APPENDIX G-8

MARINE RESOURCES STUDY REPORT

TC K838-0402

MARINE RESOURCES STUDY
FIELD SAMPLING RESULTS AND RISK ASSESSMENT

MĀKUA MILITARY RESERVATION
O`AHU, HAWAI`I

Contract Number GS-10F-0268K
Delivery Order Number DACA 83-02-F-002

August 2008

Prepared for:

US Army Corps of Engineers
Honolulu District
Environmental & Special Projects Branch
Building 252
CEPOH-PP-E
Fort Shafter, Hawai`i 96858-5440

Prepared by:

Tetra Tech, Inc.
737 Bishop Street, Suite 3020
Honolulu, Hawai`i 96813

EXECUTIVE SUMMARY

Tetra Tech conducted a marine resources study to determine if marine resources near Mākua Beach and in the Mākua muliwai are contaminated with constituents primarily associated with proposed training activities at Mākua Military Reservation. This study also evaluated the potential that activities at Mākua Military Reservation contribute to any contamination detected in the marine resources, and evaluated whether the proposed training activities at MMR pose a human health risk to area residents that rely on marine resources for subsistence. The study consisted of the following elements:

- Collecting fish samples from two muliwai located near Mākua Military Reservation and collecting fish samples from a background muliwai location (Nanakuli muliwai). Fifteen fish samples were submitted for laboratory analysis from the muliwai;
- Collecting fish and limu samples from a nearshore sampling location in the vicinity of Mākua Military Reservation and fish samples from a background nearshore location (Sandy Beach). Eleven fish samples and four limu samples were submitted for laboratory analysis from the nearshore areas;
- Analyzing samples for a variety of analytes, including explosives, metals, organochlorine pesticides, dioxins/furans, volatile organic compounds, and semivolatile organic compounds;
- Performing a human health risk assessment, using the fish and limu sample data, to evaluate the incremental risk (i.e. risk greater than background risk) from consuming seafood caught in the vicinity of the Mākua Military Reservation; and
- Performing a screening level ecological risk assessment, using the fish and limu sample data and muliwai sediment data collected in 2003, to evaluate the incremental risk to marine organisms of being in the muliwai or nearshore area in the vicinity of Mākua Military Reservation.

Fish sample analytical results did not indicate any obvious patterns of analyte detection, with the results from the Mākua Military Reservation vicinity samples being similar to the results from the background location samples. Samples from the muliwai locations tended to have

higher concentrations of metals than the nearshore samples, although the nearshore samples typically had higher concentrations of arsenic. Very few volatile organic compounds and semivolatile organic compounds were detected in the fish and limu samples, and, when detected, these compounds were typically present at only trace concentrations. A variety of dioxins/furans were detected in the samples at relatively low concentrations, which ranged from approximately 10^{-13} milligrams per kilogram (mg/kg) to 10^{-11} mg/kg. The data indicate that the contaminants detected in the fish likely did not come from the Mākua Military Reservation.

We attempted to collect shellfish and invertebrates for analysis as part of the Marine Resources Study. However, because the large amount of tissue mass needed for a single sample (over 200 grams) required the collection of many individual organisms for a single sample, we were unable to collect shellfish and invertebrates in sufficient quantities for sample analysis; however, it is likely that the shellfish are not contaminated by substances associated with the proposed training activities at MMR, for the following reasons:

- The analytical data for the fish samples indicate that the fish are likely not contaminated by substances associated with the proposed training activities at MMR.
- Most of the shellfish that we observed (sea urchins and crabs) were located in the nearshore area, although there were some crabs observed in the muliwai.There is very little interchange between the muliwai where contaminants might accumulate and the near-shore area, which provides the habitat for the most of the shellfish on which area residents rely.
- Transport of chemicals, if any, from the muliwai to the nearshore area would result in significant dilution of the chemicals.

The human health risk assessment evaluated risks to both subsistence fishermen and recreational fishermen. The exposure scenarios assumed that subsistence fishermen eat approximately 100 grams of fish, 365 days a year for 30 years and that recreational fishermen eat approximately 34 grams of fish, 365 days a year for 30 years. This exceeds the standard residential exposure frequency of 350 days per year and the average per capita fish and shellfish consumption frequency in the US of 48 days a year, and was used to provide a conservative estimate of exposure to fish. It is also assumed in the risk summaries presented here that fishermen are exposed to the mean chemical concentrations in fish.

The human health risk assessment indicated that the incremental risk (i.e., over background) from fish consumption at the Mākua muliwai is approximately 7×10^{-6} for subsistence fishermen, and 2×10^{-6} for recreational fishermen,, which are both below the USEPA 1×10^{-5} risk level used in assessing fish consumption (USEPA 2000a). This means that up to 7 people out of one million people who subsist on fish caught in the Mākua muliwai are expected to develop cancer over their lifetime from eating the fish. To put these numbers in perspective, EPA's target risk level of 1×10^{-5} is higher than the risk of being hit by lightning. This means that the increased risk of developing cancer from eating fish caught at

the Mākua muliwai versus eating fish caught at background muliwai on O`ahu is significantly less than the risk of being hit by lightning.

A primary source of uncertainty in this risk estimate is the assumption that a subsistence fisherman could rely only on the muliwai for fish. The muliwai are generally the size of a small pond having a maximum water surface area of less than one acre. It is unlikely that the two muliwai evaluated here could hold enough fish to support even one subsistence fisherman, let alone a population of subsistence fishermen. The assumption of a subsistence fisherman relying exclusively on the muliwai is unrealistic and, therefore, the risk estimate likely overestimates exposures to chemicals in the fish.

The human health risk assessment indicated that the incremental (i.e. over background) risk from subsistence fishermen eating fish from the Mākua nearshore area is approximately 3×10^{-5}, which exceeds the risk level used in assessing fish consumption of 1×10^{-5} (USEPA 2000a), although it is within the USEPA (1990) target risk range of 10^{-6} to 10^{-4}. The incremental risks over background are largely due to assumed exposures to BHC, bis (2-ethylhexyl) phthalate and heptachlor epoxide. The difference between the risk estimated for the Mākua nearshore area and the risk estimated for the background nearshore area is not considered to be significant, given the level of uncertainty in the risk estimates. Additionally, BHC and heptachlor epoxide were historically used as agricultural pesticides in Hawaii, and their presence in fish in the Mākua nearshore area may be unrelated to Army activities at the Mākua Military Reservation.

The combined cumulative risk from recreational fishermen eating fish from the Mākua nearshore area is approximately 3×10^{-5}, while the combined cumulative risk for the background nearshore location is 2×10^{-5}, which both exceed the USEPA 1×10^{-5} risk level used in assessing fish consumption (USEPA 2000a). The incremental risk (i.e. over background) is approximately 1×10^{-5}, which does not exceed the USEPA risk level.

The human health risk assessment indicated that the combined cumulative risk for current and future subsistence fishermen potentially exposed to the chemicals of potential concern in seaweed harvested from the shallow nearshore waters at Mākua Beach is approximately 8×10^{-3}. This risk estimate exceeds the risk level used in assessing fish consumption of 1×10^{-5} (USEPA 2000a) and the USEPA (1990) target risk range of 10^{-6} to 10^{-4}. This risk estimate is almost entirely due to assumed exposures to arsenic in seaweed, which was present at concentrations up to 109 mg/kg in the seaweed samples. The arsenic in seaweed was assumed to be entirely inorganic, which can be toxic. In many seaweed species, arsenic can be present entirely in nontoxic organic forms, although it is present in some species in inorganic forms at up to 50 percent or more. A review of the secondary literature did not indicate if the identified seaweed typically contained arsenic in organic or inorganic form. It is likely that at least some of the arsenic in the seaweed harvested from the shallow nearshore waters at Mākua Beach is present in nontoxic inorganic forms, indicating that the risks here may be overestimated to a certain degree. Seaweed samples were not collected from the background location (Sandy Beach), so it is not possible to determine whether the arsenic levels detected in seaweed at Mākua Beach are elevated over background.

A screening level ecological risk assessment was conducted to evaluate the potential for adverse effects on ecological receptors that may be exposed to chemicals in muliwai and nearshore waters. Data from the fish and limu sampling conducted as part of this study and data from muliwai sediment sampling conducted in 2003 were used in this assessment. Two sets of receptors were evaluated: (1) benthic invertebrates exposed to chemicals of potential ecological concern in sediments and (2) fish exposed to chemicals from multiple pathways, represented by measured concentrations in fish tissues. The results from the screening level ecological risk assessment indicated that there were no hazards to fish in the north muliwai, the south muliwai and the nearshore Mākua area, and that there was a potential hazard to benthic invertebrates from 2,3,7,8-tetrachlorodibenzo-*p*-dioxin in sediments in the south muliwai. Dioxins are not man-made or produced intentionally, but are created when other chemicals or products are made. The uncontrolled burning of waste, such as household trash, is one of the largest sources of dioxin.

TABLE OF CONTENTS

Section Page

EXECUTIVE SUMMARY ES-1

1. INTRODUCTION 1-1

1.1 Site Description 1-2
1.2 Previous Investigations 1-2
1.3 Objectives and Scope of Work 1-4
1.3.1 Objectives 1-4
1.3.2 Scope of Work 1-4

2. FIELD METHODS AND ACTIVITIES 2-1

2.1 Marine Resources Study Sampling Strategy 2-1
2.2 Species of Interest 2-2
2.3 Sampling Methodology And Activities 2-3
2.3.1 Seine Nets 2-3
2.3.2 Gill Nets 2-3
2.3.3 Hook and Line 2-4
2.3.4 Crab and Minnow Traps 2-4
2.3.5 Hand Picked Limu 2-4
2.4 Sampling Handling 2-4
2.5 Results of Sampling 2-4
2.6 Analytical Procedures 2-5

3. ANALYTICAL RESULTS 3-1

3.1 Summary of Chemical Analytical Groups 3-1
3.1.1 Dioxins and Furans 3-1
3.1.2 Organochlorine Pesticides 3-2
3.1.3 Metals 3-3
3.1.4 VOCs 3-3
3.1.5 SVOCs 3-3
3.2 Explosives Results 3-4
3.3 Organochlorine Pesticide Results 3-4
3.4 Metals Results 3-5
3.5 Dioxins/Furans Results 3-5
3.6 Semivolatile Organic Compound Results 3-5
3.7 Volatile Organic Compound Results 3-6

4. HUMAN HEALTH RISK ASSESSMENT 4-1

4.1 Selection of Chemicals of Potential Human Health Concern 4-1
4.1.1 Data Review 4-2
4.1.2 Chemicals of Potential Concern in the Mākua Valley Muliwai 4-3
4.1.3 Chemicals of Potential Concern Offshore at Mākua Beach 4-3
4.1.4 Determination of Exposure Point Concentrations 4-3
4.2 Identification of Human Receptors 4-4
4.3 Human Exposure Assessment 4-4
4.3.1 Exposure Pathway Analysis 4-4
4.3.2 Estimation of Chemical Intake 4-5
4.4 Human Toxicity Assessment 4-8
4.4.1 Human Toxicity Values 4-8
4.5 Human Health Risk Characterization 4-11
4.5.1 Risk Estimation Procedures 4-11

TABLE OF CONTENTS *(continued)*

Section Page

4.5.2 Risk Estimates 4-13
4.6 Uncertainty Analysis 4-17
4.7 Conclusions 4-18
4.7.1 Mākua Muliwai—Fish Consumption 4-18
4.7.2 Mākua Beach—Fish Consumption 4-19
4.7.3 Mākua Beach—Seaweed Consumption 4-19

5. ECOLOGICAL RISK ASSESSMENT 5-1

5.1 Guidance 5-2
5.2 Problem Formulation 5-2
5.3 Areas of Concern 5-3
5.4 Chemicals of Potential Ecological Concern 5-3
5.4.1 Data Review 5-4
5.4.2 Chemicals of Potential Concern in the North Muliwai at MMR 5-6
5.4.3 Chemicals of Potential Concern in the South Muliwai at MMR 5-7
5.4.4 Chemicals of Potential Concern in the Nearshore Habitat off MMR 5-7
5.5 Assessment Endpoints and Measures 5-7
5.5.1 Assessment Endpoints 5-7
5.5.2 Measures 5-8
5.6 Ecological Conceptual Site Model 5-8
5.6.1 Identification of Receptors 5-8
5.6.2 Exposure Pathway Inclusion/Exclusion 5-9
5.7 Analysis 5-10
5.7.1 Exposure Assessment 5-10
5.7.2 Exposure Profile 5-11
5.7.3 Exposure Point Concentrations 5-11
5.7.4 Effects Assessment 5-12
5.7.5 Toxicity Benchmarks and TRVs 5-12
5.8 Risk Characterization 5-14
5.8.1 Risk Estimation 5-14
5.9 Potential Ecological Risks 5-15
5.9.1 Potential Risks at the North Background Area 5-15
5.9.2 Potential Risks at the South Background Muliwai 5-15
5.9.3 Potential Risks at the Nanakuli Background Muliwai 5-15
5.9.4 Potential Risks at the Nearshore at Sandy Beach Background Site 5-16
5.9.5 Potential Risks at the North Muliwai 5-16
5.9.6 Potential Risks at the South Muliwai at MMR 5-17
5.9.7 Potential Risks at the Nearshore 5-19
5.10 Hazard Indices and Incremental Risks 5-20
5.10.1 North Muliwai 5-20
5.10.2 South Muliwai 5-21
5.10.3 Nearshore Habitat 5-21
5.11 Uncertainty Analysis 5-21
5.11.1 Uncertainties in the Exposure Assessment 5-22
5.11.2 Uncertainties in the Effects Assessment 5-23
5.12 Conclusions 5-23

6. CONCLUSIONS 6-1

7. REFERENCES 7-1

TABLE OF CONTENTS *(continued)*

Section Page

LIST OF TABLES

Table

2-1 Marine Resources Sampling Locations and Species of Interest at MMR
2-2 Summary of Fish and Limu Samples, Mākua Military Reservation Marine Resources Study
2-3 Sample Analytes and Analytical Methods
3-1 Mākua Military Reservation Fish and Limu Study Analytical Results
3-2 Summary Statistics for Metals and Organochlorine Pesticides
4-1 Tissue COPCs
4-2 Fish and Seaweed Tissue EPCs
4-3 Oral Carcinogenic Slope Factors
4-4 Toxicity Equivalency Factors (TEFs) for Dioxins and Furans
4-5 Chronic Oral Reference Doses
4-6 Carcinogenic Risk Estimates from Likely Fish Consumption Rates at the Muliwai Using Mean Contaminant Concentrations
4-7 Carcinogenic Risk Estimates from Likely Fish Consumption Rates at the Muliwai Using Maximum Contaminant Concentrations
4-8 Non-carcinogenic Hazard Index Estimates from Likely Fish Consumption Rates at the Muliwai Using Mean Contaminant Concentrations
4-9 Non-carcinogenic Hazard Index Estimates from Likely Fish Consumption Rates at the Muliwai Using Maximum Contaminant Concentrations
4-10 Carcinogenic Risk Estimates from Likely Fish Consumption Rates at Mākua Beach Using Mean Contaminant Concentrations
4-11 Carcingenic Risk Estimates from Likely Fish Consumption Rates at Mākua Beach Using Maximum Contaminant Concentrations
4-12 Non-carcingenic Hazard Index Estimates from Likely Fish Consumption Rates at Mākua Beach Using Mean Contaminant Concentrations
4-13 Non-carcinogenic Hazard Index Estimates from Likely Fish Consumption Rates at Mākua Beach Using Maximum Contaminant Concentrations
4-14 Carcinogenic Risks and Non-carcinogenic Hazards from Consumption of Seaweed (Mean COPC Concentrations)
4-15 Carcinogenic Risks and Non-carcinogenic Hazards from Consumption of Seaweed (Mean COPC Concentrations)
5-1a Sediment COPECs
5-1b Tissue COPECs
5-2 Toxicity Reference Values for Benthic Invertebrates
5-3 Fish Tissue-Based Toxicity Reference Values

LIST OF TABLES *(continued)*

Table

5-4 North and South Background Muliwai Sediment Mākua Military Reservation
5-5 Nanakuli Muliwai Fish Tissue Mākua Military Reservation
5-6 Nearshore at Sandy Beach Fish Tissue Mākua Military Reservation
5-7 North Muliwai Sediment Mākua Military Reservation
5-8 North Muliwai Fish Tissue Mākua Military Reservation
5-9 South Muliwai Sediment Mākua Military Reservation
5-10 South Muliwai Fish Tissue Mākua Military Reservation
5-11 Nearshore at Mākua Fish Tissue Mākua Military Reservation
5-12 North Muliwai HIs Sediment Mākua Military Reservation
5-13 North Muliwai HIs Fish Tissue Mākua Military Reservation
5-14 South Muliwai HIs Sediment Mākua Military Reservation
5-15 South Muliwai HIs Fish Tissue Mākua Military Reservation
5-16 Nearshore HIs Fish Tissue Mākua Military Reservation

LIST OF FIGURES

Figure

1-1 Site Location Map
2-1 Fish and Limu Sample Location Map
2-2 Sediment Sampling Location Map
4-1 Conceptual Site Model for Human and Ecological Receptors

APPENDICES

Appendix

A Field Sheets
B Lab Data
C Analytical Data QA/QC Summary
D HHRA
E ERA
F Response to Comments on the Draft Marine Resources Study

ACRONYMS

μg/dL	micrograms per deciliter
APPL	Agricultural and Priority Pollutants, Inc.
COPC	chemicals of potential concern
COPEC	chemicals of potential ecological concern
CSM	conceptual site model
DOD	U.S. Department of Defense
EIS	environmental impact statement
EPCs	exposure point concentrations
ERA	ecological risk assessment
HDOH	Hawai`i Department of Health
HI	hazard index
HI_{High}	high hazard index
HI_{Low}	low hazard index
HQ	hazard quotient
HQ_{High}s	high hazard quotient
HQ_{Low}s	low hazard quotient
mg/kg/	milligrams per kilogram
MMR	Mākua Military Reservation
PRGs	preliminary remediation goals
QA/QC	quality assurance/quality control
RDX	Cyclotrimethylenetrinitramine
RfDs	reference doses
SAP	sampling and analysis plan
SEA	supplemental environmental assessment
SVOC	semivolatile organic compound
TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TOW	tube-launched, optically-tracked, wire command-link guided
TRVs	toxicity reference values
UCL_{95}	95th percentile upper confidence limit
UCLs	upper confidence limits
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compounds

This page intentionally left blank.

1. INTRODUCTION

SECTION 1
INTRODUCTION

The objectives of this marine resources study are as follows:

- To determine if constituents primarily associated with military training are present in samples of selected species of fish and limu collected near Mākua Beach and the Mākua muliwai.

- To evaluate the potential that activities at Mākua Military Reservation (MMR) contribute to any contamination detected in the fish and limu samples, and to evaluate whether the proposed training activities at MMR pose a human health risk to area residents that rely on marine resources for subsistence.

The scope of work and methods for the field sampling and risk assessments were previously presented in the *Marine Resources Study Sampling and Analysis Plan, Mākua Military Reservation, O`ahu, Hawai`i* (the sampling and analysis plan [SAP])(Tetra Tech 2007). This report is organized into the following sections:

- **Section 1: Introduction—**presents a site description, project history and project description, and outlines the objectives and scope of work for this study;
- **Section 2: Field Methods and Activities—**presents a description of the fish and limu sampling activities performed as part of this marine resources study, a description of the methods used to perform these activities and a summary of the results of the field sampling activities;
- **Section 3: Analytical Results—**presents a summary of the analytical results for the fish and limu sampling;
- **Section 4: Human Health Risk Assessment—**presents the human health risk assessment conducted to evaluate the potential risk from consuming fish and limu caught in the muliwai and nearshore area at Mākua, and compares these results to the potential risk from consuming fish and limu caught in background locations on O`ahu;

- **Section 5: Screening Level Ecological Risk Assessment—**presents the screening level ecological risk assessment conducted to evaluate the potential risk to marine organisms from contaminants present in the muliwai and nearshore area at Mākua, and compares these results to the potential risk to marine organisms from contaminants present in background locations on O`ahu; and
- **Section 6: Conclusions—**provides conclusions regarding the results of the marine resources study.
- **Section 7: References**; and
- Tables and Figures are presented after the references.

1.1 SITE DESCRIPTION

MMR is approximately 38 miles northwest of Honolulu, on the western shore of O`ahu, near Ka`ena Point, and is in the adjoining Mākua and Kahanahāiki Valleys (Figure 1-1) (see Figures section after the Tables section). MMR is bordered on the west by the Pacific Ocean and is surrounded by the Wai`anae Mountains on the north, east, and south. MMR borders Farrington Highway and extends west from the Wai`anae Mountains ridgeline to the Pacific Ocean; Mākaha, the nearest township, is approximately three miles south. The installation encompasses almost 4,190 acres and is arid, with annual rainfall ranging from about 50 inches toward the head of the valley, to less than 15 inches at the mouth of the valley. The precipitous valley walls surrounding the installation reach heights of 2,100 to 2,900 feet. The broad range in rainfall and topography results in diverse vegetation types within the valley.

There are no wetlands at the MMR, but there are four streams in the Mākua Valley. Mākua Stream and its tributaries, which originate on the western slope of the Waianae Range, drain most of the Mākua Valley. The Mākua Stream system is intermittent and flows only about five percent of the year, rarely flowing for two consecutive days. This is a typical characteristic of streams in arid regions. Three other intermittent streams at Mākua also drain the eastern higher elevations west to the Pacific: 1) Kaluakaula Stream borders the northern boundary of Mākua, 2) Punopahaku Stream is north-central, and 3) the Kaiahi Gulch is found in the southern portion of Mākua.

Muliwai are located near the outlets of Mākua Stream, Punopahaku Stream, and the Kaiahi Gulch, although the muliwai at the mouth of Punopahaku Stream is usually dry. The muliwai are transition zones between the streams and the Pacific Ocean, with water flowing from Mākua Valley or from incoming high tides collecting in the muliwai. The water levels and salinity of the muliwai vary daily, and typically the muliwai are completely flushed each year by heavy rainfall. The muliwai in the vicinity of the Mākua Beach area that were sampled for this task include the muliwai near the outlet of Mākua Stream (north muliwai) and Kaiahi Gulch (south muliwai).

1.2 PREVIOUS INVESTIGATIONS

A number of field investigations have been performed relating to MMR, including the Halliburton NUS study, the Mākua SEA, the muliwai sampling conducted by the US Environmental Protection Agency during 1999 (Tetra Tech, 2005a), and the muliwai

sampling conducted by Tetra Tech in 2003 (Tetra Tech 2005b). In addition, a few studies have been performed along the leeward coast that include or apply to Mākua Valley, including US Geological Survey Professional Paper 1412B and Hydrologic Investigation HA-358.

The Halliburton NUS study evaluated the potential for chemicals associated with past training activities at MMR and with the open burn/open detonation area to migrate from surface water to groundwater beneath the MMR. This study concluded that groundwater samples did not have detectable concentrations of explosive or semivolatile organic compounds (SVOCs), and contained levels of nitrate, nitrite and several metals at concentrations that were below risk-based health criteria and drinking water standards. The study concluded that the basal aquifer at MMR was not impacted by contaminants (Tetra Tech 2005a).

The USEPA sampled the muliwais at Mākua Valley and an adjacent dry streambed for background data in 1999. They concluded that "further investigation does not appear warranted at this time because the overall concentrations of the metals of concern are relatively low, and do not tend to indicate a significant adverse impact on ecoreceptors" (Tetra Tech 2005a).

US Army Corps of Engineers and their contractors performed a hydrogeologic investigation at MMR between 2002 and 2004, as part of the EIS for resumption of live-fire training at MMR (Tetra Tech 2005c). Soil, sediment from streambeds, surface water and groundwater were sampled as part of this investigation. Eighteen areas of concern that were associated with training areas and several background locations were targeted for sampling. Samples were analyzed for a wide variety of chemicals, including explosives and their byproducts, metals, cyanide, dioxins/furans, polychlorinated biphenyls, SVOCs, VOCs and chlorinated herbicides.

Analytical results of 123 shallow soil samples from the areas of concern were compared to USEPA Region IX industrial preliminary remediation goals (PRGs). This comparison indicated the only chemicals detected at concentrations exceeding the PRG were iron (approximately 30 samples), lead (1 sample), dibenzanthracene (2 samples) and 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), a dioxin (3 samples). Iron is a naturally occurring byproduct of weathered basalt, which is prevalent on O`ahu, and is likely present due to these natural conditions. Iron also exceeded the PRG in one of the five soil samples collected from the background areas at MMR. Dibenzanthracene was detected in laboratory blanks analyzed with the samples that exceeded the PRGs, suggesting dibenzanthracene may not have been present in the soil samples.

Analytical results of 11 streambed sediment samples were compared to the Region IX PRGs, with all of the sample results below the PRGs. No dioxins/furans, PCBs, chlorinated pesticides or cyanide were detected in the samples and 1,3-dinitrobenzene was the only explosive compound detected in the samples (1 sample). Several volatile organic compounds (VOCs) and SVOCs were detected in the samples, although dibenzanthracene was not detected. Aldrin, alpha-BHC and gamma-BHC were the only pesticides detected in the

samples. Many of these sample results were "J-qualified," indicating the detected concentrations are low enough that the laboratory cannot accurately quantify the concentration.

A total of 81 surface water samples were collected during three different sampling events from all four of the intermittent streams present in Mākua Valley (Mākua Stream, Kaluakaula Stream Punopahaku Stream and Kaiahi Gulch). Perchlorate (1 sample) and 2,4--dinitrotoluene (2 samples) were the only explosives chemicals detected in the samples. Trace levels of dioxins/furans and trace levels of gasoline-related chemicals were also detected in the surface water samples.

Tetra Tech sampled the sediment from the muliwais at Mākua Valley and in several background muliwai in 2003 (Tetra Tech 2005b). The primary objectives of the sampling program were to evaluate if various chemicals, primarily explosives and metals, were present in the muliwai sediments, and to evaluate if chemicals from the open burn/open detonation area or the range complex at MMR had migrated off-site. Concentrations of metals detected in the muliwai were within the ranges found in the background samples, although arsenic and chromium were detected at concentrations above USEPA Region IX soil preliminary remediation goals (PRGs). Several organic compounds were detected in the sediment samples, but all of the detected concentrations were well below USEPA Region IX residential soil PRGs. Trace concentrations of two dioxin isomers were detected in two of the twelve muliwai sediment samples analyzed for dioxins/furans, with the 2,3,7,8-TCDD isomer being the only isomer detected at a concentration above the USEPA Region IX industrial soil PRG.

1.3 OBJECTIVES AND SCOPE OF WORK

1.3.1 Objectives

The objectives of this marine resources study are 1) to determine if marine resources near Mākua Beach and in the muliwai are contaminated with certain target chemicals associated with proposed training activities at MMR, and 2) to evaluate the potential that activities at MMR have contributed to or will contribute to any contamination detected in the marine resources, and to evaluate whether the proposed training activities at MMR pose a human health risk to area residents that rely on marine resources for subsistence.

The primary military activity at MMR is live fire training. The target chemicals associated with these proposed training activities are explosive compounds and byproducts of explosives and metals that may be released to the environment from the munitions. However, in response to comments from the public to the SAP, a large number of additional, non-target chemicals, including dioxins/furans, organochlorine pesticides and volatile and semi-volatile organic compounds (VOCs and SVOCs) were also included in this marine resources study.

1.3.2 Scope of Work

The draft SAP was issued in December 2005, and proposed that fish and limu samples be analyzed only for explosive and energetic compounds, using USEPA Method 8330. These

are the target chemicals that are associated with the proposed training activities at MMR. Based upon comments from the public to the draft SAP, the SAP was modified to include analysis of fish and limu samples for a wide variety of analytes, including 1) explosives, 2) dioxins/furans, 3) metals, 4) organochlorine pesticides, 5) selected VOCs, and 6) selected SVOCs. The final SAP was published in January, 2007.

The scope of work for the marine resources study and risk assessments included the following elements:

- ***Sample Collection and Analysis.*** Tetra Tech collected samples of target species in accordance with the SAP, including samples from "background" locations. Samples were analyzed by certified contract laboratories for the analytes specified in the SAP. These analytes are also listed in Section 2 of this report;
- ***Human Health Risk Assessment and Screening Level Ecological Risk Assessment.*** Tetra Tech performed a human health risk assessment for consumption of seafood from both the muliwai and the ocean. Ecological exposures were estimated for invertebrates and fish, based upon sediment data collected during earlier studies; and
- ***Marine Resources Sampling Report.*** Tetra Tech prepared this report, including a description of the methods and procedures used to collect and analyze the samples, a presentation of the results and observations of the investigation, the results of the risk assessments, and a discussion of the interpretation and significance of the results.

2. FIELD METHODS AND ACTIVITIES

SECTION 2
FIELD METHODS AND ACTIVITIES

2.1 MARINE RESOURCES STUDY SAMPLING STRATEGY

Tetra Tech conducted its sampling program to provide sufficient data to evaluate the incremental risks to human health from eating fish collected from the muliwais downstream of MMR and in the nearshore waters, limu collected in nearshore waters and the ecological risks to several taxonomic groups identified in the muliwai. A complete description of the sampling program strategy and objectives is provided in the SAP.

The study was designed to compare analytical results of fish and limu tissue samples collected in the vicinity of the MMR, with analytical results for fish and limu tissue samples collected from background, or control, locations. Two different environments, the muliwai environment and the nearshore environment, were included in the study. Quantifying all hazards related to the consumption of fish and limu from this area, whether or not the hazards are attributable to training activities at MMR, is beyond the scope of this study.

The north and south muliwai, in the vicinity of the MMR, were identified for sampling, as shown on Figure 2-1. The north muliwai is the pond that results from runoff from Mākua Stream, the principal stream that runs through the center of MMR. The south muliwai is the pond that results from runoff from Kaiahi Gulch, which runs along the south side of MMR. Based on the topography and the drainage ditches along the MMR access road, runoff from most of the live-fire areas and the disposal areas at MMR drains to the south muliwai. The nearshore area in the vicinity of MMR was selected for nearshore sampling near MMR, as shown on Figure 2-1.

The selection of background locations for the Marine Resources Study was made after careful consideration of a wide variety of factors. The objective of the Marine Resources Study is to identify if Army activities at the MMR have impacted Mākua Valley resources above and beyond impacts from all other sources. Using an uncontaminated or pristine watershed for a background location would not allow for the apportioning of impacts between the Army and other sources. This is a significant concern as there are many potential sources of contamination to the muliwai and nearshore environments other than

the MMR. To adequately address the Army's impact alone on Mākua Valley resources, an appropriate control site (i.e., background location) would be a valley where all aspects are as similar as possible to Mākua. Since inter-watershed transport of contaminants is facilitated by wind and rain, the control valley should have similar wind and rain patterns as that of Mākua. Biogeochemical processes affecting contaminants are a function of temperature and substrate, and these attributes also should be as similar as possible to Mākua Valley in order to identify impacts that can be attributed solely to Army activity. There are distinct differences in the substrate (mineralogy and age) between the different Hawaiian Islands, making the selection of background locations on another island inappropriate.

Because of this, the most appropriate control watersheds are on the leeward (Waianae) coast of O`ahu. As long as the background sites selected are representative of ambient conditions for the general Mākua vicinity and have not received contamination from the MMR, they are considered acceptable, according to the USEPA (1989, 2002a) risk assessment guidance. It is for this reason that the SAP states "Background muliwai will be located on the Waianae Coast within watersheds that are not subjected to military activity" (Section 2.2). The SAP further states that "Samples will be collected from locations distant enough from Mākua Valley that biota would be unlikely to be affected by target chemicals originating from MMR. Background muliwai will be located in watersheds that are not subject to military activity" (Section 2.2.3).

The background muliwai selected for this study was the Nanakuli muliwai, which is located on the Waianae Coast, south of the town of Nanakuli, approximately 15 miles south of MMR. Nanakuli muliwai results from runoff from Nanakuli Stream. Other muliwai located on the Waianae Coast were evaluated as potential background sampling locations, but none of these other muliwai contained water during the summer, when the sampling program was implemented.

The background nearshore area was located at Sandy Beach, on the southeast side of O`ahu, as shown on Figure 2-1. Sandy Beach is considered to be similar to the Mākua nearshore area because they are both rocky areas, with very low rainfall. Additionally, because there is much greater movement of water and fish in nearshore areas than in a muliwai, there is much less of a need for the background nearshore area to be located in a watershed that is similar to Mākua than the need for the background muliwai to be located in a watershed that is similar to Mākua.

2.2 SPECIES OF INTEREST

One of the goals of the Marine Resources Study was to sample a representative range of species that may be consumed by subsistence and recreational fishers on the Waianae Coast. Species of interest for this study were identified through discussions with regional commercial fishermen, local recreational fishermen, area divers and spear fishermen, and local residents from the Waianae coast. These discussions indicated that local fishermen are typically opportunists who consume most of the fish they are able to catch and are not selective of species. Substantial effort was made to select and collect species that were representative of and readily available in the habitats of the Mākua muliwai and nearshore waters and similar watersheds where military training exercises have not occurred in the

recent past. Since trophic level influences the potential uptake and concentration of contaminants, species from a range of trophic levels (primary producer, herbivore, omnivore and carnivore) were targeted in the study.

Target species were prioritized by the following criteria:

- Serve as a food source for humans;
- Spend part of their life cycle in or near brackish or freshwater (e.g., muliwai); and
- Represent a variety of trophic levels and feeding niches.

Table 2-1 (see Tables section after the References section) identifies the target species that were collected in each habitat.

2.3 SAMPLING METHODOLOGY AND ACTIVITIES

Field sampling for the marine resources study occurred between August 2 and August 24, 2006. Field data sheets are provided in Appendix A. Multiple sampling methods were employed to accommodate the irregular shapes and rocky bottoms of the muliwai and the surf conditions in the nearshore waters. Hook and line sampling was used in the nearshore waters, while sampling methods used in the muliwai included seine nets, gill nets, hook and line, crab and minnow traps. Limu was handpicked from the nearshore area. Each of these field methods is described below. A variety of other methods used by local fishermen, including spear fishing, were not used in the study because of the potential to introduce metals and other types of contamination into the fish.

2.3.1 Seine Nets

The seine nets used in this study ranged from 10 to 30 feet long and three feet in depth, with 1/4 inch mesh. The top of the nets were lined with floats and the bottoms of the nets were lined with lead. Each end was tied to a 4 foot pole, which was pulled by two team members through the water, dragging the leaded net bottom across the muliwai bottom and floating the top across the water surface, in effect creating a netted wall which was used to corral fish up to the banks of the muliwai. While two team members pulled the net across the bottom, a third person followed behind to free the net from an assortment of rocks or debris. Seining continued until sufficient biomass was obtained for each sample and no new species were collected.

2.3.2 Gill Nets

Gill nets used in this study were 20 feet long and 5 feet in width, with ½ or ¾ inch mesh. The top length of the net was lined with floats and the bottom length of the net was lined with lead. Gill nets were deployed across the width of the muliwai. The gill nets were used independently and in conjunction with the seine nets. Gill nets were stretched across the muliwai to compartmentalize the muliwai and facilitate seining within a smaller area restricting fish from escaping into the inaccessible areas of the muliwai. Gill nets were deployed for periods ranging from 30 minutes to 1 hour; Tetra Tech personnel remained on site whenever gill nets were deployed. Gill net sampling continued until sufficient biomass was collected for each sample and no new species were recorded.

2.3.3 Hook and Line

The hook and line method was used in the muliwai and in the nearshore fishing areas. Appropriate weight fishing lines and hook size for each target species were used for hook and line sampling in the muliwai and nearshore waters. Bread, limu, aku belly, shrimp, squid, and in some cases live fish were used for bait. Sampling continued until sufficient biomass was collected for each sample and no new species were recorded.

2.3.4 Crab and Minnow Traps

Several minnow trap designs with ¼ inch mesh were employed. These traps were baited with aku belly, chicken parts, squid, shrimp, and canned tuna. Traps were placed in a variety of habitats in the evening and collected the next morning.

2.3.5 Hand Picked Limu

Limu was hand picked using clippers and was cut at the stipe above the hold fast and placed in a netted bag or a bucket of water during collection. Before being weighed and documented, the limu samples were checked for any accidental removal of holdfasts. Any holdfast that may have been removed was returned to the reef.

2.4 SAMPLING HANDLING

Samples were handled in accordance with procedures outlined in the SAP. Once caught, the fish were placed in buckets and brought to the sample station where they were identified, measured, and documented. Samples were wrapped in foil and a plastic bag and placed on ice until delivery to the laboratory. Information describing the individual fish was recorded on field data sheets, including the time, date and approximate location of collection, length and weight of the fish, and method of collection. Samples were shipped to the analytical laboratories in dry ice under chain-of-custody control.

2.5 RESULTS OF SAMPLING

The analytical suite for the fish and limu samples included six analyte groups and approximately 43 compounds. In order to have enough tissue mass for the entire suite of analytes, each sample was required to weigh 200 grams or more, which was achieved by the laboratories compositing the fish for all of the samples except one.

Twenty-six fish samples (22 primary and 4 quality control samples) and four limu samples (3 primary and 1 quality control sample) were analyzed for the full suite of compounds. A list of the samples collected and fish type from each sampling location is provided in Table 2-2. Although we were unable to catch every single species of fish that was identified as being consumed by the community, the fish that were caught and analyzed from the muliwai (tilapia, stripped mullet, medaka, and Hawaiian flagtail) were included on the community's list of muliwai species that are commonly eaten.

We attempted to collect shellfish and invertebrates for analysis as part of the Marine Resources Study. Sea urchins were collected from the nearshore area, but the total tissue mass needed for a single sample exceeded 200 grams, which required collecting upwards of 40 sea urchins to achieve this tissue mass. Sea urchins typically live in the wild for 5 to 6 years, and start reproduction at around 2.5 years of age, but does not reproduce quickly. If a

population of the urchin is cleared from an area during sampling, there is no immigration of surrounding populations. Instead, a new population, starting with new larvae, will need to settle the cleared area before there will be any growth of the species. The field team determined that continued collection of sea urchins might negatively impact their population in the nearshore area and could result in the destruction of this living resource, so the team stopped collecting sea urchins. Crab traps were set in the muliwai for several days, and although some crabs were collected in this manner, the field team was unable to collect crabs in sufficient numbers for even a single sample to be analyzed for the complete list of analytes.

The only additional species collected using passive traps were a species of freshwater gobie and a shrimp (Macrobrachium grandimanus). Both the gobi and the shrimp were identified as indigenous to Hawaiian waters and reportedly were nonexistent in the lower reaches of streams on O`ahu. Although these species are assumed to be present statewide and neither of these species is threatened or endangered, they reportedly are not present in abundant numbers in any one location. Because of this, and because there did not seem to be sufficient numbers of these species present to collect enough tissue for a sample, these specimens were released back to the muliwai.

2.6 ANALYTICAL PROCEDURES

Chemical parameters and analytes for sample analysis were identified in the SAP and are presented in Table 2-3. Primary samples were submitted to Columbia Analytical Services and Agricultural and Priority Pollutants, Inc. (APPL). APPL analyzed the samples for nitroaromatics and nitroamines, and analyzed the samples for the remaining analytes listed in Table 2-2. APPL, Battelle Marine Sciences Laboratory, and Severn Trent Laboratories analyzed the quality control samples. The laboratory sample analysis scheme is also presented in Table 2-3.

This page intentionally left blank.

3. ANALYTICAL RESULTS

SECTION 3
ANALYTICAL RESULTS

Full analytical results for the fish and limu samples are presented in Appendix B, a summary of the analytical results is presented in Table 3-1, and a discussion of potential sources of the chemicals in each analytical group, and the analytical results are discussed below. Appendix C provides a Quality Assurance/Quality Control for the sample results.

3.1 SUMMARY OF CHEMICAL ANALYTICAL GROUPS

The target analytical group for the Marine Resources Study is the explosives compounds (RDX, nitroglycerin, 2,4-dinitrotoluene and perchlorate). These are the primary chemicals that are associated with the proposed training activities at MMR. In addition to these target chemicals, the following additional, non-target analytical groups were included in this study:

- Dioxins/furans,
- Organochlorine pesticides,
- Volatile organic compounds (VOCs),
- Semi-volatile organic compounds (SVOCs), and
- Metals.

Chemicals in these other analytical groups are considered non-target chemicals because there are a variety of potential sources for these chemicals, and if they are detected in the fish and limu samples, it is difficult to identify where they have come from. A discussion of potential sources of each of these non-target analytical groups is provided below.

3.1.1 Dioxins and Furans

Dioxins and furans is a general term that describes a group of hundreds of chemicals that are highly persistent in the environment. Dioxins and furans are not man-made or produced intentionally, but are created when other chemicals or products are made.

Combustion, chlorine bleaching of pulp and paper, certain types of chemical manufacturing and other industrial processes all can create small quantities of dioxins. Uncontrolled combustion, such as burning of household waste ("burn barrels") is expected to become the largest quantified source of dioxin emissions to the environment. (USEPA 2004a). Dioxins may also result from the grass burning operations that have taken place over the years at MMR. Additional types of combustion that create dioxins include the incineration of municipal refuse and certain chemical wastes, combustion of leaded gasoline in automobiles, forest fires, wood burning in the presence of chlorine and accidental fires involving transformers containing PCBs and chlorinated benzenes (USEPA Technical Fact Sheet on: Dioxin (2,3,7,8-TCDD)).

Combustion causes dioxins to be released into the air, where they can be transported long distances. Because of this, dioxins are found in most places in the world, and most of the population has low-level exposure to dioxins (USFDA 2006).

3.1.2 Organochlorine Pesticides

Organochlorine pesticides were widely and commonly used in the past to protect crops, livestock, buildings and households from the damaging effects of insects. Commonly used organochlorine pesticides were DDT, lindane (gamma BHC), chlordane, dieldrin, aldrin, heptachlor and pentachlorophenol. These pesticides were developed because of their toxicity and persistence in the environment, but these same characteristics led to the removal of many organochlorine pesticides from the market due to their health and environmental effects and their persistence.

USEPA has classified chlordane, aldrin, dieldrin and DDT as Level 1 persistent, bioaccumulative, and toxic (PBT) chemicals. The pesticide uses of all Level 1 PBTs were cancelled by the EPA during the 1970s and 1980's. Most of the pesticide uses of dieldrin were canceled in 1974, although use for subterranean control of termites was allowed to continue. Most remaining dieldrin products were canceled by 1987; the last product was canceled in 1989. All surface uses of chlordane were discontinued in 1983, and all other uses were cancelled by 1988. Technical chlordane is a mixture of up to approximately 150 compounds, including heptachlor epoxide.

On O`ahu, organochlorine pesticides such as aldrin, chlordane and heptachlor were widely used for termite control and for agriculture. For example, approximately 9,000 pounds of aldrin and 150,000 pounds of chlordane and heptachlor were used in Hawaii for pest control in 1977. Organochlorine pesticides are typically transported from agricultural and urban areas by soil erosion and surface runoff, where they may accumulate in stream bed sediments and in fish tissue. A National Water Quality Assessment study performed by the USGS on Oahu between 1992 and 1994 found that the distribution of organochlorine pesticides was associated with land-use practices, with higher concentrations of chlordane and dieldrin detected in samples from urban streams, and the highest concentrations of DDT detected at an agricultural site.

3.1.3 Metals

Nineteen different metals were included in the analytical suite for the Marine Resources Study. Metals are naturally occurring in the environment, and some metals, such as iron, are considered essential nutrients for human health. The presence of naturally occurring metals in the environment makes identifying the source of metals that may be detected in animal and plant tissue as part of this study problematic.

The data presented in the 2005 draft EIS for Military Training Activities at Mākua Military Reservation, Hawai`i (Tetra Tech, 2005) indicated that most of the metals detected in soils at MMR are present at concentrations that are within the background range for soils in Hawai`i (Tetra Tech, 2005). Some of these metals, such as aluminum, chromium, cobalt, iron and manganese, occur in the rock of the Waianae Mountain Range, and subsequent weathering of the mountains cause these metals to be present in relatively high concentrations in the soil on Oahu. Exceptions to this are arsenic, lead and selenium, which were present in soils at concentrations in excess of expected background concentrations.

Arsenic is used in rodenticides and wood preservatives, and is a common contaminant in developed areas of O`ahu. Additionally, arsenic can occur in animal and plant tissue in an organic form, which is considered non-toxic. Lead may be a component of the various munitions used in training exercises at MMR, but it was also used as an additive to gasoline, and residual concentrations of lead in the environment may be due to automobile exhaust. Selenium is also naturally occurring in the rock on O`ahu, and elevated concentrations of selenium may be associated with recent volcanic eruptions. However, there is no obvious anthropogenic source to explain elevated levels of selenium in soils at MMR.

3.1.4 VOCs

Volatile organic compounds (VOCs) are organic chemicals that have a high vapor pressure and easily form vapors at normal temperature and pressure.

The term is generally applied to organic solvents, certain paint additives, aerosol spray can propellants, fuels (such as gasoline, and kerosene), petroleum distillates, dry cleaning products and many other industrial and consumer products ranging from office supplies to building materials. VOCs are also naturally emitted by a number of plants and trees. However, releases into the environment are primarily from petroleum refining (USEPA Technical Fact Sheet on: VOCs).

3.1.5 SVOCs

Semi-volatile organic compounds (SVOCs) are organic chemicals that volatilize relatively slowly at standard temperature (20 ^{o}C) and pressure (1 atm).

The term is generally applied to organic compounds found in a wide range of products, including: insect repellants, cosmetics, rubbing alcohol, liquid soap, detergents, decorative inks, lacquers, munitions, industrial and lubricating oils, wood preserving industries, defoaming agents for paper/paperboard manufacturing, pesticide carriers, photographic film processing, as a plastic softening agent, and as a dielectric in capacitators (USEPA Technical Fact Sheets on: bis(2-ethylhexyl) phthalate, diethyl phthalate, di-n-butylphthalate).

Additionally, the polycyclic organic chemical Pyrene is the product of combustion (e.g., cigarette smoke, vehicle exhaust, home heating, laying tar, and grilling meat) (USEPA Technical Fact Sheet on: Polycyclic Organic Matter). Pentachlorophenol was once one of the most widely used biocides in the United States, but it is now a restricted use pesticide and is no longer available to the general public. The principal use for pentachlorophenol is as a wood preservative; it is also used for the formulation of fungicidal and insecticidal solutions and for incorporation into other pesticide products (USEPA Technical Fact Sheet on: Pentachlorophenol).

3.2 EXPLOSIVES RESULTS

Four analytes were included in the explosives analysis, 2,4-dinitrotoluene, nitroglycerin, perchlorate, and cyclotrimethylenetrinitramine (RDX). RDX was detected in only one of the fish samples (a near-shore sample), at a concentration of 0.057 milligrams per kilogram (mg/kg), and 2,4-dinitrotoluene was not detected in any of the fish samples. Perchlorate was the explosive compound detected the most frequently, in 11 of the 26 samples at concentrations of between 0.0012 and 0.16 mg/kg.

Perchlorates are used in the manufacture of fireworks, as well as in the munitions used at MMR. Their presence in fish tissue in both background and Mākua area locations suggests that there are likely multiple sources of perchlorate in these areas.

The presence of RDX in even one sample of fish tissue is surprising, given its low bioconcentration factor (BCF). The BCFs for RDX calculated for catfish and fathead minnow ranged between 0.5 and 2.1 ml/g (Belden et al. 2005; Lotufo and Lydy 2005). By contrast, bioconcentration factors for some dioxins are as high as 2,000 to 3,000 ml/g, and for organochlorine pesticides such as heptachlor as high as 10,000 ml/g (USEPA 1999). Because the BCF for RDX is so low, a relatively high concentration of RDX would need to be present in the water to account for the RDX detection in the fish tissue. Given the amount of water circulation in the ocean, it is unlikely that the ocean water in the Makua near-shore area would contain RDX at a sufficient concentration to result in the observed detection of RDX in the fish tissue sample.

The one sample where RDX was detected was NW1fd, at a concentration of 0.057 mg/kg. This result was flagged by the laboratory (STL) as an estimated (J) value, because it was below the lab reporting limit of 0.25 mg/kg. This sample is a field duplicate for sample NW1, which was analyzed by APPL. The RDX result for NW1 was not detected at a reporting limit of 0.6 mg/kg. These data suggest that the RDX result for NW1fd reported by STL may be a false positive, and this suggestion is supported by the BCF data cited above, which would require a relatively high concentration of RDX in the ocean water to result in the concentration of RDX detected in the fish tissue sample. Nitroglycerin and 2,4-dinitrotoluene were not detected in any of the limu samples, RDX was detected in only one of the limu samples, and perchlorate was detected in two of the four limu samples.

3.3 ORGANOCHLORINE PESTICIDE RESULTS

Samples were analyzed for eight organochlorine pesticides. A comparison of the analytical results presented in Table 3-1 indicates that organochlorine pesticide concentrations were

generally the same between the samples collected from the different sampling locations. Table 3-2 presents summary statistics (average, maximum, and minimum concentrations) for each organochlorine pesticide for each of the five sampling locations. These data indicate that aldrin and heptachlor were generally detected in samples from the nearshore areas, but not in the muliwai, and that heptachlor epoxide was detected at higher concentrations in samples from the nearshore locations than in samples from the muliwai locations.

3.4 METALS RESULTS

Samples were analyzed by a variety of USEPA methods for 19 metals, including methyl mercury. The full list of analytes and analytical methods is provided in Table 2-2. A comparison of the analytical results presented in Table 3-1 indicates that metals concentrations were generally the same between the samples collected from the different sampling locations. Table 3-2 presents summary statistics (average, maximum, and minimum concentrations) for each metal for each of the five sampling locations. These data indicate the following:

- Metals concentrations tended to be higher in samples from the muliwai compared to the nearshore samples, although arsenic concentrations were higher in the nearshore samples than in the muliwai samples.
- There is no obvious difference in chemical concentrations detected in samples from the Mākua-vicinity samples compared with the background location samples.

3.5 DIOXINS/FURANS RESULTS

Twenty-five analytes were included in the dioxins/furans analysis, and 13 of these were not detected in any of the fish samples. Concentrations of the remaining twelve analytes ranged between 1.29×10^{-13} to 8.7×10^{-12}. The data indicate the following:

- Dioxins/furans were detected more frequently in samples collected from the muliwai, compared to the samples collected from the nearshore locations, with only five of the analytes detected there. No dioxins/furans were detected in the fish samples collected from the Mākua nearshore area.
- HpCDD was the dioxin detected most frequently and was detected in 12 of the 16 muliwai samples and 4 of 11 nearshore samples.

Nine of the 25 dioxins/furans were detected in the limu samples, at concentrations ranging from between 5.7×10^{-14} and 1.65×10^{-11} mg/kg. Similar to the fish samples, HpCDD was the dioxin detected most frequently and was detected in three of the four limu samples.

3.6 SEMIVOLATILE ORGANIC COMPOUND RESULTS

Seven analytes were included in the SVOC analysis, and only three of these, bis(2-ethylhexyl)phthalate, diethyl phthalate, and di-n-butylphthalate, were detected in any of the fish samples collected from the muliwai and nearshore sample locations.

Di-n-butylphthalate was detected in all of the fish samples. The 22 primary samples analyzed by Columbia Analytical Services had concentrations ranging from 0.0098 to 0.053 mg/kg.

The four quality control samples analyzed by APPL had di-n-butylphthalate concentrations, ranging between 0.61 and 1.5 mg/kg. Bis(2-ethylhexyl)phthalate was detected in four of the five samples collected from the Mākua nearshore area, with concentrations ranging between 0.055 and 3.5 mg/kg, and was only detected at a concentration of 3.1 mg/kg in a sample collected from the south muliwai. Diethyl phthalate was detected, at a concentration of 0.19 mg/kg, in only the sample collected from the Sandy Beach nearshore area. There is no obvious explanation for this pattern of detections of SVOCs in the fish samples.

Bis(2-ethylhexyl)phthalate and di-n-butylphthalate were the only SVOCs detected in the limu samples. Similar to the fish samples, di-n-butylphthalate was detected in all of the limu samples, with the primary sample concentrations ranging from 0.02 to 0.024 mg/kg. The quality control sample analyzed by APPL had a concentration of 0.48 mg/kg.

3.7 VOLATILE ORGANIC COMPOUND RESULTS

Eight analytes were included in the VOC analysis, and only two of these, acetone and m,p-xylene, were detected in any of the fish samples collected from the muliwai and nearshore sample locations. There is no obvious detection pattern for either of these analytes, with at least one sample from all five locations having an acetone detection and only samples from the south muliwai, Mākua nearshore, and Sandy Beach nearshore locations having an m,p-xylene detection. The acetone detections ranged from 0.23 to 0.73 mg/kg, while the m,p-xylene detections ranged from 0.016 to 0.02 mg/kg.

VOCs were detected in only one of the limu samples, with a concentration of 0.016 mg/kg m,p-xylene. This was the only VOC detection in any of the limu samples.

4. HUMAN HEALTH RISK ASSESSMENT

SECTION 4
HUMAN HEALTH RISK ASSESSMENT

This section is an evaluation of the potential risks to humans who may be exposed to environmental contaminants at Mākua Beach and the Mākua muliwai and compares those risks to risks determined for background locations on O`ahu. The difference between the risks calculated for the Mākua sites and the background locations is called the incremental risk. Potential human exposures to contaminants in fish and seaweed are evaluated below.

The risk assessment consists of six major components:

- Selection of chemicals of potential concern (COPCs);
- Identification of human receptors;
- Assessment of potential chemical exposures;
- Assessment of chemical toxicity;
- Characterization of risk; and
- Analysis of sources of uncertainty in the predicted risk estimates.

The risk assessment is consistent with guidance developed by the USEPA in the *Risk Assessment Guidance for Superfund* (USEPA 1989, 1990, 1991a, 1992a, 1996, 1997a, 2002a) and the Hawai`i Department of Health (HDOH) Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater (HDOH 2006).

4.1 SELECTION OF CHEMICALS OF POTENTIAL HUMAN HEALTH CONCERN

COPCs are those chemicals detected in environmental media at the Mākua Beach and muliwai for which human contact may result in adverse health effects. The three environmental media sampled at the Mākua Beach and muliwai were sediment, fish tissue, and seaweed. It is assumed that human receptors will not have contact with sediments at the muliwai, so sediment samples were not evaluated in the selection of COPCs.

Tissue sample analyses were discussed in Section 2, and tissue sample analytical results were discussed in Section 3:

All chemical data collected for each environmental medium were reviewed during the selection of COPCs. All detected chemicals were identified as COPCs.

4.1.1 Data Review

All of the analytical results from the tissue samples collected during 2006 (see Sections 2 and 3) were reviewed and evaluated in the selection of COPCs. Additionally, sediment samples collected in 2003 (Tetra Tech 2005) were evaluated for use in this risk assessment. Soil, sediment, groundwater, and surface water data collected from 2002 to 2004 from the Mākua Valley were not used in this risk assessment. These data were collected upstream of the muliwai and represent locations that could serve as sources of contaminants to the muliwai and Mākua Beach.

Sample locations used in the risk assessment are shown in Figures 2-1 and 2-2. Descriptions of the analytical methods used for sediment and tissue samples are provided in Tetra Tech (2005).

Data validation efforts classified the data through the use of several qualifiers. Data without qualifiers were considered appropriate for risk assessment purposes. Following USEPA guidance (1989), data with J qualifiers were used for risk assessment purposes. U and UJ qualified data were considered to be nondetected but usable for risk assessment purposes. B and BJ qualified data were treated as nondetected chemicals because the estimated chemical concentrations were not significantly higher than levels in quality assurance/quality control (QA/QC) blanks associated with the samples. R qualified data were excluded from the risk assessment.

Areas of Concern

The muliwai that were sampled for fish include the north and south muliwai at the base of the Mākua Valley (see Figure 2-1) and the muliwai at Nanakuli (see Figure 2-1). As both of the muliwai in the Mākua Valley are fed by streams that run through the MMR, both of these muliwai may be impacted by potential upstream releases at the MMR. Therefore, for the purposes of this risk assessment, both of the muliwai in the Mākua Valley were considered as a single area of concern and were evaluated together. The Nanakuli muliwai was considered to be a background location for the muliwai in the Mākua Valley. Background samples will be used to determine if exposures at the Mākua muliwai are higher than background conditions.

Fish were also collected offshore at Mākua Beach and Sandy Beach, and limu was collected from offshore at Mākua Beach(see Figure 2-1). The offshore samples from Mākua Beach could show impacts from the releases to the streams in the Mākua Valley. The samples from Sandy Beach are assumed to be representative of offshore background conditions. Background samples will be used to determine if exposures at offshore of Mākua beach are higher than background conditions

Evaluation of Tissue Samples

Fish were collected from the two muliwai at the MMR (see Figure 2-1) and were composited into twelve samples. The species collected included striped mullet, tilapia, Hawaiian flagtail, and medaka, although each composite sample consisted of only one type of fish. Three composite fish samples were collected from the background muliwai at Nanakuli (see Figure 2-1). All of the fish samples collected at Nanakuli were tilapia.

Six composite fish samples were collected from the offshore at Mākua Beach (see Figure 2-1), consisting of goatfish (i.e., sidespot and manybar), picasso triggerfish, blackspot triggerfish, and christmas wrasse. These same fish species were collected in six samples at the offshore background location (i.e., Sandy Beach; see Figure 2-1), with the addition of saddle wrasse. Additionally, four seaweed samples were collected from the nearshore waters at Mākua and are listed by location in Section 3.

4.1.2 Chemicals of Potential Concern in the Mākua Valley Muliwai

The COPCs for fish from the Mākua muliwai included 19 metals, 5 organochlorine pesticides, 2 VOCs, 2 SVOCs, 1 explosive, as well as dioxins/furans. No seaweed (limu) was collected from the muliwai. The COPCs are listed in Table 4-1.

4.1.3 Chemicals of Potential Concern Offshore at Mākua Beach

The COPCs for fish from Mākua Beach included 16 metals, 7 organochlorine pesticides, 2 VOCs, 2 SVOCs, and 3 explosives. Dioxins/furans were not detected in the fish samples collected from Mākua Beach. The COPCs are listed in Table 4-1.

The COPCs for seaweed from Mākua Beach included 17 metals, one organochlorine pesticide, one VOC, 2 SVOCs, one explosive, and dioxins/furans.

4.1.4 Determination of Exposure Point Concentrations

In order to have enough fish mass to analyze the samples for the full analytical suite, the samples were composited, as described in Section 2. The use of composite samples to assess exposures is consistent with USEPA (2000a) and HDOH (2006) guidance. Composite samples are used to determine the mean concentration in the environmental medium sampled (USEPA 2000b). As is consistent with this aim, the mean concentrations in fish and seaweed samples were used as the exposure point concentrations. In the calculation of the mean of several composites, nondetects were replaced with one-half of the method detection limit (USEPA 1992b). For the locations where more than one fish species was sampled, the samples that were collected were representative of what a typical fisherman would catch and, therefore, the unweighted means were used as the exposure point concentrations. To provide additional perspective on the risk estimates, the maximum detected concentrations were also used to assess exposures and risks.

Field duplicates were collected as part of the QA/QC process. Since the field duplicates represent different individual fish, the analytical results of the field duplicates were treated as unique samples in the calculation of exposure point concentrations.

4.2 IDENTIFICATION OF HUMAN RECEPTORS

Human receptors potentially at risk from chemicals at Mākua Beach and the Mākua muliwai were identified by characterizing population groups in the area. The potential human receptors are discussed below.

Soldiers training at MMR are stationed at Schofield Barracks Military Reservation (SBMR) and are transported to MMR by ground or air. From 1988 to September 1998, the number of training days at the MMR ranged from 153 to 259 days per year, with a 10-year annual average of 210 days. Thus, there is a steady population of soldiers at the MMR that could conceivably visit Mākua Beach and the muliwai. These receptors, however, are unlikely to rely on fish from the muliwai or beach for subsistence; rather, they are more likely to fish recreationally.

In addition to military personnel, there are several towns to the southeast of the MMR, the closest of which is Makaha, which is approximately three miles south of MMR. According to the US Census Bureau (2001), the populations of Makaha and Makaha Valley were 7,753 and 1,289. Additional urban areas are southeast of Makaha and Makaha Valley (see Figure 1-1). Residents of these locations may travel to the Mākua area and fish at Mākua Beach and the Mākua muliwai. These include both recreational fishermen as well as subsistence fishermen, so potential health risks were evaluated for these two groups.

4.3 HUMAN EXPOSURE ASSESSMENT

An exposure assessment was conducted to estimate the magnitude of exposures resulting from eating fish and limu collected from the Mākua Beach area and the Mākua muliwai. The primary goals of the exposure assessment were to identify potentially complete exposure pathways resulting in human receptor exposure to COPCs and quantitative evaluation of potential chemical exposure using measured and predicted chemical concentrations and estimates of the frequency and duration of potential chemical exposure.

Exposures were evaluated for both current and potential future site conditions.

4.3.1 Exposure Pathway Analysis

An exposure pathway describes the course that a chemical takes from a source to an exposed individual. A complete exposure pathway consists of the following four factors:

- A source of potentially toxic chemicals;
- A contaminated medium, such as fish or limu;
- An exposure or contact point with the contaminated medium, such as fish or limu consumption; and
- An exposure route for chemical intake by a receptor, such as uptake through the gastro-intestinal tract.

Designation of an exposure pathway as complete indicates that human exposure is possible but does not necessarily mean that exposure will occur nor that exposure will occur at the

levels estimated in this report. When any one of the factors is missing in a pathway, it is considered to be incomplete. Incomplete exposure pathways do not pose health hazards and were not evaluated in this risk assessment.

The conceptual site model (CSM) provides the basis for identifying and evaluating the potentially complete exposure pathways at Mākua Beach and the Mākua muliwai. As shown in the CSM diagram (Figure 4-1), potential sources of COPCs include surface water, sediments, and fish. The CSM shown also illustrates the potential chemical migration pathways, exposure points, and exposure routes evaluated at Mākua Beach and the Mākua muliwai. Chemical fate and transport processes were used to define the potential migration pathway, and included transfer of COPCs between environmental media, such as surface water and fish tissue, and transport of COPCs through movement of an environmental medium by natural dispersive processes, such as surface water flow.

An exposure pathway is complete when there is a point at which chemical uptake by a human receptor may occur. Exposure routes considered in this human health risk assessment are limited to fish consumption. Exposure to contaminants via surface water contact and sediment contact are considered to be minimal, and therefore are not evaluated here.

4.3.2 Estimation of Chemical Intake

Chemical exposure is a result of the intake or uptake of a chemical from the environment. This section is a description of the methods used to quantitatively evaluate potential receptor exposures at Mākua Beach and the Mākua muliwai.

Exposure Models

Potential chemical exposures were quantitatively estimated using an exposure model defined by the USEPA guidance for fish consumption (1989). The model results in exposures normalized for time and body weight and are expressed as the amount of chemical taken into the body per unit body weight per unit time (i.e., mg/kg/day):

$$Intake = \frac{C_{sf} \times CR \times EF \times ED}{BW \times AT}$$

where

Intake = Effective ingested dose (mg/kg/day);
C_{sf} = Chemical concentration in seafood (mg/kg);
CR = Consumption rate per unit time (kg/day);
ED = Exposure duration (days);
BW = Body weight (kg); and
AT = Averaging time (days).

The exposure parameters are discussed below for each of the two receptor groups at Mākua Beach and the Mākua muliwai: recreational fishermen and subsistence fishermen.

Exposure Frequency

For both subsistence and recreational fishermen, it is assumed that fish are consumed every day of the year, that is, 365 days per year. This exceeds the standard residential exposure frequency of 350 days per year (USEPA 1989, 1991a, 2002a) and the average per capita fish and shellfish consumption frequency in the US of 48 days a year (USEPA 1989).

Exposure Duration

Standard USEPA guidance is to assume that residents may be present at a site for 30 years (1989, 1991a, 2002a).

Body Weight

Standard USEPA guidance is to assume that adults weigh 70 kg (1989, 1991a, 2000a, 2002a).

Consumption Rate

USEPA has guidance for fish consumption rates to be used for national risk assessments and the calculation of fish advisories (1991a, 1997a, 2002c). The USEPA Superfund Program guidance assumes an ingestion rate of 54 grams of fish per day (g/day) for high consumers of locally caught fish (USEPA 1991a). For the general US population, the USEPA Exposure Factors Handbook recommends a mean marine fish consumption rate of 14.1 g/day for the general US population and a mean of 70 g/day and 95th percentile of 170 g/day fish consumption rate for Native American subsistence populations (USEPA 1997a). Based on a sample size of 20,607 individuals, later USEPA (2002c) guidance provides a mean uncooked fish consumption rate for the general US population of 12.59 g/day, with a 95th percentile rate of 81.75 g/day; and a shellfish consumption rate of 4.29 g/day with a 95th percentile rate of 23.21 g/day

To estimate the risks from the consumption of fish, it is vital to have an accurate estimate of the fish consumption rate of the receptors to be evaluated. Fish consumption rates may vary by ethnic group, lifestyle, economic status, and geography, among other factors (OEHHA 2001). Therefore, it is desirable to use a fish consumption rate that is applicable to the receptors being evaluated. For this risk assessment it is desirable to use a fish consumption rate that is protective of the multiple ethnic groups and lifestyles in Hawai`i.

No guidance on fish consumption rates is available from the State of Hawai`i. However, fish consumption survey data are available from California, Hawai`i, and Washington

In California, there are two notable studies: one from the Santa Monica Bay (OEHHA 2001) and one for the San Francisco Bay (SFEI 2000). The Santa Monica Bay study recommended that a seafood consumption rate of "21 grams per day for the median, 50 grams per day for the mean, 107 grams per day for the 90th percentile, and 161 grams per day for the 95th percentile…be used to estimate consumption from both marine and freshwater sources of sport fish and shellfish in California. These values are most applicable to fishers that consume sport fish and shellfish on a regular and frequent basis (i.e., at least once a month). For cases where the target population is the general fishing population and fish is not a major exposure pathway, the adjusted (weighted) results of 30.5 grams per day for the mean value and 85.2 grams per day at the 95th percentile can be used" (OEHHA 2001). The San

Francisco Estuary Institute (2000) surveyed people fishing in the San Francisco Bay and reported fish consumption rates among those that had recently consumed fish (n = 448) of 14 g/day (geometric mean) with a 95th percentile upper confidence limit (UCL_{95}) of 15.2 g/day. When the data was separated by ethnic groups, several groups were found to have higher fish consumption rates than the overall mean, with the most notable being Pacific Islanders (n = 70, geometric mean 22.4 g/day, UCL_{95} 44.7 g/day) and "other" (n = 7, geometric mean 27.5 g/day, UCL_{95} 55.0 g/day), with "other" being Russians, Middle Easterners, and individuals of unspecified mixed ethnicity.

Several fish consumption surveys have recently been conducted in Hawai`i. The relevant scientific studies are reviewed here and used to derive a health-protective estimate of fish consumption rates. However, UCL_{95s} are often not presented for these studies.

Koizumi et al. (2002) surveyed fish consumption rates of people in Pacific Rim countries, including the United States. The authors reported results for Americans from the mainland US and for Japanese-Americans living in Hawai`i, as well as for residents of several other countries. For this risk assessment, the most interesting result is the average consumption rate of fish by Japanese-Americans living in Hawai`i, which was based on survey results from 369 households and was determined to be 65 g/day. This value was higher than the consumption rates determined for Australia, Japan, and the mainland US (50.7, 42.4, and 38.5 g/day, respectively), but lower than fish consumption rates in some Asian countries, such as China, Taiwan, and Thailand (95.6, 78.3, and 178.4 g/day). Only mean consumption rates were provided.

Kolonel et al. (1990) surveyed 632 residents of all major ethnic groups from O`ahu and reported consumption rates for shellfish, fish, and seaweed, as well as all seafood combined. The average rate of seafood consumption for all respondents was found to be 49.1 g/day. Fish consumption rates were not reported for separate ethnic groups. The seaweed consumption rate was estimated at 2.1 g/day. Only mean consumption rates were provided.

Sharma et al. (2003) surveyed Japanese Americans (n = 54,248), native Hawaiians (n = 13,629), and whites (n = 47,236) in Hawai`i. Average fish consumption rates were found to be 25.5 ± standard deviation of 22.7, 34.0 ± 34, and 17.0 ± 17.0 g/day, respectively. From these, the 95th percentile can be calculated using the following formula:

$$95^{th}\text{ percentile} = \text{mean} + (\text{standard deviation} \times 1.96)$$

Using this formula, the 95th percentile fish consumption rates are 70.0 g/day for Japanese-Americans, 100.6 g/day for Hawaiians, and 50.3 g/day for whites.

Lastly, Sechena et al. (2003) surveyed 202 members of the Asian American and Pacific Islander community, of various ethnic backgrounds, living in Washington state. Although none were Hawaiian, respondents included many ethnic groups that are also present in Hawai`i, including Vietnamese, Chinese, Filipinos, Japanese, and Koreans. The average fish consumption rate across all Asian American and Pacific Islanders was 117.2 g/day, with a

UCL_{95} of 122.5 g/day, and a 90th percentile of 242 g/day. The ethnic group in Washington with the highest fish consumption rate was the Vietnamese, with a mean consumption rate of 161.1 g/day (n=26). Therefore, the 90th percentile fish consumption rate in this study is likely to have been influenced by Vietnamese fish consumption rates. A seaweed/kelp consumption rate was also provided of 5.2 g/day, with a UCL_{95} of 5.8 g/day, and a 90th percentile of 18.2 g/day.

The studies summarized above show that there are substantial ethnic and geographic differences in fish consumption rates. Therefore, to represent the most likely consumption of all potential groups fishing at the muliwai, a fish consumption rate of 100.6 g/day is used to assess the potential risks to subsistence fishermen. This consumption rate was derived from the 95th percentile fish consumption rate of Hawaiians living in O`ahu (Sharma et al. 2003). The fish consumption rate used here is higher than the 95th percentile fish consumption rates for Japanese-Americans and whites (i.e., 70.0 and 50.3 g/day, respectively) living in Hawai`i (Sharma et al. 2003). To estimate the most likely exposures for recreational fishermen, a consumption rate of 34.0 g/day was used, which is the average fish consumption rate for Hawaiians living in O`ahu (Sharma et al. 2003). To estimate exposures from the consumption of seaweed, the 90th percentile seaweed/kelp consumption rate of Asian-Pacific Islanders living in Washington state of 18.2 g/day was used for subsistence fishermen (Sechena et al. 2003), and mean rate of 5.2 g/day was used for recreational fishermen (Sechena et al. 2003).

4.4 HUMAN TOXICITY ASSESSMENT

The toxicity assessment provides information on the potential for COPCs at Mākua Beach and the Mākua muliwai to cause either carcinogenic or noncarcinogenic adverse health effects. The toxicity assessment is primarily a data compilation task that relies heavily on the hazard identification and dose-response evaluations performed by the USEPA and the HDOH. The toxicity assessment consists primarily of tabular presentations of specific toxicity for potential carcinogenic and noncarcinogenic health effects of the COPCs. These presentations consist of cancer slope factors and chronic reference doses (RfDs).

4.4.1 Human Toxicity Values

Key dose-response variables (critical toxicity values) used in quantitative risk assessments are cancer potency (or slope factors) for carcinogens and RfD values for noncarcinogens or noncarcinogenic endpoints of carcinogens. Toxicity values were obtained from several sources, according to the following order of priority: (1) the USEPA's Integrated Risk Information System (USEPA 2006a), (2) the annual version of the USEPA's Health Effects Assessment Summary Tables (USEPA 1997b), and (3) the USEPA (2004b) Region IX PRG tables.

Carcinogenic Slope Factors

The USEPA's Carcinogen Assessment Group has developed slope factors for estimating the individual upper bound excess lifetime cancer risks associated with various levels of lifetime exposure to potential human carcinogens. In practice, slope factors (expressed in units of $[mg/kg/day]^{-1}$) are derived from the results of human epidemiology studies or chronic

animal bioassays. Based on evaluations of these studies, chemicals are placed into one of the following categories:

Group	Category
A	Human carcinogen
B	Probable human carcinogen: • B1 indicates limited human evidence; • B2 indicates sufficient evidence in animals or no evidence in humans
C	Possible human carcinogen
D	Not classifiable as to human carcinogenicity

The oral slope factors used in assessing potential carcinogenic health effects are shown in Table 4-3. Potential health risks were evaluated for the Class A, B, and C carcinogens detected at Mākua Beach and the Mākua muliwai for which slope factors were available. Table 4-3 also provides the tumor type caused by each COPC, the experimental test species, and the source of each slope factor.

Toxicity values (i.e., cancer slope factors and noncarcinogenic reference doses) have not been developed for most of the polychlorinated dibenzodioxins and -furans. The USEPA has developed a slope factor for only 2,3,7,8-TCDD. However, by using toxicity equivalency factors given in Table 4-4 (USEPA 2000a), the measured concentrations of the dioxins and furans were converted to an estimated 2,3,7,8-TCDD-equivalent concentration for each sample. For nondetected concentrations, a result of zero was used. The exposure point concentrations (EPCs) for TCDD-equivalents were then used in evaluating the risks from potential exposures to dioxins and furans at the site.

Noncarcinogenic Reference Doses

The toxicity values used to assess noncarcinogenic health risks were the chronic RfDs (Table 4-3). The table also provides information on the health effect of concern or critical effect for each chemical and the test species in which the effect was demonstrated. The USEPA (1989) assigns several measures of confidence to each RfD, as follows:

- Confidence levels are categorical measures of the uncertainty associated with the experimental procedures used as the basis of an RfD;
- The USEPA uses uncertainty factors and modifying factors to reflect scientific judgment regarding the data used to estimate RfD values
  - The USEPA uses an uncertainty factor of 10 to account for variations in human sensitivity when extrapolating from human studies involving subchronic or chronic exposures of average healthy subjects,
  - Additional factors of 10 are applied for extrapolations from long-term animal studies and for extrapolations from subchronic exposure experiments to chronic exposures, and

- Finally, the USEPA assigns values between 0 and 10 for the modifying factor to quantify professional assessment of the uncertainties of the data used to calculate the RfD. The default value for the modifying factor is 1.

The confidence levels, uncertainty factors, and modifying factors assigned to each RfD are also shown in Table 4-3.

Chemicals for Which the USEPA Has Not Developed Toxicity Values

Surrogate toxicity values were determined by assuming that certain chemical isomers have similar toxic effects. Chemicals evaluated with surrogate toxicity values are noted in Tables 4-2 and 4-3.

A review of the published literature shows that arsenic is present almost exclusively as organic forms in marine fish tissues (Neff 1997; de Gieter et al. 2002; Kirby and Maher 2002; Frankenberger 2002; Kirby et al. 2002; Sloth et al. 2005). Bacteria and algae tend to methylate inorganic arsenic and convert it to simple organoarsenic compounds (e.g., arsenosugars) (Tamaki and Frankenberger 1989). Marine animals subsequently convert these simple organic arsenic compounds to more complex organic forms (Kirby and Maher 2002; Neff 1997). In marine fish, arsenobetaine may represent 70 to 90 percent of the total arsenic present in tissue (de Gieter et al. 2002; Kirby and Maher 2002), with the rest being almost completely other organic forms of arsenic (Frankenberger 2002; Sloth et al. 2005). Organic arsenic species are considered nontoxic to both fish and to their predators, including humans. Therefore, the arsenic measured in fish tissues was assumed to be a nontoxic form and was not evaluated here. In contrast, the arsenic in marine algae may be greater than 50 percent arsenic V (Frankenberger 2002; Kirby et al. 2005), which is toxic; therefore, arsenic in seaweed was evaluated as inorganic arsenic.

The USEPA has not developed an RfD for lead, primarily because there is considerable controversy regarding the threshold at which adverse health effects from lead occur. The USEPA has determined that lead exposure can result in various health effects, depending on the level of exposure. Also, potential health effects differ, depending on whether exposure occurs to an adult or a child. At blood-lead levels of 10 to 15 micrograms per deciliter (μg/dL), or possibly lower, health effects may include inhibited activity of enzymes involved in red blood cell metabolism, interference with heme synthesis, interference with vitamin D hormone synthesis, altered brain wave activity, deficits in intelligence quotient and other mental indices, early childhood growth reductions, and small increases in blood pressure (*Federal Register* 56[110]:26460-26564). To evaluate potential risks from exposures to lead, a computer spreadsheet application developed by the State of California was used, and the predicted blood-lead levels were compared to an action level of 10 μg/dL. Defaults were used for all model inputs, with the exception of "homegrown produce," which was assumed to be the fish consumed by subsistence fishermen and were therefore assumed to be 100 percent. Additionally, the concentration of "lead in homegrown produce" was modified to that of the maximum detected lead concentration in fish sampled in each of the four areas.

4.5 HUMAN HEALTH RISK CHARACTERIZATION

Risk characterization integrates the exposure assessment and chemical toxicity information to quantitatively estimate potential health risks from COPCs. Risk estimates were determined for individual routes of chemical exposure as well as for additive effects. The results of the risk characterization provide a basis for decisions regarding further action at Mākua Beach and the Mākua muliwai.

4.5.1 Risk Estimation Procedures

Because of fundamental differences in the calculation of critical toxicity values, the estimates of potential individual carcinogenic risks and noncarcinogenic health effects were developed separately.

Carcinogenic Risk Probabilities

For carcinogens, the risk of cancer is assumed to be proportional to dose and that any exposure results in a nonzero probability of risk. Carcinogenic risk probabilities were calculated by multiplying the estimated exposure level by the route-specific cancer slope factor for each carcinogen:

$$R = E \times SF$$

where

R = Estimated individual lifetime cancer risk;
E = Exposure or intake level for each chemical of potential concern (mg/kg/day); and
SF = Route- and chemical-specific slope factor ($(mg/kg/day)^{-1}$).

Risk probabilities determined for each carcinogen were also considered to be additive over all exposure pathways so that an overall risk of cancer was estimated for each group of potentially exposed receptors.

Risk probabilities can be compared to the generally acceptable risk range specified by the USEPA. According to the revised National Contingency Plan (USEPA 1990), carcinogenic risks from exposures at Superfund sites are considered to be unacceptable at a level greater than 1×10^{-4}, whereas risks less than 1×10^{-6} are considered to be of minimal concern. For Superfund sites, action may not be necessary in the risk range of 10^{-6} to 10^{-4}. This is supported in the directive *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions* (USEPA 1991b), which indicates action is generally warranted at a Superfund site when the cumulative carcinogenic risk for any *medium* is greater than 10^{-4}. In general, a potential individual lifetime cancer risk of 1×10^{-5} (i.e. 1 person out of 100,000 people may develop cancer) is used when determining whether chemical exposures for fish consumption represent a potentially unacceptable level of risk to public health (USEPA 2000a). Altogether, this range of potentially acceptable risks helps put the numerical risk estimates into perspective. MMR is not on the National Priorities List, and therefore is not in the Superfund program. However, the risk assessment was performed in accordance with Superfund guidance documents.

Noncarcinogenic Hazard Quotients and Hazard Indices

In contrast to carcinogens, noncarcinogens are considered to be threshold chemicals: a critical chemical dose must be exceeded before a health effect is observed. The likelihood of a potential adverse health effect is represented by the ratio of a chemical exposure level and the route-specific RfD:

$$HQ = E / RfD$$

where

HQ	= Hazard Quotient for each chemical of potential concern;
E	= Exposure or intake level for chemical of potential concern; and
RfD	= Route- and chemical-specific Reference Dose.

Also, in a manner similar to carcinogens, HQ values were summed across exposure pathways and for all chemical exposures to develop hazard index (HI) values. An HQ or HI value greater than 1 indicates that an adverse health effect may occur due to a chemical exposure. HQs and HIs are not risk probabilities, but the USEPA currently accepts them as quantitative levels of risk for noncarcinogens or the noncarcinogenic endpoints of carcinogens.

Background

Chemicals at the Mākua muliwai and Mākua Beach may originate from releases attributable to the MMR, as well as from other sources, including natural and anthropogenic sources not attributable to the MMR (USEPA 1989, 2002d). The chemicals most likely attributable to the MMR are explosives compounds, although a wide variety of other chemicals were included in the risk assessment. A discussion of the sources of many of these chemicals is provided in Section 3. When the source of chemicals in the environment cannot be determined, one approach is to quantify the risks from exposures both at the site and under background conditions (USEPA 1989, 2002d). To distinguish the contribution to the risk estimates from background exposures, as recommended by the USEPA (2002d), the risk estimates are presented for exposures at the site minus the risks from exposures under background conditions.

Lead Risk Evaluations

An RfD has not been developed for lead, so a different approach was used to evaluate potential health risks from lead exposure. The blood-lead level predicted for receptors potentially exposed to lead at the Site 8 Cluster was compared to a blood-lead level of concern. A clear no-observed-effect level has not been established for many adverse health effects associated with lead exposure. Dose-response curves for some of these health effects appear to extend down to a blood-lead level of 10 μg of lead per dL of whole blood (10 μg/dL) or less. USEPA typically considers that action may be warranted if the 95th percentile of predicted blood-lead levels exceeds 10 μg/dL; that is, action may be considered if there is a five percent chance that a receptor exposed to lead could have a blood-lead level greater than 10 μg/dL. The results of the model indicate that the maximum predicted 95th percentile blood lead concentration for adults and children consuming fish from the Mākua

muliwai and Mākua Beach is 3.8 μg/dL, which does not exceed the action level. The lead spread spreadsheets are provided in Appendix D.

4.5.2 Risk Estimates

Using likely fish consumption rates for Hawaii, the total carcinogenic risks and overall noncarcinogenic HI values were estimated for each receptor of potential concern (i.e., subsistence fishermen and recreational fishermen) in the two areas of concern at Mākua, i.e., the Mākua muliwai and Mākua Beach. Risks are provided for each receptor group and each COPC. Each set of risk analyses is accompanied by the risks from exposures under background conditions. The risk analyses, therefore, provide an indication of the contributing influence of background exposures to the risk estimates. Detailed exposure and risk calculations are provided in Appendix D.

Risks estimated for each group of receptors evaluated are described below.

Mākua Muliwai—Fish Consumption

Subsistence Fishermen

Using likely fish consumption rates for Hawaii, carcinogenic risk probabilities were calculated for current and future subsistence fishermen potentially exposed to the mean concentrations of COPCs in fish caught at the Mākua muliwai. Table 4-6 shows that the overall risk estimate is approximately 1×10^{-5}, with background contribution of 6×10^{-6}. Therefore, the incremental risks (i.e., over background) from fish consumption at the muliwai is approximately 7×10^{-6} for subsistence fishermen. This risk estimate is below the 1×10^{-5} risk level (one person in 100,000 people may develop cancer) used in assessing fish consumption (USEPA 2000a).

As an upper bound on these risk estimates, note that if subsistence fishermen are assumed to be exposed to the maximum concentrations of COPCs in fish caught at the Mākua muliwai, the overall risk estimate is approximately 4×10^{-5}, with a background contribution of 6×10^{-6}, giving an incremental risk from fish consumption at the muliwai of 3×10^{-5} (Table 4-7).

Noncarcinogenic hazards were also calculated for subsistence fishermen potentially exposed to the mean concentrations of COPCs in fish caught at the Mākua muliwai. Table 4-8 shows that the overall HI was estimated at approximately 20, with a background contribution of 47. Therefore, there is no incremental hazard (i.e., over background) from fish consumption at the muliwai.

As an upper bound on these hazard estimates, it should be noted that if subsistence fishermen are assumed to be exposed to the maximum concentrations of COPCs in fish caught at the Mākua muliwai, the overall HI is estimated at approximately 44, with a background contribution of 51. Therefore, there is no incremental hazard (i.e., over background) from fish consumption at the muliwai.

Recreational Fishermen

Using likely fish consumption rates for Hawaii, carcinogenic risk probabilities were calculated for current and future recreational fishermen potentially exposed to the mean concentrations of COPCs in fish caught at the Mākua muliwai. Table 4-6 shows that the overall risk estimate is approximately 4 x 10^{-6}, with background contribution of 2 x 10^{-6}. Therefore, the incremental risks (i.e., over background) from fish consumption at the muliwai is approximately 2 x 10^{-6} for recreational fishermen. This risk estimate is below the 1 x 10^{-5} risk level used in assessing fish consumption (USEPA 2000a).

As an upper bound on these risk estimates, it should be noted that if recreational fishermen are assumed to be exposed to the maximum concentrations of COPCs in fish caught at the Mākua muliwai, the overall risk estimate is approximately 1 x 10^{-5}, with a background contribution of 2 x 10^{-6}; giving an incremental risk from fish consumption at the muliwai of 1 x 10^{-5} (Table 4-7).

Noncarcinogenic hazards were also calculated for recreational fishermen potentially exposed to the mean concentrations of COPCs in fish caught at the Mākua muliwai. Table 4-8 shows that the overall HI was estimated at approximately 7, with a background contribution of 16. Therefore, there is no incremental hazard (i.e., over background) from fish consumption at the muliwai.

As an upper bound on these hazard estimates, it should be noted that if subsistence fishermen are assumed to be exposed to the maximum concentrations of COPCs in fish caught at the Mākua muliwai, the overall HI is estimated at approximately 15, with a background contribution of 17 (Table 4-9). Therefore, there is no incremental hazard (i.e., over background) from fish consumption at the muliwai.

Nearshore Mākua Beach—Fish Consumption

Subsistence Fishermen

Using likely fish consumption rates for Hawaii, carcinogenic risk probabilities were calculated for current and future subsistence fishermen potentially exposed to the mean concentrations of COPCs in fish caught in the shallow nearshore waters at Mākua Beach. Table 4-10 shows that the overall risk estimate is approximately 9 x 10^{-5}, with background contribution of 6 x 10^{-5}. The incremental risks (i.e., over background) from fish consumption is approximately 3 x 10^{-5} for subsistence fishermen. This risk estimate exceeds the risk level used in assessing fish consumption of 1 x 10^{-5} (USEPA 2000a), although it is within the USEPA (1990) target risk range of 10^{-6} to 10^{-4}. The incremental risks over background are largely due to assumed exposures to alpha-BHC, bis(2-ethylhexyl)phthalate, and heptachlor epoxide.

As an upper bound on these risk estimates, it should be noted that if subsistence fishermen are assumed to be exposed to the maximum concentrations of COPCs in fish caught in the shallow nearshore waters at Mākua Beach, the overall risk estimate is approximately 2 x 10^{-4}, with a background contribution of 1 x 10^{-4}. The incremental risks (i.e., over background) from fish consumption is approximately 7 x 10^{-5} for subsistence fishermen. This risk

estimate exceeds the risk level used in assessing fish consumption of 1 x 10^{-5} (USEPA 2000a), although it is within the USEPA (1990) target risk range of 10^{-6} to 10^{-4}. These incremental risks over background are largely due to assumed exposures to alpha-BHC, bis(2-ethylhexyl)phthalate, and heptachlor epoxide (Table 4-11).

Noncarcinogenic hazards were also calculated for subsistence fishermen potentially exposed to the mean concentrations of COPCs in fish caught in the shallow nearshore waters at Mākua Beach. Table 4-12 shows that the overall HI was estimated at approximately 4, with a background contribution of 5. Therefore, there is no incremental hazard (i.e., over background) from fish consumption.

As an upper bound on these hazard estimates, it should be noted that if subsistence fishermen are assumed to be exposed to the maximum concentrations of COPCs (Table 4-13), the overall HI is estimated at approximately 9 with a background contribution of 23. Therefore, there is no incremental hazard (i.e., over background).

Recreational Fishermen

Using likely fish consumption rates for Hawaii, carcinogenic risk probabilities were calculated for current and future recreational fishermen potentially exposed to the mean concentrations of COPCs in fish caught in the shallow nearshore waters at Mākua Beach. Table 4-10 shows that the overall risk estimate is approximately 3 x 10^{-5}, with background contribution of 2 x 10^{-5}. Therefore, the incremental risks (i.e., over background) from fish consumption at the muliwai is approximately 1 x 10^{-5} for recreational fishermen. This risk estimate does not exceed the risk level used in assessing fish consumption of 1 x 10^{-5} (USEPA 2000a).

As an upper bound on these risk estimates, note that if recreational fishermen are assumed to be exposed to the maximum concentrations of COPCs in fish caught at the Mākua muliwai, the overall risk estimate is approximately 7 x 10^{-5}, with background contribution of 4 x 10^{-5}; giving an incremental risk from fish consumption of 2 x 10^{-5} (Table 4-11). This risk estimate exceeds the risk level used in assessing fish consumption of 1 x 10^{-5} (USEPA 2000a), although it is within the USEPA (1990) target risk range of 10^{-6} to 10^{-4}. These incremental risks over background are largely due to assumed exposures to alpha-BHC, bis(2-ethylhexyl)phthalate, and heptachlor epoxide (Table 4-11).

Noncarcinogenic hazards were also calculated for recreational fishermen potentially exposed to the mean concentrations of COPCs in fish caught at Mākua Beach. Table 4-12 shows that the overall HI was estimated at approximately 2, with background contribution of 2. Therefore, there is no incremental hazard (i.e., over background) from fish consumption.

