At its eastern and southeastern end are a network of well over a hundred supersaline, enclosed lagoons, many dotted with small islands — over 700 in all. Many of these islands provide predator-free nesting sites for seabirds. Three islands in the main lagoon, Cook Island, Motu Upua, and Motu Tabu, have large seabird colonies and have been designated protected areas.

Native vegetation is comprised of 18 native species and about 50 non-native species, the latter of which are confined mostly to villages and now abandoned military sites. Most plants are low-growing shrubs and annuals, with only one prevalent species reaching small tree size. The introduced coconut palm, however, because of its height, dominates the landscape in and near inhabited areas where it has been planted. The terrestrial fauna is dominated by seabirds, which comprise the largest collection of seabirds in the world. Only one resident landbird occurs on Christmas Island, and several species of migrant shorebirds spend their non-breeding season here. One formerly resident shorebird is now extinct. Other than birds, the only native terrestrial vertebrates are three species of lizards.

Christmas Island was uninhabited when discovered by Captain Cook on 24 December 1777, and not permanently settled until 1882. Presently, there are 3,271 people (1995 census) living on the island, primarily in four villages, London (Ronton), Tabakea, and Banana on the northern peninsula, and Poland at the base of the southern peninsula. Fifteen years ago, only 1,500 people inhabited the island; thus, the population has more than doubled during this short period, mostly from immigration.

Vessels with a draft of more than 2 m must anchor outside the lagoon on the reef and ship their cargo via barge to the wharf in London. Fuel is pumped ashore through a pipeline from the reef to a fuel farm just north of London on the reef side of the island. A network of paved and unpaved roads link most of the island, these having been constructed by the British during their nuclear weapons testing program in the mid-1950s. A paved road extends from London 82 km to South-east Point. Dirt tracks crisscross the island in a number of places. Because the island is flat and vegetation low and relatively sparse, almost any part of the island can be reached by four-wheel vehicle.

Christmas Island has been designated a wildlife sanctuary under Section 8 (1) of the country's Wildlife Conservation Oridnance, 1975, as amended in 1979 and 1989. Designated as closed areas within the wildlife sanctuary under Section 8 (3) of the ordinance are Cook Island, Motu Upua, Motu Tabu, North-west Point, and Ngaon te Taake (an area between the main lagoon and Central Lagoons). While wildlife sanctuaries and closed areas protect birds (in theory), they have no provision for protecting habitat. Recommendations have been made (MBA International 1997) to designate Christmas Island a Conservation Area, which does protect habitat, and expand the scope of closed areas to include Paris Peninsula, South-east Point, Frigatebird Island, and all Sooty Tern colonies during the duration of the nesting season (see Garnett 1983).

PROJECT DESCRIPTION

A full description of the proposed project (the preferred alternative) can be found in the main report. Below is a brief description with an emphasis placed on aspects of the project with the greatest likelihood of having impacts on terrestrial flora and fauna. Mitsubishi Corporation proposes to develop landing facilities on Christmas Island for its HOPE-X space shuttle which will be launched from Kagoshima, Japan. The Aeon Field landing strip near South-east Point (Figure 1), which is currently not in use, is proposed as the landing site, with nearby Dakota Field (Figure 1) as an alternative landing site. Ancillary facilities will be developed in conjunction with tracking and landing operations, and the wharf at London (Figure 2) will be improved to accommodate a barge large enough to transport the shuttle back to Japan.

METHODOLOGY

Terrestrial biological resource surveys were conducted from 3-20 May 1997 by Lee Jones, with the assistance of Wildlife Conservation Unit Chief Warden Katino Teebaki, Warden Aobure Teataata, and MESD Environment Unit Assistant Coordinator Andrew Teem. The localities surveyed and dates of these surveys are given in Table 1.

All sites affected by the proposed shuttle landing site and ancillary facilities, employee lodging, and supporting transportation network were surveyed. A major emphasis was placed on the large breeding colonies of seabirds, which are of international importance. Vegetation associations and relative abundances of plant species were also recorded at each site. The island's one resident land bird and three lizard species were incidentally recorded during the course of vegetation and seabird surveys.

Because of the large size of Christmas Island, the widely separated areas of potential impact resulting from project implementation, and the relatively short time frame in which existing conditions were to be characterized, a qualitative approach was taken in describing the current or baseline condition of the island's terrestrial vascular flora and vertebrate (principally seabird) fauna. This approach is similar to the methodology used in rapid assessment programs now in use around the world.

VEGETATION

In the interest of covering as much ground as possible during the limited time available, quantitative vegetation surveys were not conducted. Instead, the relative abundances of the various vascular plant species were estimated visually and assigned abundance criteria as follows (see Tables 2-8):

- Abundant: Species dominates the landscape, or if low growing, dominates the ground cover beneath higher plants.
- Common: Species is widespread and conspicuous but not dominant; may be patchily distributed.
- Frequent: May not be apparent at first (unless a conspicuous, but not common, shrub or tree), but easily found if searched for.
- Occasional: Few individuals present, but generally one or more per hectare.
- Rare: Only one or two individuals found within the area surveyed.

SEABIRDS

In order to obtain a baseline or current condition in areas of potential impact, total counts of active nest sites were attempted for most species. Estimates were derived based on the numbers counted plus, in some cases, approximate number of nests presumed missed. While this method is subjective, it is better than just presenting only the numbers of nests actually counted, especially in instances where some difficult to find nests may have been overlooked. For example, frigatebird nests are very conspicuous; Brown Noddy eggs and chicks can be well camoflagued (or in the case of small chicks, hidden in the vegetation), and a certain percentage are likely to be missed on all but the smallest islands during a cursory survey. Christmas Shearwaters and Phoenix Petrels usually nest under bushes and matted vegetation and can be even harder to detect, thus estimates for these species are very rough. No attempt was made to estimate the numbers of burrow-nesting shearwaters (Wedge-tailed and Audubon's).

All but the largest, most heavily vegetated islands were surveyed in their entirety. For example, Islands 11 and 31 in Isles Lagoon (see Lagoon 10, Figure 4) had little evidence of nesting birds in the interior, other than a few Red-footed Boobies, thus the interiors of these were not thoroughly checked.

Fledglings were not included in the counts because they are too mobile. Some would leave a small island upon our approach, and others on the island may have come from another island. Only active nests, either empty or containing an egg, chick, or unknown contents (incubating bird obscuring nest contents), were counted.

EXISTING CONDITIONS

The current, or baseline, condition for terrestrial flora and fauna is described below based on results of the May 1997 survey.

VASCULAR PLANTS

Because of its isolation in the central Pacific Ocean, Christmas Island has very few native plant species. All 18 native species are common and widespread in the Pacific and have excellent dispersal capabilities and colonizing potential. No plants are endemic. Most of the native species and at least one non-native are common and widespread, and are frequently dominants or subdominants in areas with appropriate soil and microclimatic conditions.

Within the five general areas surveyed, 14 of the 18 native species found on Christmas Island were recorded. Three of the four species that were not recorded do not occur in the areas surveyed, and the fourth, the grass *Digitaria pacifica*, is a fairly widespread but generally uncommon (at this season?) annual that was found in only one location (not a survey area) on this visit. In survey areas, only seven non-native species were recorded. Other than *Tribulus cistoides*, which may be native, and *Cocos nucifera*, which is widely cultivated, all introduced species recorded were in the immediate vicinity of Aeon Field, Dakota Strip, Poland, and the old South Pacific Airways Hotel site, an indication that few introduced plant species have yet become widespread on the island.

The most abundant and widespread species on the island are the grass *Lepturus repens*, the shrub *Scaevola taccada*, its associated parasite *Cassytha filiformis*, and in saline soil on the lagoon side of the island, the shrub *Suriana maritima*. Other species, notably the prostrate or semi-prostrate *Boerhavia repens*, *Sesuvium portulacastrum*, *Tribulus cistoides*, and *Heliotropium anomalum*, and the prostrate to (usually) erect subshrub *Sida fallax* are locally common but generally not dominant.

The only native trees on Christmas Island are *Pisonia grandis*, found only in one cluster near the east end of Dakota Strip at South-east Point and the widespread *Messerschmidia* [or *Tournefortia*] *argentea*, which is more often than not a large shrub. The widely cultivated, non-native coconut palm dominates the landscape in and near inhabited areas.

Aeon Field

Seventeen species, 11 native and 6 non-native, were recorded in the vicinity of Aeon Field, with the grass *Lepturus repens* the dominant species (Table 2). Here, the grassland landscape is broken only by the occasional clump of *Scaevola*. Around the immediate edge of the paved strip, especially in the western half, the non-native *Euphorbia hirta* is common. A few stands of *Messerschmidia* are evident along the coastal strand to the north. The closest grove of coconut palms is more than 3 km away.

Dakota Strip

The vegetation in the vicinity of Dakota Strip is very similar to that of Aeon Field and differs primarily in the presence of fewer non-natives, which accounts for four of the five fewer species recorded here (Table 3). Other than the questionably non-native *Tribulus,* the only non-native found was the grass *Eragrostis tenella,* and here it was considerably less abundant. Unlike Aeon Field, the unpaved Dakota Strip is completely overgrown with vegetation, *Lepturus, Tribulus,* and *Sida fallax* prevailing. The island's only stand of *Pisonia grandis* is located 1 km southeast of Dakota Strip at South-east Point.

Poland to the Old South Pacific Airways Hotel Site

Fourteen species of plants, all but three native, were recorded along the Paris Peninsula from 1 km northwest of Poland to the site of the old South Pacific Airways hotel ruins (Table 4). Several dominant vegetation types were present. Near Poland, coconut palms dominate the landscape. Beneath the coconuts, where present, at the elbow of the peninsula, grassland liberally sprinkled with *Sida, Tribulus, Boerhavia, Heliotropium,* and the non-native *Pluchea odorata* predominates. Scattered patches of *Scaevola* can also be found in this area. At the base of the peninsula above the elbow is a *Lepturus/Tribulus*-dominant grassland. On the lagoon side of the peninsula, *Suriana maritima* is dominant. Along the outer coast, *Messerschmidia* is dominant in a strip immediately behind the sandy beach throughout most of the length of the peninsula. Closer to the hotel ruins are periodically inundated flats covered with *Sesuvium*. *Scaevola* is dominant on higher ground in this area. The non-native weed *Euphorbia hirta* was found only at the hotel ruins.

Central Lagoons in the Vicinity of Carver Way

Vegetation types here differ significantly between the mainland and islands within the enclosed lagoons, so they are described separately below and in Tables 5 and 6. On the mainland between Artemia Corner and "Algeria", no one species dominates in frequency; however, *Scaevola* clearly dominates the landscape in most areas. Perhaps, equally common, but less conspicuous, are *Lepturus* and *Suriana*. Although *Lepturus* is fairly common, it is found beneath *Scaevola* and does not form extensive grasslands as it does in places on the South-east Peninsula. *Sesuvium* is common on compacted soil near the lagoons, and *Portulaca, Sida,* and *Heliotropium* are also common in places.

On the lagoon islands, vegetation varies primarily according to island size (small islands lack a well developed soil) and, to a lesser extent, distance from shore. On the smallest islands, *Sesuvium* is abundant, with only an occasional *Suriana* or patches of inconspicuous *Eragrostis whitneyi*. On larger islands, *Lepturus* may be common, along with *Suriana, Messerschmidia, Heliotropium,* and *Scaevola*. *Boerhavia* is common in the interior of the largest islands. *Messerschmidia* is frequently used by Red-footed Boobies and Black Noddies, and *Suriana* forms the main nesting platform for frigatebirds. *Eragrostis whitneyi* and the parasitic vine *Cuscuta campestris* were found only on islands and nowhere on the mainland.

Boating and Bathing Lagoons

Vegetation on the mainland in the vicinity of the Boating and Bathing Lagoons (Table 7) is quite homogeneous, consisting almost exclusively of *Scaevola*, *Suriana* (adjacent to the lagoon), and *Lepturus* which, although less conspicuous, is at least as common as the other two. Although not as common, coconut palms dominate the landscape in places. The only other vascular plants recorded here were an occasional patch of *Sesuvium* near the Bathing Lagoon and the vine *Cassytha* which is parasitic primarily on *Scaevola*.

On the large island off the Bathing Lagoon and the two smaller islands off the Boating Lagoon (Table 8), the vegetation is considerably more diverse with twice the number of species (12).

SEABIRDS

Because they play such an important role on Christmas Island, and because they are probably the most vulnerable to human disturbance, an emphasis was placed on seabirds throughout this study. Christmas Island is reported to have the largest seabird colony in the world, both in terms of numbers of birds and number of species. Its inner lagoon is a mosaic of islets that provide predator-free nesting sites for many birds. Eighteen species of seabirds and one endemic land bird nest on Christmas Island. Based on estimates from the early 1980s (Perry 1980, Garnett 1983, Schreiber and Schreiber 1984), Christmas Island has the largest known colonies of at least four species, with populations of several other species among the world's largest. No other island can claim as many numbers of so many different species, and few, if any, can boast more species. It is not surprising, then, that the seabirds of Christmas Island are of international importance.

Yet, by all accounts, the numbers of seabirds nesting on Christmas Island have dropped precipitously in the past fifteen to twenty years. Some attribute the drop to rats and feral cats, others to illegal poaching of birds and sooty tern eggs (see Ongoing Impacts, below). It is clear that all have played a significant role in their demise. With the island's rapidly expanding human population, increased access to motorized vehicles and boats, inadequate regulations and virtually no enforcement of these regulations, poaching of birds and harvesting of sooty tern eggs have played a major role in population declines. Cats and rats are also a serious problem.

The only breeding seabird not recorded on this visit was the Polynesian Storm-Petrel (*Nesofregetta fuliginosa*). It has been recorded breeding only from July to January (Figure 6), and may not be present at this season.

It should be kept in mind that mid-May surveys represent only a snapshot of a very dynamic and complex breeding bird population. For some species, mid-May is the "off" season with very few or no birds breeding. For others, it may be the height of the breeding season. For still others, the breeding season varies seasonally from year to year, enough to make it nearly impossible to determine if mid-May 1997 was a relatively productive or non-productive year, depending upon what stage each is in during its breeding cycle in this particular year. For example, no evidence was found that Blue-gray Noddies were nesting, yet most previous studies had at least some breeding at this time of year. What this lack of breeding evidence means cannot be determined in such a brief period. The same can be said for the Masked Booby.

Another variable that will not be detected in a brief survey conducted on only part of the island is the possibility that the centers of abundance of some species may have shifted since Garnett's thorough surveys in 1979-1981. For example, are the relatively low numbers of Phoenix Petrels representative of an actual decline, an off-peak period in their breeding cycle, or an indication that many of the birds have shifted to another part of the island since 1980 — or is it a combination of these?

Therefore, it would be highly speculative to attempt to extrapolate the condition of seabird populations on Christmas Island as a whole from sampling only a small portion of the island over a two-week period in May.

<u>Carver Way Lagoons</u>

Immediately adjacent to Carver Way along the 12 km stretch where it bisects the island are a number of land-locked lagoons. Ten of these have islands (Figure 4), but four of these (Lagoons 5, 6, 8, and 9) appeared to have few breeding seabirds and were not visited. In each of the six lagoons visited, all significant islands (or, in a few instances, island clusters) are numbered. Island-by-island results are given in Tables 9-14. Results of these surveys are given below, first by lagoon, and then by species (see also Table 15).

Lagoon 1

Lagoon 1 has two large islands and one small island. The two large islands are among the most productive visited. Island 3 had the largest Brown Noddy colony by far and the second largest Black Noddy colony. Among the 58 islands visited, it ranked first in number of species (12) and estimated number of nests (603, not counting the two burrowing shearwater species). Island 1 ranked third with 10 species and sixth with an estimated 255 nests, not counting the burrowing shearwaters.

Lagoon 1 had the largest colonies of Christmas Shearwater, Phoenix Petrel, and Red-tailed Tropicbird, and the second largest colonies of both Brown and Black noddies. In all, Lagoon 1 may be one of the most productive lagoons on Christmas Island, despite its small size and the presence of only 3 islands.

Lagoon 2

Lagoon 2 has six small to medium-sized islands. Island 2, the largest, is clearly the most productive with 10 species and approximately 448 nests, excluding the two burrowing shearwaters. Island 2 had the largest Gray-backed Tern colony with an estimated 300 active nests at the time of the visit. It also had perhaps the largest Wedge-tailed Shearwater colony of any of the islands visited. An abandoned Gray-backed Tern colony (old, addled eggs) was present on Island 5.

Lagoon 3

Even though Lagoon 3 is about the same size as Lagoons 1 and 2, its two small and one medium-sized islands had only two breeding species between them — Great Frigatebird (Island 3) and Brown Noddy (Island 1). Island 2 had no breeding birds.

Lagoon 4

This is a very shallow lagoon, and the number of islands comes and goes with fluctuating water levels in the lagoon. At the time of our visit, there were only five islands large enough to support breeding seabirds. Islands two and four, the two largest, and each supporting trees, also had the most birds. Each had nine species, with Island 4 having slightly more active nests. Lagoon 4 had the largest colony of Black Noddies and the second largest colonies of Christmas Shearwaters and Gray-backed Terns.

Lagoons 5 & 6

These lagoons were not visited, as they are small with only a few small, treeless islands that, from the mainland, appeared to have few if any seabirds.

Lagoon 7

Lagoon 7, with eight islands, was nearly as productive as Lagoon 1. Island 3, the largest, had 11 species and about 85% of the nests in this lagoon. Islands 5, 6, and 8 had no nesting seabirds, and Island 4 had only a few Brown Noddies. This lagoon had the largest population of Common Fairy-Terns and the second largest of Red-footed Boobies and Great Frigatebirds (although barely a tenth of the collective population of frigatebirds in Isles Lagoon).

Lagoon 10 (Isles Lagoon)

This large lagoon, the second largest enclosed lagoon on Christmas Island, has over 60 islands, about 50 of which are large enough to support breeding birds. Of these, all but a few in the southwestern part of the lagoon were visited. Some of the numbered "islands" are actually clusters of small islands. "Island" 34, for example is actually 15 closely associated small islets. Islands 29 and 33 are also small clusters of islands. Isles Lagoon had more than 1,000 Great Frigatebird nests at the time of our visit, by far the largest colony in the Carver Way lagoons. It also had the largest numbers of Red-footed Boobies and Brown Noddies collectively, even though no one island had a particularly large colony of either species and no one island had more than seven breeding species.

Seabird Accounts for Carver Way Lagoons

Wedge-tailed Shearwater *Puffinus pacificus*. This species breeds from May through November (Schreiber and Ashmole 1970), with most eggs present in late June through July (Figure 6). Based on intensive island-wide surveys in 1979-1981, Garnett (1983) estimated about 500,000 pairs on the island, making this easily the second most abundant seabird at Christmas Island and one of the largest Wedge-tailed Shearwater colonies in the world.

Because this species nests in burrows and, when not attending the nest, spends its time out at sea beyond the reef, it is very difficult to obtain meaningful numbers of breeding Wedge-tails by conventional means. A substantial effort that entails identifying active burrows in a series of grids or quadrants within each colony, is necessary in order to obtain meaningful numbers. Often, this involves late evening and pre-dawn observations when the birds are exchanging duties at the nest. In the brief period of time allotted for this study, only the presence or absence of active colonies on the various islands was determined.

Even an educated guess as to numbers of shearwaters now present is not feasible based on the limited results of this survey. For this reason, this species is not represented in Table 15. Active colonies of unknown size were found on Islands 1 and 3 in Lagoon 1, Island 2 in Lagoon 2 (large colony), Islands 1 and 4 in Lagoon 4, Islands 1, 3, and 7 in Lagoon 7, and Island 16 in Isles Lagoon. Inactive or abandoned colonies were found on Island 2 in Lagoon 1, and Island 17 in Isles Lagoon.

Chief wildlife warden Katino Teebaki believes that Wedge-tailed Shearwater populations have declined substantially in the past 15-20 years. In 1995, for example, wardens found thousands of weakened and dead birds washed ashore in the lagoons; yet, despite autopsies on several birds, the cause of this die-off remains unknown.

Christmas Shearwater *Puffinus nativitatis*. According to Schreiber and Ashmole (1970), breeding occurs throughout the year, with peak numbers in November through February (Figure 6); however, Gallagher (1960) observed no peak laying period. Garnett (1983) estimated 6,000 adults on the island; whereas, Perry (1980) estimated 15,000 adults during the same period, and Schreiber and Schreiber (1984) estimated 6,000 pairs as the "normal" breeding population. Garnett, based on his and Perry's estimates, assessed this as the largest colony in the central Pacific and probably the world.

Only four eggs and seven chicks were located during the current limited survey. In addition, nine birds at presumed nest sites with no eggs or chicks and 28 birds at presumed nest sites with unknown contents were counted. More than two-thirds were on islets in Lagoon 1. Based on these counts, an estimate for the total number of active nest sites in the area covered was determined to be roughly 104, assuming an average detection rate of between 40-45%. It is unknown if birds not attending eggs or chicks were actually nesting or attempting to nest, since this species does not build a nest as such. Thus, the only true indication of a nest is the presence of an egg or chick.

This species also nests on Cook Island, Motu Tabu, and Motu Upua, as well as elsewhere in the Central Lagoons region (see map in Garnett 1983). An extrapolation of numbers island-wide from the results of the present survey would be premature for two reasons: the breeding season apparently varies considerably from year to year, and it is not known what percent of birds estimated in earlier surveys (or the current survey year) bred in the Carver Way lagoons.

Audubon's Shearwater *Puffinus lherminieri*. This species was not known to breed on Christmas Island prior to 1955, and the first confirmed breeding was not documented until 1965. Schreiber and Ashmole (1970) concluded that some nesting may occur throughout the year, but that the peak laying period is from June to November (Figure 6). Schreiber found it nesting on only one of over 125 islets he visited in 1967; however, Garnett (1983) found it on a number of islets, all within the Central Lagoons area, and estimated a population of 1,000 breeding pairs.

This species, like the Wedge-tailed Shearwater, is a burrow nester, and thus, is very difficult to survey accurately. While some of the active burrows attributed to Wedge-tailed Shearwater (a much larger bird) in the current survey may have been those of this species, it is unlikely, as the two species usually nest in discrete colonies. This species was recorded as follows: in Lagoon 1, a dead adult found on Islet 1 and three adults in active burrows on Islet 3; an adult incubating an egg in Lagoon 2, Islet 2; a colony of unknown size (estimated at about 10 pairs) with one burrow containing a chick in Lagoon 7, Islet 1; and two adults incubating eggs in Isles Lagoon, Islet 5. As with Wedge-tailed Shearwater, no attempt was made to extrapolate a total population in these lagoons, and the results are not included in Table 15.

Phoenix Petrel *Pterodroma alba*. Breeding occurs throughout the year, however, with two distinct egg-laying peaks roughly from November to February and April to July (Figure 6). Motu Tabu and Motu Upua apparently support the largest colonies, but colonies also occur on islets throughout the Central Lagoons area and on Cook Island. Garnett (1983) and Perry (1980) estimated 20,000 and 25,000 adults (= 10,000 - 12,500 pairs) on the island around 1980.

The Phoenix Petrel is now one of the most endangered seabird species in the Pacific Ocean with active colonies restricted to Christmas and Phoenix islands (E. Flint pers. comm.), but the colony on Phoenix Island was estimated at only 225 adults by Garnett (1983). Apparently, no systematic surveys have been conducted there since Garnett's study, so the present status of that colony is uncertain.

This species' nesting sites are similar to those of the Christmas Shearwater in that it nests on the surface under bushes and matted vegetation, but not in burrows. It constructs no nest *per se*, so birds on islets not attending an egg or chick may or may not be "nesting". During this survey, five adults attending eggs, and one adult attending a chick were counted. In addition, adults were counted at 50 presumed nest sites, and an extrapolated count of 110 presumed active nest sites was derived from these observations. More than half were in Lagoon 1. Of the 58 islands visited, this species was found on only 14, and no concentrations of birds were found at any site.

Both the total and extrapolated counts and relative numbers of birds attending presumed nest sites with no eggs or young, are very similar for this species and the Christmas Shearwater; however, previous work at Christmas Island shows that this species should be at or near its peak egg-laying period in May. Nevertheless, these same studies indicate that neither species demonstrates much synchrony in its breeding season from year to year or between pairs in any given year. Thus, surveys conducted over a longer period are necessary to determine the present numbers and relative success of breeding for this species.

Like the Christmas Shearwater, this species also nests on Cook Island, Motu Tabu, and Motu Upua, as well as elsewhere in the Central Lagoons region (see map in Garnett 1983).

Polynesian [White-throated] Storm-Petrel *Nesofregetta fuliginosa*. Schreiber and Ashmole (1970) determined the peak egg-laying period to be from July or August to January, with some breeding throughout the year (Figure 6). They and others have found most breeding birds on islets in Manulu Lagoon, with a few present on Motu Tabu, Motu Upua, and islets in the Central Lagoons area. Garnett also found it on several islands in the Central Lagoons area, but apparently not on Motu Upua. He estimated a minimum of 1,000 pairs (2,000 adult birds) in 1979-1981, and Schreiber and Schreiber (1984) gave the "normal" number of pairs as 500. Despite the relatively small numbers, this is assumed to be the largest population of this rare species in the world.

This species leaves the island when not breeding, and none were recorded during the present survey.

Red-tailed Tropicbird *Phaethon rubricauda*. According to Schreiber and Ashmole (1970), this species breeds mostly from June to December, but a few may be breeding at any time of the year (Figure 6). It nests on both the mainland and islands, with the majority of the population nesting on islands in the Central Lagoons area. Garnett (1983), however, indicates a number of nesting sites on mainland areas throughout the Central Lagoons area as well as in the interior of the Southeast Peninsula.

If present numbers are comparable to those of Garnett (1983) and Perry (1980), Christmas Island has the largest population of Red-tailed Tropicbirds in the world with between 8,000 and 9,000 breeding adults (= 4,000 - 4,500 pairs).

Approximately 281 nests were estimated in the Carver Way lagoons in the present survey, making this the fifth most abundant species surveyed. If this species nests primarily from June to December as Schreiber and Ashmole suggest, then the number of nests should be higher later in the year. Islands 1 and 3 in Lagoon 1 and Island 3 in Lagoon 7 had the largest populations, each with an estimated 50 - 60 nests.

Masked Booby *Sula dactylatra*. This species breeds throughout the year, with a slight peak egg-laying period from April or May until October (Figure 6). Schreiber and Ashmole (1970) found most Masked Boobies breeding on the South-east Peninsula between A-Site and M-Site. Garnett (1983), however, shows roughly an equal breeding distribution in the Central Lagoons area and the South-east Peninsula but does not indicate relative abundance in the two areas. Garnett estimated 1,500 or more pairs breeding on the island.

This species was not observed breeding anywhere on the island on this or a previous visit in April 1996; however, a few paired birds were evident on several lagoon islands, notably Island 31 in Isles Lagoon and Island 1 in Lagoon 3. Yet, May should represent one of the months of peak egg-laying for this species according to Schreiber and Ashmole. Warden Teebaki believes that this is one of three species that has suffered the greatest declines in recent years, along with the Wedge-tailed Shearwater (see above) and Sooty Tern (see below).

E. Schreiber (pers. comm.) found piles of poached carcasses in all colonies she visited in 1993, and local residents say that a colony northeast of Manulu Lagoon was extirpated by poachers because of its accessibility from nearby Banana Village.

Brown Booby *Sula leucogaster*. Although information is scant, Brown Boobies appear to have two distinct laying periods, April to May and September to October (Figure 6); however, the laying season may vary from year to year. A few birds may be nesting at any time of year. Brown Boobies have nested at South-east Point, on islets in Manulu Lagoon, and on both the mainland and islands in the Central Lagoons area. The most productive site appears to be the one at South-east Point. Garnett (1983) estimated 300 pairs on the island in 1979-1981.

Few nesting Brown Boobies were found in the current survey, all on large islands as follows: a chick on Island 3 in Lagoon 1; 4 pairs attending eggs (and an estimated 7 nests total) on Island 3 in Lagoon 7; and 1 empty nest presumed to be active on Island 11 in Isles Lagoon.

Red-footed Booby *Sula sula*. Red-footed Boobies nest throughout the year at Christmas with peak laying periods averaged over several years in December to January and April to June (Figure 6). There is some seasonal variation from year to year. This species breeds in many areas throughout much of the island, and is without question the most widely distributed and common booby.

This species was the sixth most abundant seabird found in the current survey and was rather evenly distributed on all the larger islands with beach heliotrope (*Messerschmidia*). Of nests with known contents, 88% had chicks, although a higher percentage of nests with unknown contents probably contained eggs instead of chicks. Based on the number of flighted immatures seen in the vicinity of the colonies and personal observations of K. Teebaki, the previous breeding season was also successful.

Great Frigatebird *Fregata minor*. Great Frigatebirds have a distinct breeding season, with egg laying generally commencing no earlier than March or early April and continuing through July and occasionally September (Figure 6). Fledglings are generally present from May until December. Juveniles are dependent on their parents until past the beginning of the next annual breeding cycle, thus females that successfully raise young in one year do not nest in the following year. Great Frigatebirds nest throughout most of the interior of the island on both the mainland and islets.

Garnett estimated the annual breeding population at about 12,000 birds, and Schreiber and Schreiber (1984) estimated 6,000 pairs, probably based on Garnett's work.

This was the most abundant species in the Central Lagoons area near Carver Way during the present survey, with an estimated 1,247 active nests. The largest colonies were on Islands 17, 22, 33, 34, and 37 in Isles Lagoon with 253, 110, 160, 108, and 123 nests respectively, and Island 3 in Lagoon 7 with 120 nests. Of nests with known contents, 75% had chicks, but the majority of the 966 nests with unknown contents (due to presence of an incubating bird) may have contained eggs. If so, this would considerably reduce the relative percentage of nests with chicks.

Lesser Frigatebird *Fregata ariel*. Although about as common as the Great Frigatebird, this species nests on only one island, known appropriately as Frigatebird Island, which is the large island in the lagoon just southeast of Isles Lagoon. This lagoon lies outside the study area and was not surveyed. The Lesser Frigatebird nests at the same time of year as the preceding, but with apparent closer synchrony of egg laying. Eggs are laid from late April until June and fledglings are present from June until September (Figure 6).

Lesser Frigatebirds were first discovered breeding on the island by Gallagher (1960) in June 1959 in a colony south of Isles Lagoon where he found about 500 nests. Ashmole (Schreiber and Ashmole 1970) found about 100 nests in September 1963 and 1,000 nests in June the following year. R. Schreiber determined that only 80-100 eggs were laid in 1967. A minimum of 56 young hatched, but cats ate most or all of them, with probably no young fledgling that year. He predicted that the species may soon be extirpated from the island.

Garnett found that this colony had been abandoned by 1980, but found a new colony on an island in a land-locked lagoon just to the north, which he dubbed "Frigatebird" Island. He estimated that between 2,500 and 4,500 pairs bred on the island during his tenure and that the total population was about 14,000 (including immatures). Schreiber and Schreiber (1984) gave a figure of 4,500 breeding pairs.

Fully grown, fledged immature Lesser Frigatebirds were seen frequently in most of the Great Frigatebird colonies visited in the present survey, and a few were even perched on old nests; however, no adults were present and, as expected, no breeding was evident.

Gray-backed Tern *Sterna lunata*. This species generally breeds from February or March to August or September on islets in Manulu Lagoon and the Central Lagoons area (Figure 6). The entire population leaves the island in the fall and returns again in December.

Perry (1980) estimated only 1,500 birds, but Garnett (1983) estimated a total population in excess of 10,000 birds in 1979-1981 based on "more recent surveys." He also observed birds attempting to nest on the mainland in March 1982, but this colony was destroyed by cats. Schreiber and Schreiber (1984) gave 3,000 pairs as the estimated norm. The wide disparity in estimates suggests that populations fluctuate widely from year to year for reasons that are not yet apparent.

During the present survey, the Gray-backed Tern was found in small to moderate-size colonies on 10 of 58 islands visited and was the fourth most abundant species. Two additional colonies had been recently abandoned, and only fledglings were found on another island, suggesting recent breeding there. The largest colony was on Island 2 in Lagoon 2 (an estimated 300 nests), with significant, but smaller, colonies on Islands 1 and 2 in Lagoon 4 (about 60 and 100 nests, respectively). Manulu Lagoon was not visited, as it should not be affected by the proposed project.

Brown Noddy *Anous stolidus*. Brown Noddies breed throughout the year, with the majority laying eggs between December and June (Figure 6). They are distributed over most of the islands in the main and land-locked lagoons except for those on the South-east Peninsula (Garnett 1983). Garnett estimated a total population of 10,000 birds (= about 5,000 pairs), with most on Motu Upua, and Schreiber and Schreiber (1984) gave an estimate of 3,000 pairs.

This was the most widespread and third most common species recorded on the present survey, with at least one nest found on 32 of 58 islands. Most colonies were small and loosely defined, the largest being an estimated 200 nests on Island 3 in Lagoon 1. The next largest colony on Island 3 in Lagoon 7 had only about 65 nests. Based on an estimated 676 nesting pairs in the limited area surveyed and during only a two week period, the number of birds breeding on the entire island over the course of a year may match or exceed previous estimates.

Black Noddy *Anous minutus*. Black Noddies have a distinct egg-laying peak in April and May (Figure 6), and many leave the island in late summer to early winter, returning again in late January. According to Garnett (1983), Black Noddies nest primarily on Cook Island, Motu Tabu, and Motu Upua, with only a few small colonies on islands in the Central Lagoons area; however, Schreiber and Ashmole (1970) found more in the Central Lagoons islands than these three islands in the main lagoon. Garnett estimated a total population of 10,000 breeding pairs or 20,000 individuals, and Schreiber and Schreiber (1984) also estimated a normal breeding population of 10,000 pairs.

In the present survey, Black Noddies were the second most abundant bird with an estimated 869 nests. Most birds were on Islands 1 and 3 in Lagoon 1 and Islands 1 and 4 in Lagoon 4, together comprising 70% of all nests in the study area. Garnett shows Lagoons 1 and 4, along with Lagoon 7, as three of only thirteen areas in the Central Lagoons region where this species nests.

Thus, assuming more or less equal size colonies in each of the areas shown by Garnett, and a similar distribution today, there would be approximately 3,300 breeding pairs in the Central Lagoons region, a figure not inconsistent with Garnett's statement that most (of 10,000 breeding pairs) do not breed in the Central Lagoons.

Blue-gray Noddy *Procelsterna cerulea*. This species nests throughout much of the year, with laying occurring from May to December in most years (Figure 6). It nests on small barren islets and the sparsely vegetated perimeters of larger islets, with the largest concentration in Manulu Lagoon. Garnett estimated a total population of about 5,000 birds while acknowledging that this species is difficult to census. Schreiber and Schreiber (1984) gave 2,000 pairs as the "normal" number.

No Blue-gray Noddy eggs or chicks were located during the present survey, although birds were present on many of the islands visited. Many birds appeared to be paired and defending territories; however, what appeared to be territorial defense may well have been only inquisitive birds. Island 2 in Lagoon 4 had the largest number of Blue-gray Noddies with 90 birds present. It seems a bit surprising that no Blue-gray Noddies were breeding during the period of this survey, unless mid-May is a bit too early.

Common Fairy-Tern *Gygis alba*. This species breeds throughout the year, with a slight peak in egg laying from April to August (Figure 6). Most fairy-terns nest on Cook Island, Motu Tabu, and Motu Upua, but a few nest on a number of other islets in the Central Lagoons area that have *Messerschmidia* trees, the branches of which they use as platforms for their single egg.

Garnett (1983) estimated a total population of 2,000 birds in 1979-1981, but Perry (1980) estimated 5,000 birds in the same time period. Schreiber and Schreiber (1984) gave 4,000 *pairs* as the estimated norm, considerably higher than the other two estimates. This is one of the few instances where Garnett's estimates are substantially lower than those of the Schreibers.

As this species does not nest widely in the Central Lagoons region, it is nearly impossible to speculate on numbers island-wide from the few found during the course of the current survey. In all, only 36 nest sites were estimated in the six lagoons surveyed.

Aeon Field to Dakota Strip

There are two large **Sooty Tern** (*Sterna fuscata*) breeding colonies in the general area of Aeon Field and Dakota Strip (Figure 1). At the time of the survey in May, birds were just beginning to lay eggs, so an accurate estimate of numbers could not be obtained. It is believed that both colonies, however, contained in excess of 100,000 pairs based on observations of flying birds in the vicinity of each. In the beginning of May, only the Dakota Strip colony was present, and it expanded greatly over the next 2-3 weeks. The colony west of Aeon Field did not materialize until the second week of May, with egg laying reported by 18 May (A. Teem). The closest approach of these two colonies to Aeon and Dakota fields was approximately 1.5 km in both cases.

This species is by far the most abundant seabird on Christmas Island, and is perhaps still the largest in the world despite its considerable reduction in the past two to three decades. Traditionally, it has had breeding colonies on Cook Island, between North-west Point and the Captain Cook Hotel, at the tip of the Paris Peninsula, near South-east Point and variously along portions of the South-east Peninsula. Except for Paris Peninsula (K. Teebaki pers. comm.), two sets of Sooty Terns nest in each locality, one incubating eggs in December and January and the other in May and June after the first group has fledged young and left the island. In June 1967, R. Schreiber estimated 3.5 million eggs in six colonies. Since studies on other islands have shown that at least four birds use the breeding island for every egg that is laid (the breeding pair and two non-breeders), Schreiber and Ashmole (1970) estimated 14 million birds to be present in June 1967. Since two separate sets of birds breed on the island (assuming both sets of birds occupied all six sites), the total number of adult birds using the island in a year would be approximately 28 million.

Such large numbers are certainly not the case today. Schreiber and Ashmole describe the almost complete failure of the colony near the present NASDA site in 1967. Egg gathering by residents was the principal reason, with an estimated 250,000 eggs collected of the approximately 600,000 laid. Great Frigatebirds also destroyed a number of chicks, and feral cats killed large numbers of adults. They found 50-75 fresh cat-eaten carcasses each morning. In all, only 25 chicks survived to fledge.

Garnett commented on this species' apparent decline since 1967. He estimated a population of only 4-6 million birds per season (= 8-12 million/year) during the 1979-1981 period, a decline of 65% in just over a decade. Although, he did not give figures for each colony, he especially noticed a decline in the colony near the NASDA site, which he also attributed primarily to the illegal gathering of eggs by local residents. In addition to egg collecting, feral cats, and frigatebirds, he identified feral pigs as yet another problem.

Because of the time of year of the current survey, population estimates were impossible to obtain. However, on Cook Island where the birds bred nearly a month earlier than elsewhere this year, a rapid, but presumably accurate, survey conducted on 17 May 1997 revealed approximately 94,000 eggs, which compares favorably with Schreiber's estimate of 100,000 eggs in June 1967. However, Cook Island is considered the most productive site now because of its isolation and its protected status as a closed area.

Masked Booby *Sula dactylatra*. Although about 30 pairs of birds were estimated to be scattered throughout the area within 1 km of each airstrip, none seen appeared to be nesting. All birds observed were standing; none were sitting — an indication of incubation. Although a few immature birds were observed, especially in the Central Lagoons area, the ratio of immatures to adults was much lower than for Red-footed Boobies, suggesting relatively poor breeding success over at least the past year or two (immatures take two years to attain adult plumage).

Bathing and Boating Lagoons

The large island just offshore of the Bathing Lagoon and two smaller islands closer to the Boating Lagoon were surveyed on 10 and 18 May (Figure 5). Compared with those in the Central Lagoons region, few birds nest on these islands. Despite the size of the Bathing Lagoon Island, only about 10 **Red-tailed Tropicbird** nests, 5 **Red-footed Booby** nests, 10-20 **Brown Noddy** nests, and 5 **Common Fairy-Tern** nests were estimated in the survey period. Other species such as the **Christmas Shearwater** and **Phoenix Petrel** may also nest in small numbers, but none were detected.

Between this island and the Boating Lagoon are two smaller islands (Figure 5). The larger of the two was the only one with nesting seabirds, and it had only 1-2 **Red-footed Booby** nests, an estimated 10 **Brown Noddy** nests, and 5 **Black Noddy** nests.

Vicinity of Poland

No seabirds nest in the vicinity of Poland other than, perhaps, **Masked Booby**. Near Benson Point is a large **Sooty Tern** colony, but it is only active in December through March according to warden Teebaki. A few birds were observed at Paris but no indication of a breeding colony was evident.

London

No seabirds breed in the immediate vicinity of London; however, nearby Cook Island (2 km to the south) is a major seabird breeding colony (Figure 2), as is Motu Upua, 2 km to the northeast, and Motu Tabu, 4.5 km to the east. All of these colonies are readily accessible by boat from London, the largest village on the island, and Motu Upua can be reached by wading during the lowest tides. Each of these three islands has been designated a closed area, but enforcement is nil.

OTHER FAUNA

Reptiles

Three species of terrestrial reptiles occur on Christmas Island, and each is widespread in the Pacific. However, only one was seen in the study sites during the surveys.

Snake-eyed Skink *Ablepharus boutonii*. This small skink was seen frequently in all mainland study areas, as well as on one island in the Central Lagoons region.

Mourning Gecko *Lepidodactylus lugubris*. None were observed in the study areas, although this species is supposed to be widespread and common (Garnett 1983).

Stump-toed Gecko *Gehyra mutilata*. This species may be found only in villages and other inhabited areas. None were observed in the study areas.

Land Birds and Migrants

Only one resident land bird occurs on Christmas Island, and it is endemic to the northern Line Islands. In addition, several species of shorebirds and waterfowl, all known for their long-distance migrations, may be found on Christmas Island at various times of the year. All the shorebirds (Charadriidae; Scolopacidae) that visit Christmas Island breed in the arctic. One of these is discussed below because of its limited world range and its vulnerability.

Line Islands Warbler or **Bokikokiko** *Acrocephalus aequinoctialis*. This small, drab warbler is found only on Christmas, Washington, and Fanning islands (Pratt, Bruner, and Berrett 1987) but apparently has been exterminated from Fanning (Garnett 1983). It is still common on Washington and Christmas. Garnett shows this species occurring throughout both peninsulas in the northern and southwestern portions of the island and at the base of the South-east Peninsula, but not in the Central Lagoons area. The current survey found them still widespread in all areas shown by Garnett (except the base of the South-east Peninsula, which was not visited), but also in the Central Lagoons area. Garnett's failure to map them from this area may have been an oversight, as warden Teebaki recalls them being present in this region at least since the mid-1970s when he arrived on the island. No quantitative surveys were conducted for this species; however, individuals were routinely heard and occasionally seen flying across the highway during this visit, suggesting that they remain fairly common.

Bristle-thighed Curlew *Numenius tahitiensis*. This species has one of the most restricted breeding ranges of any shorebird, being confined to a small area of western Alaska. It winters exclusively on islands in the central tropical Pacific from the western Hawaiian Islands and the Line Islands west to the Marshall Islands and Fiji. It has traditionally been hunted on many islands, resulting in significant declines in many areas of its wintering range.

Christmas Island may be one of the few islands where this species is still plentiful because it has not been persecuted here. A few of this species were seen almost daily during the current visit, and a few individuals may be present at any time of the year; those in late May to early July probably being non-breeding birds (perhaps in their first year) that failed to migrate north.

Mammals

No terrestrial mammals are native to Christmas Island with the possible exception of the **Polynesian Rat** (*Rattus exulans*). It is generally presumed, however, that this species was brought to Christmas Island and many other islands by aboriginal explorers. Dogs, cats, and pigs have all been introduced more recently. Because of a strict by-law that permits only male **dogs** be brought onto the island, they have not spread and no feral population exists. **Feral cats**, on the other hand, are a major problem for seabirds (see, for example, Flint in press, as well as discussion below) and can now be found over most of the island (see map in Garnett 1983). **Feral pigs**, to lesser extent, can also present problems for nesting seabirds near villages.

ENDEMIC, RARE, AND ENDANGERED SPECIES

Christmas Island has no endemic or especially rare vascular plants, and special searches were not required. Among the terrestrial fauna, two bird species, the Phoenix Petrel and Polynesian Storm-Petrel, are considered rare worldwide, although neither is yet afforded any special designation under international treaties (see Flint, in press, for discussion of their present status and vulnerability). One additional species, the Line Islands Warbler, is endemic to the northern Line Islands. Any island endemic or near endemic, no matter how abundant, must be considered potentially imperiled because of its vulnerability to disease, introduced vectors, feral animals, and other man-caused threats such as widespread habitat alteration and water, air, or soil pollution.

IMPACTS

Impacts that may result from implementation of the HOPE-X Landing Site and associated facilities are best evaluated in the context of ongoing impacts on the terrestrial fauna and flora. Ongoing, man-caused impacts have the potential to be exacerbated as the population increases and activities expand to other parts of the island through implementation of this project.