As an upper bound on these hazard estimates, note that if subsistence fishermen are assumed to be exposed to the maximum concentrations of COPCs in fish caught at the Mākua muliwai, the overall HI is estimated at approximately 3, with background contribution of 8. Therefore, there is no incremental hazard (i.e., over background) from fish consumption (Table 4-13).

Nearshore Mākua Beach—Seaweed Consumption

Subsistence Fishermen

Carcinogenic risk probabilities were calculated for current and future subsistence fishermen potentially exposed to the mean concentrations of COPCs in seaweed harvested from the shallow nearshore waters at Mākua Beach. Table 4-14 shows that the overall risk estimate is approximately 1×10^{-2}. This risk estimate exceeds the risk level used in assessing fish consumption of 1×10^{-5} (USEPA 2000a) and the USEPA (1990) target risk range of 10^{-6} to 10^{-4}. This risk estimate is almost entirely due to assumed exposures to arsenic in seaweed, which was up to 109 mg/kg.

The arsenic in seaweed was assumed to be entirely inorganic; however, the arsenic was not speciated and the seaweed was not identified to species. In many seaweed species, arsenic can be present entirely in nontoxic organic forms, although it is present in some species in inorganic forms at up to 50 percent or more (Frankenberger 2002). Therefore, it is likely that at least some of the arsenic present in the seaweed harvested from the shallow nearshore waters at Mākua Beach is present in nontoxic inorganic forms, indicating that the risks here are overestimated to a certain degree. Further, since no background samples were collected, it is not possible to determine whether the arsenic levels detected in seaweed at Mākua Beach are elevated over background. The levels detected at Mākua Beach may well be naturally occurring.

As an upper bound on these risk estimates, note that if subsistence fishermen are assumed to be exposed to the maximum concentrations of COPCs in seaweed harvested at Mākua Beach, the overall risk estimate is approximately 2×10^{-2} (Table 4-15). Again, this is almost entirely due to arsenic.

Noncarcinogenic hazards were also calculated for subsistence fishermen potentially exposed to the mean concentrations of COPCs in seaweed harvested in the shallow nearshore waters at Mākua Beach. Table 4-14 shows that the overall HI was estimated at approximately 58, which exceeds the threshold HI of 1. As for the carcinogenic risk estimates presented above, this is almost entirely due to assumed exposures to arsenic. As an upper bound on these hazard estimates, note that if subsistence fishermen are assumed to be exposed to the maximum concentrations of COPCs (Table 4-15), the overall HI is estimated at approximately 96.

Recreational Fishermen

Carcinogenic risk probabilities were calculated for current and future recreational fishermen potentially exposed to the mean concentrations of COPCs in seaweed harvested from the shallow nearshore waters at Mākua Beach. Table 4-14 shows that the overall risk estimate is approximately 3×10^{-3}. This risk estimate exceeds the risk level used in assessing fish consumption of 1×10^{-5} (USEPA 2000a) and the USEPA (1990) target risk range of 10^{-6} to 10^{-4}. This risk estimate is almost entirely due to assumed exposures to arsenic in seaweed. As an upper bound on these risk estimates, note that if recreational fishermen are assumed to be exposed to the maximum concentrations of COPCs in seaweed from Mākua Beach, the overall risk estimate is approximately 5×10^{-3} (Table 4-15).

Noncarcinogenic hazards were also calculated for recreational fishermen potentially exposed to the mean concentrations of COPCs in fish caught at the Mākua muliwai. Table 4-14 shows that the overall HI was estimated at approximately 17. This HI is almost entirely due to assumed exposures to arsenic and exceeds the threshold HI of 1. As an upper bound on these hazard estimates, note that if subsistence fishermen are assumed to be exposed to the maximum concentrations of COPCs in seaweed from Mākua Beach, the overall HI is estimated at approximately 27 (Table 4-15).

4.6 UNCERTAINTY ANALYSIS

A major uncertainty in this risk assessment was the assumption that fishermen could rely on the muliwai for all of their fishing. The muliwai are generally the size of a small pond, so it is unlikely that the two muliwai evaluated here could hold enough fish to support even one subsistence fisher. Before long, a subsistence fisher would depopulate the muliwai and be forced to go fishing elsewhere. In addition, the barrier separating the muliwai from the ocean is occasionally breached due to either heavy stream flows or strong waves. In either case, the fish population of the muliwai can change dramatically at that time, with new species appearing and other species disappearing. When heavy rainfall leads to a breach in the barrier separating the muliwai from the ocean, the fish in the muliwai also get expelled into the ocean, leading to a period of lower fish abundance in the muliwai. Both of these factors indicate that the assumption of a subsistence fisher relying exclusively on the muliwai is unrealistic and, therefore, the risk estimates for the subsistence fisher at the muliwai should be regarded as an artificial scenario that overestimates exposures to chemicals present in the muliwai fish.

Fishermen were assumed to eat whatever fish were caught rather than just fish of a specific species; however, some fishermen may target only certain species. Therefore, depending on the preference of the individual fisherman, exposures could vary from that presented here.

As discussed in Section 4.4.1.3, the arsenic in marine fish was assumed to be almost exclusively organic arsenic, which is nontoxic to humans. Although these assumptions are supported by the scientific literature, fish from the site were not specifically analyzed for inorganic versus organic arsenic. Therefore, there is a possibility that the arsenic in the fish at the site may be in the inorganic form, which is toxic. While the assumption that the arsenic in the fish is organic reflects the best available scientific information, the assumption may have resulted in underestimating risks.

The seaweed samples collected in the nearshore waters off Mākua Beach were not identified to species. In some species of brown algae and red algae, arsenic may occur in inorganic forms at more than 50 percent (Frankenberger 2002; Kirby et al. 2005); however, there are many species of algae in which all arsenic is present in nontoxic organic forms (Frankenberger 2002). Therefore, the assumption that the arsenic in the seaweed was inorganic may have resulted in overestimating risks. Additionally, seaweed was not collected from background locations as part of this study; therefore, it is unknown whether arsenic in the seaweed collected off Mākua Beach is elevated over background conditions.

Some of the analytical data for the organochlorine pesticides was flagged by the analytical laboratory as having unacceptable relative percent differences between the high pressure liquid chromatography and gas chromatograph columns. This indicates that there was either interference from polychlorinated biphenyl compounds or co-elution of a nontarget compound on one of the columns. This provides an unacceptable level of uncertainty to the results flagged in this manner, so all analytical results flagged by the analytical laboratories this way were considered suspect and were not used.

Some metals data from the fish and seaweed samples were flagged by the analytical laboratory as having matrix spike sample recoveries outside of acceptable limits. USEPA (1989) guidance states that data flagged in this way is usable in a risk assessment.

The highest detected concentration of nitroglycerin in fish tissue from the muliwai was flagged by the analytical laboratory as follows: "There was a positive detection for nitroglycerin on the primary analysis. Nitroglycerin was tentatively confirmed on the confirmation column analysis although a large interference peak eluted at the retention time of the analyte. There is a shoulder on the side of the peak that could possibly be the analyte. The analyte is being reported as positively identified in a conservative approach to protecting the environment." Therefore, the concentration of nitroglycerin in fish tissues at the Mākua muliwai may have been overestimated by the laboratory.

Fishermen were assumed to eat fish whole and not remove the skin, head, gonads, or gastro-intestinal tract. Many fishermen do not eat whole fish, only fish fillets. In the process of filleting and cooking a fish, the concentrations of some contaminants may be reduced. Therefore, the risk estimates presented here may overestimate the exposures and risks for fishermen that do not eat whole fish.

4.7 CONCLUSIONS

The potential risks to subsistence and recreational fishermen were evaluated for the consumption of fish caught at the Mākua muliwai and Mākua Beach. The consumption of seaweed harvested off Mākua Beach was also evaluated. The results of assumed exposure to mean concentrations are shown below.

4.7.1 Mākua Muliwai—Fish Consumption

Subsistence Fishermen

The incremental risk (assuming mean concentrations in fish) is approximately 7×10^{-6}, which is below the 1×10^{-5} risk level used in assessing fish consumption of (USEPA 2000a). The noncarcinogenic HI from fish consumption does not exceed background.

Recreational Fishermen

The incremental risk (assuming the more likely fish consumption rate and mean concentrations in fish) is approximately 2×10^{-6}, which is below the risk level used in assessing fish consumption of 1×10^{-5} (USEPA 2000a). The noncarcinogenic HI from fish consumption does not exceed background.

4.7.2 Mākua Beach—Fish Consumption

Subsistence Fishermen

The incremental risk (assuming mean concentrations in fish) is approximately 3 x 10^{-5}, which exceeds the risk level used in assessing fish consumption of 1 x 10^{-5} (USEPA 2000a). This was primarily due to assumed exposures to alpha-BHC, bis(2-ethylhexyl)phthalate and heptachlor epoxide. The noncarcinogenic HI from fish consumption does not exceed background.

Given that the fish are likely not contaminated by substances associated with the proposed training activities at MMR, that there is very little interchange between the muliwai where such substances might accumulate and the near-shore area which provides the habitat for the shellfish on which area residents rely, that any such transport of chemicals from the muliwai to the nearshore area would result in significant dilution of the chemicals, it is reasonable to conclude that the shellfish are not contaminated by substances associated with the proposed training activities at MMR.

Despite the conclusion that the shellfish are likely not contaminated from activities at MMR, field staff did attempt to collect shellfish and benthic invertebrates, including crabs and sea urchins, during the MRS. However, the selected method (passive traps) was not successful in capturing crabs. Additionally, because of the large number of analytes included in the chemical analytical program, field staff were unable to collect a sufficient number of sea urchins to provide enough sample mass (more than 200 grams) for all of the analyses. It is important to recognize that this project required destructive sampling of a living resource, which has the potential to negatively impact a species population in the muliwai. The Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with MMR, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is possible that shellfish and benthic invertebrates will be included as species of interest in this monitoring plan if it is determined that the sampling will not have a negative impact on the species population.

Recreational Fishermen

The incremental risk (assuming the more likely fish consumption rate and mean concentrations in fish) is approximately 1 x 10^{-5}, which does not exceed the risk level used in assessing fish consumption of 1 x 10^{-5} (USEPA 2000a). The noncarcinogenic HI from fish consumption does not exceed background.

4.7.3 Mākua Beach—Seaweed Consumption

The risk estimates for both subsistence and recreational fishermen assumed to be consuming seaweed from Mākua Beach exceeded the risk level used in assessing fish consumption of 1 x 10^{-5} (USEPA 2000a) and the USEPA (1990) target risk range of 10^{-6} to 10^{-4}. Similarly, the HIs for both subsistence and recreational fishermen exceeded the threshold HI of 1. However, it should be noted that there is significant uncertainty in these estimates; for example, all of the arsenic detected in the seaweed was assumed to be inorganic, even though the arsenic in the seaweed was not speciated. Further, the incremental risks from seaweed consumption could not be determined because background seaweed samples were not collected.

This page intentionally left blank.

5. ECOLOGICAL RISK ASSESSMENT

SECTION 5
ECOLOGICAL RISK ASSESSMENT

This risk assessment addresses the potential ecological risks associated with current and future exposures to environmental media at the Mākua muliwai and nearshore habitat. A screening level ERA evaluates the potential for adverse ecological effects that might occur as a result of assumed exposures to a variety of chemicals at these locations.. The ERA process systematically evaluates and organizes data, assumptions, and uncertainties to help understand and predict the relationships between chemical stressors and ecological effects in a way that is useful for decision making. The predictive ERA for the Mākua muliwai and nearshore habitat was conducted in accordance with federal guidance (USEPA 1992b, 1997, 1998, 2006a) and consists of the following elements:

- Problem formulation;
- Analysis; and
- Risk characterization.

Each of these elements of the screening level ERA is explained below.

Problem Formulation

The problem formulation establishes the scope of the screening level ecological risk assessment, identifies the major factors to be considered, and ensures that both the ecological receptors most likely to be exposed and the exposure scenarios most likely to contribute to ecological risks are evaluated. The problem formulation consists of the following tasks, each of which is discussed in further detail in Section 5.3:

- Identify potentially affected areas of concern;
- Identify chemicals of potential ecological concern (COPECs);
- Identify potentially complete exposure pathways; and
- Establish assessment endpoints.

Analysis

The analysis phase consists of an evaluation of the data required to estimate exposures and to characterize effects (USEPA 1992b, 1998). The analysis phase consists of the following tasks, each of which is discussed in further detail in Section 5.4:

- Select indicator species and wildlife exposure factors;
- Characterize bioaccumulation of chemicals through the food chain; and
- Establish toxicity reference values (TRVs).

Risk Characterization

The risk characterization integrates the results of the analysis phase (i.e., exposure and effects) to evaluate the likelihood of adverse ecological impacts associated with exposure to COPECs (USEPA 1992a). The risk characterization consists of the following subtasks:

- Calculate risk estimates (i.e., hazard quotients);
- Identify and characterize sources of uncertainty; and
- Conduct risk interpretation.

5.1 GUIDANCE

This ERA was performed according to the following guidance documents and work plans:

- *Guidelines for Ecological Risk Assessment* (USEPA 1998);
- *Ecological Risk Assessment Guidance for Superfund Sites: Process for Designing and Conducting Ecological Risk Assessments—Interim Final* (USEPA 1997c);
- *Framework for Ecological Risk Assessment* (USEPA 1992b);
- *Assessing Risks to Populations at Superfund and RCRA Sites Characterizing Effects on Populations* (USEPA 2006b).

5.2 PROBLEM FORMULATION

The problem formulation presents and evaluates information that is used to develop and focus the analysis component of the ERA. The problem formulation phase is a process for generating and evaluating preliminary hypotheses about why ecological effects have occurred, or may occur, from environmental conditions at the site in question. As such, the problem formulation lays the foundation for the risk assessment and, therefore, requires the careful integration of many pieces of information. The information evaluated includes a description of the following:

- Areas evaluated for potential risks;
- Preliminary identification of COPECs, based on the sampling efforts, including preliminary evaluations of data usability and comparisons of preliminary data to screening effect levels to identify COPECs;

- Development of assessment endpoints (i.e., important aspects of the site to be protected), risk hypotheses (i.e., statements of how potential exposure to stressors could occur at the site and potential adverse effects), and measures (of exposure, effect, and of ecosystem and receptor characteristics).

A principal result of the problem formulation phase is an ecological CSM that describes potential ecological receptors that may be affected at the site. This conceptual site model is also used to guide the development of the analysis plan which delineates the assessment design, data needs, measures, and methods for conducting the analysis phase of the risk assessment. Upon completion of the problem formulation, the next step in the ERA process is the analysis.

5.3 AREAS OF CONCERN

The muliwai evaluated for potential risks consist of the north and south muliwai at the base of the Mākua Valley (Figure 2-1). The muliwai are estuarine ponds that are typically cut off from direct contact with the ocean but that periodically become open to tidal flow. As both of the muliwai in the Mākua Valley are fed by streams that run through the MMR, both may be impacted by potential upstream releases at MMR. For the purposes of this risk assessment, each of the muliwai in the Mākua Valley were considered individual areas of concern. The north and south background areas and the muliwai at Nanakuli (Figure 2-1) were considered representative background locations for the muliwai in the Mākua Valley and were used to compare exposures under background conditions to those downstream from the MMR.

Fishes and seaweed were also collected in the nearshore areas off MMR and Sandy Beach (Figure 2-1). The nearshore samples off MMR could show impacts from the releases to the streams in the Mākua Valley. Sandy Beach was considered to be a background location for the nearshore samples from Mākua and was used to compare exposures under background conditions to those offshore of the MMR.

5.4 CHEMICALS OF POTENTIAL ECOLOGICAL CONCERN

COPECs are chemicals detected in environmental media at the Mākua muliwai and nearshore habitat that may adversely impact the identified receptors of concern. The three environmental media were sampled at the Mākua muliwai and nearshore area were sediment, fish tissue, and seaweed.

Sediment samples were analyzed for metals (USEPA methods 314.0, 6010B, and 7471A), cyanide (USEPA method 335.2), VOCs (USEPA method 8021B), SVOCs (USEPA method 8270C), organochlorine pesticides (USEPA method 8081A), chlorinated herbicides (USEPA method 8151A), dioxins/furans (USEPA method 8280/8290), explosives (USEPA methods 8330A and 8332), and general chemistry parameters (USEPA methods 354.1 and 9045C and SM4500).

Tissue samples were analyzed for metals (USEPA methods 200.7, 200.8, 245.6, 270.3, 6010B, 6020, 7471A, and 7740), methyl mercury (USEPA method 1630), VOCs (USEPA method 8260B), SVOCs (USEPA method 8270C), organochlorine pesticides (USEPA

method 8081A), dioxins/furans (USEPA method 8280/8290), explosives (USEPA method 8330A), and perchlorate (DOD method).

All chemical data collected for each environmental medium were reviewed during the selection of COPECs.

5.4.1 Data Review

All of the analytical results from the sediment samples collected in 2003 (Tetra Tech 2005b) and tissue samples collected during 2006 (see Sections 2.3) were reviewed and evaluated in the selection of COPECs. Soil, sediment, groundwater, and surface water data collected in 2002-2004 from the Mākua Valley were not used in this risk assessment. These data were collected upstream of the muliwai and represent locations that could serve as sources of contaminants to the muliwai and the nearshore habitat off MMR, but no samples were collected from either the muliwai or the ocean.

Sample locations where fish and limu were collected for use in the risk assessment are shown in Figures 2-1 and 2-2. Detailed descriptions of the analytical methods used for sediment and tissue samples are provided in Tetra Tech (2005b) and Section 2, respectively.

Data validation efforts classified the data through the use of several qualifiers. Data without qualifiers were considered appropriate for risk assessment purposes. Following USEPA guidance (1989), data with J qualifiers were used for risk assessment purposes. U and UJ qualified data were considered to be nondetected but usable for risk assessment purposes. B and BJ qualified data were treated as nondetected chemicals because the estimated chemical concentrations were not significantly higher than levels in QA/QC blanks associated with the samples. R qualified data were excluded from the risk assessment.

Evaluation of Sediment Samples

Twenty-three sediment samples (22 primary and 1 duplicate) were collected from the north muliwai at MMR (Figure 2-2). These samples were from 22 locations from one to three feet deep. All samples were analyzed for metals and explosives, and six were also analyzed for organic constituents.

Eighteen sediment samples (17 primary and 1 duplicate) were collected from the south muliwai at MMR (Figure 2-2) from 18 locations, from one to three feet deep. All samples were analyzed for metals and explosives, and five samples were also analyzed for organic constituents.

Four sediment samples (three primary and one duplicate) were collected from each of the north and south background areas (Figure 2-2). These samples were from one to two feet deep. All samples were analyzed for metals and explosives.

The sediment samples collected are listed by location in Tetra Tech (2005b). As part of the QA/QC process, laboratory duplicates were analyzed for some samples. Since the laboratory duplicates are duplicates of sediment samples, the difference among the

duplicates should include heterogeneous variations in the sediment matrix. Therefore, the laboratory duplicates were included in the ecological risk.

Background Comparisons

Metals at concentrations equivalent to or lower than background concentrations do not need to be considered in the risk assessment. Therefore, the metal COPECs were selected by comparing metal concentrations detected in muliwai sediments to local background metal concentrations (Appendix E.2).

The site dataset consisted of metals concentrations in 35 sediment samples (including one duplicate) collected from the north and south muliwai at MMR combined. The background dataset consisted of metal concentrations from eight sediment samples (including two duplicate samples) collected from the north and south background areas combined. The background comparison consisted of the following steps:

1. Metals detected in less than 50 percent of the samples from either background or the site were conservatively assumed to be elevated at the site over background; however, metals that were not detected in any site samples were not evaluated;
2. The distributions of the data for each metal in both background and site samples were determined using the Shapiro-Wilk's test (USEPA 2002a, 2006b); as a result of this test, the distribution of the data for each metal was classified as normal, log-normal, or neither.
3. The types of distributions determined which statistical tests were used to compare the concentrations of each metal in sediments from the background and the site, as follows:
    a. Normal in both the background and site samples; the mean concentrations were compared (i.e., background versus site) using the *t*-test (USEPA 2002a, 2006b);
    b. Log-normal in both the background and site samples; the data were natural logarithm transformed and then the mean concentrations were compared (i.e., background versus site) using the *t*-test (USEPA 2002a, 2006b)
    c. Log-normal in either background or site samples and normal in the other; the data were natural logarithm transformed and then the mean concentrations were compared (i.e., background versus site) using the *t*-test (USEPA 2002a, 2006b); and
    d. Neither distribution in either background or site samples or in both locations; the median concentrations were compared using the Wilcoxon rank sum test (also known as the Mann-Whitney U test) (USEPA 2002a, 2006b).
4. The Behrens-Fisher version of the *t*-test was used for all cases. This version accounts for differences in variance between the two populations, and the results are the same as the student's *t*-test when the variances are equal;
5. The results of the *t*-tests or Wilcoxon rank sum tests were interpreted as follows:

a. $p > 0.05$: background and site metal concentrations do not significantly differ,

b. $p < 0.05$: background and site metal concentrations do significantly differ; the direction of the difference (i.e., whether site concentrations were greater than or less than background) was determined using a box plot (i.e., mean ± standard error for normally or log-normally distributed data and median ± 25 percentiles for non-normally and non-log-normally distributed data) (see Appendix E.2).

For these statistical evaluations, nondetects were replaced by one-half of the method detection limit. Metals not detected in site sediments were not evaluated. The results of these comparisons are shown in Appendix E.2. Antimony was identified as a COPEC because it was not detected in the background sediments but was detected in site sediments, though infrequently. Cadmium and selenium were identified as COPECs because they were not detected in the background sediments but were detected in site sediments. Lead was identified as a COPEC because it was less than 50 percent detected in the site sediments. Thus, four metals were identified as elevated over background in the north and south muliwai sediments. These COPECs are also listed in Table 5-1(a).

Evaluation of Tissue Samples

Twelve composite fish samples were collected from the two muliwai at the MMR (Figure 2-1). The species collected included striped mullet, tilapia, Hawaiian flagtail, and medaka. Three composite fish samples were collected from the background muliwai at Nanakuli (Figure 2-1). All of the fish samples collected at Nanakuli were tilapia.

Six composite fish samples were collected from the nearshore habitat off MMR (Figure 2-1), consisting of goatfish (i.e., sidespot and manybar), picasso triggerfish, blackspot triggerfish, and Christmas wrasse. These same fish species were collected in six samples at Sandy Beach, the nearshore background location (Figure 2-1), with the addition of saddle wrasse. Additionally, four seaweed samples were collected from the nearshore waters at Mākua.

The tissue samples collected are listed by location in Section 3. As part of the QA/QC process, laboratory duplicates were analyzed for metals for some samples. Since the laboratory duplicates are duplicates of homogenized samples, the difference among the duplicates should be due to only analytical variation. Therefore, the laboratory duplicates were excluded from the analyses presented here.

5.4.2 Chemicals of Potential Concern in the North Muliwai at MMR

In sediments, the COPECs for the north muliwai included four metals, five VOCs, one SVOC, one organochlorine pesticide, one explosive, and one dioxin. The COPECs are listed in Table 5-1(a).

In fish tissues, the COPECs for the north muliwai included 18 metals, one VOC, one SVOC, four organochlorine pesticides, one explosive, and dioxins and furans. No seaweed (limu) was collected from the north muliwai. The COPECs are listed in Table 5-1(b).

5.4.3 Chemicals of Potential Concern in the South Muliwai at MMR

In sediments, the COPECs for the south muliwai included four metals, four VOCs, two SVOCs, one chlorinated herbicide, and one dioxin. The COPECs are listed in Table 5-1(a).

In fish tissues, the COPECs for the south muliwai included 19 metals, two VOCs, two SVOCs, four organochlorine pesticides, one explosive, and dioxins and furans. No seaweed (limu) was collected from the south muliwai. The COPECs are listed in Table 5-1(b).

5.4.4 Chemicals of Potential Concern in the Nearshore Habitat off MMR

Sediments were not collected from the nearshore habitat off MMR.

The COPECs in fish from the nearshore habitat included 16 metals, two VOCs, two SVOCs, seven organochlorine pesticides, and three explosives. Dioxins and furans were not detected in the fish samples collected from the nearshore area off MMR. The COPECs are listed in Table 5-1(b).

The COPECs in seaweed from the nearshore habitat included 17 metals, one VOC, two SVOCs, one organochlorine pesticide, one explosive, and dioxins and furans.

5.5 ASSESSMENT ENDPOINTS AND MEASURES

A key goal of an ERA is to identify and characterize the potential for significant adverse impacts resulting from exposures at a site, so that methods to reduce, avoid, or eliminate these impacts may be considered. Assessment endpoints link the risk assessment to management concerns to ensure that the ERA provides information to assist in risk management decision making. To support the risk evaluation, assessment endpoints for this ERA help define significant adverse impacts and to focus ERA analyses.

Measures of exposure are contaminant concentrations in environmental media to which ecological receptors may be exposed (USEPA 1998), including contaminant concentrations in sediments and tissues at the sites. Receptor exposures were estimated from contaminant concentrations measured in environmental media.

Measures of effect are measurable responses by ecological receptors to contaminants (USEPA 1998). The measures of effect used in this ERA were sediment screening benchmarks and fish tissue-based toxicity data.

5.5.1 Assessment Endpoints

A key task of problem formulation is the establishment of assessment endpoints. Assessment endpoints are "explicit expressions of the actual environmental value that is to be protected" (USEPA 1992b, 1998) and provide the basis for all subsequent ERA efforts. Assessment endpoints were established to protect potentially affected benthic invertebrates, seaweed, and fish in the muliwai and nearshore waters. Assessment endpoints are composed of the receptor of concern and a characteristic of that receptor that is important to protect and is potentially at risk (USEPA 1992b).

Assessment endpoints for the muliwai and nearshore habitat off MMR were survival and persistence of seaweed and benthic invertebrates exposed to COPECs and survival, reproduction, and growth of fish chronically exposed to COPECs.

5.5.2 Measures

The three measure categories that are predictive of the assessment endpoints are measures of exposure, measures of effect, and measures of ecosystem and receptor characteristics (USEPA 1998). In this ERA, the measures below were used to determine the assessment endpoints.

- **Measures of Exposure:** The concentration of COPECs in sediments, seaweed tissues, and fish tissues;
- **Measures of Effects:** The adverse effects in benthic invertebrates, seaweed, and fish in response to exposure to a COPEC. For benthic invertebrates, adverse effects were based on toxicity observed in sediment bioassays or reduced abundance of invertebrates. Applicable measures of effects on seaweed based on tissue concentrations were not identified due to the absence of toxicity data. For fish, different adverse effects may have been selected in the development of the TRV_{Low} (based on the no observed effects concentration) and the TRV_{High} (based on the lowest observed effects concentration). These effects include reductions in survival, reproduction, and growth.

5.6 ECOLOGICAL CONCEPTUAL SITE MODEL

The ecological CSM combines information about the COPECs, potential ecological receptors, and potential exposure pathways to provide an overall picture of site-related exposures that is used to refine and focus the ERA. An ecological CSM for the north and south muliwai and nearshore habitat off MMR is presented in Figure 5-1.

5.6.1 Identification of Receptors

As it is impractical to evaluate all receptors at a site, this screening-level ERA evaluated risks for a set of representative receptors. Risks estimated for representative receptors are subsequently used to infer the potential for adverse impacts on taxonomically and functionally related receptors of concern.

Representative ecological receptors were identified as the biological organisms most likely to be exposed to the COPECs. Representative receptors were selected to fulfill as many of the following criteria as possible:

- Organisms that have been observed, or are likely to occur, in the muliwai or nearshore waters;
- Organisms that are likely to be maximally exposed to the COPECs;
- Organisms that are likely to play an integral role in the ecological community structure at the sites; and

- Organisms that are representative of specific foraging guilds or serve as food items for higher trophic levels.

The representative ecological receptors selected for the ERA areas follows:

- Benthic invertebrates;
- Aquatic invertebrates;
- Aquatic plants including seaweed; and
- Fish.

Each of the representative receptors is described below.

Benthic invertebrates: Sediment-dwelling organisms in the muliwai and nearshore waters include crustaceans, bivalves, polychaetes, echinoderms (sea urchins, sea stars), and other estuarine or marine biota. Benthic invertebrates were assumed to be exposed to COPECs in sediments at the sites.

***Aquatic invertebrates*:** Invertebrates in the water column in the muliwai and nearshore waters may include plankton, jellyfish, crustaceans and other estuarine or marine biota. Potential exposures to these receptors could not be assessed due to the absence of surface water data.

Aquatic plants: Marine macrophytes and algae, including seaweed, are potentially present in the muliwai or nearshore habitat. Aquatic plants could be exposed to constituents in water but could not be assessed due to the lack of surface water data or seaweed tissue-based toxicity data.

Fish: Several species of fish are present in the muliwai, including striped mullet, tilapia, Hawaiian flagtail, and medaka. Numerous species are potentially present in the nearshore habitat off MMR, including goatfish (i.e., sidespot and manybar), picasso triggerfish, blackspot triggerfish, and Christmas wrasse.

5.6.2 Exposure Pathway Inclusion/Exclusion

The exposure pathway inclusion/exclusion evaluation is based on information gathered from the problem formulation (Section 5.4), COPEC selection (Section 5.6), representative species selection (Section 5.7.1), the probable completeness of each exposure pathway, and the potential for that pathway to be a major or minor route of exposure and risk.

An exposure pathway describes the course that a chemical takes from a source to an exposed individual. A complete exposure pathway consists of the following four factors:

- A source of potentially toxic chemicals;
- A contaminated medium, such as sediment;
- An exposure or contact point with the contaminated medium; and

- An exposure route for chemical intake by a receptor, such as uptake across gills or membranes.

Designation of an exposure pathway as complete indicates that ecological exposure is possible but does not necessarily mean that exposure will occur or that exposure will occur at the levels estimated in this report. When any one of the factors is missing in a pathway, it is considered to be incomplete. Incomplete exposure pathways do not pose hazards and were not evaluated in this risk assessment.

The CSM provides the basis for identifying and evaluating the potentially complete exposure pathways at the muliwai and nearshore habitat off MMR. As shown in the CSM diagram (Figure 4-1), potential sources of COPECs include surface water, sediments, and fish. The CSM also illustrates the potential chemical migration pathways, exposure points, and exposure routes evaluated at the Mākua muliwai and nearshore habitat. Chemical fate and transport processes were used to define the potential migration pathway, and included transfer of COPECs between environmental media, such as surface water and fish tissue, and transport of COPECs through movement of an environmental medium by natural dispersive processes, such as surface water flow.

An exposure pathway is complete when there is a point at which chemical uptake by an ecological receptor may occur. Exposure routes considered in this ecological risk assessment consist of uptake from sediments (benthic invertebrates), uptake from surface water (such as across gills of fish), and ingestion of sediment, water, and food ingestion (fish). Exposures of invertebrates in the water column could not be assessed due to the absence of surface water data.

5.7 ANALYSIS

The analysis phase provides the information necessary to determine or predict ecological responses to COPECs under exposure conditions of interest. This phase consists of exposure and effects assessment (USEPA 1992b). Potential risks to receptors were estimated using exposure point concentrations. To evaluate the effects of the COPECs on the representative receptors, TRVs were selected.

5.7.1 Exposure Assessment

The exposure assessment includes an exposure analysis for the selected representative receptors and an exposure profile. The exposure analysis describes the relationships between the concentrations of COPECs at the site and the ecological receptors. Information used to establish this link includes the pathway by which the receptors are exposed to the COPECs in each medium and estimates of EPCs.

To estimate exposures of COPECs to ecological receptors, three essential inputs were needed:

- Representative receptors;
- Exposure profile; and

- EPCs for each COPEC;

The selection of representative receptors was previously discussed in Section 5.7.1. The following sections describe the technical approach for quantifying the exposures to COPECs by each of the receptors.

5.7.2 Exposure Profile

The exposure profile describes the complete exposure pathways between COPECs and receptors based on the potential for exposure under conditions at the sites. Complete exposure pathways were established through identification of ecological receptors and identification of COPECs in the media at the site. The pathways are evaluated by calculating EPCs for each COPEC in each environmental medium.

The potential exposure pathways for various receptors in the north and south muliwai and nearshore habitat off MMR were evaluated in the CSM presented in Section 5.7. The identified receptors and the pathways by which they are assumed to be exposed to the COPECs are listed below:

Benthic invertebrates—Contact with and uptake of COPECs in sediment;

Aquatic invertebrates—Contact with and uptake of COPECs in surface water;

Seaweed—Contact with and uptake of COPECs in surface water;

Fish—Contact with and uptake of COPECs in sediment, surface water, and food.

For benthic invertebrates, exposures to COPECs were estimated as the measured concentrations of COPECs in sediment ($mg_{COPEC}/kg_{sediment}$). Exposures of aquatic invertebrates could not be assessed due to the lack of surface water data. Exposures of seaweed may be estimated as the measured concentrations of COPECs in seaweed tissue (mg_{COPEC}/kg_{tissue}), but these exposures were not evaluated further due to the absence of applicable tissue-based toxicity data. Exposures of fish were estimated as the measured concentrations of COPECs in fish tissue (mg_{COPEC}/kg_{tissue}).

This exposure information was used, along with the ecological effects information described in Section 5.8.2, to estimate the potential risks to receptors presented in the risk characterization (Sections 5.9 and 5.10).

5.7.3 Exposure Point Concentrations

For sediments, EPCs were estimated using the reasonable maximum exposure concentration. This method ensures that the potential risks calculated from these concentrations are conservative and will not underestimate the possible risks. The reasonable maximum exposure concentration is defined as the UCL_{95} of the mean concentration or the maximum observed concentration, whichever is less (USEPA 1989, 2002b). The UCL_{95} was calculated following current USEPA (2002b) guidance using the latest version of ProUCL (USEPA 2004c).

In order to have enough fish mass to analyze the samples for the full analytical suite, the samples were composited, as described in Section 2. The use of composite samples to assess exposures is consistent with USEPA (2000a) and HDOH (2006) guidance. Composite samples are used to determine the mean concentration in the environmental medium sampled (USEPA 2000b). However, it is not possible to calculate upper confidence limits (UCLs) from composited samples because the variance (which is used in the calculation of UCLs) in the individual samples that were composited is not available. Instead of using the UCL_{95} of the mean concentration as the EPC, the maximum detected concentrations in composite fish samples were used as the EPCs, which is more conservative than using the UCL_{95}.

Field duplicates were collected as part of the QA/QC process. Since the field duplicates represent different sample material (i.e., different individual fish), the analytical results of the field duplicates were treated as unique samples in exposure point concentration calculations. However, as stated previously, laboratory duplicates were excluded. This is because the laboratory duplicates should show the variance due to analytical error and not due to differences in the actual environmental medium sampled.

The EPCs are provided in the risk tables (Tables 5-4 to 5-11). The distributions for each chemical detected in sediment and tissues are provided in Appendix E.1. Also provided in Appendix E.1 are tabulations of each COPEC's detection frequency, concentration range, mean, minimum, maximum, and UCL_{95} concentration, when available. The summary statistics are provided separately for each COPEC detected in each of the areas evaluated.

5.7.4 Effects Assessment

The effects assessment identifies and quantifies potential adverse effects caused by exposures to the COPECs at the site and, where possible, evaluates cause-and-effect relationships (USEPA 1992b). This screening level ERA used toxicity data obtained from the primary literature, review documents, and available toxicity databases. Potential adverse effects are quantitatively calculated as HQs, which are calculated by dividing a receptor's exposure to a COPEC by the COPEC's TRV.

5.7.5 Toxicity Benchmarks and TRVs

For benthic invertebrates, the measures of exposure used to calculate risks is the EPC in sediment for each COPEC, and the TRV is a concentration in sediment. Both are in units of mg/kg. Likewise, for fish the measure of exposure is the EPC in fish tissue, and the TRV is a concentration in fish tissue, both in mg/kg.

TRVs for ecological receptors were calculated for metals and organic compounds identified as COPECs. TRVs were derived for each receptor as follows:

- Benthic invertebrates—TRVs were selected from relevant screening benchmarks; and
- Fish tissues—TRVs were selected from relevant toxicity studies, followed by the application of an uncertainty factor, if warranted.

Where possible, both a TRV_{Low} and TRV_{High} were selected to provide a range of protectiveness for the risk estimates. Tissue-based screening level TRVs for aquatic plants, such as seaweed, were not identified.

Selection of Studies

The benthic invertebrate TRVs used in this ERA were selected from the sediment screening benchmark compilation in the National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Tables (Buchman 1999). Screening benchmarks for marine sediments were used to correspond to the brackish conditions in the estuarine muliwai. The TRV_{Low} was based on the threshold effects level or, if none was available, the apparent effects threshold. The threshold effects level is a conservative screening value defined as the concentration below which adverse effects would be rarely observed. It does not necessarily predict toxicity. The apparent effects level is a test species-specific concentration observed in the highest nontoxic sample. It represents the concentration above which adverse effects would always be expected for that biological indicator (bioassay or population abundance) due to exposure to that contaminant alone. The apparent effects level is also a conservative screening value because it was selected from the lowest apparent effects level among individual indicators. The TRV_{High} was based on the probable effect level, the concentration above which adverse effects are expected to occur frequently. Benthic invertebrate TRVs are presented in Table 5-2.

Fish tissue-based TRVs were developed to assess potential risks to fish based on measured concentrations in their tissues. Accumulation of chemicals in fish can occur via food ingestion, sediment and water ingestion, or uptake across gills. Tissue concentrations therefore represent the end result of different exposure routes and kinetics. Interspecies differences in bioaccumulation and sensitivity also contributes to the variation observed in the range of tissue-based toxicity values. Fish TRVs were selected from studies satisfying the following:

- Saltwater or freshwater fish;
- Adult, juvenile, fingerling, or fry life stages (not embryos or alevin);
- Whole body, carcass, or muscle tissues; and
- Survival, growth, or reproduction endpoints.

Test endpoints based on survival, reproduction, and to some extent, growth are indirect indicators of potential population-level effects on fish. The TRV_{Low} represents the upper end of the range of tissue levels associated with no adverse effects (i.e., no effect levels). No effect levels that were higher than the selected TRV_{High} were excluded from final consideration. If no-effect level data were not available, then the TRV_{Low} was extrapolated from the TRV_{High} using an uncertainty factor of 10. The TRV_{High} represents the lower end of the range of tissue levels corresponding to adverse effects (i.e., effect levels). The lowest effect level across all species that satisfied the above criteria was typically selected as the TRV_{Low}. Fish tissue TRVs are provided in Appendix E.4 and are summarized in Table 5-3.

5.8 RISK CHARACTERIZATION

Risk characterization integrates available exposure and effects information to evaluate the likelihood of adverse ecological impacts associated with exposure to COPECs (USEPA 1992b, 1998). This risk characterization describes the risk estimates for receptors in the north and south muliwai at MMR, nearshore habitat at MMR, and associated background areas. This section also includes a discussion of the uncertainty associated with the risk estimates. As identified in current ERA guidance (USEPA 1998), professional judgment plays a significant role when characterizing potential risks.

5.8.1 Risk Estimation

Hazard Quotient and Other Lines of Evidence

HQs were used to estimate the potential for adverse ecological impacts when sufficient exposure and toxicity data existed. An HQ is the ratio of the exposure to the TRV:

$$HQ = \frac{Exposure}{TRV}$$

An HQ less than 1 indicates that there is a negligible potential for adverse ecological impacts due to exposure to a particular COPEC, whereas an HQ greater than 1 indicates that there is a potential for adverse ecological impacts due to exposure to that COPEC. However, there are a large number of conservative assumptions that are incorporated in the estimated HQs. Therefore, HQs that are in the single digits are often not considered to represent significant risks.

Where possible, both TRV_{Low}s and TRV_{High}s were derived and were used to calculate corresponding HQ_{High}s and HQ_{Low}s. An HQ_{High} gives a conservative estimate of the comparison between exposure at site conditions and maximum safe exposure levels. An HQ_{High} of less than 1 would indicate that no risks are likely to occur from that particular exposure. The HQ_{Low} represents a comparison of exposure at site conditions with doses known to result in effects. An HQ_{Low} greater than or equal to 1 would indicate that a potential for risks exists. If the HQ_{High} is greater than or equal to 1, and the HQ_{Low} is less than 1, a conclusion must be drawn by close evaluation of several factors (including exposure parameters, magnitude of the HQ, source of the TRV, and probability of site use by the receptor).

Ecological Significance of Potential Risks

Several lines of evidence were examined in order to evaluate the ecological significance of risks. Risks are generally not considered to warrant remedial action if exposures are comparable to or less than background conditions. HQs calculated for the north and south background muliwai, Nanakuli muliwai, and sandy beach nearshore site are representative of background risks and are discussed to place potential risks at the sites in perspective.

Risk Estimates

Risk tables are provided for each receptor evaluated at the north and south muliwai, nearshore habitat at MMR, and representative background areas (Tables 5-4 to 5-11). These

risk tables present the EPCs, TRVs, and HQs for all COPECs and receptors considered in each area.

5.9 POTENTIAL ECOLOGICAL RISKS

The risks from potential exposures to each of the COPECs in each of the areas identified in Section 5.5 are discussed here.

5.9.1 Potential Risks at the North Background Area

Risk estimates for sediments in the north background area are indicative of local background conditions for sediments in the north muliwai at MMR.

Potential Risks to Benthic Invertebrates

HQs for benthic invertebrates that are exposed to sediments in the north background area are shown in Table 5-4. Lead was the only chemical detected at the north background area that was also identified as a COPEC in the north muliwai. The HQ for lead was less than 1, indicating that adverse effects are unlikely.

5.9.2 Potential Risks at the South Background Muliwai

Risk estimates for sediments in the south background area are indicative of local background conditions for sediments in the south muliwai.

Potential Risks to Benthic Invertebrates

HQs for benthic invertebrates that are exposed to sediments in the south background area are shown in Table 5-4. Lead was the only chemical detected at the south background area that was also identified as a COPEC in the south muliwai. The HQ for lead was less than 1.

5.9.3 Potential Risks at the Nanakuli Background Muliwai

Risk estimates for fish in the Nanakuli background muliwai are indicative of local background conditions for fish in both the north and south muliwai.

Potential Risks to Fish

HQs for fish in the Nanakuli background muliwai are shown in Table 5-5. Of the 15 COPECs for which tissue-based TRVs were available, all but six had HQs less than 1. The HQs for aluminum, chromium, copper, silver, vanadium, and zinc exceeded 1, as described below:

- Aluminum, copper, vanadium, and zinc—Both the HQ_{High}s and HQ_{Low}s exceeded the threshold value of 1.
- Chromium and silver—The HQ_{High}s exceeded 1. HQ_{Low}s were not calculated due to the absence of TRV_{High}s.

HQs for barium, beryllium, cobalt, iron, manganese, di-*n*-butylphthalate, and perchlorate could not be calculated due to the absence of fish tissue-based TRVs.

5.9.4 Potential Risks at the Nearshore at Sandy Beach Background Site

Risk estimates for fish at the nearshore at Sandy Beach background site are indicative of background conditions for fish at the nearshore.

Potential Risks to Fish

HQs for fish at the nearshore at Sandy Beach background site are shown in Table 5-6. Of the 19 COPECs for which tissue-based TRVs were available, all but six had HQs less than 1. The HQs for aluminum, arsenic, chromium, copper, vanadium, and zinc exceeded 1, as described below:

- Aluminum, arsenic, copper, vanadium, and zinc: Both the HQ_{High}s and HQ_{Low}s exceeded the threshold value of 1.
- Chromium: The HQ_{High} exceeded 1. An HQ Low was not calculated due to the absence of a TRV_{High} for chromium.

HQs for barium, beryllium, cobalt, iron, manganese, thallium, acetone, *bis*(2-ethylhexyl)phthalate, diethyl phthalate, di-*n*-butylphthalate, *m,p*-xylenes, and perchlorate could not be calculated due to the absence of fish tissue-based TRVs.

5.9.5 Potential Risks at the North Muliwai

Potential ecological risks at the north muliwai were estimated from assumed exposures of benthic invertebrates to COPECs in sediments and fish to COPECs accumulated in tissues.

Potential Risks to Benthic Invertebrates

HQs for benthic invertebrates that are exposed to sediments in the north muliwai are shown in Table 5-7. Of the nine COPECs for which tissue-based TRVs were available, all but one had HQs less than 1. For selenium, the HQ_{Low} exceeded 1 the threshold value of 1. An HQ_{Low} was not calculated due to the absence of a TRV_{High}.

HQs for benzene, toluene, octachlorodibenzodioxin, and RDX could not be calculated due to the absence of fish tissue-based TRVs.

These results suggest that potential risks due to chemical exposures in sediments at the north muliwai do not represent imminent hazards to benthic invertebrates, given the following:

- Selenium was the only chemical with an HQ greater than 1.
- The HQ for selenium (4.0) does not greatly exceed 1. The TRV was based on the apparent effects level for amphipods, which is the lowest of the apparent effects levels among different biological indicators (Buchman 1999). There is uncertainty in the apparent effects level because the apparent effects levels were developed for use in Puget Sound, Washington, and are not easily compared to other sediment benchmarks. No threshold effects levels or probable effect levels have been developed for selenium.

- Selenium levels in the north muliwai may not be associated with anthropogenic releases at MMR but may be a natural result of accumulation and concentration in sediments over time due to repeated evaporation.

Potential Risks to Fish

HQs for fish in the north muliwai are shown in Table 5-8. Of the 18 COPECs for which tissue-based TRVs were available, all but six had HQs less than 1. The HQs for aluminum, chromium, copper, silver, vanadium, and zinc exceeded 1 as described below:

- Aluminum, copper, vanadium, and zinc—Both the HQ_{High}s and HQ_{Low}s exceeded the threshold value of 1; and
- Chromium and silver—The HQ_{High} exceeded 1. HQ_{Low}s were not calculated due to the absence of TRV_{High}s.

HQs for barium, beryllium, cobalt, iron, manganese, acetone, di-*n*-butylphthalate, and perchlorate could not be calculated due to the absence of fish tissue-based TRVs.

These results suggest that potential risks due to chemical exposures at the north muliwai do not represent imminent hazards to fish, given the following:

- HQ_{High}s for chromium (5.1), silver (3.8), and zinc (2.3) do not greatly exceed 1 (i.e., were less than or comparable to 5). HQ_{High}s represent potential hazards based on no-effect levels, which are lower than the levels at which adverse effects begin to occur;
- The HQ_{High}s for chromium and silver were based on TRVs for no-effect levels, but no effect levels at higher concentrations were identified for these chemicals;
- Fish tissue TRVs for chromium, copper, and zinc were based on muscle concentrations, which may differ from whole-body concentrations measured at the site;
- No other fish tissue COPECs in the north muliwai had HQs greater than 1;
- HQs exceeding 1 for aluminum, chromium, copper, silver, vanadium, and zinc also exceeded 1 for fish tissues collected at the Nanakuli background muliwai (Table 5-5); and
- The fish tissue HIs for the north muliwai were lower than the HIs for the Nanakuli background muliwai, indicating that overall hazards are less than background (see Section 5.12.1).

5.9.6 Potential Risks at the South Muliwai at MMR

Potential ecological risks at the south muliwai were estimated from assumed exposures of benthic invertebrates to COPECs in sediments and of fish to COPECs accumulated in tissues.

Potential Risks to Benthic Invertebrates

HQs for benthic invertebrates that are exposed to sediments in the south muliwai are shown in Table 5-9. Of the eight COPECs for which tissue-based TRVs were available, all but two had HQs less than 1. For selenium and 2,3,7,8-TCDD, the HQ_{Low}s exceeded the threshold value of 1. HQ_{Low}s were not calculated due to the absence of TRV_{High}s for these chemicals.

HQs for picloram and toluene could not be calculated due to the absence of fish tissue-based TRVs.

These results suggest that the potential risk due to selenium in sediments does not represent imminent hazards to benthic invertebrates, given the following:

- The HQ for selenium (4.7) is less than or comparable to 5.
- The TRV for selenium was based on the apparent effects level for amphipods, which is the lowest of the apparent effects levels among different biological indicators (Buchman 1999). There is uncertainty in the apparent effects level because the apparent effects levels were developed for use in Puget Sound, Washington, and are not easily compared to other sediment benchmarks (Buchman 1999). No threshold effects levels or probable effect levels have been developed for selenium.
- Selenium levels in the south muliwai may not be associated with anthropogenic releases at MMR but may be a natural result of accumulation and concentration in sediments over time due to repeated evaporation.
- 2,3,7,8-TCDD, which occurred at a maximum concentration of 0.00003 mg/kg in sediments, may represent a hazard to benthic invertebrates. Although the TRV for 2,3,7,8-TCDD was also based on the lowest apparent effects level (for the *Neanthes* polychaete) and subject to uncertainty, the HQ (8.3) approached 10.

Potential Risks to Fish

HQs for fish in the north muliwai are shown in Table 5-10. Of the 18 COPECs for which tissue-based TRVs were available, all but seven had HQs less than 1. The HQs for aluminum, arsenic, chromium, copper, silver, vanadium, and zinc exceeded 1, as described below:

- Aluminum, arsenic, copper, vanadium, and zinc—Both the HQ_{High}s and HQ_{Low}s exceeded the threshold value of 1; and
- Chromium and silver—The HQ_{High} exceeded 1. HQ_{Low}s were not calculated due to the absence of TRV_{High}s.

HQs for barium, beryllium, cobalt, iron, manganese, thallium, acetone, *m,p*-xylenes, *bis*(2-ethylhexyl)phthalate, di-*n*-butylphthalate, and perchlorate could not be calculated due to the absence of fish tissue-based TRVs.

These results suggest that potential risks due to chemical exposures at the south muliwai do not represent imminent hazards to fish, given the following:

- HQ_{High}s for arsenic (3.0), silver (2.7), and zinc (3.5), and HQ_{Low}s for arsenic (2.0), and zinc (3.0), do not greatly exceed 1. HQ_{High}s represent potential hazards based on no-effect levels, which are lower than the levels at which adverse effects begin to occur;
- The HQ_{High}s for chromium and silver were based on TRVs for no-effect levels, but no effect levels at higher concentrations were identified for these chemicals;
- Arsenic concentrations in fish tissues likely consist of organic arsenic only, which is nontoxic. The HQs for arsenic likely greatly overestimate the risk since the TRVs are based on inorganic arsenic;
- Fish tissue TRVs for chromium, copper, and zinc were based on muscle concentrations, which may differ from whole-body concentrations measured at the site;
- No other fish tissue COPECs in the south muliwai had HQs greater than 1;
- HQs exceeding 1 for aluminum, arsenic, chromium, copper, silver, vanadium, and zinc also exceeded 1 for fish tissues collected at the Nanakuli background muliwai (Table 5-5); and
- The fish tissue HIs for the south muliwai were lower than the HIs for the Nanakuli background muliwai, indicating that overall hazards are less than background (see Section 5.12.2).

5.9.7 Potential Risks at the Nearshore

Potential ecological risks at the nearshore site were estimated from assumed exposures of fish to COPECs accumulated in tissues. Potential risks to seaweed could not be calculated due to the absence of applicable tissue-based TRVs.

Potential Risks to Fish

HQs for fish at the nearshore area are shown in Table 5-11. Of the 19 COPECs for which tissue-based TRVs were available, all but six had HQs less than 1. The HQs for aluminum, arsenic, chromium, copper, vanadium, and zinc exceeded 1, as described below:

- Arsenic, copper, and zinc—Both the HQ_{High}s and HQ_{Low}s exceeded the threshold value of 1; and
- Aluminum, chromium, and vanadium—Only the HQ_{High} exceeded 1. An HQ_{Low} was not calculated for chromium due to the absence of a TRV_{High}.

HQs for barium, cobalt, iron, manganese, acetone, *m,p*-xylenes, *bis*(2-ethylhexyl)phthalate, di-*n*-butylphthalate, nitroglycerin, RDX, and perchlorate could not be calculated due to the absence of fish tissue-based TRVs.

These results suggest that potential risks due to chemical exposures at the nearshore habitat do not represent imminent hazards to fish, given the following:

- HQ_{High}s for aluminum (1.5), arsenic (3.7), chromium (3.6), copper (2.0), and zinc (2.6), and HQ_{Low}s for arsenic (2.5), copper (1.2), and zinc (2.2), do not greatly exceed 1. HQ_{High}s represent potential hazards based on no-effect levels, which are lower than the levels at which adverse effects begin to occur;
- The HQ_{High} for chromium was based on a TRV for no-effect levels, but no effect levels at higher concentrations were identified for chromium;
- Arsenic concentrations in fish tissues likely consist of organic arsenic only, which is nontoxic. The HQs for arsenic likely greatly overestimate the risk since the TRVs are based on inorganic arsenic;
- Fish tissue TRVs for chromium, copper, and zinc were based on muscle concentrations, which may differ from whole-body concentrations measured at the site;
- No other fish tissue COPECs in nearshore habitat off MMR had HQs greater than 1;
- HQs exceeding 1 for aluminum, chromium, copper, vanadium, and zinc also exceeded 1 for fish tissues collected at the background nearshore habitat off Sandy Beach (Table 5-6); and
- The fish tissue HIs for the nearshore habitat off MMR were lower than the HIs for the background nearshore habitat off Sandy Beach, indicating that overall hazards are less than background (see Section 5.12.3).

5.10 HAZARD INDICES AND INCREMENTAL RISKS

HIs were calculated by summing the HQs for all COPECs at a given site to identify if multiple chemical exposures could have a cumulative impact on receptors (Tables 5-12 to 5-16). For comparative purposes, HIs for both sites and background areas were calculated. Separate HIs were tabulated as the sums of HQ_{High}s and HQ_{Low}s.

In fish tissues, both mercury and methyl mercury were measured. Since virtually all of the mercury in biological tissues is methyl mercury, by including both mercury and methyl mercury in the calculated HI, it would overestimate the sum of risks. Therefore, the higher HQ between mercury and methyl mercury was used in each case.

5.10.1 North Muliwai

The HI_{High} for benthic invertebrates at the north muliwai was 5.51, driven primarily by the HQ_{High} for selenium (Table 5-12). As discussed in Section 5.11.5, selenium in sediments is not expected to be anthropogenic but is likely naturally occurring. Thus, the HI for benthic invertebrates in the north muliwai likely does not represent cumulative hazards from releases associated with the MMR. Incremental risks were calculated as the HIs for the north muliwai minus the HIs for the north background area. Due to the relatively fewer number of chemicals detected in the background sediments, the incremental risk for invertebrates in

the north muliwai was only slightly lower than that indicated by north muliwai HI (Table 5-12).

The HI_{High} and HI_{Low} for fish in the north muliwai were 338 and 75, indicating a potential for cumulative impacts from multiple COPECs (Table 5-13). However, the HIs for fish in the Nanakuli background muliwai were higher. Thus, the overall potential for hazards to fish in the north muliwai was lower than under background conditions, and the incremental risk was zero.

5.10.2 South Muliwai

The HI_{High} for benthic invertebrates at the south muliwai was 14.4, driven mainly by the HQ_{High}s for selenium and 2,3,7,8-TCDD (Table 5-14). As noted in Section 5.11.6, selenium in sediments is not expected to be anthropogenic but is likely naturally occurring. Incremental risks were calculated as the HIs for the north muliwai minus the HIs for the south background area. Due to the relatively fewer number of chemicals detected in the background sediments, the incremental risk for invertebrates in the south muliwai was only slightly lower than that indicated by south muliwai HI (Table 5-14). The HI for benthic invertebrates in the south muliwai represents potential cumulative hazards, primarily a result of 2,3,7,8-TCDD.

The HI_{High} and HI_{Low} for fish in the south muliwai were 290 and 55, indicating a potential for cumulative impacts from multiple COPECs (Table 5-15). However, the HIs for fish in the Nanakuli background muliwai were higher. Thus, the overall potential for hazards to fish in the south muliwai was lower than under background conditions, and the incremental risk was zero.

5.10.3 Nearshore Habitat

The HI_{High} and HI_{Low} for fish in the nearshore area off MMR were 23 and 5.1, indicating a potential for cumulative impacts from multiple COPECs (Table 5-16). However, the HIs for fish in the background nearshore area off Sandy Beach were substantially higher. Thus, the overall potential for hazards to fish in the nearshore waters was lower than under background conditions, and the incremental risk was zero.

5.11 UNCERTAINTY ANALYSIS

The uncertainty analysis identifies the key assumptions and data gaps associated with the analyses performed. The three major types of uncertainties in all risk assessments are variability, uncertainty of the true value (i.e., measurement error), and data gaps (USEPA 1998). Topics included in this uncertainty analysis address all three types of uncertainties.

The approach used in this risk assessment was designed to mitigate the effects of uncertainties that may result in the underestimation of risks. Conservative assumptions were used throughout the exposure and effects analyses to minimize the probability of underestimating ecological risks.

5.11.1 Uncertainties in the Exposure Assessment

Sources of uncertainty in the exposure assessment include COPEC concentrations and exposure concentrations and bioavailability. These are discussed below, along with whether they are likely to under or overestimate exposures to COPECs.

Uncertainty in COPEC Concentrations

COPEC concentrations in media were based on samples collected in single sampling events, and the results were used to assess the risks under those conditions at the time of sampling. Exposure estimates are based on these results and do not take into account possible fluctuations in COPEC concentrations that may occur over time or vary with other environmental factors.

Chemical analyses of tissues (e.g., seaweed, fish) were subject to limitations in availability during field sampling. Characterization of COPEC concentrations in biota may be biased in favor of organisms that were more abundantly collected at each site. The assumption that concentrations measured in these tissues are representative of those dominant at the sites is uncertain.

Surface water was not sampled from the north muliwai, south muliwai, or the nearshore waters off MMR. Since surface water represents a potential exposure route to aquatic invertebrates and fish, this constitutes a data gap for the ecological risk assessment. Likewise, seaweed was not sampled from either the north or south muliwai and thus was not assessed as a receptor at these sites.

Chemicals that were not detected above laboratory detection limits were not included in the analysis. This may result in an underestimation of the risks to receptors.

Uncertainty in Exposures

An EPC was computed for each chemical in sediments and fish tissues. This value was used in risk calculations to estimate potential risks by comparison to TRVs. For sediments, the EPCs used were the UCL_{95} of the mean, unless the UCL_{95} exceeded the maximum detected concentration, in which case the maximum detected concentration was used as the EPC. Using the maximum detected value as the EPC could result in an overestimation of the risks. For fish tissues, the EPCs applied were the maximum concentrations detected. This approach was followed because fish tissue samples consisted of composites of multiple species. To ensure a protective evaluation, the maximum detects across all samples were used.

All COPECs in sediments were assumed to be 100 percent bioavailable to benthic invertebrates, which could overestimate exposure. Depending on differences in sediment parameters between the muliwai and those sediments used to derive toxicity benchmarks (e.g., grain size, total organic carbon, pH), bioavailability could differ.

5.11.2 Uncertainties in the Effects Assessment

When it was necessary to fill a data gap, conservative assumptions were used to minimize the probability of underestimating ecological risks. Assumptions used to characterize estimates of COPEC effects are as follows:

- Use of both TRV_{Low}s (i.e., threshold effects level s for benthic invertebrates and no observed effect concentrations for fish tissues) and TRV_{High}s (i.e., probable effect levels for benthic invertebrates and lowest observed effects concentrations for fish tissues) to calculate HQs;
- Use of species-to-species toxicity extrapolations;
- Use of laboratory-to-field toxicity extrapolations;
- Use of individual-to-population level effect extrapolations;
- Use of chemical-to-chemical extrapolations;
- Lack of relevant tissue-based toxicity data for seaweed; and
- Lack of relevant toxicity data for specific chemicals in sediments and fish tissues.

Fish tissue-based TRVs were developed as described in Section 5.8.2. One source of uncertainty is interspecies variability in sensitivity. In general, the lowest effect level across all species was selected as the lowest observed effects concentration. In many cases, no-effect levels were identified for the same or different endpoints that were higher than the selected lowest observed effects concentration. To provide a protective assessment, only no-effect levels that were lower than the selected lowest observed effects concentration were considered in deriving the no observed effect concentration. Another source of uncertainty in fish tissue TRVs is the potential variability in concentrations between whole body, carcass, and muscle. All three were used in deriving TRVs, though whole body data were given preference since whole fish samples from the sites were analyzed. Test endpoints considered in selecting fish toxicity values were survival, growth, and reproduction. TRVs based on growth are more difficult to relate to population-level responses than those based on survival or reproduction. Finally, some fish TRVs were based on a limited data set, which could result in an overestimation or underestimation of toxicity. These included aluminum, antimony, chromium, lead, vanadium, zinc, heptachlor, and aldrin.

The above sources of uncertainty should be taken into account when making decisions based on the risk estimates presented here.

5.12 CONCLUSIONS

This screening level ecological risk assessment was an evaluation of the potential for adverse effects on ecological receptors that may be exposed to chemicals in muliwai and nearshore waters as a result of past releases from MMR. The north and south muliwai and nearshore habitat off MMR were assessed as potentially impacted sites. Due to the absence of aquatic habitat at the dry muliwai, this site was not evaluated for ecological risks. Risk estimates at each site were compared to risk estimates from representative background areas.

Two sets of receptors were evaluated: benthic invertebrates exposed to COPECs in sediments and fish exposed to chemicals from multiple pathways, represented by measured concentrations in fish tissues.

Several lines of evidence were considered in evaluating the potential for risks: the number of chemicals with calculated HQs above 1, the magnitudes of HQs above 1, likely sources of chemicals, confidence in toxicity values, cumulative risks represented by HIs, and comparisons of site HIs to HIs from background sites. Based on the weight of evidence, limited hazards were identified:

- North muliwai—No hazards to benthic invertebrates or fish;
- South muliwai—Potential hazard to benthic invertebrates from 2,3,7,8-TCDD in sediments; no hazards to fish; and
- Nearshore waters—No hazards to fish.

Three data gaps contributed uncertainty to the ecological risk assessment. First, surface water data for the two muliwai and nearshore waters were not available. As a result, potential exposures of aquatic invertebrates and fish to constituents in surface water could not be assessed. Second, potential risks to seaweed collected in the nearshore waters were not evaluated due to the absence of applicable tissue-based toxicity data. Seaweed was not collected from the two muliwai. Third, TRVs were not available for selected chemicals in sediments and fish tissues. In general, these TRV data gaps are unlikely to result in a significant underestimation of risks, due to the relatively low concentrations of organic constituents detected.

6. CONCLUSIONS

SECTION 6
CONCLUSIONS

The objectives of this marine resources study are as follows:

- To determine if constituents primarily associated with military training are present in samples of selected species of fish and limu collected near Mākua Beach and the Mākua muliwai.

- To evaluate the potential that activities at MMR contribute to any contamination detected in the fish and limu samples, and to evaluate whether the proposed training activities at MMR pose a human health risk to area residents that rely on marine resources for subsistence.

Tetra Tech conducted a marine resources study to determine if constituents primarily associated with military training are present in samples of selected species of fish and limu collected near Mākua Beach and the Mākua muliwai.. These constituents include the explosives compounds RDX, 2,4-DNT, nitroglycerine and perchlorate. A variety of other chemicals were also included in this study, including dioxins/furans, organochlorine pesticides, metals, VOCs and SVOCs, although there many different potential sources for these other chemicals. For example, one of the largest sources of dioxins/furans to the environment is the uncontrolled burning of household waste, while organochlorine pesticide use for agricultural purposes and the control of termites was widespread in Hawaii, before many of these chemicals were banned.

This study also evaluated the potential that activities at Mākua Military Reservation contribute to any contamination detected in the marine resources, and evaluated whether the proposed training activities at MMR pose a human health risk to area residents that rely on marine resources for subsistence.

Finally, the study evaluated the potential for adverse ecological effects to fish and invertebrates that might occur as a result of assumed exposures to a variety of chemicals at these locations

Environmental studies conducted at the site indicated occasional detections of various chemicals in soil, streambed sediment, surface water, muliwai sediment and groundwater samples collected at MMR, with occasional exceedences of USEPA Region IX industrial PRGs in the soil, streambed sediment and muliwai sediment samples.

Based on the analytical data, there is no obvious pattern of deposition of the explosive-related chemicals in the soil or surface water of MMR or in transport to the Mākua muliwai. For example, the only explosive-related chemical detected in the muliwai sediment samples was RDX, while 1,3-dinitrobenzene was the only explosive-related chemical detected in the streambed sediment samples and perchlorate and 2,4-dinitrotoluene were the only explosive-related chemicals detected in the surface water samples. Nitroglycerin (2 samples) and perchlorate (6 samples) were detected in muliwai fish samples, while 2,4-dinitrotoluene and RDX were not. The nitroglycerin results were considered invalid, because QA/QC issues precluded quantification of this analyte (see Appendix C).

The analytical results for dioxins/furans also show no obvious pattern. Although dioxins/furans were detected in soil, muliwai sediment, surface water and fish samples, different isomers were detected in different media. For example, 2,3,7,8-TCDD exceeded the industrial PRG in two muliwai sediment samples and three soil samples, but was not detected in the surface water samples or muliwai fish samples.

Low levels of gasoline-related compounds were detected in soil, muliwai sediment, streambed sediment and surface water samples. The concentrations detected in the soil, muliwai sediment and streambed sediment samples were all well below industrial PRGs. Xylene was the only gasoline-related chemical detected in the fish samples.

The analytical data for the fish samples do not appear to follow any obvious geographic pattern. The results from the MMR vicinity samples were similar to the results from the background location samples. Samples from the muliwai locations tended to have higher concentrations of metals than the nearshore samples, although the nearshore samples typically had higher concentrations of arsenic. Based upon these results, there is no definitive link between the training activities at MMR and the presence of contaminants detected in the marine resources.

Although we were unable to collect a sufficient amount of shellfish or invertebrates for sample analysis, it is likely that the shellfish are not contaminated by substances associated with the proposed training activities at MMR, for the following reasons:

- The analytical data for the fish samples indicate that the fish are likely not contaminated by substances associated with the proposed training at MMR;
- Most of the shellfish that we observed (sea urchins and crabs) were located in the nearshore area, although there were some crabs observed in the muliwai. There is very little interchange between the muliwai where contaminants might accumulate and the nearshore area that provides the habitat for most of the shellfish on which area residents rely; and

- Transport of chemicals, if any, from the muliwai to the nearshore area would result in significant dilution of the chemicals.

Results of the human health risk assessment indicated that for recreational fishermen, the risk from consuming fish caught in the vicinity of MMR from both the muliwai and nearshore areas were similar to the risks from consuming fish caught from background locations on O`ahu. The risks due to eating fish from the muliwai were below the USEPA's risk level of 10^{-5}(up to one person in 100,000 people may develop cancer), which is used in assessing risk from fish consumption. The risks due to eating fish from the nearshore area was slightly above the USEPA's risk level of 10^{-5}, but was similar to the risks from eating fish from the background location nearshore area. The noncancer hazard indices were all below the background hazard indices.

The human health risk assessment indicated that for subsistence fishermen, the risk from consuming fish caught in the vicinity of MMR from both the muliwai and nearshore areas were similar to the risks from consuming fish caught from background locations on O`ahu, although the risks in the Mākua areas were slightly higher than from the background areas. Under the most likely fish consumption scenario, the incremental risk from consuming fish caught at the Mākua muliwai was 7×10^{-6} (seven people in a million), which is below USEPA's risk level of 10^{-5}. The incremental risk from consuming fish caught at the Mākua nearshore area was 3×10^{-5} (three people in a hundred thousand), which is slightly above USEPA's risk level. Given the high level of uncertainty associated with the human health risk assessment (discussed below) the difference in risk due to consuming fish caught near MMR versus fish caught at background locations is not considered to be significant. The noncancer hazard indices for the Mākua areas were all below background levels. The risks from consuming seaweed harvested from the Mākua nearshore area was above the USEPA's 10^{-5} risk level, for both subsistence and recreational fishermen, and the HI for both subsistence and recreational fishermen exceeded the threshold HI of 1.

There were several sources of uncertainty in the risk estimates that would tend to indicate the risk estimates are high. One source of uncertainty is the assumption of fish consumption rates. The 95th percentile fish consumption rate for Hawaiians from a 2003 study, 100.6 g/day, was used in the human health risk assessment, to provide a health-protective estimate of risk from consuming fish caught in the muliwai and nearshore areas in the vicinity of MMR. However, use of a lower fish consumption rate would have resulted in a lower calculated risk. Additionally, the assumption that a subsistence fisherman would catch all of his fish at the MMR muliwai is unrealistic. The small sizes of these muliwai indicate it is unlikely that the muliwai could support even one subsistence fisherman.

The primary source of uncertainty in the seaweed consumption risk estimate is the assumption that all arsenic in the seaweed was inorganic and toxic However, there are many species of algae in which all arsenic is present in nontoxic organic forms. Although the seaweed was identified to at least a genus level and in some cases a species level, a review of the secondary literature did not identify the type of arsenic (organic or inorganic) that is expected to be present in the seaweed samples. Therefore, depending on the species actually consumed by fishers, the risks may be much lower than estimated here. Additionally,

seaweed was not collected from background locations as part of this study. Therefore, it is unknown whether arsenic in the seaweed collected off Mākua Beach is elevated over background conditions.

Results of the screening level ERA indicated that there were no hazards to fish in the muliwai and nearshore areas in the vicinity of MMR, and there was a potential hazard to benthic invertebrates from 2,3,7,8-TCDD in sediments in the south muliwai. The uncontrolled burning of household waste is considered to be one of the largest sources of dioxin to the environment.

7. REFERENCES

SECTION 7
REFERENCES

Belden J. B., G. R. Lotufo and M. J. Lydy. 2005. Accumulation of RDX in channel catfish (Ictalurus punctatus) and aquatic oligochaetes (*Lumbriculus variegatus*). *Environmental Toxicology and Chemistry*.

Buchman, M. F. 1999. NOAA Screening Quick Reference Tables, NOAA HAZMAT Report 99-1. Seattle, Washington, Coastal Protection and Restoration Division, National Oceanic and Atmospheric Administration.

de Gieter, M., M. Leermakers, R. Van Ryssen, J. Noyen, L. Goeyens, and W. Baeyens. 2002. "Total and toxic arsenic levels in North Sea fish." Arch. Environ. Contam. Toxicol. 43: 406-417.

DTSC (Department of Toxic Substances Control). 2000 LeadSpread v7.0. Internet Web site: http://www.dtsc.ca.gov/ScienceTechnology/ledspred.html.

Frankenberger, W.T. 2002. *Environmental Chemistry of Arsenic*. New York, Marcel Dekker.

HDOH (Hawai`i Department of Health). 2006. Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater. Interim Final. August 2006.

Kirby, J., and W. Maher. 2002. "Tissue accumulation and distribution of arsenic compounds in three marine fish species: relationship to trophic position." Applied Organometalic Chemistry 16: 108-115.

Kirby, J., W. Maher, and D. Spooner. 2002. "Arsenic occurrence and species in nearshore macroalgae-feeding marine animals." Environmental Science and Technology 39: 5999-6005.

Koizumi, S., S. Kobayashi, I-J. Pan, S. Takaku, M. Baba, R. A. Jussaume, P. Riethmuller, J. Morison, J. C. Ryoo, C. W. Lin, I. H. Lin, H. Zhou, A. Ratanawaraha, and M. Nagano. 2002. "Similarities and differences in meat consumption patterns in Asia and Pacific Rim Countries." Animal Science Journal 73:293–300.

Kolonel, L. N., J. H. Hankin, L. R. Wilkens, F. H. Fukunaga, M. W. Hin. 1990. "An epidemiologic study of thyroid cancer in Hawai`i." Cancer Causes and Control. 1: 223-234.

Lotufo G. R., and M. J. Lydy. 2005. Comparative toxicokinetics of explosive compounds in sheepshead minnows. *Archives of Environmental Contamination and Toxicology* 49 (2): 206-214.

Neff, J. M. 1997. "Ecotoxicology of arsenic in the marine environment." Environmental Toxicology and Chemistry 16(5): 917-927.

OEHHA (Office of Environmental Health Hazard Assessment). 2001. *Chemicals in Fish: Consumption of Fish and Shellfish in California and the United States*. Final report.

San Francisco Estuary Institute. 2000. San Francisco Bay Seafood Consumption Study.

Sechena, R., S. Liao, R. Lorenzana, C. Nakano, N. Polissar, and R. Fenske. 2003. "Asian American and Pacific Islander seafood consumption—a community-based study in King County, Washington." Journal of Exposure Analysis and Environmental Epidemiology 13: 256–266.

Sharma, S., S. Murphy, L. Wilkens, J. Hankin, B. Henderson, L. Kolonel. 2003. "Adherence to the Food Guide Pyramid Recommendations among Japanese Americans, Native Hawaiians and Caucasians: Results from the Multiethnic Cohort." Journal of the American Dietetic Association 103:1195-1198.

Sloth, J. J., E. H. Larsen, and K. Julshamn. 2005. "Survey of Inorganic Arsenic in Marine Animals and Marine Certified Reference Materials by Anion Exchange High-Performance Liquid Chromatography-Inductively Coupled Plasma Mass Spectrometry." Journal of Agricultural and Food Chemistry 53:6011-6018

Tamaki, S., and W. T. Frankenberger. 1989. Environmental Biochemistry of arsenic. US Department of the Interior, Bureau of Reclamation.

Tetra Tech, Inc. 2005a. Draft Environmental Impact Statement. Military Training Activities at Mākua Military Reservation. O`Ahu, Hawai`i Prepared for the 25th Infantry (Light) and US Army, Hawai`i.

_____. 2005b. Draft Environmental Impact Statement. Military Training Activities at Mākua Military Reservation. Appendix G-3: Muliwai Sediment Sampling Report. O`Ahu, Hawai`i Prepared for the 25th Infantry (Light) and US Army, Hawai`i.

_____. 2005c. Draft Environmental Impact Statement. Military Training Activities at Mākua Military Reservation. Appendix G-1: Hydrogeologic Investigation Report. O`Ahu, Hawai`i Prepared for the 25th Infantry (Light) and US Army, Hawai`i.

_____. 2007. Marine Resources Study Sampling and Analysis Plan. Mākua Military Reservation, O`Ahu, Hawai`i Prepared for US Army Corps of Engineers.

US Census Bureau. 2001. Profile of General Demographic Characteristics. 2000 Census of Population and Housing, Hawaii. Available on-line at: http://www.census.gov/prod/cen2000/dp1/ 2kh15.pdf

USEPA (US Environmental Protection Agency). 1989. Risk Assessment Guidance for Superfund (RAGS). Human Health Evaluation Manual Part A. Office of Emergency and Remedial Response. USEPA/540/1-89/002.

_____. 1990. National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (Final Rule). 40 CFR Part 300: 55 *Federal Register* 8666.

_____. 1991a. Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors. Publication 9285.6-03.

_____. 1991b. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. OSWER Directive 9355.0-30.

_____. 1992a. Supplemental Guidance to RAGS: Calculating the Concentration Term. Office of Emergency and Remedial Response. Publ. 9285.7-081.

_____. 1992b. Framework for Ecological Risk Assessment. Risk Assessment Forum.

_____. 1996. Soil screening guidance: user's guide. Office of Solid Waste and Emergency Response. USEPA/540/R-95/018.

_____. 1997a. Exposure Factors Handbook. Office of Research and Development, National Center for Environmental Assessment. USEPA/600/P-95/002Fa.

_____. 1997b. Health Effects Assessment Summary Tables (HEAST). FY-1997 Annual. Office of Solid Waste and Emergency Response. USEPA 540/R-94/020.

_____. 1997c. Ecological Risk Assessment Guidance for Superfund Sites: Process for Designing and Conducting Ecological Risk Assessments—Interim Final. Office of Solid Waste and Emergency Response, Washington, D.C. USEPA 540/R-97/006.

_____. 1998. Guidelines for Ecological Risk Assessment. Risk Assessment Forum. USEPA/630/R-95/002F.

_____. 1999. Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Volume One, Peer Review Draft. August 1999.

_____. 2000a. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Volume 1: Fish Sampling and Analysis, Third Edition. Office of Water, Washington, DC. EPAUSEPA 823-B-00-007.

_____. 2000b. Practical methods for data analysis. EPAUSEPA QA/G-9. Office of Environmental Information. EPAUSEPA/600/R-96/084

_____. 2002a. *Guidance for comparing background and chemical concentrations in soil for CERCLA sites*. Office of Emergency and Remedial Response. USEPA 540-R-01-003. OSWER 9285.7-41.

_____. 2002b. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Solid Waste and Emergency Response. OSWER 9355.4-24.

_____. 2002c. Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites. Office of Emergency and Remedial Response. OSWER 9285.6-10. December 2002.

_____. 2002d. Estimated per Capita Fish Consumption in the United States. Engineering and Analysis Division, Office of Science and Technology, Washington, DC. EPAUSEPA/821/C-02/003. August 2002.

_____. 2004a. Information Sheet 1, Dioxin: Summary of the Dioxin Reassessment Science. Office of Research and Development, Washington, DC. October 14, 2004, update.

_____. 2004b. USEPA Region IX Preliminary Remediation Goals (PRGs). Internet Web site: http://www.epa.gov/region9/waste/sfund/prg/index.html.

_____. 2004c. ProUCL Version 3.0. User Guide. USEPA/600/R04/079. Internet Web site: http://www.epa.gov/nerlesd1/tsc/software.htm.

_____. 2006a. Integrated Risk Information System (IRIS). Internet Web site: http://www.epa.gov/iris/.

_____. 2006b. Assessing Risks to Populations at Superfund and RCRA Sites Characterizing Effects on Populations. Office of Research and Development. April 2006. USEPA/600/R-06/038. ERASC-006.

USFDA (US Food and Drug Administration). 2006. Center for Food Safety and Applied Nutrition, Questions and Answers about dioxin. http://www.cfsan.fda.gov/~lrd/dioxinqa.html#g2. July 2006.

This page intentionally left blank.

Table 2-1
Marine Resources Sampling Locations and Species of Interest at MMR

Common Name	***Scientific Name***
Muliwai Target Species	
Hawaiian flagtail (aholehole)	*Kuhlia sandvicensis*
Striped mullet (`ama`ama)	*Mugil cephalus*
Medaka	*Poeciliidae* sp.
Tilapia	*Talapia zillii*, *T. rendalii*, *Oreochromis macrochir*, *O. mossambicus*, *Sarotherdon melanotheron melanotheron*
Nearshore Target Species	
Picasso triggerfish (humuhumu nukunuku a puaa)	*Rhinecanthus rectangulus*
Blackspot sergeant (kupipi)	*Abudefduf sordidus*
Christmas wrasse (hinalea)	*Thalassoma trilobatum*
Saddle wrasse (hinalea lau-wili)	*T. duperry*
Manybar goatfish (moano)	*Parupeneus multifasciatus*
(Limu wawae`iole)	*Codium edule*
(Limu manauea)	*Gracilaria coronopifolia*

Table 2-2
Summary of Fish and Limu Samples, Makua Military Reservation Marine Resources Study

Site	Sample ID	Matrix	Fish Species	Sample Type
Makua North Muliwai	1	Fish	Striped mullet	Primary
Makua North Muliwai	3	Fish	Hawaiian flagtail	Primary
Makua North Muliwai	4	Fish	Tilapia	Primary
Makua North Muliwai	1b	Fish	Tilapia	Primary
Makua North Muliwai	5	Fish	Tilapia	Primary
Makua South Muliwa	6	Fish	Striped mullet	Primary
Makua South Muliwa	2fd	Fish	Striped mullet	QC
Makua South Muliwa	7	Fish	Striped mullet	Primary
Makua South Muliwa	Comp 8,8a	Fish	Medaka	Primary
Makua South Muliwa	9	Fish	Tilapia	Primary
Makua South Muliwa	Comp 9fd, 10a	Fish	Tilapia	QC
Makua South Muliwa	10	Fish	Tilapia	Primary
Nanakuli Muliwai	12	Fish	Tilapia	Primary
Nanakuli Muliwai	13	Fish	Tilapia	Primary
Nanakuli Muliwai	14	Fish	Tilapia	Primary
Near shore waters at Makua	NW2	Fish	Picasso triggerfish	Primary
Near shore waters at Makua	NW3	Fish	Blackspot sergeant	Primary
Near shore waters at Makua	NW4	Fish	Manybar goatfish	Primary
Near shore waters at Makua	NW1fd	Fish	Manybar goatfish	QC
Near shore waters at Makua	NW5	Fish	Christmas wrasse	Primary
Near shore waters at Sandy Beach	NW6	Fish	Christmas wrasse	Primary
Near shore waters at Sandy Beach	NW7	Fish	Saddle wrasse	Primary
Near shore waters at Sandy Beach	NW8	Fish	Blackspot sergeant	Primary
Near shore waters at Sandy Beach	NW2fd	Fish	Blackspot sergeant	QC
Near shore waters at Sandy Beach	NW9	Fish	Picasso triggerfish	Primary
Near shore waters at Sandy Beach	NW10	Fish	Manybar goatfish	Primary
Near shore waters at Makua	NW1SW3-1	Seaweed		Primary
Near shore waters at Makua	NW1SW1-1	Seaweed		Primary
Near shore waters at Makua	NW1SW2-2	Seaweed		Primary
Near shore waters at Makua	NW1SW1-1fd	Seaweed		QC

Notes: Several species of tilapia and ??? Are included in these samples.