ONGOING IMPACTS

Poaching of Seabirds

Present impacts on the seabird colonies are several in nature, all man-caused. Residents have been poaching hundreds, if not thousands, of birds for food and sport probably since the island was first settled more than a hundred years ago, but the extent of poaching has increased dramatically with the rapidly expanding human population and the proliferation of motor vehicles and motor boats which allow access to areas previously considered secure. There is some indication that poaching activities have declined significantly in the recent past (2-3 years) as a result of a more stringent prohibition against poaching (but enforcement appears non-existent) and educational programs in the schools.

According to one person asked, there is no preference for poaching one species over another. When asked if the recent lifting of the government ban on importing chickens for consumption has alleviated the need to poach birds, the answers were as varied as the number of people asked. One person said people now raise chickens for food and there is no need to poach. Another said the government does not allow them to raise chickens for food, and the chickens they have are for special occasions. When asked if they are eating fewer wild birds because they can now buy chicken in the market, some said they still catch birds because chickens are too expensive. Others said chickens are inexpensive and most people buy them. Obviously, there are various explanations depending upon the family's income, customary practice, and understanding of government policy. When asked if most people are aware that it is prohibited to kill the birds, most invariably said they are, but they do not understand why it is prohibited. Everyone agreed that the prohibition against killing birds is not being enforced.

Everyone interviewed agreed that there are many fewer birds on the island now than in the past; although one person pointed out that at least some species were increasing again. This same person said that when he first came to the island in 1976, many birds nested on the main island but that people had scared them away to the harder-to-reach islets [while this may be true, cats may be the main culprit in the exodus from the main island].

Harvesting Eggs of the Sooty Tern

In a separate category because of its severity, is the poaching of Sooty Tern eggs for food. This practice continues and has devastated one of the largest single-species populations of any bird in the world in only three decades. In addition to the hundreds of thousands of eggs reportedly taken each breeding season, entire colonies are disrupted by the presence of humans in the colony (especially at night) and during critical periods in the nesting cycle. People continue to engage in this activity, although apparently to a lesser extent than previously, and freely admit it, despite their awareness of the laws against poaching and the severe penalties (in principle, at least) if convicted. People interviewed admit to poaching when they know no wardens are around. Some say they cannot afford to buy eggs in the store. Others say that people do not eat the eggs that their own chickens lay, either for cultural reasons or because the Sooty Tern eggs taste better. Still others say they do not think much about the prohibition because it has been customary to harvest tern eggs ever since they can remember. One person said they will collect enough eggs for three days when wardens are not around, but that they do not collect more than they can eat.

Rats and Feral Cats

Another serious problem is the destruction of seabirds by feral cats and Polynesian Rats. Destruction of entire island faunas by cats has been well documented in the literature. Polynesian Rats, although much smaller than cats, and significantly smaller than Norway and Black Rats (*Rattus norvegicus* and *rattus*, respectively), have also decimated populations of burrow- and ground-nesting shearwaters and petrels (Procellariidae, Hydrobatidae) in the Pacific (Flint in press and pers. comm.). Because of cats and rats, all four species of shearwaters, the Polynesian Storm-Petrel, and six of seven species of terns that breed at Christmas Island are now restricted to offshore islands in the lagoons. However, rats, which are excellent short-distance swimmers, have invaded several major seabird islands, including Motu Upua (personal observation) in recent years.

The near destruction and ultimate relocation of the island's only Lesser Frigatebird colony from the main island to a lagoon island was also attributed to cats, even though frigatebirds are among the largest flighted birds in the world and have dangerously sharp, hooked bills. Nevertheless, their young are vulnerable, especially at night when vision and orientation in these diurnal birds is severely limited.

The tiny Line Islands Warbler seems not to have suffered, perhaps because it builds its nest in the uppermost branches of *Messerschmidia* trees and *Scaevola* bushes.

One person said the ongoing cat-trapping program was effective in that there are a lot fewer cats now. Others said cats were still a big problem. One person pointed out that the controversial introduction of the feline distemper virus to the island around 1990 was ineffective.

DIRECT IMPACTS RESULTING FROM PROJECT DEVELOPMENT

Direct impacts associated with project development may include direct removal of vegetation and destruction of bird nesting sites, dredging of fill material for road construction and building pads, deepening and ongoing maintenance dredging of channels leading from either the Boating Lagoon or Bathing Lagoon, contamination of soil and lagoon water from chemical, hazardous, and toxic spills, sewage, and garbage, and bird collisions with both stationary and non-stationary objects.

Construction of building pads and roads will result in the direct removal of vegetation; however, this loss of vegetation should be minimal and is not seen as significant. No plant species or plant associations (communities) are locally or regionally rare or endemic.

The only bird nesting sites or habitats likely to be destroyed are those of the Masked Booby near Aeon and Dakota strips and the Line Islands Warbler along Carver Way and in the vicinity of the hotel. But these impacts, too, are seen as minimal, as boobies are very sparsely distributed in the vicinity of Aeon and Dakota strips and vegetation removal in these areas should also be minimal. The same is true of the Line Islands Warbler. Habitat destruction along Carver Way for road improvements will be minimal with respect to the wide distribution of the warbler on the island, and the proposed emplyee lodging site is in an area where little warbler habitat exists.

It is anticipated that bed material will be needed for elevating Carver Way, and perhaps as fill for building pads at the employee lodging site on the Paris Peninsula. If this material is dredged from the lagoons, the potential exists for disturbance of seabird feeding areas and disruption of nearby breeding colonies, especially near Carver Way. The impact from dredging sand from the lagoon side of Paris Peninsula is seen as minimal, and may even be beneficial if properly conducted, as this area has filled in following construction of a jetty several decades ago. Dredging material from the lagoons adjacent to Carver Way, however, has the potential to become a significant impact if it is extensive or is conducted in such a way that water circulation patterns are significantly altered, bottom sediments are suspended and spread over large areas, or nearby seabird nesting colonies are disrupted. This, however, is not likely as long as improvements to the road are minimal (i.e., the road is not significantly raised above its present level) and routine precautions are taken (see Mitigation section, below).

If passengers or cargo are to be routinely transported by boat across the main lagoon to a lodging complex on the Paris Peninsula, the shallow channels leading out from either the Boating or Bathing Lagoon would need to be deepened and widened (see Figure 5). Logistically, these are the most feasible over-water departure points in the vicinity of Cassidy Airfield. The Captain Cook Hotel staff would also prefer to have one or both of these channels deepened so that they can transport fishermen to bonefish flats from the hotel rather than London, which is 20 km away. No significant impacts from channel improvements in this area are foreseen; however, ongoing dredging will be necessary to maintain these channels. In fact, a potentially beneficial impact would result from deepening the channel across the flats between the mainland west of the Boating Lagoon and Motu Upua, which is now occasionally accessible on foot during the lowest low tides.

Perhaps of greatest concern is the spillage or runoff into the lagoons of asphalt or other petroleum-based material used to resurface Carver Way. Petroleum residues can contaminate the water surface and oil birds' feathers, causing them to lose their water repellency and insulating properties. Seabirds that feed on or beneath the surface of oil-contaminated lagoons (all three booby species are especially vulnerable) are readily killed when their feathers become oiled. An uncontained surface film of oil or accumulated tar in the lagoons near Carver Way would be considered a significant impact.

The potential for birds to collide with towers, guy wires, or even the landing space shuttle itself must be considered; however, it is very unlikely that birds would collide with the approaching space shuttle. Only the Sooty Tern flies high enough and in large enough numbers for a collision to be feasible. However, observations of Sooty Terns in the large colony west of Aeon Field indicated that the vast majority of birds were flying at or below the crowns of coconut palms in a nearby plantation. Also, Sooty Terns are highly maneuverable, strong fliers that can easily avoid a large object such as a space shuttle or other landing aircraft approaching at relatively slow speed. Frigatebirds, a much larger species, also fly high, but few occur in this area, and despite their large size, they are also quite agile fliers.

Many species of birds are attracted to lights at night, presumably because migratory species use the stars and other celestial bodies for orientation during migration and may confuse lights with stars. Resident species should not be attracted to lights, and if they are, they are likely to adapt readily to their presence. Large numbers of night-migrating landbirds, under certain weather conditions, can collide with tall towers that have a light or beacon at the top. Often, they collide with unseen guy wires rather than the tower itself. This phenomenon is well documented for continental areas; however, very few migrant landbirds ever reach islands as remote as Christmas Island, and none have been recorded on Christmas. Thus, this potential impact is not seen as significant. Nevertheless, it should be closely monitored in case large numbers of resident birds or migrant shorebirds do become attracted to the lights.

INDIRECT AND LONG-TERM IMPACTS

Indirect and long-term impacts resulting from project implementation pose a greater threat to terrestrial biotic resources than direct impacts. Existing impacts resulting from poaching and feral animal predation are very serious and if not curtailed will ultimately destroy most, or even all, seabird colonies on the island. Construction of a space shuttle landing site and ancillary facilities, along with a employee lodging complex, will result in a significant increase in both the resident and transient human population. Frequent arrivals of passenger and cargo planes and ships will greatly increase the chance of unwanted pests and disease vectors being inadvertently introduced to the island. The potential for a significant increase in the number of pets, especially cats, and the resultant increase in feral animals also exists.

An increase in the number of and access to motor vehicles and motor boats, along with improved roads and people employed in areas now considered remote, such as at Aeon Field and the Paris Peninsula, will greatly increase the opportunities for poaching over a much wider area than currently practiced.

These potential impacts are highly significant if not carefully monitored and controlled and, ideally, eliminated.

ALTERNATIVES TO THE PROPOSED PROJECT

A number of alternatives to the project as currently proposed exist and must be considered. Depending on the alternative, significant adverse impacts may be lesser or greater, and opportunities for mitigating those impacts may also be less or more feasible.

NO PROJECT

If the project is not approved in its present or any modified form, then no direct impacts would occur. However, the opportunity for mitigating ongoing significant adverse impacts as a condition of project approval (see below) would be lost, and these impacts may continue unabated. Also, as a matter of government policy the population of Christmas Island will continue to increase, primarily through immagration from the Gilberts. Those coming to Christmas may also be less skilled and more dependent on a subsistence lifestyle; thus, potentially elevating current levels of poaching.

MITIGATION

In summary, potentially significant adverse impacts resulting from the preferred alternative that should be avoided or mitigated are:

- Bird poaching opportunities will increase with an increase in the human population and easier access to breeding colonies.
- The feral cat population is likely to increase.
- The likelihood of undesirable pests and disease vectors inadvertently being brought to and becoming established on the island is greatly increased.
- Lagoons near Carver Way may become polluted from seepage or spillage of petroleum-based materials.
- Dredging activities in the lagoons near Carver Way may suspend sediments in the lagoons, destroying benthic food items, and otherwise disrupt the lagoon ecology, and decrease visibility for foraging seabirds.

AVOIDANCE

Many otherwise significant impacts can be avoided by project modification or redesign. If improvements to Carver Way do not include paving or treating with a petroleum-based substance to suppress dust, and do not include dredging in the adjacent lagoons for fill material, then these potentially significant impacts will be avoided.

If extensive improvements to Carver Way are to occur, fill material should be taken from on-shore areas near the road, not from the lagoons. Care must be taken to contain all petroleum-based (and other) pollutants so that they do not enter the lagoons. All garbage and trash should also be contained and transported to designated disposal sites. Even seemingly harmless litter can cause serious impacts on seabirds. Birds frequently become entangled in plastic "six-pack" rings and discarded monofilament lines left lying around. Small pieces of plastic and paper products floating on the water are often mistaken for food items. These are picked up and eaten or fed to young in place of legitimate food.

ELIMINATION OF POACHING

Increased employment opportunities created by project implementation should eliminate or greatly reduce the need for subsistence-level harvesting of birds, eggs, and other organisms as long as I-Kiribati are preferentially hired for jobs for which they are qualified and trained for jobs in which they are not presently qualified. The Government of Kiribati must assure that the I-Kiribati people are maximally employed for jobs created by this project, and that non-citizens/non-residents are employed only for more highly skilled jobs that cannot be filled locally, and for purposes of training the local people to ultimately fill these positions.

However, jobs alone will not necessarily result in the elimination of bird poaching and harvesting of Sooty Tern eggs. The people inhabiting the island, as well as I-Kiribati visitors from Tarawa and elsewhere, must be educated in the importance of protecting their valuable seabird resource, both for its intrinsic value as a major component of a complex ecosystem that could be severely disrupted if the bird populations are lost or greatly diminished, and for its economic potential in attracting tourists from around the world. They must learn that seabirds play an important role in supporting fish, coral, and other marine animal and plant communities (as well as vice versa). They must learn that most tourists will not come to the island once the large numbers and variety of birds are gone, or the birds become so wary that they cannot be approached easily.

Educational and environmental awareness programs can be sponsored and financed by Mitsubishi at minimal expense as mitigation to offset potentially significant adverse impacts associated with project implementation. Programs should be established in the schools and churches to teach children the value of their seabird resources, and how non-sustainable levels of seabird and egg harvesting will quickly cause the extirpation of these birds from the island, and why birds will not come from elsewhere to fill the void (see Schreiber and Schreiber 1988). School textbooks are seriously deficient in matters of environmental science and need to be revised and updated to reflect the atoll environment. Various environmental awareness programs should be established that include important lessons in seabird ecology as well as marine ecology. Suggested programs are discussed in detail in the recent 3-volume *Republic of Kiribati Institutional Strengthening of the Environment Unit TA No: 2199-KIR* (MBA International 1997).

ERADICATION OF POLYNESIAN RATS AND FERAL CATS

The problem with Polynesian Rats and feral cats is already serious. Not only should it not become worse, it can and should be effectively eliminated. Feral cats have already forced most breeding seabird species off the main island, and Polynesian Rats have now reached several key offshore seabird colonies. The birds most at risk are shearwaters, petrels, and storm-petrels, including the very rare Phoenix Petrel and Polynesian Storm-Petrel.

As mitigation for project implementation, the present feral cat eradication program should be expanded by increasing the number of traps and trapping locations and the intensity of trapping effort. The possibility of using poisoned bait and bait laced with the recently developed oral feline sterilization vaccine should also be explored. If feasible, these programs should be introduced as soon as possible to augment the trapping effort.

Rats should be removed from the islands as soon as possible, especially Motu Upua and any other major seabird nesting islands where they may have become established. Poisoning and trapping are the most effective means of eradicating the rats.

Associated with many lagoons are many peninsulas, some with constricted bases making them "near islands." Some of these have already been separated from the main island by cutting channels across their base. As a result, cats have either been eliminated from these newly created islands through trapping or have been prevented from reaching them. Additional "near islands" should be identified and turned into islands, with appropriate care being taken not to cut channels between two separate lagoons and not to disrupt the marine ecology through undue spreading of suspended sediments during excavation operations.

PEST AND VECTOR CONTROL

As on other islands throughout the Pacific such as Guam and Hawaii, the Republic of Kiribati should rigorously enforce inspections at all ports of entry, especially on Christmas Island with its internationally important bird resource. The Brown Tree Snake (*Boiga irregularis*) is of particular concern because of its remarkable reproductive capacity, its voracious appetite for birds and lizards, and its highly aggressive behavior which may pose a threat to small children. All cargo that could contain a hidden snake, even a small one, must be carefully inspected before release for distribution on the island.

The potential introduction of Norway Rats (*Rattus norvegicus*) or Black Rats (*Rattus rattus*), is another serious concern associated with the great increase in traffic from the mainland and other islands. All precautions should be taken to prevent their introduction, which is especially likely from cargo vessels and barges that may dock at London Wharf. All containers destined for Christmas Island should be closely inspected for rodents before they are off-loaded, and effective rat barriers between ship and dock must be maintained to prevent rats from moving directly from ship to shore. Inspections of shoreline facilities in London should be conducted routinely, and people should be strongly encouraged to report any sighting of a rat larger than the small Polynesian Rat. These inspections should also include searches for and reports of snakes.

The potential for introducing various agricultural insect pests and both plant and animal disease vectors increases directly with the increase in number of boat and plane arrivals. Importation of all fruits, vegetables, meats, and other organic products should be closely regulated and monitored.

PROTECTION OF SOOTY TERN NESTING COLONIES

Sooty Tern populations can rapidly return to previous numbers of three decades ago if their colonies are protected to ensure maximum breeding success. Ideally, no egg harvesting should be allowed. However, if for cultural or economic reasons, some harvesting is found to be necessary, it should be conducted only by wardens trained in the proper times and locations for harvesting, for example, early in the egg-laying phase, in the daytime, and around the periphery of the colony only. A moratorium on all egg collecting should remain in effect for at least three full years; and only after this period should any harvesting occur, and only then if it is deemed absolutely necessary.

The proposed employee lodging site on the Paris Peninsula is close to one of the island's largest Sooty Tern colonies. The colony should be protected from intrusion by placing a fence across the peninsula south of the southernmost area where terns routinely nest. Access to the tip of the peninsula should be by permit when terns are present.

MONITORING PROGRAMS

In order to assure the effectiveness of the programs discussed above, ongoing monitoring programs are necessary. It is especially important that monitoring of seabird populations take place throughout the construction phase of the project. If any mitigation efforts are found not to be effective and significant impacts result or have the potential to result, then these mitigation programs must be modified or abandoned in favor of a program that is effective. If, for example, lights atop communications towers are found to attract large numbers of Sooty Terns which, in turn, are killed or injured in collisions with the towers and guy wires, then some modification of the lighting may be necessary, such as lower intensity lights, shielding so that the lights cannot be seen from above, use of a different or more intense color (blue? red?), or creating a flashing pattern with longer "off" time and shorter "on" time.

Baseline surveys of seabirds should be initiated prior to commencement of construction in seasons other than May when the current survey was conducted in order to obtain a reasonably complete picture of seabird population levels at all times of the year. Only then, once a baseline condition is determined, can monitoring programs meaningfully assess the effectiveness of mitigation efforts.

Monitoring programs are also an opportunity for training and should serve as a vehicle for institutional strengthening of the Wildlife Conservation Unit. Ultimately, it will be the responsibility of the local I-Kiribati population to manage and protect Christmas Island's valuable natural resources while participating in the country's economic growth well into the next century.

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TABLE 1

SURVEY DATES

Date	Locality	Purpose
3 May	Aeon Field, Dakota Strip	general assessment
4 May	Carver Way (mainland only)	general assessment
7 May	Poland to Benson Point	general assessment
9 May	Lagoon 10 (Islands 1-3)	seabirds, plants
10 May	Bathing Lagoon Island	seabirds, plants
12 May	Isles Lagoon (Islands 6-8, 11, 14, 15)	seabirds, plants
13 May	Isles Lagoon (Islands 18-22, 29, 31-33)	seabirds, plants
14 May	Isles Lagoon (Islands 16, 17, 34-40)	seabirds, plants
15 May	Aeon Field, Dakota Strip Carver Way, Boating Lagoon, Bathing Lagoons (mainland)	Sooty Tern, plants plants
16 May	Isles Lagoon (Islands 4,5,9,10,12,13); Lagoon 7 (Islands 1-8)	seabirds, plants
17 May	Cook Island	Sooty Tern
18 May	Boating and Bathing Lagoon Islands Poland to South Pacific Airways Hotel ruins	seabirds, plants plants
19 May	Lagoon 1 (Islands 1-3); Lagoon 2 (Islands 1-6)	seabirds, plants
20 May	Lagoon 3 (Islands 1-3), Lagoon 4 (Islands 1-5)	seabirds, plants

TABLE 2

VASCULAR PLANTS IN VICINITY OF AEON FIELD

Species	Occurrence	Abundance	Growth Form
POACEAE			
Cenchrus echinatus (I)	One - two small patches near west end of air strip	Occasional	Erect, annual grass, to 1 m high
Eleusine indica (I)	Along roadside	Occasional	Erect, annual grass, to 1 m high
Eragrostis tenella (I)	Patchy distribution in *Lepturus* grassland	Frequent-common	Annual grass, to 0.5 m high
Lepturus repens	Dominant	Abundant	Clumped, perennial grass, ~1 m high
CYPERACEAE			
Fimbristylis atollensis	Principally along road and airstrip edge	Occasional-frequent	Tightly clumped sedge, <0.5 m high
NYCTAGINACEAE			
Boerhavia repens	Widespread in *Lepturus* grassland	Common-abundant	Prostrate herb, <0.5 m high
AIZOACEAE			
Sesuvium portulacastrum	Open, compacted soil in western portion of site	Occasional	Prostrate, succulent herb
PORTULACACEAE			
Portulaca lutea	Widespread, but somewhat patchy	Common	Erect to prostrate perennial, to ~1 m
CASSYTHACEAE			
Cassytha filiformis	Primarily on *Scaevola*	Common	Parasitic vine, forms tangled mats
ZYGOPHYLLACEAE			
Tribulus cistoides (I)	Patchy, but locally common, in grassland	Occasional-frequent	Semi-prostrate perennial, to ~0.5 m
SURIANACEAE			
Suriana maritima	One plant near west end of strip	Rare	Small shrub, 1.5 m high

TABLE 2 (continued)

VASCULAR PLANTS IN VICINITY OF AEON FIELD

Species	Occurrence	Abundance	Growth Form
EUPHORBIACEAE			
Euphorbia hirta (I)	In immediate vicinity of air strip (western half)	Frequent	Small, erect herb
MALVACEAE			
Sida fallax	Very patchy, but mostly in vicinity of air strip	Occasional-common	Erect to semi-prostrate shrub, ≤1.5m
BORAGINACEAE			
Heliotropium anomalum	Patchy, but locally common, in grassland	Frequent-common	Prostrate, mat-like subshrub, to 0.5m
Messerschmidia [Tournefortia] argentea	A few stands in one area near beach	Occasional	Large shrub to small tree, to 5 m
GOODENIACEAE			
Scaevola taccada	Stands occur sporadically within grassland	Frequent-common	Shrub, to 3 m high
ASTERACEAE			
Bidens pilosa (I)	One plant near air strip	Rare	Herb, about 1 m high