Table 2-3
Sample Analytes and Analytical Methods

Analyte	Analytical Procedure	Primary Sample Analysis	QC Sample Analysis
Dioxins/Furans (17 isomers of concern)		**Columbia**	**STL**
HpCDD	USEPA Method 8290		
HpCDF	USEPA Method 8290		
HxCDF	USEPA Method 8290		
OCDD	USEPA Method 8290		
OCDF	USEPA Method 8290		
TCDD	USEPA Method 8290		
Gasoline (Purgeable Organics)		**Columbia**	**APPL**
Ethylbenzene	USEPA Method 8260B		
m-Xylene	USEPA Method 8260B		
p-Xylene	USEPA Method 8260B		
o-Xylene	USEPA Method 8260B		
Toluene	USEPA Method 8260B		
Metals		**Columbia**	**Battelle**
Aluminum	USEPA Method 200.8		
Antimony	USEPA Method 200.8		
Arsenic	USEPA Method 200.8		
Barium	USEPA Method 200.8		
Beryllium	USEPA Method 200.8		
Cadmium	USEPA Method 200.8		
Chromium	USEPA Method 6010B		
Cobalt	USEPA Method 200.8		
Copper	USEPA Method 200.8		
Iron	USEPA Method 6010B		
Lead	USEPA Method 200.8		
Manganese	USEPA Method 200.8		
Mercury	USEPA 7471A (USEPA Method 245.6)		
Methyl Mercury	USEPA Method 1630 modified		
Selenium	USEPA Method 7740		
Silver	USEPA Method 200.8		
Thallium	USEPA Method 200.8		
Vanadium	USEPA Method 6010B		
Zinc	USEPA Method 200.8		
Explosives (Nitroaromatics/Nitramines)		**APPL**	**STL**
2,4-DNT	USEPA Method 8330		
RDX (Cyclonite)	USEPA Method 8330		
Nitroglycerine	USEPA Method 8330 modified		
Perchlorate	USEPA Method 314		
Organochlorine Pesticides		**Columbia**	**APPL**
4,4'-DDT	USEPA 8081A		
Aldrin	USEPA 8081A		
alpha BHC	USEPA 8081A		

Table 2-3
Sample Analytes and Analytical Methods

Analyte	Analytical Procedure	Primary Sample Analysis	QC Sample Analysis
beta BHC	USEPA 8081A		
delta BHC	USEPA 8081A		
gamma BHC (lindane)	USEPA 8081A		
Heptachlor	USEPA 8081A		
Heptachlor epoxide	USEPA 8081A		
VOCs/SVOCs		**Columbia**	**APPL**
Styrene	USEPA Method 8260B		
1,2,4-Trimethylbenzene	USEPA Method 8260B		
Pyrene	USEPA Method 8270C		
Phthalate Esters			
Bis(2-ethylhexyl) phthalate	USEPA Method 8270C		
Di-n-butyl phthalate	USEPA Method 8270C		
Diethyl phthalate	USEPA Method 8270C		
Dimethyl phthalate	USEPA Method 8270C		
Di-n-octyl phthalate	USEPA Method 8270C		

Table 3-1
Makua Military Reservation
Fish and Limu Study Analytical Results
(all results in mg/kg)

		Sample Location	North muliwai	North muliwai	North muliwai	North muliwai	North muliwai	South muliwai	South muliwai	South muliwai	South muliwai	South muliwai	South muliwai	South muliwai	Nanakuli muliwai	Nanakuli muliwai	Nanakuli muliwai	Makua near-shore	Makua near-shore	Makua near-shore	Makua near-shore	Makua near-shore	Sandy Beach near-shore	Sandy Beach near-shore	Sandy Beach near-shore	Sandy Beach near-shore	Sandy Beach near-shore	Sandy Beach near-shore	Makua near-shore	Makua near shore	Makua near shore	Makua near shore
		Matrix	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Fish	Seaweed	Seaweed	Seaweed	Seaweed
Analytical Group	**Chemical**	**Sample ID**	**1**	**1b**	**3**	**4**	**5**	**2fd**	**6**	**7**	**Comp 8,8a**	**9**	**9afd and 10a Comp**	**10**	**12**	**13**	**14**	**NW1fd**	**NW2**	**NW3**	**NW4**	**NW5**	**NW2fd**	**NW6**	**NW7**	**NW8**	**NW9**	**NW10**	**NW1SW1-1**	**NW1SW1-1fd**	**NW1SW2-1**	**NW1SW3-1**
		Sample type	**SMPL**	**SMPL**	**SMPL**	**SMPL**	**SMPL**	**QC**	**SMPL**	**SMPL**	**SMPL**	**SMPL**	**QC**	**SMPL**	**SMPL**	**SMPL**	**SMPL**	**QC**	**SMPL**	**SMPL**	**SMPL**	**SMPL**	**QC**	**SMPL**	**SMPL**	**SMPL**	**SMPL**	**SMPL**	**SMPL**	**QC**	**SMPL**	**SMPL**
Dioxins/Furans	1,2,3,4,6,7,8-HpCDD		ND	ND	ND	ND	ND	ND	ND	5.31E-13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.71E-13	2.05E-13	ND	ND	ND	ND	ND	ND
	1,2,3,4,6,7,8-HpCDF		ND	ND	ND	ND	ND	ND	ND	ND	ND	2.95E-13	ND	ND	2.07E-13	1.78E-13	3.71E-13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.13E-12	ND	ND	ND
	1,2,3,4,7,8,9-HpCDF		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1,2,3,4,7,8-HxCDD		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1,2,3,4,7,8-HxCDF		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8.90E-14	ND	1.14E-13	ND
	1,2,3,6,7,8-HxCDD		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.42E-13	ND
	1,2,3,6,7,8-HxCDF		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.70E-14	ND	ND	ND
	1,2,3,7,8,9-HxCDD		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.16E-13	ND
	1,2,3,7,8,9-HxCDF		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1,2,3,7,8-PeCDD		ND	ND	1.42E-12	4.49E-13	ND	ND	ND	ND	ND	1.76E-12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.72E-13	ND	ND	ND	ND	ND
	1,2,3,7,8-PeCDF		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	2,3,4,6,7,8-HxCDF		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	2,3,4,7,8-PeCDF		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	2,3,7,8-TCDD		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	2,3,7,8-TCDF		ND	ND	ND	ND	ND	5.90E-13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	OCDD		ND	ND	ND	ND	ND	8.70E-12	ND	ND	ND	ND	6.90E-12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	OCDF		ND	ND	ND	ND	ND	ND	ND	1.31E-12	ND	1.26E-12	ND	5.49E-13	6.49E-13	6.44E-13	8.78E-13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.01E-12	ND	ND	ND
	HpCDD, total		1.40E-12	2.03E-12	1.50E-12	1.02E-11	2.62E-12	ND	ND	1.69E-12	3.02E-12	2.04E-12	ND	6.99E-13	1.73E-12	1.92E-12	2.46E-12	ND	ND	ND	ND	ND	ND	ND	1.62E-12	4.28E-13	6.58E-13	3.06E-13	1.25E-12	ND	1.65E-11	3.23E-13
	HPCDF, total		ND	ND	ND	7.99E-13	ND	ND	ND	ND	1.35E-12	2.95E-13	ND	ND	2.07E-13	1.78E-13	3.71E-13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.87E-13	1.76E-12	ND	4.58E-12	ND
	HxCDD, total		ND	ND	ND	ND	ND	ND	ND	ND	ND	1.45E-13	ND	ND	ND	ND	3.69E-13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.91E-12	ND
	HxCDF, total		ND	ND	ND	ND	ND	ND	ND	ND	1.29E-13	ND	ND	ND	ND	ND	1.67E-13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8.90E-14	ND	4.30E-13	ND
	PeCDD, total		ND	ND	1.42E-12	ND	ND	ND	ND	ND	ND	1.76E-12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	PeCDF, total		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	TCDD, total		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	TCDF, total		ND	ND	ND	ND	ND	5.90E-13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.47E-13	ND	ND	ND	ND	ND
Volatiles																																	
	Acetone		0.25	ND	ND	ND	ND	-	0.28	0.24	0.38	ND	-	0.23	ND	ND	ND	-	0.73	0.71	ND	0.27	-	0.23	0.6	ND	0.28	0.34	ND	-	ND	ND
	Benzene		ND	ND	ND	ND	ND	-	ND	ND	ND	ND	-	ND	ND	ND	ND	-	ND	ND	ND	ND	-	ND	ND	ND	ND	ND	ND	-	ND	ND
	Ethylbenzene		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Styrene		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Toluene		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1,2,4-Trimethylbenzene		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	m,p-Xylenes		ND	ND	ND	ND	ND	0.0016	ND	ND	ND	ND	0.017	ND	ND	ND	ND	0.02	ND	ND	ND	ND	0.016	ND	ND	ND	ND	ND	ND	0.016	ND	ND
	o-Xylene		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Semi-volatiles																																	
	bis(2-ethylhexyl)phthalate		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.1	ND	ND	ND	ND	3.5	0.63	ND	2.8	0.055	ND	ND	ND	ND	ND	0.049	ND	ND	ND	0.086
	Diethyl phthalate		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.019	ND	ND	0.018	ND	ND	ND	ND	ND
	Dimethyl phthalate		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Di-n-butylphthalate		0.011	0.01	0.011	0.015	0.0098	1.5	0.015	0.013	0.017	0.013	0.96	0.011	0.016	0.018	0.012	1.4	0.048	0.022	0.031	0.046	0.61	0.047	0.038	0.043	0.014	0.053	0.02	0.48	0.02	0.024
	Di-n-octylphthalate		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Pentachlorophenol		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Pyrene		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Organochlorine pesticides																																	
	Aldrin		ND	ND	0.0009P	ND	ND	ND	0.003P	0.001P	ND	ND	ND	ND	ND	ND	ND	ND	0.0027	ND	0.0024	ND	ND	ND	ND	ND	ND	0.0064	ND	ND	0.00035P	ND
	BHC, alpha		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0082	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	BHC, beta		0.014P	0.0019P	ND	ND	ND	ND	0.0041	ND	ND	0.00081	ND	ND	ND	0.0012P	0.00084P	ND	0.024P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00036P	ND
	BHC, delta		0.00056P	ND	ND	ND	0.00031	ND	ND	ND	ND	ND	ND	0.00076P	ND	0.0011P	ND	ND	ND	0.0003	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	BHC, gamma		ND	0.00082P	ND	0.00089	0.0013	ND	0.0016	0.0017	0.0011P	ND	ND	ND	ND	ND	ND	ND	0.0063	ND	ND	0.0054P	ND	0.0025P	0.0019	ND	ND	ND	ND	ND	ND	ND	ND
	4,4'-DDT		ND	ND	0.00068P	0.00074	0.0005	ND	0.0027	0.0029	0.0012	0.00067	ND	0.00088	ND	0.0014	0.0013	ND	ND	0.00018	ND	ND	ND	ND	ND	ND	0.0021	0.0019	ND	ND	ND	ND	ND
	Heptachlor		0.0082P	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.033P	ND	ND	ND	0.0056	ND	ND	0.0057	0.0045	ND	ND	0.0007	ND	0.0004	0.0007
	Heptachlor epoxide		ND	0.00087P	0.00094P	0.00051	0.0013P	ND	0.00093	ND	0.0027P	0.00058	ND	0.0013P	0.00087P	0.00098	0.0011	0.014	0.0041P	ND	0.0032	0.0025P	0.0076	ND	0.0028	ND	0.003	0.0052P	ND	ND	0.00088P	ND
Explosives																																	
	2,4-Dinitrotoluene		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Nitroglycerin		ND	ND	ND	ND	ND	0.69	ND	ND	ND	ND	0.95P	ND	ND	ND	ND	0.33	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Perchlorate		0.0019	ND	ND	ND	ND	0.16	0.097	0.04	0.0042	0.0012	0.021	ND	ND	0.0014	ND	0.0088	ND	ND	ND	ND	0.01	ND	ND	ND	0.11	ND	0.052	ND	ND	0.011
	RDX		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.057	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.38P	ND	ND
Metals																																	
	Aluminum		2,950	2,840	48	2,000	4,240	1,517	1,250	1,150	1,450	2,880	2,711	2,140	3,810	5,170	4,420	21	51	65	7	9	16	4	9	13	4,720	15	1,120	337	172	58
	Antimony		ND	ND	0.04	ND	ND	0.0527	ND	ND	ND	ND	0.0481	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0259	ND	ND	ND	ND	ND	0.05	0.145	ND	0.04
	Arsenic		2.25	3.18	2.87	2.53	3.81	1.46	2.35	2.18	1.46	1.72	29.8	1.46	2.51	2.57	2.54	25.2	37.3	4.06	23.9	24.6	6.17	53	6.62	5.13	4.52	36.6	55.4	109	4.56	96
	Barium		22.7	26.1	5.53	26.1	23.5	19.5	16.6	15.1	12.9	21.2	12.5	18.7	39.7	43.6	39.1	0.62	1.27	31.6	0.46	0.97	7.58	1.51	1.66	7.98	14.2	0.96	10.9	13.3	1.48	10.2
	Beryllium		0.037	0.034	ND	0.028	0.051	0.01	0.018	0.018	0.017	0.032	0.0261	0.024	0.078	0.094	0.082	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.069	ND	0.02	0.006	0.004	ND
	Cadmium		0.06	0.06	0.02	0.05	0.08	0.0292	0.02	0.03	0.03	0.05	0.147	0.05	0.11	0.12	0.13	0.155	0.21	0.12	0.13	0.14	0.132	0.2	0.09	0.1	0.04	0.09	0.17	0.265	0.28	0.26
	Chromium		11.9	10.5	0.9	8.2	14.7	12.4	23	31.5	8.4	12.4	13.2	10.9	22.3	24.7	19.7	1.56	8.8	6.8	0.8	10.4	1.49	2.7	4.9	2.2	31.7	0.7	6	1.59	0.8	ND
	Cobalt		2.58	3.25	0.397	2.67	4.17	2.58	2.53	2.39	1.98	2.21	2.23	1.94	4.59	5.25	4.86	0.133	0.413	0.324	0.107	0.176	0.133	0.109	0.141	0.18	4.31	0.116	1.25	0.791	0.374	0.472
	Copper		166	45.3	6.39	44.1	48.8	17.3	20.9	14.2	9.56	109	67.8	67.3	70	64.9	79.9	3.32	9.78	3	2.75	2.2	2.95	2.87	1.86	2.46	16.5	2.02	4.57	2.34	2.83	0.85
	Iron		3,460	2,810	122	2,140	4,530	2,818	2,570	2,690	1,900	3,450	3,460	2,540	5,410	7,010	5,570	71.5	302	258	62.5	121	80.5	68.4	83.7	113	6,960	71.5	1,860	459	296	67.4
	Lead		3.16	1.25	5.39	2.04	1.34	1.31	1.2	1.02	0.973	2.6	2.61	2.25	2.01	2.02	2.15	0.146	0.945	2.01	0.076	0.32	2.24	0.626	0.463	2.75	1.18	1.38	3.88	0.967	0.708	0.529
	Manganese		239	328	11.9	259	386	125	94.9	113	122	184	150	159	501	603	611	2.23	15.7	11.5	1.44	7.54	6.27	4.17	4.82	6.68	147	1.4	39	10.1	8.84	5.51
	Mercury		0.074	0.029	0.038	0.024	0.03	0.0581	0.044	0.034	0.103	0.068	0.0922	0.075	0.042	0.047	0.043	0.0978	0.055	0.07	0.044	0.055	0.0285	0.035	0.027	0.024	ND	0.043	0.013	ND	0.006	0.012
	Methyl mercury		0.07	0.021	0.044	0.02	0.012	0.05	0.038	0.04	0.17	0.072	0.06	0.086	0.053	0.033	0.032	0.20	0.059	0.08	0.043	0.034	0.05	0.045	0.038	0.027	0.006	0.056	ND	ND	ND	ND
	Selenium		3.71	1.97	1.83	2.24	2.16	2.14	2.03	1.61	3.59	2.8	2.83	2.65	2.19	2.39	2.57	1.19	1.6	0.79	1.35	1.09	0.879	0.98	0.94	0.66	1.18	1.8	ND	0.0743	ND	ND
	Silver		1.13	0.245	0.014	0.285	0.302	0.0546	0.047	0.046	0.157	0.822	0.61	0.657	0.527	0.594	0.703	0.0132	ND	0.008	0.01	0.01	ND	ND	ND	ND	0.031	ND	0.141	0.0601	0.061	0.029
	Thallium		ND	ND	ND	ND	ND	0.00325	ND	ND	ND	ND	0.006	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0126	ND	ND	0.011	ND	ND	0.013	0.0268	0.024	ND
	Vanadium		19.3	15	1.24	11.2	17.3	10.3	9.23	9.19	7.76	18.2	12.9	11.7	19.6	23.6	19.7	0.106	1.24	0.9	0.26	0.56	0.312	0.35	0.35	0.66	20.3	0.92	13.2	4.42	4.05	2.35
	Zinc		129	112	98.8	103	127	104	91.5	85.2	94.6	106	201	117	108	111	116	54.2	149	64.9	36.8	67.8	73	77	74.5	59.4	69.9	44.7	12.3	12.1	9.04	8.9
General																																	
	Solids, Total		24.4	28.1	27.7	27.4	26.1	-	29	30.6	26.3	26.3	-	25.7	28.7	28.2	27.3	-	30.3	30.7	34.2	27.6	-	27.1	26.5	28.7	31.8	30	18.8	-	11.6	18.1
	Lipids, Total		2.1	5.1	6.4	4.2	4.3	-	6	6.4	2.5	3.3	-	3	4.8	3.8	3.3	-	4.4	2.6	9.6	2.3	-	1.7	2.3	3.2	9.1	3.9	0.079	-	ND	ND
	Percent Lipids		-	-	-	-	-	16	-	-	-	-	13.9	-	-	-	-	21.3	-	-	-	-	9.09	-	-	-	-	-	-	-	-	-
	Percent moisture		75.6	71.9	72.3	72.6	73.9	69.2	71	69.4	73.7	73.7	72.9	74.3	71.3	71.8	72.7	66.9	69.7	69.3	65.8	72.4	71.2	72.9	73.5	71.3	68.2	70	81.2	75.4	88.4	81.9

Notes:

SMPL Primary sample
QC Quality control sample submitted to QC laboratory
J Detected below PQL but above PDL.
P The relative percent difference between the HPLC and GC columns was greater than 40% (25% for pesticides). The sample results should not be used.
ND Chemical was not detected in this sample
\- Sample not analyzed for this chemical.
All analytical results are reported as ug/kg.

Table 3-2
Summary Statistics for Metals and Organochlorine Pesticides
(all results in mg/kg)

Group	Chemical	Average Concentration Muliwai			Average Conc. Near-shore		Maximum Concentration Muliwai			Max. Conc. Near-shore		Minimum Concentration Muliwai			Min. Conc. Near-shore	
		North	South	Nanakuli	Makua	Sandy Beach	North	South	Nanakuli	Makua	Sandy Beach	North	South	Nanakuli	Makua	Sandy Beach
Organochlorine pesticides																
	Aldrin	ND	ND	ND	0.0027	0.0064	ND	ND	ND	0.0027	0.0064	ND	ND	ND	0.0027	0.0064
	BHC, alpha	ND	ND	ND	0.0082	ND	ND	ND	ND	0.0082	ND	ND	ND	ND	0.0082	ND
	BHC, beta	ND	0.0025	ND	ND	ND	ND	0.0041	ND	ND	ND	ND	0.0008	ND	ND	ND
	BHC, delta	0.0003	ND	ND	0.0003	ND	0.0003	ND	ND	0.0003	ND	0.0003	ND	ND	0.0003	ND
	BHC, gamma	0.0011	0.0017	ND	0.0063	0.0019	0.0013	0.0017	ND	0.0063	0.0019	0.0009	0.0016	ND	0.0063	0.0019
	4,4'-DDT	0.0006	0.0017	0.0014	0.0002	0.0020	0.0007	0.0029	0.0014	0.0002	0.0021	0.0005	0.0007	0.0013	0.0002	0.0019
	Heptachlor	ND	ND	ND	0.0056	0.0051	ND	ND	ND	0.0056	0.0057	ND	ND	ND	0.0056	0.0045
	Heptachlor epoxide	0.0005	0.0008	0.0010	0.0086	0.0045	0.0005	0.0009	0.0011	0.0140	0.0076	0.0005	0.0006	0.0010	0.0032	0.0028
Metals																
	Aluminum	2415.66	1871.14	4466.67	30.64	796.00	4240.00	2880.00	5170.00	65.00	4720.00	48.30	1150.00	3810.00	6.80	3.80
	Antimony	0.04	0.05	ND	ND	0.03	0.04	0.05	ND	ND	0.03	0.04	0.05	ND	0.00	0.03
	Arsenic	2.93	5.78	2.54	23.01	18.67	3.81	29.80	2.57	37.30	53.00	2.25	1.46	2.51	4.06	4.52
	Barium	20.79	16.64	40.80	6.98	5.65	26.10	21.20	43.60	31.60	14.20	5.53	12.50	39.10	0.46	0.96
	Beryllium	0.04	0.02	0.08	ND	0.07	0.05	0.03	0.09	0.07	0.07	0.03	0.01	0.08	0.00	0.07
	Cadmium	0.05	0.05	0.12	0.15	0.11	0.08	0.15	0.13	0.21	0.20	0.02	0.02	0.11	0.12	0.04
	Chromium	9.24	15.97	22.23	5.67	7.28	14.70	31.50	24.70	10.40	31.70	0.90	8.40	19.70	0.80	0.70
	Cobalt	2.61	2.27	4.90	0.23	0.83	4.17	2.58	5.25	0.41	4.31	0.40	1.94	4.59	0.11	0.11
	Copper	62.12	43.72	71.60	4.21	4.78	166.00	109.00	79.90	9.78	16.50	6.39	9.56	64.90	2.20	1.86
	Iron	2612.40	2775.43	5996.67	163.00	1229.52	4530.00	3460.00	7010.00	302.00	6960.00	122.00	1900.00	5410.00	62.50	68.40
	Lead	2.64	1.71	2.06	0.70	1.44	5.39	2.61	2.15	2.01	2.75	1.25	0.97	2.01	0.08	0.46
	Manganese	244.78	135.41	571.67	7.68	28.39	386.00	184.00	611.00	15.70	147.00	11.90	94.90	501.00	1.44	1.40
	Mercury	0.04	0.07	0.04	0.06	0.03	0.07	0.10	0.05	0.10	0.04	0.02	0.03	0.04	0.04	0.02
	Methyl mercury	0.03	0.07	0.04	0.08	0.04	0.07	0.17	0.05	0.20	0.06	0.01	0.04	0.03	0.03	0.01
	Selenium	2.38	2.52	2.38	1.20	1.07	3.71	3.59	2.57	1.60	1.80	1.83	1.61	2.19	0.79	0.66
	Silver	0.40	0.34	0.61	0.01	0.03	1.13	0.82	0.70	0.01	0.03	0.01	0.05	0.53	0.01	0.03
	Thallium	ND	0.00	ND	ND	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
	Vanadium	12.81	11.33	20.97	0.61	3.82	19.30	18.20	23.60	1.24	20.30	1.24	7.76	19.60	0.11	0.31
	Zinc	113.96	114.19	111.67	74.54	66.42	129.00	201.00	116.00	149.00	77.00	98.80	85.20	108.00	36.80	44.70

Note: All analytical results are reported as ug/kg.

Table 4-1
Tissue COPCs

	North and South	Near Shore at Nakua	
	Fish Tissue	Fish Tissue	Seaweed Tissue
Metals			
Aluminum	X	X	X
Antimony	X		X
Arsenic	X	X	X
Barium	X	X	X
Beryllium	X		X
Cadmium	X	X	X
Chromium	X	X	X
Cobalt	X	X	X
Copper	X	X	X
Iron	X	X	X
Lead	X	X	X
Manganese	X	X	X
Mercury	X	X	
Methyl Mercury	X	X	
Selenium	X	X	X
Silver	X	X	X
Thallium	X		X
Vanadium	X	X	X
Zinc	X	X	X
Organochlorine pesticides			
4,4'-DDT	X	X	
Aldrin		X	
BHC, alpha		X	
BHC, beta	X		
BHC, delta	X	X	
BHC, gamma	X	X	
Heptachlor		X	X
Heptachlor epoxide	X	X	
Volatiles			
Acetone	X	X	
m,p-Xylenes	X	X	X
Semi-Volatiles			
Bis(2-ethylhexyl)phthalate	X	X	X
Di-n-butylphthalate	X	X	X
Explosives			
Nitroglycerin		X	
Perchlorate	X	X	X
RDX		X	
Dioxins/furans			
1,2,3,4,6,7,8-HpCDD	X		
1,2,3,4,6,7,8-HpCDF	X		X
1,2,3,4,7,8-hxcdf			X
1,2,3,6,7,8-hxcdd			X
1,2,3,6,7,8-hxcdf			X
1,2,3,7,8,9-hxcdd			X
1,2,3,7,8-PeCDD	X		
2,3,7,8-TCDF	X		
HpCDD,total	X		X
HpCDF,total	X		X
HxCDD,total	X		X
HxCDF,total	X		X
OCDD	X		
OCDF	X		X
PeCDD,total	X		
TCDF,Total	X		

Table 4-2
Fish and Seaweed Tissue EPCs

North and South Muliwai Fish Tissue			Muliwai Background (Nanakuli) Fish Tissue			Nearshore Makua Beach Fish Tissue			Nearshore Makua Beach Seaweed Tissue			Nearshore Background (Sandy Beach) Fish Tissue		
Chemical	**Arithmetic Mean**	**MaxD**	**Chemical**	**Arithmetic Mean**	**MaxD**	**Chemical**	**Arithmetic Mean**	**MaxD**	**Chemical**	**Arithmetic Mean**	**MaxD**	**Chemical**	**Arithmetic Mean**	**MaxD**
4,4'-DDT	0.001	0.003	4,4'-DDT	0.001	0.001	4,4'-DDT	0.0005	0.0002	4,4'-DDT	-	-	4,4'-DDT	0.001	0.002
Acetone	0.35	0.38	Acetone	-	-	Acetone	0.48	0.73	Acetone	-	-	Acetone	0.33	0.60
Aldrin	-	-	Aldrin	-	-	Aldrin	0.002	0.003	Aldrin	-	-	Aldrin	0.003	0.01
Aluminum	-	-	Aluminum	4467	5170	Aluminum	31	65	Aluminum	422	1,120	Aluminum	796	4720
Antimony	0.02	0.05	Antimony	-	-	Antimony	-	-	Antimony	0.06	0.15	Antimony	0.02	0.03
Arsenic, organic	4.6	30	Arsenic, organic	2.5	2.6	Arsenic, organic	23	37	Arsenic, inorganic	66	109	Arsenic, organic	19	53
Barium	18	26	Barium	41	44	Barium	7.0	32	Barium	9.0	13	Barium	5.6	14
Beryllium	0.02	0.05	Beryllium	0.08	0.09	Beryllium	-	-	Beryllium	0.01	0.02	Beryllium	0.01	0.07
BHC, alpha	-	-	BHC, alpha	-	-	BHC, alpha	0.002	0.008	BHC, alpha	-	-	BHC, alpha	-	-
BHC, beta	0.001	0.004	BHC, beta	-	-	BHC, beta	-	-	BHC, beta	-	-	BHC, beta	-	-
BHC, delta	0.001	0.0003	BHC, delta	-	-	BHC, delta	0.001	0.0003	BHC, delta	-	-	BHC, delta	-	-
BHC, gamma	0.001	0.002	BHC, gamma	-	-	BHC, gamma	0.003	0.006	BHC, gamma	-	-	BHC, gamma	0.004	0.002
Bis(2-ethylhexyl)phthalate	0.35	3.1	Bis(2-ethylhexyl)phthala	-	-	Bis(2-ethylhexyl)phthalate	1.4	3.5	Bis(2-ethylhexyl)phthalate	0.08	0.09	Bis(2-ethylhexyl)phthalate	0.06	0.05
Cadmium	0.05	0.15	Cadmium	0.12	0.13	Cadmium	0.15	0.21	Cadmium	0.24	0.28	Cadmium	0.11	0.20
Chromium	13	32	Chromium	22	25	Chromium	5.7	10	Chromium	2.2	6.0	Chromium	7.3	32
Cobalt	2.4	4.2	Cobalt	4.9	5.3	Cobalt	0.23	0.41	Cobalt	0.72	1.3	Cobalt	0.83	4.3
Copper	51	166	Copper	72	80	Copper	4.2	9.8	Copper	2.6	4.6	Copper	4.8	17
Diethyl phthalate	-	-	Diethyl phthalate	-	-	Diethyl phthalate	-	-	Diethyl phthalate	-	-	Diethyl phthalate	0.04	0.02
di-n-Butylphthalate	0.22	1.5	di-n-Butylphthalate	0.02	0.02	di-n-Butylphthalate	0.31	1.4	di-n-Butylphthalate	0.14	0.48	di-n-Butylphthalate	0.13	0.61
Heptachlor	-	-	Heptachlor	-	-	Heptachlor	0.002	0.01	Heptachlor	0.001	0.001	Heptachlor	0.003	0.01
Heptachlor epoxide	0.001	0.001	Heptachlor epoxide	0.001	0.001	Heptachlor epoxide	0.01	0.01	Heptachlor epoxide	-	-	Heptachlor epoxide	0.003	0.01
Iron	2708	4530	Iron	5997	7010	Iron	163	302	Iron	671	1,860	Iron	1230	6960
Lead	2.1	5.4	Lead	2.1	2.2	Lead	0.70	2.0	Lead	1.5	3.9	Lead	1.4	2.8
m,p-Xylenes	0.01	0.02	m,p-Xylenes	-	-	m,p-Xylenes	0.01	0.02	m,p-Xylenes	0.02	0.02	m,p-Xylenes	0.01	0.02
Manganese	181	386	Manganese	572	611	Manganese	7.7	16	Manganese	16	39	Manganese	28	147
Mercury	0.06	0.10	Mercury	0.04	0.05	Mercury	0.06	0.10	Mercury	-	-	Mercury	0.03	0.04
Methyl mercury	0.06	0.17	Methyl mercury	0.04	0.05	Methyl mercury	0.08	0.20	Methyl mercury	-	-	Methyl mercury	0.04	0.06
Nitroglycerin	-	-	Nitroglycerin	-	-	Nitroglycerin	0.17	0.33	Nitroglycerin	-	-	Nitroglycerin	-	-
Perchlorate	0.03	0.16	Perchlorate	0.0006	0.001	Perchlorate	0.002	0.01	Perchlorate	0.02	0.05	Perchlorate	0.02	0.11
RDX	-	-	RDX	-	-	RDX	0.06	0.06	RDX	-	-	RDX	-	-
Selenium	2.5	3.7	Selenium	2.4	2.6	Selenium	1.2	1.6	Selenium	0.28	0.07	Selenium	1.0	1.8
Silver	0.36	1.1	Silver	0.61	0.70	Silver	0.01	0.01	Silver	0.07	0.14	Silver	0.01	0.03
Thallium	0.01	0.01	Thallium	-	-	Thallium	-	-	Thallium	0.02	0.03	Thallium	0.01	0.01
Vanadium	12	19	Vanadium	21	24	Vanadium	0.61	1.2	Vanadium	6.0	13	Vanadium	3.8	20
Zinc	114	201	Zinc	112	116	Zinc	75	149	Zinc	11	12	Zinc	66	77
TCDD equivalents	3.1E-13	1.8E-12	TCDD equivalents	2.6E-15	3.8E-15	TCDD equivalents	ND	ND	TCDD equivalents	2.33E-14	6.72E-14	TCDD equivalents	3.6E-14	1.7E-13

Note: All analytical results are reported as mg/kg.

Table 4-3
Oral Carcinogenic Slope Factors

Chemical	Oral Slope Factor $(mg/kg/day)^{-1}$	Weight of Evidence	Tumor	Test Species	Slope Factor Source	Date
Acetone	-	-	-	-	-	-
Aldrin	1.70E+01	B2	Liver carcinoma	Mouse	IRIS	Nov-06
Aluminum	-	-	-	-	1	-
Antimony	-	-	-	-	1	-
Arsenic, inorganic	1.50E+00	A	Skin	Human	IRIS	Nov-06
Arsenic, organic	-	-	-	-	1	-
Barium	-	D	-	-	1	-
Beryllium	-	B1	-	-	2	-
BHC, alpha	6.30E+00	B2	Hepatic nodules and hepatocellular carcinomas	Mouse	IRIS	Nov-06
BHC, beta	1.80E+00	C	Hepatic nodules and hepatocellular carcinomas	Mouse	IRIS	Nov-06
BHC, delta	-	D	-	-	-	-
BHC, gamma	1.30E+00	B2	Liver tumors	Mouse	HEAST	Jul-97
bis(2-ethylhexyl)phthalate	1.40E-02	B2	Liver tumors	Mouse	IRIS	Nov-06
Cadmium	-	B1	-	-	2	-
Chromium	-	D	-	-	-	-
Cobalt	-	B1	-	-	2	-
Copper	-	D	-	-	-	-
4,4'-DDT	3.40E-01	B2	Liver tumors	Rat	IRIS	Nov-06
Diethyl phthalate	-	D	-	-	-	-
Di-n-butylphthalate	-	D	-	-	-	-
Ethylbenzene	-	D	-	-	-	-
Heptachlor	4.50E+00	B2	Liver tumors	Mouse	IRIS	Nov-06
Heptachlor epoxide	9.10E+00	B2	Hepatocellular carcinomas	Mouse	IRIS	Nov-06
Iron	–	–	-	-	1	–
Lead	-	B2	–	–	3	–
Manganese	-	D	-	-	-	-
Mercury	-	D	-	-	-	-
Methyl mercury	-	-	-	-	1	-
Nitroglycerin	1.40E-02	-	-	-	PRG	Oct-04
Perchlorate	-	NA	-	-	-	-
RDX	1.10E-01	C	Liver, hepatocellular carcinoma, and adenomas	Mouse	IRIS	Nov-06
Selenium	-	D	-	-	-	-
Silver	-	D	-	-	-	-
TCDD equivalents	1.50E+05	B2	Respiratory and liver tumors	Rat	HEAST	Jul-97
Thallium	-	D	-	-	-	-
Toluene	-	D	-	-	-	-
Vanadium	-	-	-	-	1	-
m,p-Xylenes	-	NA	-	-	1	-
o-Xylene	-	NA	-	-	1	-
Zinc	-	D	-	-	-	-

Definitions:

A	-	Chemical cancer classification (human carcinogen).
B1	-	Chemical cancer classification (probable human carcinogen; limited human evidence).
B2	-	Chemical cancer classification (probable human carcinogen; sufficient animal evidence and/or no human evidence).
C	-	Chemical cancer classification (possible human carcinogen).
Cal/EPA	-	California Environmental Protection Agency.
D	-	Chemical cancer classification (not classifiable as to carcinogenicity).
$(mg/kg/day)^{-1}$	-	Risk per milligrams per kilogram per day.
IRIS	-	Integrated Risk Information System.
NC	-	not classified
SF	-	slope factor

Notes:

All weight of evidence classifications were obtained from U.S. EPA (2004) Integrated Risk Information System (IRIS), except for cobalt, which is from the PPRTV web page.

1	-	This chemical has not been demonstrated to be carcinogenic.
2	-	Has not been demonstrated to be carcinogenic via the oral route of exposure.
3	-	Lead is also evaluated using the DTSC lead spreadsheet, LeadSpread v 7.0.

Table 4-4
Toxicity Equivalency Factors (TEFs) for Dioxins and Furans

Chemical	TEF-98
Dioxins	
2,3,7,8-TCDD	1.00
1,2,3,7,8-PeCDD	1.00
1,2,3,4,7,8-HxCDD	0.10
1,2,3,6,7,8-HxCDD	0.10
1,2,3,7,8,9-HxCDD	0.10
1,2,3,4,6,7,8-HpCDD	0.01
OCDD	0.0001
Furans	
2,3,7,8-TCDF	0.10
1,2,3,7,8-PeCDF	0.05
2,3,4,7,8-PeCDF	0.50
1,2,3,4,7,8-HxCDF	0.10
1,2,3,6,7,8-HxCDF	0.10
1,2,3,7,8,9-HxCDF	0.10
2,3,4,6,7,8-HxCDF	0.10
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
OCDF	0.0001

Table 4-5
Chronic Oral Reference Doses

Chemical	RfD (mg/kg/day)	Confidence	MF	UF	Critical Effect	Test Species	Source	Date
Acetone	9.00E-01	Medium	1	1,000	Nephropathy	Rat	IRIS	Nov-06
Aldrin	3.00E-05	Medium	1	1,000	Liver toxicity	Rat	IRIS	Nov-06
Aluminum	1.00E+00	-	-	-	-	-	PPRTV	-
Antimony	4.00E-04	Low	1	1,000	Longevity, blood glucose, and cholesterol	Rat	IRIS	Nov-06
Arsenic, inorganic	3.00E-04	Medium	1	3	Hyperpigmentation, keratosis and possible vascular complications	Human	IRIS	Nov-06
Arsenic, organic	-	-	-	-	-	-	2	-
Barium	7.00E-02	High	-	300	Nephropathy	Mouse	IRIS	Nov-06
Beryllium	2.00E-03	Medium	1	300	Small intestinal lesions	Dog	IRIS	Nov-06
BHC, alpha	5.00E-04	-	-	-	-	-	PRG Table	Oct-04
BHC, beta	2.00E-04	-	-	-	-	-	PRG Table	Oct-04
BHC, delta	3.00E-04	-	-	-	-	-	1	-
BHC, gamma	3.00E-04	Medium	1	1,000	Liver and kidnet toxicity	Rat	IRIS	Nov-06
bis(2-ethylhexyl)phthalate	2.00E-02	Medium	1	1,000	Increased relative liver weight	Guinea pig	IRIS	Nov-06
Cadmium	5.00E-04	-	1	10	Significant proteinuria	Human	IRIS	Nov-06
Chromium	1.50E+00	Low	10	100	No effects observed	Rat	IRIS	Nov-06
Cobalt	2.00E-02	Low/Medium	1	10	Hematological effects (increased hemoglobin)	Human	PPRTV	Jul-97
Copper	4.00E-02	-	-	-	Gastrointestinal irritation	Human	HEAST	Jul-97
4,4'-DDT	5.00E-04	Medium	1	100	Liver lesions	Rat	IRIS	Nov-06
Diethyl phthalate	8.00E-01	Medium	1	1,000	Decreased growth rate, food consumption and altered organ weights	Rat	IRIS	Nov-06
Di-n-butylphthalate	1.00E-01	Low	1	1,000	Increased mortality	Rat	IRIS	Nov-06
Ethylbenzene	1.00E-01	Low	1	1,000	Liver and kidnet toxicity	Rat	IRIS	Nov-06
Heptachlor	5.00E-04	Low	1	300	Liver weight increases in males	Rat	IRIS	Nov-06
Heptachlor epoxide	1.30E-05	Low	1	1,000	Increased liver-to-body weight ration	Dog	IRIS	Nov-06
Iron	-	-	-	-	-	-	2	-
Lead	-	-	-	-	-	-	3	-
Manganese	2.40E-02	Medium	1	1	CNS effects	Human	IRIS	Nov-06
Mercury	3.00E-04	Medium	1	3,000	Hand tremor, increases in memory disturbance; slight subjective and objective evidence of autonomic dysfunction	Human	IRIS	Nov-06
Methyl mercury	1.00E-04	High	1	10	Developmental neuropsychological impairment	Human	IRIS	Nov-06
Nitroglycerin	-	-	-	-	-	-	2	-
Perchlorate	7.00E-04	Medium/High	-	10	Radioactive iodide uptake inhibition	Human	IRIS	Nov-06
RDX	3.00E-03	High	1	100	Inflammation of the prostate	Rat	IRIS	Nov-06
Selenium	5.00E-03	Medium	1	3	Clinical seleniosis	Human	IRIS	Nov-06
Silver	5.00E-03	Medium	1	3	Argyria	Human	IRIS	Nov-06
TCDD equivalents	-	-	-	-	-	-	2	-
Thallium	8.00E-05	Low	1	3,000	No adverse effects	Rat	IRIS	Nov-06
Toluene	2.00E-01	Medium	-	3,000	Increased kidney weight	Rat	IRIS	Nov-06
Vanadium	2.00E-02	-	-	100	No adverse effects	Rat	HEAST; 4	Jul-97
m,p-Xylenes	2.00E-01	Medium	1	1,000	Decreased body weight, increased mortality	Rat	IRIS; 5	Nov-06
o-Xylene	2.00E-01	Medium	1	1,000	Decreased body weight, increased mortality	Rat	IRIS; 5	Nov-06
Zinc	3.00E-01	Medium	-	3	Decrease in erythrocyte superoxide dismutase (ESOD) concentration	Human	IRIS	Nov-06

Definitions:

DTSC - Department of Toxic Substances Control
HEAST - Health Effects Assessment Summary Tables
IRIS - Integrated Risk Information System
MF - modifying factor
mg/kg/day - milligram per kilogram per day
RfD - reference dose
UF - uncertainty factor

Notes:

1 - gamma-BHC used as a surrogate
2 No RfDs developed by IRIS USEPA 2004a), HEAST (U.S. EPA, 1997b), or the PPRTVs (USEPA 2004b).
3 - Lead is evaluated using the DTSC lead spreadsheet, LeadSpread v 7.0.
4 - Vanadium sulfate values were used.
5 - Xylene toxicity values were used.

Table 4-6
Carcinogenic Risk Estimates from Fish Consumption at the Muliwai Using Mean Contaminant Concentrations

	Subsistence Fishers		Recreational Fishers	
Chemical	**Site**	**Background**	**Site**	**Background**
Acetone	-	-	-	-
Aluminum	-	-	-	-
Antimony	-	-	-	-
Arsenic, organic	-	-	-	-
Barium	-	-	-	-
Beryllium	-	-	-	-
BHC, beta	1.35E-06	-	4.56E-07	-
BHC, delta	-	-	-	-
BHC, gamma	8.14E-07	-	2.75E-07	-
Bis(2-ethylhexyl)phthalate	2.98E-06	-	1.01E-06	-
Cadmium	-	-	-	-
Chromium	-	-	-	-
Cobalt	-	-	-	-
Copper	-	-	-	-
4,4'-DDT	2.35E-07	2.58E-07	7.94E-08	8.71E-08
di-n-Butylphthalate	-	-	-	-
Heptachlor epoxide	7.51E-06	5.83E-06	2.54E-06	1.97E-06
Iron	-	-	-	-
Lead	-	-	-	-
m,p-Xylenes	-	-	-	-
Manganese	-	-	-	-
Mercury	-	-	-	-
Methyl mercury	-	-	-	-
Perchlorate	-	-	-	-
Selenium	-	-	-	-
Silver	-	-	-	-
Thallium	-	-	-	-
Vanadium	-	-	-	-
Zinc	-	-	-	-
TCDD equivalents	2.85E-11	2.40E-13	9.62E-12	8.09E-14
Total Carcinogenic Risk	1E-05	6E-06	4E-06	2E-06

Table 4-7
Carcinogenic Risk Estimates from Fish Consumption at the Muliwai Using Maximum Contaminant Concentrations

	Subsistence Fishers		Recreational Fishers	
Chemical	**Site**	**Background**	**Site**	**Background**
Acetone	-	-	-	-
Aluminum	-	-	-	-
Antimony	-	-	-	-
Arsenic, organic	-	-	-	-
Barium	-	-	-	-
Beryllium	-	-	-	-
BHC, beta	4.55E-06	-	1.54E-06	-
BHC, delta	-	-	-	-
BHC, gamma	1.36E-06	-	4.60E-07	-
Bis(2-ethylhexyl)phthalate	2.67E-05	-	9.03E-06	-
Cadmium	-	-	-	-
Chromium	-	-	-	-
Cobalt	-	-	-	-
Copper	-	-	-	-
4,4'-DDT	6.07E-07	2.93E-07	2.05E-07	9.91E-08
di-n-Butylphthalate	-	-	-	-
Heptachlor epoxide	5.21E-06	6.17E-06	1.76E-06	2.08E-06
Iron	-	-	-	-
Lead	-	-	-	-
m,p-Xylenes	-	-	-	-
Manganese	-	-	-	-
Mercury	-	-	-	-
Methyl mercury	-	-	-	-
Perchlorate	-	-	-	-
Selenium	-	-	-	-
Silver	-	-	-	-
Thallium	-	-	-	-
Vanadium	-	-	-	-
Zinc	-	-	-	-
TCDD equivalents	1.63E-10	3.51E-13	5.49E-11	1.19E-13
Total Carcinogenic Risk	4E-05	6E-06	1E-05	2E-06

Table 4-8
Non-carcinogenic Hazard Index Estimates from Fish Consumption at the Muliwai Using Mean Contaminant Concentrations

	Subsistence Fishers		Recreational Fishers	
Chemical	**Site**	**Background**	**Site**	**Background**
Acetone	6E-04	-	2E-04	-
Aluminum	3E+00	6E+00	1E+00	2E+00
Antimony	8E-02	-	3E-02	-
Arsenic, organic	-	-	-	-
Barium	4E-01	8E-01	1E-01	3E-01
Beryllium	2E-02	6E-02	6E-03	2E-02
BHC, beta	9E-03	-	3E-03	-
BHC, delta	4E-03	-	1E-03	-
BHC, gamma	5E-03	-	2E-03	-
Bis(2-ethylhexyl)phthalate	2E-02	-	8E-03	-
Cadmium	1E-01	3E-01	5E-02	1E-01
Chromium	1E-02	2E-02	4E-03	7E-03
Cobalt	2E-01	4E-01	6E-02	1E-01
Copper	2E+00	3E+00	6E-01	9E-01
4,4'-DDT	3E-03	4E-03	1E-03	1E-03
di-n-Butylphthalate	3E-03	2E-04	1E-03	7E-05
Heptachlor epoxide	1E-01	1E-01	5E-02	4E-02
Iron	-	-	-	-
Lead	-	-	-	-
m,p-Xylenes	9E-05	-	3E-05	-
Manganese	1E+01	3E+01	4E+00	1E+01
Mercury	3E-01	2E-01	9E-02	7E-02
Methyl mercury	8E-01	6E-01	3E-01	2E-01
Perchlorate	6E-02	1E-03	2E-02	4E-04
Selenium	7E-01	7E-01	2E-01	2E-01
Silver	1E-01	2E-01	4E-02	6E-02
Thallium	1E-01	-	4E-02	-
Vanadium	9E-01	2E-01	3E-01	5E-02
Zinc	5E-01	5E-01	2E-01	2E-01
TCDD equivalents	-	-	-	-
Total HI	20	47	7	16

Table 4-9
Non-carcinogenic Hazard Index Estimates from Fish Consumption at the Muliwai Using Maximum Contaminant Concentrations

	Subsistence Fishers		Recreational Fishers	
Chemical	**Site**	**Background**	**Site**	**Background**
Acetone	6E-04	-	2E-04	-
Aluminum	6E+00	7E+00	2E+00	3E+00
Antimony	2E-01	-	6E-02	-
Arsenic, organic	-	-	-	-
Barium	5E-01	9E-01	2E-01	3E-01
Beryllium	4E-02	7E-02	1E-02	2E-02
BHC, beta	3E-02	-	1E-02	-
BHC, delta	1E-03	-	5E-04	-
BHC, gamma	8E-03	-	3E-03	-
Bis(2-ethylhexyl)phthalate	2E-01	-	8E-02	-
Cadmium	4E-01	4E-01	1E-01	1E-01
Chromium	3E-02	2E-02	1E-02	8E-03
Cobalt	3E-01	4E-01	1E-01	1E-01
Copper	6E+00	3E+00	2E+00	1E+00
4,4'-DDT	8E-03	4E-03	3E-03	1E-03
di-n-Butylphthalate	2E-02	3E-04	7E-03	9E-05
Heptachlor epoxide	1E-01	1E-01	3E-02	4E-02
Iron	-	-	-	-
Lead	-	-	-	-
m,p-Xylenes	1E-04	-	4E-05	-
Manganese	2E+01	4E+01	8E+00	1E+01
Mercury	5E-01	2E-01	2E-01	8E-02
Methyl mercury	2E+00	8E-01	8E-01	3E-01
Perchlorate	3E-01	3E-03	1E-01	1E-03
Selenium	1E+00	7E-01	4E-01	2E-01
Silver	3E-01	2E-01	1E-01	7E-02
Thallium	1E-01	-	4E-02	-
Vanadium	1E+00	2E-01	5E-01	6E-02
Zinc	1E+00	6E-01	3E-01	2E-01
TCDD equivalents	-	-	-	-
Total HI	44	51	15	17

Table 4-10
Carcinogenic Risk Estimates from Fish Consumption at Makua Beach Using Mean Contaminant Concentrations

	Subsistence Fishers		Recreational Fishers	
Chemical	**Site**	**Background**	**Site**	**Background**
Acetone	-	-	-	-
Aldrin	2.06E-05	2.80E-05	6.96E-06	9.45E-06
Aluminum	-	-	-	-
Antimony	-	-	-	-
Arsenic, organic	-	-	-	-
Barium	-	-	-	-
BHC, alpha	7.97E-06	-	2.69E-06	-
BHC, delta	-	-	-	-
BHC, gamma	2.14E-06	3.09E-06	7.22E-07	1.04E-06
Beryllium	-	-	-	-
Bis(2-Ethylhexyl)Phthalate	1.21E-05	4.83E-07	4.09E-06	1.63E-07
Cadmium	-	-	-	-
Chromium	-	-	-	-
Cobalt	-	-	-	-
Copper	-	-	-	-
4,4'-DDT	1.03E-07	2.07E-07	3.48E-08	7.00E-08
Diethyl phthalate	-	-	-	-
di-n-Butylphthalate	-	-	-	-
Heptachlor	5.18E-06	8.13E-06	1.75E-06	2.75E-06
Heptachlor epoxide	3.42E-05	1.66E-05	1.16E-05	5.61E-06
Iron	-	-	-	-
Lead	-	-	-	-
m,p-Xylenes	-	-	-	-
Manganese	-	-	-	-
Mercury	-	-	-	-
Methyl mercury	-	-	-	-
Nitroglycerin	1.47E-06	-	4.97E-07	-
Perchlorate	-	-	-	-
RDX	3.84E-06	-	1.30E-06	-
Selenium	-	-	-	-
Silver	-	-	-	-
Thallium	-	-	-	-
Vanadium	-	-	-	-
Zinc	-	-	-	-
TCDD equivalents	-	3.36E-12	-	1.14E-12
Total Carcinogenic Risk	9.E-05	6.E-05	3.E-05	2.E-05

Table 4-11
Carcinogenic Risk Estimates from Fish Consumption at Makua Beach Using Maximum Contaminant Concentrations

	Subsistence Fishers		Recreational Fishers	
Chemical	**Site**	**Background**	**Site**	**Background**
Acetone	-	-	-	-
Aldrin	3.E-05	7.E-05	1.E-05	2.E-05
Aluminum	-	-	-	-
Antimony	-	-	-	-
Arsenic, organic	-	-	-	-
Barium	-	-	-	-
Beryllium	-	-	-	-
BHC, alpha	3.E-05	-	1.E-05	-
BHC, delta	-	-	-	-
BHC, gamma	5.E-06	2.E-06	2.E-06	5.E-07
Bis(2-Ethylhexyl)Phthalate	3.E-05	4.E-07	1.E-05	1.E-07
Cadmium	-	-	-	-
Chromium	-	-	-	-
Cobalt	-	-	-	-
Copper	-	-	-	-
4,4'-DDT	4.E-08	4.E-07	1.E-08	1.E-07
Diethyl phthalate	-	-	-	-
di-n-Butylphthalate	-	-	-	-
Heptachlor	2.E-05	2.E-05	5.E-06	5.E-06
Heptachlor epoxide	8.E-05	4.E-05	3.E-05	1.E-05
Iron	-	-	-	-
Lead	-	-	-	-
m,p-Xylenes	-	-	-	-
Manganese	-	-	-	-
Mercury	-	-	-	-
Methyl mercury	-	-	-	-
Nitroglycerin	3.E-06	-	1.E-06	-
Perchlorate	-	-	-	-
RDX	4.E-06	-	1.E-06	-
Selenium	-	-	-	-
Silver	-	-	-	-
Thallium	-	-	-	-
Vanadium	-	-	-	-
Zinc	-	-	-	-
TCDD equivalents	-	2.E-11	-	5.E-12
Total Carcinogenic Risk	2.E-04	1.E-04	7.E-05	4.E-05

Table 4-12
Non-carcinogenic Hazard Index Estimates from Fish Consumption at Makua Beach Using Mean Contaminant Concentrations

	Subsistence Fishers		Recreational Fishers	
Chemical	**Site**	**Background**	**Site**	**Background**
Acetone	8.E-04	2.E-04	3.E-04	2.E-04
Aldrin	9.E-02	4.E-02	3.E-02	4.E-02
Aluminum	4.E-02	4.E-01	1.E-02	4.E-01
Antimony	-	2.E-02	-	2.E-02
Arsenic, organic	-	-	-	-
Barium	1.E-01	4.E-02	5.E-02	4.E-02
Beryllium	-	3.E-03	-	3.E-03
BHC, alpha	6.E-03	-	2.E-03	-
BHC, delta	5.E-03	-	2.E-03	-
BHC, gamma	1.E-02	2.E-02	4.E-03	6.E-03
Bis(2-Ethylhexyl)Phthalate	1.E-01	4.E-03	3.E-02	1.E-03
Cadmium	4.E-01	3.E-01	1.E-01	1.E-01
Chromium	5.E-03	7.E-03	2.E-03	2.E-03
Cobalt	2.E-02	6.E-02	6.E-03	2.E-02
Copper	2.E-01	2.E-01	5.E-02	6.E-02
4,4'-DDT	1.E-03	3.E-03	5.E-04	1.E-03
Diethyl phthalate	-	7.E-05	-	2.E-05
di-n-Butylphthalate	4.E-03	2.E-03	2.E-03	7.E-04
Heptachlor	5.E-03	2.E-05	2.E-03	7.E-06
Heptachlor epoxide	7.E-01	3.E-01	2.E-01	1.E-01
Iron	-	-	-	-
Lead	-	-	-	-
m,p-Xylenes	1.E-04	1.E-04	4.E-05	3.E-05
Manganese	5.E-01	2.E+00	2.E-01	6.E-01
Mercury	3.E-01	1.E-01	1.E-01	4.E-02
Methyl mercury	1.E+00	5.E-01	4.E-01	2.E-01
Nitroglycerin	-	-	-	-
Perchlorate	3.E-03	4.E-02	1.E-03	1.E-02
RDX	3.E-02	-	9.E-03	-
Selenium	3.E-01	3.E-01	1.E-01	1.E-01
Silver	3.E-03	3.E-03	9.E-04	1.E-03
Thallium	-	1.E-01	-	5.E-02
Vanadium	4.E-02	3.E-01	1.E-02	9.E-02
Zinc	4.E-01	3.E-01	1.E-01	1.E-01
Total HI	4	5	2	2

Table 4-13
Non-carcinogenic Hazard Index Estimates from Fish Consumption at Makua Beach Using Maximum Contaminant Concentrations

	Subsistence Fishers		Recreational Fishers	
Chemical	**Site**	**Background**	**Site**	**Background**
Acetone	1.E-03	1.E-03	4.E-04	3.E-04
Aldrin	1.E-01	3.E-01	4.E-02	1.E-01
Aluminum	9.E-02	7.E+00	3.E-02	2.E+00
Antimony	-	9.E-02	-	3.E-02
Arsenic, organic	-	-	-	-
Barium	6.E-01	3.E-01	2.E-01	1.E-01
Beryllium	-	5.E-02	-	2.E-02
BHC, alpha	2.E-02	-	8.E-03	-
BHC, delta	1.E-03	-	5.E-04	-
BHC, gamma	3.E-02	9.E-03	1.E-02	3.E-03
Bis(2-Ethylhexyl)Phthalate	3.E-01	4.E-03	9.E-02	1.E-03
Cadmium	6.E-01	6.E-01	2.E-01	2.E-01
Chromium	1.E-02	3.E-02	3.E-03	1.E-02
Cobalt	3.E-02	3.E-01	1.E-02	1.E-01
Copper	4.E-01	6.E-01	1.E-01	2.E-01
4,4'-DDT	5.E-04	6.E-03	2.E-04	2.E-03
Diethyl phthalate	-	3.E-05	-	1.E-05
di-n-Butylphthalate	2.E-02	9.E-03	7.E-03	3.E-03
Heptachlor	2.E-02	4.E-05	5.E-03	1.E-05
Heptachlor epoxide	2.E+00	8.E-01	5.E-01	3.E-01
Iron	-	-	-	-
Lead	-	-	-	-
m,p-Xylenes	1.E-04	1.E-04	5.E-05	4.E-05
Manganese	9.E-01	9.E+00	3.E-01	3.E+00
Mercury	5.E-01	2.E-01	2.E-01	7.E-02
Methyl mercury	3.E+00	8.E-01	1.E+00	3.E-01
Nitroglycerin	-	-	-	-
Perchlorate	2.E-02	2.E-01	6.E-03	8.E-02
RDX	3.E-02	-	9.E-03	-
Selenium	5.E-01	5.E-01	2.E-01	2.E-01
Silver	4.E-03	9.E-03	1.E-03	3.E-03
Thallium	-	2.E-01	-	8.E-02
Vanadium	9.E-02	1.E+00	3.E-02	5.E-01
Zinc	7.E-01	4.E-01	2.E-01	1.E-01
Total HI	9	23	3	8

Table 4-14
Carcinogenic Risks and Non-carcinogenic Hazards from Consumption of Seaweed (Mean COPC Concentrations)

	Carcinogenic Risk		Hazard Index (HI)	
Chemical	**Subsistence fisher**	**Recreational fisher**	**Subsistence fisher**	**Recreational fisher**
Aluminum	-	-	1.E-01	3.E-02
Antimony	-	-	4.E-02	1.E-02
Arsenic, inorganic	1.11E-02	3.16E-03	6.E+01	2.E+01
Barium	-	-	3.E-02	1.E-02
Beryllium	-	-	1.E-03	3.E-04
Bis(2-Ethylhexyl)Phthalate	1.30E-07	3.70E-08	1.E-03	3.E-04
Cadmium	-	-	1.E-01	4.E-02
Chromium	-	-	4.E-04	1.E-04
Cobalt	-	-	9.E-03	3.E-03
Copper	-	-	2.E-02	5.E-03
di-n-Butylphthalate	-	-	4.E-04	1.E-04
Heptachlor	6.26E-07	1.79E-07	6.E-04	2.E-04
Iron	-	-	-	-
Lead	-	-	-	-
m,p-Xylenes	-	-	3.E-05	8.E-06
Manganese	-	-	2.E-01	5.E-02
Perchlorate	-	-	6.E-03	2.E-03
Selenium	-	-	1.E-02	4.E-03
Silver	-	-	4.E-03	1.E-03
Thallium	-	-	5.E-02	2.E-02
Vanadium	-	-	8.E-02	2.E-02
Zinc	-	-	9.E-03	3.E-03
TCDD equivalents	3.90E-13	1.11E-13	-	-
Total	**1E-02**	**3E-03**	**58**	**17**

Table 4-15
Carcinogenic Risks and Non-carcinogenic Hazards from Consumption of Seaweed (Mean COPC Concentrations)

	Carcinogenic Risk		Hazard Index (HI)	
Chemical	**Subsistence fisher**	**Recreational fisher**	**Subsistence fisher**	**Recreational fisher**
Aluminum	-	-	3.E-01	8.E-02
Antimony	-	-	9.E-02	3.E-02
Arsenic, inorganic	1.82E-02	5.21E-03	9.E+01	3.E+01
Barium	-	-	5.E-02	1.E-02
Beryllium	-	-	3.E-03	7.E-04
Bis(2-Ethylhexyl)Phthalate	1.34E-07	3.83E-08	1.E-03	3.E-04
Cadmium	-	-	1.E-01	4.E-02
Chromium	-	-	1.E-03	3.E-04
Cobalt	-	-	2.E-02	5.E-03
Copper	-	-	3.E-02	8.E-03
di-n-Butylphthalate	-	-	1.E-03	4.E-04
Heptachlor	3.61E-07	1.03E-07	4.E-04	1.E-04
Iron	-	-	-	-
Lead	-	-	-	-
m,p-Xylenes	-	-	2.E-05	6.E-06
Manganese	-	-	4.E-01	1.E-01
Perchlorate	-	-	2.E-02	6.E-03
Selenium	-	-	4.E-03	1.E-03
Silver	-	-	7.E-03	2.E-03
Thallium	-	-	9.E-02	2.E-02
Vanadium	-	-	2.E-01	5.E-02
Zinc	-	-	1.E-02	3.E-03
TCDD equivalents	1.12E-12	3.21E-13	-	-
Total	**2E-02**	**5E-03**	**96**	**27**

Table 5-1(a)
Sediment COPECs

Chemical	North Muliwai	South Muliwai
Metals		
Antimony	X	X
Cadmium	X	X
Lead	X	X
Selenium	X	X
Volatile Organic Compounds		
Benzene	X	X
Ethylbenzene	X	X
Toluene	X	X
m,p-Xylenes	X	X
o-Xylene	X	
Semi-volatile Organic Compounds		
Bis(2-ethylhexyl)phthalate	X	X
Pentachlorophenol		X
Organochlorine Pesticides		
4,4'-DDT	X	
Chlorinated Herbicides		
Picloram		X
Explosives		
RDX	X	
Dioxins and Furans		
OCDD	X	
2,3,7,8-TCDD		X

Table 5-1(b)
Tissue COPECs

Chemical	North Muliwai Fish Tissue	South Muliwai Fish Tissue	Near Shore at Makua Fish Tissue	Near Shore at Makua Seaweed Tissue
Metals				
Aluminum	X	X	X	X
Antimony	X	X		X
Arsenic	X	X	X	X
Barium	X	X	X	X
Beryllium	X	X		X
Cadmium	X	X	X	X
Chromium	X	X	X	X
Cobalt	X	X	X	X
Copper	X	X	X	X
Iron	X	X	X	X
Lead	X	X	X	X
Manganese	X	X	X	X
Mercury	X	X	X	
Methyl Mercury	X	X	X	
Selenium	X	X	X	X
Silver	X	X	X	X
Thallium		X		X
Vanadium	X	X	X	X
Zinc	X	X	X	X
Volatile Organic Compounds				
Acetone	X	X	X	
m,p-Xylenes		X	X	X
Semi-volatile Organic Compounds				
Bis(2-ethylhexyl)phthalate		X	X	X
Di-n-butylphthalate	X	X	X	X
Organochlorine Pesticides				
4,4'-DDT	X	X	X	
Aldrin			X	
BHC, alpha			X	
BHC, beta		X		
BHC, delta	X		X	
BHC, gamma	X	X	X	
Heptachlor			X	X
Heptachlor Epoxide	X	X	X	
Explosives				
Nitroglycerin			X	
Perchlorate	X	X	X	X
RDX			X	
Dioxins and Furans				
TCDD equivalent	X	X		X

Table 5-2
Toxicity Reference Values for Benthic Invertebrates

Chemical	TRV_{Low}[a] ($mg/kg_{sediment}$)	TRV_{High}[b] ($mg/kg_{sediment}$)
Metals		
Antimony	9.3[c]	-
Cadmium	0.676	4.21
Lead	30.2	112
Selenium	1.0[c]	-
Organics		
Benzene	-	-
bis(2-ethylhexyl)phthalate	0.182	2.65
4,4'-DDT	0.00119	0.00477
Ethylbenzene	0.004[c]	-
OCDD	-	-
Pentachlorophenol	0.017[c]	-
Picloram	-	-
RDX	-	-
2,3,7,8-TCDD	3.6E-6[c]	-
Toluene	-	-
m,p-Xylenes	0.004[c]	-
o-Xylene	0.004[c]	-

Notes:

a - Threshold effects level (TEL) for marine sediment, unless otherwise noted.
b - Probable effects level (PEL) for marine sediment.
c - Apparent effects threshold (AET) for marine sediment.
$mg/kg_{sediment}$ - milligram (chemical) per kilogram (sediment)
A dash indicates the absence of an applicable TRV.
Source: Buchman (1999).

Table 5-3
Fish Tissue-Based Toxicity Reference Values

	NOEC		LOEC		
Chemical	**NOEC (mg/kg dry wt.)[a]**	**Type**	**LOEC (mg/kg dry wt.)[a]**	**Type**	**Reference**
Metals					
Aluminum	42.7	NOEC - Survival	100	LOEC - Reduced survival	Jarvinen and Ankley, 1999
Antimony	25	NOEC - Survival	45	LOEC - Reduced survival 50%	Jarvinen and Ankley, 1999
Arsenic	10	NOEC - Survival	15	LOEC - Reduced survival 50%	Jarvinen and Ankley, 1999
Cadmium	0.375	NOEC - Survival	0.70	LOEC - Reduced survival 20%	Jarvinen and Ankley, 1999
Chromium	2.9	NOEC - Survival	-	-	Jarvinen and Ankley, 1999
Copper	5.0	NOEC - Survival	8.0	LOEC - Reduced survival 80-100%	Jarvinen and Ankley, 1999
Lead	13	NOEC - Growth	20	LOEC - Reduced growth	Jarvinen and Ankley, 1999
Mercury	15	NOEC - Behavioral, reproductive, physiological effects	25	LOEC - Behavioral, reproductive, physiological effects	Weiner and Spry, 1996
Silver	0.30	NOEC - Survival, growth	-	-	Jarvinen and Ankley, 1999
Selenium	3.96	NOEC - Mortality (estimated)	39.6	LOEC - Mortality	U.S. EPA, 2004
Vanadium	0.10	NOEC - Growth	2.1	LOEC - Reduced growth	Jarvinen and Ankley, 1999
Zinc	57.0	NOEC - Survival	68.0	LOEC - Reduced survival; immobilized	Jarvinen and Ankley, 1999
Pesticides					
Aldrin	10.7	NOEC - Survival, growth	28.3	LOEC - Reduced survival 50%	Jarvinen and Ankley, 1999
alpha-BHC	210	NOEC - Survival, growth	850	LOEC - Reduced survival/ immobilization	Jarvinen and Ankley, 1999
beta-BHC	24.3	NOEC - Survival (estimated)	243	LOEC - Reduced survival 50%	Jarvinen and Ankley, 1999
delta-BHC	24.3	NOEC - Survival (estimated)	243	LOEC - Reduced survival 50%	Jarvinen and Ankley, 1999
gamma-BHC	0.065	NOEC - Survival	5.35	LOEC - Reduced survival 50%	Jarvinen and Ankley, 1999
4,4'-DDT	13.3	NOEC - Survival (estimated)	133	LOEC - Reduced survival 50%	Jarvinen and Ankley, 1999
Heptachlor	27	NOEC - Survival	57.5	LOEC - Reduced survival	Jarvinen and Ankley, 1999
Dioxins and Furans					
2,3,7,8-TCDD	0.00049	NOEC - Survival (estimated)	0.0049	LOEC - Reduced survival 45%	Jarvinen and Ankley, 1999

Definitions:

NOEC	No Observable Effect Concentration
LOEC	Lowest Observable Effect Concentration
mg/kg	Milligrams per kilogram

Notes:

[a]Tissue concentrations were converted from wet weight to dry weight assuming a moisture content of 80 percent (Stephen et al., 1985).
A dash indicates the absence of an applicable LOEC.

Table 5-4
North and South Background Muliwai Sediment
Makua Military Reservation

Chemical	RME Concentration (mg/kg)	TRV_{Low}	HQ_{High}	TRV_{High}	HQ_{Low}
North Background Muliwai					
Metals					
Lead	1.6	30.24	0.05	112	0.01
South Background Muliwai					
Metals					
Lead	2.4	30.24	0.08	112	0.02

Definitions:

HQ - Hazard Quotient
mg/kg - milligrams per kilogram
RME - Reasonable maximum exposure
TRV - Toxicity Reference Value

Notes:

A dash indicates the absence of an applicable TRV.

Table 5-5
Nanakuli Muliwai
Fish Tissue
Makua Military Reservation

Chemical	Maximum Detected Concentration (mg/kg)	TRV_{Low}	HQ_{High}	TRV_{High}	HQ_{Low}
Metals					
Aluminum	5170	42.65	121	100	52
Arsenic	2.57	10	0.26[a]	15	0.17[a]
Barium	43.6	-	-	-	-
Beryllium	0.094	-	-	-	-
Cadmium	0.13	0.375	0.35	0.7	0.19
Chromium	24.7	2.9	8.5	-	-
Cobalt	5.25	-	-	-	-
Copper	79.9	5	16	8	10.0
Iron	7010	-	-	-	-
Lead	2.15	12.5	0.17	20	0.11
Manganese	611	-	-	-	-
Mercury	0.047	15	0.003	25	0.002
Methyl Mercury	0.053	15	0.004	25	0.002
Selenium	2.57	3.955	0.65	39.55	0.06
Silver	0.703	0.3	2.3	-	-
Vanadium	23.6	0.1	236	2.05	12
Zinc	116	57	2.0	68	1.7
Organics					
4,4'-DDT	0.0014	13.25	0.0001	132.5	0.00001
di-n-Butylphthalate	0.018	-	-	-	-
Heptachlor Epoxide	0.0011	26.5	0.00004	57.5	0.00002
Perchlorate	0.0014	-	-	-	-
TCDD Equivalent	3.80E-15	0.00049	7.8E-12	0.0049	7.8E-13

Definitions:

mg/kg - milligrams per kilogram
TRV - Toxicity Reference Value
HQ - Hazard Quotient

Notes:

[a]Arsenic concentrations in fish tissues likely consist of organic arsenic only, which is nontoxic. The HQ for arsenic is assumed to overestimate the risk since the TRVs are based on inorganic arsenic.

A dash indicates the absence of an applicable TRV.

Shaded values indicate HQs greater than 1.

Table 5-6
Nearshore at Sandy Beach
Fish Tissue
Makua Military Reservation

Chemical	Maximum Detected Concentration (mg/kg)	TRV_{Low}	HQ_{High}	TRV_{High}	HQ_{Low}
Metals					
Aluminum	4720	42.65	111	100	47
Antimony	0.0259	25	0.001	45	0.0006
Arsenic	53	10	5.3[a]	15	3.5[a]
Barium	14.2	-	-	-	-
Beryllium	0.069	-	-	-	-
Cadmium	0.2	0.375	0.53	0.7	0.29
Chromium	31.7	2.9	11	-	-
Cobalt	4.31	-	-	-	-
Copper	16.5	5	3.3	8	2.1
Iron	6960	-	-	-	-
Lead	2.75	12.5	0.22	20	0.14
Manganese	147	-	-	-	-
Mercury	0.043	15	0.003	25	0.002
Methyl Mercury	0.056	15	0.004	25	0.002
Selenium	1.8	3.955	0.46	39.55	0.05
Silver	0.031	0.3	0.10	-	-
Thallium	0.0126	-	-	-	-
Vanadium	20.3	0.1	203	2.05	9.9
Zinc	77	57	1.4	68	1.1
Organics					
4,4'-DDT	0.0021	13.25	0.0002	132.5	0.00002
Acetone	0.6	-	-	-	-
Aldrin	0.0064	10.65	0.0006	28.25	0.0002
BHC,gamma	0.0019	0.065	0.03	5.35	0.0004
Bis(2-ethylhexyl)phthalate	0.049	-	-	-	-
Diethyl phthalate	0.019	-	-	-	-
di-n-Butylphthalate	0.61	-	-	-	-
Heptachlor	0.0057	26.5	0.0002	57.5	0.0001
Heptachlor Epoxide	0.0076	26.5	0.0003	57.5	0.0001
m,p-Xylenes	0.016	-	-	-	-
Perchlorate	0.11	-	-	-	-
TCDD Equivalent	1.72E-13	0.00049	3.5E-10	0.0049	3.5E-11

Definitions:

mg/kg - milligrams per kilogram
TRV - Toxicity Reference Value
HQ - Hazard Quotient

Notes:

[a]Arsenic concentrations in fish tissues likely consist of organic arsenic only, which is nontoxic. The HQ for arsenic is assumed to overestimat the risk since the TRVs are based on inorganic arsenic.

A dash indicates the absence of an applicable TRV.

Shaded values indicate HQs greater than 1.

Table 5-7
North Muliwai Sediment
Makua Military Reservation

Chemical	RME Concentration (mg/kg)	TRV_{Low}	HQ_{High}	TRV_{High}	HQ_{Low}
Metals					
Antimony	3.7	9.3	0.39	-	-
Cadmium	0.11	0.676	0.16	4.21	0.03
Lead	5.8	30.2	0.19	112	0.05
Selenium	4.0	1.0	4.0	-	-
Organics					
4,4'-DDT	0.0001	0.00119	0.08	0.00477	0.02
Benzene	0.00004	-	-	-	-
bis(2-ethylhexyl)phthalate	0.02	0.182	0.10	2.65	0.007
Ethylbenzene	0.001	0.004	0.31	-	-
m,p-Xylenes	0.001	0.004	0.25	-	-
OCDD	0.0002	-	-	-	-
o-Xylene	0.0001	0.004	0.03	-	-
RDX	0.05	-	-	-	-
Toluene	0.001	-	-	-	-

Definitions:

HQ - Hazard Quotient
mg/kg - milligrams per kilogram
RME - Reasonable maximum exposure
TRV - Toxicity Reference Value

Notes:

A dash indicates the absence of an applicable TRV.
Shaded values indicate HQs greater than 1.

Table 5-8
North Muliwai
Fish Tissue
Makua Military Reservation

Chemical	Maximum Detected Concentration (mg/kg)	TRV_{Low}	HQ_{High}	TRV_{High}	HQ_{Low}
Metals					
Aluminum	4240	42.7	99	100	42
Antimony	0.04	25	0.002	45	0.001
Arsenic	3.81	10	0.38[a]	15	0.25[a]
Barium	26.1	-	-	-	-
Beryllium	0.051	-	-	-	-
Cadmium	0.08	0.375	0.21	0.70	0.11
Chromium	14.7	2.9	5.1	-	-
Cobalt	4.17	-	-	-	-
Copper	166	5.0	33	8.0	21
Iron	4530	-	-	-	-
Lead	5.39	13	0.43	20	0.27
Manganese	386	-	-	-	-
Mercury	0.074	15	0.005	25	0.003
Methyl Mercury	0.07	15	0.005	25	0.003
Selenium	3.71	3.96	0.94	39.6	0.09
Silver	1.13	0.30	3.8	-	-
Vanadium	19.3	0.10	193	2.1	9.4
Zinc	129	57.0	2.3	68.0	1.9
Organics					
4,4'-DDT	0.00074	13.3	0.0001	133	0.00001
Acetone	0.25	-	-	-	-
BHC,delta	0.00031	24.3	0.00001	243	0.000001
BHC,gamma	0.0013	0.065	0.020	5.35	0.0002
di-n-Butylphthalate	0.015	-	-	-	-
Heptachlor Epoxide	0.00051	27	0.00002	57.5	0.00001
Perchlorate	0.0019	-	-	-	-
TCDD Equivalent	4.49E-13	0.00049	9.2E-10	0.0049	9.2E-11

Definitions:

mg/kg - milligrams per kilogram
TRV - Toxicity Reference Value
HQ - Hazard Quotient

Notes:

[a]Arsenic concentrations in fish tissues likely consist of organic arsenic only, which is nontoxic. The HQ for arsenic is assumed to overestimate the risk since the TRVs are based on inorganic arsenic.

A dash indicates the absence of an applicable TRV.

Shaded values indicate HQs greater than 1.

Table 5-9
South Muliwai Sediment
Makua Military Reservation

Chemical	RME Concentration (mg/kg)	TRV_{Low}	HQ_{High}	TRV_{High}	HQ_{Low}
Metals					
Antimony	0.63	9.3	0.07	-	-
Cadmium	0.09	0.676	0.13	4.2	0.02
Lead	19	30.2	0.63	112	0.17
Selenium	4.7	1.0	4.7	-	-
Organics					
2,3,7,8-TCDD	0.00003	3.6E-6	8.3	-	-
Ethylbenzene	0.001	0.004	0.25	-	-
m,p-Xylenes	0.001	0.004	0.18	-	-
Pentachlorophenol	0.001	0.017	0.05	-	-
Picloram	0.0004	-	-	-	-
Toluene	0.001	-	-	-	-

Definitions:

HQ - Hazard Quotient
mg/kg - milligrams per kilogram
RME - Reasonable maximum exposure
TRV - Toxicity Reference Value

Notes:

A dash indicates the absence of an applicable TRV.
Shaded values indicate HQs greater than 1.

Table 5-10
South Muliwai
Fish Tissue
Makua Military Reservation

Chemical	Maximum Detected Concentration (mg/kg)	TRV_{Low}	HQ_{High}	TRV_{High}	HQ_{Low}
Metals					
Aluminum	2880	42.7	68	100	29
Antimony	0.0527	25	0.002	45	0.001
Arsenic	29.8	10	3.0[a]	15	2.0[a]
Barium	21.2	-	-	-	-
Beryllium	0.032	-	-	-	-
Cadmium	0.147	0.375	0.39	0.7	0.21
Chromium	31.5	2.9	11	-	-
Cobalt	2.58	-	-	-	-
Copper	109	5	22	8	14
Iron	3460	-	-	-	-
Lead	2.61	12.5	0.21	20	0.13
Manganese	184	-	-	-	-
Mercury	0.103	15	0.007	25	0.004
Methyl Mercury	0.17	15	0.01	25	0.007
Selenium	3.59	3.955	0.91	39.55	0.09
Silver	0.822	0.3	2.7	-	-
Thallium	0.00586	-	-	-	-
Vanadium	18.2	0.1	182	2.05	8.9
Zinc	201	57	3.5	68	3.0
Organics					
4,4'-DDT	0.0029	13.25	0.0002	132.5	0.00002
Acetone	0.38	-	-	-	-
BHC,delta	0.0041	24.3	0.0002	243	0.00002
BHC,gamma	0.0017	0.065	0.03	5.35	0.0003
Bis(2-ethylhexyl)phthalate	3.1	-	-	-	-
di-n-Butylphthalate	1.5	-	-	-	-
Heptachlor Epoxide	0.00093	26.5	0.00004	57.5	0.00002
m,p-Xylenes	0.017	-	-	-	-
Perchlorate	0.16	-	-	-	-
TCDD Equivalent	1.76E-12	0.00049	3.6E-9	0.0049	3.6E-10

Definitions:

mg/kg - milligrams per kilogram
TRV - Toxicity Reference Value
HQ - Hazard Quotient

Notes:

[a]Arsenic concentrations in fish tissues likely consist of organic arsenic only, which is nontoxic. The HQ for arsenic is assumed to overestimate the risk since the TRVs are based on inorganic arsenic.

A dash indicates the absence of an applicable TRV.

Shaded values indicate HQs greater than 1.

Table 5-11
Nearshore at Makua
Fish Tissue
Makua Military Reservation

Chemical	Maximum Detected Concentration (mg/kg)	TRV_{Low}	HQ_{High}	TRV_{High}	HQ_{Low}
Metals					
Aluminum	65	42.65	1.5	100	0.65
Arsenic	37.3	10	3.7[a]	15	2.5[a]
Barium	31.6	-	-	-	-
Cadmium	0.21	0.375	0.56	0.7	0.30
Chromium	10.4	2.9	3.6	-	-
Cobalt	0.413	-	-	-	-
Copper	9.78	5	2.0	8	1.2
Iron	302	-	-	-	-
Lead	2.01	12.5	0.16	20	0.10
Manganese	15.7	-	-	-	-
Mercury	0.0978	15	0.007	25	0.004
Methyl Mercury	0.20009	15	0.01	25	0.008
Selenium	1.6	3.955	0.40	39.55	0.04
Silver	0.0132	0.3	0.04	-	-
Vanadium	1.24	0.1	12	2.05	0.60
Zinc	149	57	2.6	68	2.2
Organics					
4,4'-DDT	0.00018	13.25	0.00001	132.5	0.000001
Acetone	0.73	-	-	-	-
Aldrin	0.0027	10.65	0.0003	28.25	0.0001
BHC,alpha	0.0082	210	0.00004	850	0.00001
BHC,delta	0.0003	24.3	0.00001	243	0.000001
BHC,gamma	0.0063	0.065	0.10	5.35	0.001
Bis(2-ethylhexyl)phthalate	3.5	-	-	-	-
di-n-Butylphthalate	1.4	-	-	-	-
Heptachlor	0.0056	26.5	0.0002	57.5	0.0001
Heptachlor Epoxide	0.014	26.5	0.0005	57.5	0.0002
m,p-Xylenes	0.02	-	-	-	-
Nitroglycerin	0.33	-	-	-	-
Perchlorate	0.0088	-	-	-	-
RDX	0.057	-	-	-	-

Definitions:

mg/kg - milligrams per kilogram
TRV - Toxicity Reference Value
HQ - Hazard Quotient

Notes:

[a]Arsenic concentrations in fish tissues likely consist of organic arsenic only, which is nontoxic. The HQ for arsenic is assumed to overestimate the risk since the TRVs are based on inorganic arsenic.

Shaded values indicate HQs greater than 1.

Table 5-12
North Muliwai HIs
Sediment
Makua Military Reservation

Chemical	North Muliwai		North Background Muliwai		North Muliwai Incremental Risk	
	HQ_{High}	HQ_{Low}	HQ_{High}	HQ_{Low}	High	Low
Metals						
Antimony	0.39	-	-	-	-	-
Cadmium	0.16	0.03	-	-	-	-
Lead	0.19	0.05	0.05	0.01	-	-
Selenium	4.0	-	-	-	-	-
Organics						
4,4'-DDT	0.08	0.02	-	-	-	-
Benzene	-	-	-	-	-	-
bis(2-ethylhexyl)phthalate	0.10	0.007	-	-	-	-
Ethylbenzene	0.31	-	-	-	-	-
m,p-Xylenes	0.25	-	-	-	-	-
OCDD	-	-	-	-	-	-
o-Xylene	0.03	-	-	-	-	-
RDX	-	-	-	-	-	-
Toluene	-	-	-	-	-	-
HI	5.51	0.10	0.05	0.01	5.46	0.09

Definitions:

HI - Hazard Index
HQ - Hazard Quotient
mg/kg - milligrams per kilogram
RME - Reasonable maximum exposure
TRV - Toxicity Reference Value

Notes:

A dash indicates the absence of an applicable HQ.
Shaded values indicate HQs and HIs greater than 1.

Table 5-13
North Muliwai HIs
Fish Tissue
Makua Military Reservation

Chemical	North Muliwai		Nanakuli Background Muliwai		North Muliwai Incremental Risk	
	HQ_{High}	HQ_{Low}	HQ_{High}	HQ_{Low}	High	Low
Metals						
Aluminum	99	42	121	52	N/A	N/A
Antimony	0.002	0.001	-	-	N/A	N/A
Arsenic[a]	-	-	-	-	N/A	N/A
Barium	-	-	-	-	N/A	N/A
Beryllium	-	-	-	-	N/A	N/A
Cadmium	0.21	0.11	0.35	0.19	N/A	N/A
Chromium	5.1	-	8.5	-	N/A	N/A
Cobalt	-	-	-	-	N/A	N/A
Copper	33	21	16	10.0	N/A	N/A
Iron	-	-	-	-	N/A	N/A
Lead	0.43	0.27	0.17	0.11	N/A	N/A
Manganese	-	-	-	-	N/A	N/A
Mercury/Methyl Mercury	0.005	0.003	0.004	0.002	N/A	N/A
Selenium	0.94	0.09	0.65	0.06	N/A	N/A
Silver	3.8	-	2.3	-	N/A	N/A
Vanadium	193	9.4	236	12	N/A	N/A
Zinc	2.3	1.9	2.0	1.7	N/A	N/A
Organics						
4,4'-DDT	0.0001	0.00001	0.0001	0.00001	N/A	N/A
Acetone	-	-	-	-	N/A	N/A
BHC,delta	0.00001	0.000001	-	-	N/A	N/A
BHC,gamma	0.020	0.0002	-	-	N/A	N/A
di-n-Butylphthalate	-	-	-	-	N/A	N/A
Heptachlor Epoxide	0.00002	0.00001	0.00004	0.00002	N/A	N/A
Perchlorate	-	-	-	-	N/A	N/A
TCDD Equivalent	9.2E-10	9.2E-11	7.8E-12	7.8E-13	N/A	N/A
HI	338	75	387	75	0	0

Definitions:

HI - Hazard Index
HQ - Hazard Quotient
mg/kg - milligrams per kilogram
N/A - Not applicable
RME - Reasonable maximum exposure
TRV - Toxicity Reference Value

Notes:

[a]HQs for arsenic were excluded from HIs, since arsenic concentrations in fish tissues likely consist of organic arsenic only, which is nontoxic.
A dash indicates the absence of an applicable HQ.
Shaded values indicate HQs and HIs greater than 1.

Table 5-14
South Muliwai HIs
Sediment
Makua Military Reservation

Chemical	South Muliwai HQ_{High}	South Muliwai HQ_{Low}	South Background Muliwai HQ_{High}	South Background Muliwai HQ_{Low}	South Muliwai Incremental Risk High	South Muliwai Incremental Risk Low
Metals						
Antimony	0.07	-	-	-	-	-
Cadmium	0.13	0.02	-	-	-	-
Lead	0.63	0.17	0.08	0.02	-	-
Selenium	4.7	-	-	-	-	-
Organics						
2,3,7,8-TCDD	8.3	-	-	-	-	-
Ethylbenzene	0.25	-	-	-	-	-
m,p-Xylenes	0.18	-	-	-	-	-
Pentachlorophenol	0.05	-	-	-	-	-
Picloram	-	-	-	-	-	-
Toluene	-	-	-	-	-	-
HI	14.4	0.19	0.08	0.02	14.3	0.17

Definitions:

HI - Hazard Index
HQ - Hazard Quotient
mg/kg - milligrams per kilogram
RME - Reasonable maximum exposure
TRV - Toxicity Reference Value

Notes:

A dash indicates the absence of an applicable HQ.
Shaded values indicate HQs and HIs greater than 1.

Table 5-15
South Muliwai HIs
Fish Tissue
Makua Military Reservation

Chemical	South Muliwai		Nanakuli Background Muliwai		South Muliwai Incremental Risk	
	HQ_{High}	HQ_{Low}	HQ_{High}	HQ_{Low}	High	Low
Metals						
Aluminum	68	29	121	52	N/A	N/A
Antimony	0.002	0.001	-	-	N/A	N/A
Arsenic[a]	-	-	-	-	N/A	N/A
Barium	-	-	-	-	N/A	N/A
Beryllium	-	-	-	-	N/A	N/A
Cadmium	0.39	0.21	0.35	0.19	N/A	N/A
Chromium	11	-	8.5	-	N/A	N/A
Cobalt	-	-	-	-	N/A	N/A
Copper	22	14	16	10.0	N/A	N/A
Iron	-	-	-	-	N/A	N/A
Lead	0.21	0.13	0.17	0.11	N/A	N/A
Manganese	-	-	-	-	N/A	N/A
Methyl Mercury	0.01	0.007	0.004	0.002	N/A	N/A
Selenium	0.91	0.09	0.65	0.06	N/A	N/A
Silver	2.7	-	2.3	-	N/A	N/A
thallium	-	-	-	-	N/A	N/A
Vanadium	182	8.9	236	12	N/A	N/A
Zinc	3.5	3.0	2.0	1.7	N/A	N/A
Organics						
4,4'-DDT	0.0002	0.00002	0.0001	0.00001	N/A	N/A
Acetone	-	-	-	-	N/A	N/A
BHC,delta	0.0002	0.00002	-	-	N/A	N/A
BHC,gamma	0.03	0.0003	-	-	N/A	N/A
Bis(2-ethylhexyl)phthalate	-	-	-	-	N/A	N/A
di-n-Butylphthalate	-	-	-	-	N/A	N/A
Heptachlor Epoxide	0.00004	0.00002	0.00004	0.00002	N/A	N/A
m,p-Xylenes	-	-	-	-	N/A	N/A
Nitroglycerin	-	-	-	-	N/A	N/A
Perchlorate	-	-	-	-	N/A	N/A
TCDD Equivalent	3.6E-9	3.6E-10	7.8E-12	7.8E-13	N/A	N/A
HI	290	55	387	75	0	0

Definitions:

HI - Hazard Index
HQ - Hazard Quotient
mg/kg - milligrams per kilogram
N/A - Not applicable
RME - Reasonable maximum exposure
TRV - Toxicity Reference Value

Notes:

[a]HQs for arsenic were excluded from HIs, since arsenic concentrations in fish tissues likely consist of organic arsenic only, which is nontoxic.
A dash indicates the absence of an applicable HQ.
Shaded values indicate HQs and HIs greater than 1.

Table 5-16
Nearshore HIs
Fish Tissue
Makua Military Reservation

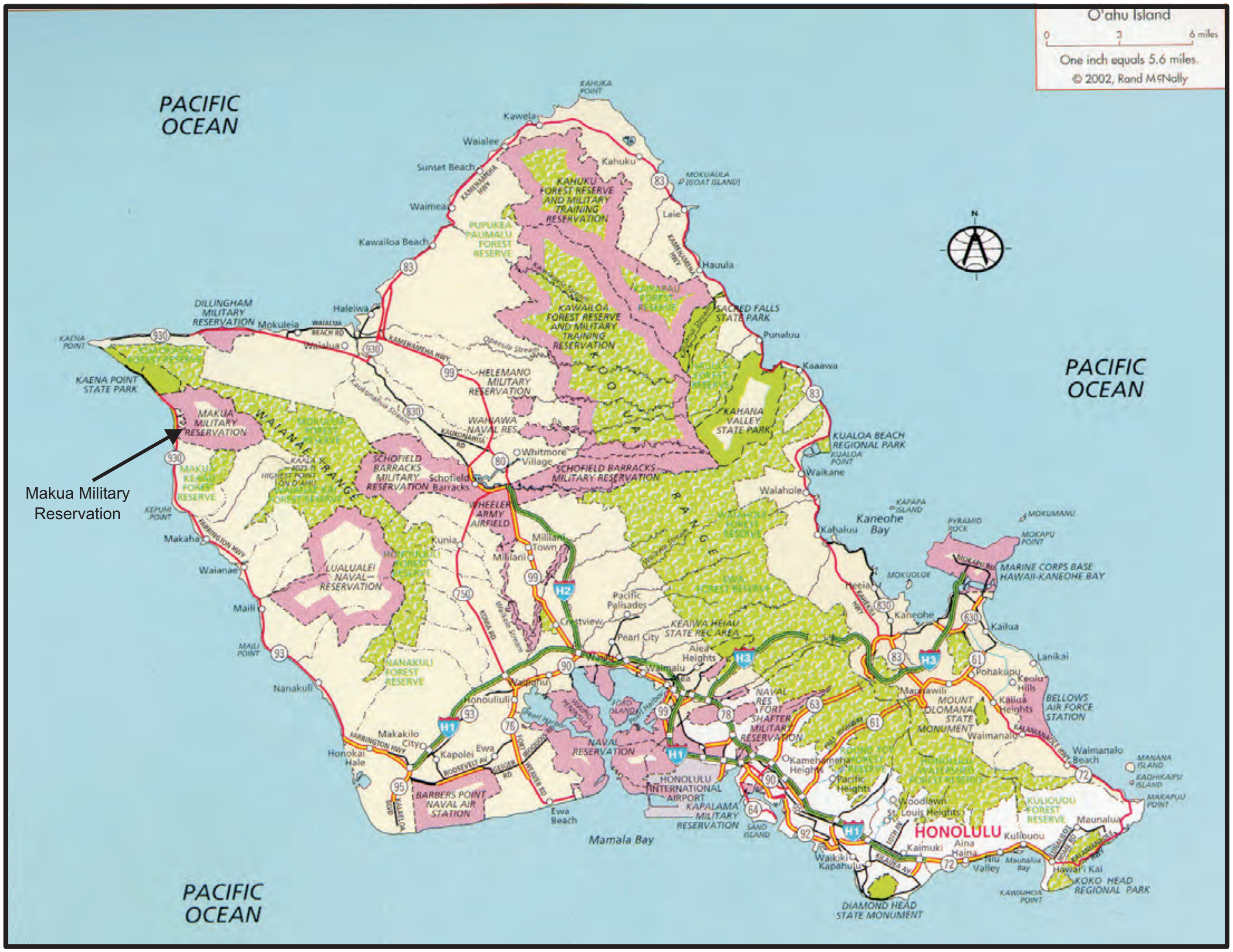
Chemical	Near Shore at Makua		Sandy Beach Background		Near Shore at Makua Incremental Risk	
	HQ_{High}	HQ_{Low}	HQ_{High}	HQ_{Low}	High	Low
Metals						
Aluminum	1.5	0.65	111	47	N/A	N/A
Antimony	-	-	0.001	0.0006	N/A	N/A
Arsenic[a]	-	-	-	-	N/A	N/A
Barium	-	-	-	-	N/A	N/A
Beryllium	-	-	-	-	N/A	N/A
Cadmium	0.56	0.30	0.53	0.29	N/A	N/A
Chromium	3.6	-	11	-	N/A	N/A
Cobalt	-	-	-	-	N/A	N/A
Copper	2.0	1.2	3.3	2.1	N/A	N/A
Iron	-	-	-	-	N/A	N/A
Lead	0.16	0.10	0.22	0.14	N/A	N/A
Manganese	-	-	-	-	N/A	N/A
Methyl Mercury	0.01	0.008	0.004	0.002	N/A	N/A
Selenium	0.40	0.04	0.46	0.05	N/A	N/A
Silver	0.04	-	0.10	-	N/A	N/A
Thallium	-	-	-	-	N/A	N/A
Vanadium	12	0.60	203	9.9	N/A	N/A
Zinc	2.6	2.2	1.4	1.1	N/A	N/A
Organics						
4,4'-DDT	0.00001	0.000001	0.0002	0.00002	N/A	N/A
Acetone	-	-	-	-	N/A	N/A
Aldrin	0.0003	0.0001	0.0006	0.0002	N/A	N/A
BHC,alpha	0.00004	0.00001	-	-	N/A	N/A
BHC,delta	0.00001	0.000001	-	-	N/A	N/A
BHC,gamma	0.10	0.001	0.03	0.0004	N/A	N/A
Bis(2-ethylhexyl)phthalate	-	-	-	-	N/A	N/A
Diethyl phthalate	-	-	-	-	N/A	N/A
di-n-Butylphthalate	-	-	-	-	N/A	N/A
Heptachlor	0.0002	0.0001	0.0002	0.0001	N/A	N/A
Heptachlor Epoxide	0.0005	0.0002	0.0003	0.0001	N/A	N/A
m,p-Xylenes	-	-	-	-	N/A	N/A
Nitroglycerin	-	-	-	-	N/A	N/A
Perchlorate	-	-	-	-	N/A	N/A
RDX	-	-	-	-	N/A	N/A
TCDD Equivalent	-	-	3.5E-10	3.5E-11	N/A	N/A
HI	23	5.1	331	61	0	0

Definitions:

HI - Hazard Index
HQ - Hazard Quotient
mg/kg - milligrams per kilogram
N/A - Not applicable
RME - Reasonable maximum exposure
TRV - Toxicity Reference Value

Notes:

[a]HQs for arsenic were excluded from HIs, since arsenic concentrations in fish tissues likely consist of organic arsenic only, which is nontoxic.
A dash indicates the absence of an applicable HQ.
Shaded values indicate HQs and HIs greater than 1.