TABLE 3

VASCULAR PLANTS IN VICINITY OF DAKOTA STRIP

Species	Occurrence	Abundance	Growth Form
POACEAE			
Eragrostis tenella (I)	A few patches within *Lepturus* grassland	Occasional	Annual grass, to 0.5 m high
Lepturus repens	Dominant vegetation type	Abundant	Clumped, perennial, to 1 m high
CYPERACEAE			
Fimbristylis atollensis	Along roadside only	Occasional	Tightly clumped sedge, <0.5 m high
NYCTAGINACEAE			
Boerhavia repens	Widespread ground cover throughout grassland	Abundant	Prostrate herb, <0.5 m high
Pisonia grandis	Clump of trees at "The Bump", Southeast Point	Rare	Cluster of trees, ~6 m high
PORTULACACEAE			
Portulaca lutea	Widespread, somewhat patchily distributed	Common	Generally, erect perennial, to 0.5 m
CASSYTHACEAE			
Cassytha filiformis	On *Scaevola*, but spreading onto other species	Frequent	Parasitic tangled vine
ZYGOPHYLLACEAE			
Tribulus cistoides (I)	Primarily on strip and along road edge	Occasional-frequent	Semi-prostrate perennial
MALVACEAE			
Sida fallax	Mostly along remains of airstrip	Occasional-frequent	Erect shrub, to 1.5 m
BORAGINACEAE			
Heliotropium anomalum	Widespread, but patchily distributed	Common	Prostrate, forms dense mats
Messerschmidia [Tournefortia] argentea	Only near beach	Frequent	Small tree, averaging 4 m
GOODENIACEAE			
Scaevola taccada	Discrete stands	Frequent	Shrub, to 3 m high

TABLE 4
VASCULAR PLANTS IN VICINITY OF POLAND TO OLD SOUTH PACIFIC AIRWAYS HOTEL SITE

Species	Occurrence	Abundance	Growth Form
POACEAE			
Lepturus repens	Especially common at base of peninsula where dominant, least common at hotel ruins	Frequent-abundant	Clumped, perennial grass
ARACEAE			
Cocos nucifera (I) Coconut Palm	Plantations nr. Poland; scattered trees elsewhere	Occasional-frequent	Tree
NYCTAGINACEAE			
Boerhavia repens	Scattered, most common near Poland	Occasional-common	Prostrate herb
AIZOACEAE			
Sesuvium portulacastrum	On periodically inundated flats near hotel ruins	Locally common	Prostrate succulent herb
PORTULACACEAE			
Portulaca lutea	Widespread, but primarily away from outer coast	Common-occasional	Generally erect perennial, ≤ 1 m high
CASSYTHACEAE			
Cassytha filiformis	Parallels distribution of *Scaevola* (see below)	Occasional-common	Parasitic, tangled vine
ZYGOPHYLLACEAE			
Tribulus cistoides (I)	Extensive population at base of peninsula; patchy elsewhere; absent near old hotel ruins	Occasional-common	Semi-prostrate perennial, to 0.5 m
SURIANACEAE			
Suriana maritima	Widespread on lagoon side; sparse or absent on outer coast	Common (lagoon side only)	Woody shrub, averages 1.5 m high
EUPHORBIACEAE			
Euphorbia hirta (I)	Only in vicinity of hotel ruins	Occasional	Small, erect herb
MALVACEAE			
Sida fallax	Widespread, but most occur at base of peninsula	Occasional-frequent	Mostly erect shrub, to 1.5 m high
BORAGINACEAE			
Heliotropium anomalum	Local populations sw of hotel ruins & nr Poland	Occasional-common	Prostrate, mat-like subshrub
Messerschmidia [Tournefortia] argentea	Forms barrier behind seaward beach	Frequent	Large shrub to small tree, to 5 m
GOODENIACEAE			
Scaevola taccada	Dominant, except grasslands at base of peninsula	Common	Shrub, to 3 m high
ASTERACEAE			
Pluchea odorata (I)	Patches near Poland	Locally frequent	Woody shrub, to 2.5 m high

TABLE 5
VASCULAR PLANTS OF MAINLAND IN VICINITY OF CARVER WAY

Species	Occurrence	Abundance	Growth Form
POACEAE			
Lepturus repens	Fairly evenly distributed	Frequent-common	Clumped perennial grass
CYPERACEAE			
Fimbristylis atollensis	Patchily distributed near road	Occasional	Tightly clumped small sedge
ARACEAE			
Cocos nucifera (I) Coconut Palm	Only one mature tree	Rare	Tree
NYCTAGINACEAE			
Boerhavia repens	Scattered patches	Occasional	Prostrate, spreading herb
AIZOACEAE			
Sesuvium portulacastrum	Patchy, on compacted sandy soil near lagoons	Occasional-frequent	Prostrate succulent herb
PORTULACACEAE			
Portulaca lutea	Scattered patches and individual plants	Occasional-frequent	Small erect to prostrate perennial
CASSYTHACEAE			
Cassytha filiformis	Primarily on *Scaevola*	Frequent	Tangled parasitic vine
ZYGOPHYLLACEAE			
Tribulus cistoides (I)	Isolated patches	Rare	Prostrate perennial
SURIANACEAE			
Suriana maritima	Locally dense clusters, especially near lagoons	Frequent-common	Woody shrub
MALVACEAE			
Sida fallax	Widely scattered	Occasional-frequent	Small, open shrub
BORAGINACEAE			
Heliotropium anomalum	Patchily distributed on coarse-grained soils	Occasional-frequent	Prostrate, mat-like subshrub
Messerschmidia [Tournefortia] argentea	Scattered individuals and small stands	Occasional	Shrub, to 4 m high
GOODENIACEAE			
Scaevola taccada	Dominant shrub in many areas	Frequent-common	Soft, woody shrub, to 3 m high

TABLE 10
LAGOON 2

Species Islet:	1	2	3	4	5	6
Wedge-tailed Shearwater		large colony				
Christmas Shearwater		1n,1c(4)				
Audubon's Shearwater		1e(??)				
Phoenix Petrel		3n,3u(10)				
Red-tailed Tropicbird		7u(8)				
Red-footed Booby		1u(1)	3c(3)	2e,4c,1u(7)		
Great Frigatebird		1c,4u(5)	1n,1u(2)			
Gray-backed Tern		101e,20c(300)	11c(11)		abandoned	2c(2)
Brown Noddy	21e,11c(40)	12e,7c(40)				7e,3c(10)
Black Noddy		2e,8c,69u(90)				

CODES: n = active, empty nest; e = egg(s); c = chick(s); u = nest contents unknown; p = pair present and presumed nesting.

Numbers in parentheses are estimates of total population extrapolated from actual counts.

TABLE 14
LAGOON 10 (ISLES LAGOON)

Species Islet:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Wedge-tailed Shearwater																1n(~50?)
Christmas Shearwater				1u(1)												
Audubon's Shearwater					2e(3?)											
Phoenix Petrel			2n?(2)				1n?(1)						4n(5)	2n(4)		
Red-tailed Tropicbird							1e,2u(3)				3u(6)					9u(12)
Brown Booby											1n(1)					
Red-footed Booby							1c,4u(5)				3c,5u(8)					1n,3c,6u(10)
Great Frigatebird											1n,1u(2)					2n,2c,19u(23)
Gray-backed Tern														39e(45)	abandoned	
Brown Noddy	1e(1)	6e,13c(22)			1c(2)	4e,12c(20)			1e,3c(5)				8e,13c(25)	7e,4c(14)		1c(5)
Black Noddy							1n,2e(3)									1n,1e,6u(8)

Species Islet:	17	18	19	20	21	22	29	31
Wedge-tailed Shearwater	old colony							
Christmas Shearwater								
Audubon's Shearwater								
Phoenix Petrel	1n(4)	1n(2)			1e(2)			
Red-tailed Tropicbird	15u(20)	1e(1)						1n,2u(15)
Brown Booby								
Red-footed Booby	1n,17c,22u(40)	1e(1)				4c,1u(5)		1n,1e,6c,10u(20)
Great Frigatebird	10n,2e,27c,214u(253)	1n,1c,1u(3)	1n,5e,1c(7)	4e(4)		3c,107u(110)	4e,3c,31u(38)	3n,11c,40u(60)
Gray-backed Tern								
Brown Noddy	4e,6c(50)			1e(2)	1e,1c(3)			
Black Noddy	1e(4)							

Species Islet:	32	33	34	35	36	37	38	39	40
Wedge-tailed Shearwater									
Christmas Shearwater							1e(1)		
Audubon's Shearwater									
Phoenix Petrel	1n?(3)				1n?(1)		1e(1)		
Red-tailed Tropicbird	1e(3)	1n,1u(2)	1e(1)			7u(8)			
Brown Booby									
Red-footed Booby	1n,1e,2u(4)	5c,1u(6)				2c,4u(6)			
Great Frigatebird	1n,1e,5c,49u(56)	3n,13e,10c,134u(160)	4n,2e,10c,92u(108)	2c,4u(6)	12u(12)	1n,2e,40c,80u(123)	11u(11)	2c,8u(10)	1n,1e,2c,29u(33)
Gray-backed Tern			1c(1)						
Brown Noddy	4e,3c(10)	6n,9e(18)	5e,16c(30)		3c(3)	1e,3c(5)	1e(1)		
Black Noddy									

CODES: n = active, empty nest; e = egg(s); c = chick(s); u = nest contents unknown; p = pair present and presumed nesting.

Numbers in parentheses are estimates o[redacted]ation extrapolated[redacted] d c [redacted]

TABLE 13
LAGOON 7

Species Islet:	1	2	3	4	5	6	7	8
Wedge-tailed Shearwater	?n(5?)		?n(??)				colony(??)	
Christmas Shearwater			1e,1c,1u(8)					
Audubon's Shearwater	1c,?n(10?)						1u(??)	
Phoenix Petrel			1n,1e,1u(8)					
Red-tailed Tropicbird		4u(4)	1c,45u(55)					
Brown Booby			4e(7)					
Red-footed Booby	2c,4u(6)	1c,3u(4)	3n,1e,20c,39u(70)					
Great Frigatebird	1c,3u(4)		1n,1e,38c,70u(120)					
Gray-backed Tern		21e(25)	6e(8)					
Brown Noddy	7e(14)		7e,9c,3u(65)	5e,3c(11)			6e,6c(15)	
Black Noddy			10n,17e,2c,70u(140)					
Common Fairy-Tern			2e(20)					

CODES: n = active, empty nest; e = egg(s); c = chick(s); u = nest contents unknown; p = pair present and presumed nesting.

Numbers in parentheses are estimates of total population extrapolated from actual counts.

TABLE 12
LAGOON 4

Species Islet:	1	2	3	4	5
Wedge-tailed Shearwater	2u(??)			(??)	
Christmas Shearwater	5u(5)			3n,6u(15)	
Phoenix Petrel	1u(1)		2u(4)	1e(2)	
Red-tailed Tropicbird	7u(7)		2u(2)	24u(24)	
Red-footed Booby	5c,8u(13)			8c,12u(20)	
Great Frigatebird	1e,4c,8u(13)			2c(2)	
Gray-backed Tern	48c(60)	75e,7c(100)			
Brown Noddy	2e,5c(10)	14e,11c(25)	4c(4)	1e(5)	7u(10)
Black Noddy	19n,29e,10c,59u(117)		2e,10u(12)	16n,33e,22c,119u(190)	
Common Fairy-Tern			1e,1c(4)	1e,2c(5)	

CODES: n = active, empty nest; e = egg(s); c = chick(s); u = nest contents unknown; p = pair present and presumed nesting.

Numbers in parentheses are estimates of total population extrapolated from actual counts.

TABLE 11
LAGOON 3

Species Islet:	1	2	3
Great Frigatebird			4c,28u(32)
Brown Noddy	3e(3)		

CODES: n = active, empty nest; e = egg(s); c = chick(s); u = nest contents unknown; p = pair present and presumed nesting.
Numbers in parentheses are estimates of total population extrapolated from actual counts.

TABLE 10
LAGOON 2

Species Islet:	1	2	3	4	5	6
Wedge-tailed Shearwater		large colony				
Christmas Shearwater		1n,1c(4)				
Audubon's Shearwater		1e(??)				
Phoenix Petrel		3n,3u(10)				
Red-tailed Tropicbird		7u(8)				
Red-footed Booby		1u(1)	3c(3)	2e,4c,1u(7)		
Great Frigatebird		1c,4u(5)	1n,1u(2)			
Gray-backed Tern		101e,20c(300)	11c(11)		abandoned	2c(2)
Brown Noddy	21e,11c(40)	12e,7c(40)				7e,3c(10)
Black Noddy		2e,8c,69u(90)				

CODES: n = active, empty nest; e = egg(s); c = chick(s); u = nest contents unknown; p = pair present and presumed nesting.

Numbers in parentheses are estimates of total population extrapolated from actual counts.

TABLE 9
LAGOON 1

Species Islet:	1	2	3
Wedge-tailed Shearwater	1u(??)	old colony	6u(??)
Christmas Shearwater	3n,1e,2c,4u(30)		2n,1e,3c,11u(40)
Audubon's Shearwater	1 dead		3u(??)
Phoenix Petrel	1n,12u(25)		1e,1c,13u(35)
Red-tailed Tropicbird	1e,4c,37u(50)		1n,3c,44(60)
Brown Booby			1c(1)
Red-footed Booby	2c,4u(6)		1n,11c,20u(32)
Great Frigatebird	5c,4u(11)	1e,10c(11)	2e,10c,16u(28)
Gray-backed Tern		fledglings	4c(20)
Brown Noddy	1e,3c(8)		17e,17c,9u(200)
Black Noddy	11n,16e,4c,79u(120)		9n,35e,25c,80u(185)
Common Fairy-Tern	5p(5)		2p(2)

CODES: n = active, empty nest; e = egg(s); c = chick(s); u = nest contents unknown; p = pair present and presumed nesting.
Numbers in parentheses are estimates of total population extrapolated from actual counts.

TABLE 8

VASCULAR PLANTS ON ISLANDS IN VICINITY OF BOATING AND BATHING LAGOONS

Species	Occurrence	Abundance	Growth Form
POACEAE			
Lepturus repens	Patchily distributed understory plant	Occasional	Clumped, perennial grass
ARACEAE			
Cocos nucifera (I) Coconut Palm	Large stand, east side of Bathing Lagoon Island	Frequent	Tree, to 12 m high
NYCTAGINACEAE			
Boerhavia repens	Bathing Lagoon Island only	Occasional	Prostrate herb
AIZOACEAE			
Sesuvium portulacastrum	More common on Bathing Lagoon Island	Frequent-occasional	Prostrate, succulent herb
PORTULACACEAE			
Portulaca lutea	Scattered small groups of plants	Occasional	Sub-shrub to prostrate perennial
CASSYTHACEAE			
Cassytha filiformis	Grows primarily on *Scaevola*	Frequent	Parasitic vine, forming tangled mats
ZYGOPHYLLACEAE			
Tribulus cistoides (I)	One to two small patches, Boating Lagoon Islet	Rare	Prostrate perennial
SURIANACEAE			
Suriana maritima	Dominant shrub	Common-abundant	Woody shrub, to 1.5 m high
MALVACEAE			
Sida fallax	Scattered small groups of plants	Occasional	Subshrub, to 1 m high
BORAGINACEAE			
Heliotropium anomalum	Scattered clumps on coarse-grained soil	Frequent	Prostrate, mat-like perennial
Messerschmidia [Tournefortia] argentea	Visually dominant plant, unevenly distributed	Frequent	Large shrub to small tree, to 5 m
GOODENIACEAE			
Scaevola taccada	Mostly on Bathing Lagoon Island; sub-dominant	Common-occasional	Soft, woody shrub, to 2.5 m high

[redacted]

TABLE 15

SEABIRD DISTRIBUTION BY LAGOON

Species Lagoon:	1	2	3	4	7	10	TOTAL
Christmas Shearwater	70 (67)	4 (4)	-	20 (19)	8 (8)	2 (2)	104
Phoenix Petrel	60 (55)	10 (9)	-	7 (6)	8 (7)	25 (23)	110
Red-tailed Tropicbird	110 (39)	8 (3)	-	33 (12)	59 (21)	71 (25)	281
Brown Booby	1 (11)	-	-	-	7 (78)	1 (11)	9
Red-footed Booby	38 (14)	11 (4)	-	33 (12)	80 (30)	105 (39)	267
Great Frigatebird	50 (4)	7 (<1)	32 (3)	15 (1)	124 (10)	1,019 (82)	1,247
Gray-backed Tern	20 (3)	313 (55)	-	160 (28)	33 (6)	46 (8)	572
Brown Noddy	208 (31)	90 (13)	3 (<1)	54 (8)	105 (16)	216 (32)	676
Black Noddy	305 (35)	90 (10)	-	319 (37)	140 (16)	15 (2)	869
Common Fairy-Tern	7 (19)	-	-	9 (25)	20 (56)	-	36
TOTAL	869 (21)	533 (13)	35 (<1)	650 (16)	584 (14)	1,500 (36)	4,171

TABLE 6

VASCULAR PLANTS OF LAGOON ISLANDS IN VICINITY OF CARVER WAY

Species	Occurrence	Abundance	Growth Form
POACEAE			
Eragrostis whitneyi	Scattered colonies on small islets	Occasional	Isolated small clumps
Lepturus repens	Mostly on larger islands in interior	Absent (small islands) - common (largest islands)	Clumped perennial grass, to 0.8 m
ARACEAE			
Cocos nucifera (I) Coconut Palm	Occasional small tree or two on larger islands	Rare	None over 3 m high
NYCTAGINACEAE			
Boerhavia repens	Primarily in interior of larger islands	Occasional-frequent	Prostrate herb
AIZOACEAE			
Sesuvium portulacastrum	Dominant plant on smaller islands; less numerous on larger islands	Abundant (small islands) - frequent (large islands)	Prostrate succulent herb
PORTULACACEAE			
Portulaca lutea	Sparsely distributed on most islands; common on a few	Occasional-common	Semi-erect perennial subshrub
CASSYTHACEAE			
Cassytha filiformis	Grows primarily on *Scaevola*	Frequent	Parasitic vine; forms tangled mats
ZYGOPHYLLACEAE			
Tribulus cistoides (I)	Patchily distributed, mostly larger islands	Occasional	Semi-prostrate perennial
SURIANACEAE			
Suriana maritima	Primarily on larger islands; a few on smaller ones	Frequent-common	Woody shrub, to 1.5 m high
MALVACEAE			
Sida fallax	Patchy distribution; larger plants on larger islets	Occasional	Shrub to subshrub, 0.1 - 1.5 m high
CUSCUTACEAE			
Cuscuta campestris	Only seen on one island, but perhaps overlooked	Rare	Threadlike vine, forms tangled mats
BORAGINACEAE			
Heliotropium anomalum	Primarily on coarser soils	Occasional-common	Semi-prostrate mat-like subshrub
Messerschmidia [Tournefortia] argentea	Conspicuous patches on larger islands; important bird nesting trees	Frequent (larger islands only)	Tall shrub or small tree, to 5 m
GOODENIACEAE			
Scaevola taccada	Grows with *Messerschmidia* on larger islands	Frequent-occasional	Soft, woody shrub, to 2 m high

[redacted] [redacted] [redacted] [redacted]

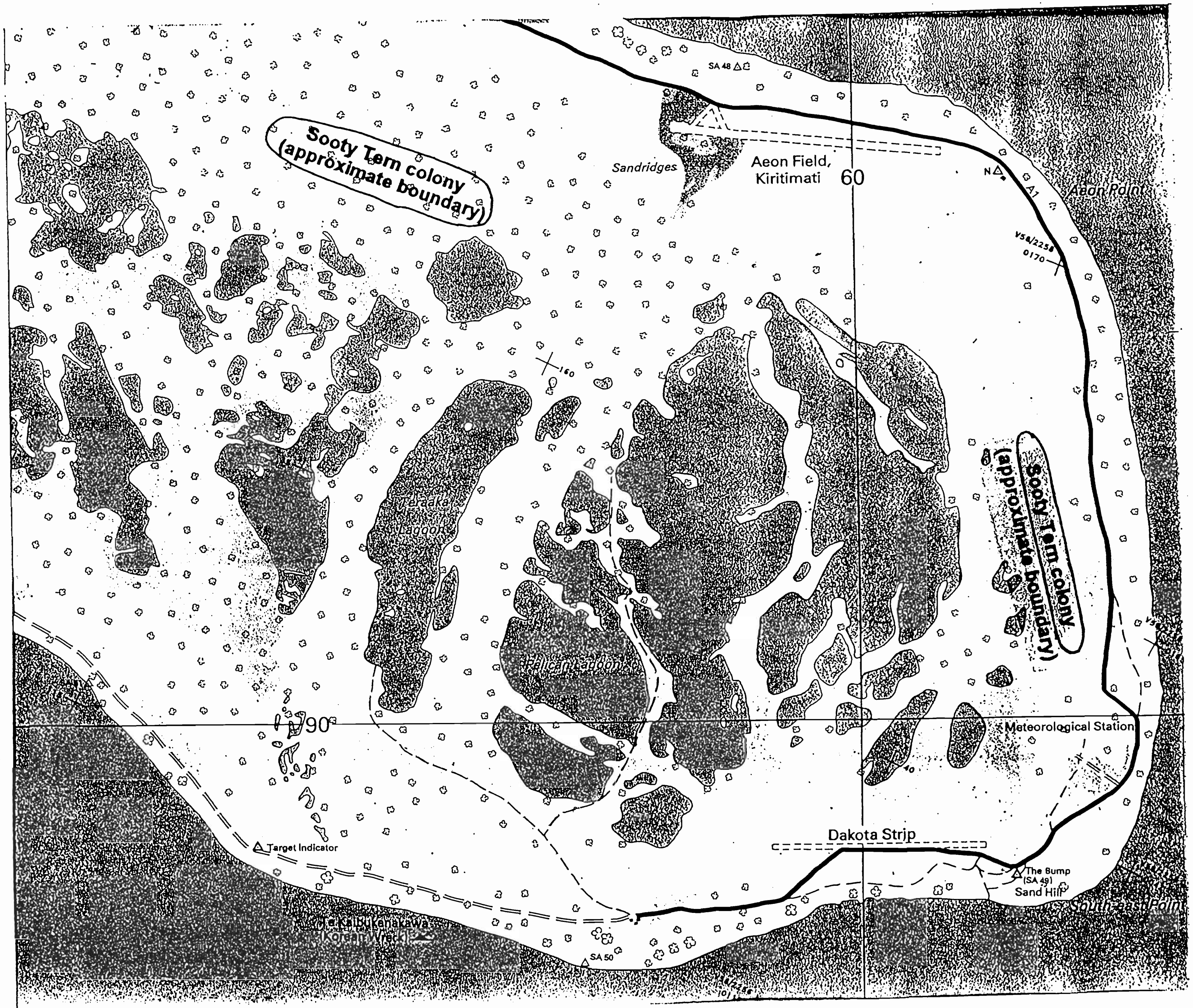

Sooty Tern colony
(approximate boundary)
Sandridges
Aeon Field,
Kiritimati
60
SA 48
Aeon Point
A1
V54/2258
0170
160
Pelican Lagoon
90
Sooty Tern colony
(approximate boundary)
Meteorological Station
40
Dakota Strip
The Bump
(SA 49)
Sand Hill
South-east Point
Target Indicator
SA 50