Source: Rand McNally 2002

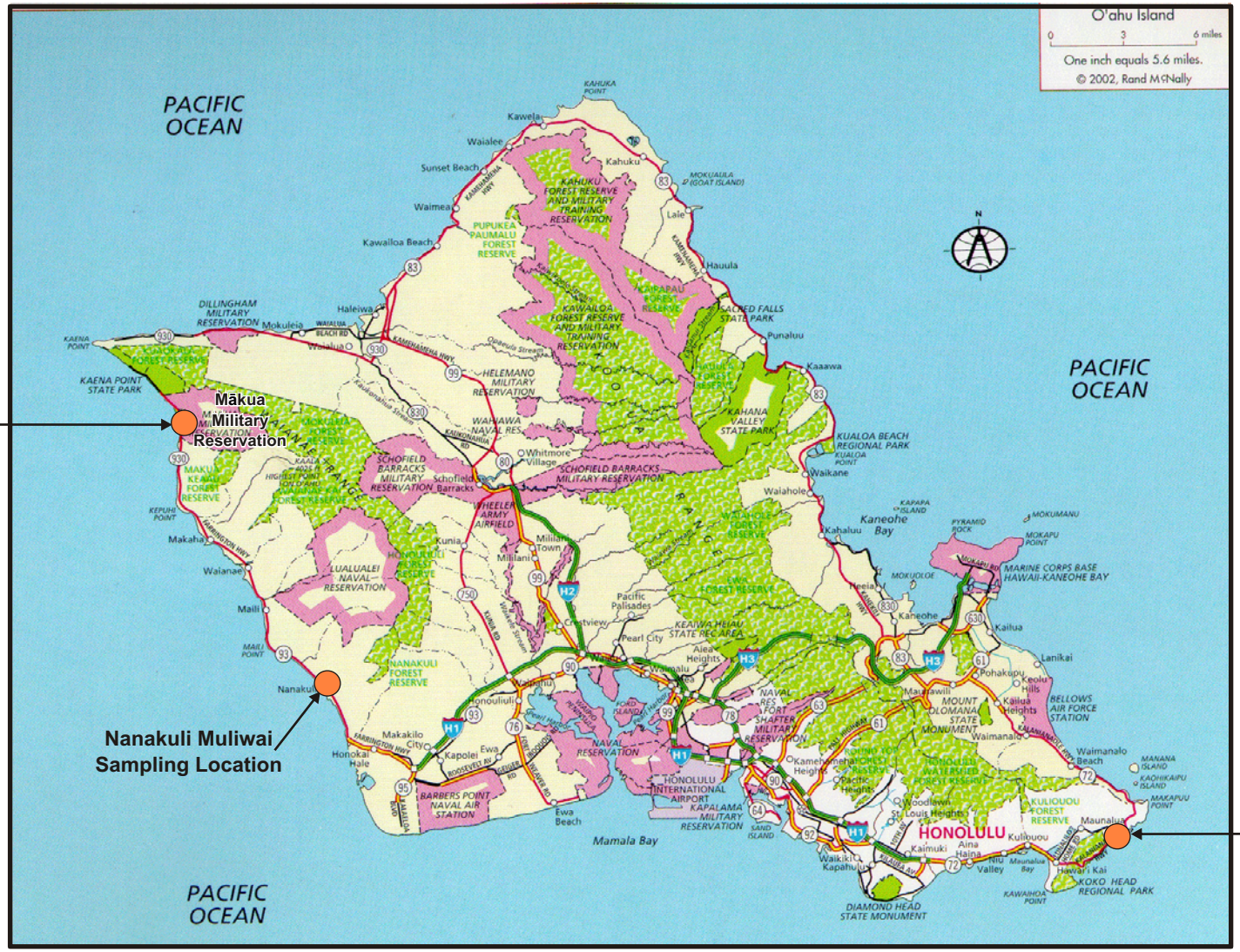
R:\new\K838\Site_Location_Map.cdr - 5/23/02 - YE

Site Location Map

Mākua Military Reservation
O´ahu, Hawai´i

Tetra Tech, Inc.

Figure 1-1



Source: Rand McNally 2002

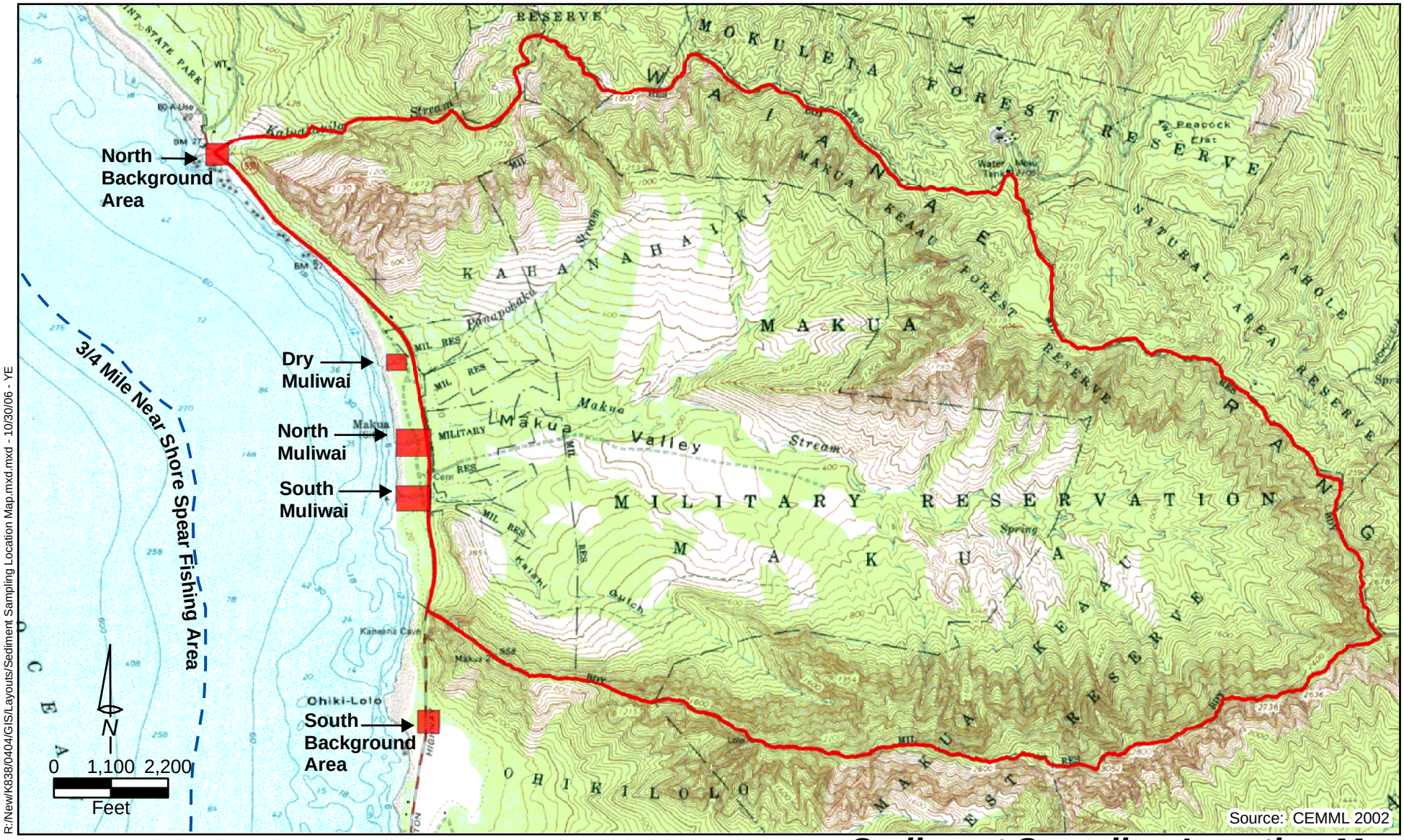
R:\new\K838\0404\Site_Location_Map.cdr - 10/30/06 - YE

Fish and Limu Sample Location Map

Mākua Military Reservation
O´ahu, Hawai´i

Tetra Tech, Inc.

Figure 2-1



R:/New/K838/0404/GIS/Layouts/Sediment Sampling Location Map.mxd - 10/30/06 - YE

Sediment Sampling Location Map

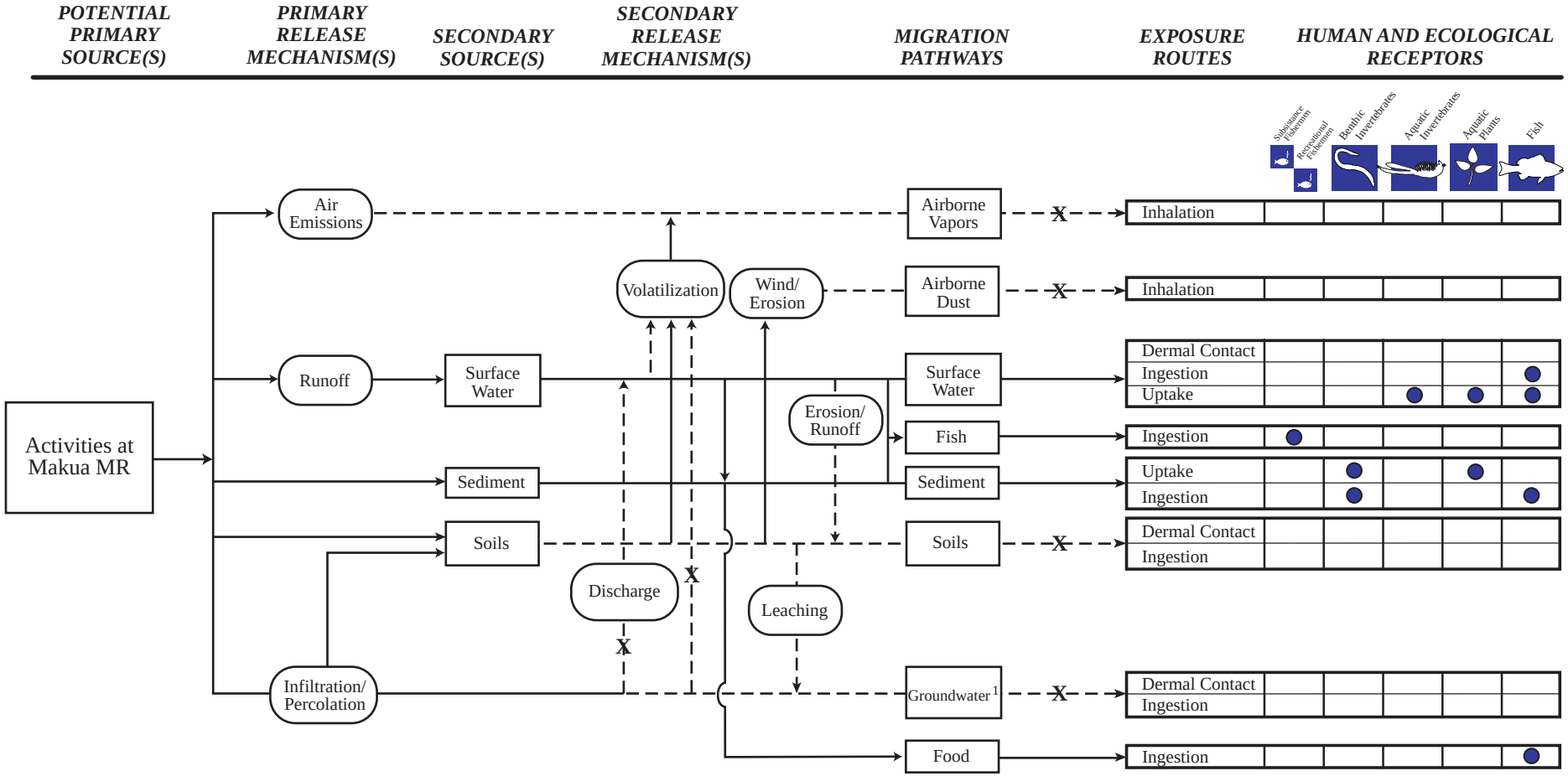
Legend

Mākua Military Reservation

Mākua Military Reservation
Oʻahu, Hawaiʻi

Tetra Tech, Inc

Figure 2-2



Legend

- Potentially complete exposure pathway
- Potentially incomplete exposure pathway
- Incomplete exposure pathway
- Potentially complete exposure route
- 1 Groundwater not used for water supply at this site.

Current & Future Conditions
Conceptual Site Model for Human & Ecological Receptors

Tetra Tech, Inc. San Francisco, CA
180 Howard Street, Suite 250
San Francisco, CA 94105

TASK NO.	DATE	DRAWN BY	FILE NAME	FIGURE NO.
	11/20/06	Rigby		4-1

APPENDIX A
FIELD SHEETS

Codes for Fish Tissue Sampling

Location codes

Location	Name	code
Muliwai 1	North Muliwai	M1
Muliwai 2	South Muliwai	M2
Muliwai 3	Nānākuli Muliwai	M3
Muliwai 4		M4
Muliwai 5		M5
Nearshore Waters 1	off south Muliwai	NW1
Nearshore Waters 2	Sandy Beach	NW2
Nearshore Waters 3		NW3
Seaweed 1	Limu kala	SW1
Seaweed 2	Limu 2	SW2
Seaweed 3		SW3
Seaweed 4		SW4
Fish 1	Striped mullet	F1
Fish 2	Aholehole	F2
Fish 3	Medaka	F3
Fish 4	"Tilapia"	F4
Fish 5	Moana (Parupeneus multifasciatus)	F5
Fish 6	Hinalea (Thalassoma trilobatum)	F6 Christmas wrass
Fish 7	hmanhuma hi ukole (Melichthys vidua)	F7 Brown trigger
Fish 8	a'awa (Bodianus bilunulatus)	F8 Haw. Hogfish
Fish 9	hinalea lau-wili (T. duperrey)	F9 – Saddle wrasse
Fish 10	Taape (Lutjanus kasmira)	F10 Lutjanus fulvus (to'au)
Fish 11	Moano2 (P. pleurostigma)	F11
Fish 12	Fistularia commersonii	F12 Cornet fish
Fish 13	Sufflumen fraenatus	F13 Bridled triggerfish
Fish 14	Rhinecanthus rectangulus	F14 Picasso "
Fish 15	Reef lizardfish	F15 Synodus variegatus
Fish 16	Hou (Surge wrasse)	F16 T. purpureum
Fish 17	Kupipi (A. sordidus)	F17 Blackspot sergeant
Fish 18	Nenue (K. bigibbus)	F18 gray chub
Fish 19	Po'opa'a (Cirrhitus pinnulatus)	F19 stocky hawkfish
Fish 20	Humuhumu lei Sufflamen bursa	F20

Urchin | Hā ukeuke'e = ul kaupali (Colobocentrotus atratus)

Example: M2F1-15S

second muliwai, first fish species on list, sequential composite number 15, S=standard sample.

Field Record for Study of Chemical Residues in Fish Tissue

Sampling Date: 2 Aug 2006
Collection Method: Beach Seine
Colector Name: Andy Jahn
Affiliation: Tetra Tech contractor Phone: 707-468-7432
Address: 1000 Riverside Dr. Ukiah, CA 95482

Site Location County: Hono

Sidt Name: North Mulkwai
Description:
Mākua Beach

Composite Sample ID: MI FI F1 - 1 S
site matrix seq. S/D

Species: Striped Mullet

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	0925	115mm					
2	1040	205	140	99	75	72	
3		74	65	75			
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Composite Sample ID: MI F2 - 2
site matrix seq. S/D

Species: Ahole hole

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	0925	75mm	90	89	106	75	
2	↓	109	68	67	74	75	
3	↓	61	63	67	80	65	
4	0930	77	67	62	69		
5	0940	85	85	75	62	65	
6							
7							
8							

Number of fish in composite: Total Weight (g):

Notes/Diagrams:

Continuation sheet. Date: Location:

Composite Sample ID: M1 ___ F2 - 3 S
site matrix seq. S/D

Species: Aholehole

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1050	63	75	60	79	62	
2		66	64	72	65	60	
3		64	65	67	70	64	
4		63	63	65	75	65	
5	1100	85	110	87	65	64	
6	1	103	90	91	67		
7							
8							

Number of fish in composite: Total Weight (g):

Composite Sample ID: M1 ___ F1 - 4 ___
site matrix seq. S/D

Species: Striped Mullet

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1050	72	74	69			
2	1310	193	60	77	74	71	
3		60	67	66	211		
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Composite Sample ID: M1 F0 - ~~1~~5 ___
site matrix seq. S/D

Species: Medaka

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1050	82	69	48	50	52	
2		78	78	69	55		
3							
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Continuation sheet. Date: Location:

Composite Sample ID: M 1 F4 - 6 S
site matrix seq. S/D

Species: Tilapia

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1145	173	199	155	153	137	
2		193	200	176	155	190	
3		147					
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Composite Sample ID: M 1 F4 - 7 ___
site matrix seq. S/D

Species: Tilapia

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1145	110	93	126	135	107	
2		110	112	112	101	117	
3		140	140	130	127	127	
4		134	105				
5	1245	124					
6							
7							
8							

Number of fish in composite: Total Weight (g):

Composite Sample ID: MT ___ F2-8 ___
site matrix seq. S/D

Species: Aholehole

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1200	100	95	95	89	104	
2		91	107	105	113	100	
3		101	91				
4	1310	72	108	104	102	106	
5		59	105				
6							
7							
8							

Number of fish in composite: Total Weight (g):

Field Record for Study of Chemical Residues in Fish Tissue

Sampling Date: August 3, 2010
Collection Method: Seine / hook + line
Colector Name: Andy Jahr
Affiliation: contractor - TetraTech Phone: 707-468-7432
Address: 1000 Riverside Dr. Ukiah, CA 95482

Site Location County: Hono.

Sidt Name: South Muliwai
Description:
Mākua Beach

Composite Sample ID: M 2 F1 - 1 ___
site matrix seq. S/D

Species: Striped Mullet

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1130	145	164	145	147	157	RBT 530g
2		161	176	146	170	151	
3		185	169				
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Composite Sample ID: M 2 F4 - 2 ___
site matrix seq. S/D

Species: Tilapia

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1130	144	121	124	119	124	BGadj. 900g
2		125	115	125	125	119	
3		109	123	115	115	112	
4		109	122	131	122	115	
5		109	120	114	111		
6							
7							
8							

Number of fish in composite: Total Weight (g):

Notes/Diagrams:

Continuation sheet. Date: Location:

Composite Sample ID: M 2 F4- 3 ____
site matrix seq. S/D

Species: Tilapia

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1130	90	~~72~~	107	106	106	
2		95	105	94	96	97	
3		94	101	90	97	99	
4		100	~~105~~	95	97	111	
5		101	95	97	97	94	
6		94	92	99			
7							
8							

BG Adg 500

Number of fish in composite: Total Weight (g):

Composite Sample ID: M 2 F3 -4 ____
site matrix seq. S/D

Species: Medaka

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1130	61	63	62	60	59	
2		70	70	70	71	64	
3		56	71	66	65	63	
4		65	59	55	59	55	
5		67	67	65	59	56	
6		60	63	62	60	67	
7		59	60	55	59	67	
8		55	57	64	57	55	

Number of fish in composite: Total Weight (g):

Composite Sample ID: M 2 F3 -4 ____
site matrix seq. S/D

Species: Medaka (continued)

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1130	57	55	59	70	59	
2		59	63	59	56	64	
3		60					
4							
5							
6							
7							
8							

RBT 119g

51 fish
55-77 mm

Number of fish in composite: Total Weight (g):

Field Record for Study of Chemical Residues in Fish Tissue

Sampling Date: August 3, 2006
Collection Method: Hand
Colector Name: Landin Johnson
Affiliation: Tetra Tech Phone: (808) 533-3366
Address: 820 Mililani St Suite 700 Honolulu 96813

Site Location: Makua Beach County: _____

Sidt Name: _____
Description:

Composite Sample ID: NW1 ML-1 ____
site matrix seq. S/D

Species: _____

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1330						
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: _____ Total Weight (g): _____

Composite Sample ID: ____ ____ ____ ____ ____
site matrix seq. S/D

Species: _____

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1							
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: _____ Total Weight (g): _____

Notes/Diagrams:

Field Record for Study of Chemical Residues in Fish Tissue

Sampling Date: 4 August 2006
Collection Method: hook + line
Colector Name: Andy Jahn
Affiliation: Tetra Tech contractor Phone: 707-468-7452
Address: 1000 Riverside Dr. Ukiah, CA 95482

Site Location County: Humo

Sidt Name: South Mulinni
Description: Mākua Beach

Composite Sample ID: M2 F4 - 5 D
site matrix seq. S/D

Species: Tilapia

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1030	102	121	119	120	136	
2		106	100	115	141	130	
3		120	132	114	119	130	
4		109	106	106	105		
5							
6							
7							
8							

BG
1117g

Number of fish in composite: Total Weight (g):

Composite Sample ID: ___ ___ ___ ___ ___
site matrix seq. S/D

Species:

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1							
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Notes/Diagrams:

Field Record for Study of Chemical Residues in Fish Tissue

Sampling Date 4 August 2010
Collection Method Hook & line
Colector Name Dawn A. Leeds
Affiliation: Tetra Tech Phone: (808) 533-3366
Address: 820 Mililani St. Suite 700 Honolulu Hi 96813

Site Location County:

Sidt Name: Nānākuli Muliwai
Description:

Nānākuli Beach Park

Composite Sample ID: M 3 F4-1 ___
site matrix seq. S/D

Species: tilapia

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1500	125	115	130	115	119	1290-2099
2		120	120	117	115	136	
3		139	117	119	120	110	
4		110	119	113	116	119	
5		130	122	119	120	111	
6		121	120	113	115	135	
7		120	121	131	111		
8							

Number of fish in composite: Total Weight (g):

Composite Sample ID: ___ ___ ___ ___ ___
site matrix seq. S/D

Species:

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1							
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Notes/Diagrams:

(Seq 2 is Aug 6)

Field Record for Study of Chemical Residues in Fish Tissue

Sampling Date 5 Aug '06
Collection Method Seine
Colector Name A Jahn
Affiliation: Tetra tech contractor Phone: 707-468-7432
Address: 1000 Riverside Dr. Ukiah, CA 95482

Site Location County: Hono

Sidt Name: South Muliwai
Description:
Makua Beach

Composite Sample ID: M 2 F1 5 ___
site matrix seq. S/D

Species: Striped mullet

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1000	192	195	200	197	203	
2		153					
3							
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Composite Sample ID: NW 1 U1 7 ___
site matrix seq. S/D

Species: Urchin - Hāuke'uke

Specimen/Lot Number	time	Lengths (mm TL)					Notes 43 urchin
1	1000						
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Notes/Diagrams:

Continuation sheet. Date: Location:

Composite Sample ID: NW 1 FG - 1 ___
site matrix seq. S/D

Species: Mpana (Parapeneus

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1300	191	~~202~~ 210	290	208	217	
2		190	177	176	177		
3							
4							
5							
6							
7							
8							

~ 2.5 lb

Number of fish in composite: Total Weight (g):

Composite Sample ID: NW 1 FG - 1 ___
site matrix seq. S/D

Species: Hinalea

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1300	213					
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Composite Sample ID: NW 1 ~~FG~~ F7 - 1 ___
site matrix seq. S/D

Species: Humuhumu hinukolu - Brown humu

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1		199	182				
2							
3							
4							
5							
6							
7							
8							

~ 3/4 lb

Number of fish in composite: Total Weight (g):

Continuation sheet. Date: Location:

Composite Sample ID: NW1 F8 1 ___
site matrix seq. S/D

Species: ___

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1300	175					
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Composite Sample ID: NW1 F9 - 1 ___
site matrix seq. S/D

Species: Hinalea lau-wili (Saddle wrasse)

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1		165					
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Composite Sample ID: NW1 F10 1 ___
site matrix seq. S/D

Species: ~~Iacpe~~ To'au

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1300	176					
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

+6 (seq. 2 to 6 tag)

Continuation sheet. Date: 5 Aug 06 Location: Makua Beach

Composite Sample ID: NW1 F4 - 1 ____
site matrix seq. S/D

Species: moana 2 (P. pleurostigma)

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1300	179					
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: ____ Total Weight (g): ____

Composite Sample ID: NW1 F11 - 2 ____
site matrix seq. S/D

Species: moana 2

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	0900	199	190				
2	1000	205					
3	1230	212					
4							
5							
6							
7							
8							

Number of fish in composite: ____ Total Weight (g): ____

Composite Sample ID: NW1 F5 - 2 ____
site matrix seq. S/D

Species: moana

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	0900	231	212	190	256		
2	1000	190	195				
3	1230	211					
4							
5							
6							
7							
8							

Number of fish in composite: ____ Total Weight (g): ____

Continuation sheet. Date: Location:

Composite Sample ID: NW1 F12-2 ___
site matrix seq. S/D

Species: Fistularia commersonii (cornet fish)

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1000	415					Measurement does not include tail filament.
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Composite Sample ID: NW1 F14-2 ___ ___
site matrix seq. S/D

Species: Rhinecan ~~Humumum~~ Humuhumunukunuku apua'a

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1000	172					
2	1230	212					
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Composite Sample ID: NW1 F13-2 ___
site matrix seq. S/D

Species: ~~Fistularia commersonii~~ Bridled triggerfish

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1000	190	147	130			
2	1230	235					
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Continuation sheet. Date: Location:

Composite Sample ID: NW1 F15 -2 ____
site matrix seq. S/D

Species: Lizzard Fish

Specimen/Lot Number	time	Lengths (mm TL)				Notes
1	1000	240				
2						
3						
4						
5						
6						
7						
8						

Number of fish in composite: Total Weight (g):

Composite Sample ID: NW1 F16- 2 ____
site matrix seq. S/D

Species: Surgeon Wrasse

Specimen/Lot Number	time	Lengths (mm TL)				Notes
1	1130	202	204	163	151	
2						
3						
4						
5						
6						
7						
8						

Number of fish in composite: Total Weight (g):

Composite Sample ID: ~~F~~NW1 F6- 2 ____
site matrix seq. S/D

Species: Hinalea

Specimen/Lot Number	time	Lengths (mm TL)				Notes
1	1130	166	175			
2						
3						
4						
5						
6						
7						
8						

Number of fish in composite: Total Weight (g):

Continuation sheet. Date: Location:

Composite Sample ID: NW1 ___ F17-2 ___ ___
site matrix seq. S/D

Species: Blackspot Sergeant

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1130	180	171				
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Composite Sample ID: NW1 ___ F20-2 ___ ___
site matrix seq. S/D

Species: Humuhumu ki

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1130	177					
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Composite Sample ID: NW1 ___ F10-2 ___ ___
site matrix seq. S/D

Species: Nenue

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1130	174					
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Continuation sheet. Date: Location:

Composite Sample ID: NW1 ___ F19-2 ___
site matrix seq. S/D

Species: Stocky Hawkfish

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1130	159					
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Composite Sample ID: ___ ___ ___ ___ ___
site matrix seq. S/D

Species:

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1							
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Composite Sample ID: ___ ___ ___ ___ ___
site matrix seq. S/D

Species:

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1							
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Field Record for Study of Chemical Residues in Fish Tissue

Sampling Date 8 Aug 2006
Collection Method Seine
Colector Name Dawn Llieces
Affiliation: Tetra Tech Phone:
Address:

Site Location County:

Sidt Name: Nanakuli muliwai
Description:
S. end Nanakuli Beach Park

Composite Sample ID: M3 F2 - 1
site matrix seq. S/D

Species: Ahole hole

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1000	89	89	99	95	87	
2		84	86	88			
3	1300	99					
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Composite Sample ID: M3 F2 - 2
site matrix seq. S/D

Species: Ahole hole

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1130	128					
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Notes/Diagrams:

Continuation sheet. Date: 8 Aug 06 Location: South Muliwai

Composite Sample ID: M2 F3 - 80 ___
site matrix seq. S/D

Species: Medaka

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1600						59 fish, 53-71mm measured in range 53-71
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Composite Sample ID: M2 F1 - 81 ___
site matrix seq. S/D

Species: mullet

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1		172	171	155	159	170	
2		155	152	150	175	175	
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Composite Sample ID: M2 F1 - 82 ___
site matrix seq. S/D

Species: Mullet

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1700	195	190	205	190	~~190~~	
2		103					
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Continuation sheet. Date: 8 Aug 010 Location: South Muliwai - Makua Beach

Composite Sample ID: M2 0 F1-02 ___
site matrix seq. S/D

Species: Mullet

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1300	160	142	145	135	155	
2		144	153	165	125	140	
3		144	151	153	157	139	
4		140	142	153			
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Composite Sample ID: ___ ___ ___ ___ ___
site matrix seq. S/D

Species: ___

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1							
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Composite Sample ID: ___ ___ ___ ___ ___
site matrix seq. S/D

Species: ___

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1							
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Field Record for Study of Chemical Residues in Fish Tissue

Sampling Date: 9 August 06
Collection Method: Hand U
Colector Name: Dawn A. Lieces
Affiliation: Tetra Tech, Inc Phone: (808) 533-3166
Address: 820 Mililani St, Honolulu, Hawaii 96813

Site Location: Near shoreburters of South Multiway County: Honolulu
Sidt Name: Makua Beach
Description:

Composite Sample ID: NW1 (site) SW1-1 (matrix seq.) ___ (S/D)

Species: Limu kala

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1400						
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Composite Sample ID: NW1 (site) SW1-1 (matrix seq.) ___ (S/D)

Species: Limu 2

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1400						
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: Total Weight (g):

Notes/Diagrams:

Field Record for Study of Chemical Residues in Fish Tissue

Sampling Date 8-19-06
Collection Method Hook and line
Colector Name Landin
Affiliation: Tetra Tech, Inc. Phone: (808) 533-3366
Address: 820 Mililani St, Ste 700, Honolulu, HI 96813

Site Location Sandy Beach County: Honolulu, Hawaii

Sidt Name:
Description: Rocks east of Sandy Beach.

Composite Sample ID: NW 2 FI7-1 S
site matrix seq. S/D

Species: Blackspot sergeant

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1100	145	136				weights: 190, 150 (g)
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: 2 Total Weight (g): 340

Composite Sample ID: NW 2 FI7-2 D
site matrix seq. S/D

Species: Blackspot sergeant

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1130	153	146				weights: 160, 150 (g)
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: 2 Total Weight (g): 310

Notes/Diagrams:

Continuation sheet. Date: 8-19-06 Location: Sandy Beach (Cranks)

Composite Sample ID: NW 2 F9-1 S
site matrix seq. S/D

Species: Saddle wrasse

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1200	146	144	153	119	130	Weights (g): 50, 45, 75, 30, 30, 30
2	1700	130					
3							
4							
5							
6							
7							
8							

Number of fish in composite: 6 Total Weight (g): 260

Composite Sample ID: NW 2 F6-1 S
site matrix seq. S/D

Species: Christmas wrasse

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1230	192	151	158	165		Weights (g): 115, 55, 65, 75
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: 4 Total Weight (g): 310

Composite Sample ID: NW 2 F18-1 S
site matrix seq. S/D

Species: Gray chub

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1400	178					Weight (g): 130
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: 1 Total Weight (g): 130

Continuation sheet. Date: 8-19-06 Location: Sandy Beach (rocks)

Composite Sample ID: NW2 F14-1 S
site matrix seq. S/D

Species: Picasso triggerfish

Specimen/Lot Number	time	Lengths (mm TL)					Notes weight (g): 320
1	1700	276					
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: 1 Total Weight (g): 320

Composite Sample ID: ___ ___ ___ ___ ___
site matrix seq. S/D

Species: _____

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1							
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: _____ Total Weight (g): _____

Composite Sample ID: ___ ___ ___ ___ ___
site matrix seq. S/D

Species: _____

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1							
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: _____ Total Weight (g): _____

Field Record for | Study of Chemical Residues in | Fish Tissue

Sampling Date: 8-20-06
Collection Method: Hook & Line
Colector Name: Landin
Affiliation: Tetra Tech, Inc Phone: 808-533-3366
Address:

Site Location: Sandy Beach County: Honolulu
Sidt Name: Bamboo Ridge
Description: West of Sandy Beach

Composite Sample ID: NW2 F5 F3-1 S
site matrix seq. S/D
Species: Manybar goatfish

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1200	252	160				Weights (g) 280, 125
2	weight	280	125				grams
3							
4							
5							
6							
7							
8							

Number of fish in composite: 2 Total Weight (g): 405

Composite Sample ID: NW2 F13-1 S
site matrix seq. S/D
Species: Bridled Triggerfish

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1		176					Weight (g) 150
2	weight	150					
3							
4							
5							
6							
7							
8							

Number of fish in composite: 1 Total Weight (g): 150

Notes/Diagrams:

Field Record for Study of Chemical Residues in Fish Tissue

Sampling Date 09/07/06
Collection Method Hook and line
Colector Name L. Johnson, G. Flood
Affiliation: Tetra Tech, Inc. Phone: (808) 533-3316
Address: 820 Mililani St, Suite 700, Honolulu, HI 96813

Site Location Makua (NW) County: Honolulu

Sidt Name: Makua reef
Description:

Composite Sample ID: NW 1 FG-2 S
site matrix seq. S/D

Species: Saddle wrasse

Specimen/Lot Number	time	Lengths (mm TL)					Notes Weight (g):
1	1300	156	126	105	114	96	60, 20, 15, 15, 10
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: 5 Total Weight (g): 120

Composite Sample ID: ___ ___ ___ ___ ___
site matrix seq. S/D

Species: ___

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1							
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: ___ Total Weight (g): ___

Notes/Diagrams:

Field Record for | Study of Chemical Residues in | Fish Tissue

Sampling Date: 09-07-06
Collection Method: Gill net, minnow trap, throw net
Colector Name: L. Johnson + G. Pleyl
Affiliation: Tetra Tech, Inc. Phone: (808) 533-3366
Address: 820 Mililani St, Suite 700, Honolulu, HI 96813

Site Location NANAKULI MULIWAI (M3) County: Honolulu

Sidt Name:
Description:

Composite Sample ID: M3 F3-1 S
site matrix seq. S/D

Species: MEDAKA

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1500	57	65	60	70	61	Continued below
2	1500	51	54	57	52	75	
3	↓	45	45	59	60	62	
4		62	43	67	48	65	
5		57	47	43	47	56	
6		56	65	57	66	55	
7		58	42	46	60	55	
8	↓	46	62	55	57	56	

Number of fish in composite: See next Total Weight (g): See next

Composite Sample ID: — — — —
site matrix seq. S/D

Continued from above.

Species: — (See above)

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1500	59	46	47	55	58	
2	↓	52	65	48	44	55	
3	↓	44	40	40			
4							
5							
6							
7							
8							

Number of fish in composite: 53 Total Weight (g): 150

Notes/Diagrams:

Continuation sheet. Date: Location: NANAKULI MOKUWAI

Composite Sample ID: M3 - F1 - 2 S
site matrix seq. S/D

Species: Hawaiian flagtail ("Ahole holy")

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1	1500	123	78				
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: 2 Total Weight (g): 40g

Composite Sample ID: M3 F1-1 S
site matrix seq. S/D

Species: Striped mullet

Specimen/Lot Number	time	Lengths (mm TL)					Notes weight
1	0730	250					170(g)
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: 1 Total Weight (g): 170

Composite Sample ID: ___ ___ ___ ___ ___
site matrix seq. S/D

Species: _____

Specimen/Lot Number	time	Lengths (mm TL)					Notes
1							
2							
3							
4							
5							
6							
7							
8							

Number of fish in composite: _____ Total Weight (g): _____

APPENDIX B
LAB DATA

APPENDIX C
ANALYTICAL DATA QA/QC SUMMARY

APPENDIX C
ANALYTICAL DATA QA/QC SUMMARY

Tetra Tech implemented a quality assurance/quality control (QA/QC) program to ensure that the data quality objectives of the marine resources study were met. This QA/QC program required that all analytical results be evaluated in accordance with precision, accuracy, representativeness, comparability, and completeness (PARCC) to ensure the attainment of project-specific data quality objectives. These PARCC parameters were evaluated according to the procedures described in the sampling and analysis plan for this project, entitled, *Marine Resources Sampling and Analysis Plan: Mākua Military Reservation* (Tetra Tech, 2006).

C.1 QA/QC SUMMARY

Selected field samples were analyzed by four laboratories (Columbia Analytical Services, Kelso, WA; Battelle Marine Sciences Laboratory, Sequim, WA; Severn Trent Laboratory (STL), Sacramento, CA; and APPL Laboratory, Fresno, CA) (Table 2-3).

All four laboratories generated data that were valid and usable for the stated purpose of this project. Many of the QC exceptions that were noted are the result of either matrix interferences or caused by the heterogeneous nature of the tissue being analyzed. These minor exceptions did not result in disqualifying any data.

Major QC exceptions were primarily isolated to the organochlorine pesticide analyses and were caused by confirmation column errors that precluded the accurate quantification of specific analytes. In these cases, the data were determined to be not valid and were excluded from use in any project analyses.

The specific results of this QA/QC assessment are discussed in the following sections.

C.2 PRECISION

Precision is the degree of mutual agreement between individual measurements of the same property under similar conditions. Precision is expressed quantitatively as the measure of variability of a group of measurements compared to their average value.

Field precision was evaluated by collecting and analyzing field replicates, comparing the results, and then calculating the relative percent difference (RPD). The RPD could not be calculated on samples where the parameter was "non-detected." Laboratory precision was evaluated by each laboratory as required by the analytical method being used.

C.2.1 Field Precision

Field precision was approximated by collecting and analyzing replicate samples of fish and limu. Discrete samples of fish and limu (of identical species and similar size/age class) were collected and sent to separate laboratories for analysis; thus providing an estimate of the relative variability of contaminants within species of the same size/age cohort. Precision was evaluated for both fish tissue and limu samples.

Dioxins/Furans and Gasoline (Purgeable Organics) - RPDs could not be calculated in either fish or limu samples for these classes of contaminants since at least one of the replicates contained "non-detected" concentrations of the analyte.

VOCs/SVOCs - RPDs ranging from 174 – 196% were calculated for Di-n-butyl phthalate levels in fish tissue replicate samples 6 & 2fd; 10 & Comp 9afd/10a; NW4 & NW1fd; and NW8 & NW2fd. Limu replicate samples NW1SW1-1 & NW1SW1-1fd had a calculated RPD value of 184% for Di-n-butyl phthalate.

Metals - RPDs ranging from 0.7 – 129% were calculated for all metals in every fish tissue sample, except for antimony. RPDs ranged from 1.6 – 121% for all metals in limu tissue, except for mercury, methyl mercury, and selenium.

Explosives - Fish tissue replicate samples 6 & 2fd had a calculated RPD of 49% for perchlorate. RPDs could not be calculated for the other explosives parameters since at least one of the replicates contained "non-detected" concentrations of the analyte.

RPDs could not be calculated for limu tissue samples since at least one of the replicates contained "non-detected" concentrations of the analyte.

Organochlorine Pesticides - Fish tissue replicate samples NW4 & NW1fd had a calculated RPD of 98% for heptachlor epoxide. RPDs could not be calculated for the other explosives parameters since at least one of the replicates contained "non-detected" concentrations of the analyte.

RPDs could not be calculated for limu tissue samples since at least one of the replicates contained "non-detected" concentrations of the analyte.

C.2.2 Laboratory Precision

Laboratory precision was assessed by the analysis of laboratory duplicates (a split of the sample carried through the entire sample preparation and analysis process) and duplicate matrix spikes. Precision was expressed as the RPD of replicate results. Precision was evaluated for both fish tissue and limu samples.

Dioxins/Furans - All RPDs from the duplicate analyses were within control limits.

Gasoline (Purgeable Organics)/VOCs/SVOCs - All RPDs from the duplicate analyses were within control limits.

Metals - All RPDs from the duplicate analyses were within control limits, with the following exceptions:

Battelle reported that RPD values were within the QC criterion of ≤25% for all detected metals except one fish tissue replicate (NW1fd) for aluminum (RPD = 61%). However, acceptable precision was demonstrated on the alternate measure of precision for Al.

Columbia Analytical Services reported that the RPD for the replicate analysis of aluminum and iron in sample NW1SW1-1 was outside the normal control limits.

Since the RPDs for the laboratory control sample (LCS) and laboratory control sample duplicate (LCSD) were within the QC criterion of ≤25%, the variability of the results was attributed to the heterogeneous nature of the samples.

Explosives - All RPDs from the duplicate analyses were within control limits, with the following exceptions:

APPL reported that RPD values were within the QC criterion of ≤25% for all detected explosives except one limu sample replicate (NW1SW3-1) for nitroglycerine (RPD = 33%).

STL reported no exceptions to the QC precision criteria.

Since the RPDs for the laboratory control sample (LCS) and laboratory control sample duplicate (LCSD) were within the QC criterion of ≤25%, the variability of the results was attributed to the heterogeneous nature of the samples.

Organochlorine Pesticides - All RPDs from the duplicate analyses were within control limits, with the following exceptions:

APPL reported that laboratory control sample RPD values were within the QC criterion of ≤30%, however, the RPDs for fish tissue sample NW1fd were outside control limits for the for all detected analytes (RPD range = 30.2 – 41.7%).

Columbia Analytical Services reported no exceptions to the QC precision criteria.

Since the RPDs for the laboratory control sample (LCS) and laboratory control sample duplicate (LCSD) were within the QC criterion of ≤30%, the variability of the results was attributed to the heterogeneous nature of the samples and matrix interference.

C.2.3 Precision Summary

Replicate analysis for both fish tissue and limu indicates that there is a significant level of intraspecies variability. The noted QA/QC exceptions to precision do not disqualify the data for use in this project.

C.3 ACCURACY

Accuracy is the degree of agreement between an analytical measurement and a reference accepted as a true value. The accuracy of a measurement system can be affected by errors introduced by cross-contamination in the field sampling process, sample preservation, sample handling, matrix sample preparation, analytical techniques, and cross-contamination in the laboratory. A program of sample spiking was used to evaluate laboratory accuracy. This program included analysis of the matrix spike (MS)/matrix spike duplicate (MSD) samples, LCS/LCSD samples, and method blanks.

Accuracy is expressed as the percent recovery of an analyte that has been added (spiked) to either a laboratory or environmental sample in a known concentration before extraction and subsequent analysis.

For the purposes of this project, accuracy was assessed using laboratory QC analyses only. The results of this assessment are discussed in the following sections.

C.3.1 Dioxins/Furans

All analyses were within control limits, with the following exception:

CAS reported that the LCS percent recovery (133.8%) for OCDF exceeded the QC limits of 70-130%. This did not affect the quality of the data since all MS/MSD percent recoveries were within QC limits.

STL reported no exceptions to the QC accuracy criteria.

C.3.2 Gasoline (Purgeable Organics)/VOCs/SVOCs

Columbia Analytical Services reported the following exceptions:

VOCs

Surrogate Exceptions - The control criteria were exceeded for one or more of the following surrogates (Dibromofloromethane, Toluene-d8,and 4-Bromofluorobenzene) in samples 1; 4; 10; NW4; NW5; NW6; NW7; NW9; NW10; NW1SW2-1; Comp 8, 8a; 3; 1b; 6; 7; 9; 12; 13; 14; NW2; NW3; and NW8 due to matrix interferences.

SVOCs

Matrix Spike Recovery - The matrix spike recoveries of Di-n-butyl phthalate, Pyrene, and Bis (2-ethylhexyl) Phthalate for sample 4 were outside control criteria because of matrix interference. All recoveries in the associated LCS were within control criteria limits, indicating that the analytical batch was in control.

APPL laboratory reported the following exceptions:

VOCs

Matrix Spike Recoveries – MS/MSD analysis was performed on sample NW1fd. Most target compounds recovered outside the control limits because of matrix interference. All recoveries in the associated LCS/LCSD were within control criteria limits, indicating that the analytical batch was in control.

Metals

Columbia Analytical Services reported the following exceptions:

Methyl Mercury

Matrix Spike Recovery Exceptions – The MS/MSD recoveries of Methyl mercury for samples 4 and NW1SW1-1 were outside control criteria. Recovery in the standard reference materials (SRM) as well as all other associated QA/QC results (method blanks, ongoing precision and recovery (OPR), and quality control samples (QCS)) was acceptable, which indicates that the analyses were in control. These MS/MSD outliers suggest the presence of matrix interference(s) that could cause the results to be biased low.

Total Metals

Matrix Spike Recovery Exceptions – The MS recovery of antimony for samples 4 and NW1SW1-1 and silver for samples NW2 and NW1SW1-1 were below the lower control limit established by the laboratory. The recoveries suggest a potential low bias to these samples for antimony and silver. The laboratory reported that the samples contained a relatively high amount of insoluble material which may have contributed to the low recoveries. The recoveries for silver in the SRM were within control limits indicating that the analytical batches were in control. The laboratory noted that the SRMs analyzed do not have certified values for antimony.

The control criteria for MS recoveries of aluminum, iron, and manganese for samples 4 and of aluminum and iron for sample NW1SW1-1 are not applicable since the analyte concentrations in the samples were significantly higher than the added spike concentrations, preventing accurate evaluation of the spike recoveries. Additionally, the MS recovery of manganese for sample NW1SW1-1 was outside laboratory control criteria as a result of the heterogeneous character of the sample. The RPD for the replicate analysis supports this. Variability between replicates was sufficient to bias the percent recoveries. The associated laboratory QA/QC results indicate that the analysis was in control.

Battelle reported that all accuracy criteria were within control limits.

Explosives

All accuracy QA/QC measures were within control limits, with the following exceptions:

APPL reported that samples 4 and NW1SW3-1 were selected by Tetra Tech for MS/MSD analysis. The MS/MSD results for sample 4 indicate that the percent recovery of RDX exceeded control limits with a high bias (152% and 194%). The MS/MSD results for sample

NW1SW3-1 indicate that the percent recovery for 2,4-DNT recovered below control limits, at 77.3% and 68.4%. Additionally, the laboratory reported that nitroglycerine recovered below the control limits, at 63.9%.

STL reported that nitroglycerine was positively identified in sample 2fd on the primary column. However, accurate quantification of the analyte could not be made since a large interference peak eluted at the retention time of the analyte on the confirmation column. Additionally, the nitroglycerine result for sample 9afd/10a Comp was flagged because the analyte was below the reporting limit on the confirmation column. Since this analyte could not be accurately quantified, the nitroglycerine result for these two samples should be excluded from use and not included in any project analyses.

STL flagged the RDX result for sample NW1SW1-1fd because the RPD between the primary and confirmation column exceeded the control criteria of 40%, which precluded accurate quantification of this analyte in the sample. Since this analyte could not be accurately quantified, the RDX result for this sample should be excluded from use and not included in any project analyses.

Organochlorine Pesticides

All accuracy QA/QC measures were within control limits, with the following exceptions:

Columbia Analytical Services reported that the confirmation comparison criteria of 40% difference between the primary and confirmation columns was exceeded for a few analytes in most of the field samples. Since these analytes could not be accurately quantified in these samples, they should be excluded from use and not included in any project analyses.

Accuracy Summary – The noted QA/QC exceptions do not disqualify the data for use in this project, with the following exceptions:

- Sample 2fd (Nitroglycerine)
- Sample 9afd/10a Comp (Nitroglycerine)
- Sample NW1SW1-1fd (RDX)
- Sample 1 (beta BHC, delta BHC, Heptachlor)
- Sample 1b (beta BHC, gamma BHC, Heptachlor epoxide)
- Sample 3 (Aldrin, 4,4'-DDT, Heptachlor epoxide)
- Sample 5 (Heptachlor epoxide)
- Sample 6 (Aldrin)
- Sample 7 (Aldrin)
- Sample Comp 8, 8a (gamma BHC, Heptachlor epoxide)
- Sample 10 (delta BHC, Heptachlor epoxide)
- Sample 12 (Heptachlor epoxide)

- Sample 13 (beta BHC, delta BHC)
- Sample 14 (beta BHC)
- Sample NW1fd (Heptachlor)
- Sample NW2 (beta BHC, Heptachlor epoxide)
- Sample NW5 (gamma BHC, Heptachlor epoxide)
- Sample NW6 (gamma BHC)
- Sample NW10 (Heptachlor epoxide)
- Sample NW1SW2-1 (Aldrin, beta BHC, Heptachlor epoxide)

C.4 REPRESENTATIVENESS

Representativeness expresses the degree to which sample data accurately and precisely represent the characteristics of a population, variations in a parameter at a sampling point, or an environmental condition. For this project, representative data were obtained by selecting sampling locations and by collecting multiple specimens. The following questions were used to assess representativeness:

- Were the appropriate species used?
- Were samples handled correctly?
- Were samples collected from appropriate locations?
- Were an appropriate number of samples collected and analyzed?
- Did other factors bias the results?

C.4.1 Representativeness Summary

All assessment parameters were in compliance with the project goals as described in the project document entitled, *Marine Resources Sampling and Analysis Plan: Mākua Military Reservation* (Tetra Tech, 2006), with the following exception:

A significant number of organochlorine data were disqualified because they could not be accurately quantified. Additionally, nitroglycerine and RDX data from three samples were disqualified. This resulted in a reduced number of valid data with which to use in the project assessment.

C.5 COMPARABILITY

Comparability is a qualitative parameter that expresses the degree of confidence with which one data set can be compared to another. Comparability of data was achieved by consistently following procedures for sampling and field activities, by using the same types of sampling equipment at each location, and by using standard measurement units in reporting analytical data.

C.5.1 Comparability Summary

All assessment parameters were in compliance with the project goals as described in the project document entitled, *Marine Resources Sampling and Analysis Plan: Mākua Military Reservation* (Tetra Tech, 2006).

C.6 COMPLETENESS

Completeness is a measure of the percentage of project-specific data that are valid. Valid data are obtained when samples are collected and analyzed in accordance with QC procedures outlined in the SAP and when none of the QC criteria that affect data usability are exceeded. Data that were validated and qualified as estimated will not be counted against the completeness goal because they are considered usable. Only rejected data or data not collected will be counted against the completeness goal.

As a guideline, data completeness should be approximately 90% for each analyte for all samples.

C.6.1 Comparability Summary

All analytes met or exceeded the 90% completeness guideline, with the following exception:

A significant number of organochlorine data were disqualified because they could not be accurately quantified. This resulted in a reduced number of valid data with which to use in the project assessment.

APPENDIX D
HHRA

Appendix D-1.1 Sediment Samples Used for Analysis

Data Set	Site ID	Sample ID
Background	Background North	BMN-01-MX-1
		BMN-02-MX-1
		BMN-02-MX-1-D
		BMN-03-MX-1
	Background South	BMS-01-MX-2
		BMS-02-MX-2
		BMS-03-MX-1
		BMS-03-MX-1-D
Site	Makua North Muliwai	NMM-02-MX-1
		NMM-03-MX-1
		NMM-04-FL-1
		NMM-05-MX-1
		NMM-06-MX-1
		NMM-07-MX-3
		NMM-09-MX-1
		NMM-10-FL-1
		NMM-11-MX-1
		NMM-11-MX-2
		NMM-11-MX-3
		NMM-12-FL-3
		NMM-13-MX-3
		NMM-14-MX-1
		NMM-15-MX-1
		NMM-16-FL-3
		NMM-16-FL-3-D
		NMM-17-MX-2
		NMM-18-MX-3
		NMM-20-FL-1
		NMM-21-MX-3
		NMM-22-MX-1
	Makua South Muliwai	SMM-01-MX-1
		SMM-02-FL-1
		SMM-03-MX-1
		SMM-04-MX-1
		SMM-05-MX-1
		SMM-06-FL-1
		SMM-07-MX-1
		SMM-08-MX-1
		SMM-09-MX-1
		SMM-11-MX-1
		SMM-12-MX-1
		SMM-13-FL-3
		SMM-13-FL-3-D
		SMM-14-FL-1

Appendix D-1.2 Tissue Samples Used for Analysis

Area	Data Set	Site ID	Matrix	Species	Sample ID
Muliwai	Site	Makua North Muliwai	Fish	Striped mullet	1
			Fish	Tilapia	1b
			Fish	Hawaiian flagtail	3
			Fish	Tilapia	4
			Fish	Tilapia	5
		Makua South Muliwai	Fish	Striped mullet	2fd
			Fish	Striped mullet	6
			Fish	Striped mullet	7
			Fish	Medaka	Comp 8,8a
			Fish	Tilapia	9
			Fish	Tilapia	9afd and 10a Comp
			Fish	Tilapia	10
	Background	Nanakuli Muliwai	Fish	Tilapia	12
			Fish	Tilapia	13
			Fish	Tilapia	14
Nearshore	Site	Near shore - Makua	Fish	Sidespot goatfish	NW1
			Fish	Manybar goatfish	NW1fd
			Fish	Picasso triggerfish	NW2
			Fish	Blackspot sergeant	NW3
			Fish	Manybar goatfish	NW4
			Fish	Christmas wrasse	NW5
			Seaweed	Seaweed	NW1SW1-1
			Seaweed	Seaweed	NW1SW1-1fd
			Seaweed	Seaweed	NW1SW2-1
			Seaweed	Seaweed	NW1SW3-1
	Background	Near shore - Sandy Beach	Fish	Blackspot sergeant	NW2fd
			Fish	Christmas wrasse	NW6
			Fish	Saddle wrasse	NW7
			Fish	Blackspot sergeant	NW8
			Fish	Picasso triggerfish	NW9
			Fish	Manybar goatfish	NW10

Appendix D-1.3 Fish Tissue Summary Statistics

Area	Riskstats_v1.19_Parameter	MinDepth	MaxDepth	Units	N	#D	%D	MinD	MaxD	Mean_Arith
Makua North and South Muliwai	1,2,3,4,6,7,8-hpcdd	All	All	mg/kg	12	1	8.333	5.31E-13	5.31E-13	7.6243E-13
Makua North and South Muliwai	1,2,3,4,6,7,8-hpcdf	All	All	mg/kg	12	1	8.333	2.95E-13	2.95E-13	2.3006E-13
Makua North and South Muliwai	1,2,3,7,8-pecdd	All	All	mg/kg	12	3	25	4.49E-13	1.76E-12	4.3753E-13
Makua North and South Muliwai	2,3,7,8-tcdf	All	All	mg/kg	12	1	8.333	5.9E-13	5.9E-13	2.3643E-13
Makua North and South Muliwai	4,4'-ddt	All	All	mg/kg	11	7	63.64	0.0005	0.0029	0.0011225
Makua North and South Muliwai	acetone	All	All	mg/kg	10	5	50	0.23	0.38	0.34518
Makua North and South Muliwai	aluminum	All	All	mg/kg	12	12	100	48.3	4240	2098
Makua North and South Muliwai	antimony	All	All	mg/kg	12	3	25	0.04	0.0527	0.02234
Makua North and South Muliwai	arsenic	All	All	mg/kg	12	12	100	1.46	29.8	4.5892
Makua North and South Muliwai	barium	All	All	mg/kg	12	12	100	5.53	26.1	18.369
Makua North and South Muliwai	beryllium	All	All	mg/kg	12	8	66.67	0.01	0.051	0.023475
Makua North and South Muliwai	bhc,beta	All	All	mg/kg	10	2	20	0.00081	0.0041	0.0012179
Makua North and South Muliwai	bhc,delta	All	All	mg/kg	10	1	10	0.00031	0.00031	0.00077912
Makua North and South Muliwai	bhc,gamma	All	All	mg/kg	10	4	40	0.00089	0.0017	0.0010165
Makua North and South Muliwai	bis(2-ethylhexyl)phthalate	All	All	mg/kg	12	1	8.333	3.1	3.1	0.34613
Makua North and South Muliwai	cadmium	All	All	mg/kg	12	12	100	0.02	0.147	0.052183
Makua North and South Muliwai	chromium	All	All	mg/kg	12	12	100	0.9	31.5	13.167
Makua North and South Muliwai	cobalt	All	All	mg/kg	12	12	100	0.397	4.17	2.4106
Makua North and South Muliwai	copper	All	All	mg/kg	12	12	100	6.39	166	51.387
Makua North and South Muliwai	di-n-butylphthalate	All	All	mg/kg	12	12	100	0.0098	1.5	0.21548
Makua North and South Muliwai	heptachlorepoxide	All	All	mg/kg	7	3	42.86	0.00051	0.00093	0.0013391
Makua North and South Muliwai	hpcdd,total	All	All	mg/kg	12	9	75	6.99E-13	1.02E-11	2.2993E-12
Makua North and South Muliwai	hpcdf,total	All	All	mg/kg	12	3	25	2.95E-13	1.35E-12	3.5888E-13
Makua North and South Muliwai	hxcdd,total	All	All	mg/kg	12	1	8.333	1.45E-13	1.45E-13	1.383E-13
Makua North and South Muliwai	hxcdf,total	All	All	mg/kg	12	1	8.333	1.29E-13	1.29E-13	7.8042E-14
Makua North and South Muliwai	iron	All	All	mg/kg	12	12	100	122	4530	2707.5
Makua North and South Muliwai	lead	All	All	mg/kg	12	12	100	0.973	5.39	2.0952
Makua North and South Muliwai	lipids,total	All	All	percent	10	10	100	2.1	6.4	4.33
Makua North and South Muliwai	m,p-xylenes	All	All	mg/kg	12	2	16.67	0.0016	0.017	0.012746
Makua North and South Muliwai	manganese	All	All	mg/kg	12	12	100	11.9	386	180.98
Makua North and South Muliwai	mercury	All	All	mg/kg	12	12	100	0.024	0.103	0.055775
Makua North and South Muliwai	methylmercury	All	All	mg/kg	12	12	100	0.012	0.17	0.05744
Makua North and South Muliwai	ocdd	All	All	mg/kg	12	2	16.67	6.9E-12	8.7E-12	6.1119E-12
Makua North and South Muliwai	ocdf	All	All	mg/kg	12	3	25	5.49E-13	1.31E-12	8.8211E-13
Makua North and South Muliwai	pecdd,total	All	All	mg/kg	12	2	16.67	1.42E-12	1.76E-12	4.271E-13
Makua North and South Muliwai	percentlipids	All	All	percent	2	2	100	13.9	16	14.95

Makua North and South Muliwai	percentmoisture	All	All	mg/kg	14	14	100	0	72.9	0
Makua North and South Muliwai	perchlorate	All	All	mg/kg	12	7	58.33	0.0012	0.16	0.027167
Makua North and South Muliwai	selenium	All	All	mg/kg	12	12	100	1.61	3.71	2.4633
Makua North and South Muliwai	silver	All	All	mg/kg	12	12	100	0.014	1.13	0.36413
Makua North and South Muliwai	solids,total	All	All	percent	10	10	100	24.4	30.6	27.16
Makua North and South Muliwai	tcdf,total	All	All	mg/kg	12	1	8.333	5.9E-13	5.9E-13	1.1952E-13
Makua North and South Muliwai	thallium	All	All	mg/kg	12	2	16.67	0.00325	0.00586	0.0060625
Makua North and South Muliwai	vanadium	All	All	mg/kg	12	12	100	1.24	19.3	11.943
Makua North and South Muliwai	zinc	All	All	mg/kg	12	12	100	85.2	201	114.09
Nanakuli Muliwai	1,2,3,4,6,7,8-hpcdf	All	All	mg/kg	3	3	100	1.78E-13	3.71E-13	2.52E-13
Nanakuli Muliwai	4,4'-ddt	All	All	mg/kg	3	2	66.67	0.0013	0.0014	0.00123
Nanakuli Muliwai	aluminum	All	All	mg/kg	3	3	100	3810	5170	4466.7
Nanakuli Muliwai	arsenic	All	All	mg/kg	3	3	100	2.51	2.57	2.54
Nanakuli Muliwai	barium	All	All	mg/kg	3	3	100	39.1	43.6	40.8
Nanakuli Muliwai	beryllium	All	All	mg/kg	3	3	100	0.078	0.094	0.084667
Nanakuli Muliwai	cadmium	All	All	mg/kg	3	3	100	0.11	0.13	0.12
Nanakuli Muliwai	chromium	All	All	mg/kg	3	3	100	19.7	24.7	22.233
Nanakuli Muliwai	cobalt	All	All	mg/kg	3	3	100	4.59	5.25	4.9
Nanakuli Muliwai	copper	All	All	mg/kg	3	3	100	64.9	79.9	71.6
Nanakuli Muliwai	di-n-butylphthalate	All	All	mg/kg	3	3	100	0.012	0.018	0.015333
Nanakuli Muliwai	heptachlorepoxide	All	All	mg/kg	2	2	100	0.00098	0.0011	0.00104
Nanakuli Muliwai	hpcdd,total	All	All	mg/kg	3	3	100	1.73E-12	2.46E-12	2.0367E-12
Nanakuli Muliwai	hpcdf,total	All	All	mg/kg	3	3	100	1.78E-13	3.71E-13	2.52E-13
Nanakuli Muliwai	hxcdd,total	All	All	mg/kg	3	1	33.33	3.69E-13	3.69E-13	1.5128E-13
Nanakuli Muliwai	hxcdf,total	All	All	mg/kg	3	1	33.33	1.67E-13	1.67E-13	8.1123E-14
Nanakuli Muliwai	iron	All	All	mg/kg	3	3	100	5410	7010	5996.7
Nanakuli Muliwai	lead	All	All	mg/kg	3	3	100	2.01	2.15	2.06
Nanakuli Muliwai	lipids,total	All	All	percent	3	3	100	3.3	4.8	3.9667
Nanakuli Muliwai	manganese	All	All	mg/kg	3	3	100	501	611	571.67
Nanakuli Muliwai	mercury	All	All	mg/kg	3	3	100	0.042	0.047	0.044
Nanakuli Muliwai	methylmercury	All	All	mg/kg	3	3	100	0.032	0.053	0.039333
Nanakuli Muliwai	ocdf	All	All	mg/kg	3	3	100	6.44E-13	8.78E-13	7.2367E-13
Nanakuli Muliwai	perchlorate	All	All	mg/kg	3	1	33.33	0.0014	0.0014	0.00056095
Nanakuli Muliwai	selenium	All	All	mg/kg	3	3	100	2.19	2.57	2.3833
Nanakuli Muliwai	silver	All	All	mg/kg	3	3	100	0.527	0.703	0.608
Nanakuli Muliwai	solids,total	All	All	percent	3	3	100	27.3	28.7	28.067
Nanakuli Muliwai	vanadium	All	All	mg/kg	3	3	100	19.6	23.6	20.967
Nanakuli Muliwai	zinc	All	All	mg/kg	3	3	100	108	116	111.67
Makua North Muliwai	1,2,3,7,8-pecdd	All	All	mg/kg	5	2	40	4.49E-13	1.42E-12	4.0067E-13

Makua North Muliwai	4,4'-ddt	All	All	mg/kg	4	2	50	0.0005	0.00074	0.00050445
Makua North Muliwai	acetone	All	All	mg/kg	5	1	20	0.25	0.25	0.43184
Makua North Muliwai	aluminum	All	All	mg/kg	5	5	100	48.3	4240	2415.7
Makua North Muliwai	antimony	All	All	mg/kg	5	1	20	0.04	0.04	0.019314
Makua North Muliwai	arsenic	All	All	mg/kg	5	5	100	2.25	3.81	2.928
Makua North Muliwai	barium	All	All	mg/kg	5	5	100	5.53	26.1	20.786
Makua North Muliwai	beryllium	All	All	mg/kg	5	4	80	0.028	0.051	0.0303
Makua North Muliwai	bhc,delta	All	All	mg/kg	4	1	25	0.00031	0.00031	0.00028256
Makua North Muliwai	bhc,gamma	All	All	mg/kg	4	2	50	0.00089	0.0013	0.00090105
Makua North Muliwai	cadmium	All	All	mg/kg	5	5	100	0.02	0.08	0.054
Makua North Muliwai	chromium	All	All	mg/kg	5	5	100	0.9	14.7	9.24
Makua North Muliwai	cobalt	All	All	mg/kg	5	5	100	0.397	4.17	2.6134
Makua North Muliwai	copper	All	All	mg/kg	5	5	100	6.39	166	62.118
Makua North Muliwai	di-n-butylphthalate	All	All	mg/kg	5	5	100	0.0098	0.015	0.01136
Makua North Muliwai	heptachlorepoxide	All	All	mg/kg	2	1	50	0.00051	0.00051	0.00085604
Makua North Muliwai	hpcdd,total	All	All	mg/kg	5	5	100	1.4E-12	1.02E-11	3.55E-12
Makua North Muliwai	hpcdf,total	All	All	mg/kg	5	1	20	7.99E-13	7.99E-13	2.093E-13
Makua North Muliwai	iron	All	All	mg/kg	5	5	100	122	4530	2612.4
Makua North Muliwai	lead	All	All	mg/kg	5	5	100	1.25	5.39	2.636
Makua North Muliwai	lipids,total	All	All	percent	5	5	100	2.1	6.4	4.42
Makua North Muliwai	manganese	All	All	mg/kg	5	5	100	11.9	386	244.78
Makua North Muliwai	mercury	All	All	mg/kg	5	5	100	0.024	0.074	0.039
Makua North Muliwai	methylmercury	All	All	mg/kg	5	5	100	0.012	0.07	0.0334
Makua North Muliwai	pecdd,total	All	All	mg/kg	5	1	20	1.42E-12	1.42E-12	3.1766E-13
Makua North Muliwai	percentmoisture	All	All	ug/l	5	5	100	0	0	0
Makua North Muliwai	perchlorate	All	All	mg/kg	5	1	20	0.0019	0.0019	0.00049314
Makua North Muliwai	selenium	All	All	mg/kg	5	5	100	1.83	3.71	2.382
Makua North Muliwai	silver	All	All	mg/kg	5	5	100	0.014	1.13	0.3952
Makua North Muliwai	solids,total	All	All	percent	5	5	100	24.4	28.1	26.74
Makua North Muliwai	vanadium	All	All	mg/kg	5	5	100	1.24	19.3	12.808
Makua North Muliwai	zinc	All	All	mg/kg	5	5	100	98.8	129	113.96
Makua South Muliwai	1,2,3,4,6,7,8-hpcdd	All	All	mg/kg	7	1	14.29	5.31E-13	5.31E-13	7.5306E-13
Makua South Muliwai	1,2,3,4,6,7,8-hpcdf	All	All	mg/kg	7	1	14.29	2.95E-13	2.95E-13	3.5024E-13
Makua South Muliwai	1,2,3,7,8-pecdd	All	All	mg/kg	7	1	14.29	1.76E-12	1.76E-12	4.6386E-13
Makua South Muliwai	2,3,7,8-tcdf	All	All	mg/kg	7	1	14.29	5.9E-13	5.9E-13	3.7965E-13
Makua South Muliwai	4,4'-ddt	All	All	mg/kg	7	5	71.43	0.00067	0.0029	0.0014757
Makua South Muliwai	acetone	All	All	mg/kg	5	4	80	0.23	0.38	0.25853
Makua South Muliwai	aluminum	All	All	mg/kg	7	7	100	1150	2880	1871.1
Makua South Muliwai	antimony	All	All	mg/kg	7	2	28.57	0.0481	0.0527	0.024502

Makua South Muliwai	arsenic	All	All	mg/kg	7	7	100	1.46	29.8	5.7757
Makua South Muliwai	barium	All	All	mg/kg	7	7	100	12.5	21.2	16.643
Makua South Muliwai	beryllium	All	All	mg/kg	7	4	57.14	0.01	0.032	0.018511
Makua South Muliwai	bhc,beta	All	All	mg/kg	7	2	28.57	0.00081	0.0041	0.0015742
Makua South Muliwai	bhc,gamma	All	All	mg/kg	6	2	33.33	0.0016	0.0017	0.0014162
Makua South Muliwai	bis(2-ethylhexyl)phthalate	All	All	mg/kg	7	1	14.29	3.1	3.1	0.56862
Makua South Muliwai	cadmium	All	All	mg/kg	7	7	100	0.02	0.147	0.050886
Makua South Muliwai	chromium	All	All	mg/kg	7	7	100	8.4	31.5	15.971
Makua South Muliwai	cobalt	All	All	mg/kg	7	7	100	1.94	2.58	2.2657
Makua South Muliwai	copper	All	All	mg/kg	7	7	100	9.56	109	43.723
Makua South Muliwai	di-n-butylphthalate	All	All	mg/kg	7	7	100	0.011	1.5	0.36129
Makua South Muliwai	heptachlorepoxide	All	All	mg/kg	5	2	40	0.00058	0.00093	0.0015324
Makua South Muliwai	hpcdd,total	All	All	mg/kg	7	4	57.14	6.99E-13	3.02E-12	1.4059E-12
Makua South Muliwai	hpcdf,total	All	All	mg/kg	7	2	28.57	2.95E-13	1.35E-12	4.6572E-13
Makua South Muliwai	hxcdd,total	All	All	mg/kg	7	1	14.29	1.45E-13	1.45E-13	2.1133E-13
Makua South Muliwai	hxcdf,total	All	All	mg/kg	7	1	14.29	1.29E-13	1.29E-13	1.5652E-13
Makua South Muliwai	iron	All	All	mg/kg	7	7	100	1900	3460	2775.4
Makua South Muliwai	lead	All	All	mg/kg	7	7	100	0.973	2.61	1.709
Makua South Muliwai	lipids,total	All	All	percent	5	5	100	2.5	6.4	4.24
Makua South Muliwai	m,p-xylenes	All	All	mg/kg	7	2	28.57	0.0016	0.017	0.012254
Makua South Muliwai	manganese	All	All	mg/kg	7	7	100	94.9	184	135.41
Makua South Muliwai	mercury	All	All	mg/kg	7	7	100	0.034	0.103	0.067757
Makua South Muliwai	methylmercury	All	All	mg/kg	7	7	100	0.038	0.17	0.074612
Makua South Muliwai	ocdd	All	All	mg/kg	7	2	28.57	6.9E-12	8.7E-12	5.4409E-12
Makua South Muliwai	ocdf	All	All	mg/kg	7	3	42.86	5.49E-13	1.31E-12	8.2993E-13
Makua South Muliwai	pecdd,total	All	All	mg/kg	7	1	14.29	1.76E-12	1.76E-12	5.0528E-13
Makua South Muliwai	percentlipids	All	All	percent	2	2	100	13.9	16	14.95
Makua South Muliwai	percentmoisture	All	All	mg/kg	9	9	100	0	72.9	0
Makua South Muliwai	perchlorate	All	All	mg/kg	7	6	85.71	0.0012	0.16	0.04622
Makua South Muliwai	selenium	All	All	mg/kg	7	7	100	1.61	3.59	2.5214
Makua South Muliwai	silver	All	All	mg/kg	7	7	100	0.046	0.822	0.34194
Makua South Muliwai	solids,total	All	All	percent	5	5	100	25.7	30.6	27.58
Makua South Muliwai	tcdf,total	All	All	mg/kg	7	1	14.29	5.9E-13	5.9E-13	1.7924E-13
Makua South Muliwai	thallium	All	All	mg/kg	7	2	28.57	0.00325	0.00586	0.0058471
Makua South Muliwai	vanadium	All	All	mg/kg	7	7	100	7.76	18.2	11.326
Makua South Muliwai	zinc	All	All	mg/kg	7	7	100	85.2	201	114.19
Sandy Beach	1,2,3,7,8-pecdd	All	All	mg/kg	6	1	16.67	1.72E-13	1.72E-13	1.9413E-13
Sandy Beach	4,4'-ddt	All	All	mg/kg	6	2	33.33	0.0019	0.0021	0.00098958
Sandy Beach	acetone	All	All	mg/kg	5	4	80	0.23	0.6	0.33384

Sandy Beach	aldrin	All	All	mg/kg	6	1	16.67	0.0064	0.0064	0.0026694
Sandy Beach	aluminum	All	All	mg/kg	6	6	100	3.8	4720	796
Sandy Beach	antimony	All	All	mg/kg	6	1	16.67	0.0259	0.0259	0.016102
Sandy Beach	arsenic	All	All	mg/kg	6	6	100	4.52	53	18.673
Sandy Beach	barium	All	All	mg/kg	6	6	100	0.96	14.2	5.6483
Sandy Beach	beryllium	All	All	mg/kg	6	1	16.67	0.069	0.069	0.013503
Sandy Beach	bhc,gamma	All	All	mg/kg	5	1	20	0.0019	0.0019	0.003859
Sandy Beach	bis(2-ethylhexyl)phthalate	All	All	mg/kg	6	1	16.67	0.049	0.049	0.056014
Sandy Beach	cadmium	All	All	mg/kg	6	6	100	0.04	0.2	0.10867
Sandy Beach	chromium	All	All	mg/kg	6	6	100	0.7	31.7	7.2817
Sandy Beach	cobalt	All	All	mg/kg	6	6	100	0.109	4.31	0.8315
Sandy Beach	copper	All	All	mg/kg	6	6	100	1.86	16.5	4.7767
Sandy Beach	diethylphthalate	All	All	mg/kg	6	2	33.33	0.018	0.019	0.03669
Sandy Beach	di-n-butylphthalate	All	All	mg/kg	6	6	100	0.014	0.61	0.13417
Sandy Beach	heptachlor	All	All	mg/kg	6	2	33.33	0.0045	0.0057	0.0029315
Sandy Beach	heptachlorepoxide	All	All	mg/kg	5	3	60	0.0028	0.0076	0.0029628
Sandy Beach	hpcdd,total	All	All	mg/kg	6	4	66.67	3.06E-13	1.62E-12	5.7684E-13
Sandy Beach	hpcdf,total	All	All	mg/kg	6	1	16.67	2.87E-13	2.87E-13	1.6274E-13
Sandy Beach	iron	All	All	mg/kg	6	6	100	68.4	6960	1229.5
Sandy Beach	lead	All	All	mg/kg	6	6	100	0.463	2.75	1.4398
Sandy Beach	lipids,total	All	All	percent	5	5	100	1.7	9.1	4.04
Sandy Beach	m,p-xylenes	All	All	mg/kg	6	1	16.67	0.016	0.016	0.013863
Sandy Beach	manganese	All	All	mg/kg	6	6	100	1.4	147	28.39
Sandy Beach	mercury	All	All	mg/kg	6	5	83.33	0.024	0.043	0.027782
Sandy Beach	methylmercury	All	All	mg/kg	6	5	83.33	0.027	0.056	0.036351
Sandy Beach	percentlipids	All	All	percent	1	1	100	9.09	9.09	9.09
Sandy Beach	perchlorate	All	All	mg/kg	6	2	33.33	0.01	0.11	0.020094
Sandy Beach	selenium	All	All	mg/kg	6	4	66.67	0.879	1.8	0.99506
Sandy Beach	silver	All	All	mg/kg	6	1	16.67	0.031	0.031	0.010116
Sandy Beach	solids,total	All	All	percent	5	5	100	26.5	31.8	28.82
Sandy Beach	tcdf,total	All	All	mg/kg	6	1	16.67	2.47E-13	2.47E-13	1.3203E-13
Sandy Beach	thallium	All	All	mg/kg	6	1	16.67	0.0126	0.0126	0.007639
Sandy Beach	vanadium	All	All	mg/kg	6	6	100	0.312	20.3	3.8153
Sandy Beach	zinc	All	All	mg/kg	6	6	100	44.7	77	66.417
Nearshore @ Makua	4,4'-ddt	All	All	mg/kg	5	1	20	0.00018	0.00018	0.00049138
Nearshore @ Makua	acetone	All	All	mg/kg	4	3	75	0.27	0.73	0.48407
Nearshore @ Makua	aldrin	All	All	mg/kg	5	2	40	0.0024	0.0027	0.0019675
Nearshore @ Makua	aluminum	All	All	mg/kg	5	5	100	6.8	65	30.64
Nearshore @ Makua	arsenic	All	All	mg/kg	5	5	100	4.06	37.3	23.012

Nearshore @ Makua	barium	All	All	mg/kg	5	5	100	0.46	31.6	6.984
Nearshore @ Makua	bhc,alpha	All	All	mg/kg	5	1	20	0.0082	0.0082	0.0020529
Nearshore @ Makua	bhc,delta	All	All	mg/kg	5	1	20	0.0003	0.0003	0.0011065
Nearshore @ Makua	bhc,gamma	All	All	mg/kg	4	1	25	0.0063	0.0063	0.0026692
Nearshore @ Makua	bis(2-ethylhexyl)phthalate	All	All	mg/kg	5	4	80	0.055	3.5	1.4039
Nearshore @ Makua	cadmium	All	All	mg/kg	5	5	100	0.12	0.21	0.151
Nearshore @ Makua	chromium	All	All	mg/kg	5	5	100	0.8	10.4	5.672
Nearshore @ Makua	cobalt	All	All	mg/kg	5	5	100	0.107	0.413	0.2306
Nearshore @ Makua	copper	All	All	mg/kg	5	5	100	2.2	9.78	4.21
Nearshore @ Makua	di-n-butylphthalate	All	All	mg/kg	5	5	100	0.022	1.4	0.3094
Nearshore @ Makua	heptachlor	All	All	mg/kg	4	1	25	0.0056	0.0056	0.0018685
Nearshore @ Makua	heptachlorepoxide	All	All	mg/kg	3	2	66.67	0.0032	0.014	0.0061105
Nearshore @ Makua	iron	All	All	mg/kg	5	5	100	62.5	302	163
Nearshore @ Makua	lead	All	All	mg/kg	5	5	100	0.076	2.01	0.6994
Nearshore @ Makua	lipids,total	All	All	percent	4	4	100	2.3	9.6	4.725
Nearshore @ Makua	m,p-xylenes	All	All	mg/kg	5	1	20	0.02	0.02	0.014748
Nearshore @ Makua	manganese	All	All	mg/kg	5	5	100	1.44	15.7	7.682
Nearshore @ Makua	mercury	All	All	mg/kg	5	5	100	0.044	0.0978	0.06436
Nearshore @ Makua	methylmercury	All	All	mg/kg	5	5	100	0.034	0.20009	0.084019
Nearshore @ Makua	nitroglycerin	All	All	mg/kg	5	1	20	0.33	0.33	0.17065
Nearshore @ Makua	percentlipids	All	All	percent	1	1	100	21.3	21.3	21.3
Nearshore @ Makua	percentmoisture	All	All	mg/kg	6	6	100	0	66.9	0
Nearshore @ Makua	perchlorate	All	All	mg/kg	6	1	16.67	0.0088	0.0088	0.0015845
Nearshore @ Makua	rdx	All	All	mg/kg	5	1	20	0.057	0.057	0.056655
Nearshore @ Makua	selenium	All	All	mg/kg	5	4	80	1.09	1.6	1.1577
Nearshore @ Makua	silver	All	All	mg/kg	5	4	80	0.008	0.0132	0.0093714
Nearshore @ Makua	solids,total	All	All	percent	5	5	100	27.6	34.2	30.6
Nearshore @ Makua	vanadium	All	All	mg/kg	5	5	100	0.106	1.24	0.6132
Nearshore @ Makua	zinc	All	All	mg/kg	5	5	100	36.8	149	74.54

Appendix D-1.4 Seaweed Tissue Summary Statistics

Area	Riskstats_v1.19_Parameter	MinDepth	MaxDepth	Units	N	#D	%D	MinD	MaxD	Mean_Arith
Nearshore @ Makua	1,2,3,4,6,7,8-hpcdf	All	All	mg/kg	4	1	25	1.13E-12	1.13E-12	6.8891E-13
Nearshore @ Makua	1,2,3,4,7,8-hxcdf	All	All	mg/kg	4	2	50	8.9E-14	1.14E-13	1.0484E-13
Nearshore @ Makua	1,2,3,6,7,8-hxcdd	All	All	mg/kg	4	1	25	2.42E-13	2.42E-13	1.5455E-13
Nearshore @ Makua	1,2,3,6,7,8-hxcdf	All	All	mg/kg	4	1	25	5.7E-14	5.7E-14	7.3293E-14
Nearshore @ Makua	1,2,3,7,8,9-hxcdd	All	All	mg/kg	4	1	25	3.16E-13	3.16E-13	1.6916E-13
Nearshore @ Makua	aluminum	All	All	mg/kg	4	4	100	58	1120	421.75
Nearshore @ Makua	antimony	All	All	mg/kg	4	3	75	0.04	0.145	0.062286
Nearshore @ Makua	arsenic	All	All	mg/kg	4	4	100	4.56	109	66.24
Nearshore @ Makua	barium	All	All	mg/kg	4	4	100	1.48	13.3	8.97
Nearshore @ Makua	beryllium	All	All	mg/kg	4	2	50	0.00559	0.02	0.0076349
Nearshore @ Makua	bis(2-ethylhexyl)phthalate	All	All	mg/kg	4	1	25	0.086	0.086	0.083018
Nearshore @ Makua	cadmium	All	All	mg/kg	4	4	100	0.17	0.28	0.24375
Nearshore @ Makua	chromium	All	All	mg/kg	4	3	75	0.8	6	2.1682
Nearshore @ Makua	cobalt	All	All	mg/kg	4	4	100	0.374	1.25	0.72175
Nearshore @ Makua	copper	All	All	mg/kg	4	4	100	0.85	4.57	2.6475
Nearshore @ Makua	di-n-butylphthalate	All	All	mg/kg	4	4	100	0.02	0.48	0.136
Nearshore @ Makua	heptachlor	All	All	mg/kg	4	3	75	0.00041	0.00072	0.001248
Nearshore @ Makua	hpcdd,total	All	All	mg/kg	4	3	75	3.23E-13	1.65E-11	4.5925E-12
Nearshore @ Makua	hpcdf,total	All	All	mg/kg	4	2	50	1.76E-12	4.58E-12	1.6578E-12
Nearshore @ Makua	hxcdd,total	All	All	mg/kg	4	1	25	1.91E-12	1.91E-12	5.7331E-13
Nearshore @ Makua	hxcdf,total	All	All	mg/kg	4	2	50	8.9E-14	4.3E-13	1.8968E-13
Nearshore @ Makua	iron	All	All	mg/kg	4	4	100	67.4	1860	670.6
Nearshore @ Makua	lead	All	All	mg/kg	4	4	100	0.529	3.88	1.521
Nearshore @ Makua	lipids,total	All	All	percent	3	1	33.33	0.079	0.079	0.049904
Nearshore @ Makua	m,p-xylenes	All	All	mg/kg	4	1	25	0.016	0.016	0.02044
Nearshore @ Makua	manganese	All	All	mg/kg	4	4	100	5.51	39	15.862
Nearshore @ Makua	ocdf	All	All	mg/kg	4	1	25	2.01E-12	2.01E-12	1.6512E-12
Nearshore @ Makua	percentmoisture	All	All	mg/kg	5	5	100	0	75.4	0
Nearshore @ Makua	perchlorate	All	All	mg/kg	4	2	50	0.011	0.052	0.017217
Nearshore @ Makua	selenium	All	All	mg/kg	4	1	25	0.0743	0.0743	0.27844
Nearshore @ Makua	silver	All	All	mg/kg	4	4	100	0.029	0.141	0.072775
Nearshore @ Makua	solids,total	All	All	percent	3	3	100	11.6	18.8	16.167
Nearshore @ Makua	thallium	All	All	mg/kg	4	2	50	0.024	0.0268	0.016589
Nearshore @ Makua	vanadium	All	All	mg/kg	4	4	100	2.35	13.2	6.005
Nearshore @ Makua	zinc	All	All	mg/kg	4	4	100	8.9	12.3	10.585

Appendix D-2.1 TCDD Equivalent Calculations for Fish Tissue Samples

Location ID	Field Sample ID	Parameter	Qualifier	Value	TEF	TCDD-Equiv
M1	1	1,2,3,4,6,7,8-HpCDD	U	7.23E-13		0
M1	1	1,2,3,4,6,7,8-HpCDF	U	6.8E-14		0
M1	1	1,2,3,4,7,8,9-HpCDF	U	9.3E-14		0
M1	1	1,2,3,4,7,8-HxCDD	U	4.3E-14		0
M1	1	1,2,3,4,7,8-HxCDF	U	5.6E-14		0
M1	1	1,2,3,6,7,8-HxCDD	U	3.7E-14		0
M1	1	1,2,3,6,7,8-HxCDF	U	5.3E-14		0
M1	1	1,2,3,7,8,9-HxCDD	U	4E-14		0
M1	1	1,2,3,7,8,9-HxCDF	U	7.1E-14		0
M1	1	1,2,3,7,8-PeCDD	U	6.1E-14		0
M1	1	1,2,3,7,8-PeCDF	U	4.1E-14		0
M1	1	2,3,4,6,7,8-HxCDF	U	5.9E-14		0
M1	1	2,3,4,7,8-PeCDF	U	4E-14		0
M1	1	2,3,7,8-TCDD	U	3.5E-14		0
M1	1	2,3,7,8-TCDF	U	5.5E-14		0
M1	1	OCDD	U	5.266E-12		0
M1	1	OCDF	U	1.51E-13		0
M1	1	**TCDD Equivalent**				0
M1	1b	1,2,3,4,6,7,8-HpCDD	U	7.74E-13		0
M1	1b	1,2,3,4,6,7,8-HpCDF	U	9.4E-14		0
M1	1b	1,2,3,4,7,8,9-HpCDF	U	1.28E-13		0
M1	1b	1,2,3,4,7,8-HxCDD	U	5.8E-14		0
M1	1b	1,2,3,4,7,8-HxCDF	U	4.2E-14		0
M1	1b	1,2,3,6,7,8-HxCDD	U	5E-14		0
M1	1b	1,2,3,6,7,8-HxCDF	U	4E-14		0
M1	1b	1,2,3,7,8,9-HxCDD	U	5.5E-14		0
M1	1b	1,2,3,7,8,9-HxCDF	U	5.3E-14		0
M1	1b	1,2,3,7,8-PeCDD	U	7.3E-14		0
M1	1b	1,2,3,7,8-PeCDF	U	4.6E-14		0
M1	1b	2,3,4,6,7,8-HxCDF	U	4.4E-14		0
M1	1b	2,3,4,7,8-PeCDF	U	4.4E-14		0
M1	1b	2,3,7,8-TCDD	U	3.6E-14		0
M1	1b	2,3,7,8-TCDF	U	4.9E-14		0
M1	1b	OCDD	U	7.479E-12		0
M1	1b	OCDF	U	6.6E-13		0
M2	1b	**TCDD Equivalent**				0
M1	3	1,2,3,4,6,7,8-HpCDD	U	5.47E-13		0
M1	3	1,2,3,4,6,7,8-HpCDF	U	8.5E-14		0
M1	3	1,2,3,4,7,8,9-HpCDF	U	1.17E-13		0
M1	3	1,2,3,4,7,8-HxCDD	U	6.8E-14		0
M1	3	1,2,3,4,7,8-HxCDF	U	5.6E-14		0
M1	3	1,2,3,6,7,8-HxCDD	U	5.8E-14		0
M1	3	1,2,3,6,7,8-HxCDF	U	5.2E-14		0
M1	3	1,2,3,7,8,9-HxCDD	U	6.4E-14		0
M1	3	1,2,3,7,8,9-HxCDF	U	7E-14		0
M1	3	1,2,3,7,8-PeCDD	J	1.422E-12	1	1.422E-12
M1	3	1,2,3,7,8-PeCDF	U	4.1E-14		0
M1	3	2,3,4,6,7,8-HxCDF	U	5.8E-14		0
M1	3	2,3,4,7,8-PeCDF	U	4E-14		0
M1	3	2,3,7,8-TCDD	U	4.2E-14		0
M1	3	2,3,7,8-TCDF	U	4.7E-14		0
M1	3	OCDD	U	4.114E-12		0
M1	3	OCDF	U	1.093E-12		0
M1	3	**TCDD Equivalent**				1.4E-12

Appendix D-2.1 TCDD Equivalent Calculations for Fish Tissue Samples

Location ID	Field Sample ID	Parameter	Qualifier	Value	TEF	TCDD-Equiv
M1	4	1,2,3,4,6,7,8-HpCDD	U	2.393E-12		0
M1	4	1,2,3,4,6,7,8-HpCDF	U	8.7E-14		0
M1	4	1,2,3,4,7,8,9-HpCDF	U	1.19E-13		0
M1	4	1,2,3,4,7,8-HxCDD	U	6.7E-14		0
M1	4	1,2,3,4,7,8-HxCDF	U	5.1E-14		0
M1	4	1,2,3,6,7,8-HxCDD	U	5.8E-14		0
M1	4	1,2,3,6,7,8-HxCDF	U	4.8E-14		0
M1	4	1,2,3,7,8,9-HxCDD	U	6.3E-14		0
M1	4	1,2,3,7,8,9-HxCDF	U	6.4E-14		0
M1	4	1,2,3,7,8-PeCDD	J	4.49E-13	1	4.49E-13
M1	4	1,2,3,7,8-PeCDF	U	6.6E-14		0
M1	4	2,3,4,6,7,8-HxCDF	U	5.3E-14		0
M1	4	2,3,4,7,8-PeCDF	U	6.4E-14		0
M1	4	2,3,7,8-TCDD	U	3.3E-14		0
M1	4	2,3,7,8-TCDF	U	5.6E-14		0
M1	4	OCDD	U	2.4168E-11		0
M1	4	OCDF	U	4.161E-12		0
M1	4	**TCDD Equivalent**				4.5E-13
M1	5	1,2,3,4,6,7,8-HpCDD	U	1.05E-12		0
M1	5	1,2,3,4,6,7,8-HpCDF	U	1.03E-13		0
M1	5	1,2,3,4,7,8,9-HpCDF	U	1.42E-13		0
M1	5	1,2,3,4,7,8-HxCDD	U	6.1E-14		0
M1	5	1,2,3,4,7,8-HxCDF	U	5.9E-14		0
M1	5	1,2,3,6,7,8-HxCDD	U	5.2E-14		0
M1	5	1,2,3,6,7,8-HxCDF	U	5.5E-14		0
M1	5	1,2,3,7,8,9-HxCDD	U	5.7E-14		0
M1	5	1,2,3,7,8,9-HxCDF	U	7.4E-14		0
M1	5	1,2,3,7,8-PeCDD	U	5.6E-14		0
M1	5	1,2,3,7,8-PeCDF	U	5.5E-14		0
M1	5	2,3,4,6,7,8-HxCDF	U	6.2E-14		0
M1	5	2,3,4,7,8-PeCDF	U	5.4E-14		0
M1	5	2,3,7,8-TCDD	U	4.2E-14		0
M1	5	2,3,7,8-TCDF	U	4.7E-14		0
M1	5	OCDD	U	8.795E-12		0
M1	5	OCDF	U	6.93E-13		0
M1	5	**TCDD Equivalent**				0
M2	10	1,2,3,4,6,7,8-HpCDD	U	6.99E-13		0
M2	10	1,2,3,4,6,7,8-HpCDF	U	8.2E-14		0
M2	10	1,2,3,4,7,8,9-HpCDF	U	1.15E-13		0
M2	10	1,2,3,4,7,8-HxCDD	U	6.5E-14		0
M2	10	1,2,3,4,7,8-HxCDF	U	3.2E-14		0
M2	10	1,2,3,6,7,8-HxCDD	U	6.3E-14		0
M2	10	1,2,3,6,7,8-HxCDF	U	3.4E-14		0
M2	10	1,2,3,7,8,9-HxCDD	U	6.2E-14		0
M2	10	1,2,3,7,8,9-HxCDF	U	4.2E-14		0
M2	10	1,2,3,7,8-PeCDD	U	6E-14		0
M2	10	1,2,3,7,8-PeCDF	U	4.5E-14		0
M2	10	2,3,4,6,7,8-HxCDF	U	3.6E-14		0
M2	10	2,3,4,7,8-PeCDF	U	4.4E-14		0
M2	10	2,3,7,8-TCDD	U	2.7E-14		0
M2	10	2,3,7,8-TCDF	U	9.76E-13		0
M2	10	OCDD	U	5.944E-12		0
M2	10	OCDF	J	5.49E-13	0.0001	5.49E-17
M2	10	**TCDD Equivalent**				5.5E-17