FIGURE 2

VICINITY MAP OF LONDON AND COOK ISLAND

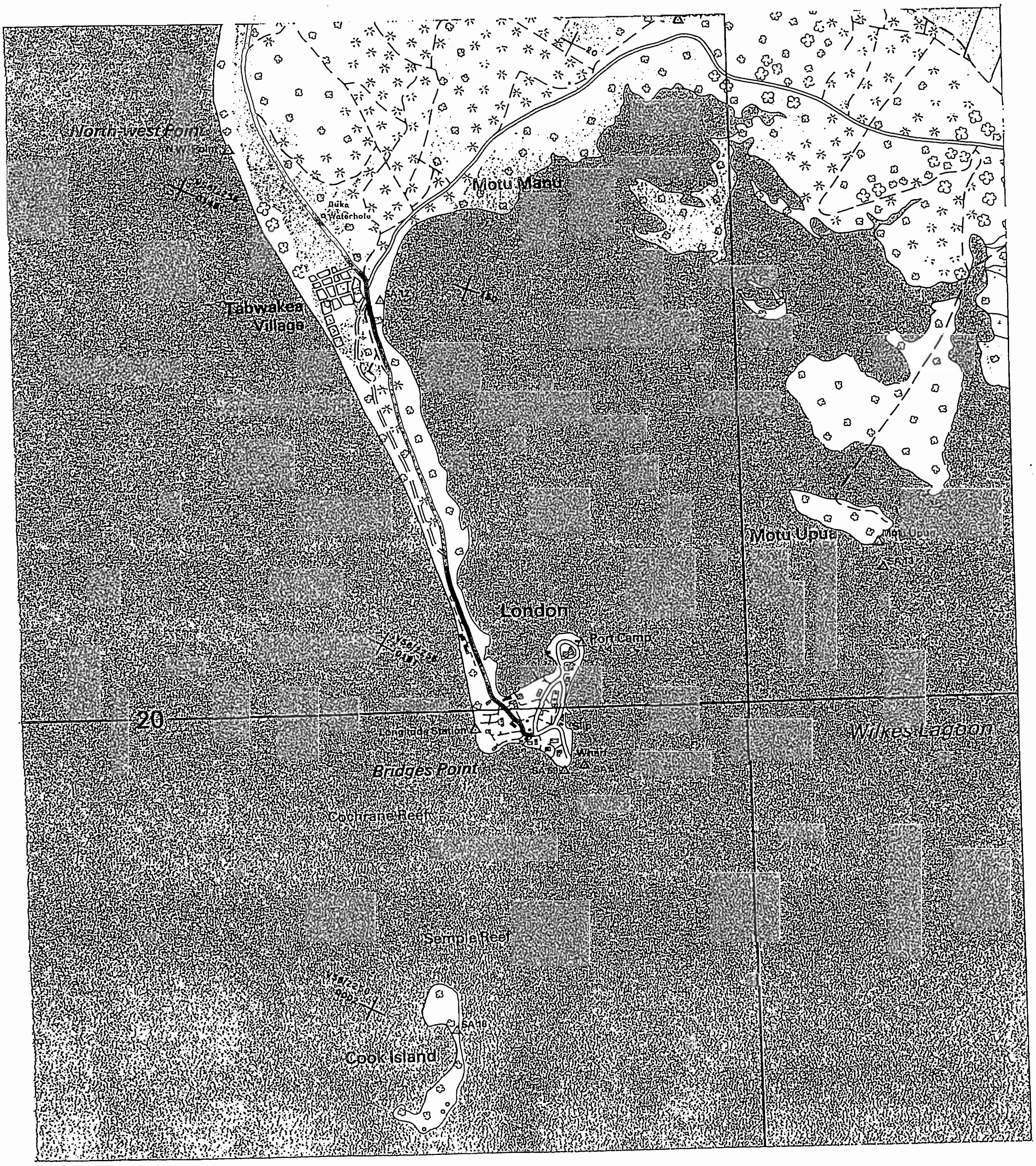


FIGURE 3

VICINITY MAP OF POLAND AND THE BASE OF THE PARIS PENINSULA

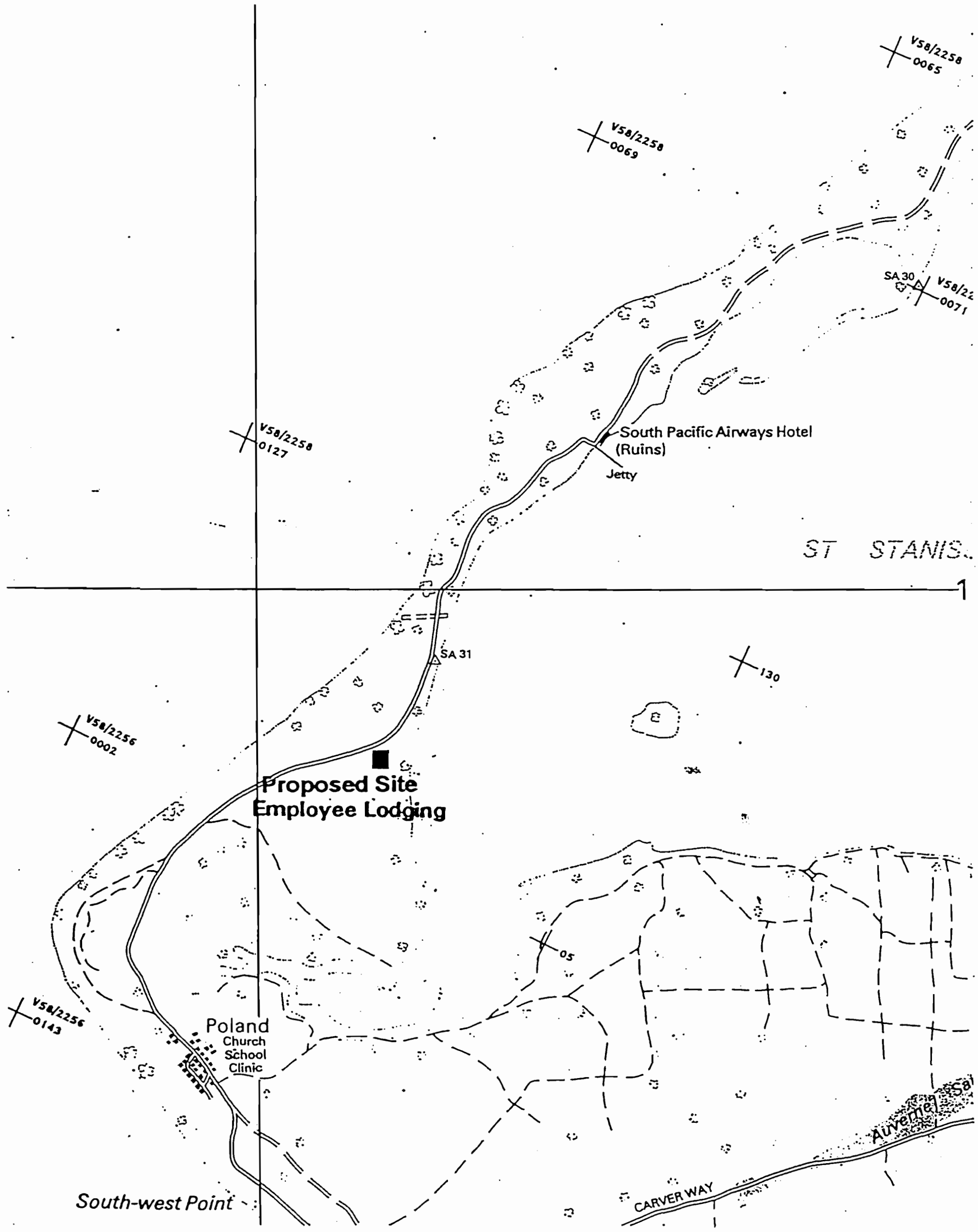


FIGURE 4

VICINITY MAP OF LAGOONS IN THE VICINITY OF CARVER WAY

Lagoons with islands adjacent to Carver Way are highlighted and numbered. Each island surveyed is represented with a smaller-sized number.

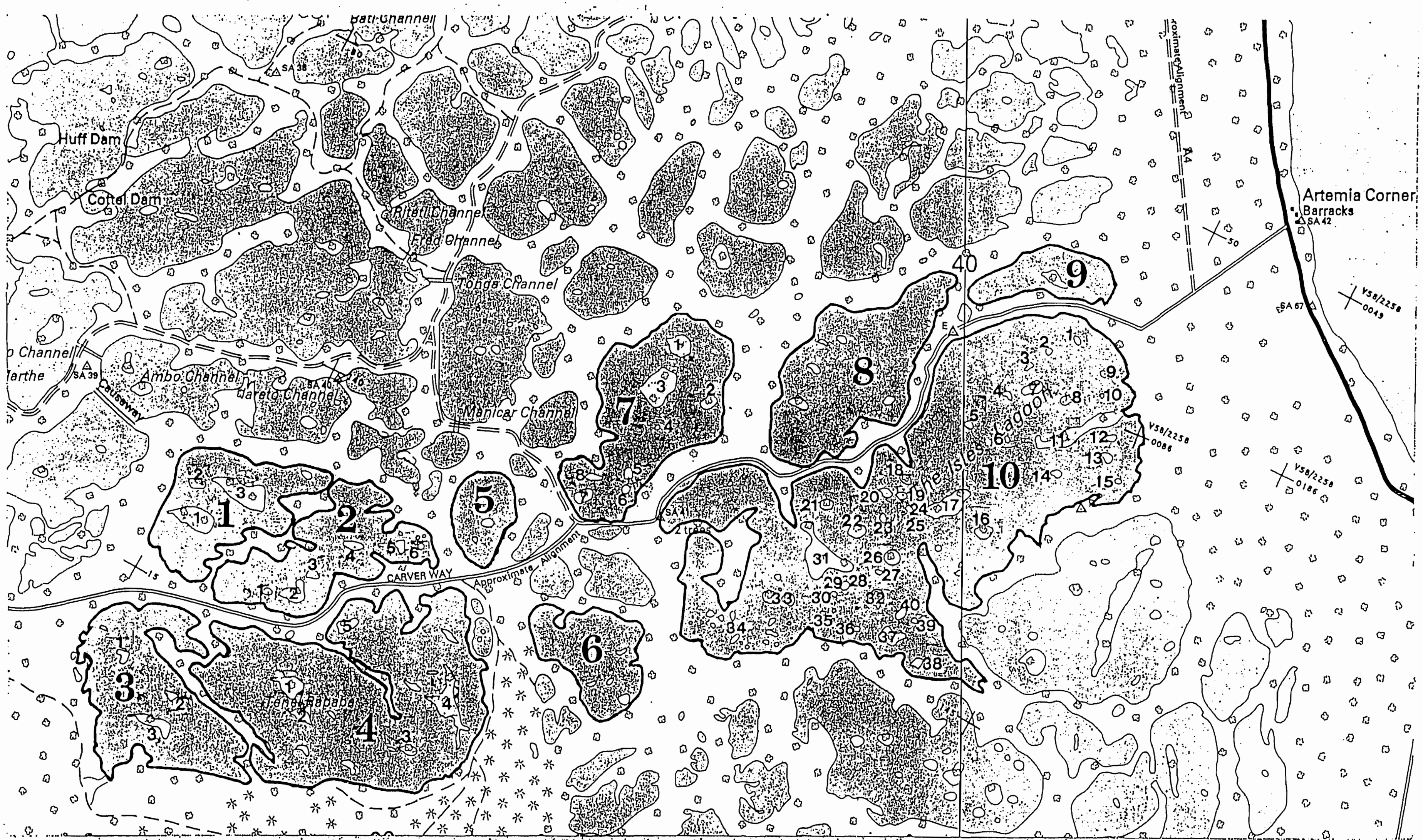
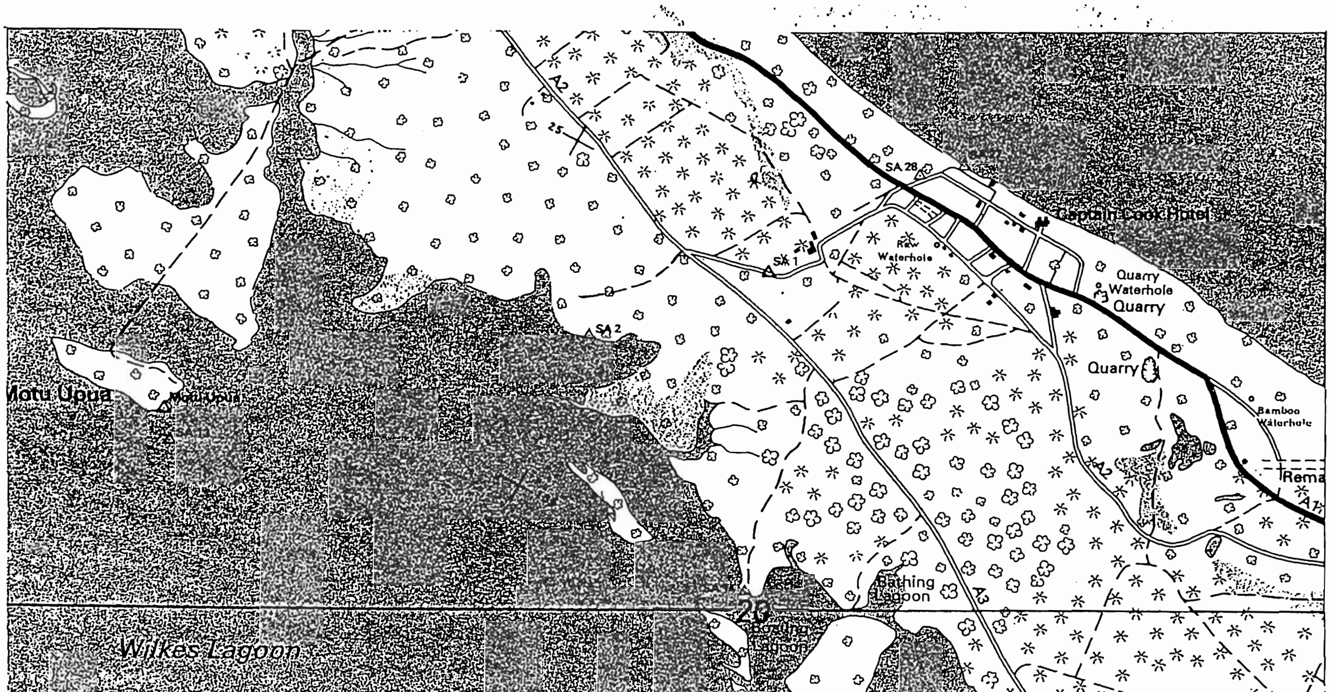


FIGURE 5

VICINITY MAP OF THE BOATING AND BATHING LAGOONS



Ecological Surveys of Corals and Reef Environments at Kiritimati Atoll for the Proposed Space Shuttle Project

by

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Introduction

The author and Dr. Alan Friedlander conducted nearshore marine surveys and interviews at Christmas (Kiritimati) Atoll during 1-8 May 1997 to assess the potential environmental effects of proposed unmanned space shuttle project at the atoll. The space shuttle project may also involve improvements to navigation, power, sewage and fuel transfer facilities which were also assessed for possible adverse effects on the marine environment at the atoll. This report covers the results of the coral and reef surveys and assessments. The results of surveys of fishery resources is covered in a separate report (Friedlander, 1997). A total of 16 field sites were surveyed including quantitative transect surveys at five of the sites; most of the survey sites are located in western ocean and lagoon marine habitats at the atoll (Table 1). Interviews and meetings were also conducted with several fishermen , government officials, and two sport fishing guides. The literature review covered (1) previous marine science reports for the Line Islands, (2) examination of preliminary planning documents for the proposed space shuttle project, and (3)previous planning reports for proposed dock improvements, sanitation and water resources plans.

Study goals and objectives

The objectives of the study concentrated on the following:

1) assessing the current status of coral reef ecosystems with particular emphasis on corals, algae, and macro-invertebrates (with fish being covered by Friedlander 1997).

2) assessing both lagoon and oceanic sites that might be affected by the proposed projects,

3) assessing the condition of reference or control sites far removed from the probable project sites to serve as a basis for comparison and future coral reef monitoring activities.

4) characterize the coral fauna and make comparisons to the coral faunas of nearby islands (Line and Phoenix islands).

5) assess the likely impacts of the projects on marine resources, and habitats

6) offer measures to reduce or avoid adverse environmental effects that may be attributed to the project,

7) offer recommendations on expanding options to implement the projects that would be feasible and avoid serious adverse environmental effects, and

8) offer recommendations on future studies and coordination for the environmental impact assessment documents and procedures

The likely features for the proposals include but are not limited to the following:

1) improvements to Aeon airfield (primary shuttle landing site) at the southeast tip of the atoll

2) improvements to existing roads, and perhaps construction of new roads to improve ground transportation linkages between Aeon, London (port and government center), Banana (near the principal hotel and commercial airfield), and Poland (the proposed HOPE-X employee lodging site)

3) improvements to the principal port at London and perhaps construction of new dock sites near North London, Boating Lagoon (near Banana), Poland, and near Aeon airfield, to facilitate barge and ship traffic to transport construction materials, personnel, the shuttle itself, and equipment and supplies

4) improvements to the existing NASDA space vehicle tracking facility near Cape Manning along the north coast

5) construction of HOPE-X employee lodging facility

6) improvements to electrical power systems on Christmas to insure an adequate and stable source of power for the shuttle, tracking, lodging, and transportation facilities.

7) possible improvements for water supply and sanitation to accommodate additional workers and their families

8) construction of facilities and special equipment such as hangars, barges, tugs, cranes, trucks, ramps and lighting to insure safe and efficient transport of the shuttle off the atoll and back to Japan

9) protection of visitor destination areas such as recreational sites (golf courses, swimming pool, snorkeling, fishing, boating, diving, and birding areas), rental cars, tour operations, handicraft shops, etc.

improvements to the existing fuel transfer facilities at North London since fuels will be needed for power, air traffic, boat traffic, ground transportation, etc. for the shuttle facilities, and

11) security fencing, sensors, and personnel to protect the space shuttle facilities, and important environmental resources (important turtle and bird nesting sites and cultural sites, if any.

In addition, the implementation of the proposed space shuttle and associated facilites would result in a number of secondary effects and developments that would mandate government actions for long-range land use planning to insure the integrity of the shuttle and adjacent "land uses" throughout the design life of the proposed projects.

In particular, important environmental resources would need to be protected from haphazard urban sprawl, and groundwater resources may need further protection against contamination. Disposal of non-biodegradable waste may also be an important future requirement especially for waste fuels, obsolete and unserviceable equipment, rubbish, and derelict vehicles, etc. during of construction, operations, and maintenance of the facilities.

The scope of the projects cannot be fully defined at this stage, and as a result the marine assessment concentrated on the sites most likely to be affected by the proposals, and at important ecological sites nearby including those proposed or designated as protected areas. Table 1 provides a synopsis of the 16 survey sites visited during the May 1997 visit to Kiritimati. These 16 sites cover all of the marine and lagoon areas likely to be affected by the projects with one exception: detailed marine resources investigations could not be accomplished off the SE point area (near the primary site at Aeon field for landing the shuttle) because of remote location and unfavorable wave conditions. Detailed assessment of this area will be needed if port construction, shore protection, dredging, blasting or fill activities are planned in the coastal zone and marine areas at SE point.

The survey sites cover the full spectrum of nearshore marine habitats at Christmas including six ocean reef sites, six lagoon sites and both main passes. The sites included ocean reef areas from north of London to south of Poland as well as interior lagoon habitats.

Methods: field survey procedures

Three types of marine surveys were conducted, based upon weather and ocean conditions and the health of the habitats:

snorkeling observations (sites 1,10)
qualitative scuba surveys and drift dives (all the rest)
quantitative surveys and transect dives (sites 2,3,6,8,12)

Underwater and above water photographs were taken at all sites using a Canon AE-1 land camera and a Nikon RS underwater camera. All survey sites were marked precisely on maps to facilitate future surveys at a later date. Local dive operator Kim Andersen also provided important useful observations and trends on marine habitats and resource use over the past decade, and Kim accompanied the team on all surveys. Waterproof slates were used to record data *in situ* at each site. Data were largely recorded on preprinted waterproof paper which included the names of expected reef species and other reef features. Each site visit averaged about one hour of diving time.

At each site a cross sectional profile of the reef was drawn with major bottom types and habitats labeled. The time, current conditions and water visibility were recorded. Stony corals were identified to species, and their abundance usually estimated using a five category scale: dominant (D), abundant (A), common (C), occasional (O) and rare (R). Table 2 provides a master list of the stony corals observed during the surveys together with their relative abundance at each site. Factors affecting coral health were also recorded including injury from pollution, smothering by sediments and predation by the crown-of-thorns starfish, a natural predator of stony corals. Other macro-invertebrates, soft corals, and marine algae were also recorded at each site and relative abundance estimated. Table 3 is a listing of these organisms at each site.

In addition to the above, quantitative transect surveys were accomplished at five sites (2, 3,6,8,12). Two of the sites were to the north of the passes - inside and outside the lagoon, and two of the sites were located south of the passes, again both inside and outside the lagoon, and one site was located along the eastern ocean coast. At each site a calibrated 20m long transect line was paid out from a reel and anchored to the bottom using bungy cords. The line was oriented along the bottom contour at depths of about 10m for the three ocean sites, and averaged about four meters depth for the two lagoon sites.

A prefabricated frame was used to mount a camera and take photo-quadrats along each of the transect lines. The coverage of each photograph inside the quadrat frame was 1m x 2/3m. The quadrat frame was centered over the transect line and photographs taken at one meter intervals along the line. At least ten photo quadrats were taken at each site. The quality of the photographs is sufficient to identify all corals to species, all other invertebrates to genus, and to estimate the coverage of the following bottom types: live coral, sand, dead standing coral, soft coral, algae, coral rubble, and hard reef rock.

After photoquadrats were taken, live corals and the other bottom type categories above were estimated using a line intercept method. The beginning and end point for each bottom type segment on the transect line was recorded on waterproof paper attached to a slate. The data from the slates were later transcribed and analyzed to estimate percent bottom cover for each of the bottom type categories for live corals, the total number of species, and the average segment length of live corals. Table 4 presents the results of the quantitative transect study results. Table 4 also includes visual estimates of live coral coverage for the qualitative sites.

Interview procedures

Several meetings were conducted during the visit to Christmas Atoll to obtain information from knowledgeable individuals on habitat condition, sport diving locations, resource use areas, fishing methods, protected areas, previous development/anthropogenic impacts, and trends in resource abundance. Table 5 is a list of the individuals interviewed at Christmas together with a listing of valuable resources, fishing techniques, and other resource uses. The interviews also identified a number of environmental issues related to marine and coastal resources which are listed in Table 6. Interviews with fishermen and sportfishing guides included annotations on a map of Christmas showing the location of resources and gear use.

Other data collection

Oblique aerial photographs were taken over Christmas Island prior to arrival on 1 May 1997, using the Canon AE-1 land camera. Shoreside observations were also made at the dock, Boating Lagoon, South Pacific Airways site and other areas. John Bryden, a long-time resident of Christmas, provided access to old documents and maps of Christmas produced during the era of the nuclear weapons testing between 1957-1963.

Results

Christmas Atoll was uninhabited at the time of its discovery by Captain James Cook in 1777. The earlier Polynesians passed through Christmas and others of the Line Islands during their transoceanic migrations during the earlier part of the present millineum but left little trace of their occupation. With rainfall very irregular and averaging only 30 inches per year, Christmas was arid and generally inhospitable to earlier migrants and explorers. Many travelers passed through Christmas during the early part of the past century, but the atoll wasn't continuously occupied until the early 20th century. Many coconut trees were planted and dwellings constructed as part of plans by the British Gilbert and Ellice Islands Colony administration to settle the atoll and promote economic development. The atoll was also a candidate for a transoceanic cable crossing at the turn of the century to establish communication links to Australia.

The first major impacts and disturbance to coastal ecosystems to the atoll occurred near the outbreak of hostilities during World War II. The British and Americans established a road network and airfields on the atoll and initiated improvements to the port at London, including installation of sheetpiling and excavation of the turning basin. However, military engineers and construction teams did not complete the port project before moving to other islands closer to the front. Records are not clear whether a navigation channel through the northern reef pass (Cochran Pass) was completed. However, old World War II vintage photographs show large ships anchored inside Christmas lagoon, suggesting that the channel might have been deeper at one time than its present depth of about 4.5m (15 ft). As the front shifted closer to Japan during the latter stages of World War II, Christmas was abandoned by the military, but the copra plantations continued with small populations of Gilbertese settlers.

In 1957 the British decided to enter the arena of atmospheric nuclear testing and chose Christmas Atoll and nearby Malden Island as sites for early tests (Hubbard and Simmons 1985, and Oulton 1987). An extensive road network, buildings, and airfields were constructed or improved. Although the nuclear tests at Christmas were above ground shots dropped from airplanes or tethered to balloons, photographs show soils, sediment, and rock being sucked up from the land of the atoll during the tests, possibly resulting in physical and readiological impacts to land, wildlife and coastal areas. The construction of the road network also probably blocked or restricted water circulation in sections of the lagoon: time did not permit a detailed reconstruction of the situation at Christmas at the time of the nuclear testing which ended in 1963 after Americans also used Christmas for nuclear tests. The Nuclear Test Ban Treaty of 1963 brought to an end the era of nuclear testing in the Line Islands including Christmas.

During the past three decades, the British colonial administration brought in additional settlers and promoted research and development for agriculture and mariculture (*Artemia*) prior to transferring administrative control of the Atoll to the new Republic of Kiribati in 1979. Since that time, the population of Christmas has grown rapidly since it has the largest land area and greatest potential for alleviating the crowded conditions on many of the atolls in the Gilbert (Tungaru) group of Kiribati. The atoll and two others in the Northern Lines (Teraina =Washington, Tabuaeran=Fanning) are targets for resettlement plans, and the population of Christmas (Kiritimati) now exceeds 3,500. The Japanese space agency also established the NASDA satellite tracking facility near Tabakea village in the 1970's. Other recent effects on coastal resources at Christmas include occasional shipwrecks, such as the "Korean Wreck" off SE point, increasing subsistence fishing pressure at reef and lagoon sites near the 3 largest villages to the north (London, Tabakea, Banana) and unmanaged exploitation of sea cucumbers, sharks (tuna) and aquarium fish for overseas markets. As discussed elsewhere by Friedlander (1997) and Jones (1997), the fish and wildlife of Christmas has attracted world renown sportfishing and birding enthusiasts and the Captain Cook Hotel is the only hotel presently on the atoll accommodating visitors including tourists. In order to protect fish and wildlife, especially bonefishing opportunities for sportfishers and the huge nesting seabird colonies, government ministries have established several protected areas on the atoll. These include (a) about a dozen ponds in the central lagoon to protect bonefish, (b) Cook Islet between the two passes of the west side of the atoll to protect birds and vegetation and nesting sea turtles, (c) major seabird nesting populations on the atoll, away from the settlements, and (d) two smaller lagoon islets (Motu Upua and Motu Tabu).

Status of coral reef habitats

Coral reef habitats are abundant and diverse at Christmas atoll and include several logical categories:

(a) exposed ocean reefs (e.g. sites 1,2,3)
(b) protected ocean reefs (e.g. sites 7,8,9,14,15)
(c) passes (e.g. sites 4,9,12,16)
(d) outer lagoon (e.g. 5,6,9,10)
(e) inner lagoon (e.g. 11,13)

Water circulation and exposure to ocean waves appear to be the most important natural factors influencing development of coral reef communities in these habitats. For example, stony and soft corals achieve their greatest abundance and diversity on ocean reef slopes off the protected west and southwest sides of the atoll and at sheltered habitats in the outer southern pass and adjacent lagoon (Table 4). Here stony corals ranged from 30 to 46 species per site and displayed live coral coverage of about 50 to 90% per site. In contrast the innermost lagoon habitats showed no live coral coverage or species of coral present. Water circulation was sluggish, temperatures warmer, salinites probably higher, (see Schoonmaker et al. 1985), and bottom habitats covered with sediments - factors all unfavorable to coral growth.

Coral reef communities were present at several northern lagoon stations (sites 5,6,10) and two exposed ocean reef stations (sites 2,3), but the level of coral development was poor, averaging less than 12% live coral cover (Table 4) and less than 20 species of corals per site. In the case of the two ocean reef sites, exposure to heavy wave action and scour from suspended sediments probably limits greater coral development. Also, huge expanses of dead standing coral (staghorn *Acropora* spp) were reported at site 3, the result of a recent coral kill, possibly from lethal or sublethal temperatures from a recent El Nino, excessive predation from a crown-of-thorns starfish infestation (*Acanthaster*) or some other undetermined cause. Large waves can also generate considerable scour, suspending sediments and abrading living corals during heavy surge and wave action.

Depressed coral abundance in the northern outer lagoon appears to be related to anthropogenic stress (sites 5,6,10). Urban populations are close by at Banana, Tabakea and London, and a prior history of dredging, navigation traffic and fuel spills are likely, especially at sites 5 and 10. At site 6, the reef has deteriorated to piles of loose sediment and rubble, indicative of several decades of chronic stress and the lack of coral recovery. It is possible that natural factors may also be contributing to the decline of reef communities in the northern lagoon possibly from temperature stress and/or *Acanthaster* infestations. Yet, comparable pass and lagoon habitats nearby and just south of Cook islet show very healthy and diverse coral reef communities despite water circulation and depth regimes comparable to those of the degraded lagoon and pass habitats just north of Cook Islet. Also, ocean reef habitats just offshore and west of Cook Islet (site 15) appear unaffected suggesting the following:

a) the regular strong ebb and flow of water out of the two passes serves as a barrier against adverse environmental/ecological conditions spreading to coral reefs south of Cook islet
b) coral community abundance and diversity is very high on pass and adjacent lagoon reef habitats near the south pass (Benson Pass), and
c) coral community development is degraded on pass and adjacent lagoon reef habitats north of Cochran Pass.

It appears that the history of port development and urban development over the past half century, particularly during the World War II and nuclear weapons testing epochs, are partially responsible for degraded lagoon reef conditions in the northern (Wilkes) lagoon and Cochran pass region. Chronic sewage pollution, boat traffic, fuel spills, and sedimentation from urban activities may be preventing or impeding natural recovery of coral reef communities.

Coral biodiversity

A total of 87 species belonging to 33 genera of stony corals were reported from Christmas Atoll during the May 1997 surveys (table 7). Of these, 30 genera belong to the order Scleractinia while the remaining three are hydrozoan corals. These numbers compare to 72 species belonging to 31 genera reported during more detailed surveys at Fanning (Tabuaeran) Atoll, the next atoll up the chain from Christmas (Maragos, 1974), 30 genera and 94 species reported at Palmyra which is two atolls up the chain (Maragos 1988), 14 genera and 32 species at Johnston Atoll 1300 km southwest of Honolulu (Maragos and Jokiel 1986), 16 genera and 50 species from Hawaii which is about 1900 km north of Christmas (Maragos 1995), and 35 genera and 84 species from Kanton in the Phoenix Islands which is about 1500 km southwest of Christmas (Maragos and Jokiel 1978). The 1997 surveys include many new coral species and 3 new genera records for the Line Islands (*Plerogyra, Oxypora* and *Barabattoia)* two of which are new records for both the Phoenix and Line Islands region (except *Plerogyra*). The coral fauna for Christmas compares closely with the other well-surveyed atolls of the northern Line Islands, which average about 32 genera and 80 species. The only exception is Johnston Atoll with much lower totals for both genera and species and which compares more closely to Hawaii.

Some interesting aspects of the coral biota are evident: 1)there is good representation by several genera including *Acropora, Astreopora, Favia, Favites, Fungia, Montipora, Pavona, Porites, Platygyra* and *Pocillopora,* 2)these same genera are also well represented in the other island groups nearby except for three braincorals *(Favia, Favites, Platygyra)* and one acroporid *(Astreopora)* which are absent from Hawaii and Johnston. One very peculiar observation was the scarcity of the normally common genus *Acropora* at Christmas. Nowhere was *Acropora* abundant, and large dead stands of staghorn *Acropora* were observed at two exposed ocean sites (2 & 3). The 10 species of *Acropora* at Christmas is compariable to those of nearby Fanning and Kanton but is much lower than the 29 species reported at Palmyra.

Other invertebrates and algae

Table 4 provides a listing of other conspicuous algae and macroinvertebrates. In general, green algae were more common in the lagoon and on ocean facing reef flats along the shores of southeast point. The most common alga, *Ulva,* is thought to be an indicator of high nutrient outflow. Brown algae were most common on the reef flats in the lagoon. The cyanobacteria (formerly blue-green algae) occur most commonly in the inner lagoon experiencing sluggish circulation and high temperatures and salinities. Red algae was most common on exposed ocean facing reef slopes, especially crustose coralline algae which form butresses and ridges on the outer reef margins facing towards prevailing wave action. The one exception was the abundance of the fleshy red alga *Eucheuma,* a species intentionally introduced and released on Christmas' reefs a few decades ago to promote future mariculture (Maxwell Doty, personal communication, 1975). In fact this alga is now successfully cultured in several reef flat and shallow lagoon plots near London and

Benson Points near the passes. The alga grows quickly, and after drying, it is sold to commercial interests in Denmark which processes the algae for several cosmetic and industrial purposes. Some fishermen feel the *Euchema* seaweed mariculture plots may be disrupting bonefish runs between the lagoon and ocean reefs. Escaped patches of the alien species were seen in several places in the lagoon.

Several macro-invertebrates are very common and a few are now surprisingly rare. The small giant clams (*Tridacna maxima*) are still very common in the vicinity of shallow reefs near the south (Poland) pass and the starfish *Linckia* were widespread on many ocean and pass environments. The crown-of-thorns starfish was exceedingly abundant on reefs, fringing the south pass, and was also common on other ocean reef sites. The preferred prey corals include *Acropora* and *Favia* which may help to explain the present rarity of *Acropora* at Christmas. The sea cucumber population was surprisingly sparce in the outer lagoon and pass environments but more conspicuous at inner lagoon reef sites. Fishermen reported that large quantities of the sea-cucumbers were previously collected and sold to commercial interests as beche-du-mer, a delicacy in many Asian areas. Lobsters also used to be very common at Christmas, but were only rarely seen diving the surveys. Also, ornamental mollusks (cowries, cones, spider conches, etc) were not common. It may be that these species are depleted because of their commercial value. Fisherman also reported that sea turtle abundance, both at nesting beaches and swimming in nearshore waters, is also declining. Overharvesting of sea turtles, especially at nesting beaches may be responsible. Although the beaches of Cook Islet are protected, apparently only a few turtles now nest there.

Resource user surveys

Alan Friedlander conducted in depth interviews with fishermen and sport guides and he will report separately on the results of those surveys. My interviews focused on mapping the distribution of important renewable marine resources harvested at Christmas and the types of gear used to catch or collect fishery resources (shellfish and finfish). An unpublished map accompanies this report which provides the raw data collected during the mapping exercise. Figure 1 summarizes the results of the exercise. Figure 2 is a map showing the location of sport diving sites at Christmas provided by a local commercial dive operator, Kim Andersen. What both maps reveal is that fishing and sportdiving are concentrated along the western ocean reefs where more protection is afforded from wave action from the prevailing trade winds and where the two passes afford access between the ocean and lagoon. In addition, figure 1 and the interviews with fishers also demonstrate that fishing pressure is intense in the western lagoon and at marine habitats close to the three main villages. Friedlander (1997) describes these activities and associated issues in more detail.

DISCUSSION

Effects of the proposed actions on coral reef habitats

Several aspects of the proposed projects could have adverse effects on marine resources at Christmas

(1) improvements to existing port or construction of a new port near SE Point/Aeon field
(2) construction of "taxi" docks in the lagoon (near Boating Lagoon or South Pacific Island Airways wharf sites)
(3) improvements to fuel transfer facilities and operation of the facilities
(4) dredging of the navigation channel in the main (north) pass
(5) any dredging, blasting, filling, or discharge of dredged or fill material to create land or obtain materials
(6) disposal of rubbish, solid waste, sewage, thermal effluents and waste fuels near the coast or in marine waters resulting in pollution
(7) improvements to road causeways across lagoon habitats
(8) stormwater discharge into marine waters from the new facilities (dock, airfield, landing craft complex, employee lodging etc.)
(9) loss of sandy beach habitat if the employee lodging or other buildings are constructed too close to the shoreline

Indirect or secondary effects could result in the following adverse impacts:

(10) increased population growth with consequent increased exploitation of marine resources and local extinction of rare species (e.g. sea turtles, giant clams)
(11) increased demand on sportfishing and sportdiving sites due to increased visitor use
(12) conflicts between commercial, sportfishing, and subsistence use of edible marine resources, and
(13) construction of new deep water port shuttle and landing port facilities in the SE point area, leading to urban and industrial encroachment into valuable fish and wildlife habitat.

Each of these are discussed at greater length below.

Improvements to existing port or construction of a new port

The existing port at London was constructed in the World War II era and has not been repaired or maintained in recent years. The dock face consists of corroded sheet piling with some holes through which backfill erodes, piling up in the water adjacent the dock. Sediment accumulation against the sheet piling may also be attributed to the erosion or removal of a sand spit previously located a few hundred meters to the south. An old World War II era map shows the sand spit extending east from the tip of London's Bridges Point (figure 3). The erosion or removal of the spit may have changed water current and sediment transport patterns along the coast in the vicinity of the dock, and some of the sediment may be depositing at the dock face, carried into the lagoon during certain tidal or wave conditions.

It is not clear why sediment is accumulating in front of the dock. However, the causative factor (e.g. holes in the sheetpiling?, sediment deposit from outside sources?) must be identified before any corrective action is taken to replace sheet piling and dredge out the berthing area to accommodate shoreside docking by medium draft vessels. Otherwise the area around the dock may need to be frequently dredged to allow ships to moor at the dock.

Marine life around the dock was sparse and water visibility very low. Aside from a few sea urchins and benthic algal growths on the face of the sheetpiling no other marine life was present. Excavation of the berthing area near the dock to accommodate shoreside mooring of vessels should not affect the nearest coral reefs or other important marine ecological habitat nearby, provided that a bucket dredge or clamshell dredge is used to remove the sediment. Use of a suction dredge should include discharge of dredged slurries on land within a containment berm. Open water discharge of dredged materials should not be permitted. Silt curtains or temporary barriers consisting of sheet piling driven into the sand may be needed to keep suspended sediments from being transported out of the area where they could affect coral reefs and seaweed farms nearby.

A new port constructed landward of the shoreline near Aeon Field at the SE point would cause damage to some coral reef and shoreline habitat that would need to be blasted and dredged as part of a new entrance channel. However, most of the excavation to create the interior turning basin could be accomplished before the entrance channel is opened to the sea or dredged. Containment of most of the excavation behind a temporary barrier would greatly reduce the amount of sediment that would be discharged to reef areas. The adjacent reef areas are generally undisturbed and probably support large fish populations due to lack of easy access by fishermen and boats, thereby reducing fishing pressure. Coral reefs are expected to be robust and adapted to withstand heavy constant wave action at the point. It is likely that blasting would be needed for channel excavation through the shallow reef and shoreline. Drilling and shooting should be used to the maximum extent possible for channel excavation to limit the detrimental effects of blasting (e.g. shattering and concussion effects) to coral, fish and sea turtle populations.

Although placement of a new port near Aeon field would greatly diminish the need for road transportation and existing dock improvements, the new port could result in unregulated urban growth and disturbance to important seabird nesting areas nearby. The port would also open up easy access to new fishing grounds leading to rapid depletion of fish stocks for commercial export including food fish, aquarium fish, and shark fishing. If a new port option is pursued, careful planning and strengthening of land use and environmental conservation measures will be needed to protect and sustain world-class seabird populations and lagoon/marine fishery resources nearby.

Construction of shallow draft docks in the lagoon

Construction of shallow draft docks may be proposed to allow a speed boat shuttle service between the employee lodging facility at Poland and the airport. The boat shuttles would transport passengers (visitors, space shuttle port workers) between the main airfield at Cassidy, the existing hotel, the main port and the employee lodging facility. The most likely sites for docks to service the water taxis or shuttles would be in the vicinity of Boating Lagoon (near the Captain Cook Hotel) and the ruins of the wharf at the South Pacific Airways hotel site near Poland. Both of these sites were investigated during the May 1997 surveys (sites 11 and 13).

At both locations marine habitats lack coral reef organisms due to restricted lagoon circulation resulting from high temperatures and salinities. A few sea cucumbers, cyanobacteria patches, small sharks, small fish, and possibly a few crabs were noted. Construction of fill docks or open pile docks to a depth of 2-4m would pose no serious ecological or engineering problems. However, in order for the docks to be functional as serving as the destination points for water shuttle or taxi service, many lagoon reef flats would need to be dredged to a depth of 2-4m between the destinations to accommodate the boat traffic. Aside from the expense and logistical problems of dredging several kilometers of reef to a depth of 2-4m and a minimum width of 15m, the dredging of the channels would materially change water circulation patterns in the lagoon, including temperature and salinity regimes and disturb important subsistence and sport fishing grounds. Dredging operations may also result in transport of suspended sediments to adjacent areas of the lagoon and main passes via tidal currents, potentially disrupting important coral reef habitat. There is already evidence that construction activities and pollution in the main port area at London has deteriorated reefs in the north pass and adjacent coral reef areas, and that recovery of the reefs has not occurred. Additional massive amounts of dredging for the channels linking up the water shuttle/taxi docks may likewise spread damage to what are now healthy reefs in the lagoon, especially those south of Cook Island and fringing the southern main pass.

The high cost of dock construction and channel dredging may not be worth the expense of a water taxi option since other options are available, probably at less cost, to provide a shuttle service to transport passengers and workers use of hovercraft, improvements to existing roadways and renovation of the small abandoned "New Zealand Airfield" site at Poland seem more feasible and less environmentally damaging. Grading and resurfacing a 400m long and 30m wide airfield at the New Zealand site would render it capable of supporting the operation of STOL (short takeoff and landing) aircraft that could provide shuttle service between the main airfield at Casady, Aeon field (at the space shuttle landing site) and the New Zealand airfield at Poland. The improved road system could serve as a backup for transporting passengers when aircraft were being serviced.

Nevertheless, small docks, but without dredging navigation channels, may be useful at the South Pacific Airways and Boating Lagoon sites to enhance recreation and visitor opportunities. The docks could serve as departure points for sportfishermen, sport divers and provide swimming platforms for residents and visitors. Subsistence fishers could also land catch more conveniently at the new docks. The construction of open pile docks at both sites seems feasible and would not pose serious environmental problems.

small boat access "channel" between London dock and the main navigation channel (Cochran Pass) shows the presence of deteriorated reefs which pose hazards to navigation. Some of these reef areas may need to be cleared to allow safe passage of small boats, barges, and tugs at any stage of the tide. In addition, possible improvements to Aeon Field, the New Zealand Airfield, or to Casady Airfield may also require fill for extension, raising or leveling. These sources of fill and the possible use of dredging equipment and explosives have not yet been identified or specified as part of the proposal. These types of activities can result in potentially serious environmental impacts, especially if conducted near healthy coral reefs.

Precautions will be needed to control the effects of such activities including measures to reduce shock and concussion from explosives and to contain spoils and suspended sediments during dredging and filling. Shore or embankment protection may be needed to protect fill structures situated where wave action could erode them. Culverts and bridge openings may also be needed to maintain lagoon circulation and improve draining along the roadways. The specific mitigation measures, alternative designs, and monitoring schemes for such operations cannot be specified at this stage without knowing more of the specific details of the proposed project.

Disposal of rubbish, solid waste, sewage, construction debris, thermal effluents, waste fuels, etc.

Construction and operation of the employee lodging facility and especially the space shuttle landing facility will generate large quantities of waste including dunnage, packing crates, construction debris, excess chemicals (e.g. asphalt or concrete), empty containers, and worn or broken down construction equipment/heavy machinery. A plan should be in place to identify which of these materials can be used or recycled on island, burned, removed from the atoll, or disposed at the atoll. An assessment of disposal sites and maintenance for ecological, aesthetic, and public health purposes should be planned once the details are known on type and quantities. Ocean disposal should not be a preferred option for any of the above except perhaps for concrete debris, and thoroughly cleaned and drained equipment. Disposal sites either in the lagoon or ocean should be examined at several alternative locations for disposal based upon the expected ecological consequences. Since Christmas has extensive land area, a designated solid waste disposal site should probably be planned for both construction and operational phases. The site could also be used to collect much of the derelict machinery and scrap metal now scattered over the atoll.