Appendix D-2.1 TCDD Equivalent Calculations for Fish Tissue Samples

Location ID	Field Sample ID	Parameter	Qualifier	Value	TEF	TCDD-Equiv
M2	2fd	1,2,3,4,6,7,8-HpCDD	U	1.7E-12		0
M2	2fd	1,2,3,4,6,7,8-HpCDF	U	1.3E-12		0
M2	2fd	1,2,3,4,7,8,9-HpCDF	U	4.3E-13		0
M2	2fd	1,2,3,4,7,8-HxCDD	U	5.4E-13		0
M2	2fd	1,2,3,4,7,8-HxCDF	U	5.1E-13		0
M2	2fd	1,2,3,6,7,8-HxCDD	U	5.2E-13		0
M2	2fd	1,2,3,6,7,8-HxCDF	U	3.7E-13		0
M2	2fd	1,2,3,7,8,9-HxCDD	U	5.1E-13		0
M2	2fd	1,2,3,7,8,9-HxCDF	U	4.5E-13		0
M2	2fd	1,2,3,7,8-PeCDD	U	7.9E-13		0
M2	2fd	1,2,3,7,8-PeCDF	U	4.9E-13		0
M2	2fd	2,3,4,6,7,8-HxCDF	U	4.1E-13		0
M2	2fd	2,3,4,7,8-PeCDF	U	4.9E-13		0
M2	2fd	2,3,7,8-TCDD	U	3.3E-13		0
M2	2fd	2,3,7,8-TCDF	J	5.9E-13	0.1	5.9E-14
M2	2fd	OCDD	J	8.7E-12	0.0001	8.7E-16
M2	2fd	OCDF	U	1.1E-12		0
M2	2fd	**TCDD Equivalent**				6.0E-14
M2	6	1,2,3,4,6,7,8-HpCDD	U	1.83E-13		0
M2	6	1,2,3,4,6,7,8-HpCDF	U	1.19E-13		0
M2	6	1,2,3,4,7,8,9-HpCDF	U	1.61E-13		0
M2	6	1,2,3,4,7,8-HxCDD	U	1.54E-13		0
M2	6	1,2,3,4,7,8-HxCDF	U	9.8E-14		0
M2	6	1,2,3,6,7,8-HxCDD	U	1.46E-13		0
M2	6	1,2,3,6,7,8-HxCDF	U	1.01E-13		0
M2	6	1,2,3,7,8,9-HxCDD	U	1.53E-13		0
M2	6	1,2,3,7,8,9-HxCDF	U	1.25E-13		0
M2	6	1,2,3,7,8-PeCDD	U	1.7E-13		0
M2	6	1,2,3,7,8-PeCDF	U	1.17E-13		0
M2	6	2,3,4,6,7,8-HxCDF	U	1.07E-13		0
M2	6	2,3,4,7,8-PeCDF	U	1.11E-13		0
M2	6	2,3,7,8-TCDD	U	3.66E-13		0
M2	6	2,3,7,8-TCDF	U	3.45E-13		0
M2	6	OCDD	U	1.999E-12		0
M2	6	OCDF	U	3.75E-13		0
M2	6	**TCDD Equivalent**				0
M2	7	1,2,3,4,6,7,8-HpCDD	J	5.31E-13	0.01	5.31E-15
M2	7	1,2,3,4,6,7,8-HpCDF	U	1.53E-13		0
M2	7	1,2,3,4,7,8,9-HpCDF	U	2.07E-13		0
M2	7	1,2,3,4,7,8-HxCDD	U	4.81E-13		0
M2	7	1,2,3,4,7,8-HxCDF	U	2.68E-13		0
M2	7	1,2,3,6,7,8-HxCDD	U	4.58E-13		0
M2	7	1,2,3,6,7,8-HxCDF	U	2.74E-13		0
M2	7	1,2,3,7,8,9-HxCDD	U	4.78E-13		0
M2	7	1,2,3,7,8,9-HxCDF	U	3.41E-13		0
M2	7	1,2,3,7,8-PeCDD	U	2.43E-13		0
M2	7	1,2,3,7,8-PeCDF	U	9.8E-14		0
M2	7	2,3,4,6,7,8-HxCDF	U	2.9E-13		0
M2	7	2,3,4,7,8-PeCDF	U	9.4E-14		0
M2	7	2,3,7,8-TCDD	U	2.4E-13		0
M2	7	2,3,7,8-TCDF	U	2.21E-13		0
M2	7	OCDD	U	4.848E-12		0
M2	7	OCDF	J	1.311E-12	0.0001	1.311E-16
M2	7	**TCDD Equivalent**				5.4E-15

Appendix D-2.1 TCDD Equivalent Calculations for Fish Tissue Samples

Location ID	Field Sample ID	Parameter	Qualifier	Value	TEF	TCDD-Equiv
M2	9	1,2,3,4,6,7,8-HpCDD	U	9.82E-13		0
M2	9	1,2,3,4,6,7,8-HpCDF	J	2.95E-13	0.01	2.95E-15
M2	9	1,2,3,4,7,8,9-HpCDF	U	1.14E-13		0
M2	9	1,2,3,4,7,8-HxCDD	U	5.3E-14		0
M2	9	1,2,3,4,7,8-HxCDF	U	4.6E-14		0
M2	9	1,2,3,6,7,8-HxCDD	U	5.1E-14		0
M2	9	1,2,3,6,7,8-HxCDF	U	4.8E-14		0
M2	9	1,2,3,7,8,9-HxCDD	U	5E-14		0
M2	9	1,2,3,7,8,9-HxCDF	U	6E-14		0
M2	9	1,2,3,7,8-PeCDD	J	1.756E-12	1	1.756E-12
M2	9	1,2,3,7,8-PeCDF	U	3E-14		0
M2	9	2,3,4,6,7,8-HxCDF	U	5.2E-14		0
M2	9	2,3,4,7,8-PeCDF	U	2.8E-14		0
M2	9	2,3,7,8-TCDD	U	3.1E-14		0
M2	9	2,3,7,8-TCDF	U	1.086E-12		0
M2	9	OCDD	U	6.609E-12		0
M2	9	OCDF	J	1.264E-12	0.0001	1.264E-16
M2	9	**TCDD Equivalent**				1.8E-12
M2	9afd and 10a Comp	1,2,3,4,6,7,8-HpCDD	U	1.5E-12		0
M2	9afd and 10a Comp	1,2,3,4,6,7,8-HpCDF	U	6.3E-13		0
M2	9afd and 10a Comp	1,2,3,4,7,8,9-HpCDF	U	4.9E-13		0
M2	9afd and 10a Comp	1,2,3,4,7,8-HxCDD	U	6.3E-13		0
M2	9afd and 10a Comp	1,2,3,4,7,8-HxCDF	U	3.4E-13		0
M2	9afd and 10a Comp	1,2,3,6,7,8-HxCDD	U	6.1E-13		0
M2	9afd and 10a Comp	1,2,3,6,7,8-HxCDF	U	3.2E-13		0
M2	9afd and 10a Comp	1,2,3,7,8,9-HxCDD	U	5.8E-13		0
M2	9afd and 10a Comp	1,2,3,7,8,9-HxCDF	U	4E-13		0
M2	9afd and 10a Comp	1,2,3,7,8-PeCDD	U	7.9E-13		0
M2	9afd and 10a Comp	1,2,3,7,8-PeCDF	U	6.1E-13		0
M2	9afd and 10a Comp	2,3,4,6,7,8-HxCDF	U	3.6E-13		0
M2	9afd and 10a Comp	2,3,4,7,8-PeCDF	U	6E-13		0
M2	9afd and 10a Comp	2,3,7,8-TCDD	U	3.9E-13		0
M2	9afd and 10a Comp	2,3,7,8-TCDF	U	2.6E-13		0
M2	9afd and 10a Comp	OCDD	J	6.9E-12	0.0001	6.9E-16
M2	9afd and 10a Comp	OCDF	U	8.2E-13		0
M2	9afd and 10a Comp	**TCDD Equivalent**				6.9E-16
M2	Comp 8,8a	1,2,3,4,6,7,8-HpCDD	U	1.636E-12		0
M2	Comp 8,8a	1,2,3,4,6,7,8-HpCDF	U	7.66E-13		0
M2	Comp 8,8a	1,2,3,4,7,8,9-HpCDF	U	1.08E-13		0
M2	Comp 8,8a	1,2,3,4,7,8-HxCDD	U	5.2E-14		0
M2	Comp 8,8a	1,2,3,4,7,8-HxCDF	U	3.1E-14		0
M2	Comp 8,8a	1,2,3,6,7,8-HxCDD	U	5E-14		0
M2	Comp 8,8a	1,2,3,6,7,8-HxCDF	U	3.2E-14		0
M2	Comp 8,8a	1,2,3,7,8,9-HxCDD	U	5E-14		0
M2	Comp 8,8a	1,2,3,7,8,9-HxCDF	U	3.9E-14		0
M2	Comp 8,8a	1,2,3,7,8-PeCDD	U	5E-14		0
M2	Comp 8,8a	1,2,3,7,8-PeCDF	U	3.5E-14		0
M2	Comp 8,8a	2,3,4,6,7,8-HxCDF	U	3.4E-14		0
M2	Comp 8,8a	2,3,4,7,8-PeCDF	U	3.4E-14		0
M2	Comp 8,8a	2,3,7,8-TCDD	U	1.6E-14		0
M2	Comp 8,8a	2,3,7,8-TCDF	U	3.2E-14		0
M2	Comp 8,8a	OCDD	U	1.2396E-11		0
M2	Comp 8,8a	OCDF	U	1.505E-12		0
M2	Comp 8,8a	**TCDD Equivalent**				0

Appendix D-2.1 TCDD Equivalent Calculations for Fish Tissue Samples

Location ID	Field Sample ID	Parameter	Qualifier	Value	TEF	TCDD-Equiv
M3	12	1,2,3,4,6,7,8-HpCDD	U	8.62E-13		0
M3	12	1,2,3,4,6,7,8-HpCDF	J	2.07E-13	0.01	2.07E-15
M3	12	1,2,3,4,7,8,9-HpCDF	U	1.23E-13		0
M3	12	1,2,3,4,7,8-HxCDD	U	6.8E-14		0
M3	12	1,2,3,4,7,8-HxCDF	U	5.3E-14		0
M3	12	1,2,3,6,7,8-HxCDD	U	6.6E-14		0
M3	12	1,2,3,6,7,8-HxCDF	U	5.5E-14		0
M3	12	1,2,3,7,8,9-HxCDD	U	6.5E-14		0
M3	12	1,2,3,7,8,9-HxCDF	U	6.8E-14		0
M3	12	1,2,3,7,8-PeCDD	U	6.1E-14		0
M3	12	1,2,3,7,8-PeCDF	U	4.6E-14		0
M3	12	2,3,4,6,7,8-HxCDF	U	5.9E-14		0
M3	12	2,3,4,7,8-PeCDF	U	4.4E-14		0
M3	12	2,3,7,8-TCDD	U	2.4E-14		0
M3	12	2,3,7,8-TCDF	U	4.5E-14		0
M3	12	OCDD	U	6.191E-12		0
M3	12	OCDF	J	6.49E-13	0.0001	6.49E-17
M3	12	**TCDD Equivalent**				2.1E-15
M3	13	1,2,3,4,6,7,8-HpCDD	U	8.96E-13		0
M3	13	1,2,3,4,6,7,8-HpCDF	J	1.78E-13	0.01	1.78E-15
M3	13	1,2,3,4,7,8,9-HpCDF	U	1.38E-13		0
M3	13	1,2,3,4,7,8-HxCDD	U	5.6E-14		0
M3	13	1,2,3,4,7,8-HxCDF	U	5E-14		0
M3	13	1,2,3,6,7,8-HxCDD	U	5.4E-14		0
M3	13	1,2,3,6,7,8-HxCDF	U	5.3E-14		0
M3	13	1,2,3,7,8,9-HxCDD	U	5.3E-14		0
M3	13	1,2,3,7,8,9-HxCDF	U	6.5E-14		0
M3	13	1,2,3,7,8-PeCDD	U	5.3E-14		0
M3	13	1,2,3,7,8-PeCDF	U	2.6E-14		0
M3	13	2,3,4,6,7,8-HxCDF	U	5.6E-14		0
M3	13	2,3,4,7,8-PeCDF	U	2.5E-14		0
M3	13	2,3,7,8-TCDD	U	3.3E-14		0
M3	13	2,3,7,8-TCDF	U	5.8E-14		0
M3	13	OCDD	U	6.76E-12		0
M3	13	OCDF	J	6.44E-13	0.0001	6.44E-17
M3	13	**TCDD Equivalent**				1.8E-15
M3	14	1,2,3,4,6,7,8-HpCDD	U	1.193E-12		0
M3	14	1,2,3,4,6,7,8-HpCDF	J	3.71E-13	0.01	3.71E-15
M3	14	1,2,3,4,7,8,9-HpCDF	U	1.26E-13		0
M3	14	1,2,3,4,7,8-HxCDD	U	5.2E-14		0
M3	14	1,2,3,4,7,8-HxCDF	U	3.8E-14		0
M3	14	1,2,3,6,7,8-HxCDD	U	5E-14		0
M3	14	1,2,3,6,7,8-HxCDF	U	4E-14		0
M3	14	1,2,3,7,8,9-HxCDD	U	4.9E-14		0
M3	14	1,2,3,7,8,9-HxCDF	U	4.9E-14		0
M3	14	1,2,3,7,8-PeCDD	U	6.1E-14		0
M3	14	1,2,3,7,8-PeCDF	U	4E-14		0
M3	14	2,3,4,6,7,8-HxCDF	U	4.2E-14		0
M3	14	2,3,4,7,8-PeCDF	U	3.9E-14		0
M3	14	2,3,7,8-TCDD	U	3.4E-14		0
M3	14	2,3,7,8-TCDF	U	3.8E-14		0
M3	14	OCDD	U	9.246E-12		0
M3	14	OCDF	J	8.78E-13	0.0001	8.78E-17
M3	14	**TCDD Equivalent**				3.8E-15

Appendix D-2.1 TCDD Equivalent Calculations for Fish Tissue Samples

Location ID	Field Sample ID	Parameter	Qualifier	Value	TEF	TCDD-Equiv
NW1	NW1fd	1,2,3,4,6,7,8-HpCDD	U	8.2E-13		0
NW1	NW1fd	1,2,3,4,6,7,8-HpCDF	U	1.2E-12		0
NW1	NW1fd	1,2,3,4,7,8,9-HpCDF	U	4.4E-13		0
NW1	NW1fd	1,2,3,4,7,8-HxCDD	U	4.6E-13		0
NW1	NW1fd	1,2,3,4,7,8-HxCDF	U	3.6E-13		0
NW1	NW1fd	1,2,3,6,7,8-HxCDD	U	4.4E-13		0
NW1	NW1fd	1,2,3,6,7,8-HxCDF	U	3.4E-13		0
NW1	NW1fd	1,2,3,7,8,9-HxCDD	U	4.3E-13		0
NW1	NW1fd	1,2,3,7,8,9-HxCDF	U	4.1E-13		0
NW1	NW1fd	1,2,3,7,8-PeCDD	U	7.7E-13		0
NW1	NW1fd	1,2,3,7,8-PeCDF	U	5.1E-13		0
NW1	NW1fd	2,3,4,6,7,8-HxCDF	U	3.7E-13		0
NW1	NW1fd	2,3,4,7,8-PeCDF	U	5.1E-13		0
NW1	NW1fd	2,3,7,8-TCDD	U	4.1E-13		0
NW1	NW1fd	2,3,7,8-TCDF	U	4.1E-13		0
NW1	NW1fd	OCDD	U	3.3E-12		0
NW1	NW1fd	OCDF	U	8.7E-13		0
NW1	NW1fd	**TCDD Equivalent**				0
NW1	NW2	1,2,3,4,6,7,8-HpCDD	U	1.58E-13		0
NW1	NW2	1,2,3,4,6,7,8-HpCDF	U	9.2E-14		0
NW1	NW2	1,2,3,4,7,8,9-HpCDF	U	1.29E-13		0
NW1	NW2	1,2,3,4,7,8-HxCDD	U	7.9E-14		0
NW1	NW2	1,2,3,4,7,8-HxCDF	U	4.3E-14		0
NW1	NW2	1,2,3,6,7,8-HxCDD	U	7.6E-14		0
NW1	NW2	1,2,3,6,7,8-HxCDF	U	4.5E-14		0
NW1	NW2	1,2,3,7,8,9-HxCDD	U	7.5E-14		0
NW1	NW2	1,2,3,7,8,9-HxCDF	U	5.5E-14		0
NW1	NW2	1,2,3,7,8-PeCDD	U	5.7E-14		0
NW1	NW2	1,2,3,7,8-PeCDF	U	4.5E-14		0
NW1	NW2	2,3,4,6,7,8-HxCDF	U	4.8E-14		0
NW1	NW2	2,3,4,7,8-PeCDF	U	4.3E-14		0
NW1	NW2	2,3,7,8-TCDD	U	3E-14		0
NW1	NW2	2,3,7,8-TCDF	U	5.7E-14		0
NW1	NW2	OCDD	U	1.201E-12		0
NW1	NW2	OCDF	U	1.96E-13		0
NW1	NW2	**TCDD Equivalent**				0
NW1	NW3	1,2,3,4,6,7,8-HpCDD	U	4.1E-14		0
NW1	NW3	1,2,3,4,6,7,8-HpCDF	U	6.7E-14		0
NW1	NW3	1,2,3,4,7,8,9-HpCDF	U	9.4E-14		0
NW1	NW3	1,2,3,4,7,8-HxCDD	U	7.8E-14		0
NW1	NW3	1,2,3,4,7,8-HxCDF	U	3.8E-14		0
NW1	NW3	1,2,3,6,7,8-HxCDD	U	7.5E-14		0
NW1	NW3	1,2,3,6,7,8-HxCDF	U	4E-14		0
NW1	NW3	1,2,3,7,8,9-HxCDD	U	7.4E-14		0
NW1	NW3	1,2,3,7,8,9-HxCDF	U	4.9E-14		0
NW1	NW3	1,2,3,7,8-PeCDD	U	6.9E-14		0
NW1	NW3	1,2,3,7,8-PeCDF	U	3.6E-14		0
NW1	NW3	2,3,4,6,7,8-HxCDF	U	4.3E-14		0
NW1	NW3	2,3,4,7,8-PeCDF	U	3.5E-14		0
NW1	NW3	2,3,7,8-TCDD	U	2.6E-14		0
NW1	NW3	2,3,7,8-TCDF	U	4.2E-14		0
NW1	NW3	OCDD	U	1.505E-12		0
NW1	NW3	OCDF	U	1.41E-13		0
NW1	NW3	**TCDD Equivalent**				0

Appendix D-2.1 TCDD Equivalent Calculations for Fish Tissue Samples

Location ID	Field Sample ID	Parameter	Qualifier	Value	TEF	TCDD-Equiv
NW1	NW4	1,2,3,4,6,7,8-HpCDD	U	1.43E-13		0
NW1	NW4	1,2,3,4,6,7,8-HpCDF	U	6.6E-14		0
NW1	NW4	1,2,3,4,7,8,9-HpCDF	U	9.2E-14		0
NW1	NW4	1,2,3,4,7,8-HxCDD	U	6E-14		0
NW1	NW4	1,2,3,4,7,8-HxCDF	U	3.6E-14		0
NW1	NW4	1,2,3,6,7,8-HxCDD	U	5.7E-14		0
NW1	NW4	1,2,3,6,7,8-HxCDF	U	3.8E-14		0
NW1	NW4	1,2,3,7,8,9-HxCDD	U	5.7E-14		0
NW1	NW4	1,2,3,7,8,9-HxCDF	U	4.6E-14		0
NW1	NW4	1,2,3,7,8-PeCDD	U	4E-14		0
NW1	NW4	1,2,3,7,8-PeCDF	U	3.3E-14		0
NW1	NW4	2,3,4,6,7,8-HxCDF	U	4E-14		0
NW1	NW4	2,3,4,7,8-PeCDF	U	3.2E-14		0
NW1	NW4	2,3,7,8-TCDD	U	2.2E-14		0
NW1	NW4	2,3,7,8-TCDF	U	3.4E-14		0
NW1	NW4	OCDD	U	1.138E-12		0
NW1	NW4	OCDF	U	1.4E-13		0
NW1	NW4	**TCDD Equivalent**				0
NW1	NW5	1,2,3,4,6,7,8-HpCDD	U	6E-14		0
NW1	NW5	1,2,3,4,6,7,8-HpCDF	U	7.1E-14		0
NW1	NW5	1,2,3,4,7,8,9-HpCDF	U	1E-13		0
NW1	NW5	1,2,3,4,7,8-HxCDD	U	9.5E-14		0
NW1	NW5	1,2,3,4,7,8-HxCDF	U	3.2E-14		0
NW1	NW5	1,2,3,6,7,8-HxCDD	U	9.1E-14		0
NW1	NW5	1,2,3,6,7,8-HxCDF	U	3.3E-14		0
NW1	NW5	1,2,3,7,8,9-HxCDD	U	9E-14		0
NW1	NW5	1,2,3,7,8,9-HxCDF	U	4.1E-14		0
NW1	NW5	1,2,3,7,8-PeCDD	U	6.5E-14		0
NW1	NW5	1,2,3,7,8-PeCDF	U	5E-14		0
NW1	NW5	2,3,4,6,7,8-HxCDF	U	3.5E-14		0
NW1	NW5	2,3,4,7,8-PeCDF	U	4.8E-14		0
NW1	NW5	2,3,7,8-TCDD	U	3.1E-14		0
NW1	NW5	2,3,7,8-TCDF	U	5.5E-14		0
NW1	NW5	OCDD	U	1.236E-12		0
NW1	NW5	OCDF	U	1.61E-13		0
NW1	NW5	**TCDD Equivalent**				0
NW2	NW10	1,2,3,4,6,7,8-HpCDD	U	2.46E-13		0
NW2	NW10	1,2,3,4,6,7,8-HpCDF	U	2.87E-13		0
NW2	NW10	1,2,3,4,7,8,9-HpCDF	U	9.3E-14		0
NW2	NW10	1,2,3,4,7,8-HxCDD	U	7.7E-14		0
NW2	NW10	1,2,3,4,7,8-HxCDF	U	2.7E-14		0
NW2	NW10	1,2,3,6,7,8-HxCDD	U	7.4E-14		0
NW2	NW10	1,2,3,6,7,8-HxCDF	U	2.8E-14		0
NW2	NW10	1,2,3,7,8,9-HxCDD	U	7.3E-14		0
NW2	NW10	1,2,3,7,8,9-HxCDF	U	3.5E-14		0
NW2	NW10	1,2,3,7,8-PeCDD	U	6.5E-14		0
NW2	NW10	1,2,3,7,8-PeCDF	U	6.6E-14		0
NW2	NW10	2,3,4,6,7,8-HxCDF	U	3E-14		0
NW2	NW10	2,3,4,7,8-PeCDF	U	6.4E-14		0
NW2	NW10	2,3,7,8-TCDD	U	2.3E-14		0
NW2	NW10	2,3,7,8-TCDF	U	4E-14		0
NW2	NW10	OCDD	U	2.195E-12		0
NW2	NW10	OCDF	U	1.08E-13		0
NW2	NW10	**TCDD Equivalent**				0

Appendix D-2.1 TCDD Equivalent Calculations for Fish Tissue Samples

Location ID	Field Sample ID	Parameter	Qualifier	Value	TEF	TCDD-Equiv
NW2	NW2fd	1,2,3,4,6,7,8-HpCDD	U	4.8E-13		0
NW2	NW2fd	1,2,3,4,6,7,8-HpCDF	U	4.8E-13		0
NW2	NW2fd	1,2,3,4,7,8,9-HpCDF	U	4.1E-13		0
NW2	NW2fd	1,2,3,4,7,8-HxCDD	U	4.9E-13		0
NW2	NW2fd	1,2,3,4,7,8-HxCDF	U	3.2E-13		0
NW2	NW2fd	1,2,3,6,7,8-HxCDD	U	4.8E-13		0
NW2	NW2fd	1,2,3,6,7,8-HxCDF	U	3E-13		0
NW2	NW2fd	1,2,3,7,8,9-HxCDD	U	4.6E-13		0
NW2	NW2fd	1,2,3,7,8,9-HxCDF	U	3.7E-13		0
NW2	NW2fd	1,2,3,7,8-PeCDD	U	6.9E-13		0
NW2	NW2fd	1,2,3,7,8-PeCDF	U	4.8E-13		0
NW2	NW2fd	2,3,4,6,7,8-HxCDF	U	3.4E-13		0
NW2	NW2fd	2,3,4,7,8-PeCDF	U	4.7E-13		0
NW2	NW2fd	2,3,7,8-TCDD	U	3.4E-13		0
NW2	NW2fd	2,3,7,8-TCDF	U	2.2E-13		0
NW2	NW2fd	OCDD	U	1.3E-12		0
NW2	NW2fd	OCDF	U	6.8E-13		0
NW2	NW2fd	**TCDD Equivalent**				0
NW2	NW6	1,2,3,4,6,7,8-HpCDD	U	1.55E-13		0
NW2	NW6	1,2,3,4,6,7,8-HpCDF	U	1.22E-13		0
NW2	NW6	1,2,3,4,7,8,9-HpCDF	U	1.65E-13		0
NW2	NW6	1,2,3,4,7,8-HxCDD	U	1.3E-13		0
NW2	NW6	1,2,3,4,7,8-HxCDF	U	8.4E-14		0
NW2	NW6	1,2,3,6,7,8-HxCDD	U	1.24E-13		0
NW2	NW6	1,2,3,6,7,8-HxCDF	U	8.6E-14		0
NW2	NW6	1,2,3,7,8,9-HxCDD	U	1.29E-13		0
NW2	NW6	1,2,3,7,8,9-HxCDF	U	1.07E-13		0
NW2	NW6	1,2,3,7,8-PeCDD	U	3.64E-13		0
NW2	NW6	1,2,3,7,8-PeCDF	U	2.42E-13		0
NW2	NW6	2,3,4,6,7,8-HxCDF	U	9.1E-14		0
NW2	NW6	2,3,4,7,8-PeCDF	U	2.31E-13		0
NW2	NW6	2,3,7,8-TCDD	U	3.24E-13		0
NW2	NW6	2,3,7,8-TCDF	U	2.9E-13		0
NW2	NW6	OCDD	U	1.011E-12		0
NW2	NW6	OCDF	U	5.83E-13		0
NW2	NW6	**TCDD Equivalent**				0
NW2	NW7	1,2,3,4,6,7,8-HpCDD	J	7.71E-13	0.01	7.71E-15
NW2	NW7	1,2,3,4,6,7,8-HpCDF	U	2.64E-13		0
NW2	NW7	1,2,3,4,7,8,9-HpCDF	U	3.56E-13		0
NW2	NW7	1,2,3,4,7,8-HxCDD	U	1.7E-13		0
NW2	NW7	1,2,3,4,7,8-HxCDF	U	8.9E-14		0
NW2	NW7	1,2,3,6,7,8-HxCDD	U	1.62E-13		0
NW2	NW7	1,2,3,6,7,8-HxCDF	U	9.1E-14		0
NW2	NW7	1,2,3,7,8,9-HxCDD	U	1.69E-13		0
NW2	NW7	1,2,3,7,8,9-HxCDF	U	1.13E-13		0
NW2	NW7	1,2,3,7,8-PeCDD	U	2.09E-13		0
NW2	NW7	1,2,3,7,8-PeCDF	U	1.12E-13		0
NW2	NW7	2,3,4,6,7,8-HxCDF	U	9.6E-14		0
NW2	NW7	2,3,4,7,8-PeCDF	U	1.07E-13		0
NW2	NW7	2,3,7,8-TCDD	U	1.5E-13		0
NW2	NW7	2,3,7,8-TCDF	U	1.44E-13		0
NW2	NW7	OCDD	U	5.225E-12		0
NW2	NW7	OCDF	U	4.33E-13		0
NW2	NW7	**TCDD Equivalent**				7.7E-15

Appendix D-2.1 TCDD Equivalent Calculations for Fish Tissue Samples

Location ID	Field Sample ID	Parameter	Qualifier	Value	TEF	TCDD-Equiv
NW2	NW8	1,2,3,4,6,7,8-HpCDD	J	2.05E-13	0.01	2.05E-15
NW2	NW8	1,2,3,4,6,7,8-HpCDF	U	5.7E-14		0
NW2	NW8	1,2,3,4,7,8,9-HpCDF	U	7.7E-14		0
NW2	NW8	1,2,3,4,7,8-HxCDD	U	7.3E-14		0
NW2	NW8	1,2,3,4,7,8-HxCDF	U	5.2E-14		0
NW2	NW8	1,2,3,6,7,8-HxCDD	U	7E-14		0
NW2	NW8	1,2,3,6,7,8-HxCDF	U	5.3E-14		0
NW2	NW8	1,2,3,7,8,9-HxCDD	U	7.3E-14		0
NW2	NW8	1,2,3,7,8,9-HxCDF	U	6.6E-14		0
NW2	NW8	1,2,3,7,8-PeCDD	U	7.6E-14		0
NW2	NW8	1,2,3,7,8-PeCDF	U	4.9E-14		0
NW2	NW8	2,3,4,6,7,8-HxCDF	U	5.6E-14		0
NW2	NW8	2,3,4,7,8-PeCDF	U	4.7E-14		0
NW2	NW8	2,3,7,8-TCDD	U	9.6E-14		0
NW2	NW8	2,3,7,8-TCDF	U	7.7E-14		0
NW2	NW8	OCDD	U	1.18E-12		0
NW2	NW8	OCDF	U	2.23E-13		0
NW2	NW8	**TCDD Equivalent**				2.1E-15
NW2	NW9	1,2,3,4,6,7,8-HpCDD	U	5.76E-13		0
NW2	NW9	1,2,3,4,6,7,8-HpCDF	U	4.98E-13		0
NW2	NW9	1,2,3,4,7,8,9-HpCDF	U	7.4E-14		0
NW2	NW9	1,2,3,4,7,8-HxCDD	U	4.9E-14		0
NW2	NW9	1,2,3,4,7,8-HxCDF	U	3.9E-14		0
NW2	NW9	1,2,3,6,7,8-HxCDD	U	4.7E-14		0
NW2	NW9	1,2,3,6,7,8-HxCDF	U	4.1E-14		0
NW2	NW9	1,2,3,7,8,9-HxCDD	U	4.7E-14		0
NW2	NW9	1,2,3,7,8,9-HxCDF	U	5E-14		0
NW2	NW9	1,2,3,7,8-PeCDD	J	1.72E-13	1	1.72E-13
NW2	NW9	1,2,3,7,8-PeCDF	U	5.4E-14		0
NW2	NW9	2,3,4,6,7,8-HxCDF	U	4.4E-14		0
NW2	NW9	2,3,4,7,8-PeCDF	U	5.2E-14		0
NW2	NW9	2,3,7,8-TCDD	U	1.8E-14		0
NW2	NW9	2,3,7,8-TCDF	U	6.83E-13		0
NW2	NW9	OCDD	U	4.734E-12		0
NW2	NW9	OCDF	U	6.74E-13		0
NW2	NW9	**TCDD Equivalent**				1.7E-13

Appendix D-2.2 TCDD Equivalent Calculations for Seaweed Tissue Samples

Location ID	Field Sample ID	Parameter	Qualifier	Value	TEF	TCDD-Equiv
NW1	NW1SW1-1	1,2,3,4,6,7,8-HpCDD	U	1.25E-12		0
NW1	NW1SW1-1	1,2,3,4,6,7,8-HpCDF	J	1.127E-12	0.01	1.13E-14
NW1	NW1SW1-1	1,2,3,4,7,8,9-HpCDF	U	1.27E-13		0
NW1	NW1SW1-1	1,2,3,4,7,8-HxCDD	U	5.8E-14		0
NW1	NW1SW1-1	1,2,3,4,7,8-HxCDF	J	8.9E-14	0.1	8.90E-15
NW1	NW1SW1-1	1,2,3,6,7,8-HxCDD	U	5.6E-14		0
NW1	NW1SW1-1	1,2,3,6,7,8-HxCDF	J	5.7E-14	0.1	5.70E-15
NW1	NW1SW1-1	1,2,3,7,8,9-HxCDD	U	5.5E-14		0
NW1	NW1SW1-1	1,2,3,7,8,9-HxCDF	U	3.6E-14		0
NW1	NW1SW1-1	1,2,3,7,8-PeCDD	U	5.1E-14		0
NW1	NW1SW1-1	1,2,3,7,8-PeCDF	U	4E-14		0
NW1	NW1SW1-1	2,3,4,6,7,8-HxCDF	U	3.1E-14		0
NW1	NW1SW1-1	2,3,4,7,8-PeCDF	U	3.8E-14		0
NW1	NW1SW1-1	2,3,7,8-TCDD	U	2.4E-14		0
NW1	NW1SW1-1	2,3,7,8-TCDF	U	3E-14		0
NW1	NW1SW1-1	OCDD	U	1.1072E-11		0
NW1	NW1SW1-1	OCDF	J	2.01E-12	0.0001	2.01E-16
NW1	NW1SW1-1	**TCDD Equivalent**				2.61E-14
NW1	NW1SW1-1fd	1,2,3,4,6,7,8-HpCDD	U	4.2E-13		0
NW1	NW1SW1-1fd	1,2,3,4,6,7,8-HpCDF	U	3E-13		0
NW1	NW1SW1-1fd	1,2,3,4,7,8,9-HpCDF	U	3.4E-13		0
NW1	NW1SW1-1fd	1,2,3,4,7,8-HxCDD	U	4.2E-13		0
NW1	NW1SW1-1fd	1,2,3,4,7,8-HxCDF	U	2.6E-13		0
NW1	NW1SW1-1fd	1,2,3,6,7,8-HxCDD	U	4.1E-13		0
NW1	NW1SW1-1fd	1,2,3,6,7,8-HxCDF	U	2.4E-13		0
NW1	NW1SW1-1fd	1,2,3,7,8,9-HxCDD	U	3.9E-13		0
NW1	NW1SW1-1fd	1,2,3,7,8,9-HxCDF	U	2.9E-13		0
NW1	NW1SW1-1fd	1,2,3,7,8-PeCDD	U	5.5E-13		0
NW1	NW1SW1-1fd	1,2,3,7,8-PeCDF	U	4.2E-13		0
NW1	NW1SW1-1fd	2,3,4,6,7,8-HxCDF	U	2.7E-13		0
NW1	NW1SW1-1fd	2,3,4,7,8-PeCDF	U	4.2E-13		0
NW1	NW1SW1-1fd	2,3,7,8-TCDD	U	3.7E-13		0
NW1	NW1SW1-1fd	2,3,7,8-TCDF	U	2.1E-13		0
NW1	NW1SW1-1fd	OCDD	U	5.5E-13		0
NW1	NW1SW1-1fd	OCDF	U	5.9E-13		0
NW1	NW1SW1-1fd	**TCDD Equivalent**				0

Appendix D-2.2 TCDD Equivalent Calculations for Seaweed Tissue Samples

Location ID	Field Sample ID	Parameter	Qualifier	Value	TEF	TCDD-Equiv
NW1	NW1SW2-1	1,2,3,4,6,7,8-HpCDD	U	8.041E-12		0
NW1	NW1SW2-1	1,2,3,4,6,7,8-HpCDF	U	1.673E-12		0
NW1	NW1SW2-1	1,2,3,4,7,8,9-HpCDF	U	1.08E-13		0
NW1	NW1SW2-1	1,2,3,4,7,8-HxCDD	U	4.4E-14		0
NW1	NW1SW2-1	1,2,3,4,7,8-HxCDF	J	1.14E-13	0.1	1.14E-14
NW1	NW1SW2-1	1,2,3,6,7,8-HxCDD	J	2.42E-13	0.1	2.42E-14
NW1	NW1SW2-1	1,2,3,6,7,8-HxCDF	U	4.5E-14		0
NW1	NW1SW2-1	1,2,3,7,8,9-HxCDD	J	3.16E-13	0.1	3.16E-14
NW1	NW1SW2-1	1,2,3,7,8,9-HxCDF	U	5.5E-14		0
NW1	NW1SW2-1	1,2,3,7,8-PeCDD	U	4.2E-14		0
NW1	NW1SW2-1	1,2,3,7,8-PeCDF	U	3.5E-14		0
NW1	NW1SW2-1	2,3,4,6,7,8-HxCDF	U	4.8E-14		0
NW1	NW1SW2-1	2,3,4,7,8-PeCDF	U	3.4E-14		0
NW1	NW1SW2-1	2,3,7,8-TCDD	U	1.1E-14		0
NW1	NW1SW2-1	2,3,7,8-TCDF	U	2.4E-14		0
NW1	NW1SW2-1	OCDD	U	6.849E-11		0
NW1	NW1SW2-1	OCDF	U	5.791E-12		0
NW1	NW1SW2-1	**TCDD Equivalent**				6.7E-14
NW1	NW1SW3-1	1,2,3,4,6,7,8-HpCDD	U	3.23E-13		0
NW1	NW1SW3-1	1,2,3,4,6,7,8-HpCDF	U	3.29E-13		0
NW1	NW1SW3-1	1,2,3,4,7,8,9-HpCDF	U	1.01E-13		0
NW1	NW1SW3-1	1,2,3,4,7,8-HxCDD	U	6.9E-14		0
NW1	NW1SW3-1	1,2,3,4,7,8-HxCDF	U	4.6E-14		0
NW1	NW1SW3-1	1,2,3,6,7,8-HxCDD	U	6.6E-14		0
NW1	NW1SW3-1	1,2,3,6,7,8-HxCDF	U	4.9E-14		0
NW1	NW1SW3-1	1,2,3,7,8,9-HxCDD	U	6.5E-14		0
NW1	NW1SW3-1	1,2,3,7,8,9-HxCDF	U	6E-14		0
NW1	NW1SW3-1	1,2,3,7,8-PeCDD	U	6.9E-14		0
NW1	NW1SW3-1	1,2,3,7,8-PeCDF	U	4.9E-14		0
NW1	NW1SW3-1	2,3,4,6,7,8-HxCDF	U	5.2E-14		0
NW1	NW1SW3-1	2,3,4,7,8-PeCDF	U	4.7E-14		0
NW1	NW1SW3-1	2,3,7,8-TCDD	U	2.8E-14		0
NW1	NW1SW3-1	2,3,7,8-TCDF	U	4.4E-14		0
NW1	NW1SW3-1	OCDD	U	2.323E-12		0
NW1	NW1SW3-1	OCDF	U	1.18E-13		0
NW1	NW1SW3-1	**TCDD Equivalent**				0.0E+00

LEADSPREAD v7.0

CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL (DTSC)

Fish Consumption
North and South Muliwai - Maximum Detected Lead Concentration
Makua Military Reservation
Makua, HI

INPUT	
MEDIUM	LEVEL
Lead in Air (ug/m^3)	0.028
Lead in Soil/Dust (ug/g)	5.4
Lead in Water (ug/l)	15
% Home-grown Produce	100%
Respirable Dust (ug/m^3)	1.5

OUTPUT							
	Percentile Estimate of Blood Pb (ug/dl)					PRG-99	PRG-95
	50th	90th	95th	98th	99th	(ug/g)	(ug/g)
BLOOD Pb, ADULT	**1.1**	**2.0**	**2.3**	**2.8**	**3.2**	**70**	**107**
BLOOD Pb, CHILD	**1.5**	**2.7**	**3.2**	**3.8**	**4.4**	**27**	**42**
BLOOD Pb, PICA CHILD	1.5	2.7	3.2	3.9	4.5	25	39
BLOOD Pb, OCCUPATIONAL	1.1	2.0	2.4	2.9	3.3	3,475	5,464

EXPOSURE PARAMETERS			
	units	adults	children
Days per week	days/wk	7	
Days per week, occupational		5	
Geometric Standard Deviation		1.6	
Blood lead level of concern (ug/dl)		10	
Skin area, residential	cm^2	5,700	2,900
Skin area occupational	cm^2	2,900	
Soil adherence	ug/cm^2	70	200
Dermal uptake constant	(ug/dl)/(ug/d	0.0001	
Soil ingestion	mg/day	50	100
Soil ingestion, pica	mg/day		200
Ingestion constant	(ug/dl)/(ug/d	0.04	0.16
Bioavailability	unitless	0.44	
Breathing rate	m^3/day	20	6.8
Inhalation constant	(ug/dl)/(ug/d	0.08	0.192
Water ingestion	l/day	1.4	0.4
Food ingestion	kg/day	1.9	1.1
Lead in market basket	ug/kg	3.1	
Lead in home-grown produce	ug/kg	5400.0	

PATHWAYS						
ADULTS	Residential			Occupational		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	3.8E-5	0.00	0%	1.4E-5	0.00	0%
Soil Ingestion	8.8E-4	0.00	0%	6.3E-4	0.00	0%
Inhalation, bkgrnd		0.05	4%		0.03	3%
Inhalation	2.5E-6	0.00	0%	1.8E-6	0.00	0%
Water Ingestion		0.84	78%		0.84	76%
Food Ingestion, bkgrnd		0.00	0%		0.23	21%
Food Ingestion	3.4E-2	0.18	17%			0%

CHILDREN	typical			with pica		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	5.6E-5	0.00	0%		0.00	0%
Soil Ingestion	7.0E-3	0.04	3%	1.4E-2	0.08	5%
Inhalation	2.0E-6	0.00	0%		0.00	0%
Inhalation, bkgrnd		0.04	2%		0.04	2%
Water Ingestion		0.96	66%		0.96	64%
Food Ingestion, bkgrnd		0.00	0%		0.00	0%
Food Ingestion	7.9E-2	0.43	29%		0.43	29%

LEADSPREAD v7.0

CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL (DTSC)

Fish Consumption
Background Muliwai - Maximum Detected Lead Concentration
Makua Military Reservation
Makua, HI

INPUT	
MEDIUM	LEVEL
Lead in Air (ug/m^3)	0.028
Lead in Soil/Dust (ug/g)	2.2
Lead in Water (ug/l)	15
% Home-grown Produce	100%
Respirable Dust (ug/m^3)	1.5

OUTPUT	Percentile Estimate of Blood Pb (ug/dl)					PRG-99	PRG-95
	50th	90th	95th	98th	99th	(ug/g)	(ug/g)
BLOOD Pb, ADULT	**1.0**	**1.8**	**2.1**	**2.5**	**2.9**	**70**	**107**
BLOOD Pb, CHILD	**1.2**	**2.2**	**2.6**	**3.1**	**3.5**	**27**	**42**
BLOOD Pb, PICA CHILD	1.2	2.2	2.6	3.2	3.6	25	39
BLOOD Pb, OCCUPATIONAL	1.1	2.0	2.4	2.9	3.3	3,475	5,464

EXPOSURE PARAMETERS	units	adults	children
Days per week	days/wk	7	
Days per week, occupational		5	
Geometric Standard Deviation		1.6	
Blood lead level of concern (ug/dl)		10	
Skin area, residential	cm^2	5,700	2,900
Skin area occupational	cm^2	2,900	
Soil adherence	ug/cm^2	70	200
Dermal uptake constant	(ug/dl)/(ug/d	0.0001	
Soil ingestion	mg/day	50	100
Soil ingestion, pica	mg/day		200
Ingestion constant	(ug/dl)/(ug/d	0.04	0.16
Bioavailability	unitless	0.44	
Breathing rate	m^3/day	20	6.8
Inhalation constant	(ug/dl)/(ug/d	0.08	0.192
Water ingestion	l/day	1.4	0.4
Food ingestion	kg/day	1.9	1.1
Lead in market basket	ug/kg	3.1	
Lead in home-grown produce	ug/kg	2200.0	

PATHWAYS						
ADULTS	Residential			Occupational		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	3.8E-5	0.00	0%	1.4E-5	0.00	0%
Soil Ingestion	8.8E-4	0.00	0%	6.3E-4	0.00	0%
Inhalation, bkgrnd		0.05	5%		0.03	3%
Inhalation	2.5E-6	0.00	0%	1.8E-6	0.00	0%
Water Ingestion		0.84	87%		0.84	76%
Food Ingestion, bkgrnd		0.00	0%		0.23	21%
Food Ingestion	3.4E-2	0.08	8%			0%

CHILDREN	typical			with pica		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	5.6E-5	0.00	0%		0.00	0%
Soil Ingestion	7.0E-3	0.02	1%	1.4E-2	0.03	3%
Inhalation	2.0E-6	0.00	0%		0.00	0%
Inhalation, bkgrnd		0.04	3%		0.04	3%
Water Ingestion		0.96	81%		0.96	80%
Food Ingestion, bkgrnd		0.00	0%		0.00	0%
Food Ingestion	7.9E-2	0.17	15%		0.17	14%

LEADSPREAD v7.0

CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL (DTSC)

Fish Consumption
Background Muliwai - Maximum Detected Lead Concentration
Makua Military Reservation
Makua, HI

INPUT	
MEDIUM	LEVEL
Lead in Air (ug/m^3)	0.028
Lead in Soil/Dust (ug/g)	2.0
Lead in Water (ug/l)	15
% Home-grown Produce	100%
Respirable Dust (ug/m^3)	1.5

OUTPUT	Percentile Estimate of Blood Pb (ug/dl)					PRG-99	PRG-95
	50th	90th	95th	98th	99th	(ug/g)	(ug/g)
BLOOD Pb, ADULT	**1.0**	**1.7**	**2.1**	**2.5**	**2.9**	**70**	**107**
BLOOD Pb, CHILD	**1.2**	**2.1**	**2.5**	**3.1**	**3.5**	**27**	**42**
BLOOD Pb, PICA CHILD	1.2	2.2	2.6	3.1	3.5	25	39
BLOOD Pb, OCCUPATIONAL	1.1	2.0	2.4	2.9	3.3	3,475	5,464

EXPOSURE PARAMETERS	units	adults	children
Days per week	days/wk	7	
Days per week, occupational		5	
Geometric Standard Deviation		1.6	
Blood lead level of concern (ug/dl)		10	
Skin area, residential	cm^2	5,700	2,900
Skin area occupational	cm^2	2,900	
Soil adherence	ug/cm^2	70	200
Dermal uptake constant	(ug/dl)/(ug/d	0.0001	
Soil ingestion	mg/day	50	100
Soil ingestion, pica	mg/day		200
Ingestion constant	(ug/dl)/(ug/d	0.04	0.16
Bioavailability	unitless	0.44	
Breathing rate	m^3/day	20	6.8
Inhalation constant	(ug/dl)/(ug/d	0.08	0.192
Water ingestion	l/day	1.4	0.4
Food ingestion	kg/day	1.9	1.1
Lead in market basket	ug/kg	3.1	
Lead in home-grown produce	ug/kg	2000.0	

PATHWAYS						
ADULTS	Residential			Occupational		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	3.8E-5	0.00	0%	1.4E-5	0.00	0%
Soil Ingestion	8.8E-4	0.00	0%	6.3E-4	0.00	0%
Inhalation, bkgrnd		0.05	5%		0.03	3%
Inhalation	2.5E-6	0.00	0%	1.8E-6	0.00	0%
Water Ingestion		0.84	88%		0.84	76%
Food Ingestion, bkgrnd		0.00	0%		0.23	21%
Food Ingestion	3.4E-2	0.07	7%			0%

CHILDREN	typical			with pica		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	5.6E-5	0.00	0%		0.00	0%
Soil Ingestion	7.0E-3	0.01	1%	1.4E-2	0.03	2%
Inhalation	2.0E-6	0.00	0%		0.00	0%
Inhalation, bkgrnd		0.04	3%		0.04	3%
Water Ingestion		0.96	82%		0.96	81%
Food Ingestion, bkgrnd		0.00	0%		0.00	0%
Food Ingestion	7.9E-2	0.16	14%		0.16	13%

LEADSPREAD v7.0

CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL (DTSC)

Fish Consumption
Background Muliwai - Maximum Detected Lead Concentration
Makua Military Reservation
Makua, HI

INPUT	
MEDIUM	LEVEL
Lead in Air (ug/m^3)	0.028
Lead in Soil/Dust (ug/g)	2.8
Lead in Water (ug/l)	15
% Home-grown Produce	100%
Respirable Dust (ug/m^3)	1.5

OUTPUT	Percentile Estimate of Blood Pb (ug/dl)					PRG-99	PRG-95
	50th	90th	95th	98th	99th	(ug/g)	(ug/g)
BLOOD Pb, ADULT	**1.0**	**1.8**	**2.1**	**2.6**	**2.9**	**70**	**107**
BLOOD Pb, CHILD	**1.2**	**2.3**	**2.7**	**3.3**	**3.7**	**27**	**42**
BLOOD Pb, PICA CHILD	1.3	2.3	2.7	3.3	3.8	25	39
BLOOD Pb, OCCUPATIONAL	1.1	2.0	2.4	2.9	3.3	3,475	5,464

EXPOSURE PARAMETERS	units	adults	children
Days per week	days/wk	7	
Days per week, occupational		5	
Geometric Standard Deviation		1.6	
Blood lead level of concern (ug/dl)		10	
Skin area, residential	cm^2	5,700	2,900
Skin area occupational	cm^2	2,900	
Soil adherence	ug/cm^2	70	200
Dermal uptake constant	(ug/dl)/(ug/d	0.0001	
Soil ingestion	mg/day	50	100
Soil ingestion, pica	mg/day		200
Ingestion constant	(ug/dl)/(ug/d	0.04	0.16
Bioavailability	unitless	0.44	
Breathing rate	m^3/day	20	6.8
Inhalation constant	(ug/dl)/(ug/d	0.08	0.192
Water ingestion	l/day	1.4	0.4
Food ingestion	kg/day	1.9	1.1
Lead in market basket	ug/kg	3.1	
Lead in home-grown produce	ug/kg	2800.0	

PATHWAYS						
ADULTS	Residential			Occupational		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	3.8E-5	0.00	0%	1.4E-5	0.00	0%
Soil Ingestion	8.8E-4	0.00	0%	6.3E-4	0.00	0%
Inhalation, bkgrnd		0.05	5%		0.03	3%
Inhalation	2.5E-6	0.00	0%	1.8E-6	0.00	0%
Water Ingestion		0.84	85%		0.84	76%
Food Ingestion, bkgrnd		0.00	0%		0.23	21%
Food Ingestion	3.4E-2	0.10	10%			0%

CHILDREN	typical			with pica		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	5.6E-5	0.00	0%		0.00	0%
Soil Ingestion	7.0E-3	0.02	2%	1.4E-2	0.04	3%
Inhalation	2.0E-6	0.00	0%		0.00	0%
Inhalation, bkgrnd		0.04	3%		0.04	3%
Water Ingestion		0.96	78%		0.96	76%
Food Ingestion, bkgrnd		0.00	0%		0.00	0%
Food Ingestion	7.9E-2	0.22	18%		0.22	18%

Appendix D.4-1 - North and South Site Human Health Risk Calculations for Fish Consumption

$$Intake = \frac{C_{sf} \times CR \times EF \times ED}{BW \times AT}$$

CR = 0.1006 for subsistence; 0.034
EF = 365
ED = 30
BW = 70
AT = noncarcinogens = 30 yrs * 36
carcinog = 70 yrs * 3

			Noncarcinogens				Carcinogens				
			Subsistence Intake (mg/kg-day)		**Recreational Intake (mg/kg-day)**		**Subsistence Intake (mg/kg-day)**		**Recreational Intake (mg/kg-day)**		**Non-carcinogen**
Chemical	**Arithmetic Mean**	**MaxD**	Arithmetic Mean	MaxD	Arithmetic Mean	MaxD	Arithmetic Mean	MaxD	Arithmetic Mean	MaxD	RfDo
Acetone	0.35	0.38	4.96E-04	5.46E-04	1.68E-04	1.85E-04	2.13E-04	2.34E-04	7.19E-05	7.91E-05	0.9
Aluminum	2098	4240	3.02E+00	6.09E+00	1.02E+00	2.06E+00	1.29E+00	2.61E+00	4.37E-01	8.83E-01	1
Antimony	0.02	0.05	3.21E-05	7.57E-05	1.09E-05	2.56E-05	1.38E-05	3.25E-05	4.65E-06	1.10E-05	0.0004
Arsenic, organic	4.6	30	6.60E-03	4.28E-02	2.23E-03	1.45E-02	2.83E-03	1.84E-02	9.55E-04	6.20E-03	-
Barium	18	26	2.64E-02	3.75E-02	8.92E-03	1.27E-02	1.13E-02	1.61E-02	3.82E-03	5.43E-03	0.07
Beryllium	0.02	0.05	3.37E-05	7.33E-05	1.14E-05	2.48E-05	1.45E-05	3.14E-05	4.89E-06	1.06E-05	0.002
BHC, beta	0.001	0.004	1.75E-06	5.89E-06	5.92E-07	1.99E-06	7.50E-07	2.53E-06	2.54E-07	8.53E-07	0.0002
BHC, delta	0.001	0.0003	1.12E-06	4.46E-07	3.78E-07	1.51E-07	4.80E-07	1.91E-07	1.62E-07	6.45E-08	0.0003
BHC, gamma	0.001	0.002	1.46E-06	2.44E-06	4.94E-07	8.26E-07	6.26E-07	1.05E-06	2.12E-07	3.54E-07	0.0003
Bis(2-ethylhexyl)phthalate	0.35	3.1	4.97E-04	4.46E-03	1.68E-04	1.51E-03	2.13E-04	1.91E-03	7.21E-05	6.45E-04	0.02
Cadmium	0.05	0.15	7.50E-05	2.11E-04	2.53E-05	7.14E-05	3.21E-05	9.05E-05	1.09E-05	3.06E-05	0.0005
Chromium	13	32	1.89E-02	4.53E-02	6.40E-03	1.53E-02	8.11E-03	1.94E-02	2.74E-03	6.56E-03	1.5
Cobalt	2.4	4.2	3.46E-03	5.99E-03	1.17E-03	2.03E-03	1.48E-03	2.57E-03	5.02E-04	8.68E-04	0.02
Copper	51	166	7.39E-02	2.39E-01	2.50E-02	8.06E-02	3.17E-02	1.02E-01	1.07E-02	3.46E-02	0.04
4,4'-DDT	0.001	0.003	1.61E-06	4.17E-06	5.45E-07	1.41E-06	6.91E-07	1.79E-06	2.34E-07	6.04E-07	0.0005
di-n-Butylphthalate	0.22	1.5	3.10E-04	2.16E-03	1.05E-04	7.29E-04	1.33E-04	9.24E-04	4.49E-05	3.12E-04	0.1
Heptachlor epoxide	0.001	0.001	1.92E-06	1.34E-06	6.50E-07	4.52E-07	8.25E-07	5.73E-07	2.79E-07	1.94E-07	1E-05
Iron	2708	4530	3.89E+00	6.51E+00	1.32E+00	2.20E+00	1.67E+00	2.79E+00	5.64E-01	9.43E-01	-
Lead	2.1	5.4	3.01E-03	7.75E-03	1.02E-03	2.62E-03	1.29E-03	3.32E-03	4.36E-04	1.12E-03	-
m,p-Xylenes	0.01	0.02	1.83E-05	2.44E-05	6.19E-06	8.26E-06	7.85E-06	1.05E-05	2.65E-06	3.54E-06	0.2
Manganese	181	386	2.60E-01	5.55E-01	8.79E-02	1.87E-01	1.11E-01	2.38E-01	3.77E-02	8.04E-02	0.024
Mercury	0.06	0.10	8.02E-05	1.48E-04	2.71E-05	5.00E-05	3.44E-05	6.34E-05	1.16E-05	2.14E-05	0.0003
Methyl mercury	0.06	0.17	8.25E-05	2.44E-04	2.79E-05	8.26E-05	3.54E-05	1.05E-04	1.20E-05	3.54E-05	0.0001
Perchlorate	0.03	0.16	3.90E-05	2.30E-04	1.32E-05	7.77E-05	1.67E-05	9.85E-05	5.66E-06	3.33E-05	0.0007
Selenium	2.5	3.7	3.54E-03	5.33E-03	1.20E-03	1.80E-03	1.52E-03	2.29E-03	5.13E-04	7.72E-04	0.005
Silver	0.36	1.1	5.23E-04	1.62E-03	1.77E-04	5.49E-04	2.24E-04	6.96E-04	7.58E-05	2.35E-04	0.005
Thallium	0.01	0.01	8.71E-06	8.42E-06	2.94E-06	2.85E-06	3.73E-06	3.61E-06	1.26E-06	1.22E-06	8E-05
Vanadium	12	19	1.72E-02	2.77E-02	5.80E-03	9.37E-03	7.36E-03	1.19E-02	2.49E-03	4.02E-03	0.02
Zinc	114	201	1.64E-01	2.89E-01	5.54E-02	9.76E-02	7.03E-02	1.24E-01	2.37E-02	4.18E-02	0.3
TCDD equivalents	3.1E-13	1.8E-12	4.43E-16	2.53E-15	1.50E-16	8.54E-16	1.90E-16	1.08E-15	6.41E-17	3.66E-16	-

Appendix D.4-1 - North and Sou for recreation

	65 days/y										
	365 days/y										
	nic HI (Arithmetic Mean)		**Non-carcinogenic HI (MaxD)**			**Carcinogenic Risk (Mean)**			**Carcinogenic Risk (MaxD)**		
Chemical	Subsistence	Recreational	RfDo	Subsistence	Recreational	SF	Subsistence	Recreational	SF	Subsistence	Recreational
Acetone	5.51E-04	1.86E-04	0.9	6.07E-04	2.05E-04	-	-	-	-	-	-
Aluminum	3.02E+00	1.02E+00	1	6.09E+00	2.06E+00	-	-	-	-	-	-
Antimony	8.03E-02	2.71E-02	0.0004	1.89E-01	6.40E-02	-	-	-	-	-	-
Arsenic, organic	-	-	-	-	-	-	-	-	-	-	-
Barium	3.77E-01	1.27E-01	0.07	5.36E-01	1.81E-01	-	-	-	-	-	-
Beryllium	1.69E-02	5.70E-03	0.002	3.66E-02	1.24E-02	-	-	-	-	-	-
BHC, beta	8.75E-03	2.96E-03	0.0002	2.95E-02	9.96E-03	1.8	1.35E-06	4.56E-07	1.8	4.55E-06	1.54E-06
BHC, delta	3.73E-03	1.26E-03	0.0003	1.49E-03	5.02E-04	-	-	-	-	-	-
BHC, gamma	4.87E-03	1.65E-03	0.0003	8.14E-03	2.75E-03	1.3	8.14E-07	2.75E-07	1.3	1.36E-06	4.60E-07
Bis(2-ethylhexyl)phthalate	2.49E-02	8.41E-03	0.02	2.23E-01	7.53E-02	0.014	2.98E-06	1.01E-06	0.014	2.67E-05	9.03E-06
Cadmium	1.50E-01	5.07E-02	0.0005	4.23E-01	1.43E-01	-	-	-	-	-	-
Chromium	1.26E-02	4.26E-03	1.5	3.02E-02	1.02E-02	-	-	-	-	-	-
Cobalt	1.73E-01	5.85E-02	0.02	3.00E-01	1.01E-01	-	-	-	-	-	-
Copper	1.85E+00	6.24E-01	0.04	5.96E+00	2.02E+00	-	-	-	-	-	-
4,4'-DDT	3.23E-03	1.09E-03	0.0005	8.34E-03	2.82E-03	0.34	2.35E-07	7.94E-08	0.34	6.07E-07	2.05E-07
di-n-Butylphthalate	3.10E-03	1.05E-03	0.1	2.16E-02	7.29E-03	-	-	-	-	-	-
Heptachlor epoxide	1.48E-01	5.00E-02	0.000013	1.03E-01	3.47E-02	9.1	7.51E-06	2.54E-06	9.1	5.21E-06	1.76E-06
Iron	-	-	-	-	-	–	-	-	–	-	-
Lead	-	-	-	-	-	-	-	-	-	-	-
m,p-Xylenes	9.16E-05	3.10E-05	0.2	1.22E-04	4.13E-05	-	-	-	-	-	-
Manganese	1.08E+01	3.66E+00	0.024	2.31E+01	7.81E+00	-	-	-	-	-	-
Mercury	2.67E-01	9.03E-02	0.0003	4.93E-01	1.67E-01	-	-	-	-	-	-
Methyl mercury	8.25E-01	2.79E-01	0.0001	2.44E+00	8.26E-01	-	-	-	-	-	-
Perchlorate	5.58E-02	1.89E-02	0.0007	3.28E-01	1.11E-01	-	-	-	-	-	-
Selenium	7.08E-01	2.39E-01	0.005	1.07E+00	3.60E-01	-	-	-	-	-	-
Silver	1.05E-01	3.54E-02	0.005	3.25E-01	1.10E-01	-	-	-	-	-	-
Thallium	1.09E-01	3.68E-02	0.00008	1.05E-01	3.56E-02	-	-	-	-	-	-
Vanadium	8.58E-01	2.90E-01	0.02	1.39E+00	4.69E-01	-	-	-	-	-	-
Zinc	5.47E-01	1.85E-01	0.3	9.63E-01	3.25E-01	-	-	-	-	-	-
TCDD equivalents	-	-	-	-	-	150000	2.85E-11	9.62E-12	150000	1.63E-10	5.49E-11

Appendix D.4-2 - Background (Nanakuli Muliwai) Human Health Risk Calculations for Fish Consumption

$$Intake = \frac{C_{sf} \times C}{B}$$

			Noncarcinogens				Carcinogens
			Subsistence Intake (mg/kg-day)		**Recreational Intake (mg/kg-day)**		**Subsistence Inta**
Chemical	**Arithmetic Mean**	**MaxD**	Arithmetic Mean	MaxD	Arithmetic Mean	MaxD	Arithmetic Mean
Aluminum	4467	5170	6.42E+00	7.43E+00	2.17E+00	2.51E+00	2.75E+00
Arsenic, organic	2.5	2.6	3.65E-03	3.69E-03	1.23E-03	1.25E-03	1.56E-03
Barium	41	44	5.86E-02	6.27E-02	1.98E-02	2.12E-02	2.51E-02
Beryllium	0.08	0.09	1.22E-04	1.35E-04	4.11E-05	4.57E-05	5.21E-05
Cadmium	0.12	0.13	1.72E-04	1.87E-04	5.83E-05	6.31E-05	7.39E-05
Chromium	22	25	3.20E-02	3.55E-02	1.08E-02	1.20E-02	1.37E-02
Cobalt	4.9	5.3	7.04E-03	7.55E-03	2.38E-03	2.55E-03	3.02E-03
Copper	72	80	1.03E-01	1.15E-01	3.48E-02	3.88E-02	4.41E-02
4,4'-DDT	0.001	0.001	1.77E-06	2.01E-06	5.97E-07	6.80E-07	7.58E-07
di-n-Butylphthalate	0.02	0.02	2.20E-05	2.59E-05	7.45E-06	8.74E-06	9.44E-06
Heptachlor epoxide	0.001	0.001	1.49E-06	1.58E-06	5.05E-07	5.34E-07	6.41E-07
Iron	5997	7010	8.62E+00	1.01E+01	2.91E+00	3.40E+00	3.69E+00
Lead	2.1	2.2	2.96E-03	3.09E-03	1.00E-03	1.04E-03	1.27E-03
Manganese	572	611	8.22E-01	8.78E-01	2.78E-01	2.97E-01	3.52E-01
Mercury	0.04	0.05	6.32E-05	6.75E-05	2.14E-05	2.28E-05	2.71E-05
Methyl mercury	0.04	0.05	5.65E-05	7.62E-05	1.91E-05	2.57E-05	2.42E-05
Perchlorate	0.0006	0.001	8.06E-07	2.01E-06	2.72E-07	6.80E-07	3.45E-07
Selenium	2.4	2.6	3.43E-03	3.69E-03	1.16E-03	1.25E-03	1.47E-03
Silver	0.61	0.70	8.74E-04	1.01E-03	2.95E-04	3.41E-04	3.74E-04
Vanadium	21	24	3.01E-02	3.39E-02	1.02E-02	1.15E-02	1.29E-02
Zinc	112	116	1.60E-01	1.67E-01	5.42E-02	5.63E-02	6.88E-02
TCDD equivalents	2.6E-15	3.8E-15	3.73E-18	5.46E-18	1.26E-18	1.84E-18	1.60E-18

Appendix D.4-2 - Backgro

$$= \frac{C_{sf} \times CR \times EF \times ED}{BW \times AT}$$

CR = 0.1006 for subsistence; 0.034 for recreational
EF = 365
ED = 30
BW = 70
AT = noncarcinogens = 30 yrs * 365 days/yr;
carcinog = 70 yrs * 365 days/yr

	ake (mg/kg-day)		Recreational Intake (mg/kg-day)		Non-carcinogenic HI (Arithmetic Mean)			Non-carcinogenic HI (MaxD)	
Chemical	MaxD	Arithmetic Mea	MaxD	RfDo	Subsistence	Recreational	RfDo	Subsistence	Recreational
Aluminum	3.18E+00	9.30E-01	1.08E+00	1.0	6.42E+00	2.17E+00	1.0	7.43E+00	2.51E+00
Arsenic, organic	1.58E-03	5.29E-04	5.35E-04	-	-	-	-	-	-
Barium	2.69E-02	8.49E-03	9.08E-03	0.07	8.38E-01	2.83E-01	0.07	8.95E-01	3.03E-01
Beryllium	5.79E-05	1.76E-05	1.96E-05	0.002	6.08E-02	2.06E-02	0.002	6.75E-02	2.28E-02
Cadmium	8.01E-05	2.50E-05	2.71E-05	0.0005	3.45E-01	1.17E-01	0.0005	3.74E-01	1.26E-01
Chromium	1.52E-02	4.63E-03	5.14E-03	1.5	2.13E-02	7.20E-03	1.5	2.37E-02	8.00E-03
Cobalt	3.23E-03	1.02E-03	1.09E-03	0.02	3.52E-01	1.19E-01	0.02	3.77E-01	1.28E-01
Copper	4.92E-02	1.49E-02	1.66E-02	0.04	2.57E+00	8.69E-01	0.04	2.87E+00	9.70E-01
4,4'-DDT	8.62E-07	2.56E-07	2.91E-07	0.0005	3.54E-03	1.19E-03	0.0005	4.02E-03	1.36E-03
di-n-Butylphthalate	1.11E-05	3.19E-06	3.75E-06	0.1	2.20E-04	7.45E-05	0.1	2.59E-04	8.74E-05
Heptachlor epoxide	6.78E-07	2.16E-07	2.29E-07	1.30E-05	1.15E-01	3.89E-02	1E-05	1.22E-01	4.11E-02
Iron	4.32E+00	1.25E+00	1.46E+00	-	-	-	-	-	-
Lead	1.32E-03	4.29E-04	4.48E-04	-	-	-	-	-	-
Manganese	3.76E-01	1.19E-01	1.27E-01	0.024	3.42E+01	1.16E+01	0.024	3.66E+01	1.24E+01
Mercury	2.89E-05	9.16E-06	9.78E-06	0.0003	2.11E-01	7.12E-02	0.0003	2.25E-01	7.61E-02
Methyl mercury	3.26E-05	8.19E-06	1.10E-05	0.0001	5.65E-01	1.91E-01	0.0001	7.62E-01	2.57E-01
Perchlorate	8.62E-07	1.17E-07	2.91E-07	0.0007	1.15E-03	3.89E-04	0.0007	2.87E-03	9.71E-04
Selenium	1.58E-03	4.96E-04	5.35E-04	0.005	6.85E-01	2.32E-01	0.005	7.39E-01	2.50E-01
Silver	4.33E-04	1.27E-04	1.46E-04	0.005	1.75E-01	5.91E-02	0.005	2.02E-01	6.83E-02
Vanadium	1.45E-02	4.36E-03	4.91E-03	0.2	1.51E-01	5.09E-02	0.2	1.70E-01	5.73E-02
Zinc	7.14E-02	2.32E-02	2.41E-02	0.3	5.35E-01	1.81E-01	0.3	5.56E-01	1.88E-01
TCDD equivalents	2.34E-18	5.40E-19	7.91E-19	-	-	-	-	-	-

Appendix D.4-2 - Backgro

Chemical	Carcinogenic Risk (Mean)			Carcinogenic Risk (MaxD)		
	SF	Subsistence	Recreational	SF	Subsistence	Recreational
Aluminum	-	-	-	-	-	-
Arsenic, organic	-	-	-	-	-	-
Barium	-	-	-	-	-	-
Beryllium	-	-	-	-	-	-
Cadmium	-	-	-	-	-	-
Chromium	-	-	-	-	-	-
Cobalt	-	-	-	-	-	-
Copper	-	-	-	-	-	-
4,4'-DDT	0.34	2.58E-07	8.71E-08	0.34	2.93E-07	9.91E-08
di-n-Butylphthalate	-	-	-	-	-	-
Heptachlor epoxide	9.1	5.83E-06	1.97E-06	9.1	6.17E-06	2.08E-06
Iron	–	-	-	–	-	-
Lead	-	-	-	-	-	-
Manganese	-	-	-	-	-	-
Mercury	-	-	-	-	-	-
Methyl mercury	-	-	-	-	-	-
Perchlorate	-	-	-	-	-	-
Selenium	-	-	-	-	-	-
Silver	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-
Zinc	-	-	-	-	-	-
TCDD equivalents	150000	2.40E-13	8.09E-14	150000	3.51E-13	1.19E-13

Appendix D.4-3 - Nearshore at Makua Human Health Risk Calculations for Fish Consumption

$$Intake = \frac{C_{sf}}{}$$

			Noncarcinogens				Carcinogens
			Subsistence Intake (mg/kg-day)		**Recreational Intake (mg/kg-day)**		**Subsistence Intal**
Chemical	**Arithmetic Mean**	**MaxD**	Arithmetic Mean	MaxD	Arithmetic Mean	MaxD	Arithmetic Mean
Acetone	0.48	0.73	6.96E-04	1.05E-03	2.35E-04	3.55E-04	2.98E-04
Aldrin	0.002	0.003	2.83E-06	3.88E-06	9.56E-07	1.31E-06	1.21E-06
Aluminum	31	65	4.40E-02	9.34E-02	1.49E-02	3.16E-02	1.89E-02
Arsenic, organic	23	37	3.31E-02	5.36E-02	1.12E-02	1.81E-02	1.42E-02
Barium	7.0	32	1.00E-02	4.54E-02	3.39E-03	1.53E-02	4.30E-03
BHC, alpha	0.002	0.008	2.95E-06	1.18E-05	9.97E-07	3.98E-06	1.26E-06
BHC, delta	0.001	0.0003	1.59E-06	4.31E-07	5.37E-07	1.46E-07	6.82E-07
BHC, gamma	0.003	0.006	3.84E-06	9.05E-06	1.30E-06	3.06E-06	1.64E-06
Bis(2-Ethylhexyl)Phthalate	1.4	3.5	2.02E-03	5.03E-03	6.82E-04	1.70E-03	8.65E-04
Cadmium	0.15	0.21	2.17E-04	3.02E-04	7.33E-05	1.02E-04	9.30E-05
Chromium	5.7	10	8.15E-03	1.49E-02	2.75E-03	5.05E-03	3.49E-03
Cobalt	0.23	0.41	3.31E-04	5.94E-04	1.12E-04	2.01E-04	1.42E-04
Copper	4.2	9.8	6.05E-03	1.41E-02	2.04E-03	4.75E-03	2.59E-03
4,4'-DDT	0.0005	0.0002	7.06E-07	2.59E-07	2.39E-07	8.74E-08	3.03E-07
di-n-Butylphthalate	0.31	1.4	4.45E-04	2.01E-03	1.50E-04	6.80E-04	1.91E-04
Heptachlor	0.002	0.01	2.69E-06	8.05E-06	9.08E-07	2.72E-06	1.15E-06
Heptachlor epoxide	0.01	0.01	8.78E-06	2.01E-05	2.97E-06	6.80E-06	3.76E-06
Iron	163	302	2.34E-01	4.34E-01	7.92E-02	1.47E-01	1.00E-01
Lead	0.70	2.0	1.01E-03	2.89E-03	3.40E-04	9.76E-04	4.31E-04
m,p-Xylenes	0.01	0.02	2.12E-05	2.87E-05	7.16E-06	9.71E-06	9.08E-06
Manganese	7.7	16	1.10E-02	2.26E-02	3.73E-03	7.63E-03	4.73E-03
Mercury	0.06	0.10	9.25E-05	1.41E-04	3.13E-05	4.75E-05	3.96E-05
Methyl mercury	0.08	0.20	1.21E-04	2.88E-04	4.08E-05	9.72E-05	5.17E-05
Nitroglycerin	0.17	0.33	2.45E-04	4.74E-04	8.29E-05	1.60E-04	1.05E-04
Perchlorate	0.002	0.01	2.28E-06	1.26E-05	7.70E-07	4.27E-06	9.76E-07
RDX	0.06	0.06	8.14E-05	8.19E-05	2.75E-05	2.77E-05	3.49E-05
Selenium	1.2	1.6	1.66E-03	2.30E-03	5.62E-04	7.77E-04	7.13E-04
Silver	0.01	0.01	1.35E-05	1.90E-05	4.55E-06	6.41E-06	5.77E-06
Vanadium	0.61	1.2	8.81E-04	1.78E-03	2.98E-04	6.02E-04	3.78E-04
Zinc	75	149	1.07E-01	2.14E-01	3.62E-02	7.24E-02	4.59E-02

Appendix D.4-3 - Nearshore at

$$\frac{C_{sf} \times CR \times EF \times ED}{BW \times AT}$$

CR = 0.1006 for subsistence; 0.034 for recreational
EF = 365
ED = 30
BW = 70
AT = noncarcinogens = 30 yrs * 365 days/yr;
carcinog = 70 yrs * 365 days/yr

	ke (mg/kg-day)	Recreational Intake (mg/kg-day)		Non-carcinogenic Risk (Arithmetic Mean)			Non-carcinogenic Risk (Ma	
Chemical	MaxD	Arithmetic Mean	MaxD	RfDo	Subsistence	Recreational	RfDo	Subsistence
Acetone	4.50E-04	1.01E-04	1.52E-04	0.9	7.73E-04	2.61E-04	0.9	1.17E-03
Aldrin	1.66E-06	4.10E-07	5.62E-07	0.00003	9.43E-02	3.19E-02	0.00003	1.29E-01
Aluminum	4.00E-02	6.38E-03	1.35E-02	1	4.40E-02	1.49E-02	1	9.34E-02
Arsenic, organic	2.30E-02	4.79E-03	7.76E-03	-	-	-	-	-
Barium	1.95E-02	1.45E-03	6.58E-03	0.07	1.43E-01	4.85E-02	0.07	6.49E-01
BHC, alpha	5.05E-06	4.27E-07	1.71E-06	0.0005	5.90E-03	1.99E-03	0.0005	2.36E-02
BHC, delta	1.85E-07	2.30E-07	6.24E-08	0.0003	5.30E-03	1.79E-03	0.0003	1.44E-03
BHC, gamma	3.88E-06	5.56E-07	1.31E-06	0.0003	1.28E-02	4.32E-03	0.0003	3.02E-02
Bis(2-Ethylhexyl)Phthalate	2.16E-03	2.92E-04	7.29E-04	0.02	1.01E-01	3.41E-02	0.02	2.52E-01
Cadmium	1.29E-04	3.14E-05	4.37E-05	0.0005	4.34E-01	1.47E-01	0.0005	6.04E-01
Chromium	6.41E-03	1.18E-03	2.16E-03	1.5	5.43E-03	1.84E-03	1.5	9.96E-03
Cobalt	2.54E-04	4.80E-05	8.60E-05	0.02	1.66E-02	5.60E-03	0.02	2.97E-02
Copper	6.02E-03	8.76E-04	2.04E-03	0.04	1.51E-01	5.11E-02	0.04	3.51E-01
4,4'-DDT	1.11E-07	1.02E-07	3.75E-08	0.0005	1.41E-03	4.77E-04	0.0005	5.17E-04
di-n-Butylphthalate	8.62E-04	6.44E-05	2.91E-04	0.1	4.45E-03	1.50E-03	0.1	2.01E-02
Heptachlor	3.45E-06	3.89E-07	1.17E-06	0.0005	5.37E-03	1.82E-03	0.0005	1.61E-02
Heptachlor epoxide	8.62E-06	1.27E-06	2.91E-06	0.000013	6.76E-01	2.28E-01	0.000013	1.55E+00
Iron	1.86E-01	3.39E-02	6.29E-02	-	-	-	-	-
Lead	1.24E-03	1.46E-04	4.18E-04	-	-	-	-	-
m,p-Xylenes	1.23E-05	3.07E-06	4.16E-06	0.2	1.06E-04	3.58E-05	0.2	1.44E-04
Manganese	9.67E-03	1.60E-03	3.27E-03	0.024	4.60E-01	1.55E-01	0.024	9.40E-01
Mercury	6.02E-05	1.34E-05	2.04E-05	0.0003	3.08E-01	1.04E-01	0.0003	4.69E-01
Methyl mercury	1.23E-04	1.75E-05	4.17E-05	0.0001	1.21E+00	4.08E-01	0.0001	2.88E+00
Nitroglycerin	2.03E-04	3.55E-05	6.87E-05	-	-	-	-	-
Perchlorate	5.42E-06	3.30E-07	1.83E-06	0.0007	3.25E-03	1.10E-03	0.0007	1.81E-02
RDX	3.51E-05	1.18E-05	1.19E-05	0.003	2.71E-02	9.17E-03	0.003	2.73E-02
Selenium	9.85E-04	2.41E-04	3.33E-04	0.005	3.33E-01	1.12E-01	0.005	4.60E-01
Silver	8.13E-06	1.95E-06	2.75E-06	0.005	2.69E-03	9.10E-04	0.005	3.79E-03
Vanadium	7.64E-04	1.28E-04	2.58E-04	0.02	4.41E-02	1.49E-02	0.02	8.91E-02
Zinc	9.18E-02	1.55E-02	3.10E-02	0.3	3.57E-01	1.21E-01	0.3	7.14E-01

Appendix D.4-3 - Nearshore at

	axD)	Carcinogenic Risk (Mean)			Carcinogenic Risk (MaxD)		
Chemical	Recreational	SF	Subsistence	Recreational	SF	Subsistence	Recreational
Acetone	3.94E-04	-	-	-	-	-	-
Aldrin	4.37E-02	17	2.06E-05	6.96E-06	17	2.83E-05	9.55E-06
Aluminum	3.16E-02	-	-	-	-	-	-
Arsenic, organic	-	-	-	-	-	-	-
Barium	2.19E-01	-	-	-	-	-	-
BHC, alpha	7.97E-03	6.3	7.97E-06	2.69E-06	6.3	3.18E-05	1.08E-05
BHC, delta	4.86E-04	-	-	-	-	-	-
BHC, gamma	1.02E-02	1.3	2.14E-06	7.22E-07	1.3	5.04E-06	1.70E-06
Bis(2-Ethylhexyl)Phthalate	8.50E-02	0.014	1.21E-05	4.09E-06	0.014	3.02E-05	1.02E-05
Cadmium	2.04E-01	-	-	-	-	-	-
Chromium	3.37E-03	-	-	-	-	-	-
Cobalt	1.00E-02	-	-	-	-	-	-
Copper	1.19E-01	-	-	-	-	-	-
4,4'-DDT	1.75E-04	0.34	1.03E-07	3.48E-08	0.34	3.77E-08	1.27E-08
di-n-Butylphthalate	6.80E-03	-	-	-	-	-	-
Heptachlor	5.44E-03	4.5	5.18E-06	1.75E-06	4.5	1.55E-05	5.25E-06
Heptachlor epoxide	5.23E-01	9.1	3.42E-05	1.16E-05	9.1	7.85E-05	2.65E-05
Iron	-	–	-	-	–	-	-
Lead	-	-	-	-	-	-	-
m,p-Xylenes	4.86E-05	-	-	-	-	-	-
Manganese	3.18E-01	-	-	-	-	-	-
Mercury	1.58E-01	-	-	-	-	-	-
Methyl mercury	9.72E-01	-	-	-	-	-	-
Nitroglycerin	-	0.014	1.47E-06	4.97E-07	0.014	2.85E-06	9.62E-07
Perchlorate	6.11E-03	-	-	-	-	-	-
RDX	9.23E-03	0.11	3.84E-06	1.30E-06	0.11	3.86E-06	1.31E-06
Selenium	1.55E-01	-	-	-	-	-	-
Silver	1.28E-03	-	-	-	-	-	-
Vanadium	3.01E-02	-	-	-	-	-	-
Zinc	2.41E-01	-	-	-	-	-	-

Appendix D.4-4 - Nearshore Background (at Sandy Beach) Human Health Risk Calculations for Fish Consumption

$$Intake = \frac{C_{sf} \times CR \times EF \times ED}{BW \times AT}$$

CR = 0.1006 fo
EF = 365
ED = 30
BW = 70
AT = noncarcin

			Noncarcinogens				Carcinogens				
			Subsistence Intake (mg/kg-day)		**Recreational Intake (mg/kg-day)**		**Subsistence Intake (mg/kg-day)**		**Recreational Intake (mg/kg-day**		**Non-carcinoge**
Chemical	**Arithmetic Mean**	**MaxD**	Arithmetic Mean	MaxD	Arithmetic Mean	MaxD	Arithmetic Mean	MaxD	Arithmetic Mear	MaxD	RfDo
Acetone	0.33	0.60	4.80E-04	8.62E-04	1.62E-04	2.91E-04	2.06E-04	3.70E-04	6.95E-05	1.25E-04	0.9
Aldrin	0.003	0.006	3.84E-06	9.20E-06	1.30E-06	3.11E-06	1.64E-06	3.94E-06	5.56E-07	1.33E-06	0.00003
Aluminum	796	4720	1.14E+00	6.78E+00	3.87E-01	2.29E+00	4.90E-01	2.91E+00	1.66E-01	9.83E-01	1
Antimony	0.02	0.03	2.31E-05	3.72E-05	7.82E-06	1.26E-05	9.92E-06	1.60E-05	3.35E-06	5.39E-06	0.0004
Arsenic, organic	19	53	2.68E-02	7.62E-02	9.07E-03	2.57E-02	1.15E-02	3.26E-02	3.89E-03	1.10E-02	-
Barium	5.6	14	8.12E-03	2.04E-02	2.74E-03	6.90E-03	3.48E-03	8.75E-03	1.18E-03	2.96E-03	0.07
Beryllium	0.01	0.07	1.94E-05	9.92E-05	6.56E-06	3.35E-05	8.32E-06	4.25E-05	2.81E-06	1.44E-05	0.002
BHC, gamma	0.004	0.002	5.55E-06	2.73E-06	1.87E-06	9.23E-07	2.38E-06	1.17E-06	8.03E-07	3.96E-07	0.0003
Bis(2-Ethylhexyl)Phthalate	0.06	0.05	8.05E-05	7.04E-05	2.72E-05	2.38E-05	3.45E-05	3.02E-05	1.17E-05	1.02E-05	0.02
Cadmium	0.11	0.20	1.56E-04	2.87E-04	5.28E-05	9.71E-05	6.69E-05	1.23E-04	2.26E-05	4.16E-05	0.0005
Chromium	7.3	32	1.05E-02	4.56E-02	3.54E-03	1.54E-02	4.48E-03	1.95E-02	1.52E-03	6.60E-03	1.5
Cobalt	0.83	4.3	1.19E-03	6.19E-03	4.04E-04	2.09E-03	5.12E-04	2.65E-03	1.73E-04	8.97E-04	0.02
Copper	4.8	17	6.86E-03	2.37E-02	2.32E-03	8.01E-03	2.94E-03	1.02E-02	9.94E-04	3.43E-03	0.04
4,4'-DDT	0.001	0.002	1.42E-06	3.02E-06	4.81E-07	1.02E-06	6.10E-07	1.29E-06	2.06E-07	4.37E-07	0.0005
Diethyl phthalate	0.04	0.02	5.27E-05	2.73E-05	1.78E-05	9.23E-06	2.26E-05	1.17E-05	7.64E-06	3.96E-06	0.8
di-n-Butylphthalate	0.13	0.61	1.93E-04	8.77E-04	6.52E-05	2.96E-04	8.26E-05	3.76E-04	2.79E-05	1.27E-04	0.1
Heptachlor	0.003	0.01	4.21E-06	8.19E-06	1.42E-06	2.77E-06	1.81E-06	3.51E-06	6.10E-07	1.19E-06	0.2
Heptachlor epoxide	0.003	0.01	4.26E-06	1.09E-05	1.44E-06	3.69E-06	1.82E-06	4.68E-06	6.17E-07	1.58E-06	0.000013
Iron	1230	6960	1.77E+00	1.00E+01	5.97E-01	3.38E+00	7.57E-01	4.29E+00	2.56E-01	1.45E+00	-
Lead	1.4	2.8	2.07E-03	3.95E-03	6.99E-04	1.34E-03	8.87E-04	1.69E-03	3.00E-04	5.72E-04	-
m,p-Xylenes	0.01	0.02	1.99E-05	2.30E-05	6.73E-06	7.77E-06	8.54E-06	9.85E-06	2.89E-06	3.33E-06	0.2
Manganese	28	147	4.08E-02	2.11E-01	1.38E-02	7.14E-02	1.75E-02	9.05E-02	5.91E-03	3.06E-02	0.024
Mercury	0.03	0.04	3.99E-05	6.18E-05	1.35E-05	2.09E-05	1.71E-05	2.65E-05	5.78E-06	8.95E-06	0.0003
Methyl mercury	0.04	0.06	5.22E-05	8.05E-05	1.77E-05	2.72E-05	2.24E-05	3.45E-05	7.57E-06	1.17E-05	0.0001
Perchlorate	0.02	0.11	2.89E-05	1.58E-04	9.76E-06	5.34E-05	1.24E-05	6.78E-05	4.18E-06	2.29E-05	0.0007
Selenium	1.0	1.8	1.43E-03	2.59E-03	4.83E-04	8.74E-04	6.13E-04	1.11E-03	2.07E-04	3.75E-04	0.005
Silver	0.01	0.03	1.45E-05	4.46E-05	4.91E-06	1.51E-05	6.23E-06	1.91E-05	2.11E-06	6.45E-06	0.005
Thallium	0.01	0.01	1.10E-05	1.81E-05	3.71E-06	6.12E-06	4.71E-06	7.76E-06	1.59E-06	2.62E-06	0.00008
Vanadium	3.8	20	5.48E-03	2.92E-02	1.85E-03	9.86E-03	2.35E-03	1.25E-02	7.94E-04	4.23E-03	0.02
Zinc	66	77	9.55E-02	1.11E-01	3.23E-02	3.74E-02	4.09E-02	4.74E-02	1.38E-02	1.60E-02	0.3
TCDD equivalents	3.6E-14	1.7E-13	5.22E-17	2.47E-16	1.77E-17	8.35E-17	2.24E-17	1.06E-16	7.57E-18	3.58E-17	-