The operational phase of both the employee lodging facility and space shuttle landing port will also generate solid waste, effluents and air emissions. Solid waste would include rubbish and garbage, non-serviceable equipment, appliances, and vehicles, and waste oils and chemicals. Effluents would include sewage discharges from both the lodging facility and space shuttle port, and perhaps thermal (heated water) effluents from power generating stations, air conditioning, and flash distillation systems to produce freshwater from saltwater. Air emissions shouldn't have much of an effect on marine resources

Clearly the present navigation channel is too shallow to accommodate ships drawing more than 10-12 feet (3-4m), and cannot be used during the periods of heavy swells and wave action from the north to southwest directions. Also, it is likely that if the channel is dredged to a greater depth, the huge reservoir of sand now accumulating in the channel would fill it up again after dredging, in a matter of a few months or years. To remove all loose sand from the channel and adjacent sand flats would be a massive undertaking since our observations revealed extensive sand deposits in the pass averaging at least 200 wide over a depth of 2 kilometers. If sand from the channel were to be excavated to lower its depth from 4 to 8m, the amount of sand that would need to be removed is estimated at 4 x 2000 x 200 = 1,600,000 m^3 of sand. Such a massive dredging operation would not only be expensive and potentially damaging to adjacent reef and beach habitats, but would also require disposal of sand slurry in an environmentally responsible manner. The quantity of dredging would require a suction dredge equipped with a cutterhead. The dredging operation would generate a sand slurry approximately 80% water and 20% sand that would need to be transported off site via a pipeline. The disposal site on land for such a quantity of sand would need to be huge and dedicated for long term stockpiling and drying before a use and disposition of the sand was decided upon. Discharging of the sand via open pipeline into deep ocean waters would be potentially damaging to deep coral reef habitats and bottom fishing grounds offshore from the west side of the atoll.

Realistically, dredging the existing navigation channel does not seem technically, environmentally, or economically feasible especially in relation to other options available for transporting the space shuttle, construction materials, equipment, supplies, cargo, heavy equipment, fuel, bitumuls, etc. Use of a tug and barge operation could accomplish the same without the need to deepen the existing channel. Cargos could be loaded on the barge either in Japan (at the departure point) or at a staging area offshore from the atoll. The barge in the latter case would serve as a lighter, taking on cargo from a bigger ship offshore that draws too much water to use the channel.

In a similar manner, the space shuttle, after landing at Christmas, could be transported by truck to London and loaded by crane onto the barge moored at the renovated dock. Then the accompanying tug could tow the barge out of the lagoon into the deep ocean where it could either be transferred to a larger ship or where the tug and barge would transport the shuttle all the way back to Japan. The tug and barge option for local transport of the shuttle would probably be cheaper and safer in the long run and avoid the costly environmental impacts of a massive dredging operation.

<u>Other dredging, blasting or filling to create and/or acquire construction materials</u>

The marine team is not knowledgeable about the exact details, if any, at this stage regarding the space shuttle project. It is conceivable that dredging, filling, or blasting may be needed to acquire fill for roads or render minor improvements to navigation. For example, some segments of the existing road network are low lying and poorly drained, especially during and after periods of heavy rainfall. Elevating the roadbed may be necessary, which in turn would require a source of sand or coral rubble as fill. Also, the

Airai (Palau), Garapan (Saipan), and Agana (Guam). A particularly relevant example of urban growth in Micronesia was the rapid in-migration of Marshallese and other Micronesians to Ebeye island shortly after the missile range was constructed at Kwajalein Atoll in the early 1960s. In a matter of a decade, Ebeye's population increased from less than 1,000 to over 10,000 on what was then a 70 acre island. Only a small fraction of the huge population was actually successful in getting jobs at the missile range - 90% about 1,000 Micronesians; the remaining 10% continued to live in Ebeye, dependent on the wages of the working family members and ever hopeful of landing jobs themselves. Many young residents were simply attracted to the prospect of modern night life and excitement associated with living in a boom town.

The public health and environmental consequences of earlier population growth at Ebeye have still not been completely resolved despite nearly 3 decades and abundant sources of funds to restore adequate living and environmental conditions. Solid waste disposal, sewage discharge, poor sanitation, contaminated water supply, poor nutrition, poverty, crime, lack of adequate education for children, and other social impacts continue to challenge government and non-government organizations at Kwajalein and Ebeye.

Fortunately, the situation is not the same for Christmas in that the Kiribati government "owns" the land and is in a position to control immigration to Christmas and otherwise implement other preventive measures. Of particular concern at Christmas will be the potential for rapid population growth in the London-Tabakea-Banana urban center, the influx of families and workers to Poland, and haphazard urban development at Aeon Point, especially housing the families of workers. In turn this growth, if unplanned could result in serious impacts to fish and wildlife including decimation of nearby seabird breeding colonies, depletion of inshore fish populations, sewage pollution, groundwater contamination, and uncontrolled rubbish and garbage dumping. The government of Kiribati will need to make advanced, plans on what levels of urban development it desires, where, and how to control it. It will need to work closely with the proponents of the space shuttle port to address the need for proper and realistic plans and measures to protect public health and the environment.

Increased demand for sportfishing and sportdiving

The construction and operational phases of the space shuttle port will increase the population of outside visitors and workers at Christmas, which in turn would increase demand for sportdiving and sportfishing opportunities. Interviews with sportfishing guides in May 1997 revealed that there are already conflicts between sportfishing interests and subsistence fishermen at the inner lagoon bonefish habitats and that there are also conflicts with commercial fishermen (especially aquarium fish collectors) and sportdiving interests. Clearly there is inadequate regulation and control of commercial and subsistence fishing at Christmas even though several regulations and protected areas have been designated. These conflicts are related in part to increasing population and immigration levels at Christmas and in part to inadequate management regimes for marine resources exploitation. These regimes will need to be strengthened in the near future to protect the although possible effects on terrigenous wildlife and settlements should be assessed. At this stage it is difficult to estimate the quantities and possible disposition options for all of the above but eventually long-range plans should be developed for proper disposal of all waste and pollutants.

Improvements to roads and causeways

Improved road networks will be an obvious need of the project especially to allow faster and more reliable ground transportation between the existing hotel, the employee lodging facility near Poland, the port at London, and the space shuttle port at Aeon. Some roads will need to be improved to withstand heavy loads for transporting equipment, machinery, construction materials, fuels, and the space shuttle itself. Other roads will need to be improved to promote safe, quick, and reliable transportation of visitors and passengers, including possible "short-cuts" across lagoon areas. Several previous road projects across the lagoon have blocked circulation in some ponds and may have degraded the ecology of the systems by lower nutrient flux and increasing temperature and salinity regimes, based on observing road asphalt, dead shells/skeletons, and few live organisms in the inner lagoon environment near Boating Lagoon. The proposed road improvements provide the opportunity to design for small bridge crossings and adequately sized and designed culverts to maintain or restore adequate tidal circulation in the back lagoon and also allow more passages for fish runs and migrations. Again the sources of fill for road improvements need to be identified and assessed at a later stage to minimize unnecessary adverse effects on marine, coastal, and terrigenous habitats.

Stormwater discharge into marine waters

Extensive paving and sealing of airfield and road surfaces and the construction of hangars and other buildings will increase freshwater runoff at localized areas during periods of heavy runoff. Drainage facilities will need to be properly designed to avoid localized flooding and standing water and prevent contamination of stormwater runoff from oils, fuels, and other potentially toxic, hazardous or otherwise undesirable chemicals. Eventually all stormwater runoff will seep into lagoon and nearshore ocean environments, either as surface runoff or groundwater discharges. Plans will be needed to avoid contamination of groundwater, especially from improper handling and disposal of toxic and hazardous waste, and from contaminated stormwater runoff.

INDIRECT EFFECTS

Increased population growth and urbanization

The construction and operation of a space shuttle landing port at Christmas, especially if it is eventually expanded to include launching facilities, will attract residents from other atolls in Kiribati to live at Christmas. The prospect of increased opportunities for jobs, businesses and cultural diversity has led to rapid urbanization in many other Micronesian Islands: Majuro, Tarawa, Weno (Chuuk), Kolonia (Pohnpei), Colonia (Yap), Koror and lifestyle that would be stimulated by the proposals. Protection of important coral reef, fish, and wildlife resources as well as improved management of existing protected areas is needed.

RECOMMENDATIONS

Several port options should be evaluated before any one option is selected for implementation. These include:

1) improvements to the existing main dock and berthing area at London
2) deepening the navigation channel through the north pass into the lagoon
3) construction of a open-pile pier off the ocean side of north London
4) construction of an inland harbor at Aeon Pt.
5) Construction of small docks in the lagoon at the Boating Lagoon and South Pacific Airways sites,
6) tug and barge operation to transport equipment, construction materials and the shuttle, and
7) dredging or clearing of a small access channel from the north pass to the main dock

Of the above options, 2 and 3 do not seem feasible: the dredged channel would likely fill in again; and a dock off the ocean side of the reef would likely be destroyed by high waves. Options 1,6, and 7 seem to be the most favorable from technical, cost, and environmental standpoints. A tug and barge operation precludes the need for dredging the main (north) pass. Improvements to the main dock and access channel would certainly be favored by existing residents and the government, and would eliminate urban sprawl in new areas. An ocean facing dock off North London also has government support.

Improved water transportation between the various foci of activity on the atoll (London, Banana, Casady, Poland & Aeon) should also involve evaluation of several options:

1) a boat taxi or shuttle between London, Boating Lagoon [near Casady and Banana] and the South Pacific Airways wharf [near Poland] sites
2) improved road network connecting all five destinations, and
3) development of a small airfield at the "New Zealand Airfield" site near Poland and use of an air taxi service

Of these three options, the first is clearly expensive and would result in major damage to reefs from dredging and changes in water circulation; it may also not be feasible in reducing travel time compared to road transportation. Option 2 appears to be necessary for a variety of proposed actions including construction of facilities and movement of heavy equipment between Aeon and London, including the shuttle itself. Option 3 could serve as the preferred means for shuttling passengers between points, with the road option serving as backup during unfavorable flight conditions or when the plane was off island or being serviced. The plane option would also help support commercial/commuter air variety of uses and values of marine resources and avoid serious conflicts and lost opportunities.

CONCLUSIONS

Christmas atoll supports relatively healthy coral reef ecosystems except for degraded reefs in the north lagoon and pass area near the atoll's urban center and main port. Anthropogenic stress, especially previous dredging and filling, pollution, and excessive filling may likely explain depressed levels of corals and deteriorating reefs in the north lagoon and pass. Natural stresses also limit coral and reef development elsewhere at Christmas. Unfavorable water circulation, temperature, and salinity conditions are the causes for the lack of corals and most other reef invertebrate species within the inner lagoon. Wave action appears to restrict coral and reef growth along ocean facing reefs except along the more protected southwestern side of the atoll. There is also evidence of a large previous infestation of the crown-of-thorns starfish, a natural predator of corals, and populations of the starfish were quite high on reefs fringing the outer southern pass. Large fields of dead standing staghorn-coral were reported in the Bay of Wrecks (site 2) and serve as evidence for previous outbreaks of the starfish and predation on stony corals.

Corals, other reef invertebrates, and reef algae are well represented at Christmas and are comparable to the levels of species richness reported for corals at nearby atolls in the northern Line Islands (Fanning=Tabuaeran, Palmyra) and in the Phoenix Islands (Kanton). The species and generic diversity of corals at Christmas is much higher than reported for Johnston Atoll and the Hawaiian Islands well to the north. Many of the reefs on the SW ocean facing slopes and in the central outer lagoon and fringing the south pass are in excellent condition and serve as excellent sportdiving sites. The reefs are also exploited for a variety of fisheries including commercial, sport, subsistence and aquarium trade. The reefs also support important shellfish including small giant clams, and lobsters which also have subsistence and commercial value. Sea turtles forage on ocean reefs and apparently still nest at a few beaches on the atoll. Clearly coral reefs are among the most important of the natural resources at Christmas and deserve priority attention in terms of minimizing the adverse environmental effects of the proposed space shuttle port and ancilliary facilities.

Principal sources of potential impact would stem from construction or renovation of the main London port and navigation channel and from the construction of new docks in the lagoon. Dredging, filling, blasting, or shore protection associated with the airfields, or acquisition of construction materials from marine environments also pose serious threats to marine ecosystems. Improvement to existing fuel transfer, waste management and fish and wildlife conservation measures are also needed to reduce impacts from future space shuttle facilities and operations. Road improvements will need to accommodate improved drainage and installation of culverts or small bridges to restore circulation in some of the inner lagoon ponds. Stormwater runoff and shoreline setbacks structures near beaches must be carefully planned. Of major concern will be the need to control future population growth and urban sprawl attributed to immigrants seeking jobs and a more "modern"

atoll. I thank Kim Andersen for providing boat and diving support and advice on marine environments at Christmas. I thank the members of the Kiritimati Government Hope-X Coordinating Committee for meeting with the environmental team including Katino Teebaki, Retati Smith, Iotam Kirati, Andrew Teem, Mapuola Iosua, Depweh Kanono, and Michael Tekanene. I thank John Bryden for serving as our host and providing ground transportation support and historic information about Christmas dating from the 1950's. I thank Philip Wilder for briefing the marine team on the status of the aquarium fishing industry on Christmas Atoll. Finally, I thank Sandy Osaki, Jane Ho, Vivian Gutierrez, and Shayne Hasegawa of the East-West's Center's Program on Environment for word processing support.

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service between Christmas, Fanning and Washington, which would defray some of the expense of maintaining a functional airplane on site.

Management of fish and wildlife seasons, beaches, and existing protected areas is needed to withstand more intensive impacts when the proposed space shuttle port is operational. In particular long-range plans are needed to reduce urban encroachment (including water reserves). Enhanced monitoring and enforcement activities are needed. These actions would also help to defuse the expanding level of conflict between subsistence, sport and commercial fishers.

Mitigation measures will be needed to reduce the effects of waste disposal, sewage discharges, and other pollutants. Recycling, burning, compaction, and consolidation of solid waste should be planned. A landuse or zoning plan needs to be finalized, implemented, and enforced to prevent urban encroachment into valuable fish and wildlife areas. Measures may also be needed to minimize the effects of dredging, filling, and blasting including:

1) use of silt curtains or other barriers to contain resuspended sediments,
2) use of sedimentation basins or enclosed discharge basin for pipeline slurry, if any
3) preconstruction of shore protection and then backfilling behind the structures to limit sedimentation of fill operations,
4) selecting dredging and quarrying sites away from coral reef and beach sites,
5) use of drilling and shooting for explosive excavation and fracturing of rock,
6) establishing turbidity monitoring during construction and a water quality performance standard,
7) institute a long range monitoring program before, during and after construction or operational phases, including the training of local government staff to implement the monitoring
8) stockpiling dredged or fill materials on land or within enclosed basins

Finally an atoll-wide public involvement program is needed to solicit the views of residents on their concerns, opinions, and suggestions. This will be especially important in promoting jobs and business opportunities, but without haphazard urban sprawl and unmanaged waste disposal. These meetings might also help to diffuse existing conflicts between fishers and identify other useful measures and ideas to reduce the effects of the proposals on the environment.

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Table 2. Master list of stony coral species reported at Christmas Atoll in May 1997. Numbers refer to site location and letters in parenthesis following each number are the estimate of the relative abundance of the species at the site.
D=dominant, A=abundant, C=common, O=occasional, and R=rare. + = non scleractinians

Acropora himilis	9 (O)
A. formosa	2 (dead)
A. gemmifera	3 (O)
A. clathrata	4 (O), 7(R), 15 (R)
A. nasuta	2 (C/A)
A. robusta	2 (A)
A. secale	2 (O)
A. selago	2 (O)
A. valida	3 (O), 8(O)
A. spicifera	3 (O)
Astreopora gracilis	7(O), 8(O), 9(O), 16(C)
A. myriophthalma	2(C), 4(C), 5(C), 7(A), 8(A), 9(C), 15 (A), 16(C)
A. sp	16 (R)
A. cucullata	15(R)
A. listeri	7(R)
Barabattoia amicorum	7(R)
Cycloseris sp	9(O), 15(O)
C. tenuis	7(C)
C. vaughani	7(O), 9(O), 15(O)
+*Distichopora violacea*	7(C)
Echinophyllia aspera	2(R), 7(O), 15(C)
Favia matthai	2(O), 7(A), 8(A), 9(C), 15(C), 16(O)
F. pallida	15(C)
F. speciosa	2(C), 7(A), 8(A), 9(A), 15(A)
F. stelligera	2(A), 3(A), 4(A), 5(R), 7(A), 8(A), 9(A), 15(D), 16(D)
Favites halicora	8(R), 15(O), 16(O)
F. pentagona	2(C), 3(D), 7(A), 8(A), 9(A), 15(A), 16(A)
Fungia (Danafungia) danai	15(A)
F. (Verrillofungia) concinna	2(C), 16(O)
F. (Lobactis) scutaria	2(C), 7(C), 8(O), 9(C), 15(O)
F. (Pleuractis) paumotensis	9(R), 7(O)
F. fungites	2(A), 7(C), 8(C), 9(C), 15(C), 16(C)
F. (D.) horrida	16(A)
Gardineroseris planulata	2(R), 15(A), 16(O)
Halomitra pileus	15(R)
Herpolitha limax	2(C), 7(A), 8(C), 9(A), 16(R)

Table 1. Synopsis of the marine sites surveyed during the May 1997 visit to Kiritimati Atoll.

Site No:	Site Name	Location	Type of Survey	Relevance to proposed development
1	Aeon	SE point	ocean shoreline survey	closest marine area to shuttle landing site & possible port site
2	Bay of Wrecks	E Coast	ocean scuba survey and transects	closest accessible "reference" site to Aeon field
3	Navy/ N. London	NW Coast	ocean scuba survey	close to proposed ocean dock site and fuel transfer facilities
4	Outer Cochran Pass	W Coast	scuba drift dive in pass (begin)	existing navigation channel between lagoon and ocean for main port
5	Inner Cochran Pass	W Lagoon	scuba drift dive in pass (end)	close to access channel from navigation channel to main port
6	Wilkes Lagoon	NW Lagoon	lagoon scuba survey and transect	shallow reef areas that may need to be dredged to improve access to main port
7, 14	Poland Caves	SW Coast	ocean scuba drift dives (two)	most important recreational sport dive site on atoll and reference site for survey
8	View Finder	SW Coast	ocean scuba survey and transects	most important recreational dive site nearest to proposed Poland employee lodging site
9	Cook Pass	W Coast	scuba survey and drift dive in pass	only other pass into lagoon; reference site and two sport diving sites
10	London Dock	NW Lagoon	lagoon snorkel survey	existing main port and seaweed culture sites
11	South Pacific Airways employee lodging-wharf site (ruins)	SW Lagoon	lagoon snorkel survey	proposed dock and water taxi landing for proposed Poland lodging facilities
12	Inner Cook Pass	W Lagoon	lagoon scuba survey and transect	excellent shallow reference reef inside the South Pass
13	Boating Lagoon	NW Lagoon	lagoon snorkel survey	proposed dock and water taxi landing for existing Capt Cook Hotel and Banana Village
15	Ocean Pinnacles/ Grapple Reef	W Coast	ocean scuba survey	ocean reef closest to protected area of Cook Islet
16	Cook Lagoon Reef	W Lagoon	lagoon scuba drift dive	lagoon reef closest to Cook Island protected area

Table 2. Continued	
P. lobata	2(C), 3(C), 4(A), 5(R), 6(R), 7(A), 8(A), 9(A), 15(D), 16(D)
P. lutea	2(C), 7(C), 9(C), 16(C)
P. solida	9(O), 5(O)
P. sp.	6(R)
P. pukoensis	16(C)
Sandalolitha robusta	7(A), 9(C), 14(A), 16(R)
+*Stylaster* sp.	14(C)
Tubastraea coccinea	14(C)
Turbinaria veluta	7(C)

Totals 31 genera 83 species

Table 2. Continued	
Hydnophora microconos	2(C), 6(O), 3(C), 4(O), 5(C), 7(A), 8(A), 16(A), 9(A), 15(A)
H. rigida	7(O), 15(C), 16(O)
Leptastrea purpurea	2(C), 3(O), 4(C), 7(C), 8(C), 9(C), 15(C), 16(C)
L. transversa	7(A), 8(C), 9(C), 15(A), 16(C)
L. sp.	16(R)
Leptoseris scabra	7(O), 15(O)
L. mycetoseroides	2(R), 7(R), 15(O)
Lobophyllia costata	7(O)
L. hemprichii	2(O), 7(O), 8(O), 9(O), 15(O), 16(O)
Montastrea curta	2(C), 3(A), 4(O), 7(C), 8(O), 16(O)
M. sp	16(R)
Montipora aequituberculata	2(A), 7(A), 8(A), 16(C)
M. caliculata	4(R), 9(C), 16(O)
M. foveolata	3(O), 4(O), 16(R)
M. grisea	14(C), 16(C)
M. millepora	14(C)
M. sp	8(O)
M. tuberculosa	2(O), 3(A), 4(C), 7(C), 8(C), 9(A), 15(A), 16(A)
M. verrilli	2(C), 4(C), 7(C), 8(C), 15(C), 16 (O)
+*Millepora platyphylla*	3(C/A), 7(A), 8(A), 9(C), 15(O), 16(O)
Oxypora lacera	2(O), 15(O)
Pavona duerdeni	2(C), 3(C), 7(C), 8(C), 9(A), 16(A)
P. minuta	8(C), 9(C)
P. varians	2(A), 7(C), 8(A), 15(A)
P. explanulata	9(R), 15(O)
P. venosa	6(R), 3(C), 4(O), 7(C), 8(O), 9(O), 15(O), 16(A)
P. clavus	15(R), 15(R)
Platygyra daedalea	2(C/A), 7(C), 8(C), 9(C), 15(O)
P. lamellina	2(C), 3(A), 4(A), 7(A), 8(A), 9(C), 16(A)
P. sinensis	2(O), 7(C), 8(C), 15(C), 16(C)
Pachyseris rugosa	2(C), 3(C), 7(O), 15(R)
Plerogyra sinuosa	7(R)
Pocillopora elegans	2(R)
P. eydouxi	2(A), 6(D), 3(A), 4(A), 5(D), 7(A), 8(A), 9(D), 15(D),16(D)
P. meandrina	2(D), 3(C), 4(C), 5(O), 6(C), 7(A), 8(A), 9(A), 15(D), 16(A)
P. verrucosa	7(O)
Psammocora profundacella	2(C), 12(R)
Porites australiensis	5(O), 16(A)

Table 3 continued

Soft corals, colonial anemones, and black corals

Palythoa tuberculosa 2(C), 3(A), 7(C), 9(C), 15(C), 16(0)
Sarcophyton sp 3(C), 7(D), 8(C), 9(A), 14(D)
Simularia sp 3(0), 7(C), 8(C)
Sclerophytum sp 3(C), 7(A), 8(A), 9(A), 14(A), 16(0)
Cirrhipathes sp 9(A), 14(A), 7(A)

Worms and other invertebrates

spagetti worms 4(0), 5(0),
Pinna sp 5(C)

Table 3. *List* of conspicuous invertebrates and marine algae reported at Christmas Atoll during the field surveys in May 1997. For *Acanthaster*, the actual number seen per site is reported in parentheses.