Appendix D.4-4 - Nearshore Bar subsistence; 0.034 for recreational

nogens = 30 yrs * 365 days/yr;
carcinog = 70 yrs * 365 days/yr

	enic Risk (Arithmetic Mean)		**Non-carcinogenic Risk (MaxD)**			**Carcinogenic Risk (Mean)**			**Carcinogenic Risk (MaxD)**		
Chemical	Subsistence	Recreational	RfDo	Subsistence	Recreational	SF	Subsistence	Recreational	SF	Subsistence	Recreational
Acetone	5.33E-04	1.80E-04	0.9	9.58E-04	3.24E-04	-	-	-	-	-	-
Aldrin	1.28E-01	4.32E-02	0.00003	3.07E-01	1.04E-01	17	2.80E-05	9.45E-06	17	6.70E-05	2.26E-05
Aluminum	1.14E+00	3.87E-01	1	6.78E+00	2.29E+00	-	-	-	-	-	-
Antimony	5.79E-02	1.96E-02	0.0004	9.31E-02	3.15E-02	-	-	-	-	-	-
Arsenic, organic	-	-	-	-	-	-	-	-	-	-	-
Barium	1.16E-01	3.92E-02	0.07	2.92E-01	9.85E-02	-	-	-	-	-	-
Beryllium	9.70E-03	3.28E-03	0.002	4.96E-02	1.68E-02	-	-	-	-	-	-
BHC, gamma	1.85E-02	6.25E-03	0.0003	9.10E-03	3.08E-03	1.3	3.09E-06	1.04E-06	1.3	1.52E-06	5.14E-07
Bis(2-Ethylhexyl)Phthalate	4.03E-03	1.36E-03	0.02	3.52E-03	1.19E-03	0.014	4.83E-07	1.63E-07	0.014	4.23E-07	1.43E-07
Cadmium	3.12E-01	1.06E-01	0.0005	5.75E-01	1.94E-01	-	-	-	-	-	-
Chromium	6.98E-03	2.36E-03	1.5	3.04E-02	1.03E-02	-	-	-	-	-	-
Cobalt	5.97E-02	2.02E-02	0.02	3.10E-01	1.05E-01	-	-	-	-	-	-
Copper	1.72E-01	5.80E-02	0.04	5.93E-01	2.00E-01	-	-	-	-	-	-
4,4'-DDT	2.84E-03	9.61E-04	0.0005	6.04E-03	2.04E-03	0.34	2.07E-07	7.00E-08	0.34	4.40E-07	1.49E-07
Diethyl phthalate	6.59E-05	2.23E-05	0.8	3.41E-05	1.15E-05	-	-	-	-	-	-
di-n-Butylphthalate	1.93E-03	6.52E-04	0.1	8.77E-03	2.96E-03	-	-	-	-	-	-
Heptachlor	2.11E-05	7.12E-06	0.2	4.10E-05	1.38E-05	4.5	8.13E-06	2.75E-06	4.5	1.58E-05	5.34E-06
Heptachlor epoxide	3.28E-01	1.11E-01	0.000013	8.40E-01	2.84E-01	9.1	1.66E-05	5.61E-06	9.1	4.26E-05	1.44E-05
Iron	-	-	-	-	-	–	-	-	–	-	-
Lead	-	-	-	-	-	-	-	-	-	-	-
m,p-Xylenes	9.96E-05	3.37E-05	0.2	1.15E-04	3.89E-05	-	-	-	-	-	-
Manganese	1.70E+00	5.75E-01	0.024	8.80E+00	2.98E+00	-	-	-	-	-	-
Mercury	1.33E-01	4.50E-02	0.0003	2.06E-01	6.96E-02	-	-	-	-	-	-
Methyl mercury	5.22E-01	1.77E-01	0.0001	8.05E-01	2.72E-01	-	-	-	-	-	-
Perchlorate	4.13E-02	1.39E-02	0.0007	2.26E-01	7.63E-02	-	-	-	-	-	-
Selenium	2.86E-01	9.67E-02	0.005	5.17E-01	1.75E-01	-	-	-	-	-	-
Silver	2.91E-03	9.83E-04	0.005	8.91E-03	3.01E-03	-	-	-	-	-	-
Thallium	1.37E-01	4.64E-02	0.00008	2.26E-01	7.65E-02	-	-	-	-	-	-
Vanadium	2.74E-01	9.27E-02	0.02	1.46E+00	4.93E-01	-	-	-	-	-	-
Zinc	3.18E-01	1.08E-01	0.3	3.69E-01	1.25E-01	-	-	-	-	-	-
TCDD equivalents	-	-	-	-	-	150000	3.36E-12	1.14E-12	150000	1.59E-11	5.37E-12

Appendix D.4-5 - Nearshore at Makua Human Health Risk Calculations for Consumption of Seaweed Tissue

$$Intake = \frac{C_{sf} \times CR \times}{BW \times}$$

			Noncarcinogens				Carcinogens	
			Subsistence Intake (mg/kg-day)		**Recreational Intake (mg/kg-day)**		**Subsistence Intake (mg/kg-day)**	
Chemical	**Arithmetic Mean**	**MaxD**	Arithmetic Mean	MaxD	Arithmetic Mean	MaxD	Arithmetic Mean	MaxD
Aluminum	422	1,120	1.10E-01	2.91E-01	3.13E-02	8.32E-02	4.70E-02	1.25E-01
Antimony	0.06	0.15	1.62E-05	3.77E-05	4.63E-06	1.08E-05	6.94E-06	1.62E-05
Arsenic, inorganic	66	109	1.72E-02	2.83E-02	4.92E-03	8.10E-03	7.38E-03	1.21E-02
Barium	9.0	13	2.33E-03	3.46E-03	6.66E-04	9.88E-04	1.00E-03	1.48E-03
Beryllium	0.01	0.02	1.99E-06	5.20E-06	5.67E-07	1.49E-06	8.51E-07	2.23E-06
Bis(2-Ethylhexyl)Phthalate	0.08	0.09	2.16E-05	2.24E-05	6.17E-06	6.39E-06	9.25E-06	9.58E-06
Cadmium	0.24	0.28	6.34E-05	7.28E-05	1.81E-05	2.08E-05	2.72E-05	3.12E-05
Chromium	2.2	6.0	5.64E-04	1.56E-03	1.61E-04	4.46E-04	2.42E-04	6.69E-04
Cobalt	0.72	1.3	1.88E-04	3.25E-04	5.36E-05	9.29E-05	8.04E-05	1.39E-04
Copper	2.6	4.6	6.88E-04	1.19E-03	1.97E-04	3.39E-04	2.95E-04	5.09E-04
di-n-Butylphthalate	0.14	0.48	3.54E-05	1.25E-04	1.01E-05	3.57E-05	1.52E-05	5.35E-05
Heptachlor	0.001	0.001	3.24E-07	1.87E-07	9.27E-08	5.35E-08	1.39E-07	8.02E-08
Iron	671	1,860	1.74E-01	4.84E-01	4.98E-02	1.38E-01	7.47E-02	2.07E-01
Lead	1.5	3.9	3.95E-04	1.01E-03	1.13E-04	2.88E-04	1.69E-04	4.32E-04
m,p-Xylenes	0.02	0.02	5.31E-06	4.16E-06	1.52E-06	1.19E-06	2.28E-06	1.78E-06
Manganese	16	39	4.12E-03	1.01E-02	1.18E-03	2.90E-03	1.77E-03	4.35E-03
Perchlorate	0.02	0.05	4.48E-06	1.35E-05	1.28E-06	3.86E-06	1.92E-06	5.79E-06
Selenium	0.28	0.07	7.24E-05	1.93E-05	2.07E-05	5.52E-06	3.10E-05	8.28E-06
Silver	0.07	0.14	1.89E-05	3.67E-05	5.41E-06	1.05E-05	8.11E-06	1.57E-05
Thallium	0.02	0.03	4.31E-06	6.97E-06	1.23E-06	1.99E-06	1.85E-06	2.99E-06
Vanadium	6.0	13	1.56E-03	3.43E-03	4.46E-04	9.81E-04	6.69E-04	1.47E-03
Zinc	11	12	2.75E-03	3.20E-03	7.86E-04	9.14E-04	1.18E-03	1.37E-03
TCDD equivalents	2.33E-14	6.72E-14	6.06E-18	1.75E-17	1.73E-18	4.99E-18	2.60E-18	7.49E-18

Appendix D.4-5 - Nearshore at

$$\frac{EF \times ED}{\times AT}$$

CR = 0.0182 subsistence; 0.0052 recreational
EF = 365
ED = 30
BW = 70
AT = noncarcinogens = 30 yrs * 365 days/yr;
carcinog = 70 yrs * 365 days/yr

	Recreational Intake (mg/kg-day)		**Non-carcinogenic Risk (Arithmetic Mean)**			**Non-carcinogenic Risk (MaxD)**		
Chemical	Arithmetic Mean	MaxD	RfDo	Subsistence	Recreational	RfDo	Subsistence	Recreational
Aluminum	1.34E-02	3.57E-02	1	1.10E-01	3.13E-02	1	2.91E-01	8.32E-02
Antimony	1.98E-06	4.62E-06	0.0004	4.05E-02	1.16E-02	0.0004	9.43E-02	2.69E-02
Arsenic, inorganic	2.11E-03	3.47E-03	0.0003	5.74E+01	1.64E+01	0.0003	9.45E+01	2.70E+01
Barium	2.86E-04	4.23E-04	0.07	3.33E-02	9.52E-03	0.07	4.94E-02	1.41E-02
Beryllium	2.43E-07	6.37E-07	0.002	9.93E-04	2.84E-04	0.002	2.60E-03	7.43E-04
Bis(2-Ethylhexyl)Phthalate	2.64E-06	2.74E-06	0.02	1.08E-03	3.08E-04	0.02	1.12E-03	3.19E-04
Cadmium	7.76E-06	8.91E-06	0.0005	1.27E-01	3.62E-02	0.0005	1.46E-01	4.16E-02
Chromium	6.90E-05	1.91E-04	1.5	3.76E-04	1.07E-04	1.5	1.04E-03	2.97E-04
Cobalt	2.30E-05	3.98E-05	0.02	9.38E-03	2.68E-03	0.02	1.63E-02	4.64E-03
Copper	8.43E-05	1.45E-04	0.04	1.72E-02	4.92E-03	0.04	2.97E-02	8.49E-03
di-n-Butylphthalate	4.33E-06	1.53E-05	0.1	3.54E-04	1.01E-04	0.1	1.25E-03	3.57E-04
Heptachlor	3.97E-08	2.29E-08	0.0005	6.49E-04	1.85E-04	0.0005	3.74E-04	1.07E-04
Iron	2.13E-02	5.92E-02	-	-	-	-	-	-
Lead	4.84E-05	1.24E-04	-	-	-	-	-	-
m,p-Xylenes	6.51E-07	5.09E-07	0.2	2.66E-05	7.59E-06	0.2	2.08E-05	5.94E-06
Manganese	5.05E-04	1.24E-03	0.024	1.72E-01	4.91E-02	0.024	4.23E-01	1.21E-01
Perchlorate	5.48E-07	1.66E-06	0.0007	6.39E-03	1.83E-03	0.0007	1.93E-02	5.52E-03
Selenium	8.86E-06	2.37E-06	0.005	1.45E-02	4.14E-03	0.005	3.86E-03	1.10E-03
Silver	2.32E-06	4.49E-06	0.005	3.78E-03	1.08E-03	0.005	7.33E-03	2.09E-03
Thallium	5.28E-07	8.53E-07	0.00008	5.39E-02	1.54E-02	0.00008	8.71E-02	2.49E-02
Vanadium	1.91E-04	4.20E-04	0.02	7.81E-02	2.23E-02	0.02	1.72E-01	4.90E-02
Zinc	3.37E-04	3.92E-04	0.3	9.17E-03	2.62E-03	0.3	1.07E-02	3.05E-03
TCDD equivalents	7.42E-19	2.14E-18	-	-	-	-	-	-

Appendix D.4-5 - Nearshore at

Chemical	Carcinogenic Risk (Mean)			Carcinogenic Risk (MaxD)		
	SF	Subsistence	Recreational	SF	Subsistence	Recreational
Aluminum	-	-	-	-	-	-
Antimony	-	-	-	-	-	-
Arsenic, inorganic	1.5	1.11E-02	3.16E-03	1.5	1.82E-02	5.21E-03
Barium	-	-	-	-	-	-
Beryllium	-	-	-	-	-	-
Bis(2-Ethylhexyl)Phthalate	0.014	1.30E-07	3.70E-08	0.014	1.34E-07	3.83E-08
Cadmium	-	-	-	-	-	-
Chromium	-	-	-	-	-	-
Cobalt	-	-	-	-	-	-
Copper	-	-	-	-	-	-
di-n-Butylphthalate	-	-	-	-	-	-
Heptachlor	4.5	6.26E-07	1.79E-07	4.5	3.61E-07	1.03E-07
Iron	–	-	-	–	-	-
Lead	-	-	-	-	-	-
m,p-Xylenes	-	-	-	-	-	-
Manganese	-	-	-	-	-	-
Perchlorate	-	-	-	-	-	-
Selenium	-	-	-	-	-	-
Silver	-	-	-	-	-	-
Thallium	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-
Zinc	-	-	-	-	-	-
TCDD equivalents	150000	3.90E-13	1.11E-13	150000	1.12E-12	3.21E-13

APPENDIX E
ERA

Appendix E.1-1
ERA Summary Stats
Sediment
Makua Military Reservation

Area	Riskstats_v3.06_Parameter	MinDepth	MaxDepth	Units	N	#D	%D	Min	Max	MinD	MaxD	ProUCL_Distribution	ProUCL_Recommended UCL	RME
North Muliwai	4,4'-DDT	All	All	mg/kg	6	1	16.67	0.000016971	0.0001	0.0001	0.0001	NON-PARAMETRIC	9.09198E-05	0.00009
North Muliwai	Aluminum	All	All	mg/kg	21	21	100	796	49700	796	49700	NON-PARAMETRIC	47918.37729	47918
North Muliwai	Antimony	All	All	mg/kg	21	13	61.9	0.084853	3.7	0.67	3.7	NON-PARAMETRIC	3.664381544	3.66
North Muliwai	Arsenic	All	All	mg/kg	22	14	63.64	0.077782	5.6	0.26	5.6	NON-PARAMETRIC	6.794666942	5.60
North Muliwai	Barium	All	All	mg/kg	22	22	100	3.8	123	3.8	123	NON-PARAMETRIC	129.4947946	123
North Muliwai	Benzene	All	All	mg/kg	6	2	33.33	0.00004	0.00022	0.00004	0.000044	NORMAL	0.000203628	0.00004
North Muliwai	bis(2-ethylhexyl)phthalate	All	All	mg/kg	6	1	16.67	0.014142	0.02687	0.022	0.022	NORMAL	0.0184307	0.02
North Muliwai	Cadmium	All	All	mg/kg	22	13	59.09	0.0077782	0.13	0.013	0.13	NON-PARAMETRIC	0.108739206	0.11
North Muliwai	Chromium	All	All	mg/kg	22	22	100	15.5	176	15.5	176	NON-PARAMETRIC	131.7095181	132
North Muliwai	Cobalt	All	All	mg/kg	22	22	100	5	60.4	5	60.4	NON-PARAMETRIC	45.59821474	46
North Muliwai	Copper	All	All	mg/kg	22	22	100	2.4	121	2.4	121	NON-PARAMETRIC	100.2345247	100
North Muliwai	Ethylbenzene	All	All	mg/kg	6	4	66.67	0.000098995	0.002	0.0003	0.002	NORMAL	0.001245813	0.001
North Muliwai	Lead	All	All	mg/kg	22	9	40.91	0.036062	9.6	0.24	9.6	NON-PARAMETRIC	5.808298119	5.81
North Muliwai	m,p-Xylenes	All	All	mg/kg	6	4	66.67	0.0002	0.001	0.0002	0.001	GAMMA	0.000991208	0.001
North Muliwai	Mercury	All	All	mg/kg	22	22	100	0.014	0.08	0.014	0.08	GAMMA	0.042492185	0.04
North Muliwai	OCDD	All	All	mg/kg	6	1	16.67	0.000014142	0.00015	0.00015	0.00015	NON-PARAMETRIC	0.000266936	0.0002
North Muliwai	o-Xylene	All	All	mg/kg	6	2	33.33	0.00009	0.00024042	0.00009	0.0001	NORMAL	0.000154434	0.0001
North Muliwai	RDX	All	All	mg/kg	22	1	4.545	0.033234	0.23	0.23	0.23	NON-PARAMETRIC	0.052694108	0.05
North Muliwai	Selenium	All	All	mg/kg	22	10	45.45	0.049497	4	0.3	4	NON-PARAMETRIC	4.297199906	4.00
North Muliwai	Toluene	All	All	mg/kg	6	6	100	0.0003	0.0007	0.0003	0.0007	NORMAL	0.000637654	0.001
North Muliwai	Vanadium	All	All	mg/kg	22	22	100	7.4	185	7.4	185	NON-PARAMETRIC	203.5614089	185
North Muliwai	Zinc	All	All	mg/kg	22	22	100	7.6	142	7.6	142	NON-PARAMETRIC	83.79020752	84
South Muliwai	2,3,7,8-TCDD	All	All	mg/kg	5	1	20	2.8284E-06	0.00003	0.00003	0.00003	NON-PARAMETRIC	6.2904E-05	0.00003
South Muliwai	Aluminum	All	All	mg/kg	12	12	100	925	67500	925	67500	NORMAL	43491.63043	43492
South Muliwai	Antimony	All	All	mg/kg	12	2	16.67	0.098995	0.98	0.86	0.98	NON-PARAMETRIC	0.634531975	0.63
South Muliwai	Arsenic	All	All	mg/kg	12	5	41.67	0.091924	5.2	0.35	5.2	NON-PARAMETRIC	6.290401781	5.20
South Muliwai	Barium	All	All	mg/kg	12	12	100	3.8	118	3.8	118	NORMAL	65.6873369	66
South Muliwai	Cadmium	All	All	mg/kg	12	12	100	0.019	0.16	0.019	0.16	NORMAL	0.087138472	0.09
South Muliwai	Chromium	All	All	mg/kg	12	12	100	20.3	271	20.3	271	NORMAL	179.8168625	180
South Muliwai	Cobalt	All	All	mg/kg	12	12	100	6.7	74	6.7	74	NORMAL	54.9804361	55
South Muliwai	Copper	All	All	mg/kg	12	12	100	3.4	108	3.4	108	NORMAL	82.0440402	82
South Muliwai	Ethylbenzene	All	All	mg/kg	3	3	100	0.0006	0.001	0.0006	0.001	N/A		0.001
South Muliwai	Lead	All	All	mg/kg	12	7	58.33	0.03677	26.9	1.2	26.9	GAMMA	18.90599221	19
South Muliwai	m,p-Xylenes	All	All	mg/kg	3	2	66.67	0.00038184	0.0007	0.0007	0.0007	N/A		0.001
South Muliwai	Mercury	All	All	mg/kg	12	10	83.33	0.0070711	0.082	0.016	0.082	NORMAL	0.052939827	0.05
South Muliwai	Pentachlorophenol-8151A	All	All	mg/kg	3	1	33.33	0.00070711	0.000823	0.000823	0.000823	N/A		0.0008
South Muliwai	Picloram	All	All	mg/kg	3	1	33.33	0.00029698	0.0004	0.0004	0.0004	N/A		0.0004
South Muliwai	Selenium	All	All	mg/kg	12	10	83.33	0.0355	7.7	2.2	7.7	NORMAL	4.74255695	4.74
South Muliwai	Toluene	All	All	mg/kg	3	3	100	0.0004	0.0006	0.0004	0.0006	N/A		0.00
South Muliwai	Vanadium	All	All	mg/kg	12	12	100	3.5	194	3.5	194	NORMAL	154.1653881	154
South Muliwai	Zinc	All	All	mg/kg	12	12	100	9.2	188	9.2	188	NORMAL	109.4232539	109
North Background	Aluminum	All	All	mg/kg	4	4	100	22600	25100	22600	25100	NORMAL	25033.60811	25034
North Background	Arsenic	All	All	mg/kg	4	1	25	0.077782	0.15	0.15	0.15	NON-PARAMETRIC	0.18227385	0.15
North Background	Barium	All	All	mg/kg	4	4	100	109	186	109	186	NORMAL	176.723426	177
North Background	Chromium	All	All	mg/kg	4	4	100	112	138	112	138	NORMAL	136.3169652	136
North Background	Cobalt	All	All	mg/kg	4	4	100	46.7	70.9	46.7	70.9	NORMAL	68.10330344	68

Appendix E.1-1
ERA Summary Stats
Sediment
Makua Military Reservation

Area	Riskstats_v3.06_Parameter	MinDepth	MaxDepth	Units	N	#D	%D	Min	Max	MinD	MaxD	ProUCL_Distribution	ProUCL_Recommended UCL	RME
North Background	Copper	All	All	mg/kg	4	4	100	50.3	56.7	50.3	56.7	NORMAL	57.44084083	57
North Background	Lead	All	All	mg/kg	4	4	100	0.32	1.7	0.32	1.7	NORMAL	1.606700783	1.61
North Background	Mercury	All	All	mg/kg	4	4	100	0.059	0.064	0.059	0.064	NORMAL	0.063675791	0.06
North Background	Vanadium	All	All	mg/kg	4	4	100	138	166	138	166	NORMAL	167.018516	166
North Background	Zinc	All	All	mg/kg	4	4	100	76.5	86.5	76.5	86.5	NORMAL	87.27674231	87
South Background	Aluminum	All	All	mg/kg	4	4	100	30200	54700	30200	54700	NORMAL	58262.68356	54700
South Background	Arsenic	All	All	mg/kg	4	3	75	0.084853	1.5	0.21	1.5	NORMAL	1.49041249	1.49
South Background	Barium	All	All	mg/kg	4	4	100	134	157	134	157	NORMAL	162.0451407	157
South Background	Chromium	All	All	mg/kg	4	4	100	195	227	195	227	NORMAL	226.9892623	227
South Background	Cobalt	All	All	mg/kg	4	4	100	70.1	83.1	70.1	83.1	NORMAL	83.06262935	83
South Background	Copper	All	All	mg/kg	4	4	100	89.9	110	89.9	110	NORMAL	110.7830879	110
South Background	Lead	All	All	mg/kg	4	4	100	1.3	2.4	1.3	2.4	NORMAL	2.604448502	2.40
South Background	Mercury	All	All	mg/kg	4	4	100	0.052	0.06	0.052	0.06	NORMAL	0.060803783	0.06
South Background	Vanadium	All	All	mg/kg	4	4	100	147	166	147	166	NORMAL	169.1590753	166
South Background	Zinc	All	All	mg/kg	4	4	100	103	125	103	125	NORMAL	124.9543098	125

Appendix E.1-2
ERA Summary Stats
Fish Tissue
Makua Military Reservation

Area	Riskstats_v1.19_Parameter	MinDepth	MaxDepth	Units	N	#D	%D	Min	Max	MinD	MaxD	Distribution	Mean_Arith	StdDev_Arith	StdError_Arith	UCL_95	RME
Nanakuli Muliwai	1,2,3,4,6,7,8-hpcdf	All	All	mg/kg	3	3	100	1.78E-13	3.71E-13	1.78E-13	3.71E-13	LogNormal+	2.52E-13	1.0407E-13	6.0086E-14	1.0406E-12	3.71E-13
Nanakuli Muliwai	4,4'-ddt	All	All	mg/kg	3	2	66.67	0.0009899	0.0014	0.0013	0.0014	LogNormal+	0.00123	0.0002138	0.00012344	0.0018713	0.0014
Nanakuli Muliwai	aluminum	All	All	mg/kg	3	3	100	3810	5170	3810	5170	LogNormal+	4466.7	681.2	393.29	6242	5170
Nanakuli Muliwai	arsenic	All	All	mg/kg	3	3	100	2.51	2.57	2.51	2.57	LogNormal+	2.54	0.03	0.01732	2.547	2.547
Nanakuli Muliwai	barium	All	All	mg/kg	3	3	100	39.1	43.6	39.1	43.6	LogNormal+	40.8	2.4434	1.4107	43.681	43.6
Nanakuli Muliwai	beryllium	All	All	mg/kg	3	3	100	0.078	0.094	0.078	0.094	LogNormal+	0.084667	0.0083267	0.0048074	0.10166	0.094
Nanakuli Muliwai	cadmium	All	All	mg/kg	3	3	100	0.11	0.13	0.11	0.13	LogNormal+	0.12	0.01	0.0057735	0.13761	0.13
Nanakuli Muliwai	chromium	All	All	mg/kg	3	3	100	19.7	24.7	19.7	24.7	LogNormal+	22.233	2.5007	1.4438	27.986	24.7
Nanakuli Muliwai	cobalt	All	All	mg/kg	3	3	100	4.59	5.25	4.59	5.25	LogNormal+	4.9	0.33181	0.19157	5.3569	5.25
Nanakuli Muliwai	copper	All	All	mg/kg	3	3	100	64.9	79.9	64.9	79.9	LogNormal+	71.6	7.6269	4.4034	88.28	79.9
Nanakuli Muliwai	di-n-butylphthalate	All	All	mg/kg	3	3	100	0.012	0.018	0.012	0.018	LogNormal+	0.015333	0.003055	0.0017638	0.025314	0.018
Nanakuli Muliwai	heptachlorepoxide	All	All	mg/kg	2	2	100	0.00098	0.0011	0.00098	0.0011	LogNormal(A)	0.00104	0.000084853	0.00006	NA	0.0011
Nanakuli Muliwai	hpcdd,total	All	All	mg/kg	3	3	100	1.73E-12	2.46E-12	1.73E-12	2.46E-12	LogNormal++	2.0367E-12	3.7873E-13	2.1866E-13	3.0817E-12	2.46E-12
Nanakuli Muliwai	hpcdf,total	All	All	mg/kg	3	3	100	1.78E-13	3.71E-13	1.78E-13	3.71E-13	LogNormal+	2.52E-13	1.0407E-13	6.0086E-14	1.0406E-12	3.71E-13
Nanakuli Muliwai	hxcdd,total	All	All	mg/kg	3	1	33.33	3.818E-14	3.69E-13	3.69E-13	3.69E-13	LogNormal+	1.5128E-13	1.8859E-13	1.0889E-13	4.054E-07	3.69E-13
Nanakuli Muliwai	hxcdf,total	All	All	mg/kg	3	1	33.33	3.748E-14	1.67E-13	1.67E-13	1.67E-13	LogNormal+	8.1123E-14	7.4375E-14	4.2941E-14	7.2712E-11	1.67E-13
Nanakuli Muliwai	iron	All	All	mg/kg	3	3	100	5410	7010	5410	7010	LogNormal+	5996.7	881.21	508.77	8139.1	7010
Nanakuli Muliwai	lead	All	All	mg/kg	3	3	100	2.01	2.15	2.01	2.15	LogNormal+	2.06	0.078102	0.045092	2.1177	2.1177
Nanakuli Muliwai	lipids,total	All	All	percent	3	3	100	3.3	4.8	3.3	4.8	LogNormal+	3.9667	0.76376	0.44096	6.1554	4.8
Nanakuli Muliwai	manganese	All	All	mg/kg	3	3	100	501	611	501	611	LogNormal+	571.67	61.33	35.409	715.42	611
Nanakuli Muliwai	mercury	All	All	mg/kg	3	3	100	0.042	0.047	0.042	0.047	LogNormal+	0.044	0.0026458	0.0015275	0.047144	0.047
Nanakuli Muliwai	methylmercury	All	All	mg/kg	3	3	100	0.032	0.053	0.032	0.053	LogNormal+	0.039333	0.011846	0.0068394	0.087301	0.053
Nanakuli Muliwai	ocdf	All	All	mg/kg	3	3	100	6.44E-13	8.78E-13	6.44E-13	8.78E-13	LogNormal+	7.2367E-13	1.3368E-13	7.718E-14	1.0819E-12	8.78E-13
Nanakuli Muliwai	perchlorate	All	All	mg/kg	3	1	33.33	0.0001414	0.0014	0.0014	0.0014	LogNormal(A)	0.00056095	0.00072664	0.00041953	7791.9	0.0014
Nanakuli Muliwai	selenium	All	All	mg/kg	3	3	100	2.19	2.57	2.19	2.57	LogNormal+	2.3833	0.19009	0.10975	2.7031	2.57
Nanakuli Muliwai	silver	All	All	mg/kg	3	3	100	0.527	0.703	0.527	0.703	LogNormal+	0.608	0.088831	0.051287	0.83165	0.703
Nanakuli Muliwai	solids,total	All	All	percent	3	3	100	27.3	28.7	27.3	28.7	LogNormal+	28.067	0.70946	0.40961	28.423	28.423
Nanakuli Muliwai	vanadium	All	All	mg/kg	3	3	100	19.6	23.6	19.6	23.6	LogNormal+	20.967	2.2811	1.317	25.886	23.6
Nanakuli Muliwai	zinc	All	All	mg/kg	3	3	100	108	116	108	116	LogNormal+	111.67	4.0415	2.3333	114.55	114.55
Makua North Muliwai	1,2,3,7,8-pecdd	All	All	mg/kg	5	2	40	3.96E-14	1.42E-12	4.49E-13	1.42E-12	LogNormal++	4.0067E-13	5.9611E-13	2.6659E-13	3.0001E-10	1.42E-12
Makua North Muliwai	4,4'-ddt	All	All	mg/kg	4	2	50	0.0002192	0.00074	0.0005	0.00074	LogNormal+	0.00050445	0.00021587	0.00010794	0.0016564	0.00074
Makua North Muliwai	acetone	All	All	mg/kg	5	1	20	0.1626	1.4142	0.25	0.25	LogNormal(A)	0.43184	0.5504	0.24615	3.6521	0.25
Makua North Muliwai	aluminum	All	All	mg/kg	5	5	100	48.3	4240	48.3	4240	Normal++	2415.7	1546.8	691.77	3890.4	3890.4
Makua North Muliwai	antimony	All	All	mg/kg	5	1	20	0.01414	0.04	0.04	0.04	LogNormal(A)	0.019314	0.011564	0.0051716	0.037522	0.037522
Makua North Muliwai	arsenic	All	All	mg/kg	5	5	100	2.25	3.81	2.25	3.81	LogNormal+	2.928	0.60475	0.27045	3.6797	3.6797
Makua North Muliwai	barium	All	All	mg/kg	5	5	100	5.53	26.1	5.53	26.1	LogNormal(A)	20.786	8.6639	3.8746	74.741	26.1
Makua North Muliwai	beryllium	All	All	mg/kg	5	4	80	0.0015	0.051	0.028	0.051	Normal++	0.0303	0.018178	0.0081296	0.047631	0.047631
Makua North Muliwai	bhc,delta	All	All	mg/kg	4	1	25	0.0001697	0.00048083	0.00031	0.00031	LogNormal+	0.00028256	0.0001478	0.000073902	0.00086005	0.00031
Makua North Muliwai	bhc,gamma	All	All	mg/kg	4	2	50	0.0007071	0.0013	0.00089	0.0013	LogNormal+	0.00090105	0.00027959	0.00013979	0.0014302	0.0013
Makua North Muliwai	cadmium	All	All	mg/kg	5	5	100	0.02	0.08	0.02	0.08	LogNormal+	0.054	0.021909	0.009798	0.12706	0.08
Makua North Muliwai	chromium	All	All	mg/kg	5	5	100	0.9	14.7	0.9	14.7	Normal++	9.24	5.2228	2.3357	14.219	14.219
Makua North Muliwai	cobalt	All	All	mg/kg	5	5	100	0.397	4.17	0.397	4.17	Normal++	2.6134	1.3915	0.62229	3.94	3.94
Makua North Muliwai	copper	All	All	mg/kg	5	5	100	6.39	166	6.39	166	LogNormal+	62.118	60.585	27.094	2127.7	166
Makua North Muliwai	di-n-butylphthalate	All	All	mg/kg	5	5	100	0.0098	0.015	0.0098	0.015	LogNormal+	0.01136	0.002109	0.00094319	0.013675	0.013675
Makua North Muliwai	heptachlorepoxide	All	All	mg/kg	2	1	50	0.00051	0.0012021	0.00051	0.00051	LogNormal(A)	0.00085604	0.00048938	0.00034604	NA	0.00051
Makua North Muliwai	hpcdd,total	All	All	mg/kg	5	5	100	1.4E-12	1.02E-11	1.4E-12	1.02E-11	LogNormal++	3.55E-12	3.7491E-12	1.6766E-12	1.8734E-11	1.02E-11

Appendix E.1-2
ERA Summary Stats
Fish Tissue
Makua Military Reservation

Area	Riskstats_v1.19_Parameter	MinDepth	MaxDepth	Units	N	#D	%D	Min	Max	MinD	MaxD	Distribution	Mean_Arith	StdDev_Arith	StdError_Arith	UCL_95	RME
Makua North Muliwai	hpcdf,total	All	All	mg/kg	5	1	20	4.808E-14	7.99E-13	7.99E-13	7.99E-13	LogNormal(A)	2.093E-13	3.2978E-13	1.4748E-13	5.1508E-12	7.99E-13
Makua North Muliwai	iron	All	All	mg/kg	5	5	100	122	4530	122	4530	Normal++	2612.4	1647.7	736.88	4183.3	4183.3
Makua North Muliwai	lead	All	All	mg/kg	5	5	100	1.25	5.39	1.25	5.39	LogNormal+	2.636	1.7186	0.7686	7.5571	5.39
Makua North Muliwai	lipids,total	All	All	percent	5	5	100	2.1	6.4	2.1	6.4	LogNormal+	4.42	1.5675	0.701	7.9524	6.4
Makua North Muliwai	manganese	All	All	mg/kg	5	5	100	11.9	386	11.9	386	Normal++	244.78	142.6	63.772	380.73	380.73
Makua North Muliwai	mercury	All	All	mg/kg	5	5	100	0.024	0.074	0.024	0.074	LogNormal+	0.039	0.020199	0.0090333	0.071998	0.071998
Makua North Muliwai	methylmercury	All	All	mg/kg	5	5	100	0.012	0.07	0.012	0.07	LogNormal+	0.0334	0.023681	0.010591	0.12593	0.07
Makua North Muliwai	pecdd,total	All	All	mg/kg	5	1	20	3.394E-14	1.42E-12	1.42E-12	1.42E-12	LogNormal(A)	3.1766E-13	6.1626E-13	2.756E-13	1.1426E-10	1.42E-12
Makua North Muliwai	percentmoisture	All	All	ug/l	5	5	100	0	0	0	0	LogNormal(A)	0	NA	NA	NA	NA
Makua North Muliwai	perchlorate	All	All	mg/kg	5	1	20	0.0001414	0.0019	0.0019	0.0019	LogNormal(A)	0.00049314	0.00078646	0.00035172	0.012147	0.0019
Makua North Muliwai	selenium	All	All	mg/kg	5	5	100	1.83	3.71	1.83	3.71	LogNormal++	2.382	0.75952	0.33967	3.3202	3.3202
Makua North Muliwai	silver	All	All	mg/kg	5	5	100	0.014	1.13	0.014	1.13	LogNormal+	0.3952	0.4268	0.19087	348.05	1.13
Makua North Muliwai	solids,total	All	All	percent	5	5	100	24.4	28.1	24.4	28.1	LogNormal+	26.74	1.5076	0.67424	27.667	27.667
Makua North Muliwai	vanadium	All	All	mg/kg	5	5	100	1.24	19.3	1.24	19.3	Normal++	12.808	7.1333	3.1901	19.609	19.3
Makua North Muliwai	zinc	All	All	mg/kg	5	5	100	98.8	129	98.8	129	LogNormal+	113.96	13.693	6.1239	129.2	129
Makua South Muliwai	1,2,3,4,6,7,8-hpcdd	All	All	mg/kg	7	1	14.29	1.294E-13	1.2021E-12	5.31E-13	5.31E-13	LogNormal++	7.5306E-13	4.0213E-13	1.5199E-13	2.2626E-12	5.31E-13
Makua South Muliwai	1,2,3,4,6,7,8-hpcdf	All	All	mg/kg	7	1	14.29	5.798E-14	9.1924E-13	2.95E-13	2.95E-13	LogNormal++	3.5024E-13	3.1287E-13	1.1825E-13	2.0837E-12	2.95E-13
Makua South Muliwai	1,2,3,7,8-pecdd	All	All	mg/kg	7	1	14.29	3.536E-14	1.76E-12	1.76E-12	1.76E-12	LogNormal++	4.6386E-13	6.1408E-13	2.321E-13	1.1366E-11	1.76E-12
Makua South Muliwai	2,3,7,8-tcdf	All	All	mg/kg	7	1	14.29	2.263E-14	7.7075E-13	5.9E-13	5.9E-13	LogNormal++	3.7965E-13	2.9657E-13	1.1209E-13	4.6892E-12	5.9E-13
Makua South Muliwai	4,4'-ddt	All	All	mg/kg	7	5	71.43	0.00067	0.0029	0.00067	0.0029	LogNormal++	0.0014757	0.000921	0.00034811	0.0027337	0.0027337
Makua South Muliwai	acetone	All	All	mg/kg	5	4	80	0.1626	0.38	0.23	0.38	LogNormal+	0.25853	0.079952	0.035756	0.37944	0.37944
Makua South Muliwai	aluminum	All	All	mg/kg	7	7	100	1150	2880	1150	2880	LogNormal+	1871.1	707.59	267.44	2647.5	2647.5
Makua South Muliwai	antimony	All	All	mg/kg	7	2	28.57	0.01414	0.0527	0.0481	0.0527	LogNormal(A)	0.024502	0.017742	0.0067058	0.049032	0.049032
Makua South Muliwai	arsenic	All	All	mg/kg	7	7	100	1.46	29.8	1.46	29.8	LogNormal(A)	5.7757	10.6	4.0064	27.693	27.693
Makua South Muliwai	barium	All	All	mg/kg	7	7	100	12.5	21.2	12.5	21.2	LogNormal+	16.643	3.3346	1.2604	19.731	19.731
Makua South Muliwai	beryllium	All	All	mg/kg	7	4	57.14	0.01	0.032	0.01	0.032	LogNormal++	0.018511	0.0086711	0.0032773	0.029403	0.029403
Makua South Muliwai	bhc,beta	All	All	mg/kg	7	2	28.57	0.0002263	0.0041	0.00081	0.0041	LogNormal+	0.0015742	0.0014845	0.00056107	0.013944	0.0041
Makua South Muliwai	bhc,gamma	All	All	mg/kg	6	2	33.33	0.0001061	0.0023335	0.0016	0.0017	LogNormal(A)	0.0014162	0.00084586	0.00034532	0.030847	0.0017
Makua South Muliwai	bis(2-ethylhexyl)phthalate	All	All	mg/kg	7	1	14.29	0.03465	3.1	3.1	3.1	LogNormal(A)	0.56862	1.144	0.4324	79.357	3.1
Makua South Muliwai	cadmium	All	All	mg/kg	7	7	100	0.02	0.147	0.02	0.147	LogNormal++	0.050886	0.043848	0.016573	0.10595	0.10595
Makua South Muliwai	chromium	All	All	mg/kg	7	7	100	8.4	31.5	8.4	31.5	LogNormal+	15.971	8.2338	3.1121	25.095	25.095
Makua South Muliwai	cobalt	All	All	mg/kg	7	7	100	1.94	2.58	1.94	2.58	LogNormal+	2.2657	0.25039	0.094639	2.4726	2.4726
Makua South Muliwai	copper	All	All	mg/kg	7	7	100	9.56	109	9.56	109	LogNormal+	43.723	37.979	14.355	182.56	109
Makua South Muliwai	di-n-butylphthalate	All	All	mg/kg	7	7	100	0.011	1.5	0.011	1.5	LogNormal(A)	0.36129	0.61358	0.23191	391.99	1.5
Makua South Muliwai	heptachlorepoxide	All	All	mg/kg	5	2	40	0.00058	0.0028991	0.00058	0.00093	LogNormal+	0.0015324	0.0011006	0.00049222	0.006758	0.00093
Makua South Muliwai	hpcdd,total	All	All	mg/kg	7	4	57.14	1.294E-13	3.02E-12	6.99E-13	3.02E-12	LogNormal++	1.4059E-12	9.4675E-13	3.5784E-13	8.5122E-12	3.02E-12
Makua South Muliwai	hpcdf,total	All	All	mg/kg	7	2	28.57	5.798E-14	1.35E-12	2.95E-13	1.35E-12	LogNormal++	4.6572E-13	4.9276E-13	1.8624E-13	4.755E-12	1.35E-12
Makua South Muliwai	hxcdd,total	All	All	mg/kg	7	1	14.29	3.536E-14	4.4548E-13	1.45E-13	1.45E-13	LogNormal+	2.1133E-13	1.6903E-13	6.3887E-14	1.1944E-12	1.45E-13
Makua South Muliwai	hxcdf,total	All	All	mg/kg	7	1	14.29	2.404E-14	3.6062E-13	1.29E-13	1.29E-13	LogNormal+	1.5652E-13	1.2883E-13	4.8692E-14	9.246E-13	1.29E-13
Makua South Muliwai	iron	All	All	mg/kg	7	7	100	1900	3460	1900	3460	LogNormal+	2775.4	547.24	206.84	3292.5	3292.5
Makua South Muliwai	lead	All	All	mg/kg	7	7	100	0.973	2.61	0.973	2.61	LogNormal+	1.709	0.74533	0.28171	2.6443	2.61
Makua South Muliwai	lipids,total	All	All	percent	5	5	100	2.5	6.4	2.5	6.4	LogNormal+	4.24	1.8174	0.81277	7.7003	6.4
Makua South Muliwai	m,p-xylenes	All	All	mg/kg	7	2	28.57	0.0016	0.017	0.0016	0.017	LogNormal(A)	0.012254	0.004882	0.0018452	0.042461	0.017
Makua South Muliwai	manganese	All	All	mg/kg	7	7	100	94.9	184	94.9	184	LogNormal+	135.41	30.446	11.508	163.65	163.65
Makua South Muliwai	mercury	All	All	mg/kg	7	7	100	0.034	0.103	0.034	0.103	LogNormal+	0.067757	0.024797	0.0093722	0.099275	0.099275
Makua South Muliwai	methylmercury	All	All	mg/kg	7	7	100	0.038	0.17	0.038	0.17	LogNormal++	0.074612	0.045358	0.017144	0.12623	0.12623

Appendix E.1-2
ERA Summary Stats
Fish Tissue
Makua Military Reservation

Area	Riskstats_v1.19_Parameter	MinDepth	MaxDepth	Units	N	#D	%D	Min	Max	MinD	MaxD	Distribution	Mean_Arith	StdDev_Arith	StdError_Arith	UCL_95	RME
Makua South Muliwai	ocdd	All	All	mg/kg	7	2	28.57	1.414E-12	8.7681E-12	6.9E-12	8.7E-12	LogNormal++	5.4409E-12	2.7751E-12	1.0489E-12	1.1901E-11	8.7E-12
Makua South Muliwai	ocdf	All	All	mg/kg	7	3	42.86	2.652E-13	1.31E-12	5.49E-13	1.31E-12	LogNormal++	8.2993E-13	3.9478E-13	1.4921E-13	1.5854E-12	1.31E-12
Makua South Muliwai	pecdd,total	All	All	mg/kg	7	1	14.29	3.536E-14	1.76E-12	1.76E-12	1.76E-12	LogNormal++	5.0528E-13	6.3107E-13	2.3852E-13	1.6251E-11	1.76E-12
Makua South Muliwai	percentlipids	All	All	percent	2	2	100	13.9	16	13.9	16	LogNormal(A)	14.95	1.4849	1.05	NA	16
Makua South Muliwai	percentmoisture	All	All	mg/kg	9	9	100	0	0	0	72.9	LogNormal(A)	0	NA	NA	NA	NA
Makua South Muliwai	perchlorate	All	All	mg/kg	7	6	85.71	0.0001414	0.16	0.0012	0.16	LogNormal+	0.04622	0.060711	0.022947	1617.6	0.16
Makua South Muliwai	selenium	All	All	mg/kg	7	7	100	1.61	3.59	1.61	3.59	LogNormal+	2.5214	0.65178	0.24635	3.1734	3.1734
Makua South Muliwai	silver	All	All	mg/kg	7	7	100	0.046	0.822	0.046	0.822	LogNormal+	0.34194	0.33983	0.12844	5.4303	0.822
Makua South Muliwai	solids,total	All	All	percent	5	5	100	25.7	30.6	25.7	30.6	LogNormal+	27.58	2.1183	0.94731	29.242	29.242
Makua South Muliwai	tcdf,total	All	All	mg/kg	7	1	14.29	2.263E-14	5.9E-13	5.9E-13	5.9E-13	LogNormal++	1.7924E-13	2.013E-13	7.6086E-14	2.2927E-12	5.9E-13
Makua South Muliwai	thallium	All	All	mg/kg	7	2	28.57	0.00325	0.006364	0.00325	0.00586	LogNormal(A)	0.0058471	0.0011605	0.00043863	0.0072772	0.00586
Makua South Muliwai	vanadium	All	All	mg/kg	7	7	100	7.76	18.2	7.76	18.2	LogNormal+	11.326	3.4784	1.3147	14.45	14.45
Makua South Muliwai	zinc	All	All	mg/kg	7	7	100	85.2	201	85.2	201	LogNormal(A)	114.19	39.694	15.003	146.28	146.28
Nearshore at Sandy Beach	1,2,3,7,8-pecdd	All	All	mg/kg	6	1	16.67	4.596E-14	4.879E-13	1.72E-13	1.72E-13	LogNormal+	1.9413E-13	1.6408E-13	6.6984E-14	1.1727E-12	1.72E-13
Nearshore at Sandy Beach	4,4'-ddt	All	All	mg/kg	6	2	33.33	0.0001202	0.0021	0.0019	0.0021	LogNormal+	0.00098958	0.00085479	0.00034897	0.036071	0.0021
Nearshore at Sandy Beach	acetone	All	All	mg/kg	5	4	80	0.2192	0.6	0.23	0.6	LogNormal+	0.33384	0.15629	0.069894	0.58104	0.58104
Nearshore at Sandy Beach	aldrin	All	All	mg/kg	6	1	16.67	0.0007071	0.0064	0.0064	0.0064	LogNormal+	0.0026694	0.002243	0.00091569	0.017827	0.0064
Nearshore at Sandy Beach	aluminum	All	All	mg/kg	6	6	100	3.8	4720	3.8	4720	LogNormal(A)	796	1922.4	784.8	78636000	4720
Nearshore at Sandy Beach	antimony	All	All	mg/kg	6	1	16.67	0.01414	0.0259	0.0259	0.0259	LogNormal(A)	0.016102	0.0048001	0.0019596	0.020477	0.020477
Nearshore at Sandy Beach	arsenic	All	All	mg/kg	6	6	100	4.52	53	4.52	53	LogNormal(A)	18.673	20.905	8.5343	212.12	53
Nearshore at Sandy Beach	barium	All	All	mg/kg	6	6	100	0.96	14.2	0.96	14.2	LogNormal+	5.6483	5.2405	2.1394	78.53	14.2
Nearshore at Sandy Beach	beryllium	All	All	mg/kg	6	1	16.67	0.002121	0.069	0.069	0.069	LogNormal(A)	0.013503	0.027194	0.011102	0.48771	0.069
Nearshore at Sandy Beach	bhc,gamma	All	All	mg/kg	5	1	20	0.001061	0.0091924	0.0019	0.0019	LogNormal+	0.003859	0.0033197	0.0014846	0.025346	0.0019
Nearshore at Sandy Beach	bis(2-ethylhexyl)phthalate	All	All	mg/kg	6	1	16.67	0.03465	0.14849	0.049	0.049	LogNormal(A)	0.056014	0.045667	0.018644	0.1222	0.049
Nearshore at Sandy Beach	cadmium	All	All	mg/kg	6	6	100	0.04	0.2	0.04	0.2	LogNormal+	0.10867	0.053616	0.021889	0.22255	0.2
Nearshore at Sandy Beach	chromium	All	All	mg/kg	6	6	100	0.7	31.7	0.7	31.7	LogNormal++	7.2817	12.047	4.918	208.67	31.7
Nearshore at Sandy Beach	cobalt	All	All	mg/kg	6	6	100	0.109	4.31	0.109	4.31	LogNormal(A)	0.8315	1.7043	0.69577	35.231	4.31
Nearshore at Sandy Beach	copper	All	All	mg/kg	6	6	100	1.86	16.5	1.86	16.5	LogNormal(A)	4.7767	5.7599	2.3515	18.262	16.5
Nearshore at Sandy Beach	diethylphthalate	All	All	mg/kg	6	2	33.33	0.009192	0.15556	0.018	0.019	LogNormal(A)	0.03669	0.058415	0.023848	0.3774	0.019
Nearshore at Sandy Beach	di-n-butylphthalate	All	All	mg/kg	6	6	100	0.014	0.61	0.014	0.61	LogNormal++	0.13417	0.2335	0.095324	2.824	0.61
Nearshore at Sandy Beach	heptachlor	All	All	mg/kg	6	2	33.33	0.0004596	0.0057	0.0045	0.0057	LogNormal+	0.0029315	0.0020788	0.00084868	0.031586	0.0057
Nearshore at Sandy Beach	heptachlorepoxide	All	All	mg/kg	5	3	60	0.0007071	0.0076	0.0028	0.0076	LogNormal+	0.0029628	0.0028155	0.0012591	0.044703	0.0076
Nearshore at Sandy Beach	hpcdd,total	All	All	mg/kg	6	4	66.67	1.096E-13	1.62E-12	3.06E-13	1.62E-12	LogNormal++	5.7684E-13	5.4129E-13	2.2098E-13	3.2084E-12	1.62E-12
Nearshore at Sandy Beach	hpcdf,total	All	All	mg/kg	6	1	16.67	3.677E-14	3.3941E-13	2.87E-13	2.87E-13	LogNormal+	1.6274E-13	1.2956E-13	5.2894E-14	1.2695E-12	2.87E-13
Nearshore at Sandy Beach	iron	All	All	mg/kg	6	6	100	68.4	6960	68.4	6960	LogNormal(A)	1229.5	2807.4	1146.1	468300	6960
Nearshore at Sandy Beach	lead	All	All	mg/kg	6	6	100	0.463	2.75	0.463	2.75	LogNormal+	1.4398	0.89938	0.36717	4.4129	2.75
Nearshore at Sandy Beach	lipids,total	All	All	percent	5	5	100	1.7	9.1	1.7	9.1	LogNormal+	4.04	2.9509	1.3197	12.353	9.1
Nearshore at Sandy Beach	m,p-xylenes	All	All	mg/kg	6	1	16.67	0.01343	0.016	0.016	0.016	LogNormal(A)	0.013863	0.0010471	0.0004275	0.014488	0.014488
Nearshore at Sandy Beach	manganese	All	All	mg/kg	6	6	100	1.4	147	1.4	147	LogNormal++	28.39	58.137	23.734	2851.3	147
Nearshore at Sandy Beach	mercury	All	All	mg/kg	6	5	83.33	0.009192	0.043	0.024	0.043	LogNormal+	0.027782	0.011355	0.0046357	0.058023	0.043
Nearshore at Sandy Beach	methylmercury	All	All	mg/kg	6	5	83.33	0.003	0.056	0.027	0.056	Normal++	0.036351	0.01911	0.0078018	0.052072	0.052072
Nearshore at Sandy Beach	percentlipids	All	All	percent	1	1	100	9.09	9.09	9.09	9.09	LogNormal(A)	9.09	NA	NA	NA	9.09
Nearshore at Sandy Beach	perchlorate	All	All	mg/kg	6	2	33.33	0.0001414	0.11	0.01	0.11	LogNormal(A)	0.020094	0.044221	0.018053	205540	0.11
Nearshore at Sandy Beach	selenium	All	All	mg/kg	6	4	66.67	0.4667	1.8	0.879	1.8	LogNormal+	0.99506	0.46565	0.1901	1.7732	1.7732
Nearshore at Sandy Beach	silver	All	All	mg/kg	6	1	16.67	0.005657	0.031	0.031	0.031	LogNormal(A)	0.010116	0.010246	0.0041831	0.02745	0.02745
Nearshore at Sandy Beach	solids,total	All	All	percent	5	5	100	26.5	31.8	26.5	31.8	LogNormal+	28.82	2.158	0.96509	30.504	30.504

Appendix E.1-2
ERA Summary Stats
Fish Tissue
Makua Military Reservation

Area	Riskstats_v1.19_Parameter	MinDepth	MaxDepth	Units	N	#D	%D	Min	Max	MinD	MaxD	Distribution	Mean_Arith	StdDev_Arith	StdError_Arith	UCL_95	RME
Nearshore at Sandy Beach	tcdf,total	All	All	mg/kg	6	1	16.67	2.828E-14	2.47E-13	2.47E-13	2.47E-13	LogNormal+	1.3203E-13	8.5791E-14	3.5024E-14	6.3284E-13	2.47E-13
Nearshore at Sandy Beach	thallium	All	All	mg/kg	6	1	16.67	0.006364	0.0126	0.0126	0.0126	LogNormal(A)	0.007639	0.0024953	0.0010187	0.010051	0.010051
Nearshore at Sandy Beach	vanadium	All	All	mg/kg	6	6	100	0.312	20.3	0.312	20.3	LogNormal(A)	3.8153	8.0793	3.2984	414.9	20.3
Nearshore at Sandy Beach	zinc	All	All	mg/kg	6	6	100	44.7	77	44.7	77	LogNormal+	66.417	12.277	5.0122	80.967	77
Nearshore at Makua	4,4'-ddt	All	All	mg/kg	5	1	20	0.0001202	0.00084853	0.00018	0.00018	LogNormal+	0.00049138	0.00032436	0.00014506	0.0039279	0.00018
Nearshore at Makua	acetone	All	All	mg/kg	4	3	75	0.2263	0.73	0.27	0.73	LogNormal+	0.48407	0.27314	0.13657	2.4246	0.73
Nearshore at Makua	aldrin	All	All	mg/kg	5	2	40	0.0007071	0.0029698	0.0024	0.0027	LogNormal+	0.0019675	0.0010173	0.00045493	0.0062739	0.0027
Nearshore at Makua	aluminum	All	All	mg/kg	5	5	100	6.8	65	6.8	65	LogNormal+	30.64	26.161	11.699	429.86	65
Nearshore at Makua	arsenic	All	All	mg/kg	5	5	100	4.06	37.3	4.06	37.3	Normal++	23.012	11.952	5.3452	34.407	34.407
Nearshore at Makua	barium	All	All	mg/kg	5	5	100	0.46	31.6	0.46	31.6	LogNormal++	6.984	13.764	6.1556	6721	31.6
Nearshore at Makua	bhc,alpha	All	All	mg/kg	5	1	20	0.0002263	0.0082	0.0082	0.0082	LogNormal++	0.0020529	0.0034441	0.0015403	0.2087	0.0082
Nearshore at Makua	bhc,delta	All	All	mg/kg	5	1	20	0.0003	0.0023335	0.0003	0.0003	LogNormal+	0.0011065	0.00078072	0.00034915	0.0053364	0.0003
Nearshore at Makua	bhc,gamma	All	All	mg/kg	4	1	25	0.0006293	0.0063	0.0063	0.0063	LogNormal+	0.0026692	0.0024907	0.0012454	0.092115	0.0063
Nearshore at Makua	bis(2-ethylhexyl)phthalate	All	All	mg/kg	5	4	80	0.03465	3.5	0.055	3.5	LogNormal+	1.4039	1.6306	0.72925	228150	3.5
Nearshore at Makua	cadmium	All	All	mg/kg	5	5	100	0.12	0.21	0.12	0.21	LogNormal+	0.151	0.035426	0.015843	0.19307	0.19307
Nearshore at Makua	chromium	All	All	mg/kg	5	5	100	0.8	10.4	0.8	10.4	LogNormal+	5.672	4.3028	1.9243	177.58	10.4
Nearshore at Makua	cobalt	All	All	mg/kg	5	5	100	0.107	0.413	0.107	0.413	LogNormal+	0.2306	0.13208	0.059067	0.60155	0.413
Nearshore at Makua	copper	All	All	mg/kg	5	5	100	2.2	9.78	2.2	9.78	LogNormal++	4.21	3.1406	1.4045	10.833	9.78
Nearshore at Makua	di-n-butylphthalate	All	All	mg/kg	5	5	100	0.022	1.4	0.022	1.4	LogNormal(A)	0.3094	0.60976	0.27269	234.64	1.4
Nearshore at Makua	heptachlor	All	All	mg/kg	4	1	25	0.0004596	0.0056	0.0056	0.0056	LogNormal++	0.0018685	0.0024904	0.0012452	0.25577	0.0056
Nearshore at Makua	heptachlorepoxide	All	All	mg/kg	3	2	66.67	0.001131	0.014	0.0032	0.014	LogNormal+	0.0061105	0.0069104	0.0039897	21187	0.014
Nearshore at Makua	iron	All	All	mg/kg	5	5	100	62.5	302	62.5	302	LogNormal+	163	110.21	49.286	665.57	302
Nearshore at Makua	lead	All	All	mg/kg	5	5	100	0.076	2.01	0.076	2.01	LogNormal+	0.6994	0.80883	0.36172	63.616	2.01
Nearshore at Makua	lipids,total	All	All	percent	4	4	100	2.3	9.6	2.3	9.6	LogNormal+	4.725	3.3797	1.6899	26.666	9.6
Nearshore at Makua	m,p-xylenes	All	All	mg/kg	5	1	20	0.01343	0.02	0.02	0.02	LogNormal(A)	0.014748	0.0029359	0.001313	0.017909	0.017909
Nearshore at Makua	manganese	All	All	mg/kg	5	5	100	1.44	15.7	1.44	15.7	LogNormal+	7.682	6.074	2.7164	130.88	15.7
Nearshore at Makua	mercury	All	All	mg/kg	5	5	100	0.044	0.0978	0.044	0.0978	LogNormal+	0.06436	0.020855	0.0093268	0.093505	0.093505
Nearshore at Makua	methylmercury	All	All	mg/kg	5	5	100	0.034	0.20009	0.034	0.20009	LogNormal+	0.084019	0.067608	0.030235	0.30444	0.20009
Nearshore at Makua	nitroglycerin	All	All	mg/kg	5	1	20	0.1308	0.33	0.33	0.33	LogNormal(A)	0.17065	0.089078	0.039837	0.29905	0.29905
Nearshore at Makua	percentlipids	All	All	percent	1	1	100	21.3	21.3	21.3	21.3	LogNormal(A)	21.3	NA	NA	NA	21.3
Nearshore at Makua	percentmoisture	All	All	mg/kg	6	6	100	0	0	0	66.9	LogNormal(A)	0	NA	NA	NA	NA
Nearshore at Makua	perchlorate	All	All	mg/kg	6	1	16.67	0.0001414	0.0088	0.0088	0.0088	LogNormal(A)	0.0015845	0.0035348	0.0014431	0.26369	0.0088
Nearshore at Makua	rdx	All	All	mg/kg	5	1	20	0.05657	0.057	0.057	0.057	LogNormal(A)	0.056655	0.00019295	0.000086291	0.056662	0.056662
Nearshore at Makua	selenium	All	All	mg/kg	5	4	80	0.5586	1.6	1.09	1.6	LogNormal+	1.1577	0.38637	0.17279	2.0237	1.6
Nearshore at Makua	silver	All	All	mg/kg	5	4	80	0.005657	0.0132	0.008	0.0132	LogNormal+	0.0093714	0.0027896	0.0012475	0.013928	0.0132
Nearshore at Makua	solids,total	All	All	percent	5	5	100	27.6	34.2	27.6	34.2	LogNormal+	30.6	2.3569	1.054	32.485	32.485
Nearshore at Makua	vanadium	All	All	mg/kg	5	5	100	0.106	1.24	0.106	1.24	LogNormal+	0.6132	0.46367	0.20736	8.1805	1.24
Nearshore at Makua	zinc	All	All	mg/kg	5	5	100	36.8	149	36.8	149	LogNormal+	74.54	43.361	19.392	162.47	149

Appendix E.2-1
Statistical Comparison
Metals in North and South Muliwai Compared to North and South Background Areas
Makua Military Reservation

	Distribution[1]		% Detected			Test results		
Metal	**Background**	**Site**	**Background**	**Site**	**Test Used**	**Statistic[2]**	***p***	**Elevated?**
Aluminum	N	N	100	100	WRS	1.9	0.06	No
Antimony	**-**	**N**	-	**45**	**< 50% detected**	**-**	**-**	**Yes[3]**
Arsenic	N	N	50	56	WRS	-1.8	0.07	No
Barium	(Log-)Normal	N	100	100	WRS	4.2	3.1E-05	No[6]
Cadmium	**-**	**N**	**-**	**74**	**-**	**-**	**-**	**Yes[4]**
Chromium (III)	(Log-)Normal	N	100	100	WRS	2.3	0.02	No[6]
Cobalt	(Log-)Normal	N	100	100	WRS	3.6	0.0004	No[6]
Copper	Normal	N	100	100	WRS	2.5	0.01	No[6]
Lead	(Log-)Normal	**N**	**100**	**47**	**< 50% detected**	**-**	**-**	**Yes[5]**
Mercury	(Log-)Normal	N	100	94	WRS	3.0	0.002	No[6]
Selenium	**-**	**N**	**-**	**59**	**-**	**-**	**-**	**Yes[4]**
Vanadium	(Log-)Normal	N	100	100	WRS	2.8	0.005	No[6]
Zinc	(Log-)Normal	N	100	100	WRS	2.8	0.006	No[6]

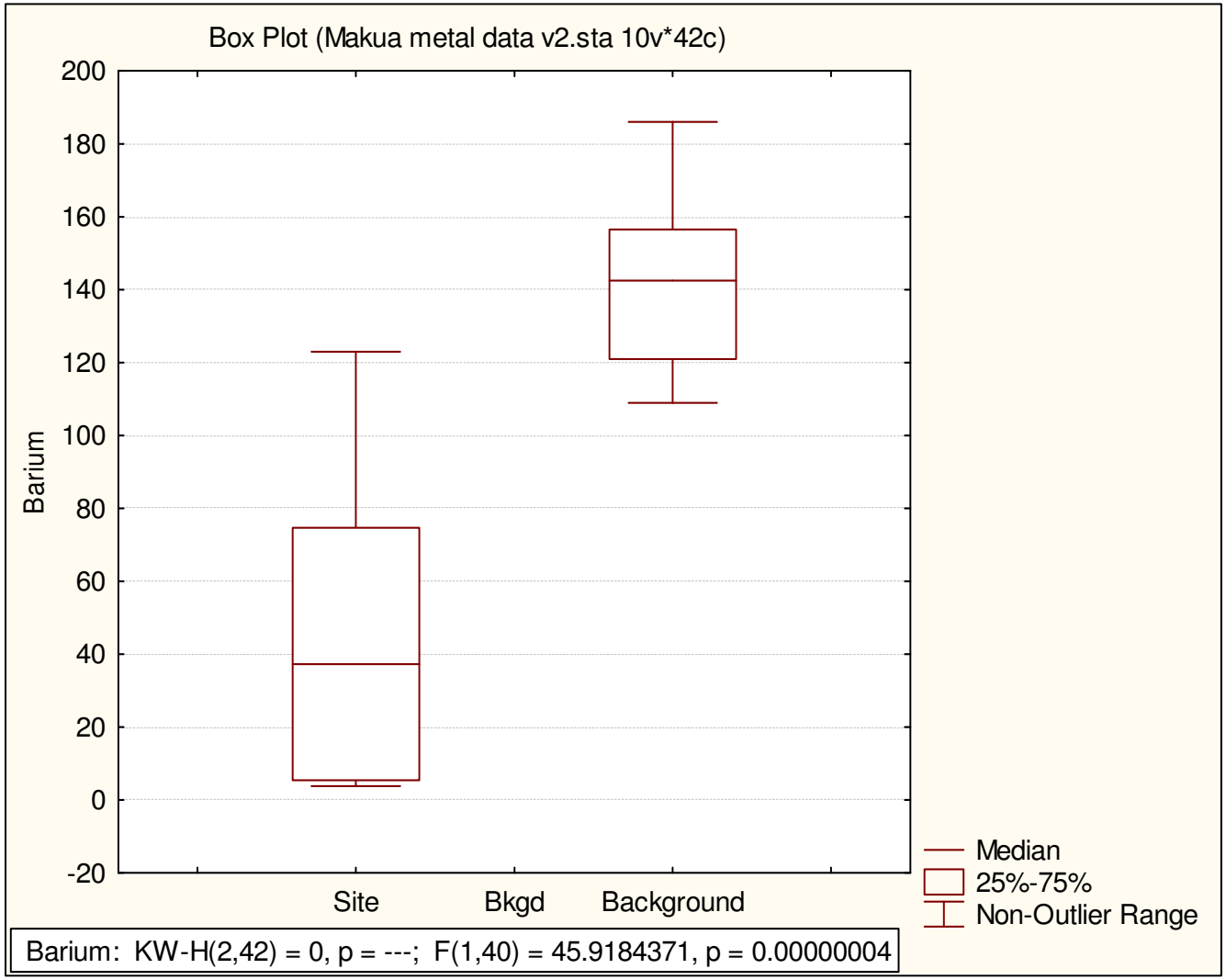
Notes:

1 - Assessed for normality and log-normality using the Shapiro-Wilks test. If the data fit neither distribution, "N" is given as the result.
2 - *U* statistic given for the WRS test.
3 - Identified as a COPEC because constituent was not in the background samples and detected at the site, although infrequently.
4 - Identified as a COPEC because constituent was not detected in the background samples and detected at the site.
5 - Identified as a COPEC because constituent was <50% detected in the site sediments.
6 - Test result indicates there is a significant difference between background and Site concentrations. However, Site concentrations are significantly lower than background concentrations.

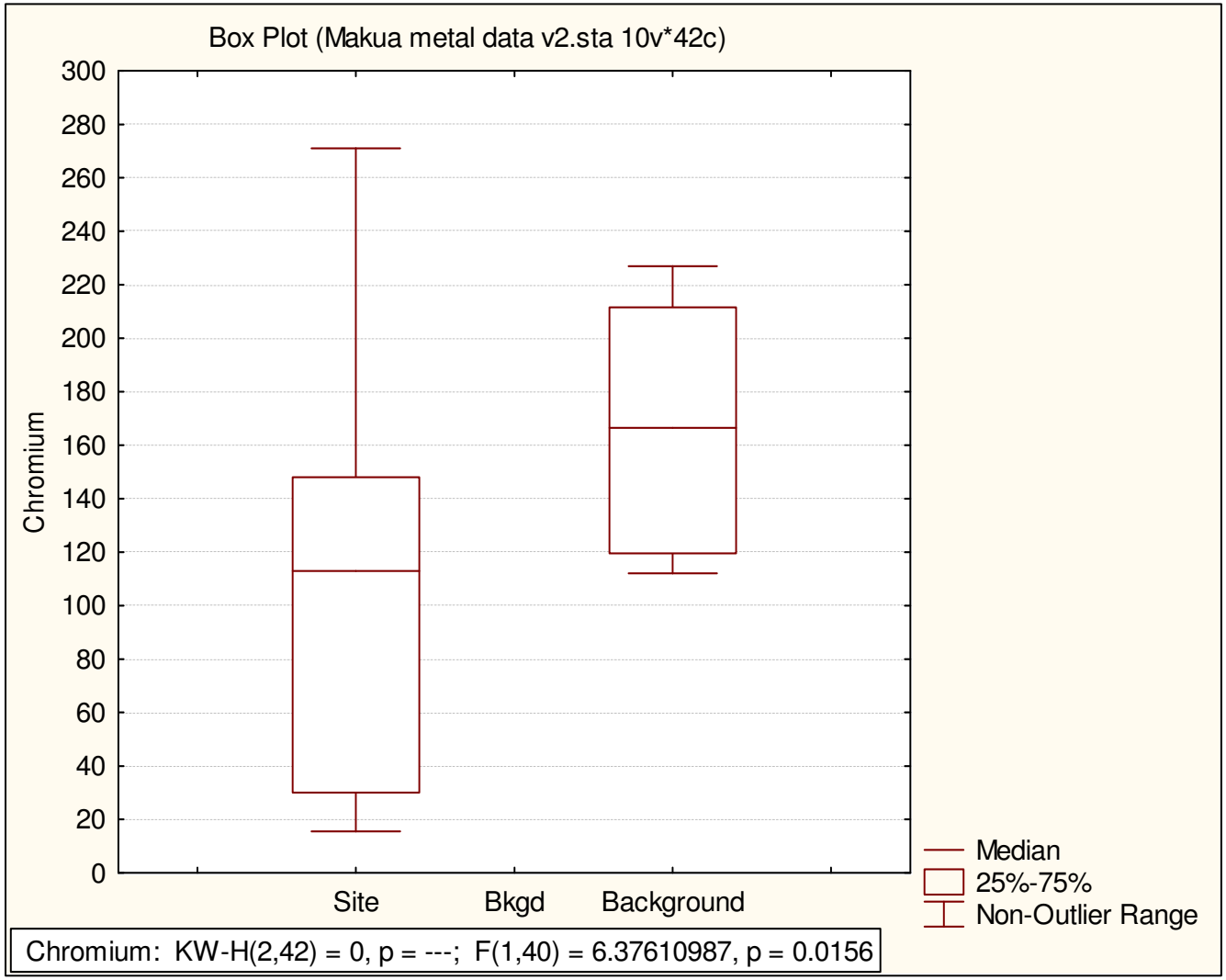
Definitions:

Log-normal - Data is log-normally distributed.
(Log-)Normal - Data fit both a log-normal and a normal distribution.
N - Data is neither log-normally or normally distributed.
Normal - Data is normally distributed.
Background - North and south background areas combined (8 samples).
Site - North and south muliwai combined (34 samples).

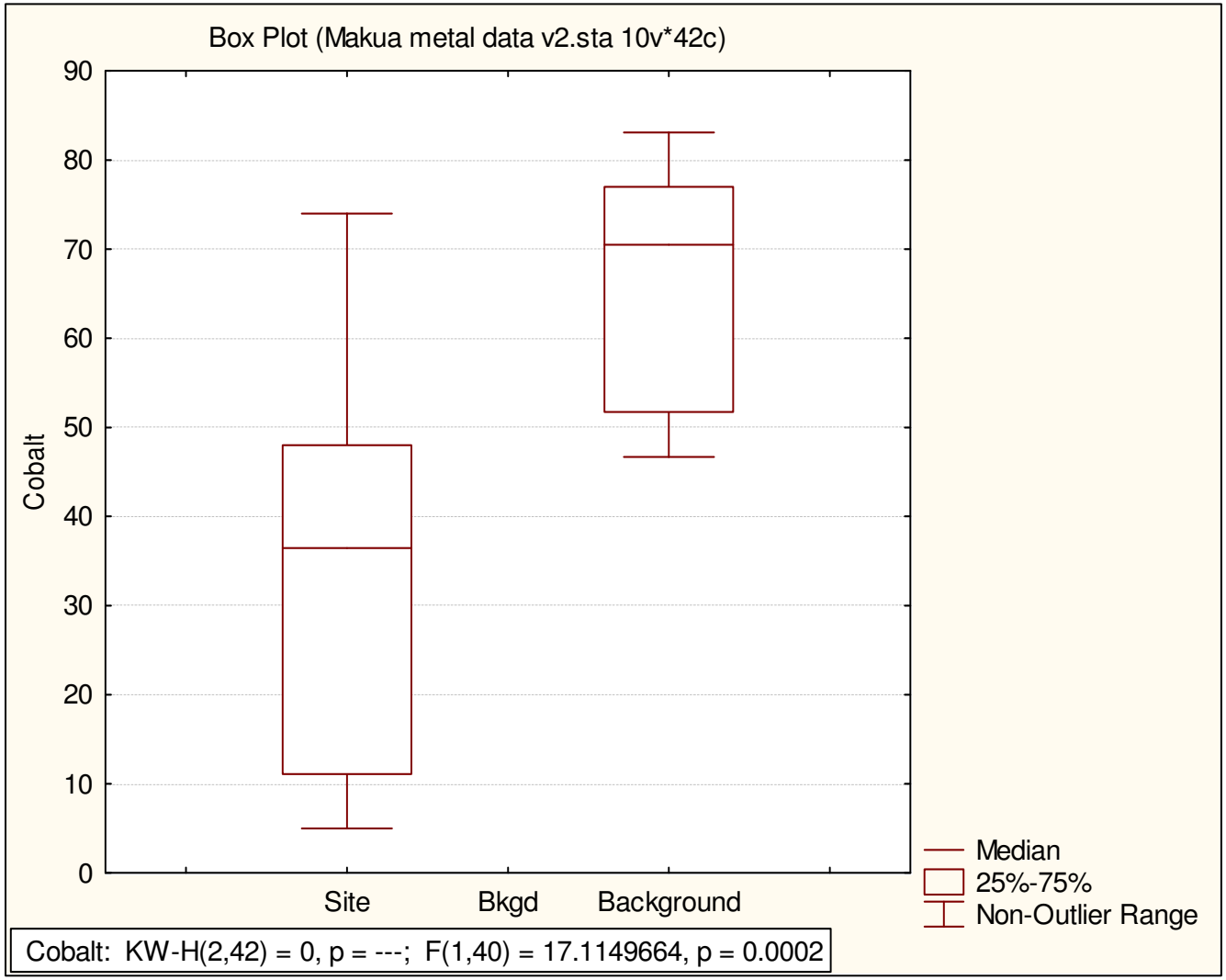
Appendix E-2.2
WRS Box Plot
Barium Sediments
Makua AFB



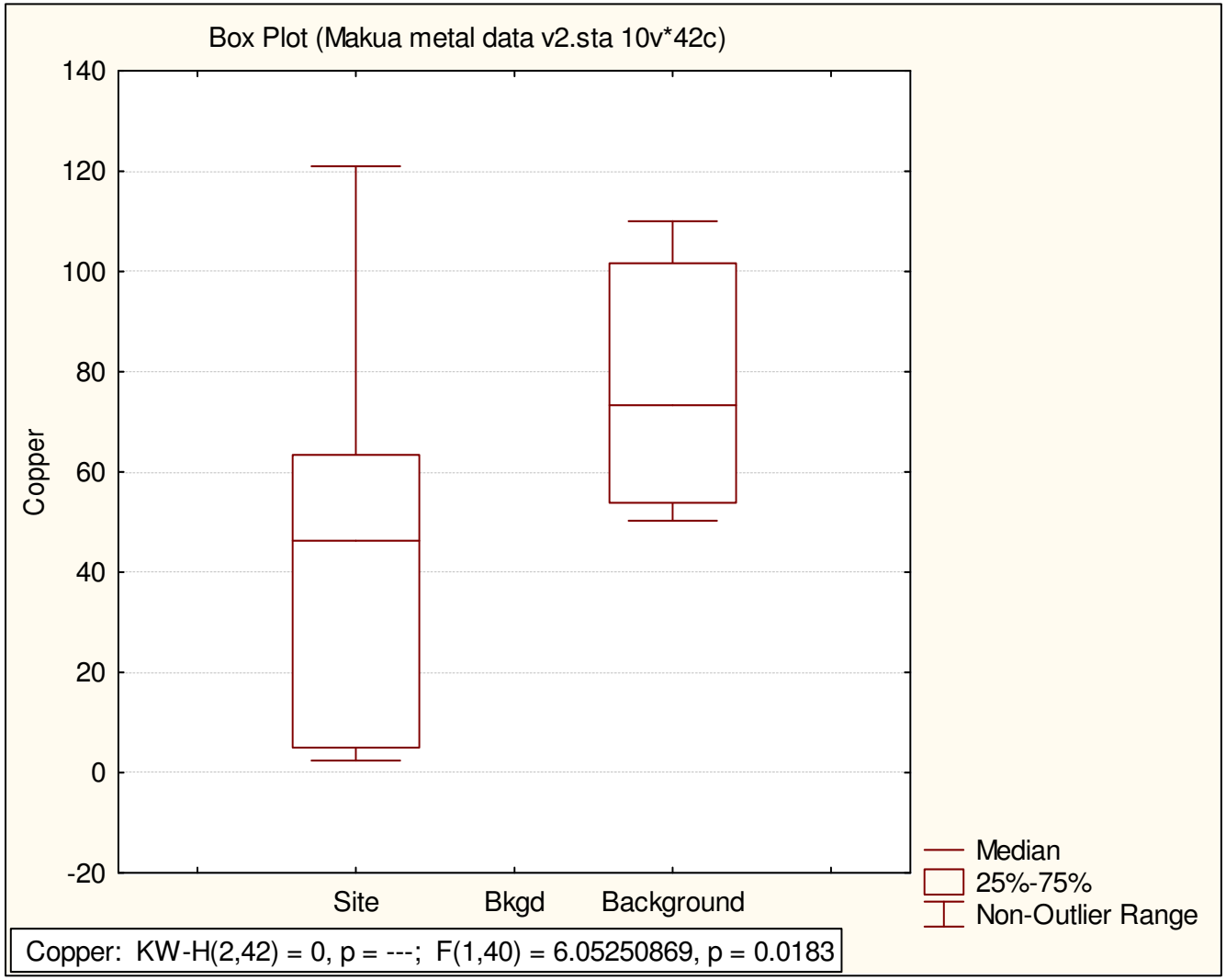
Appendix E-2.3
WRS Box Plot
Chromium Sediments
Makua AFB



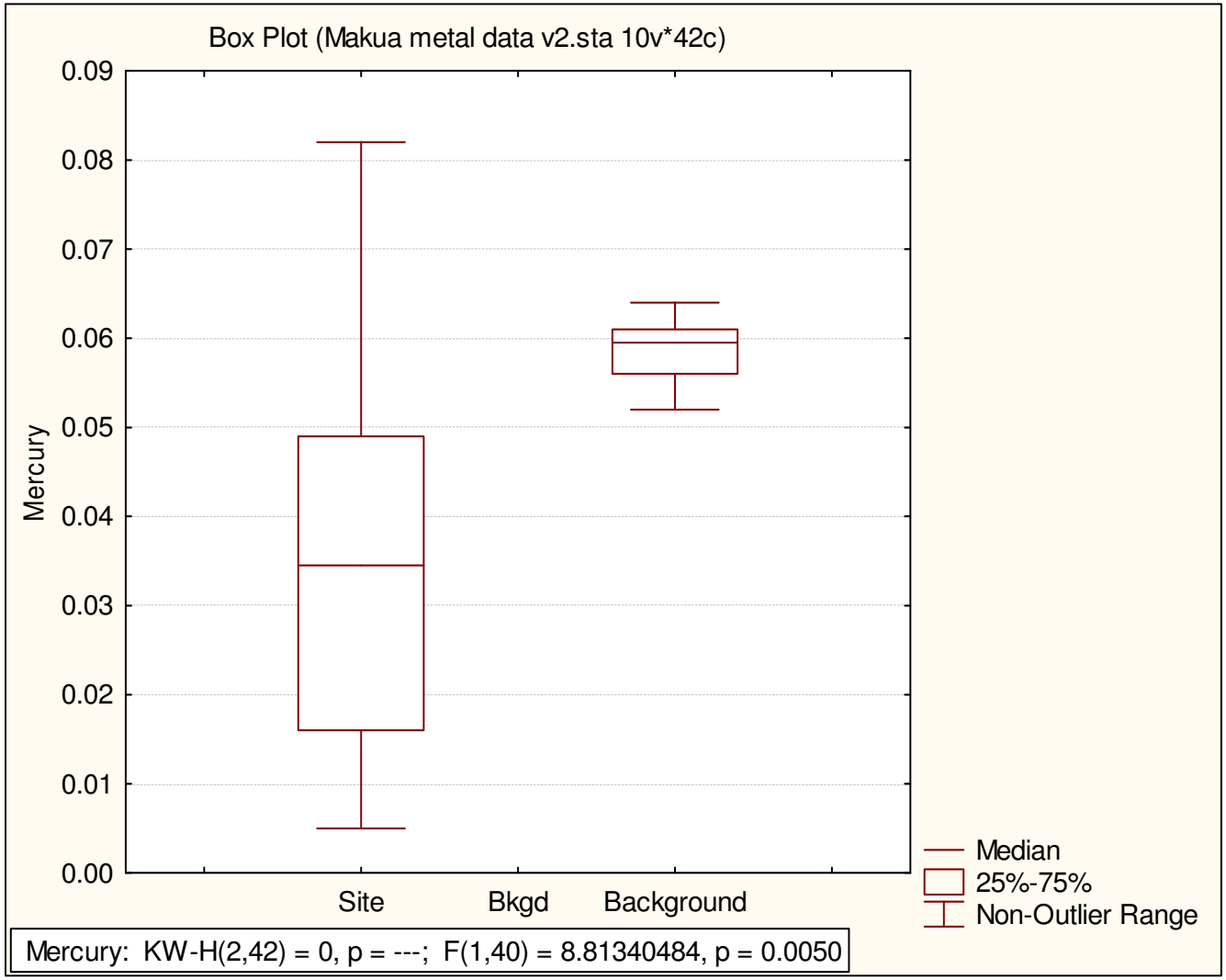
Appendix E-2.4
WRS Box Plot
Cobalt Sediments
Makua AFB



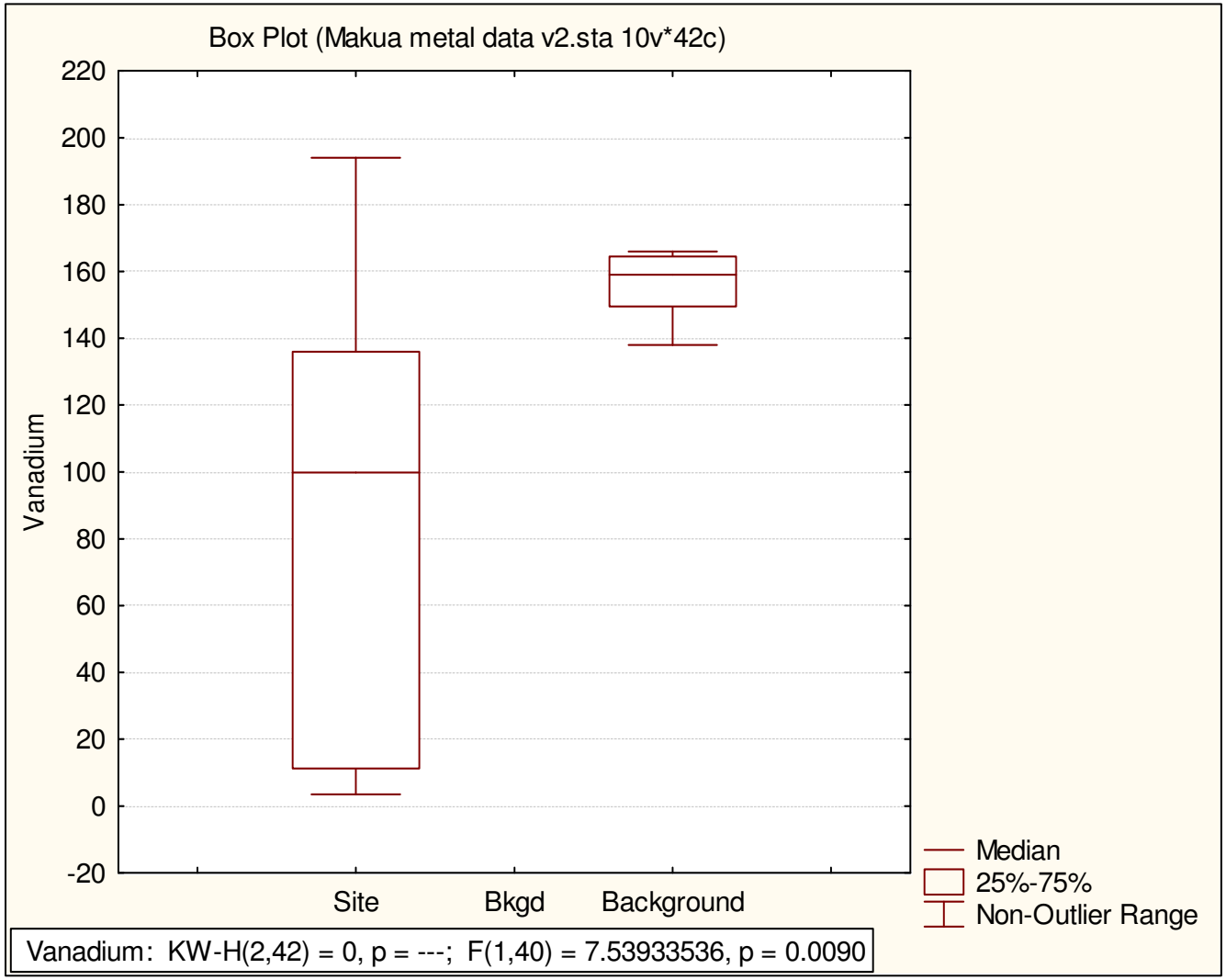
Appendix E-2.5
WRS Box Plot
Copper Sediments
Makua AFB



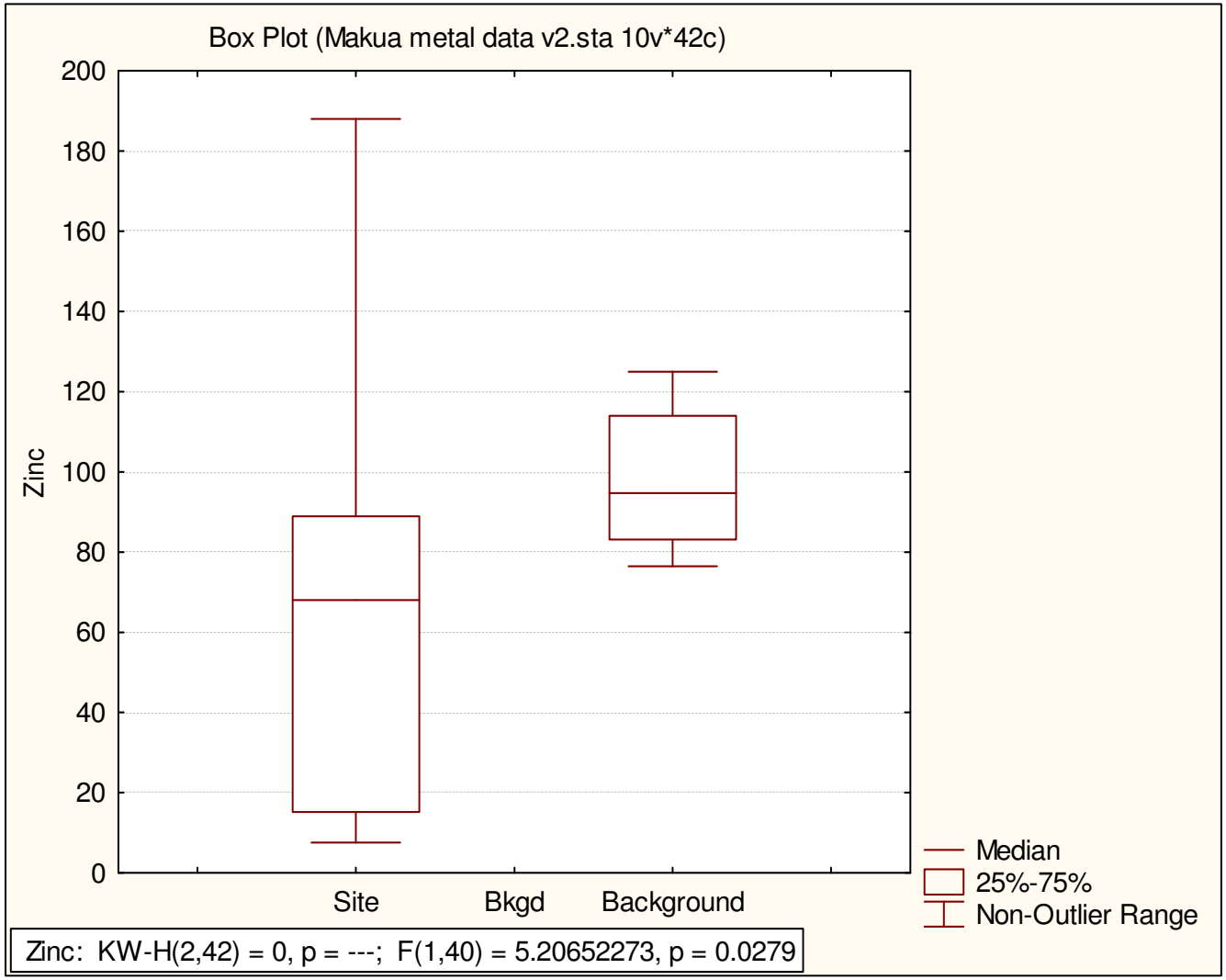
Appendix E-2.6
WRS Box Plot
Mercury Sediments
Makua AFB