Marine Algae

Ulva sp 1(A)
Caulerpa sp 1 (A), 16 (A)
Enteromorpha sp 1 (C)
Jania sp 2 (D)
Halimeda discoidea 2 (A), 3(A), 4(A), 5(A), 7(A), 9 (C)
H. opuntia 3(C), 4 (C), 7 (A), 9 (A), 16 (A)
Cladophora sp (tubes) - 4 (A)
Codium sp 4(C), 5 (C)
Padina sp 5 (A)
Eucheuma sp (escaped introduction) 5 (C)
Porolithon sp 1(A), 2 (A)
Goniolithon ? sp 16 (A)

Macro Invertebrates (other than stony corals)
Echinoderms
Holothuria atra 1(C), 2 (C), 5 (A), 9 (A)
Ophiodesoma spectabilis 5 (A), 6 (A)
Bohadshia argus 4 (A), 5 (A), 9 (A), 16 (C)
Stichopus chloronotus 5 (A)
S sp1 14 (C)
S sp 2 14 (C), 16 (A)
Echinothrix calamaris 2 (0)
E diadema 3(A), 6 (C), 5 (C), 14 (A)
E. sp (white spines) 5(C), 6 (A)
Echinometra mathaei 4 (A)
Linckia sp (grey) 3(C), 4(C), 9 (C), 14 (C), 15 (C)
Culcita novaeguinae 5(0), 7 (0), 16 (0)
Acanthastrea planci 7(4), 9 (17), 15 (4), 16 (2)
Mollusks
dead clamshells (unid) 4(C), 5(C)
Tridacna maxima 2(0), 7(C), 5 (0), 16 (A)
T. squamosa 7(0)
T. crocea 2 (C)
Pinctada margaritifera 4(0), 7(R)
gold lipped pearl shell 15 (0)
Lambus sp 9(R)
Conus sp (large, orange) 5(0)

Table 5 Summary of resource and use information for lagoon and ocean environments at Christmas Atoll, based upon interviews with fishery officers and sport fishing guides

Map Code	Use Category	Principal Resources	Location & Notes
A	gill net	milkfish	outer lagoon and all ocean coastlines except the west
B	hand line	bonefish, trevally	near outer passes and many ocean coastlines
C	drop line	deep snappers & groupers	all ocean reef slopes from 15-200 m depth
D	small nets & crowbars & snorkel	aquarium fish	ocean reefs, especially along west side and other accessible locations to depth of 6 m
E	traps	eels	off London, Cook Islet and SW ocean coastline
F	castnets (parachute & handnets)	surgeons, mullets, parrots	any accessible ocean shoreline & lagoon shore near Benson Pt.
G	spears, spearguns	surgeons, parrots, groupers	outer passes and west & north ocean coats
H	gleaning	beche du mer, sea cucumbers (for sale)	lagoon reefs & flats, outer passes, & ocean shorelines around SE Pt.
I	floats & chains, & hooks on wire leaders	sharks (fins for sale)	all ocean reef slopes, except near SE point where sharks too are big or inaccessible
J	mariculture	*Eucheuma* (red seaweed)	entrances to lagoon on flats at London & Benson Pt.
K	gleaning/collection	pearl shell	western ocean reef slopes & outer pass reefs
L	spears, ropes, or catching by hand	nesting or swimming sea turtles	Cook Islet, Artemia Corner, Joe's Hill, or South Coast beaches & ocean waters
M	gloves, catching by hand, feet	lobsters	all ocean reef slopes and flats except W and SW sides
N	catching by hand	land crabs	all land areas
O	gleaning	hermit crabs	all areas at edge of beach
P, T	gleaning	mantis (snapping), shrimp	sand flats and burrows in Central lagoon (Norman's, Ellis, Wilkes & St. Stanislas Bay)
Q	gleaning	birds and eggs	officially prohibited and no data were available
R	gleaning	giant clams (*Tridacna* spp)	southern pass and outer south lagoon (St. Stanislas Bay)

Table 4. Summary data on coral species richness, (number of species) abundance (percent cover), size (average segment length), number of colonies, and notes for each of the 16 survey sites. nd = no data collected.

Site number	coral abundance	species richness at site	no. of species on transect line	number of corals on line	stony coral size	soft coral size
1.	ND	ND	ND	ND	ND	ND
2.	5.8-12.7	36	3-4	12-15	9-24	
3.	21.2	17	9	17	6.67-9.82	
4.	10	16	ND	ND	ND	
5.	1	16	ND	ND	ND	
6.	0-0.2	5	0-1	0-1	0-14.0	
7.	50	43	ND	ND	ND	
8.	48.9	30	23	76	5.68	20.1
9.	90	31	ND	ND	ND	
10.	0	0	ND	ND	0	
11.	0	0	ND	ND	0	
12.	60.2	30	21	76	7.18	8.4
13.	0	0	ND	ND	ND	
14.	80	45	ND	ND	ND	
15.	90	35	ND	ND	ND	
16.	60	36	ND	ND	ND	

Notes

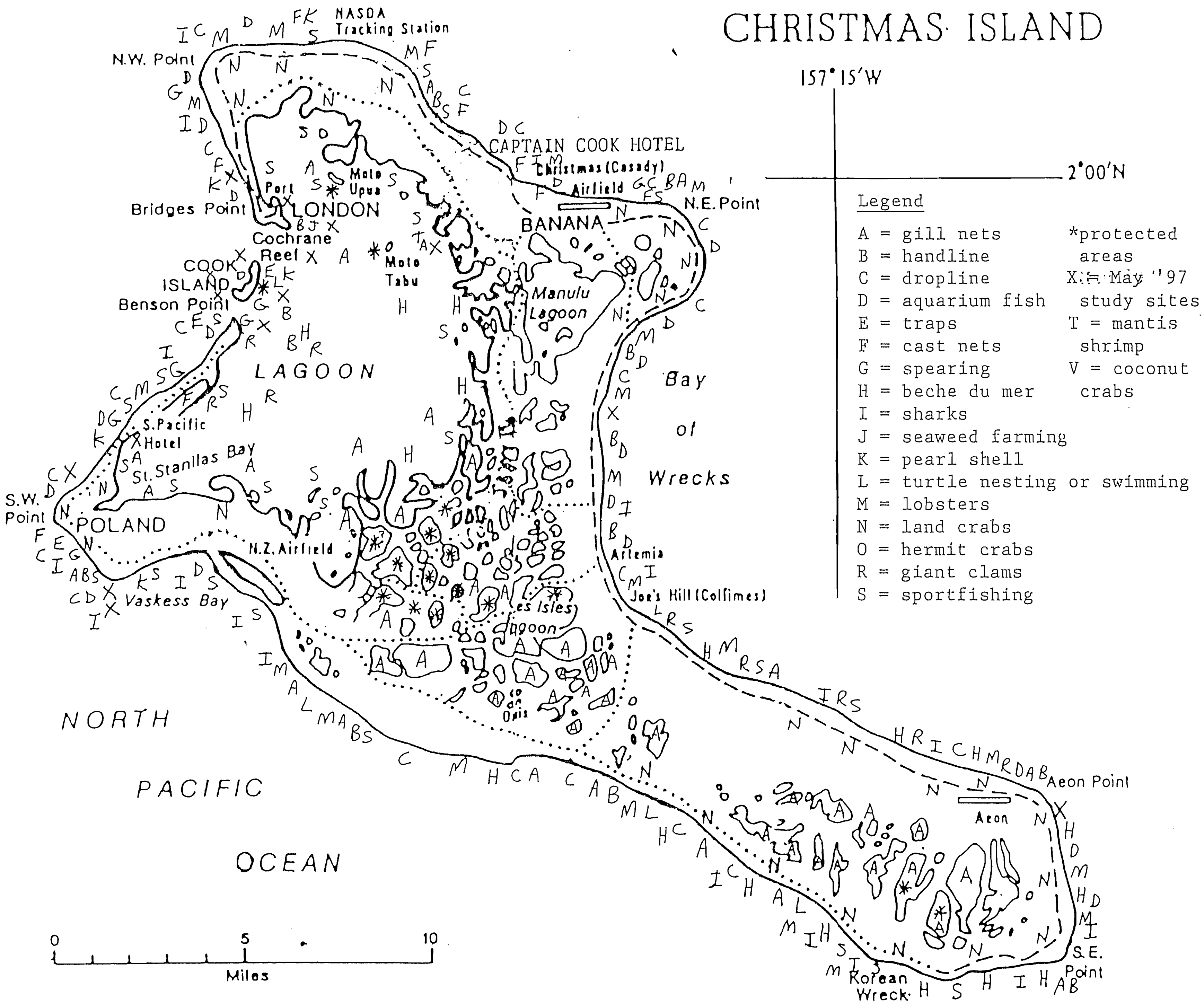
site 1	wave exposed reef flat near SE point
site 2	young ocean reef slope coral community, mostly small *Pocillopora* and *Pachyseris*, recolonizing large fields of dead standing *Acropora*
site 3	ocean reef slope of corals and sand, heavily scoured by wave action
site 4 & 5	disturbed or degraded coral reef community along edges of northern pass
site 6	deteriorated coral reef in lagoon near access channel and London village
site 7 & 14	spectacular ocean reef slope with abundant corals and fish
site 8	well developed ocean reef with abundant corals opposite Poland hotel site & beach
site 9	florishing coral & fish communities along outside and edge of southern pass
site 10	disturbed docks & basin environment, devoid of corals & with seaweds & sand
site 11	inner lagoon sand flat with sparse fish, sea cucumbers and algae
site 12	flourishing coral & fish communities, along lagoon end of southern pass
site 13	disturbed inner lagoon sand flat with mostly algae, sea cucumbers, and few fish
site 15	spectacular ocean pinnacles with abundant coral & fish off shore of Cook islet
site 16	well developed coral communities on shallow lagoon flat behind Cook islet

Table 6 List of issues and needs raised at interviews and meetings

1. unsafe diving and lack of conservation practices by aquarium fishers, especially those using SCUBA
2. conflicts over bonefishing between subsistence and sportfishing interests
3. decline of bonefish, sea cucumbers, sea turtle nesting, and giant clams
4. haphazard declaration and enforcement of lagoon areas protected for bonefish
5. pollution and other anthropogenic impact to reefs in northern (Wilkes) lagoon near major settlements (London, Tabakea, Banana)
6. seaweed culture (*Eucheuma*) blocking bonefish migration runs
7. main dock mostly unusable due to sediment buildup
8. entrance channel (north pass) unsafe due to shallow depth and periodic large waves
9. all commercially valuable fin and shell fisheries have been depleted, including lobsters, sharks, giant clams, pearl shell
10. lack of reliable air passenger and air cargo service
11. local officials desire improvement of road to London from airport
12. local officials desire improvements of road from Artemia to Poland
13. local officials question the proposed location of worker housing; housing needs to be constructed first before other facilities
14. local officials desire dredging and replacement of sheet piling at London Wharf
15. local officials have major concern over massive dredging and filling
16. local officials feel need for quarantine and rat guards to control introduction of new rat species from ships and barges
17. local officials feel there are inefficient cargo handling procedures at London (e.g. lightering rather than dock-side operations
18. removal of sand jetty in front of wharf caused sediment buildup
19. concern over bird impacts due to use of Aeon field
20. need to incorporate training of local people as part of future environmental monitoring
21. potential conflicts between water reserve designation and residential/urban encroachment
22. need for more jobs for locals as part of the new projects, especially the hotel
23. need for reliable power, possibly using waste heat generation or flash distillation systems
24. too many aquarium fish operators now; need appropriate harvest levels
25. need limits on the number of sport fishing guides/fishermen for bonefish
26. some fishers challenge protected areas designation and continue to fish anyway
27. fishery officers need to be present at the lagoon "gates" to better control unauthorized fishing
28. generally the most popular fishing areas are off the north where most people live and where there are signs of resource depletion
29. milkfish populations are declining in the lagoon
30. too crowded for bonefishers; many visitors don't want to see other fishers while fishing
31. protection of bonefish and milkfish grounds is needed on additional lagoon reef flats
32. lagoon reef is "dead" on north side and exposed to muddy, milky waters, especially during spring tide conditions
33. Cook Island needs proper policing for protection of birds and sightseeing opportunities

Sandalolitha	-	-	1	1	1	1
Stylophora	-	-	1	1	-	-
Stylaster	-	-	1	1	1	1
Tobastraea	1	-	1	1	1	2
Turbinaria	-	-	1	-	1	1
TOTALS						
genera	16	14	30	31	33	35
species	50	32	94	72	87	84

Figure 1


CHRISTMAS ISLAND
157° 15'W
2° 00'N
Legend
A = gill nets
B = handline
C = dropline
D = aquarium fish
E = traps
F = cast nets
G = spearing
H = beche du mer
I = sharks
J = seaweed farming
K = pearl shell
L = turtle nesting or swimming
M = lobsters
N = land crabs
O = hermit crabs
R = giant clams
S = sportfishing
*protected areas
X = May '97 study sites
T = mantis shrimp
V = coconut crabs
NASDA Tracking Station
N.W. Point
CAPTAIN COOK HOTEL
Christmas (Casady) Airfield
N.E. Point
Bridges Point
Port LONDON
Moto Upua
BANANA
Cochrane Reef
Moto Tabu
COOK ISLAND
Benson Point
Manulu Lagoon
LAGOON
Bay of Wrecks
S. Pacific Hotel
St. Stanilas Bay
S.W. Point
POLAND
N.Z. Airfield
Artemia
Joe's Hill (Collimes)
Vaskess Bay
Les Isles Lagoon
Oasis
NORTH PACIFIC OCEAN
Aeon Point
Aeon
Korean Wreck
S.E. Point
0
5
10
Miles

Dive Kiribati

Christmas Island Dive Sites

Christmas Island

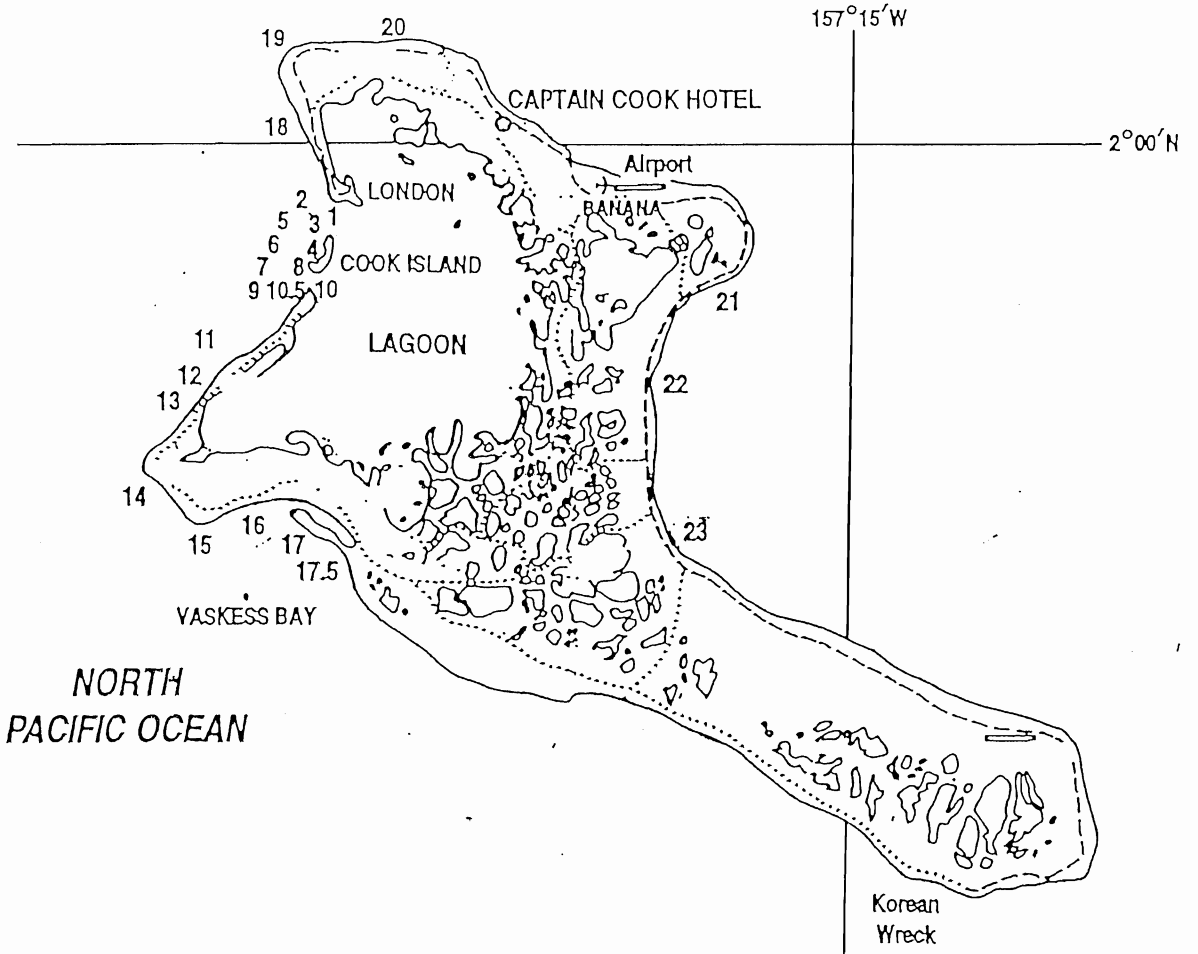
1. Cochrane Reef
2. M Spot
3. The Cable
4. Cook Island Groove
5. Pete's Mound
6. Gert's Pinnacle
7. Grapple Rocks
8. Coral Gardens
9. Table Top
10. Sand Pit

10.5 The Edge

11. Quarter Way
12. Mid Way
13. View Finder
14. The Throne
15. Poland Caves
16. The Bear
17. Cecile Point

17.5. Your Place

18. Lion Fish Wall
19. North West Drift
20. NASDA Drift
21. The Rock Crusher
22. Hede's Garden
23. Artemia Site



Presented by *Frontiers.*

Figure 2

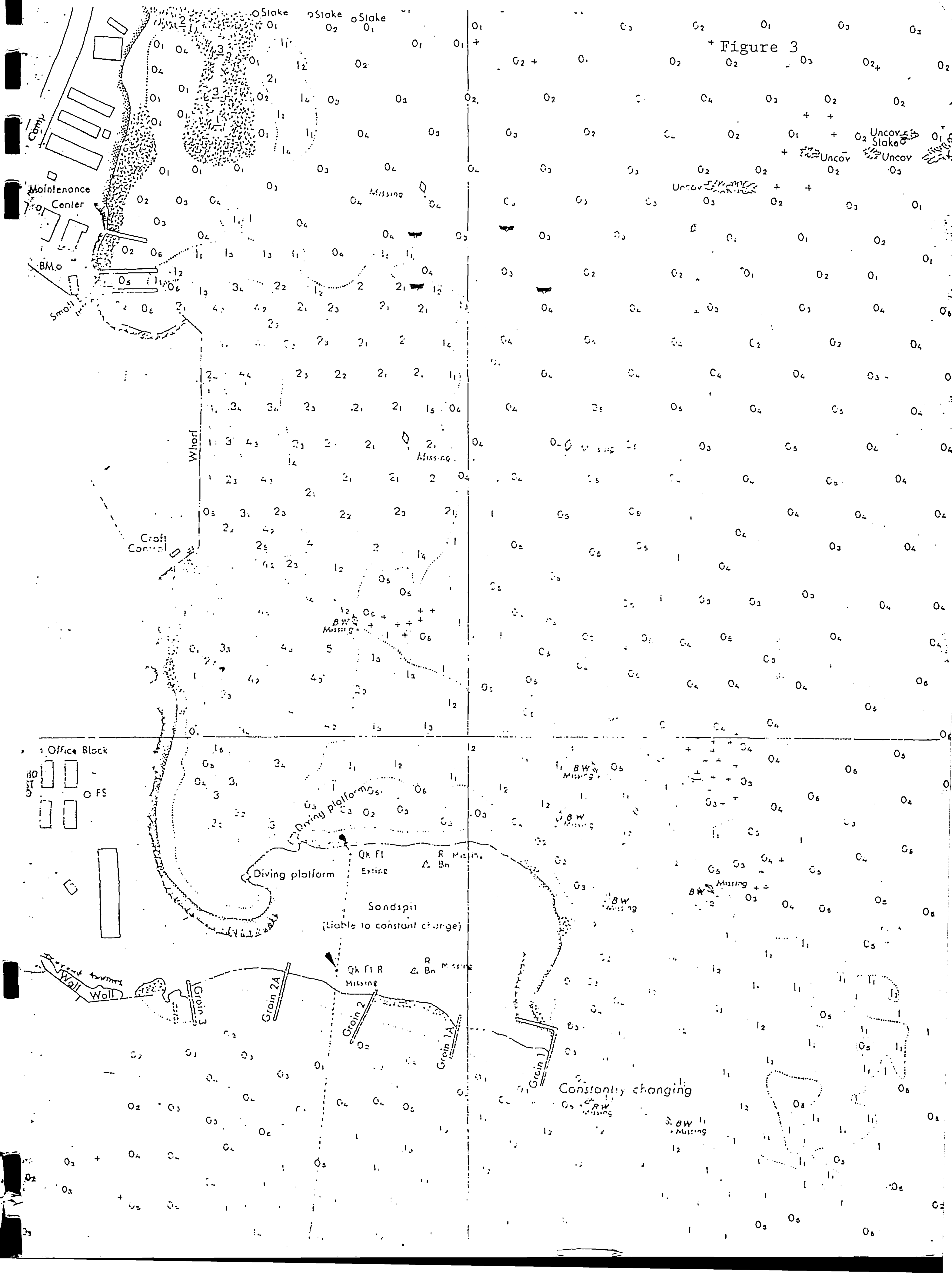

Stake
Stake
Stake
Camp
Maintenance Center
BM
Small
Wharf
Craft Control
Office Block
FS
Uncov
Stake
Uncov
Uncov
Uncov
Missing
Missing
BW Missing
Diving platform
Diving platform
Qk Fl
Extinc
Bn
Missing
Sandspit
(Liable to constant change)
Qk Fl R
Missing
Bn
Wall
Wall
Groin 3
Groin 2A
Groin 2
Groin 1A
Groin 1
Constantly changing
BW Missing
BW Missing
BW Missing
BW Missing

Figure 3