Appendix E-2.7
WRS Box Plot
Vanadium Sediments
Makua AFB



Appendix E-2.8
WRS Box Plot
Zinc Sediments
Makua AFB



Appendix E.3
TCDD Equivalent Calculation
Fish Tissue
Makua AFB

Location ID	Field Sample ID	Parameter	Qualifier	Value	TEF	TCDD-Equiv
M1	1	1,2,3,4,6,7,8-HpCDD	U	7.23E-13		0
M1	1	1,2,3,4,6,7,8-HpCDF	U	6.8E-14		0
M1	1	1,2,3,4,7,8,9-HpCDF	U	9.3E-14		0
M1	1	1,2,3,4,7,8-HxCDD	U	4.3E-14		0
M1	1	1,2,3,4,7,8-HxCDF	U	5.6E-14		0
M1	1	1,2,3,6,7,8-HxCDD	U	3.7E-14		0
M1	1	1,2,3,6,7,8-HxCDF	U	5.3E-14		0
M1	1	1,2,3,7,8,9-HxCDD	U	4E-14		0
M1	1	1,2,3,7,8,9-HxCDF	U	7.1E-14		0
M1	1	1,2,3,7,8-PeCDD	U	6.1E-14		0
M1	1	1,2,3,7,8-PeCDF	U	4.1E-14		0
M1	1	2,3,4,6,7,8-HxCDF	U	5.9E-14		0
M1	1	2,3,4,7,8-PeCDF	U	4E-14		0
M1	1	2,3,7,8-TCDD	U	3.5E-14		0
M1	1	2,3,7,8-TCDF	U	5.5E-14		0
M1	1	OCDD	U	5.266E-12		0
M1	1	OCDF	U	1.51E-13		0
M1	1	**TCDD Equivalent**				0
M1	1b	1,2,3,4,6,7,8-HpCDD	U	7.74E-13		0
M1	1b	1,2,3,4,6,7,8-HpCDF	U	9.4E-14		0
M1	1b	1,2,3,4,7,8,9-HpCDF	U	1.28E-13		0
M1	1b	1,2,3,4,7,8-HxCDD	U	5.8E-14		0
M1	1b	1,2,3,4,7,8-HxCDF	U	4.2E-14		0
M1	1b	1,2,3,6,7,8-HxCDD	U	5E-14		0
M1	1b	1,2,3,6,7,8-HxCDF	U	4E-14		0
M1	1b	1,2,3,7,8,9-HxCDD	U	5.5E-14		0
M1	1b	1,2,3,7,8,9-HxCDF	U	5.3E-14		0
M1	1b	1,2,3,7,8-PeCDD	U	7.3E-14		0
M1	1b	1,2,3,7,8-PeCDF	U	4.6E-14		0
M1	1b	2,3,4,6,7,8-HxCDF	U	4.4E-14		0
M1	1b	2,3,4,7,8-PeCDF	U	4.4E-14		0
M1	1b	2,3,7,8-TCDD	U	3.6E-14		0
M1	1b	2,3,7,8-TCDF	U	4.9E-14		0
M1	1b	OCDD	U	7.479E-12		0
M1	1b	OCDF	U	6.6E-13		0
M2	1b	**TCDD Equivalent**				0
M1	3	1,2,3,4,6,7,8-HpCDD	U	5.47E-13		0
M1	3	1,2,3,4,6,7,8-HpCDF	U	8.5E-14		0
M1	3	1,2,3,4,7,8,9-HpCDF	U	1.17E-13		0
M1	3	1,2,3,4,7,8-HxCDD	U	6.8E-14		0
M1	3	1,2,3,4,7,8-HxCDF	U	5.6E-14		0
M1	3	1,2,3,6,7,8-HxCDD	U	5.8E-14		0
M1	3	1,2,3,6,7,8-HxCDF	U	5.2E-14		0
M1	3	1,2,3,7,8,9-HxCDD	U	6.4E-14		0
M1	3	1,2,3,7,8,9-HxCDF	U	7E-14		0
M1	3	1,2,3,7,8-PeCDD	J	1.422E-12	0.05	7.11E-14
M1	3	1,2,3,7,8-PeCDF	U	4.1E-14		0
M1	3	2,3,4,6,7,8-HxCDF	U	5.8E-14		0
M1	3	2,3,4,7,8-PeCDF	U	4E-14		0
M1	3	2,3,7,8-TCDD	U	4.2E-14		0
M1	3	2,3,7,8-TCDF	U	4.7E-14		0
M1	3	OCDD	U	4.114E-12		0
M1	3	OCDF	U	1.093E-12		0
M1	3	**TCDD Equivalent**				7.1E-14

M1	4	1,2,3,4,6,7,8-HpCDD	U	2.393E-12		0
M1	4	1,2,3,4,6,7,8-HpCDF	U	8.7E-14		0
M1	4	1,2,3,4,7,8,9-HpCDF	U	1.19E-13		0
M1	4	1,2,3,4,7,8-HxCDD	U	6.7E-14		0
M1	4	1,2,3,4,7,8-HxCDF	U	5.1E-14		0
M1	4	1,2,3,6,7,8-HxCDD	U	5.8E-14		0
M1	4	1,2,3,6,7,8-HxCDF	U	4.8E-14		0
M1	4	1,2,3,7,8,9-HxCDD	U	6.3E-14		0
M1	4	1,2,3,7,8,9-HxCDF	U	6.4E-14		0
M1	4	1,2,3,7,8-PeCDD	J	4.49E-13	1	4.49E-13
M1	4	1,2,3,7,8-PeCDF	U	6.6E-14		0
M1	4	2,3,4,6,7,8-HxCDF	U	5.3E-14		0
M1	4	2,3,4,7,8-PeCDF	U	6.4E-14		0
M1	4	2,3,7,8-TCDD	U	3.3E-14		0
M1	4	2,3,7,8-TCDF	U	5.6E-14		0
M1	4	OCDD	U	2.4168E-11		0
M1	4	OCDF	U	4.161E-12		0
M1	4	**TCDD Equivalent**				4.5E-13
M1	5	1,2,3,4,6,7,8-HpCDD	U	1.05E-12		0
M1	5	1,2,3,4,6,7,8-HpCDF	U	1.03E-13		0
M1	5	1,2,3,4,7,8,9-HpCDF	U	1.42E-13		0
M1	5	1,2,3,4,7,8-HxCDD	U	6.1E-14		0
M1	5	1,2,3,4,7,8-HxCDF	U	5.9E-14		0
M1	5	1,2,3,6,7,8-HxCDD	U	5.2E-14		0
M1	5	1,2,3,6,7,8-HxCDF	U	5.5E-14		0
M1	5	1,2,3,7,8,9-HxCDD	U	5.7E-14		0
M1	5	1,2,3,7,8,9-HxCDF	U	7.4E-14		0
M1	5	1,2,3,7,8-PeCDD	U	5.6E-14		0
M1	5	1,2,3,7,8-PeCDF	U	5.5E-14		0
M1	5	2,3,4,6,7,8-HxCDF	U	6.2E-14		0
M1	5	2,3,4,7,8-PeCDF	U	5.4E-14		0
M1	5	2,3,7,8-TCDD	U	4.2E-14		0
M1	5	2,3,7,8-TCDF	U	4.7E-14		0
M1	5	OCDD	U	8.795E-12		0
M1	5	OCDF	U	6.93E-13		0
M1	5	**TCDD Equivalent**				0
M2	10	1,2,3,4,6,7,8-HpCDD	U	6.99E-13		0
M2	10	1,2,3,4,6,7,8-HpCDF	U	8.2E-14		0
M2	10	1,2,3,4,7,8,9-HpCDF	U	1.15E-13		0
M2	10	1,2,3,4,7,8-HxCDD	U	6.5E-14		0
M2	10	1,2,3,4,7,8-HxCDF	U	3.2E-14		0
M2	10	1,2,3,6,7,8-HxCDD	U	6.3E-14		0
M2	10	1,2,3,6,7,8-HxCDF	U	3.4E-14		0
M2	10	1,2,3,7,8,9-HxCDD	U	6.2E-14		0
M2	10	1,2,3,7,8,9-HxCDF	U	4.2E-14		0
M2	10	1,2,3,7,8-PeCDD	U	6E-14		0
M2	10	1,2,3,7,8-PeCDF	U	4.5E-14		0
M2	10	2,3,4,6,7,8-HxCDF	U	3.6E-14		0
M2	10	2,3,4,7,8-PeCDF	U	4.4E-14		0
M2	10	2,3,7,8-TCDD	U	2.7E-14		0
M2	10	2,3,7,8-TCDF	U	9.76E-13		0
M2	10	OCDD	U	5.944E-12		0
M2	10	OCDF	J	5.49E-13	0.0001	5.49E-17
M2	10	**TCDD Equivalent**				5.5E-17

M2	2fd	1,2,3,4,6,7,8-HpCDD	U	1.7E-12		0
M2	2fd	1,2,3,4,6,7,8-HpCDF	U	1.3E-12		0
M2	2fd	1,2,3,4,7,8,9-HpCDF	U	4.3E-13		0
M2	2fd	1,2,3,4,7,8-HxCDD	U	5.4E-13		0
M2	2fd	1,2,3,4,7,8-HxCDF	U	5.1E-13		0
M2	2fd	1,2,3,6,7,8-HxCDD	U	5.2E-13		0
M2	2fd	1,2,3,6,7,8-HxCDF	U	3.7E-13		0
M2	2fd	1,2,3,7,8,9-HxCDD	U	5.1E-13		0
M2	2fd	1,2,3,7,8,9-HxCDF	U	4.5E-13		0
M2	2fd	1,2,3,7,8-PeCDD	U	7.9E-13		0
M2	2fd	1,2,3,7,8-PeCDF	U	4.9E-13		0
M2	2fd	2,3,4,6,7,8-HxCDF	U	4.1E-13		0
M2	2fd	2,3,4,7,8-PeCDF	U	4.9E-13		0
M2	2fd	2,3,7,8-TCDD	U	3.3E-13		0
M2	2fd	2,3,7,8-TCDF	J	5.9E-13	0.05	2.95E-14
M2	2fd	OCDD	J	8.7E-12	0.0001	8.7E-16
M2	2fd	OCDF	U	1.1E-12		0
M2	2fd	**TCDD Equivalent**				3.0E-14
M2	6	1,2,3,4,6,7,8-HpCDD	U	1.83E-13		0
M2	6	1,2,3,4,6,7,8-HpCDF	U	1.19E-13		0
M2	6	1,2,3,4,7,8,9-HpCDF	U	1.61E-13		0
M2	6	1,2,3,4,7,8-HxCDD	U	1.54E-13		0
M2	6	1,2,3,4,7,8-HxCDF	U	9.8E-14		0
M2	6	1,2,3,6,7,8-HxCDD	U	1.46E-13		0
M2	6	1,2,3,6,7,8-HxCDF	U	1.01E-13		0
M2	6	1,2,3,7,8,9-HxCDD	U	1.53E-13		0
M2	6	1,2,3,7,8,9-HxCDF	U	1.25E-13		0
M2	6	1,2,3,7,8-PeCDD	U	1.7E-13		0
M2	6	1,2,3,7,8-PeCDF	U	1.17E-13		0
M2	6	2,3,4,6,7,8-HxCDF	U	1.07E-13		0
M2	6	2,3,4,7,8-PeCDF	U	1.11E-13		0
M2	6	2,3,7,8-TCDD	U	3.66E-13		0
M2	6	2,3,7,8-TCDF	U	3.45E-13		0
M2	6	OCDD	U	1.999E-12		0
M2	6	OCDF	U	3.75E-13		0
M2	6	**TCDD Equivalent**				0
M2	7	1,2,3,4,6,7,8-HpCDD	J	5.31E-13	0.001	5.31E-16
M2	7	1,2,3,4,6,7,8-HpCDF	U	1.53E-13		0
M2	7	1,2,3,4,7,8,9-HpCDF	U	2.07E-13		0
M2	7	1,2,3,4,7,8-HxCDD	U	4.81E-13		0
M2	7	1,2,3,4,7,8-HxCDF	U	2.68E-13		0
M2	7	1,2,3,6,7,8-HxCDD	U	4.58E-13		0
M2	7	1,2,3,6,7,8-HxCDF	U	2.74E-13		0
M2	7	1,2,3,7,8,9-HxCDD	U	4.78E-13		0
M2	7	1,2,3,7,8,9-HxCDF	U	3.41E-13		0
M2	7	1,2,3,7,8-PeCDD	U	2.43E-13		0
M2	7	1,2,3,7,8-PeCDF	U	9.8E-14		0
M2	7	2,3,4,6,7,8-HxCDF	U	2.9E-13		0
M2	7	2,3,4,7,8-PeCDF	U	9.4E-14		0
M2	7	2,3,7,8-TCDD	U	2.4E-13		0
M2	7	2,3,7,8-TCDF	U	2.21E-13		0
M2	7	OCDD	U	4.848E-12		0
M2	7	OCDF	J	1.311E-12	0.0001	1.311E-16
M2	7	**TCDD Equivalent**				6.6E-16

M2	9	1,2,3,4,6,7,8-HpCDD	U	9.82E-13		0
M2	9	1,2,3,4,6,7,8-HpCDF	J	2.95E-13	0.01	2.95E-15
M2	9	1,2,3,4,7,8,9-HpCDF	U	1.14E-13		0
M2	9	1,2,3,4,7,8-HxCDD	U	5.3E-14		0
M2	9	1,2,3,4,7,8-HxCDF	U	4.6E-14		0
M2	9	1,2,3,6,7,8-HxCDD	U	5.1E-14		0
M2	9	1,2,3,6,7,8-HxCDF	U	4.8E-14		0
M2	9	1,2,3,7,8,9-HxCDD	U	5E-14		0
M2	9	1,2,3,7,8,9-HxCDF	U	6E-14		0
M2	9	1,2,3,7,8-PeCDD	J	1.756E-12	1	1.756E-12
M2	9	1,2,3,7,8-PeCDF	U	3E-14		0
M2	9	2,3,4,6,7,8-HxCDF	U	5.2E-14		0
M2	9	2,3,4,7,8-PeCDF	U	2.8E-14		0
M2	9	2,3,7,8-TCDD	U	3.1E-14		0
M2	9	2,3,7,8-TCDF	U	1.086E-12		0
M2	9	OCDD	U	6.609E-12		0
M2	9	OCDF	J	1.264E-12	0.0001	1.264E-16
M2	9	**TCDD Equivalent**				1.8E-12
M2	9afd and 10a Comp	1,2,3,4,6,7,8-HpCDD	U	1.5E-12		0
M2	9afd and 10a Comp	1,2,3,4,6,7,8-HpCDF	U	6.3E-13		0
M2	9afd and 10a Comp	1,2,3,4,7,8,9-HpCDF	U	4.9E-13		0
M2	9afd and 10a Comp	1,2,3,4,7,8-HxCDD	U	6.3E-13		0
M2	9afd and 10a Comp	1,2,3,4,7,8-HxCDF	U	3.4E-13		0
M2	9afd and 10a Comp	1,2,3,6,7,8-HxCDD	U	6.1E-13		0
M2	9afd and 10a Comp	1,2,3,6,7,8-HxCDF	U	3.2E-13		0
M2	9afd and 10a Comp	1,2,3,7,8,9-HxCDD	U	5.8E-13		0
M2	9afd and 10a Comp	1,2,3,7,8,9-HxCDF	U	4E-13		0
M2	9afd and 10a Comp	1,2,3,7,8-PeCDD	U	7.9E-13		0
M2	9afd and 10a Comp	1,2,3,7,8-PeCDF	U	6.1E-13		0
M2	9afd and 10a Comp	2,3,4,6,7,8-HxCDF	U	3.6E-13		0
M2	9afd and 10a Comp	2,3,4,7,8-PeCDF	U	6E-13		0
M2	9afd and 10a Comp	2,3,7,8-TCDD	U	3.9E-13		0
M2	9afd and 10a Comp	2,3,7,8-TCDF	U	2.6E-13		0
M2	9afd and 10a Comp	OCDD	J	6.9E-12	0.0001	6.9E-16
M2	9afd and 10a Comp	OCDF	U	8.2E-13		0
M2	9afd and 10a Comp	**TCDD Equivalent**				6.9E-16
M2	Comp 8,8a	1,2,3,4,6,7,8-HpCDD	U	1.636E-12		0
M2	Comp 8,8a	1,2,3,4,6,7,8-HpCDF	U	7.66E-13		0
M2	Comp 8,8a	1,2,3,4,7,8,9-HpCDF	U	1.08E-13		0
M2	Comp 8,8a	1,2,3,4,7,8-HxCDD	U	5.2E-14		0
M2	Comp 8,8a	1,2,3,4,7,8-HxCDF	U	3.1E-14		0
M2	Comp 8,8a	1,2,3,6,7,8-HxCDD	U	5E-14		0
M2	Comp 8,8a	1,2,3,6,7,8-HxCDF	U	3.2E-14		0
M2	Comp 8,8a	1,2,3,7,8,9-HxCDD	U	5E-14		0
M2	Comp 8,8a	1,2,3,7,8,9-HxCDF	U	3.9E-14		0
M2	Comp 8,8a	1,2,3,7,8-PeCDD	U	5E-14		0
M2	Comp 8,8a	1,2,3,7,8-PeCDF	U	3.5E-14		0
M2	Comp 8,8a	2,3,4,6,7,8-HxCDF	U	3.4E-14		0
M2	Comp 8,8a	2,3,4,7,8-PeCDF	U	3.4E-14		0
M2	Comp 8,8a	2,3,7,8-TCDD	U	1.6E-14		0
M2	Comp 8,8a	2,3,7,8-TCDF	U	3.2E-14		0
M2	Comp 8,8a	OCDD	U	1.2396E-11		0
M2	Comp 8,8a	OCDF	U	1.505E-12		0
M2	Comp 8,8a	**TCDD Equivalent**				0

M3	12	1,2,3,4,6,7,8-HpCDD	U	8.62E-13		0
M3	12	1,2,3,4,6,7,8-HpCDF	J	2.07E-13	0.01	2.07E-15
M3	12	1,2,3,4,7,8,9-HpCDF	U	1.23E-13		0
M3	12	1,2,3,4,7,8-HxCDD	U	6.8E-14		0
M3	12	1,2,3,4,7,8-HxCDF	U	5.3E-14		0
M3	12	1,2,3,6,7,8-HxCDD	U	6.6E-14		0
M3	12	1,2,3,6,7,8-HxCDF	U	5.5E-14		0
M3	12	1,2,3,7,8,9-HxCDD	U	6.5E-14		0
M3	12	1,2,3,7,8,9-HxCDF	U	6.8E-14		0
M3	12	1,2,3,7,8-PeCDD	U	6.1E-14		0
M3	12	1,2,3,7,8-PeCDF	U	4.6E-14		0
M3	12	2,3,4,6,7,8-HxCDF	U	5.9E-14		0
M3	12	2,3,4,7,8-PeCDF	U	4.4E-14		0
M3	12	2,3,7,8-TCDD	U	2.4E-14		0
M3	12	2,3,7,8-TCDF	U	4.5E-14		0
M3	12	OCDD	U	6.191E-12		0
M3	12	OCDF	J	6.49E-13	0.0001	6.49E-17
M3	12	**TCDD Equivalent**				2.1E-15
M3	13	1,2,3,4,6,7,8-HpCDD	U	8.96E-13		0
M3	13	1,2,3,4,6,7,8-HpCDF	J	1.78E-13	0.01	1.78E-15
M3	13	1,2,3,4,7,8,9-HpCDF	U	1.38E-13		0
M3	13	1,2,3,4,7,8-HxCDD	U	5.6E-14		0
M3	13	1,2,3,4,7,8-HxCDF	U	5E-14		0
M3	13	1,2,3,6,7,8-HxCDD	U	5.4E-14		0
M3	13	1,2,3,6,7,8-HxCDF	U	5.3E-14		0
M3	13	1,2,3,7,8,9-HxCDD	U	5.3E-14		0
M3	13	1,2,3,7,8,9-HxCDF	U	6.5E-14		0
M3	13	1,2,3,7,8-PeCDD	U	5.3E-14		0
M3	13	1,2,3,7,8-PeCDF	U	2.6E-14		0
M3	13	2,3,4,6,7,8-HxCDF	U	5.6E-14		0
M3	13	2,3,4,7,8-PeCDF	U	2.5E-14		0
M3	13	2,3,7,8-TCDD	U	3.3E-14		0
M3	13	2,3,7,8-TCDF	U	5.8E-14		0
M3	13	OCDD	U	6.76E-12		0
M3	13	OCDF	J	6.44E-13	0.0001	6.44E-17
M3	13	**TCDD Equivalent**				1.8E-15
M3	14	1,2,3,4,6,7,8-HpCDD	U	1.193E-12		0
M3	14	1,2,3,4,6,7,8-HpCDF	J	3.71E-13	0.01	3.71E-15
M3	14	1,2,3,4,7,8,9-HpCDF	U	1.26E-13		0
M3	14	1,2,3,4,7,8-HxCDD	U	5.2E-14		0
M3	14	1,2,3,4,7,8-HxCDF	U	3.8E-14		0
M3	14	1,2,3,6,7,8-HxCDD	U	5E-14		0
M3	14	1,2,3,6,7,8-HxCDF	U	4E-14		0
M3	14	1,2,3,7,8,9-HxCDD	U	4.9E-14		0
M3	14	1,2,3,7,8,9-HxCDF	U	4.9E-14		0
M3	14	1,2,3,7,8-PeCDD	U	6.1E-14		0
M3	14	1,2,3,7,8-PeCDF	U	4E-14		0
M3	14	2,3,4,6,7,8-HxCDF	U	4.2E-14		0
M3	14	2,3,4,7,8-PeCDF	U	3.9E-14		0
M3	14	2,3,7,8-TCDD	U	3.4E-14		0
M3	14	2,3,7,8-TCDF	U	3.8E-14		0
M3	14	OCDD	U	9.246E-12		0
M3	14	OCDF	J	8.78E-13	0.0001	8.78E-17
M3	14	**TCDD Equivalent**				3.8E-15

NW1	NW1fd	1,2,3,4,6,7,8-HpCDD	U	8.2E-13	0
NW1	NW1fd	1,2,3,4,6,7,8-HpCDF	U	1.2E-12	0
NW1	NW1fd	1,2,3,4,7,8,9-HpCDF	U	4.4E-13	0
NW1	NW1fd	1,2,3,4,7,8-HxCDD	U	4.6E-13	0
NW1	NW1fd	1,2,3,4,7,8-HxCDF	U	3.6E-13	0
NW1	NW1fd	1,2,3,6,7,8-HxCDD	U	4.4E-13	0
NW1	NW1fd	1,2,3,6,7,8-HxCDF	U	3.4E-13	0
NW1	NW1fd	1,2,3,7,8,9-HxCDD	U	4.3E-13	0
NW1	NW1fd	1,2,3,7,8,9-HxCDF	U	4.1E-13	0
NW1	NW1fd	1,2,3,7,8-PeCDD	U	7.7E-13	0
NW1	NW1fd	1,2,3,7,8-PeCDF	U	5.1E-13	0
NW1	NW1fd	2,3,4,6,7,8-HxCDF	U	3.7E-13	0
NW1	NW1fd	2,3,4,7,8-PeCDF	U	5.1E-13	0
NW1	NW1fd	2,3,7,8-TCDD	U	4.1E-13	0
NW1	NW1fd	2,3,7,8-TCDF	U	4.1E-13	0
NW1	NW1fd	OCDD	U	3.3E-12	0
NW1	NW1fd	OCDF	U	8.7E-13	0
NW1	NW1fd	**TCDD Equivalent**			0
NW1	NW2	1,2,3,4,6,7,8-HpCDD	U	1.58E-13	0
NW1	NW2	1,2,3,4,6,7,8-HpCDF	U	9.2E-14	0
NW1	NW2	1,2,3,4,7,8,9-HpCDF	U	1.29E-13	0
NW1	NW2	1,2,3,4,7,8-HxCDD	U	7.9E-14	0
NW1	NW2	1,2,3,4,7,8-HxCDF	U	4.3E-14	0
NW1	NW2	1,2,3,6,7,8-HxCDD	U	7.6E-14	0
NW1	NW2	1,2,3,6,7,8-HxCDF	U	4.5E-14	0
NW1	NW2	1,2,3,7,8,9-HxCDD	U	7.5E-14	0
NW1	NW2	1,2,3,7,8,9-HxCDF	U	5.5E-14	0
NW1	NW2	1,2,3,7,8-PeCDD	U	5.7E-14	0
NW1	NW2	1,2,3,7,8-PeCDF	U	4.5E-14	0
NW1	NW2	2,3,4,6,7,8-HxCDF	U	4.8E-14	0
NW1	NW2	2,3,4,7,8-PeCDF	U	4.3E-14	0
NW1	NW2	2,3,7,8-TCDD	U	3E-14	0
NW1	NW2	2,3,7,8-TCDF	U	5.7E-14	0
NW1	NW2	OCDD	U	1.201E-12	0
NW1	NW2	OCDF	U	1.96E-13	0
NW1	NW2	**TCDD Equivalent**			0
NW1	NW3	1,2,3,4,6,7,8-HpCDD	U	4.1E-14	0
NW1	NW3	1,2,3,4,6,7,8-HpCDF	U	6.7E-14	0
NW1	NW3	1,2,3,4,7,8,9-HpCDF	U	9.4E-14	0
NW1	NW3	1,2,3,4,7,8-HxCDD	U	7.8E-14	0
NW1	NW3	1,2,3,4,7,8-HxCDF	U	3.8E-14	0
NW1	NW3	1,2,3,6,7,8-HxCDD	U	7.5E-14	0
NW1	NW3	1,2,3,6,7,8-HxCDF	U	4E-14	0
NW1	NW3	1,2,3,7,8,9-HxCDD	U	7.4E-14	0
NW1	NW3	1,2,3,7,8,9-HxCDF	U	4.9E-14	0
NW1	NW3	1,2,3,7,8-PeCDD	U	6.9E-14	0
NW1	NW3	1,2,3,7,8-PeCDF	U	3.6E-14	0
NW1	NW3	2,3,4,6,7,8-HxCDF	U	4.3E-14	0
NW1	NW3	2,3,4,7,8-PeCDF	U	3.5E-14	0
NW1	NW3	2,3,7,8-TCDD	U	2.6E-14	0
NW1	NW3	2,3,7,8-TCDF	U	4.2E-14	0
NW1	NW3	OCDD	U	1.505E-12	0
NW1	NW3	OCDF	U	1.41E-13	0
NW1	NW3	**TCDD Equivalent**			0

NW1	NW4	1,2,3,4,6,7,8-HpCDD	U	1.43E-13	0
NW1	NW4	1,2,3,4,6,7,8-HpCDF	U	6.6E-14	0
NW1	NW4	1,2,3,4,7,8,9-HpCDF	U	9.2E-14	0
NW1	NW4	1,2,3,4,7,8-HxCDD	U	6E-14	0
NW1	NW4	1,2,3,4,7,8-HxCDF	U	3.6E-14	0
NW1	NW4	1,2,3,6,7,8-HxCDD	U	5.7E-14	0
NW1	NW4	1,2,3,6,7,8-HxCDF	U	3.8E-14	0
NW1	NW4	1,2,3,7,8,9-HxCDD	U	5.7E-14	0
NW1	NW4	1,2,3,7,8,9-HxCDF	U	4.6E-14	0
NW1	NW4	1,2,3,7,8-PeCDD	U	4E-14	0
NW1	NW4	1,2,3,7,8-PeCDF	U	3.3E-14	0
NW1	NW4	2,3,4,6,7,8-HxCDF	U	4E-14	0
NW1	NW4	2,3,4,7,8-PeCDF	U	3.2E-14	0
NW1	NW4	2,3,7,8-TCDD	U	2.2E-14	0
NW1	NW4	2,3,7,8-TCDF	U	3.4E-14	0
NW1	NW4	OCDD	U	1.138E-12	0
NW1	NW4	OCDF	U	1.4E-13	0
NW1	NW4	**TCDD Equivalent**			0
NW1	NW5	1,2,3,4,6,7,8-HpCDD	U	6E-14	0
NW1	NW5	1,2,3,4,6,7,8-HpCDF	U	7.1E-14	0
NW1	NW5	1,2,3,4,7,8,9-HpCDF	U	1E-13	0
NW1	NW5	1,2,3,4,7,8-HxCDD	U	9.5E-14	0
NW1	NW5	1,2,3,4,7,8-HxCDF	U	3.2E-14	0
NW1	NW5	1,2,3,6,7,8-HxCDD	U	9.1E-14	0
NW1	NW5	1,2,3,6,7,8-HxCDF	U	3.3E-14	0
NW1	NW5	1,2,3,7,8,9-HxCDD	U	9E-14	0
NW1	NW5	1,2,3,7,8,9-HxCDF	U	4.1E-14	0
NW1	NW5	1,2,3,7,8-PeCDD	U	6.5E-14	0
NW1	NW5	1,2,3,7,8-PeCDF	U	5E-14	0
NW1	NW5	2,3,4,6,7,8-HxCDF	U	3.5E-14	0
NW1	NW5	2,3,4,7,8-PeCDF	U	4.8E-14	0
NW1	NW5	2,3,7,8-TCDD	U	3.1E-14	0
NW1	NW5	2,3,7,8-TCDF	U	5.5E-14	0
NW1	NW5	OCDD	U	1.236E-12	0
NW1	NW5	OCDF	U	1.61E-13	0
NW1	NW5	**TCDD Equivalent**			0
NW2	NW10	1,2,3,4,6,7,8-HpCDD	U	2.46E-13	0
NW2	NW10	1,2,3,4,6,7,8-HpCDF	U	2.87E-13	0
NW2	NW10	1,2,3,4,7,8,9-HpCDF	U	9.3E-14	0
NW2	NW10	1,2,3,4,7,8-HxCDD	U	7.7E-14	0
NW2	NW10	1,2,3,4,7,8-HxCDF	U	2.7E-14	0
NW2	NW10	1,2,3,6,7,8-HxCDD	U	7.4E-14	0
NW2	NW10	1,2,3,6,7,8-HxCDF	U	2.8E-14	0
NW2	NW10	1,2,3,7,8,9-HxCDD	U	7.3E-14	0
NW2	NW10	1,2,3,7,8,9-HxCDF	U	3.5E-14	0
NW2	NW10	1,2,3,7,8-PeCDD	U	6.5E-14	0
NW2	NW10	1,2,3,7,8-PeCDF	U	6.6E-14	0
NW2	NW10	2,3,4,6,7,8-HxCDF	U	3E-14	0
NW2	NW10	2,3,4,7,8-PeCDF	U	6.4E-14	0
NW2	NW10	2,3,7,8-TCDD	U	2.3E-14	0
NW2	NW10	2,3,7,8-TCDF	U	4E-14	0
NW2	NW10	OCDD	U	2.195E-12	0
NW2	NW10	OCDF	U	1.08E-13	0
NW2	NW10	**TCDD Equivalent**			0

NW2	NW2fd	1,2,3,4,6,7,8-HpCDD	U	4.8E-13		0
NW2	NW2fd	1,2,3,4,6,7,8-HpCDF	U	4.8E-13		0
NW2	NW2fd	1,2,3,4,7,8,9-HpCDF	U	4.1E-13		0
NW2	NW2fd	1,2,3,4,7,8-HxCDD	U	4.9E-13		0
NW2	NW2fd	1,2,3,4,7,8-HxCDF	U	3.2E-13		0
NW2	NW2fd	1,2,3,6,7,8-HxCDD	U	4.8E-13		0
NW2	NW2fd	1,2,3,6,7,8-HxCDF	U	3E-13		0
NW2	NW2fd	1,2,3,7,8,9-HxCDD	U	4.6E-13		0
NW2	NW2fd	1,2,3,7,8,9-HxCDF	U	3.7E-13		0
NW2	NW2fd	1,2,3,7,8-PeCDD	U	6.9E-13		0
NW2	NW2fd	1,2,3,7,8-PeCDF	U	4.8E-13		0
NW2	NW2fd	2,3,4,6,7,8-HxCDF	U	3.4E-13		0
NW2	NW2fd	2,3,4,7,8-PeCDF	U	4.7E-13		0
NW2	NW2fd	2,3,7,8-TCDD	U	3.4E-13		0
NW2	NW2fd	2,3,7,8-TCDF	U	2.2E-13		0
NW2	NW2fd	OCDD	U	1.3E-12		0
NW2	NW2fd	OCDF	U	6.8E-13		0
NW2	NW2fd	**TCDD Equivalent**				0
NW2	NW6	1,2,3,4,6,7,8-HpCDD	U	1.55E-13		0
NW2	NW6	1,2,3,4,6,7,8-HpCDF	U	1.22E-13		0
NW2	NW6	1,2,3,4,7,8,9-HpCDF	U	1.65E-13		0
NW2	NW6	1,2,3,4,7,8-HxCDD	U	1.3E-13		0
NW2	NW6	1,2,3,4,7,8-HxCDF	U	8.4E-14		0
NW2	NW6	1,2,3,6,7,8-HxCDD	U	1.24E-13		0
NW2	NW6	1,2,3,6,7,8-HxCDF	U	8.6E-14		0
NW2	NW6	1,2,3,7,8,9-HxCDD	U	1.29E-13		0
NW2	NW6	1,2,3,7,8,9-HxCDF	U	1.07E-13		0
NW2	NW6	1,2,3,7,8-PeCDD	U	3.64E-13		0
NW2	NW6	1,2,3,7,8-PeCDF	U	2.42E-13		0
NW2	NW6	2,3,4,6,7,8-HxCDF	U	9.1E-14		0
NW2	NW6	2,3,4,7,8-PeCDF	U	2.31E-13		0
NW2	NW6	2,3,7,8-TCDD	U	3.24E-13		0
NW2	NW6	2,3,7,8-TCDF	U	2.9E-13		0
NW2	NW6	OCDD	U	1.011E-12		0
NW2	NW6	OCDF	U	5.83E-13		0
NW2	NW6	**TCDD Equivalent**				0
NW2	NW7	1,2,3,4,6,7,8-HpCDD	J	7.71E-13	0.001	7.71E-16
NW2	NW7	1,2,3,4,6,7,8-HpCDF	U	2.64E-13		0
NW2	NW7	1,2,3,4,7,8,9-HpCDF	U	3.56E-13		0
NW2	NW7	1,2,3,4,7,8-HxCDD	U	1.7E-13		0
NW2	NW7	1,2,3,4,7,8-HxCDF	U	8.9E-14		0
NW2	NW7	1,2,3,6,7,8-HxCDD	U	1.62E-13		0
NW2	NW7	1,2,3,6,7,8-HxCDF	U	9.1E-14		0
NW2	NW7	1,2,3,7,8,9-HxCDD	U	1.69E-13		0
NW2	NW7	1,2,3,7,8,9-HxCDF	U	1.13E-13		0
NW2	NW7	1,2,3,7,8-PeCDD	U	2.09E-13		0
NW2	NW7	1,2,3,7,8-PeCDF	U	1.12E-13		0
NW2	NW7	2,3,4,6,7,8-HxCDF	U	9.6E-14		0
NW2	NW7	2,3,4,7,8-PeCDF	U	1.07E-13		0
NW2	NW7	2,3,7,8-TCDD	U	1.5E-13		0
NW2	NW7	2,3,7,8-TCDF	U	1.44E-13		0
NW2	NW7	OCDD	U	5.225E-12		0
NW2	NW7	OCDF	U	4.33E-13		0
NW2	NW7	**TCDD Equivalent**				7.7E-16

NW2	NW8	1,2,3,4,6,7,8-HpCDD	J	2.05E-13	0.001	2.05E-16
NW2	NW8	1,2,3,4,6,7,8-HpCDF	U	5.7E-14		0
NW2	NW8	1,2,3,4,7,8,9-HpCDF	U	7.7E-14		0
NW2	NW8	1,2,3,4,7,8-HxCDD	U	7.3E-14		0
NW2	NW8	1,2,3,4,7,8-HxCDF	U	5.2E-14		0
NW2	NW8	1,2,3,6,7,8-HxCDD	U	7E-14		0
NW2	NW8	1,2,3,6,7,8-HxCDF	U	5.3E-14		0
NW2	NW8	1,2,3,7,8,9-HxCDD	U	7.3E-14		0
NW2	NW8	1,2,3,7,8,9-HxCDF	U	6.6E-14		0
NW2	NW8	1,2,3,7,8-PeCDD	U	7.6E-14		0
NW2	NW8	1,2,3,7,8-PeCDF	U	4.9E-14		0
NW2	NW8	2,3,4,6,7,8-HxCDF	U	5.6E-14		0
NW2	NW8	2,3,4,7,8-PeCDF	U	4.7E-14		0
NW2	NW8	2,3,7,8-TCDD	U	9.6E-14		0
NW2	NW8	2,3,7,8-TCDF	U	7.7E-14		0
NW2	NW8	OCDD	U	1.18E-12		0
NW2	NW8	OCDF	U	2.23E-13		0
NW2	NW8	**TCDD Equivalent**				2.1E-16
NW2	NW9	1,2,3,4,6,7,8-HpCDD	U	5.76E-13		0
NW2	NW9	1,2,3,4,6,7,8-HpCDF	U	4.98E-13		0
NW2	NW9	1,2,3,4,7,8,9-HpCDF	U	7.4E-14		0
NW2	NW9	1,2,3,4,7,8-HxCDD	U	4.9E-14		0
NW2	NW9	1,2,3,4,7,8-HxCDF	U	3.9E-14		0
NW2	NW9	1,2,3,6,7,8-HxCDD	U	4.7E-14		0
NW2	NW9	1,2,3,6,7,8-HxCDF	U	4.1E-14		0
NW2	NW9	1,2,3,7,8,9-HxCDD	U	4.7E-14		0
NW2	NW9	1,2,3,7,8,9-HxCDF	U	5E-14		0
NW2	NW9	1,2,3,7,8-PeCDD	J	1.72E-13	1	1.72E-13
NW2	NW9	1,2,3,7,8-PeCDF	U	5.4E-14		0
NW2	NW9	2,3,4,6,7,8-HxCDF	U	4.4E-14		0
NW2	NW9	2,3,4,7,8-PeCDF	U	5.2E-14		0
NW2	NW9	2,3,7,8-TCDD	U	1.8E-14		0
NW2	NW9	2,3,7,8-TCDF	U	6.83E-13		0
NW2	NW9	OCDD	U	4.734E-12		0
NW2	NW9	OCDF	U	6.74E-13		0
NW2	NW9	**TCDD Equivalent**				1.7E-13

Appendix E.4
Fish Tissue-Based Toxicity Reference Values

	NOEC					LOEC					
Chemical	**Test Species**	**Tissue**	**NOEC (mg/kg dry wt.)[a]**	**Type**	**Notes**	**Test Species**	**Tissue**	**LOEC (mg/kg dry wt.)[a]**	**Type**	**Notes**	**Reference**
Metals											
Aluminum	Rainbow trout, *Onchorhyncus mykiss* (FW)	Whole body less gut	42.7	NOEC - Survival	Aluminum sulphate	Atlantic salmon, *Salmo salar* (FW)	Whole body	100	LOEC - Reduced survival	Aluminum chloride; alevin life stage	Jarvinen and Ankley, 1999
Antimony	Rainbow trout, *Onchorhyncus mykiss* (FW)	Whole body	25	NOEC - Survival	Antimony potassium tartrate	Rainbow trout, *Onchorhyncus mykiss* (FW)	Whole body	45	LOEC - Reduced survival 50%	Antimony potassium tartrate	Jarvinen and Ankley, 1999
Arsenic	Rainbow trout, *Onchorhyncus mykiss* (FW)	Whole body	10	NOEC - Survival	Sodium arsenate	Rainbow trout, *Onchorhyncus mykiss* (FW)	Whole body	15	LOEC - Reduced survival 50%	Sodium arsenate	Jarvinen and Ankley, 1999
Cadmium	Perch, *Perca fluviatilis (FW)*	Whole body	0.375	NOEC - Survival	Cadmium nitrate	Brook trout, *Salvelinus fontinalis* (FW)	Whole body	0.70	LOEC - Reduced survival 20%	Calcium chloride	Jarvinen and Ankley, 1999
Chromium	Rainbow trout, *Onchorhyncus mykiss* (FW)	Muscle	2.9	NOEC - Survival	Potassium dichromate	-	-	-	-	-	Jarvinen and Ankley, 1999
Copper	Stone loach, *Noemacheilus barbatulus* (FW)	Muscle	5.0	NOEC - Survival	Copper sulfate	Stone loach, *Noemacheilus barbatulus* (FW)	Muscle	8.0	LOEC - Reduced survival 80-100%	Copper sulfate	Jarvinen and Ankley, 1999
Lead	Brook trout, *Salvelinus fontinalis* (FW)	Whole body	13	NOEC - Growth	Lead nitrate	Brook trout, *Salvelinus fontinalis* (FW)	Whole body	20	LOEC - Reduced growth	Lead nitrate	Jarvinen and Ankley, 1999
Mercury	Multiple species	Whole body	15	NOEC - Behavioral, reproductive, physiological effects		Multiple species	Whole body	25	LOEC - Behavioral, reproductive, physiological effects		Weiner and Spry, 1996
Silver	Bluegill, *Lepomis macrochirus* (FW)	Whole body	0.30	NOEC - Survival, growth	Silver nitrate	-	-	-	-	-	Jarvinen and Ankley, 1999
Selenium	Bluegill, *Lepomis macrochirus* (FW)	Whole body	3.96	NOEC - Mortality (estimated)	Uncertainty factor of 10 was applied to LOEC to estimate a NOEC.	Bluegill, *Lepomis macrochirus* (FW)	Whole body	39.6	LOEC - Mortality		U.S. EPA, 2004b
Vanadium	Rainbow trout, *Onchorhyncus mykiss* (FW)	Carcass	0.10	NOEC - Growth	Sodium orthovanadate	Rainbow trout, *Onchorhyncus mykiss* (FW)	Carcass	2.1	LOEC - Reduced growth	Sodium orthovanadate	Jarvinen and Ankley, 1999
Zinc	Dogfish, *Scyliorhinus canicula* (SW)	Muscle	57.0	NOEC - Survival	Zinc sulfate	Dogfish, *Scyliorhinus canicula* (SW)	Muscle	68.0	LOEC - Reduced survival; immobilized	Zinc sulfate	Jarvinen and Ankley, 1999
Pesticides											
Aldrin	Rainbow trout, *Onchorhyncus mykiss* (FW)	Whole body	10.7	NOEC - Survival, growth	Based on surrogate TRVs for dieldrin.	Rainbow trout, *Onchorhyncus mykiss* (FW)	Whole body	28.3	LOEC - Reduced survival 50%	Based on surrogate TRVs for dieldrin.	Jarvinen and Ankley, 1999
alpha-BHC	Rainbow trout, *Onchorhyncus mykiss* (FW)	Muscle	210	NOEC - Survival, growth		Guppy, *Poecilia reticulata* (FW)	Whole body	850	LOEC - Reduced survival/ immobilization		Jarvinen and Ankley, 1999
beta-BHC	Pinfish, *Lagodon rhomboides* (SW)	Whole body	24.3	NOEC - Survival (estimated)	Based on technical grade BHC. Uncertainty factor of 10 was applied to LOEC to estimate a NOEC.	Pinfish, *Lagodon rhomboides* (SW)	Whole body	243	LOEC - Reduced survival 50%	Based on technical grade BHC.	Jarvinen and Ankley, 1999

delta-BHC	Pinfish, *Lagodon rhomboides* (SW)	Whole body	24.3	NOEC - Survival (estimated)	Based on technical grade BHC. Uncertainty factor of 10 was applied to LOEC to estimate a NOEC.	Pinfish, *Lagodon rhomboides* (SW)	Whole body	243	LOEC - Reduced survival 50%	Based on technical grade BHC.	Jarvinen and Ankley, 1999
gamma-BHC	Gudgeon, *Gobio gobio* (FW)	Muscle	0.065	NOEC - Survival		Gudgeon, *Gobio gobio* (FW)	Muscle	5.35	LOEC - Reduced survival 50%		Jarvinen and Ankley, 1999
4,4'-DDT	Mosquito fish, *Gambusia affinis* (FW)	Whole body	13.3	NOEC - Survival (estimated)	Uncertainty factor of 10 was applied to LOEC to estimate a NOEC	Mosquito fish, *Gambusia affinis* (FW)	Whole body	133	LOEC - Reduced survival 50%		Jarvinen and Ankley, 1999
Heptachlor	Spot, *Leiostomus xanthurus* (SW)	Whole body	27	NOEC - Survival	Technical grade	Spot, *Leiostomus xanthurus* (SW)	Whole body	57.5	LOEC - Reduced survival		Jarvinen and Ankley, 1999
Dioxins and Furans											
2,3,7,8-TCDD	Rainbow trout, *Onchorhyncus mykiss* (FW)	Muscle	0.00049	NOEC - Survival (estimated)	Uncertainty factor of 10 was applied to LOEC to estimate a NOEC	Rainbow trout, *Onchorhyncus mykiss* (FW)	Muscle	0.0049	LOEC - Reduced survival 45%		Jarvinen and Ankley, 1999

Definitions:

NOEC	No Observable Effect Concentration
LOEC	Lowest Observable Effect Concentration
mg/kg	Milligrams per kilogram

Notes:

[a]Tissue concentrations were converted from wet weight to dry weight assuming a moisture content of 80 percent (Stephen *et al*., 1985).
A dash indicates the absence of an applicable LOEC.

APPENDIX F
RESPONSE TO COMMENTS TO MAKUA DRAFT MARINE RESOURCES STUDY

Comments to the draft Marine Resources Study were provided to the Army both orally and in writing. Oral comments were received by the Army during the Public Meeting, held on February 24th, 2007. Formal written comments were received by the Army through the duration of the comment period, which ended on April 19th. This appendix presents the comments received by the Army and the Army's responses to those comments.

Formal written comments were provided by Mr. Doug Henkin, Dr. Jeffrey Foran and Drs. Jack Rensel and Ralph Elston. A variety of people provided oral comments during the public meeting. Both the written comments and the oral comments contained a large amount of additional text and commentary in addition to specific comments related to the draft Marine Resources Study. The Army has isolated the specific comments related to the draft Marine Resources Study, and has provided responses in a comment-response format on the following pages. The comment response format lists the comments in the order they were provided, and identifies the page, paragraph, and line the comment came from. In the case of the oral comments, the comment-response format also identifies the individual making the comment. The entire text of both the formal written comments and the transcript of the public meeting are also included in this appendix, following the responses to comments.

Responses to comments on the EIS are provided in Appendix K.

RESPONSE TO COMMENTS

RE: MAKUA MILITARY RESERVATION DRAFT ENVIRONMENTAL IMPACT STATEMENT, MR. DOUG HENKIN, APRIL 19, 2007

1. **Comment:** **Page 1, Paragraph 3, Line 1: <u>Shellfish and Other Non-Fish, Non-Limu Marine Resources</u>: The Marine Resources Study's failure to examine whether shellfish or other non-fish, non-limu marine resources near Makua Beach and in the muliwai are contaminated violates the terms of the 2007 Order, which expressly requires that shellfish and marine resources other than fish and limu be tested. 2007 Order ¶ 6. As discussed on the enclosed expert reviews, as well as in expert comments on the draft SAP, testing shellfish and other benthic or demersal invertebrates is extremely important to assess potential contamination of marine resources since these species have continual contact with sediments that may contain contaminants from activities at MMR.**

Response: The language in the 2007 order states that "As part of the preparation of the EIS for military training activities at MMR, Defendants shall complete one or more studies to determine whether fish, limu, shellfish, and other marine resources near Makua Beach and in the muliwai on which area residents rely for subsistence are contaminated by substances associated with the proposed training activities at MMR." There is nothing in this language that expressly requires that shellfish be tested, and as such, the Army is not in violation of the 2007 Order.

The results of the Marine Resources Study (MRS) indicate that relatively low levels of contamination are present in fish and limu in the Makua-area muliwai and nearshore areas, and that these levels are approximately the same as the levels detected in fish from background locations. The risk to subsistence fishermen from consuming the fish is below the levels used by USEPA for fish advisories. Furthermore, the study concludes that these contaminants are likely not coming from the MMR, because many of the chemicals are ubiquitous in the environment, and may be attributable to many different sources. Given that the fish are likely not contaminated by substances associated with the proposed training activities at MMR, that there is very little interchange between the muliwai where such substances might accumulate and the near-shore area which provides the habitat for the shellfish on which area residents rely, that any such transport of chemicals from the muliwai to the nearshore area would result in significant dilution of the chemicals, it is likely that the shellfish are not contaminated by substances associated with the proposed training activities at MMR.

Despite the conclusion that the shellfish are likely not contaminated from activities at MMR, field staff did attempt to collect shellfish and benthic invertebrates, including crabs and sea urchins, during the MRS. However, the selected method (passive traps) was not successful in capturing crabs. Additionally, because of the large number of analytes included in the chemical analytical program, field staff were unable to collect a sufficient number of sea urchins to provide enough sample mass (more than 200 grams) for all of the analyses. It is important to recognize that this project required destructive sampling of a living resource, which has the potential to negatively impact a species population in the muliwai. The Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with MMR, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is possible that shellfish and benthic invertebrates will be included as species of interest in this monitoring plan if it is determined that the sampling will not have a negative impact on the species population.

2. Comment: Page 2, Paragraph 1, Line 1: The study's failure to test shellfish and other non-fish, non-limu marine resources resulted in a failure to evaluate accurately whether military activities at MMR pose a human health risk to area residents who rely on these marine resources for subsistence, in further violation of the 2007 order. To comply with its legal obligations, the Army must complete another study that focuses on potential contamination of shellfish and other non-fish, non-limu marine resources and the health risks associated with consuming those resources, put the study out for public review and comment, and incorporate its analysis into the final EIS. Id. ¶¶ 6, 11-13.

Response: As noted in the response to comment 1, there is nothing in the 2007 Order that requires the testing of shellfish. Furthermore, the results of the MRS indicate that activities at MMR likely have not resulted in the contamination of fish and limu, and therefore these activities do not pose a human health risk to area residents who rely on these marine resources for subsistence. This evaluation is consistent with the requirements of the 2007 Order. However, the Army will be developing a long-term monitoring program to continue to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with MMR, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is possible that shellfish and benthic invertebrates will be included as species of interest in this monitoring plan if it is determined that the sampling will not have a negative impact on the species population.

3. Comment: Page 2, Paragraph 2, Line 1: Fish: As discussed in Drs. Elston and Rensel's review, the study analyzed only fish species that are present at Makua during the middle of the day. The study provides no data or analysis whether fish species that can be gathered only in the early morning or at night – marine resources on which area residents rely for subsistence – are contaminated, violating the 2007 Order.

Response: The Marine Resources Study was intended to sample a representative range of species that may be consumed by subsistence and recreational fishers on the Waianae Coast. Discussions with local subsistence fishers indicate that they typically are opportunists and are not selective of species. Substantial effort was made to select and collect species that were representative of and readily available in the habitats of the Makua muliwai and near shore waters and similar watersheds where military training exercises have not occurred in the recent past. Sampling all possible species that could be eaten by subsistence fishers is an unrealistic expectation, and was beyond the scope of the study.

Since trophic level influences the potential uptake and concentration of contaminants, species from a range of trophic levels (primary producer, herbivore, omnivore, and carnivore) were targeted in the study. Since there is no clearly defined reason why a species that may be active at night would differentially uptake and concentrate contaminants, the study focused active sampling activitities during daylight hours, and employed passive methods (i.e., fish and crab traps) overnight on several occasions and in several muliwai. The only additional species collected using passive traps were a species of freshwater gobie, a shrimp (Macrobrachium grandimanus) and several crabs. Both of the gobi and the shrimp were identified as indigenous to Hawaiian waters and reportedly were non-existent in the lower reaches of streams on Oahu. Because their status was in question (i.e., protected by

state or federal government), these specimens were released back to the muliwai. The number of crabs that were collected were insufficient to be used as even a single sample for the MRS.

4. **Comment:** **Page 2, Paragraph 3, Line 1: While the study claims "the seaweed in the samples were identified to genus," review of the field notes reveals the investigators often had no idea what they were gathering. Study at ES-3. For example, the field notes refer to one sample of limu generically as "Limu 2." These unidentified limu were then composited into mixed "seaweed" samples and then analyzed for contaminants. Study at 2-3, Table 2-2. Since it's analysis is based on composites of "mystery" limu, which may have included species of limu that no one consumes, the study fails to satisfy the 2007 Order's requirement to focus on whether limu "on which area residents rely for subsistence" is contaminated. 2007 Order ¶ 6.**

Response: Attempts were made to identify the seaweed in the samples to genus subsequent to sample collection. While some of the samples could be identified, several of the samples could not. The reference to samples being identified to genus will be removed from the MRS. The Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with Makua Military Reservation, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is likely that limu will be included as species of interest in this monitoring plan, and that the limu will be identified to species, if possible, to verify appropriate species of limu (i.e. limu consumed by the local population) are being collected.

5. **Comment:** **Page 2, Paragraph 4, Line 1: Having found extremely elevated levels of arsenic in limu from Makua, the investigators failed to perform standard analyses to determine whether the arsenic in the limu is present in its highly toxic, inorganic form or in the less toxic, organic form. Without this information, there was no way for the study to evaluate accurately whether consuming limu from Makua poses "a human health risk to area residents [who] rely on marine resources for subsistence," further violating the 2007 order. Id.**

Response: Concentrations of arsenic in limu from Makua are not elevated over naturally occurring levels in seaweed around the world. According to Frankenberger (2002) total arsenic concentrations in various types of seaweed around the world range from 4.5 to 140 mg/kg dry weight, whereas the samples collected from Makua ranged from 4.56 to 110 mg/kg dry weight. Since arsenic has never been measured in any of the seaweeds present in Hawaii previously, it cannot be determined at this point whether the arsenic concentrations measured are naturally occurring or elevated; however, the concentrations measured in limu from Makua are consistent with naturally occurring concentrations.

The language in the 2007 order states that "Defendants will evaluate the potential that activities at MMR have contributed or will contribute to any such contamination and whether the proposed training activities at MMR pose a human health risk to area residents that rely on marine resources for subsistence." The Marine Resources Study concluded that the activities at MMR likely did not contribute to the arsenic detected in fish and limu, and therefore the proposed training activities at MMR do not pose a human health risk to area residents that rely

on marine resources for subsistence. Based upon this information, the defendants are not in violation of the 2007 order. Given that the detected arsenic likely did not come from MMR, the defendants are under no obligation to determine if the arsenic is organic or inorganic in order to be in compliance with the 2007 order. Furthermore, the speciation of arsenic to organic vs. inorganic forms was not requested or recommended by Earthjustice or its experts during their review of the Sampling and Analysis Plan, and therefore was not included as part of the analysis program for the Marine Resources Study. The Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with Makua Military Reservation, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is likely that the speciation of arsenic to organic vs. inorganic forms will be included in this monitoring plan.

6. **Comment:** **Page 2, Paragraph 5, Line 1: The study failed to analyze limu from any location other than Makua. Accordingly, as the study concedes, "it is not possible to determine whether the arsenic levels detected in seaweed at Makua Beach are elevated over background." Study at ES-3. Having made no attempt to determine the levels of arsenic contamination that would be present in the absence of military activities, the study failed to satisfy the 2007 Order's requirement to "evaluate the potential that activities at MMR have contributed or will contribute to any such contamination." 2007 Order ¶ 6.**

Response: The Marine Resources Study concluded that the activities at MMR likely did not contribute to the arsenic detected in fish and limu, and therefore the proposed training activities at MMR do not pose a human health risk to area residents that rely on marine resources for subsistence. Based upon this information, the defendants are not in violation of the 2007 order. The Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with Makua Military Reservation, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is likely that collection of limu from background locations will be included in the long term monitoring plan.

7. **Comment:** **Page 3, Paragraph 1, Line 1: In their comments, Drs. Elston and Rensel detail why the study's selection of Nanakuli muliwai and Sandy Beach – both of which receive substantial inputs of anthropogenic contaminants that, in the absence of military activities, would not occur at Makua – as "background" locations was improper and rendered useless the study's analysis of human health and ecological risk from training activities at MMR. To supplement their discussion, we enclose the relevant page from an O'ahu map book, showing the location of the East Honolulu Wastewater Treatment Plant (labeled on the map as "STP" and circled in black), which is immediately across Kalaniana'ole Highway from Sandy Beach. As noted in Drs. Elston and Rensel's review, the sewage outfall is located only 400 meters offshore, at about only 12 meters in depth.**

Response: The rationale for the selection of background sites was provided in both the final SAP and the draft Marine Resources Study. In the final SAP, Section 2.2, Marine Resources Sampling Strategy, states "Background muliwai will be located on the Waianae Coast within watersheds that are not subjected to military activity." Section

2.2.3, Background Sampling, of the final SAP states "Samples will be collected from locations distant enough from Makua Valley that biota would be unlikely to be affected by target chemicals originating from MMR. Background muliwai will be located in watersheds that are not subject to military activity."

The purpose of the Marine Resources Study is to identify whether Army activities at the MMR have impacted Makua Valley resources above and beyond impacts from all other sources. Using an uncontaminated watershed for a background location would not allow the apportioning of impacts between the Army and other sources. This is a significant concern as there are many substantial sources of contamination other than the MMR. To adequately address the Army's impact alone on Makua Valley resources, an appropriate control site (i.e., background location) would be a valley where all aspects of the valley are as similar as possible to Makua. Since inter-watershed transport of contaminants is facilitated by wind and rain, the control valley should have similar wind and rain patterns as that of Makua. Biogeochemical processes affecting contaminants are a function of temperature and substrate, and these attributes should be as similar as possible to Makua Valley in order to identify impacts that can be attributed solely to Army activity. There are distinct differences in the substrate (mineralogy and age) between the different islands, making the selection of a control on another island inappropriate. Because of this, the most appropriate control watersheds are on the leeward (Waianae) coast of Oahu. As long as the background sites selected are representative of ambient conditions for the general Makua vicinity and have not received contamination from the MMR, they are considered acceptable, as per USEPA (1989, 2002a) risk assessment guidance.

8. Comment: Page 3, Paragraph 2, Line 1: We also note that, across the board, the study concluded the "non-carcinogenic hazard index estimates" from fish consumption were greater at the alleged "background" sites than at Makua, sometimes by many times. <u>See, e.g.,</u> Study at Table 4-8 (non-carcinogenic hazard index estimates from likely fish consumption rates at Nanakuli muliwai using mean contaminant concentrations more than double that at Makua); Table 4-12 (non-carcinogenic hazard index estimate from likely fish consumption rates at Sandy Beach using mean contaminant concentrations double that at Makua Beach); Table 4-13 (non-carcinogenic hazard index estimate from likely fish consumption rates at Sandy Beach using maximum contaminant concentrations more than triple that at Makua Beach); Table 4-16 (non-carcinogenic hazard index estimate from worst-case fish consumption rates at Nanakuli muliwai using mean contaminant concentrations more than double that at Makua); Table 4-20 (non-carcinogenic hazard index estimate from worst-case fish consumption rates at Sandy Beach using mean contaminant concentrations double that at Makua Beach); Table 4-21 (non-carcinogenic hazard index estimate from worst-case fish consumption rates at Sandy Beach using maximum contaminant concentrations more than triple that at Makua Beach). The study's ecological assessments similarly showed greater hazard indexes at the "background" locations than at Makua. <u>See, e.g., id.</u> at Tables 5-13, 5-15, 5-16. That contaminant hazards are <u>greater</u> at the alleged "background" sites than at Makua confirms the inappropriateness of the study's selection of reference sites.

Response: It is entirely possible that background concentrations for some metals may be higher than concentrations observed at the site. This does not automatically mean that the

background locations are not suitable. Rather, it merely indicates that there is variation in the conditions among sites, which is to be expected as the environment is not homogeneous.

The Army investigated a number of muliwai on Oahu to serve as a background location for this study. The choice of muliwai to serve as a background site was necessarily limited by a number of factors. The site, as noted above had to be physically similar to the tested area and in the same biogeographic area as Makua. This limited the locations to the leeward side of Oahu. Within this area, the Army looked at eleven different muliwai, including Kalihii, Waialaenui, Nanakuli, Wailupe, Ulehawa, Keaau, Kamilonui, Manuwai, Makaha, Kaupini, and Nuuanu. One of the characteristics of the Makua watershed is the presence of intermittent streams with a perennial mouth, and the Army sought to duplicate this condition in the background muliwai location. At the time of the sampling, a reconnaissance of these muliwai performed by the Army indicated that Nanakuli was the only other muliwai, aside from Makua, that had flowing water. As a result, the Nanakuli muliwai was selected because it was physically the most representative location available, having similar size, hydrologic, rain, wind and geochemical features as Makua.

The Army investigated the HECO pier area as a nearshore background sampling location, but rejected this location because of potential impacts from the nearby power plant, and instead selected Sandy Beach as a more representative background location for the nearshore sampling.

9. Comment: Page 3, Paragraph 3, Line 1: Having failed to select appropriate background sites, the study could not accurately "evaluate the potential that activities at MMR have contributed or will contribute" to contamination of marine resources used for subsistence, violating the 2007 Order. 2007 Order ¶ 6.

Response: As discussed in the response to comment 8, the selection of background sites was appropriate for the purposes of this scientific study.

10. Comment: Page 3, Paragraph 4, Line 1: Even if the selection of Sandy Beach and/or Nanakuli muliwai as background sites were proper, the study's narrow focus on "incremental risk" (i.e., risk over background) to evaluate human health and ecological risks would still be inappropriate and unlawful. In preparing its EIS for MMR, the Army must consider cumulative impacts, which are impacts that "result[] from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions." 40 C.F.R. § 1508.7; see also id. §§ 1508.8, 1508.25. Thus, the Army must evaluate the effect on human health and the marine environment of adding contaminants from proposed training and related activities (including, but not limited to, controlled burns, grass-cutting, herbicides and other ecosystem management) at MMR to whatever level of contamination already exists, including any background levels of contamination. See id. § 1508.27(b)(7) ("Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment"). Such an analysis is necessary to evaluate whether proposed training activities at MMR pose a human health risk to people relying on marine resources for subsistence, as the 2007 Order requires.

Response: USEPA (2002b) states that "a baseline risk assessment generally is conducted to characterize the current and potential threats to human health and the environment that may be posed by hazardous substances, pollutants, and contaminants at a site…. this policy recommends a baseline risk assessment approach that retains constituents that exceed risk-based screening concentrations. This approach involves addressing site-specific background issues at the end of the risk assessment, in the risk characterization. Specifically, the COPCs with high background concentrations should be discussed in the risk characterization, and if data are available, the contribution of background to site concentrations should be distinguished." Therefore, we have shown the risks from exposures to both chemicals at the site and under ambient conditions to distinguish the two and show the contribution over background from exposures at the site.

11. Comment: Page 4, Paragraph 1, Line 1: In the enclosed review, Dr. Foran details the flaws in the study's assumptions regarding fish and limu consumption rates, which render useless its human health risk assessment. In addition to Dr. Foran's comments, we note that the study inaccurately claims Sharma et al. (2003) present data for "Hawaiian fishermen in Hawai'i." Study at 4-8. In fact, Sharma et al. (2003) present data from average food consumers of Native Hawaiian ancestry, not necessarily Hawaiians who fish. Using this average consumption data "[t]o estimate the potential worst case exposures for recreational fishermen" (who, presumably, eat more fish than the average person) likely substantially underestimates human health risks. Id.

The "likely" consumption rate the study used for subsistence fishermen (100.6 g/day) also likely substantially underestimates actual consumption and, thus, health risk. That rate is only about 70% the default national value (from the 1994-1996 Continuing Survey of Food Intake by Individuals) of 142.4 g/day for subsistence fishers. (Sechena, et al., 2003). The study provides no basis for assuming that subsistence fishers on the Wai'anae Coast consume substantially less seafood than the national average.

In order to comply with its obligations under the 2007 Order, the Army must prepare a new human health assessment that is based on accurate data regarding area residents' consumption of marine resources, circulate that new assessment for public review, and incorporate the results of the new assessment in the final EIS for MMR.

Response: Fish consumption rates may vary by ethnic group, lifestyle, economic status, and geography, among other factors (OEHHA 2001). Therefore, it is desirable to use a fish consumption rate that is applicable to the receptors being evaluated. As part of the MRS, the Army reviewed the literature on fish consumption rates in Hawaii and selected the highest fish consumption rates recorded *for Hawaii. The Army believes that the fish consumptions rates used in the MRS were appropriate for the study.

References: Frankenberger, W.T. 2002. *Environmental Chemistry of Arsenic*. New York, Marcel Dekker.

RESPONSE TO COMMENTS

COMMENTS ON THE FINAL MARINE RESOURCES STUDY SAMPLING AND ANALYSIS PLAN (SAP), MAKUA MILITARY RESERVATION (MMR), OAHU, HAWAII AND THE DRAFT MARINE RESOURCES STUDY, VOLUME I, FIELD SAMPLING RESULTS AND RISK ASSESSMENT MAKUA MILITARY RESERVATION (MMR) OAHU, HAWAII, DR. JEFFREY A. FORAN, APRIL 18, 2007

1. **Comment:** **Page 7, Paragraph 2, Line 1: The draft Marine Resources Study (MRS) is poorly written and contains numerous errors and oversights. For example, data reported in Tables 3-1, 3-2, and 4-2 lack units (subsequent comments are based on my assumption that all data are reported in mg/kg wet weight).**

   Response: The units mg/kg have been added to Tables 3-1, 3-2 and 4-2.

2. **Comment:** **Page 8, Paragraph 1, Line 4 (Page 5): Because of the elevated concentrations of arsenic in both fish and limu, and because of the significantly elevated cancer risks of consuming arsenic-contaminated fish and limu, speculation regarding the form of arsenic in biological samples is inappropriate and should be replaced by analytical data that clearly quantify the concentrations of both inorganic and organic arsenic in fish and limu.**

   Response: Concentrations of arsenic in limu from Makua are not necessarily elevated over naturally occurring levels in fish or seaweed around the world. According to Frankenberger (2002), total arsenic concentrations in various types marine fish around the world range from 1.5 to 196 mg/kg dry weight, whereas the samples collected from Makua ranged from 1.46 to 53 mg/kg dry weight. Additionally, as stated in the report, a review of the published literature shows that arsenic is present almost exclusively as nontoxic organic forms in marine fish (Neff 1997; de Gieter et al. 2002; Kirby and Maher 2002; Frankenberger 2002; Kirby et al. 2002; Sloth et al. 2005). Further, according to Frankenberger (2002) total arsenic concentrations in various types of seaweed around the world range from 4.5 to 140 mg/kg dry weight, whereas the samples collected from Makua ranged from 4.56 to 110 mg/kg dry weight. Since arsenic has never been measured in any of the seaweeds present in Hawaii previously, it cannot be determined at this point whether the arsenic concentrations measured are naturally occurring or elevated; however, the concentrations measured in limu from Makua are consistent with naturally occurring concentrations. The Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with Makua Military Reservation, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is likely that arsenic will be speciated to determine if it is organic or inorganic as part of the long term monitoring plan.

   .

3. **Comment:** **Page 8, Paragraph 2, Line 4: The rationale for selection of sites to provide information on background concentrations of contaminants is not described in the Final SAP or the draft MRS; therefore, it is impossible to determine whether samples collected from these sites provide data that are representative of background contaminant concentrations in fish. However, the location of a discharge outfall from the East Honolulu Wastewater Treatment Plant offshore at Sandy Beach may significantly influence contaminant loads and contaminant tissue burdens at this site. Nanakuli muliwai, which is located in the middle of an urban area and downstream from Lualualei Naval Magazine, may also be subject to significant contaminant loadings. As a result, samples collected from these sites would not represent true background (uncontaminated) conditions.**

   Response: The rationale for the selection of background sites was provided in both the final SAP and the draft Marine Resources Study. In the final SAP, Section 2.2, Marine

Resources Sampling Strategy, states "Background muliwai will be located on the Waianae Coast within watersheds that are not subjected to military activity." Section 2.2.3, Background Sampling, of the final SAP states "Samples will be collected from locations distant enough from Makua Valley that biota would be unlikely to be affected by target chemicals originating from MMR. Background muliwai will be located in watersheds that are not subject to military activity."

The purpose of the Marine Resources Study is to identify whether Army activities at the MMR have impacted Makua Valley resources above and beyond impacts from all other sources. Using an uncontaminated watershed for a background location, as suggested by Dr. Foran, would not allow the apportioning of impacts between the Army and other sources. This is a significant concern as there are many substantial sources of contamination other than the MMR. To adequately address the Army's impact alone on Makua Valley resources, an appropriate control site (i.e., background location) would be a valley where all aspects of the valley are as similar as possible to Makua. Since inter-watershed transport of contaminants is facilitated by wind and rain, the control valley should have similar wind and rain patterns as that of Makua. Biogeochemical processes affecting contaminants are a function of temperature and substrate, and these attributes should be as similar as possible to Makua Valley in order to identify impacts that can be attributed solely to Army activity. There are distinct differences in the substrate (mineralogy and age) between the different islands, making the selection of a control on another island inappropriate. Because of this, the most appropriate control watersheds are on the leeward (Waianae) coast of Oahu. As long as the background sites selected are representative of ambient conditions for the general Makua vicinity and have not received contamination from the MMR, they are considered acceptable, as per USEPA (1989, 2002a) risk assessment guidance.

4. Comment: Page 9, Paragraph 2, Line 1: Data collected from background sites are used in the draft MRS to determine contaminant concentrations (or health hazards) from military operations at MMR by subtracting "background" contaminant concentrations (or quantitative estimates of hazard associated with exposure to contaminants) from MMR contaminant concentrations (or hazard estimates). The draft MRS suggests that this approach provides an estimate of contamination or risk originating from MMR. This approach ignores the fact that reference sites are impacted from local activities, are not pristine, and do not represent true background conditions. In this case, contamination from MMR would be "excused" simply because it occurs at a level similar to another contaminated site. The approach also fails to incorporate the effects of vast differences in the physical structure of the sites on the fate and transport of contaminants derived from local sources. Use of reference sites to determine background concentrations without addressing differing fate and transport phenomena will lead to an inaccurate assessment of the extent, nature, and impact of contamination at the MMR site.

Response: USEPA (2002b) states that "a baseline risk assessment generally is conducted to characterize the current and potential threats to human health and the environment that may be posed by hazardous substances, pollutants, and contaminants at a site…. this policy recommends a baseline risk assessment approach that retains constituents that exceed risk-based screening concentrations. This approach involves addressing site-specific background issues at the end of the risk assessment, in the risk characterization. Specifically, the COPCs with high background

concentrations should be discussed in the risk characterization, and if data are available, the contribution of background to site concentrations should be distinguished." Therefore, we have shown the risks from exposures to both chemicals at the site and under ambient conditions to distinguish the two and show the contribution over background from exposures at the site. see response to Comment 3 for the selection of appropriate background sampling locations.

5. Comment: Page 11, Paragraph 3, Line 1: The draft MRS manipulates (attempts to minimize) the magnitude of risk by subtracting risk estimates derived for reference sites from risk estimates associated with consumption of fish and limu from the MMR. As discussed previously, the selection of sites to quantify contaminant background concentrations is flawed; thus, risk estimates associated with exposure to contaminants at these sites are not accurate depictions of "background risk."

Response: USEPA (2002b) states that "a baseline risk assessment generally is conducted to characterize the current and potential threats to human health and the environment that may be posed by hazardous substances, pollutants, and contaminants at a site…. this policy recommends a baseline risk assessment approach that retains constituents that exceed risk-based screening concentrations. This approach involves addressing site-specific background issues at the end of the risk assessment, in the risk characterization. Specifically, the COPCs with high background concentrations should be discussed in the risk characterization, and if data are available, the contribution of background to site concentrations should be distinguished." Therefore, we have shown the risks from exposures to both chemicals at the site and under ambient conditions to distinguish the two and show the contribution over background from exposures at the site.

6. Comment: Page 11, Paragraph 3, Line 6: Regardless of the approach to assess contaminant background concentrations, however, the assessment of risk from reference sites and reduction of MMR-associated risk by subtracting reference-site risk is inappropriate. Cancer risk estimates associated with consumption of seafood gathered from Makua are calculated and expressed as "excess risk" (risk above background). These are site-specific estimates of cancer risk above those associated with all other exposure sources and stressors such as exposure to radionuclides in drinking water, overexposure to sunlight, exposure to contaminants in food, and including exposure to contaminants at reference sites. Calculations of risk at reference sites produces estimates of excess cancer risk that are specific to those sites and in excess of all other cancer risks, including risks associated with MMR. Therefore, subtracting "reference site risk" from "MMR risk" is effectively subtracting excess risk from excess risk, an exercise that is conceptually and mathematically unsound.

Response: See response to Comment 4 for the appropriateness of subtracting the risks. No change is proposed to the methodology. However, the terminology used on page 4-11 will be changed from "R = Estimated individual excess lifetime cancer risk" to "R = Estimated individual cancer risk" to resolve this apparent contradiction. "Excess cancer risk" will also be used in the document to denote risks elevated over background.

7. **Comment:** **Page 13, Paragraph 2, Line 1: These rates represent average daily consumption for populations studied by Sechena et al. (2003) and Sharma et al. (2003). However, the draft MRS adjusts these rates by multiplying by the exposure frequency (EF), which is set at 350 (out of 365) days for subsistence consumers and 48 (out of 365) days for recreational consumers. This adjustment is incorrect, as consumption rate data from Sechena et al. (2003) and Sharma et al. (2003) are annualized rates and already incorporate consideration of fish consumption that may not occur each day of the year. That is, estimates of consumption rate (such as 242 g/day) reflect the number of meals eaten during a year and the size (mass) of each meal. Therefore, the appropriate factor for EF is 365 days (which simply provides a unit conversion in the calculation of intake), not 350 days for subsistence consumers and 48 days for recreational consumers.**

Response: The risk assessment has been revised such that the exposure frequency for both subsistence and recreational fishers is increased to 365 days/year. However, for subsistence fishers, an additional 15 days per year of exposure will result in an increase in the risk estimates of only 4% (i.e., 15/365).

8. **Comment:** **Page 13, Paragraph 3, Line 6: This inappropriate reduction in intake and resultant underestimate of risk is compounded by the use of exposure duration (ED) of 24 years to establish intake via the equation on page 4-5, which results in a further underestimation of intake and risk by a factor of 2.9 (compared with an ED of 70 years). The assumption of partial life intake (24 years rather than 70 years) is unlikely to be representative of consumption and exposure among subsistence fish consumers (and potentially among recreational anglers, particularly those who share their catch with family members). Therefore, the draft MRS should assume that exposure duration (ED) in the equation on page 4-5 is 70, unless data demonstrate clearly that an ED less than 70 more accurately represents gathering and consumption of seafood from Makua. Risk estimates for consumers of fish and limu in the draft MRS may, therefore, be underestimated by more than a factor of 20 because of these calculation and assumption errors.**

Response: It is true that 70 years is the default lifetime assumed by USEPA. However, to perform residential risk estimates, USEPA and HDOH assume that residents are present at a site for 30 years (USEPA 1989, 1997, 2002b; HDOH 2006). This is the 95th th percentile residency duration in the United States (USEPA 1997) and is the default exposure duration used by USEPA in risk assessments for residential exposure scenarios. The risk assessment presented in the MRS has been revised to evaluate residents for 30 years, in order to be consistent with USEPA and HDOH.

9. **Comment:** **Page 14, Paragraph 3, Line 1: Accurate evaluation of fish and limu consumption and contaminant intake in the local population requires a comprehensive survey of local consumers. In the absence of such a survey, worst case estimates of consumption should be based on consumption from traditional diets such as those reconstructed by Smith (2003), where rates for some populations were nearly 400 g/day. Any seasonal differences in consumption rates should also be acknowledged and incorporated in estimates of intake and risk, such as those by Loranger et al. (2002) who found that daily fish intake rates were 6 to 10 times higher for recreational**

anglers in the James Bay Territory of Canada at the end of the fishing season compared to a group that reported fish consumption on an annualized basis.

Response: The references cited by Dr. Foran are abstracts from talks that were presented at symposia. As such, they are not peer-reviewed nor in the published scientific literature. Further, their conclusions may change dramatically by the time they are published. Therefore, the information contained in these sources is considered as interesting but inappropriate for use in this study. Further, fish consumption rates vary dramatically by geography and ethnic groups, among many other factors. As part of the MRS, the Army reviewed the literature on fish consumption rates in Hawaii and selected the highest fish consumption rates recorded for Hawaii. These fish consumption rates are more appropriate for the MRS than the studies of fishers in Canada that were cited by Dr. Foran.

10. Comment: Page 15, Paragraph 2, Line 1: Finally, the draft MRS suggests that risk calculations may be overestimated as contaminant concentrations in whole fish were analyzed. (Concentrations of organic contaminants, excluding methyl mercury, in skin-off fillets may be lower than concentrations in whole fish as some organic contaminants concentrate disproportionately in fatty tissue.) The final SAP and draft MRS do not thoroughly describe methods to prepare fish for contaminant analysis. However, many fish from MMR contaminated sites are eaten whole (including head, skin, and bones) and in some cases internal organs are consumed as well (Vince Dodge, personal communication). Therefore, assumptions that contaminant analysis of whole fish results in overestimates of risk are not accurate or appropriate.

Response: The MRS did not assume that use of the whole fish analysis resulted in an overestimate of risk. The intent of the cited text was to identify an area of potential uncertainty in the risk assessment, and to indicate that the most conservative assumption (use of whole fish analysis) was used in performing the data analysis and risk assessment.

References:

Frankenberger, W.T. 2002. *Environmental Chemistry of Arsenic*. New York, Marcel Dekker.

de Gieter, M., M. Leermakers, R. Van Ryssen, J. Noyen, L. Goeyens, and W. Baeyens. 2002. "Total and toxic arsenic levels in North Sea fish." Arch. Environ. Contam. Toxicol. 43: 406-417.

Hawai'i Department of Health (HDOH). 2006. Screening For Environmental Concerns at Sites With Contaminated Soil and Groundwater. Interim Final – August 2006.

Kirby, J., and W. Maher. 2002. "Tissue accumulation and distribution of arsenic compounds in three marine fish species: relationship to trophic position." Applied Organometalic Chemistry 16: 108-115.

Kirby, J., W. Maher, and D. Spooner. 2002. "Arsenic occurrence and species in nearshore macroalgae-feeding marine animals." Environmental Science and Technology 39: 5999-6005.

Neff, J. M. 1997. "Ecotoxicology of arsenic in the marine environment." Environmental Toxicology and Chemistry 16(5): 917-927.

Sloth, J. J., E. H. Larsen, and K. Julshamn. 2005. "Survey of Inorganic Arsenic in Marine Animals and Marine Certified Reference Materials by Anion Exchange High-Performance Liquid Chromatography-Inductively Coupled Plasma Mass Spectrometry." Journal of Agricultural and Food Chemistry 53:6011-6018

U.S. Environmental Protection Agency (USEPA). 1989. Risk Assessment Guidance for Superfund (RAGS). Human Health Evaluation Manual Part A. Office of Emergency and Remedial Response. EPA/540/1-89/002.

U.S. Environmental Protection Agency (USEPA). 1991. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. OSWER Directive 9355.0-30.

U.S. Environmental Protection Agency (USEPA). 1997. Exposure Factors Handbook. Office of Research and Development, National Center for Environmental Assessment. EPA/600/P-95/002Fa.

U.S. Environmental Protection Agency (USEPA). 2002a. Guidance for comparing background and chemical concentrations in soil for CERCLA sites. Office of Emergency and Remedial Response. EPA 540-R-01-003. OSWER 9285.7-41.

U.S. Environmental Protection Agency (USEPA). 2002b. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Solid Waste and Emergency Response. OSWER 9355.4-24

RESPONSE TO COMMENTS

REVIEW OF FIELD WORK AND ENVIRONMENTAL RISKS PORTIONS OF: DRAFT MARINE RESOURCES STUDY: FIELD SAMPLING RESULTS AND RISK ASSESSMENT, MAKUA MILITARY RESERVATION OAHU, HAWAII, DR. J.E JACK RENSEL AND DR. RALPH ELSTON, APRIL 19, 2007

1. **Comment:** **Page 7, Paragraph 5, Line 1: Missing entirely are important reviews of nearshore hydrographic conditions such as currents, wave, alongshore transport of sediments, physical characterization of the environment, characterization of the reference (termed "background") sites and how they compare with the Makua sites, exact fishing or capture areas in either the muliwai or nearshore areas, etc. Such factors must be considered to properly design a study involving contaminants that are transported and accumulated as a result of the site-specific conditions.**

   Response: The objective of the Marine Resources Study (MRS) was to evaluate if military activities at the Makua Military Reservation (MMR) have contributed to contaminant concentrations in area fish, and if such activities present a health risk to area fishermen who rely on the fish for subsistence. While the additional studies suggested by the reviewers may be of interest, they were not included as part of the scope of work presented in the Final SAP, and are not essential to achieving the objectives of the MRS. Data presented in the MRS indicate that relatively low levels of contaminants were detected in fish and limu in the muliwai and near-shore areas near the MMR. However, the data indicate that it is unlikely that the MMR is the source of most of these contaminants. Based upon these data, the report concludes that activities at the MMR do not present a health risk to area fishermen who rely on the fish for subsistence.

2. **Comment:** **Page 7, Paragraph 6, Line 4: We pointed out in our prior review that other seafood species such as urchins were more likely to be a conservative sampling target, easily obtained and more likely to be contaminated than either fish or lobsters.**

   Despite our comments and provision of detailed information regarding subsistence use of invertebrate and other species by local community members, the final plan and field study entirely neglected <u>all</u> macrofauna invertebrates (including lobsters) and provided no explanation for the oversight or reasons for changes from the draft SAP. We find this omission unacceptable and on this account alone the study is, in our opinion, incomplete and inadequate.

   Response: Although the Final Sampling and Analysis Plan (SAP) did not included invertebrates as species of interest, attempts were made to collect invertebrates for analysis as part of the Marine Resources Study (MRS), in order to address the concerns of the public. Sea urchins were collected from the nearshore area, however because of the extensive analytical suite included in the Final SAP, the total tissue mass needed for a single sample for all of the analyses exceeded 200 grams. The field team determined that continued collection of sea urchins might negatively impact the population of sea urchins in the nearshore area, and stopped sea urchin collection. Crab traps were set in the muliwai for several days, and although some crabs were collected in this manner, the field team was unable to collect crabs in sufficient numbers for even a single sample to be analyzed for the complete list of analytes.

3. **Comment:** **Page 7, Paragraph 8, Line 1: The final SAP calls for sampling of fishes and limu only, and includes no documentation of critical facts regarding the selection of target species. For example, nothing is said regarding the extent of the home range of nearshore fishes that were collected.**

Response: Target species were selected based on their likely presence in known near shore habitats, and the use of these species by fishermen for subsistence. Determination of the exact home range of these fish was beyond the scope of work for the MRS, and while this determination may be of academic interest, it is of little concern to the fishermen who consume these fish for subsistence.

4. Comment: Page 8, Paragraph 2, Line 1: The executive summary of the draft field report and risk assessment begins by stating:

"Tetra Tech conducted a marine resources study to determine if marine resources near Makua Beach and in the Makua muliwai are contaminated with constituents primarily associated with <u>proposed training activities</u> at Makua Military Reservation." **(Emphasis added)**

What are the "proposed training activities" and what contaminants would be involved compared to those from previous training?

Response: The proposed training activities include live fire training exercises. Target contaminants anticipated from these training activities are similar to target contaminants from previous training activities, including the explosives compounds and lead.

5. Comment: Page 8, Paragraph 4, Line 1: The draft field sampling objectives do not mention an ecological risk assessment, but an ecological risk assessment (albeit a flawed one) is included in the report.

Response: The screening level ecological risk assessment was performed to provide additional data to evaluate if proposed training activities at MMR pose a human health risk to area residents that rely on marine resources for subsistence.

6. Comment: Page 8, Paragraph 5, Line 1: Next we note that the study claims to include assessment of "marine resources," which in the draft SAP included invertebrates, fish and limu (seaweed). The invertebrates, including commonly collected and utilized urchins and mollusks, are not included in the final study, but no explanation or justification for this omission is provided.

Response: Although the Final Sampling and Analysis Plan (SAP) did not included invertebrates as species of interest, attempts were made to collect invertebrates for analysis as part of the Marine Resources Study (MRS), in order to address the concerns of the public. Sea urchins were collected from the nearshore area, however because of the extensive analytical suite included in the Final SAP, the total tissue mass needed for a single sample for all of the analyses exceeded 200 grams. The field team determined that continued collection of sea urchins might negatively impact the population of sea urchins in the nearshore area, and stopped sea urchin collection. Crab traps were set in the muliwai for several days, and although some crabs were collected in this manner, the field team was unable to collect crabs in sufficient numbers for even a single sample to be analyzed for the complete list of analytes.

7. Comment: Page 8, Paragraph 8, Line 1: The contaminant status of important ecosystem components such as the surficial sediments of muliwai and nearshore areas

remains either inadequately evaluate due to application of inappropriate methods, in the case of the muliwai (where excessively deep sampling and extensive compositing could have easily diluted the results), or completely unknown and not investigated, in the case of the nearshore areas. We discussed the inadequacy of the prior studies upon which the draft and final SAP relied in this regard, pointing out that the food web (including invertebrates and demersal fish) is affected by the shallow surface sediment layers to a few centimeters depth, while prior Tetra Tech sampling relied upon subsurface samples to greater than one meter depth in some cases. No explanation is provided for this inappropriate sampling method.

Response: The reviewers are correct that most benthic invertebrates and demersal fish are exposed within the top 10 to 15 centimeters (0.3 to 0.5 feet) of sediments. Some surface sediment samples were collected. However, all data (both surface and subsurface) were used in the determination of sediment UCL_{95} sediment concentrations. Uncertainties stemming from the inclusion of deeper sediment data (i.e., 1 to 3 feet) in the calculation of UCL_{95} concentrations are discussed in the MRS.

8. Comment: Page 9, Paragraph 2, Line 2: The prior muliwai sediment sampling data were <u>not</u> representative of the biologically active surface layers that would directly affect the aquatic food web. The risk assessment also utilizes inappropriate background or reference locations, which may bias the comparison of what is "normal" in terms of contaminant load in the region. If the underlying data are biased or non-representative, the ecological risk assessment is precluded from being accurate or representative of the actual risks. The complete lack of any data from the nearshore sediments compounds the problem, an issue that is acknowledged in the draft field report and risk assessment but not explained or mitigated.

Response: All data (both surface and subsurface) were used in the determination of sediment UCL_{95} sediment concentrations. Uncertainties stemming from the inclusion of deeper sediment data (i.e., 1 to 3 feet) in the calculation of UCL_{95} concentrations are discussed in the MRS.

We believe that the background locations selected for the MRS were appropriate. The objective of the MRS is to identify whether Army activities at the MMR have impacted Makua Valley resources above and beyond impacts from all other sources. To adequately address the Army's impact alone on Makua Valley resources, an appropriate control site (i.e., background location) is a valley where all aspects of the valley are as similar as possible to Makua. Since inter-watershed transport of contaminants is facilitated by wind and rain, the control valley should have similar wind and rain patterns as that of Makua. Biogeochemical processes affecting contaminants are a function of temperature and substrate, and these attributes should be as similar as possible to Makua Valley in order to identify impacts that can be attributed solely to Army activity. There are distinct differences in the substrate (mineralogy and age) between the different islands, making the selection of a control on another island inappropriate. Because of this, the most appropriate control watersheds are on the leeward (Waianae) coast of Oahu. As long as the background sites selected are representative of ambient conditions for the general Makua vicinity and have not received contamination from the MMR, they are considered acceptable, as per USEPA (1989, 2002a) risk assessment guidance.

9. Comment: Page 9, Paragraph 5, Line 1: No specific sampling location data were recorded or reported with the nearshore samples. It was simply one general area or another. The specific sampling area could have made a difference for some species of fish and for most invertebrates, but no data were collected in this regard. If a series of samples had been taken at increasing distance from the MMR nearshore a trend might have been detected, but this was not done.

Response: Nearshore fish were collected using a hook and line, typically from an area beyond the shore break. Using this methodology, the maximum distance from the shoreline for the nearshore sample collection was approximately 100 feet, and typically samples were collected within 50 feet of the shore break.

10. Comment: Page 9, Paragraph 6, Line 1: Apparently large- and small-sized fish were sometimes composited to construct single samples, masking any size and age specific trends that might have been present.

Response: USEPA (2000) guidance on sampling fishes was followed. All fish used for sample analysis were within 25% of the total length of the largest caught fish. Establishing size and age specific trends in contaminant concentrations is not generally the goal of fish sampling for risk assessment (USEPA 2000).

11. Comment: Page 10, Paragraph 1, Line 1: The choice of reference (background) areas, as pointed out in our review of the draft SAP, was inappropriate and not supported by information or data regarding surrounding land and aquatic use. It is possible, in our opinion, that there are <u>no</u> pristine muliwai on the Wai'anae coast of O'ahu to allow for meaningful reference comparison. This possibility is not directly addressed in the SAPs and draft report, which make an invalid comparison between what the effects of the MMR may have produced versus effects of urbanization, transportation, industry and military use on the Nanakuli muliwai. There are many areas that could have served as appropriate nearshore area reference sites on the leeward coast. These could have included any of a number of areas of similar physical exposure, without significant human residential populations on septic or sewer systems and not subject to direct drainage from agricultural or urban development. We believe that a reference area to compare to the MMR areas should be, if possible, on the leeward coast as other remote areas may have different marine species assemblages and recruitment and physical factors may be significantly different too.

Response: Background locations were selected to be representative of Makua in the absence of releases from the Makua MMR. However, that does not mean that background sites are required to be free of any anthropogenic influence, as this is impossible. As long as the background sites selected are representative of ambient conditions for the general Makua vicinity, they should be considered as acceptable (as per USEPA guidance).

12. Comment: Page 10, Paragraph 2, Line 1: The report authors selected Sandy Beach in an entirely different region of the island as a nearshore reference area. We judge Sandy Beach an inappropriate reference site because it is the site of a major sewage treatment plant and nearshore outfall. It is also a relatively great geographic distance from the MMR, possibly subject to different physical

processes. There are likely differing biological dynamics resulting from the markedly different physical processes between the southeast coast of the island and the westward, leeward shore.

Response: Background locations were selected to be representative of Makua in the absence of releases from the Makua MMR. However, that does not mean that background sites are required to be free of any anthropogenic influence, as this is impossible. As long as the background sites selected are representative of ambient conditions for the general Makua vicinity, they should be considered as acceptable (as per USEPA guidance).

13. Comment: Page 10, Paragraph 3, Line 1: No sediment sampling was conducted in the nearshore area to allow for trend estimation or risk analysis. Incremental distance sampling from the areas adjacent to the MMR muliwai to distant locations could have been conducted, but was not.

Response: Sediment sampling in the nearshore area was not part of the scope for the MRS that was outlined in the SAP. Because of the many possible sources of contamination to nearshore sediments (exhaust from automobiles, trash in the ocean, etc.), evaluation of nearshore sediment contaminant concentrations would have provided little useful information to evaluate potential impacts to human health from Army activities at MMR.

14. Comment: Page 10, Paragraph 4, Line 1: As previously pointed out, the fishes that were assess may include species that are far-ranging in their home range and geographic distribution. We would not expect these fishes to be significantly affected by contaminated sediments, limu and other habitat features near the MMR if they were essentially "passing through" the area and thus had only very limited exposure to possible contaminants from the MMR sample sites.

Response: The objective of the MRS, as outlined in the Settlement Agreement was to "…evaluate the potential that activities at MMR have contributed or will contribute to any such contamination (of marine resources) and whether the proposed training activities at MMR pose a human health risk to area residents that rely on marine resources for subsistence." The target species were selected based upon discussions with local fishermen regarding the fish that are used for subsistence. If fish were used by local fishermen for subsistence, they were included in the MRS, to the extent possible, whether or not they were far-ranging fish. This approach was consistent with the objectives of the study, as outlined in the Settlement Agreement.

15. Comment: Page 10, Paragraph 5, Line 1: The draft report's next conclusion is not supported by the data. It states:

"Samples from the muliwai locations tended to have higher concentrations of metals than the nearshore samples, although the nearshore samples typically had higher concentrations of arsenic."

This conclusion involves a comparison that is inappropriate for several reasons. Section 3.4 of the draft report describes results of metals sampling and points to Table 2-2, a summary of species sampled within general locations. Table 3-2 reports average concentrations of metals by subarea

(again, ostensibly for fish tissue) but these averages represent a mixture of different species with unequal representations among areas. Moreover, there were no samples from nearshore waters near the reference muliwai at Nanakuli, and there is no data from muliwai near Sandy Beach.

An accurate comparison would need to compare "apples and apples," or in this case, the same fish species within the muliwai and in the nearshore. This was not done. The comparison cannot be made because some of these fish represent different tropic niches, and several (e.g., tilapia and striped mullet) are omnivores but have differing food habits. Their feeding habits are a critical determinant of bioaccumulation or bio-magnification because contaminants may occur in higher tropic level niches depending on the exposure rates in the lower level niches.

Response: The italicized statement cited by the reviewers was from Section 6 (Conclusions), page 6-2 of the MRS. The statement referred to the fish tissue results for the Makua-area nearshore and muliwai sampling locations. It is not clear why the reviewers discusses the reference muliwai and near-shore sampling location in regard to the conclusion, since the conclusion only referred to the Makua-area sample results. The intent of the conclusion was to evaluate tissue concentrations detected in the muliwai fish vs. the tissue concentrations in the near-shore fish.

16. Comment: Page 11, Paragraph 2, Line 1: The comparison among muliwai is also not valid because unequal numbers of different species were collected from each muliwai (see Table 2-2). The data were collected (Table 3-1) to make a general comparison by species and subarea, but such a comparison was not done. A statistical test is not possible because of the compositing that was performed and the resulting loss of variability estimates, but summarizing these data could provide useful information.

Response: We agree with the reviewer's comment that summarizing the data provides useful information, which is consistent with the intent of this section of the report. However, we disagree with the reviewers that the data were collected to make a general comparison by species. The objective of the MRS was not to perform rigorous statistical analysis of contaminant concentrations in different species, but rather to evaluate if military activities at MMR have contributed to contaminant concentrations in area fish, and if such activities present a health risk to area fishermen who rely on the fish for subsistence. Our discussions with area fishermen indicated they are opportunistic fishermen, who consume most species of fish they are able to catch. The methodology of the MRS was consistent with this approach, and is reflective of the conditions the fishermen encounter. It is not necessary to conduct rigorous statistical analysis to achieve the objectives of the study, and therefore the study was not designed to collect data in order to perform this type of statistical analysis.

17. Comment: Page 11, Paragraph 3, Line 1: In the draft field report narratives and summaries, elevated concentrations of contaminates are reported but the significance of this is dismissed on the grounds that it is not different from one or both of the background areas. Reference (or background-comparison) areas in the present context are needed to attempt to discern possible differences between levels of contamination at Makua with or without effects of military activities. In doing so, it is important to consider what is "normal"

in areas with similar physical and biological characteristics. If the background areas are subject to elevated levels of contamination, they are not suitable for comparison to the MMR areas. Because of prior use by the military and urban effects (for the Nanakuli muliwai) and because of a major sewage discharge source (Sandy Beach) we believe that the choices were not conservative or justified.

Response: Background locations were selected to be representative of Makua in the absence of releases from the Makua MMR. However, that does not mean that background sites are required to be free of any anthropogenic influence, as this is impossible. As long as the background sites selected are representative of ambient conditions for the general Makua vicinity, they should be considered as acceptable (as per USEPA guidance).

18. Comment: Page 11, Paragraph 4, Line 1: One of the most serious flaws in the study plans and draft report deals with selection of target organisms or species of interest. The draft SAP clearly stated that specific mollusks, crustaceans and fish would be collected for analyses. However, only fish were collected and analyzed, and there is no justification or rationale provided for this alteration in the final sample plan. No invertebrates were analyzed, although the field data (included in the appendix) indicate that some were collected.

Response: Although the final SAP did not included invertebrates as species of interest, attempts were made to collect invertebrates for analysis as part of the MRS, in order to address the concerns of the public. Sea urchins were collected from the nearshore area, however because of the extensive analytical suite included in the final SAP, the total tissue mass needed for a single sample for all of the analyses exceeded 200 grams. The field team determined that continued collection of sea urchins might negatively impact the population of sea urchins in the nearshore area, and stopped sea urchin collection. Crab traps were set in the muliwai for several days, and although some crabs were collected in this manner, the field team was unable to collect crabs in sufficient numbers for even a single sample to be analyzed for the complete list of analytes.

19. Comment: Page 12, Paragraph 1, Line 8: This is highly critical as pelagic, far-ranging fish are not suitable to provide meaningful data for a human or environmental risk analysis. For the muliwai, benthic invertebrates or macroinvertebrates such as crabs should have been included as they have continual contact with contaminants associated with the sediments.

Response: Pelagic, far-ranging fish were not included in the samples analyzed as part of the MRS. Although the final SAP did not included invertebrates as species of interest, attempts were made to collect invertebrates for analysis as part of the MRS, in order to address the concerns of the public. Sea urchins were collected from the nearshore area, however because of the extensive analytical suite included in the Final SAP, the total tissue mass needed for a single sample for all of the analyses exceeded 200 grams. The field team determined that continued collection of sea urchins might negatively impact the population of sea urchins in the nearshore area, and stopped sea urchin collection. Crab traps were set in the muliwai for several days, and although some crabs were collected in this manner, the field team was unable to collect crabs in sufficient numbers for even a single sample to be analyzed for the complete list of analytes.

20. Comment: Page 12, Paragraph 3, Line 1: Seaweed: As noted in the draft report, the species of limu were not identified in the analysis but there were references to *Codium edule* and *Gracilaria coronopifolia* as species of interest. Apparently no taxonomic identification of samples was performed. This was a significant omission as it remains unknown if the samples were from edible limu likely to be consumed.

Response: The Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with Makua Military Reservation, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is likely that identification of limu to species will be included in the long term monitoring plan.

21. Comment: Page 12, Paragraph 4, Line 1: The draft report does not identify trophic levels of the "species of interest" (an important planning and analysis consideration we discussed in the draft SAP review) or even discuss results of contaminant load by species. Table 3-2 presents the raw data by composite sample and subarea, but only a limited summarization of the data are provided. At a minimum, there should be a listing of averages for contaminants of higher concentrations. Such information would be useful for the community members, as presently they fish in the muliwai for tilapia and medaka. If these species are contaminated at a risk quotient of about 1.0 or above, the community should be informed. Tables 4-8, 4-9, 4-12, 4-13, 4-16, 4-17, 4-20, 4-21 of the draft report indicate such elevated risk, at least for the composite of all COPC (chemicals of potential concern) within an area.

Response: Table 3-2 presents the average concentrations of metals and organochlorine pesticides, by fishing area (i.e. muliwai and nearshore areas). These are generally the contaminants that contributed the greatest cumulative risk to the risk calculations. Therefore, the type of data requested by the reviewer is already presented in the MRS. Table 3-1 presents the raw data by sample.

The objective of the MRS was to evaluate if military activities at MMR have contributed to contaminant concentrations in area fish, and if such activities present a health risk to area fishermen who rely on the fish for subsistence. While the additional analysis requested by the reviewer may be of interest, it was not included as part of the scope of work presented in the Final SAP, and is not essential to achieving the objectives of the MRS.

22. Comment: Page 13, Paragraph 1, Line 1: For the nearshore fishes, it appears that the samples collected were species of convenience, i.e., what was available to the samplers on the day(s) they attempted to sample. Sampling was apparently conducted during mid-day, but fishing is often done at night or early morning when other species are more commonly available, and thus the analysis may be biased if the sampled fish do not represent the other fish in terms of contaminant load. If the sampled fish do not represent the other fishes, both the ecological and human risk assessment would be flawed on this account.

Response: Target species were selected based on their likely presence in known near shore habitats, and the use of these species by fishermen for subsistence. Our discussions

with area fishermen indicated they are opportunistic fishermen, who consume most species of fish they are able to catch. The methodology of the MRS was consistent with this approach, and is reflective of the conditions the fishermen encounter.

23. Comment: Page 13, Paragraph 1, Line 8: Additionally, there was no report or analysis of body fat levels within or among species that could influence contaminant burden (as discussed and recommended in our review of the draft SAP).

Response: Lipids were measured in all samples. The information will be provided, as requested. However, the proponents should note that only some contaminants are lipophilic.

24. Comment: Page 13, Paragraph 3, Line 1: For the muliwai, no ʻoʻopu (various stream fishes) or awa (milkfish) were reported to be sampled, although they were included on the community's list of muliwai species that are commonly eaten.

Response: Target species were selected based on their likely presence in the muliwai, and the use of these species by fishermen for subsistence. Our discussions with area fishermen indicated they are opportunistic fishermen, who consume most species of fish they are able to catch. Although we were unable to catch every single species of fish that were identified as being consumed by the community, the fish that were caught and analyzed from the muliwai (tilapia, stripped mullet, medaka and Hawaiian flagtail) were also identified on the community's list of muliwai species that are commonly eaten.

25. Comment: Page 13, Paragraph 4, Line 1: In regard to the muliwai samples, page 3-1 of the final SAP states: *"Each muliwai sample will consist of a composite of five to seven individual specimens."* This statement appears to have been written after the fact to match what was actually done because the investigators selected an odd and variable number of samples. A balanced sampling plan with equal numbers of fish from the same species is always preferable to some variable or inexact number should any type of statistical assessment be attempted (i.e., that allows for use of more robust statistical analysis).

Response: The italicized statement listed above was included in the July 2006 version of the SAP, which was used to guide the field activities, and was not written after the fact. In some cases, more than 10 fish were included in the composite samples. In many instances, compositing this number of fish was necessary in order to obtain sufficient mass for the entire suite of analyses. Furthermore, with more individual samples composited, the closer the measured value will be to the true mean. Therefore, compositing samples was deemed appropriate and follows USEPA (2000) guidance for collecting fish samples for use in risk assessments. The objective of the MRS was not to perform rigorous statistical analysis of contaminant concentrations in different species, or to perform statistical comparisons between sites or to establish age/length relationships, but rather to evaluate if military activities at MMR have contributed to contaminant concentrations in area fish, and if such activities present a health risk to area fishermen who rely on the fish for subsistence.

26. Comment: Page 13, Paragraph 6, Line 1: Section 3-1 of the draft report states, *"The individuals will be collected from within a limited target region"* but no reporting of what constituted those regions appears other than some very

large scale maps with no details. Whether the fish were collected from the immediate nearshore or from farther offshore and whether there was a fixed shore location for casting or several different locations must be specified. As pointed out previously, these details matter if one is to conduct a representative and conservative assessment.

Response: Nearshore fish were collected using a hook and line, typically from an area beyond the shore break. Using this methodology, the maximum distance from the shoreline for the nearshore sample collection was approximately 100 feet, and typically samples were collected within 50 feet of the shore break.

27. Comment: Page 13, Paragraph 7, Line 1: Similarly, no estimates of the approximate home range of the fish species collected or of their general food habits are provided. There is no way to be sure which fish species is more or less risky based on its probable range of movement near and far from the potentially affected areas. Several of the fish (e.g., medaka, tilapia, and striped mullet) are omnivorous and may eat plant or animal matter. But this does not mean they eat everything all the time as feeding ecology studies sometimes indicate that some fish species focus on one type of food at a time. Some other fishes are more exclusively plankton feeders (e.g., Hawaiian flagtail) and those captured in the muliwai may have been feeding on plankton introduced by seawater overtopping that occurs periodically as a result of larger than normal waves. Alternatively, they may have been feeding on some combination of the externally-recruited plankton and internally-reproduced plankton. Since plankton are potentially transported and advected great distances by water currents, plankton feeders likely would be non-conservative choices for the study as the plakton would be unlikely to be affected by nearshore contamination associated with sediments. We believe that the report should have considered these and other food web factors to properly direct the sampling and frame the results. This was not done.

Response: The objective of the MRS was to evaluate if military activities at MMR have contributed to contaminant concentrations in area fish, and if such activities present a health risk to area fishermen who rely on the fish for subsistence. While the additional analysis requested by the reviewer may be of interest, it was not included as part of the scope of work presented in the Final SAP, and is not essential to achieving the objectives of the MRS.

28. Comment: Page 14, Paragraph 2, Line 1: Reference (or background) areas are important because they potentially provide some basis for comparison of the nearshore and muliwai areas near MMR with what might be considered "normal" or "average" in the absence of military activities. The draft field report and risk assessment goes further with the comparisons by calculating hazard indices for both types of areas and then terming the difference among contrasted pairs as an "incremental risk." The results of this process show the hazard indices for individual COPC among areas vary considerably. Total hazard indices were generally similar between areas near MMR and the comparison ("background") areas but usually greater for the latter for non-carcinogenic hazards compared to carcinogenic hazards. This is not explained or discussed in the draft.

Response: The requested information is already presented in the MRS. Section 4 of the MRS presents the results and interpretation of the human health risk assessment. Section 4 of the MRS discusses both the carcinogenic and non-carcinogenic hazards, and the information presented in this section indicates that the non-carcinogenic hazards are usually greater than the carcinogenic hazards at each location. Section 4 also presents information indicating that the non-carcinogenic hazards were generally greater at the background locations as compared to the MMR locations.

29. Comment: Page 14, Paragraph 3, Line 1: In our experience, characterization and selection of appropriate reference areas for aquatic studies is often a challenging task that requires exploration and pre-study. To serve as an accurate basis for comparison, a reference area should be physically similar in depth, exposure, flushing rates, orientation, etc. and within the same biogeographic range as the affected area. If a reference area is too distant from an affected area, the food web composition and energy fluxes may be different. There may be different patterns of juvenile recruitment, timing and species dominance. In order to demonstrate similarity of physical conditions, at least some minimal types of measurements must be taken or utilized and site characterizations performed. As pointed out in our review of the draft SAP, to compare contaminant loads among sediment from different areas, leading governmental jurisdictions such as the Washington Department of Ecology require investigators to collect sediment grain size and total organic carbon content concurrently. It is well known that concentrations of many contaminant metals positively co-vary with the amount of silt and clay and total organic carbon, hence it is always important to normalize the contaminant results with these measurements.

Response: The rationale for the selection of background sites was provided in both the final SAP and the draft Marine Resources Study. In the final SAP, Section 2.2, Marine Resources Sampling Strategy, states "Background muliwai will be located on the Waianae Coast within watersheds that are not subjected to military activity." Section 2.2.3, Background Sampling, of the final SAP states "Samples will be collected from locations distant enough from Makua Valley that biota would be unlikely to be affected by target chemicals originating from MMR. Background muliwai will be located in watersheds that are not subject to military activity." As long as the background sites selected are representative of ambient conditions for the general Makua vicinity and have not received contamination from the MMR, they are considered acceptable, as per USEPA (1989, 2002a) risk assessment guidance.

30. Comment: Page 15, Paragraph 2, Line 1: First, the Nanakuli muliwai reference area for fish collection is within an urbanized area with probable prior military base effects. The watershed includes drainage from the relatively large Navy Lualualei ammunition magazine, active since 1934. Because of the age extensive size of this facility, selection of the Nanakuli muliwai as a MMR reference area would require extensive pre-study and justification. Older military facilities in the US were often subject to on-site dumping of contaminated waste products such as spent cleaning solvents, petroleum lubricants, and other wastes. Burning of waste solids and liquids, land use practices such as the use of highly persistent and toxic pesticides, inadequate wastewater collection and treatment are but a few of the documented problems at some older military facilities. No justification or explanation is offered in either of the SAPs or the draft report for selection of this muliwai,

other than that it was unlikely to be affected by MMR activities. While that may be true, the relevant question is whether the Nanakuli site is a suitable reference area to compare with the muliwai near MMR. The latter are in a relatively remote, non-urbanized area, and again the goal is to know what they would be like without military impacts.

Response: The rationale for the selection of background sites was provided in both the final SAP and the draft Marine Resources Study. In the final SAP, Section 2.2, Marine Resources Sampling Strategy, states "Background muliwai will be located on the Waianae Coast within watersheds that are not subjected to military activity." Section 2.2.3, Background Sampling, of the final SAP states "Samples will be collected from locations distant enough from Makua Valley that biota would be unlikely to be affected by target chemicals originating from MMR. Background muliwai will be located in watersheds that are not subject to military activity." As long as the background sites selected are representative of ambient conditions for the general Makua vicinity and have not received contamination from the MMR, they are considered acceptable, as per USEPA (1989, 2002a) risk assessment guidance.

31. Comment: Page 15, Paragraph 4, Line 1: In general, there appears to be relatively little background information on fish tissue contamination near O'ahu, but the draft report should have included at least some general information on important prior studies or databases before selecting the Sandy Beach area as a reference area. As previously noted it is also on the opposite side of the island near the windward coast and therefore subject to different physical and biological pressures.

Response: see response to Comment 11.

32. Comment: Page 16, Paragraph 3, Line 3: No accounting for differing silt/clay properties was conducted, and, as we stated in our review of the draft SAP, subsurface sampling and compositing of sediment samples obfuscated and potentially skewed the results.

Response: The objective of the Marine Resources Study (MRS) was to evaluate if military activities at the Makua Military Reservation (MMR) have contributed to contaminant concentrations in area fish, and if such activities present a health risk to area fishermen who rely on the fish for subsistence. As such, the study was focused on the collection of marine resources (fish and limu) tissue data, an evaluation of the presence of the contaminants in these tissue samples, an evaluation if military activities had contributed or were likely to contribute contaminants to these marine resources, and if contaminants detected in the tissue samples that were related to military activities at MMR posed a threat to human health through the consumption of these marine resources. While an evaluation of differing silt/clay properties of the sediments in the various sampling locations may be of academic interest, these data were not necessary to achieve the objectives of the study, and therefore were not collected during the study.

33. Comment: Page 16, Paragraph 4, Line 1: The draft field report is also very unclear regarding sediment sampling. Nowhere in the draft or final SAP or elsewhere in the draft report is there a description of sampling or reference areas for sediments, but unexpectedly we see on page 5-4: *"Four sediment samples were collected from each of the north and south background areas (Figure 2-*

1). These samples were from one to two feet deep All samples were analyzed for metals and explosives." **There are no north and south reference areas shown in Figure 2-1 of the draft report. There were north and south reference stations from creek mouths shown in Figure 2-1 of a prior report (Tetra Tech 2005b) regarding muliwai sampling, but that report indicates only three samples were taken in each reference area. In any event, the sampling for the earlier study was minimal (three samples per area versus up to 22 for the muliwai) and too deep to be of the significance to biological organisms such as benthic invertebrates and epifauna. The draft report provides no analyses or discussion of the applicability or results of these samples, so the reader is left with no information to judge.**

Response: The MRS incorrectly referenced Figure 2-1. The correct reference is to Figure 2-2, and this reference has been changed in the MRS. A total of four samples (three primary and one duplicate) were collected from each of the north and south reference locations. The MRS clearly states that the sediment samples were collected in 2003 and references the appropriate document from 2005. A sentence has been added to this section to clarify that the sediment data evaluated in Section 5 came from the 2005 Muliwai Sediment Study Report, which is included as an appendix to the EIS.

34. Comment: Page 16, Paragraph 5, Line 1: Limu (seaweed) was collected, but it was not identified to any useful taxonomic level in the report.

Response: The Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with Makua Military Reservation, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is likely that identification of limu to the taxonomic level will be included in the long term monitoring plan.

35. Comment: Page 16, Paragraph 6, Line 4: As the limu identifications were not performed and pooling may have included species that are not consumed, the risk assessment involving seaweed is not valid for determining risk to local residents.

Response: The Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with Makua Military Reservation, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is likely that identification of limu to the taxonomic level will be included in the long term monitoring plan.

36. Comment: Page 17, Paragraph 1, Line 7: In addition, because the total arsenic levels found in the draft study are relatively high, an analysis of inorganic vs. organic arsenic content should be conducted using appropriate collection and analysis procedures in order to be able to evaluate the effects on humans or marine life.

Response: Concentrations of arsenic in limu from Makua are not elevated over naturally occurring levels in seaweed around the world. According to Frankenberger (2002) total arsenic concentrations in various types of seaweed around the world range from 4.5 to 140 mg/kg dry weight, whereas the samples collected from Makua ranged from 4.56 to 110 mg/kg dry weight. Since arsenic has never been measured

in any of the seaweeds present in Hawaii previously, it cannot be determined at this point whether the arsenic concentrations measured are naturally occurring or elevated; however, the concentrations measured in limu from Makua are consistent with naturally occurring concentrations. The Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with Makua Military Reservation, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is likely that the speciation of arsenic to organic vs. inorganic forms will be included in this monitoring plan.

37. Comment: **Page 17, Paragraph 2, Line 1: Compositing of fish samples was implemented, thus eliminating the possibility of assaying differences among fishes. We understand the rationale for pooling specimens in that it achieves a broader representation of average results, but pooling specimens is valid only if the pooling represents single species of similar age and size. In the present study, compositing was not conducted correctly for limu (because pooling involved potentially different species) or for fish (because there is no evidence that similar age cohorts were composited; see Table B-1 of the draft report for size information). The draft final report justifies compositing by stating that it was necessary to do so to get sufficient sample volume for analyses (200 grams or less than 1/2 pound). This is a valid justification for small specimens but many of the single fish specimens reported in Table B-1 would meet this goal.**

Response: The reference to Table B-1 in the MRS was made in error – this table was never completed, and was not intended to be included in the MRS. The reference to Table B-1 has been removed from the MRS. The version of the table that was provided to Earthjustice and its' technical experts following the February 24, 2007 public meeting was an incomplete table that was used for internal purposes.

The lengths of collected fish were measured in the field, and these measured lengths were recorded on field data sheets, which are presented in Appendix A of the MRS. It is unclear how the reviewers determined the mass of the single fish specimens reported in the table and on the field sheets in Appendix A, since the fish were only weighed once they were received at the laboratory. Individual fish specimens that met the 200 gram criteria for sample analysis were not composited, and were analyzed as individual fish.

38. Comment: **Page 17, Paragraph 3, Line 1: The compositing led to other questionable practices. For example, page 5-12 of the draft field report describes the use of the maximum detected concentrations in composite fish samples for the exposure point concentrations (EPCs). This is not valid or logical because there were few composites from each sampling area and, by definition, compositing produces an average value with no representation of the high end variability. The report claims that this is a more conservative method than using the UCL_{95} (95th percent confidence limit value results), but this claim cannot be assessed given the lack of variance data.**

Response: A UCL95 can be calculated for the composite samples. As stated in the report, using the maximum detected value provides a more health-protective estimate of the risks than using the UCL95 of the composite data.

39. Comment: **Page 18, Paragraph 2, Line 1: As one yardstick to measure the efficacy and accuracy of the ERA we refer to EPA (1998, Guidelines for Ecological Risk Assessment), which is a pertinent and appropriate reference. This document states in section 5.1.1:**

"While field studies may best represent reality, as with other kinds of studies they can be limited by (1) a lack of replication, (2) bias in obtaining representative samples, or (3) failure to measure critical components of the system or random variations. Further, a lack of observed effects in a field survey may occur because the measurements lack the sensitivity to detect ecological effects."

The present study lacked replication, which is explained by the nature of the study, a screening study. A screening study is not an adequate basis on which to conduct a risk assessment.

Response: The reviewers were not specific about the lack of replication in the data used for the ERA (e.g., numbers of samples at particular sites or in particular media). A total of 12 and 22 sediment samples were collected from the south and north muliwai, respectively. Five to seven composite samples of fish tissues were analyzed from each muliwai or the Makua nearshore area. The muliwai are generally the size of small ponds, having a maximum water surface area of less than one acre. Based on the limited sizes of the muliwai, the numbers of samples are considered adequate for the risk assessment.

A screening-level ERA can provide risk managers with adequate information for decision making, particularly if no significant hazards are identified. Screening-level and higher tier ERAs vary in their levels of detail and complexity, conservatism, and uncertainty. Although screening-level ERAs typically use a more limited data set than higher tier ERAs, they also incorporate a greater level of protectiveness in their methodology. The screening-level ERA for the MMR applied a number of protective assumptions1 in the exposure and effects assessments to minimize the likelihood of underestimating ecological hazards. Higher tier ERAs beyond a screening assessment may be considered by risk managers to verify and provide more detail on any key hazards identified in the screening assessment, or to reduce uncertainties resulting from the protective assumptions used in the screening assessment (U.S. EPA 1998).

40. Comment: **Page 18, Paragraph 4, Line 1: As noted previously, it appears that the muliwai reference area was arbitrarily selected without any field pre-study, or consideration of prior military or urban uses and contaminant loading in the watershed. In our opinion, the lack of an appropriate reference site for the muliwai near MMR renders the ERA fatally flawed. This is because a number of significant hazard quotients were detected for the marine resources near MMR, but these are simply dismissed as inconsequential and**

[1] These protective assumptions included the decision criteria for metal background comparisons, the use of maximum detected or 95 percent upper confidence limit (UCL_{95}) on the mean concentrations for exposure point concentrations, and the selection of no-effect level and threshold effect level toxicity reference values for fish and benthic invertebrates, respectively.

a result of background conditions. The potential alternative of no appropriate reference muliwai on O'ahu was not considered or discussed.

Response: A number of hazard quotients exceeding 1 for fish tissues were not considered to represent s significant potential for hazard. The lack of incremental hazards above background conditions was one factor used in this determination.

41. Comment: Page 18, Paragraph 7, Line 1: For the nearshore, the situation is similarly inappropriate as the reference area is the site of a major wastewater discharge and not in the same geographic zone as the MMR, but rather on the opposite side of the island. The complete lack of any nearshore sediment analysis in the area near MMR is a significant omission and flaw in the study.

Response: The objective of the MRS was to evaluate if military activities at the Makua Military Reservation MMR have contributed to contaminant concentrations in area fish, and if such activities present a health risk to area fishermen who rely on the fish for subsistence. As such, the study was focused on the collection of marine resources (fish and limu) tissue data, an evaluation of the presence of the contaminants in these tissue samples, an evaluation if military activities had contributed or were likely to contribute contaminants to these marine resources, and if contaminants detected in the tissue samples that were related to military activities at MMR posed a threat to human health through the consumption of these marine resources. While nearshore sediment analysis may provide some interesting data, it is not essential to achieve the objectives of the MRS.

42. Comment: Page 19, Paragraph 2, Line 1: The importance of this reference area discussion is highlighted by a quote from the draft field report as follows:

"Metals at concentrations equivalent to or lower than background concentrations do not need to be considered in the risk assessment. Therefore, the metals **[chemicals of potential ecological concerns (COPECs)]** ***were selected by comparing metal concentrations detected in muliwai sediments to local background metal concentrations..."***

By selecting reference areas with inappropriately high contamination (i.e., Nanakuli muliwai and Sandy Beach), the analysis greatly discounts risk from contaminants that otherwise may be considered unacceptably high.

Response: The quoted text describes the methodology for the selection of sediment COPECs using sediment data from the north and south background sites. Fish tissue data from the Nanakuli muliwai and nearshore at Sandy Beach background sites were not used to screen out COPECs in fish tissues. These data were used to calculate background risks to fish. Overall background risks to fish as indicated by fish tissue hazard indices (HIs) were higher at the Nanakuli muliwai and nearshore at Sandy Beach background sites than at the MMR muliwai and nearshore sites. The background HIs were driven primarily by higher concentrations of aluminum and vanadium (Nanakuli muliwai and Sandy Beach) and chromium and copper (Sandy Beach only) detected in fish tissues from the background sites (Tables 5-13, 5-15, and 5-16).

43. Comment: Page 19, Paragraph 4, Line 1: It would have been feasible to collect sediment samples near the MMR nearshore and then compare those results to a

reference area physically "upstream" of the MMR. But no prevailing alongshore current information was offered or collected. This reflects the lack of site characterization that we stressed as important in our review of the draft SAP.

Response: The objective of the MRS was to evaluate if military activities at the Makua Military Reservation MMR have contributed to contaminant concentrations in area fish, and if such activities present a health risk to area fishermen who rely on the fish for subsistence. As such, the study was focused on the collection of marine resources (fish and limu) tissue data, an evaluation of the presence of the contaminants in these tissue samples, an evaluation if military activities had contributed or were likely to contribute contaminants to these marine resources, and if contaminants detected in the tissue samples that were related to military activities at MMR posed a threat to human health through the consumption of these marine resources. While nearshore sediment analysis may provide some interesting data, it is not essential to achieve the objectives of the MRS.

44. Comment: Page 19, Paragraph 6, Line 1: An ecological conceptual site model (CSM) was used in the draft field report to assess exposure risks to fish and invertebrates using measured and estimated exposure rates of contaminants. Even if such a model were appropriate for the present case, it would be only as good as the site specific and calibration data, which are doubtful because of:

- **the absence of surficial sediment samples in any of the subject areas to properly measure sediment contaminant concentrations;**
- **inadequate and unexplained sampling of reference areas for sediments as discussed above;**
- **lack of sampling of benthic or aquatic organisms, despite the stated requirements of the model for appropriate "ecological receptors" (see bottom of page 5-8 of the draft field report) and**
- **lack of analysis or presentation of the trophic level and relative importance of the ecological receptors (fish) that were selected despite the state requirements of the model.**

Response: Comment noted.

45. Comment: Page 20, Paragraph 1, Line 1: This is a conceptual model and, by that description, is potentially useful for considering pathways and general processes, but it is not a numerical, stochastic model. Nor does the conceptual model as presented necessarily represent reality. Note in Figure 4-1 of the draft field report that the model suggests no possible ingestion exposure of benthic invertebrates to contaminants present in sediments. How is that known? Due to the lack of site-specific information, this must be considered speculation.

Response: The reviewers are correct that benthic invertebrates may ingest chemicals present in sediments, however please note that exposures of benthic invertebrates were assessed using total sediment concentrations (as per the sediment toxicity benchmarks, which are based on total exposures from sediments), not ingestion doses specifically. Figure 4-1 has been revised to show ingestion exposure of benthic invertebrates.

46. Comment: **Page 20, Paragraph 2, Line 1: Potential risks to benthic invertebrates were not evaluated by any meaningful or accurate methods. First, no samples of invertebrates were collected. Instead, the authors relied on prior sediment core data for contaminant concentration data. As we pointed out in the review of the draft SAP, prior sediment studies included mostly subsurface sediments that are not appropriate for testing if one is interested in effects on infauna, epifauna, demersal or pelagic organisms, which are exposed only to sediments within a few centimeters of the surface. In other words, the biota is never exposed to the deep sediments, and few samples were taken from top few centimeters as recommended by EPA for such studies. Therefore the foundation of the ecological risk assessment is faulty, and all the subsequent analyses are seriously flawed.**

Response: The assessment of potential hazards to benthic invertebrates using site-specific sediment data, as opposed to invertebrate tissue data, is standard practice in screening-level ERAs. Comparison of sediment data to sediment screening benchmarks is the preferred approach because (1) sediment screening benchmarks are conservative and based on large numbers of sediment bioassay results, and (2) relatively limited standardized, effect-based tissue concentrations for invertebrates are available.

47. Comment: **Page 20, Paragraph 3, Line 1: Second, even if the above is overlooked, there are no data or assessments of risks to different trophic levels of the food web. It cannot be assumed that highest trophic levels are automatically the most at risk. Some contaminants may be converted to non-toxic forms upon transfer up the food web; for example, macroalgae may contain proportionately higher levels of toxic inorganic arsenic but become organic forms when grazed.**

Response: The ecological receptors selected for the ERA were aquatic plants including seaweed, benthic invertebrates, aquatic invertebrates, and fish. As stated in the ERA, potential hazards to aquatic plants and aquatic invertebrates could not be quantified due to the lack of surface water data or seaweed tissue-based toxicity data. However, the categories of benthic invertebrates and fish include several trophic levels. Specific trophic levels within invertebrates and fish were not evaluated separately because the sediment screening benchmarks and fish tissue-based TRVs apply to all benthic invertebrates and fish, and are protective of all trophic levels. However, a conceptual food web will be provided in the ERA to illustrate the trophic levels included within the fish receptor category.

48. Comment: **Page 20, Paragraph 4, Line 1: The ERA and field study do not address aquatic invertebrates in the nearshore areas, and no credible justification is given for not sampling either the sediments or the invertebrates in these areas. Pelagic and benthic invertebrates are present, although the report claims that risk analysis was not implemented for the former due to "the absence of surface water data." This is illogical, as the organisms were there to sample, and water quality data (to estimate exposure risks) would be a poor substitute for the actual tissue data. No excuse is given for not sampling benthic or epibenthic invertebrates including commonly collected seafood species.**

Response: Although neither surface water data nor invertebrate tissue data were collected from the nearshore areas, tissue data would be a less preferred basis for evaluating potential risks. Relatively limited standardized, effect-based tissue concentration data for invertebrates are available in the literature. Demonstrating bioaccumulation in tissues does not necessarily indicate adverse effects.

49. Comment: Page 21, Paragraph 1, Line 1: There is no basis for the report's conclusion that fish in the nearshore MMR area are not significantly more contaminated than fish from other nearshore regions of O'ahu. As discussed above, the nearshore reference area the study selected is the site of a major sewage discharge outfall. As there are many beaches on O'ahu not subject to the potential influences of direct sewage discharge, the choice of this reference area is among the least appropriate of all possible choices.

Response: Background locations were selected to be representative of Makua in the absence of releases from the Makua MMR. However, that does not mean that background sites are required to be free of any anthropogenic influence, as this is impossible. As long as the background sites selected are representative of ambient conditions for the general Makua vicinity, they should be considered as acceptable (as per USEPA guidance).

50. Comment: Page 21, Paragraph 2, Line 1: Similarly, the selection of the Nanakuli muliwai as a background or reference area is not appropriate due to long-term use by a large Navy ammunition magazine in the upstream watershed, as well as impacts associated with urbanization. No water, sediment or fish tissue descriptions from other locations on O'ahu, from the study or the literature, are offered to justify the reference area choice. The report does not discuss the alternative of no suitable reference muliwai on the island, or whether there were other muliwai on neighbor islands that could have served in this regard.

Response: The purpose of the Marine Resources Study is to identify whether Army activities at the MMR have impacted Makua Valley resources above and beyond impacts from all other sources. Using an uncontaminated watershed for a background location would not allow the apportioning of impacts between the Army and other sources. This is a significant concern as there are many substantial sources of contamination other than the MMR. To adequately address the Army's impact alone on Makua Valley resources, an appropriate control site (i.e., background location) would be a valley where all aspects of the valley are as similar as possible to Makua. Since inter-watershed transport of contaminants is facilitated by wind and rain, the control valley should have similar wind and rain patterns as that of Makua. Biogeochemical processes affecting contaminants are a function of temperature and substrate, and these attributes should be as similar as possible to Makua Valley in order to identify impacts that can be attributed solely to Army activity. There are distinct differences in the substrate (mineralogy and age) between the different islands, making the selection of a control on another island inappropriate. Because of this, the most appropriate control watersheds are on the leeward (Waianae) coast of Oahu. As long as the background sites selected are representative of ambient conditions for the general Makua vicinity and have not received contamination from the MMR, they are considered acceptable, as per USEPA (1989, 2002a) risk assessment guidance.

51. Comment: **Page 21, Paragraph 3, Line 1: The assessment was supposed to evaluate human health risks to area residents who rely on "marine resources" for subsistence, but the investigators completely ignored important invertebrate seafood used by local people. Lacking actual appropriate sampling data, no method of modeling or estimation will identify what the actual risk is from consuming shellfish and other invertebrates from the muliwai and nearshore waters at Makua.**

Response: The results of the MRS indicate that relatively low levels of contamination are present in fish and limu in the Makua-area muliwai and nearshore areas, and that these levels are approximately the same as the levels detected in fish from background locations. The risk to subsistence fishermen from consuming the fish is below the levels used by USEPA for fish advisories. Furthermore, the study concludes that these contaminants are likely not coming from the MMR, because many of the chemicals are ubiquitous in the environment, and may be attributable to many different sources. Given that the fish are likely not contaminated by substances associated with the proposed training activities at MMR, that there is very little interchange between the muliwai where such substances might accumulate and the near-shore area which provides the habitat for the invertebrates on which area residents rely, that any such transport of chemicals from the muliwai to the nearshore area would result in significant dilution of the chemicals, it is likely that the shellfish are not contaminated by substances associated with the proposed training activities at MMR.

52. Comment: **Page 21, Paragraph 4, Line 1: Limu (seaweed) data shows high levels of arsenic that could be dangerous to human consumers, but the authors failed to sample reference areas for comparison, did not conduct taxonomic identifications, and did not differentiate between toxic and no toxic forms of that dangerous contaminant. Thus, the study fails to resolve questions about the risks to human health or marine life from arsenic-contaminated limu.**

Response: The speciation of arsenic to organic vs. inorganic forms was not requested or recommended by the experts during their review of the SAP, and therefore was not included as part of the analysis program for the MRS. The Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with Makua Military Reservation, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is likely that the speciation of arsenic to organic vs. inorganic forms, the collection of limu from reference areas and the identification of the limu will be included in this monitoring plan.

53. Comment: **Page 21, Paragraph 5, Line 1: Much of the risk assessment was based on use of suspect sediment data, which, as we previously pointed out, were collected from far too deep below the surface to represent the biologically active surface zone. The samples were also composited from different depths, so, if there were a stratum of contamination, it would have been diluted in the process. Discrete samples of the biologically active surficial sediment zone should have been used instead.**

Response: Comment noted.

54. Comment: Page 21, Paragraph 6, Line 1: As a result of the errors and biases in sampling, species and site selection, the environmental risk assessment has significant bias. Even when relatively high hazard quotients are found for some contaminants, the report authors simply point to the potentially contaminated reference areas to claim the hazard quotients are normal for O'ahu. This flawed study provides no valid support for this conclusion.

Response: The ERA provides an overall protective assessment of the potential for adverse effects resulting from past releases from the MMR. This screening-level evaluation applied a number of conservative assumptions to the selection of COPECs, quantification of exposure point concentrations, and selection of toxicity reference values. The collective effect of these assumptions was to minimize the likelihood of underestimating ecological hazards. To further address the reviewers' concerns, uncertainties resulting from the use of deeper sediment depth intervals to estimate exposures to benthic invertebrates will be discussed in the ERA. Calculated hazards for the background sites indicate that there are no incremental hazards to fish at the two muliwai and the nearshore area off MMR. The background sites represent relevant ambient conditions for the sites.

References:

Frankenberger, W.T. 2002. *Environmental Chemistry of Arsenic*. New York, Marcel Dekker.

USEPA. 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Volume 1: Fish Sampling and Analysis, Third Edition. Office of Water, Washington, DC. EPAUSEPA 823-B-00-007.

RESPONSE TO COMMENTS

DR. FRED DODGE, APRIL 1, 2007

1. **Comment:** **4 (a) Original S & A plan was flawed. Most recommendations by community and our consultants were not followed.**

   Response: The Army solicited comments from the community on the draft Marine Resource Sampling and Analysis Plan, and modified the plan as a result of the comments. However, the Army is ultimately responsible for ensuring that the scope of the study is feasible, appropriate to the study's objectives, and is cost effective. Unfortunately, not all recommendations could be implemented within these limits. Specific comments are addressed elsewhere in this document.

2. **Comment:** **4 (b) Nanakuli muliwae (known to local people as "stink pond") is a poor and unacceptable choice for the control muliwae. It's in an urban drainage area (e.g. from a four lane heavily used highway) as well as gets drainage from Nanakuli Ranch. Therefore it is obviously contaminated. This goes also for Sandy Beach. The area was used for military training in the past. You should have a better control muliwai, even if you have to go to an outer island - one where there is no history of military training, ranch, or urban area runoff.**

   Response: As discussed in response to similar comments by others, the background sites were selected from locations on the Waianae Coast, within watersheds that are not subjected to military activity, and distant enough from Makua Valley to be unlikely to be affected by target chemicals originating from Makua Valley. The purpose of the background sites is to compare to a reference unaffected by activities in Makua Valley, not necessarily to compare to a pristine environment.

3. **Comment:** **4 (c) Limu study found high levels of arsenic. The next obvious test was not done, i.e., to determine percentage of inorganic (toxic) vs. percentage of organic (safe) levels. Will you do it ? All limu samples need to be identified--not only by scientific but also by local names. The limu sample was too small. Needs to be larger.**

   Response: The objectives of the study have to do with determining the impacts attributable to activities at MMR, not with determining the relative safety of consuming marine resources. The comment highlights what may be a common misconception concerning the objectives of the studies conducted in response to the settlement agreement - namely that all hazards should be quantified, whether attributable to training activities at MMR or not. The presence of what appear to be elevated concentrations of arsenic in limu, whether toxic to humans or not, is not within the scope of the study to quantify, because neither the concentrations nor the form of the arsenic are related to or affected by activities at MMR.

4. **Comment:** **4 (d) Were the field notes redone to be clearly legible? Were all tables and information included in the appendices?**

   Response: Copies of original field notes are presented in the report, consistent with standard practice. The appendices contain the complete record of relevant data supporting the study. Between Section 7 and the Figures is a section containing tables. These figures are not considered part of the appendices.

5. **Comment:** **4 (e) Re fish catch: didn't include eels (puhi) which was strongly recommended in scopings. Need to do night fishing as well as diving both**

day and night. Fish sample was too small, only 34 gms. <u>EPA recommends 258 gms. Analysis of fish samples should be segregated by species.</u>

Response: Please see response to Comment 1, regarding inclusion of some species such as eels. Adequate quantities of fish tissue were collected, for a representative range of species, and did not necessitate night fishing. There is no particular reason to suspect that fish that are more easily caught at night would contain significantly different amounts of chemicals of concern than fish that forage during the day.

Users of the report can easily estimate the dose of a chemical of concern that would result from any daily rate of consumption of fish desired, based on the data provided in the report. For example, if it were assumed that the daily rate of fish consumption was 258 grams (about one-half pound), then the chemical dose would simply be multiplied by a factor of 7.6. The average daily fish consumption rate used to calculate the doses presented in the report is an accepted standard supported by the citations presented in the report.

As indicated in response to Comment 3, the purpose of the study was not to identify the all hazards, but to determine if activities at MMR would impact the health of people who depend on fish for a significant portion of their diet. There is no evidence that the local population of consumers of fish relies on only one species of fish.

6. Comment: **4 (f) Molluscs (shellfish) and crustaceans are supposed to be included in this study; e.g. crabs in muliwai and urchins near shore and benthic organisms. Please do it.**

Response: An unsuccessful attempt was made to collect sufficient numbers of specimens of shellfish for analysis. Based on the lack of evidence supporting a significant impact on human health from the most common and readily available edible species of fish and limu, the Army considers it unlikely that analysis of additional species would alter the initial conclusion that human health is not currently impacted by chemicals resulting from activities at MMR. The fact that it was difficult to obtain sufficient numbers of individuals to meet the analytical requirements of the study suggests that it would be equally difficult for local subsistence fishermen to consume the vast quantities of individuals of these species necessary to result in a significant impact on human health.

7. Comment: **4 (g) "There was a potential hazard to benthic invertebrates from 2,3,7,8-TCDD in sediments in the south muliwai" (Page 6-3 near the bottom). It is unlikely that dioxin found in the muliwai came from "burning of household waste." More likely, is the burning that occurred in the former OB/OD site. Please refer to my testimony on February 24, 2007 and the photo I took of the OB/OD site in 1979 and exhibited at that meeting. That information should be included in the revision. Dioxin/furans were also found in the "Halliburton" study of the OB/OD site (1994, I believe). This is important information regarding the cumulative effects which are supposed to be included in the EIS. Please so note in your revised report.**

Response: As discussed in the hydrogeologic investigation report, the muliwai investigation report, and in the marine resources investigation report, dioxins and furans are ubiquitous in Hawaii and throughout the world in low concentrations. The source

of these low levels is combustion. The concentrations observed in media at or near MMR are consistent with background concentrations. Regardless of whether past activities related to the OB/OD area may have contributed to the concentrations observed at MMR, the observed concentrations do not significantly differ from background levels.

8. Comment: **4 (h) Re: Draft Marine Resources Study (page 6-2) you state "there is no obvious pattern of deposition of explosive related chemicals." Yet you stated that perchlorate was found in surface water and detected in six samples of fish from the muliwai. That appears to be a pattern to me. The dioxin/furans may not show "obvious pattern" but were widely distributed" in the environment tested. Therefore, there could be a less obvious and more subtle pattern. You reported that xylene was detected in fish samples. This is disturbing and again raises more questions. Your study has raised more questions than it has answered. The critique by our consultants goes into more detail and needs to be addressed.**

Response: Additional discussion of perchlorate in fish tissue will be provided. Perchlorate was detected at highly variable concentrations in the fish samples. The concentrations in fish from the South Muliwai ranged from below the detection limit, to 160 parts per billion. One background fish sample from Sandy Beach contained 110 parts per billion. The large variability in the concentrations, and the similarity in the range of concentrations detected in the samples from both the muliwai and Sandy Beach suggests that a low level of accuracy resulting from one or more sources of error. At least one study, which investigated concentrations of perchlorate in tissues of freshwater species of fish collected near the former Naval Weapons Industrial Reserve Plant in McGregor, Texas, found elevated perchlorate concentrations in fish heads, even when the concentrations were not detected in fillets (US Army Corps of Engineers 2004). The study also found perchlorate in tissues of fish collected from watersheds thought to be isolated from sources of perchlorate. Perchlorate is a highly water-soluble salt, and would be expected to mix rapidly and disperse in a nearshore environment. Finally, although perchlorate is a constituent of rocket propellants and could be present in some munitions used in training activities at MMR, the amount of unburned rocket propellant released to the environment at MMR is expected to be very low. Therefore, although perchlorate was reported in samples of fish tissue, there is at least some reason to suspect that the reported concentrations may not accurately reflect the actual concentrations in the fish, or that perchlorate may be sequestered in certain tissues. Although the results of the study raise interesting questions for future research, the concentrations observed in the fish tissues are not of a magnitude that would present a significant threat to human health.

9. Comment: **4 (i) I quote from your Appendix C page 7 paragraph C.4.1:**

"A significant number of organochlorine data were disqualified because They could not be accurately quantified. Additionally, nitroglycerine and RDX data from three samples were disqualified. This resulted in a reduced number of valid data with which to use in the project assessment".

Your honesty is appreciated—I would expect nothing less. However, this appears to be a "significant" gap and deficiency in your data. This study needs to be redone!!!

Response: It would be unusual if environmental investigations of the broad scope and complexity of those conducted at MMR did not generate a number of interesting questions worthy of further research. However, the Army is required to consider the benefit versus the cost to the taxpayer to achieve improved confidence in analytical results that are below concentrations associated with significant human health effects. Despite the invariable uncertainty associated with detecting trace concentrations of COPCs in fish and limu tissues, the Marine Resources Study has achieved one of its primary objectives, which is to determine whether the concentrations of chemicals associated with training activities at MMR present a significant health threat to persons for whom fish represents a significant dietary input. The results of the study suggest that the threat is negligible. While additional monitoring may be warranted to confirm these results when training is resumed, the study results indicate that under current conditions, no significant adverse health effects will result from consuming fish and limu collected near MMR relative to other comparable coastal sites.

References:

U.S. Army Corps of Engineers. 2004. Final Report: Bosque and Leon River Watersheds Study. Fort Worth District. Available online at: http://www.swf.usace.army.mil/pubdata/ppmd/perchlorate/index.html. Accessed on June 6, 2007.

RESPONSE TO COMMENTS

TRANSCRIPT FROM PUBLIC MEETING HELD FEBRUARY 24, 2007

1. **Comment:** **David Henkin, Page 17, Line 6: ...field notes for the marine study are in many cases completely illegible, not suggesting anyone did anything intentional but you need to make the copies darker so one can actually read what species was collected where, and that information should be promptly provided to the public because we have a limited amount of time to comment.**

   Response: Darker copies of the field notes, which are easier to read, were provided to the public subsequent to the public meeting. Darker copies of the field notes have been included in the final Marine Resources Study (MRS).

2. **Comment:** **David Henkin, Page 17, Line 17: ...there's a table B, as in boy, one that was supposed to be in appendix B that would set forth how the samples were composited, in other words, how different fish and limu species were mixed together. I couldn't find it, I looked through every page of appendix B, hundreds of pages, I couldn't find it, so, again, that information just needs to be provided.**

   Response: The reference to Table B-1 in the MRS was made in error – this table was never completed, and was not intended to be included in the MRS. The reference to Table B-1 has been removed from the MRS. A version of the table was provided to Earthjustice and its' technical experts following the February 24, 2007 public meeting, however this was an incomplete table that was used for internal purposes.

3. **Comment:** **David Henkin, Page 18, Line 1: …even the hard copies that were provided today of the document, and it's appreciated the effort, if you look at it, and I don't know what's going on with the word processing program, but look, for example, on page 4-6, there are boxes instead of numbers, so certain numbers are coming through as boxes. So, you know, for example, if you want to, you know, they say later, USEPA guidance provides a mean uncooked fish consumption rate for the general U.S. population of box, 2.59 grams per day, and, anyway, there's boxes all over the place, so you actually don't even have the numbers, so we need to correct that.**

   Response: A printing error was responsible for mistakes cited in the comment. Electronic copies of the MRS, which did not have the errors cited in the comment, were provided to the public during the public meeting. Revised hard copies of the MRS were provided to the public following the public meeting.

4. **Comment:** **David Henkin, Page 18, Line 13[Due to missing data (see comments 6 and 7)]:…and I think we need to extend the comment period, there's a 60 day comment period as required under the settlement agreement so that people can actually review the information.:**

   Response: The comment period was extended to April 19, 2007, in response to a request from the public.

5. **Comment:** **William Alila, Page 24, Line 12: Regarding the marine study, sample size is too small.**

   Response: The Marine Resources Study was intended to sample a representative range of species that may be consumed by subsistence and recreational fishers on the Waianae Coast. Sampling all possible species that could be eaten by subsistence

fishers is an unrealistic expectation, and was beyond the scope of the study. However, the Army will be developing a long-term monitoring program to continue to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with MMR, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. Additional fish samples will likely be collected as part of this long-term monitoring plan.

6. Comment: William Alila, Page 24, Line 13: The Nanakuli Muliwai, I think we told you ahead of time that that was not a good choice to use because of the past military uses in Nanakuli, so it's not like you weren't told ahead of time don't use it, and you still went ahead and used it, so the results are mixed, the results are unsubstantiated, the results have failed to comply with our request for reasonable study.

Response: The rationale for the selection of background sites was provided in both the final SAP and the draft Marine Resources Study. In the final SAP, Section 2.2, Marine Resources Sampling Strategy, states "Background muliwai will be located on the Waianae Coast within watersheds that are not subjected to military activity." Section 2.2.3, Background Sampling, of the final SAP states "Samples will be collected from locations distant enough from Makua Valley that biota would be unlikely to be affected by target chemicals originating from MMR. Background muliwai will be located in watersheds that are not subject to military activity."

The purpose of the Marine Resources Study is to identify whether Army activities at the MMR have impacted Makua Valley resources above and beyond impacts from all other sources. Using an uncontaminated watershed for a background location would not allow the apportioning of impacts between the Army and other sources. This is a significant concern as there are many substantial sources of contamination other than the MMR. To adequately address the Army's impact alone on Makua Valley resources, an appropriate control site (i.e., background location) would be a valley where all aspects of the valley are as similar as possible to Makua. Since inter-watershed transport of contaminants is facilitated by wind and rain, the control valley should have similar wind and rain patterns as that of Makua. Biogeochemical processes affecting contaminants are a function of temperature and substrate, and these attributes should be as similar as possible to Makua Valley in order to identify impacts that can be attributed solely to Army activity. There are distinct differences in the substrate (mineralogy and age) between the different islands, making the selection of a control on another island inappropriate. Because of this, the most appropriate control watersheds are on the leeward (Waianae) coast of Oahu. As long as the background sites selected are representative of ambient conditions for the general Makua vicinity and have not received contamination from the MMR, they are considered acceptable, as per USEPA (1989, 2002a) risk assessment guidance.

7. Comment: William Alila, Page 24, Line 24: A more reasonable alternative would be to look at the baseline of a pristine muliwai, that baseline is closer to Makua 70 years ago than Nanakuli is, you're comparing apples with oranges. The baseline that we need to be looking at is the baseline that occurred before the military showed up and started bombing and started burning and started dumping and started doing OBOD disposal there, that's the baseline, not the baseline for the last 20 years, the baseline is what occurred before the military showed up and evicted people from Makua Valley, that's the baseline. That

should always be the baseline, whether it's archeological, whether it's chemical, whether it's hydrological, whether it's sociological.

Response: The rationale for the selection of background sites was provided in both the final SAP and the draft Marine Resources Study. In the final SAP, Section 2.2, Marine Resources Sampling Strategy, states "Background muliwai will be located on the Waianae Coast within watersheds that are not subjected to military activity." Section 2.2.3, Background Sampling, of the final SAP states "Samples will be collected from locations distant enough from Makua Valley that biota would be unlikely to be affected by target chemicals originating from MMR. Background muliwai will be located in watersheds that are not subject to military activity."

The purpose of the Marine Resources Study is to identify whether Army activities at the MMR have impacted Makua Valley resources above and beyond impacts from all other sources. Using an uncontaminated watershed for a background location would not allow the apportioning of impacts between the Army and other sources. This is a significant concern as there are many substantial sources of contamination other than the MMR. To adequately address the Army's impact alone on Makua Valley resources, an appropriate control site (i.e., background location) would be a valley where all aspects of the valley are as similar as possible to Makua. Since inter-watershed transport of contaminants is facilitated by wind and rain, the control valley should have similar wind and rain patterns as that of Makua. Biogeochemical processes affecting contaminants are a function of temperature and substrate, and these attributes should be as similar as possible to Makua Valley in order to identify impacts that can be attributed solely to Army activity. There are distinct differences in the substrate (mineralogy and age) between the different islands, making the selection of a control on another island inappropriate. Because of this, the most appropriate control watersheds are on the leeward (Waianae) coast of Oahu. As long as the background sites selected are representative of ambient conditions for the general Makua vicinity and have not received contamination from the MMR, they are considered acceptable, as per USEPA (1989, 2002a) risk assessment guidance.

8. Comment: William Alila, Page 25, Line 14: The marine study clearly states in several places in the executive summary about uncertainties, uncertainties of baselines by which to make comparisons, uncertainties of order of magnitude of effect, uncertainties based on assumptions which translate into risk assessment, and what we asked for was some certainty, not more uncertainty when we requested the muliwai study, we want to know with certainty, is the fish safe to eat, are the crabs safe to eat, is the limu safe to eat?

Response: According to USEPA (1989) guidance, "Uncertainties in the risk assessment must be evaluated and discussed, including uncertainties in the physical setting definition of the site, in the models used, in the exposure parameters, and in the toxicity assessment." Knowing the uncertainties in the information used to write the report allows a better evaluation of the information presented in the report and is required by both federal and state regulators.

9. Comment: William Alila, Page 26, Line 4: Is the arsenic organic or inorganic? Gee, I don't know, maybe I should stop eating the limu but until you guys tell me, because if it's inorganic, then chances are I'm going to die of cancer. You guys knew when you were doing the study that there are two forms of

arsenic, why didn't you just figure out what the percentage was in the limu and the fish instead of coming back with our report that's full of uncertainty.

Response: The Marine Resources Study concluded that the activities at MMR likely did not contribute to the arsenic detected in fish and limu, and therefore the proposed training activities at MMR do not pose a human health risk to area residents that rely on marine resources for subsistence. Given that the detected arsenic likely did not come from MMR, the Army is under no obligation to determine if the arsenic is organic or inorganic. Furthermore, the speciation of arsenic to organic vs. inorganic forms was not requested or recommended by the public or Earthjustice or its' experts during their review of the Sampling and Analysis Plan, and therefore was not included as part of the analysis program for the Marine Resources Study. However, the Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with Makua Military Reservation, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is likely that the speciation of arsenic to organic vs. inorganic forms will be included in this monitoring plan.

10. Comment: William Alila, Page 26, Line 13: The choice of Sandy Beach as an alternate control site, wow, who came up with that one? They should have gone back and checked the records. Alan Davis was used to house military folks, there were military activities that occurred at Alan Davis, Alan Davis is another name for Sandy Beach. So you compare an area that has been used for military activities with an area that is being used for military activities and, guess what, the difference shouldn't be that much, so does that make it okay? More appropriate, and we said this in our comments to you before you designed the study, we said, use someplace where there's been no military influence, use Haena on Kauai, use someplace on the North Shore of Molokai, that's the baseline, that's the appropriate baseline in which to make comparisons because you guys not going to eat the fish, you guys going to serve two years over here and you guys going to leave, but we got to eat the fish and we got to eat the limu.

Response: The rationale for the selection of background sites was provided in both the final SAP and the draft Marine Resources Study. In the final SAP, Section 2.2, Marine Resources Sampling Strategy, states "Background muliwai will be located on the Waianae Coast within watersheds that are not subjected to military activity." Section 2.2.3, Background Sampling, of the final SAP states "Samples will be collected from locations distant enough from Makua Valley that biota would be unlikely to be affected by target chemicals originating from MMR. Background muliwai will be located in watersheds that are not subject to military activity."

The purpose of the Marine Resources Study is to identify whether Army activities at the MMR have impacted Makua Valley resources above and beyond impacts from all other sources. Using an uncontaminated watershed for a background location would not allow the apportioning of impacts between the Army and other sources. This is a significant concern as there are many substantial sources of contamination other than the MMR. To adequately address the Army's impact alone on Makua Valley resources, an appropriate control site (i.e., background location) would be a valley where all aspects of the valley are as similar as possible to Makua. Since inter-

watershed transport of contaminants is facilitated by wind and rain, the control valley should have similar wind and rain patterns as that of Makua.

11. Comment: William Alila, Page 28, Line 2: where did those chemicals that are associated with Heptachlore and pesticide use, agriculture pesticide use end up in fish in Makua?

Response: The purpose of the Marine Resources Study is to identify whether Army activities at the MMR have impacted Makua Valley resources above and beyond impacts from all other sources. There are a wide variety of potential sources of contaminants in the fish that were outlined in the MRS, and it is not part of the scope of the MRS to determine the source of all of these contaminants. The data collected from the Makua Military Reservation during several environmental investigations, combined with the fish tissue data collected during the MRS indicate that the Army is likely not the source of the contaminants detected in the fish.

12. Comment: Vince Dodge, Page 41, Line 6: which brings me back to the marine study because the marine study is about food, and I love my 'ia, I love my fish, and one of the things that I noticed is missing in that study, and Gary from Tetra Tech was kind enough to tell me that they spent five weeks catching fish, they didn't catch too many species, they only fished in the daytime, they didn't fish early in the morning, they didn't fish at night, they didn't go diving, so their methodology and their window of, you know, trying to catch fish was pretty limited, you know, and as fishermen we know there's certain things you catch in the middle of the day and there's certain things you got to go in the morning early or you got to go at night, and you got to throw palu, you know.

Response: The MRS was intended to sample a representative range of species that may be consumed by subsistence and recreational fishers on the Waianae Coast. Sampling all possible species that could be eaten by subsistence fishers is an unrealistic expectation, and was beyond the scope of the study. Since trophic level influences the potential uptake and concentration of contaminants, species from a range of trophic levels (herbivore, omnivore and carnivore) were targeted in the study. Since there is no clearly defined reason why a species that may be active at night would differentially uptake and concentrate contaminants, the study focused active sampling activities during daylight hours, and employed passive methods (i.e., fish and crab traps) overnight on several occasions and in several muliwai. However, these passive traps were not successful in catching sufficient numbers of fish or invertebrates to use as even a single sample. However, the Army will be developing a long-term monitoring program to continue to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with MMR, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. Additional fish samples will likely be collected as part of this long-term monitoring plan.

13. Comment: Vince Dodge, Page 42, Line 1:...when I look at that marine study, I'm like either these guys are not good fishermen and/or there's just no fish in the ocean anymore, but one of the things that they did not catch and they did not make any real effort to catch, was the puhi, the eel, and in the scoping meetings, as folks that live down here, as folks that fish and eat fish, you know, we strongly recommended many times that they catch puhi because

the puhi is a creature that eats near shore, inshore fish and crustaceans, and he's at the top of the food chain, pretty much, you know, and he lives in the area, and he's going be to the one that if there are toxins he's going to be one that you're going to find the concentration in, you're not going to find concentration in oholiholi that are this big, you know, moana that are like eight inches, I mean, that's a fish that's maybe a year or two old, that's not an old fish but a nice big puhi, one of the green ones or a big white eel, that fish, that fish has been around for awhile, he's eaten a lot of things and we'd get some, it would be a good indicator.

Response: The MRS was intended to sample a representative range of species that may be consumed by subsistence and recreational fishers on the Waianae Coast. Sampling all possible species that could be eaten by subsistence fishers is an unrealistic expectation, and was beyond the scope of the study. Since trophic level influences the potential uptake and concentration of contaminants, species from a range of trophic levels (herbivore, omnivore and carnivore) were targeted in the study. The primary methods used for catching fish were various nets and hook and line. A variety of other methods used by local fishermen, including spear fishing, were not used in the study, because of the potential to introduce metals and other types of contamination into the fish. However, the Army will be developing a long-term monitoring program to continue to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with MMR, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. Additional fish samples will likely be collected as part of this long-term monitoring plan.

14. Comment: Dr. Jonathan Deenik, Page 44, Line 20: So here is, I think, a basic flaw in this study is the number of samples that were gathered. Now, maybe it was constrained by money, well, that's fair enough, you know, we have to operate within a budget, but if you were to look at this and say that decisions are being made on four samples of limu, that's at least what's said in the paper there, well, then, of course, you're going to have a lot of uncertainty and you cannot, anybody in their right mind can't make, you know, a good prediction of what is the health hazard on four samples. So that's a pretty fundamental basic baseline.

Response: The Army will be developing a long-term monitoring program to continue to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with MMR, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. Additional limu samples will likely be collected as part of this long-term monitoring plan.

15. Comment: Dr. Jonathan Deenik, Page 45, Line 8: The other important question is what are we comparing this to, so there's always in any kind of study a control group and an affected group, so Mr. Aila clearly pointed out the flaws associated with the control group. I don't think the study needed to select a control within the Waianae Coast, that was never one of our suggestions during the scoping meeting, so where do you go find an area that has not been affected by military use? Well, Oahu, it's not easy to find an area that hasn't been impacted by military activity, in fact, I still think there are two or three super fund sites associated with military activity on this island, so you're going to have to go somewhere else, Molokai, that's a fair enough

comparison, same type of sediments in east Molokai as Makua, similar, at least, make a comparison. That becomes a real control, and then you can say with a little bit more certainty, well, there is an impact or there isn't an impact.

Response: The rationale for the selection of background sites was provided in both the final SAP and the draft Marine Resources Study. In the final SAP, Section 2.2, Marine Resources Sampling Strategy, states "Background muliwai will be located on the Waianae Coast within watersheds that are not subjected to military activity." Section 2.2.3, Background Sampling, of the final SAP states "Samples will be collected from locations distant enough from Makua Valley that biota would be unlikely to be affected by target chemicals originating from MMR. Background muliwai will be located in watersheds that are not subject to military activity."

The purpose of the Marine Resources Study is to identify whether Army activities at the MMR have impacted Makua Valley resources above and beyond impacts from all other sources. Using an uncontaminated watershed for a background location would not allow the apportioning of impacts between the Army and other sources. This is a significant concern as there are many substantial sources of contamination other than the MMR. To adequately address the Army's impact alone on Makua Valley resources, an appropriate control site (i.e., background location) would be a valley where all aspects of the valley are as similar as possible to Makua. Since inter-watershed transport of contaminants is facilitated by wind and rain, the control valley should have similar wind and rain patterns as that of Makua. Biogeochemical processes affecting contaminants are a function of temperature and substrate, and these attributes should be as similar as possible to Makua Valley in order to identify impacts that can be attributed solely to Army activity. There are distinct differences in the substrate (mineralogy and age) between the different islands, making the selection of a control on another island inappropriate. Because of this, the most appropriate control watersheds are on the leeward (Waianae) coast of Oahu. As long as the background sites selected are representative of ambient conditions for the general Makua vicinity and have not received contamination from the MMR, they are considered acceptable, as per USEPA (1989, 2002a) risk assessment guidance.

16. Comment: David Henkin, Page 48, Line 11: So when you do a study based on very limited sampling size such that the uncertainties are so great that you cannot say anything meaningful about the potential for contamination by substances associated with proposed training at Makua, you haven't done what the court order said, you haven't done what you agreed to do, so money in this case really is not relevant, what's relevant is what the Army voluntarily entered into and what the court ordered.

Response: According to USEPA (1989) guidance, "Uncertainties in the risk assessment must be evaluated and discussed, including uncertainties in the physical setting definition of the site, in the models used, in the exposure parameters, and in the toxicity assessment." Knowing the uncertainties in the information used to write the report allows a better evaluation of the information presented in the report and is required by both federal and state regulators. The Army will be developing a long-term monitoring program to continue to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with MMR, and the Army anticipates soliciting public input for the development of the long-term monitoring

plan. Additional limu samples will likely be collected as part of this long-term monitoring plan.

17. Comment: David Henkin, Page 48, Line 21: The emphasis here is marine resources, limu, shell fish, fish on which area residents rely for subsistence. That goes to the point that Vince Dodge raised, people fish at night, people dive, people eat a variety of things out of the ocean, these are the things that the Army agreed to and is obliged to study, and that's not what we got.

Response: The MRS was intended to sample a representative range of species that may be consumed by subsistence and recreational fishers on the Waianae Coast. Sampling all possible species that could be eaten by subsistence fishers is an unrealistic expectation, and was beyond the scope of the study. Since trophic level influences the potential uptake and concentration of contaminants, species from a range of trophic levels (herbivore, omnivore and carnivore) were targeted in the study. Since there is no clearly defined reason why a species that may be active at night would differentially uptake and concentrate contaminants, the study focused active sampling activities during daylight hours, and employed passive methods (i.e., fish and crab traps) overnight on several occasions and in several muliwai. However, these passive traps were not successful in catching sufficient numbers of fish or invertebrates to use as even a single sample. The Army will be developing a long-term monitoring program to continue to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with MMR, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. Additional fish samples will likely be collected as part of this long-term monitoring plan.

18. Comment: David Henkin, Page 49, Line 20: Well, the study assumed that for recreational fishermen, so people that are not subsistence, that a meal of fish is 34 grams, 28 grams is an ounce, so we're talking a little bit more than a couple of bites, that was the, obviously, how much of something you eat has a strong correlation to the likelihood you're going to get poisoned by it or it's going to contribute to cancer rates, so if you start with an unrealistically low assumption that people take a bite of fish and that's their fish meal and that's what you're going to evaluate, you're going to get inaccurate results that are not reliable because the point of the exercise really is not to, we didn't enter into this to try and prove that marine resources at Makua are unhealthy, because that would really be damaging to this community if that were the truth, we'd like to have good data that proved that marine resources at Makua are healthy because the fact of the matter is, that healthy or unhealthy, people are going to be keep eating them... So when you do a study that assumes that we only eat an ounce of fish at a meal, that doesn't give us good information.

Response: Fish consumption rates may vary by ethnic group, lifestyle, economic status, and geography, among other factors (OEHHA 2001). Therefore, it is desirable to use a fish consumption rate that is applicable to the receptors being evaluated. As part of the MRS, the Army reviewed the literature on fish consumption rates in Hawaii and selected the highest fish consumption rates recorded for Hawaii. The Army believes that the fish consumptions rates used in the MRS were appropriate for the study. The recreational fishermen consumption rate used in this report was the average

fish consumption rate from a survey of 13,629 Hawaiian fishermen in Hawai`i (Sharma et al. 2003).

19. Comment: David Henkin, Page 51, Line 23: Now, for a subsistence fisherman, now this is someone who is relying on this area to really survive, I mean, they're not going to the supermarket for their fish, this is survival, they consume 110 grams, so that's about a four ounce portion, it's a quarter pound of meat, so those who go get a quarter pounder, not very much, again. So in terms of what the experts who do this over at EPA, EPA assumes that an average fish sized meal is 227 grams, so over twice as much they consume for subsistence fishermen or about half a pound, and based on my own experience and 41 years on this earth, that's kind of more like what people tend to eat when they sit down to eat fish, so we need studies that are based on good data, and we're entitled to them.

Response: Fish consumption rates may vary by ethnic group, lifestyle, economic status, and geography, among other factors (OEHHA 2001). Therefore, it is desirable to use a fish consumption rate that is applicable to the receptors being evaluated. As part of the MRS, the Army reviewed the literature on fish consumption rates in Hawaii and selected the highest fish consumption rates recorded for Hawaii. The fish ingestion rate of 100.6 grams/day used in this report was the 95th percentile fish consumption rate from a survey of 13,629 Hawaiian fishermen in Hawai`i (Sharma et al. 2003). USEPA guidance indicates that much lower fish consumption rates should be used in risk assessments (with the exception of Native American subsistence fishermen), as stated in the report "The USEPA Superfund Program guidance assumes an ingestion rate of 54 grams of fish per day (g/day) for high consumers of locally caught fish (USEPA 1991a). For the general US population, the USEPA Exposure Factors Handbook recommends a mean marine fish consumption rate of 14.1 g/day for the general US population and a mean of 70 g/day and 95th percentile of 170 g/day fish consumption rate for Native American subsistence populations (USEPA 1997a)." It is not clear where the reviewer obtained the estimate of 227 grams for an average fish sized meal, but in any case it should be noted that the assumption used in the MRS was that the subsistence fisherman was eating 100.6 grams/day every day for 30 years. Based upon this information, the Army believes that the fish consumption rates used in the MRS were appropriate for the study.

20. Comment: David Henkin, Page 52, Line 14: One of the big issues that's totally unresolved in this study is the likelihood that people are eating toxic levels of arsenic. They came out in the study with extremely high levels of arsenic in the fish and the limu, the problem is they don't tell us whether the arsenic is organic arsenic, which has a lower toxicity, or inorganic arsenic, which has a very high toxicity, there's no reason for that. You can analyze a sample and determine the proportion that's organic and inorganic.

Response: The Marine Resources Study concluded that the activities at MMR likely did not contribute to the arsenic detected in fish and limu, and therefore the proposed training activities at MMR do not pose a human health risk to area residents that rely on marine resources for subsistence. Given that the detected arsenic likely did not come from MMR, the Army is under no obligation to determine if the arsenic is organic or inorganic. Furthermore, the speciation of arsenic to organic vs. inorganic forms was not requested or recommended by the public or Earthjustice or its'

experts during their review of the Sampling and Analysis Plan, and therefore was not included as part of the analysis program for the Marine Resources Study. However, the Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with Makua Military Reservation, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is likely that the speciation of arsenic to organic vs. inorganic forms will be included in this monitoring plan.

21. Comment: **David Henkin, Page 53, Line 4: ...they didn't analyze whether the arsenic was organic or inorganic, they looked at studies that said worldwide, most fish has organic arsenic in it, therefore, we assume that all of the arsenic that we found is organic. Well, that doesn't follow logically because most fish aren't in a near shore area where we have surface water studies that the Army has done that inorganic arsenic is flowing in the streams into the water, so you can't just sort of assume, you know, sort of Socrates was a man, that type of logic. Unless you study the specific fish that people are going down and eating to determine whether it's organic arsenic or inorganic arsenic, you're not going to get good data. Same thing with limu, limu had very high levels of arsenic, they did not go into any analysis of whether it was organic or inorganic, that's information that we need, that's information that we're…**

Response: The Marine Resources Study concluded that the activities at MMR likely did not contribute to the arsenic detected in fish and limu, and therefore the proposed training activities at MMR do not pose a human health risk to area residents that rely on marine resources for subsistence. Given that the detected arsenic likely did not come from MMR, the Army is under no obligation to determine if the arsenic is organic or inorganic. Furthermore, the speciation of arsenic to organic vs. inorganic forms was not requested or recommended by the public or Earthjustice or its' experts during their review of the Sampling and Analysis Plan, and therefore was not included as part of the analysis program for the Marine Resources Study. However, the Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with Makua Military Reservation, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is likely that the speciation of arsenic to organic vs. inorganic forms will be included in this monitoring plan.

22. Comment: **David Henkin, Page 53, Line 22: Also, with limu, I'll get into a little bit later the references that were used for these various studies, but for limu they did not sample limu anywhere else in the Hawaiian islands, in fact, anywhere else at all, they just looked at the chemical constituents that are in this limu that people are eating, people are gathering, people are eating, I've eaten it, there's no comparison, so we don't know what pristine limu would have, maybe it is that all limu in Hawaiian waters have elevated levels of arsenic, and even if you go to pristine areas on neighbor islands that are not affected not only by military activities, and I'll get into this, but by any urbanization or human input, any anthropogenic input, maybe that's just the way our limu is, well, that would be a meaningful study, that would provide meaningful information, that this is the level arsenic that you get in limu.**

Response: The Marine Resources Study concluded that the activities at MMR likely did not contribute to the arsenic detected in fish and limu, and therefore the proposed training activities at MMR do not pose a human health risk to area residents that rely on marine resources for subsistence. Given that the detected arsenic likely did not come from MMR, the Army is under no obligation to determine if the arsenic is organic or inorganic. Furthermore, the speciation of arsenic to organic vs. inorganic forms was not requested or recommended by the public or Earthjustice or its' experts during their review of the Sampling and Analysis Plan, and therefore was not included as part of the analysis program for the Marine Resources Study. However, the Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with Makua Military Reservation, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is likely that the speciation of arsenic to organic vs. inorganic forms will be included in this monitoring plan.

23. Comment: David Henkin, Page 55, Line 1: There's nothing in this study about shell fish, they didn't gather shell fish, whether it's crabs in the muluwai or urchin in the inshore areas, there's no study of shell fish at all, none. So they have failed to comply with their agreement and the court order to study shell fish, they need to do that.

Response: The language in the 2007 order states that "As part of the preparation of the EIS for military training activities at MMR, Defendants shall complete one or more studies to determine whether fish, limu, shellfish, and other marine resources near Makua Beach and in the muliwai on which area residents rely for subsistence are contaminated by substances associated with the proposed training activities at MMR." There is nothing in this language that expressly requires that shellfish be tested, and as such, the Army is not in violation of the 2007 Order.

The results of the Marine Resources Study (MRS) indicate that relatively low levels of contamination are present in fish and limu in the Makua-area muliwai and nearshore areas, and that these levels are approximately the same as the levels detected in fish from background locations. The risk to subsistence fishermen from consuming the fish is below the levels used by USEPA for fish advisories. Furthermore, the study concludes that these contaminants are likely not coming from the MMR, because many of the chemicals are ubiquitous in the environment, and may be attributable to many different sources. Given that the fish are likely not contaminated by substances associated with the proposed training activities at MMR, that there is very little interchange between the muliwai where such substances might accumulate and the near-shore area which provides the habitat for the shellfish on which area residents rely, that any such transport of chemicals from the muliwai to the nearshore area would result in significant dilution of the chemicals, it is likely that the shellfish are not contaminated by substances associated with the proposed training activities at MMR.

Despite the conclusion that the shellfish are likely not contaminated from activities at MMR, field staff did attempt to collect shellfish and benthic invertebrates, including crabs and sea urchins, during the MRS. However, the selected method (passive traps) was not successful in capturing crabs. Additionally, because of the large number of analytes included in the chemical analytical program, field staff were unable to collect a sufficient number of sea urchins to provide enough sample mass

(more than 200 grams) for all of the analyses. It is important to recognize that this project required destructive sampling of a living resource, which has the potential to negatively impact a species population in the muliwai. The Army will be developing a long-term monitoring program to evaluate potential impacts from military activities to the muliwai and nearshore areas associated with MMR, and the Army anticipates soliciting public input for the development of the long-term monitoring plan. It is possible that shellfish and benthic invertebrates will be included as species of interest in this monitoring plan if it is determined that the sampling will not have a negative impact on the species population.

24. Comment: David Henkin, Page 57, Line 2: You need to look at a non-contaminated muluwai, which is what Makua would be, and determine what the background levels are.

Response: The rationale for the selection of background sites was provided in both the final SAP and the draft Marine Resources Study. In the final SAP, Section 2.2, Marine Resources Sampling Strategy, states "Background muliwai will be located on the Waianae Coast within watersheds that are not subjected to military activity." Section 2.2.3, Background Sampling, of the final SAP states "Samples will be collected from locations distant enough from Makua Valley that biota would be unlikely to be affected by target chemicals originating from MMR. Background muliwai will be located in watersheds that are not subject to military activity."

The purpose of the Marine Resources Study is to identify whether Army activities at the MMR have impacted Makua Valley resources above and beyond impacts from all other sources. Using an uncontaminated watershed for a background location would not allow the apportioning of impacts between the Army and other sources. This is a significant concern as there are many substantial sources of contamination other than the MMR. To adequately address the Army's impact alone on Makua Valley resources, an appropriate control site (i.e., background location) would be a valley where all aspects of the valley are as similar as possible to Makua. Since inter-watershed transport of contaminants is facilitated by wind and rain, the control valley should have similar wind and rain patterns as that of Makua. Biogeochemical processes affecting contaminants are a function of temperature and substrate, and these attributes should be as similar as possible to Makua Valley in order to identify impacts that can be attributed solely to Army activity. There are distinct differences in the substrate (mineralogy and age) between the different islands, making the selection of a control on another island inappropriate. Because of this, the most appropriate control watersheds are on the leeward (Waianae) coast of Oahu. As long as the background sites selected are representative of ambient conditions for the general Makua vicinity and have not received contamination from the MMR, they are considered acceptable, as per USEPA (1989, 2002a) risk assessment guidance.

25. Comment: David Henkin, Page 58, Line 16: Sandy Beach, there's been questions raised whether that's an appropriate background for the fish and so, in general, you need to address how you selected the locations because if they're not free of human input, if they're not pristine areas, they don't tell us what the effects are of the military being there.

Response: The rationale for the selection of background sites was provided in both the final SAP and the draft Marine Resources Study. In the final SAP, Section 2.2, Marine Resources Sampling Strategy, states "Background muliwai will be located on the

Waianae Coast within watersheds that are not subjected to military activity." Section 2.2.3, Background Sampling, of the final SAP states "Samples will be collected from locations distant enough from Makua Valley that biota would be unlikely to be affected by target chemicals originating from MMR. Background muliwai will be located in watersheds that are not subject to military activity."

The purpose of the Marine Resources Study is to identify whether Army activities at the MMR have impacted Makua Valley resources above and beyond impacts from all other sources. Using an uncontaminated watershed for a background location would not allow the apportioning of impacts between the Army and other sources. This is a significant concern as there are many substantial sources of contamination other than the MMR. To adequately address the Army's impact alone on Makua Valley resources, an appropriate control site (i.e., background location) would be a valley where all aspects of the valley are as similar as possible to Makua. Since inter-watershed transport of contaminants is facilitated by wind and rain, the control valley should have similar wind and rain patterns as that of Makua. Biogeochemical processes affecting contaminants are a function of temperature and substrate, and these attributes should be as similar as possible to Makua Valley in order to identify impacts that can be attributed solely to Army activity. There are distinct differences in the substrate (mineralogy and age) between the different islands, making the selection of a control on another island inappropriate. As long as the background sites selected are representative of ambient conditions for the general Makua vicinity and have not received contamination from the MMR, they are considered acceptable, as per USEPA (1989, 2002a) risk assessment guidance.

This page intentionally left blank

EARTHJUSTICE

BOZEMAN, MONTANA DENVER, COLORADO HONOLULU, HAWAII
INTERNATIONAL JUNEAU, ALASKA OAKLAND, CALIFORNIA
SEATTLE, WASHINGTON TALLAHASSEE, FLORIDA WASHINGTON, D.C.

April 19, 2007

Via U.S. Mail and Electronic Mail

Mr. Gary Shirakata
U.S. Army Corps of Engineers
Honolulu Engineer District, Building 230
Fort Shafter, HI 96858-5440
email: Makua-EIS@poh01.usace.army.mil

Re: Mākua Military Reservation Draft Environmental Impact Statement

Dear Mr. Shirakata,

In this letter, Earthjustice focuses on the draft Marine Resources Study, Field Sampling Results and Risk Assessment (dated January 2007).[1] As discussed herein, the draft study falls far short of satisfying the minimum requirements set forth in the 2007 Order. To comply with its legal obligations, the Army must conduct additional studies, using proper procedures, circulate those additional studies for public (including expert) comment, and incorporate the results of those studies in the final environmental impact statement ("EIS") for proposed training at Mākua Military Reservation ("MMR").

We have enclosed reviews of the marine study and of the associated final sampling and analysis plan ("SAP") prepared by technical assistants Drs. Jack Rensel, Ralph Elston, and Jeffrey Foran, which are incorporated herein by reference. In addition, we submit the following comments:

Shellfish and Other Non-Fish, Non-Limu Marine Resources

The Marine Resources Study's failure to examine whether shellfish or other non-fish, non-limu marine resources near Mākua Beach and in the muliwai are contaminated violates the terms of the 2007 Order, which expressly requires that shellfish and marine resources other than fish and limu be tested. 2007 Order ¶ 6. As discussed in the enclosed expert reviews, as well as in expert comments on the draft SAP, testing shellfish and other benthic or demersal invertebrates is extremely important to assess potential contamination of marine resources since these species have continual contact with sediments that may contain contaminants from activities at MMR.

[1] Due to the Army's failure to comply with paragraph 10 of the January 8, 2007 Joint Stipulation Re: Partial Settlement Of Plaintiff's Motion To Enforce The October 4, 2001 Settlement Agreement And Stipulated Order ("2007 Order"), the Army agreed to extend until April 19, 2007, the time for Earthjustice and Mālama Mākua's experts to submit comments on the draft marine study. These comments are, therefore, timely.

223 SOUTH KING STREET, SUITE 400, HONOLULU, HI 96813-4501
T: 808 599-2436 F: 808 521-6841 E: eajushi@earthjustice.org W: www.earthjustice.org

10% NON WOOD FIBERS · 90% POST CONSUMER PAPER · PROCESSED CHLORINE FREE

The study's failure to test shellfish and other non-fish, non-limu marine resources resulted in a failure to evaluate accurately whether military activities at MMR pose a human health risk to area residents who rely on these marine resources for subsistence, in further violation of the 2007 order. To comply with its legal obligations, the Army must complete another study that focuses on potential contamination of shellfish and other non-fish, non-limu marine resources and the health risks associated with consuming those resources, put the study out for public review and comment, and incorporate its analysis into the final EIS. Id. ¶¶ 6, 11-13.

Fish

As discussed in Drs. Elston and Rensel's review, the study analyzed only fish species that are present at Mākua during the middle of the day. The study provides no data or analysis whether fish species that can be gathered only in the early morning or at night – marine resources on which area residents rely for subsistence – are contaminated, violating the 2007 Order.

Limu

While the study claims "the seaweed in the samples were identified to genus," review of the field notes reveals the investigators often had no idea what they were gathering. Study at ES-3. For example, the field notes refer to one sample of limu generically as "Limu 2." These unidentified limu were then composited into mixed "seaweed" samples and then analyzed for contaminants. Study at 2-3, Table 2-2. Since its analysis is based on composites of "mystery" limu, which may have included species of limu that no one consumes, the study fails to satisfy the 2007 Order's requirement to focus on whether limu "on which area residents rely for subsistence" is contaminated. 2007 Order ¶ 6.

Having found extremely elevated levels of arsenic in limu from Mākua, the investigators failed to perform standard analyses to determine whether the arsenic in the limu is present in its highly toxic, inorganic form or in the less toxic, organic form. Without this information, there was no way for the study to evaluate accurately whether consuming limu from Mākua poses "a human health risk to area residents [who] rely on marine resources for subsistence," further violating the 2007 order. Id.

The study failed to analyze limu from any location other that Mākua. Accordingly, as the study concedes, "it is not possible to determine whether the arsenic levels detected in seaweed at Mākua Beach are elevated over background." Study at ES-3. Having made no attempt to determine the levels of arsenic contamination that would be present in the absence of military activities, the study failed to satisfy the 2007 Order's requirement to "evaluate the potential that activities at MMR have contributed or will contribute to any such contamination." 2007 Order ¶ 6.

"Background" Locations

In their comments, Drs. Elston and Rensel detail why the study's selection of Nanakuli muliwai and Sandy Beach – both of which receive substantial inputs of anthropogenic contaminants that, in the absence of military activities, would not occur at Mākua – as "background" locations was improper and rendered useless the study's analysis of human health and ecological risk from training activities at MMR. To supplement their discussion, we enclose the relevant page from an O'ahu map book, showing the location of the East Honolulu Wastewater Treatment Plant (labeled on the map as "STP" and circled in black), which is immediately across Kalaniana'ole Highway from Sandy Beach. As noted in Drs. Elston and Rensel's review, the sewage outfall is located only 400 meters offshore, at about only 12 meters in depth.

We also note that, across the board, the study concluded the "non-carcinogenic hazard index estimates" from fish consumption were greater at the alleged "background" sites than at Mākua, sometimes by many times. See, e.g., Study at Table 4-8 (non-carcinogenic hazard index estimate from likely fish consumption rates at Nanakuli muliwai using mean contaminant concentrations more than double that at Mākua); Table 4-12 (non-carcinogenic hazard index estimate from likely fish consumption rates at Sandy Beach using mean contaminant concentrations double that at Mākua Beach); Table 4-13 (non-carcinogenic hazard index estimate from likely fish consumption rates at Sandy Beach using maximum contaminant concentrations more than triple that at Mākua Beach); Table 4-16 (non-carcinogenic hazard index estimate from worst-case fish consumption rates at Nanakuli muliwai using mean contaminant concentrations more than double that at Mākua); Table 4-20 (non-carcinogenic hazard index estimate from worst-case fish consumption rates at Sandy Beach using mean contaminant concentrations double that at Mākua Beach); Table 4-21 (non-carcinogenic hazard index estimate from worst-case fish consumption rates at Sandy Beach using maximum contaminant concentrations more than triple that at Mākua Beach). The study's ecological assessments similarly showed greater hazard indexes at the "background" locations than at Mākua. See, e.g., id. at Tables 5-13, 5-15, 5-16. That contaminant hazards are greater at the alleged "background" sites than at Mākua confirms the inappropriateness of the study's selection of reference sites.

Having failed to select appropriate background sites, the study could not accurately "evaluate the potential that activities at MMR have contributed or will contribute" to contamination of marine resources used for subsistence, violating the 2007 Order. 2007 Order ¶ 6.

Incremental Risk

Even if the selection of Sandy Beach and/or Nanakuli muliwai as background sites were proper, the study's narrow focus on "incremental risk" (i.e., risk over background) to evaluate human health and ecological risks would still be inappropriate and unlawful. In preparing its EIS for MMR, the Army must consider cumulative impacts, which are impacts that "result[] from the incremental impact of the action when added to other past, present, and reasonably foreseeable

future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions." 40 C.F.R. § 1508.7; see also id. §§ 1508.8, 1508.25. Thus, the Army must evaluate the effect on human health and the marine environment of adding contaminants from proposed training and related activities (including, but not limited to, controlled burns, grass-cutting, herbicides and other ecosystem management) at MMR to whatever level of contamination already exists, including any background levels of contamination. See id. § 1508.27(b)(7) ("Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment"). Such an analysis is necessary to evaluate whether proposed training activities at MMR pose a human health risk to people relying on marine resources for subsistence, as the 2007 Order requires.

Consumption Rates

In the enclosed review, Dr. Foran details the flaws in the study's assumptions regarding fish and limu consumption rates, which render useless its human health risk assessment. In addition to Dr. Foran's comments, we note that the study inaccurately claims Sharma et al. (2003) present data for "Hawaiian fishermen in Hawai'i." Study at 4-8. In fact, Sharma et al. (2003) present data from average food consumers of Native Hawaiian ancestry, not necessarily Hawaiians who fish. Using this average consumption data "[t]o estimate the potential worst case exposures for recreational fishermen" (who, presumably, eat more fish than the average person) likely substantially underestimates human health risks. Id.

The "likely" consumption rate the study used for subsistence fishermen (100.6 g/day) also likely substantially underestimates actual consumption and, thus, health risk. That rate is only about 70% the default national value (from the 1994-1996 Continuing Survey of Food Intake by Individuals) of 142.4 g/day for subsistence fishers. (Sechena, et al., 2003). The study provides no basis for assuming that subsistence fishers on the Wai'anae Coast consume substantially less seafood than the national average.

In order to comply with its obligations under the 2007 Order, the Army must prepare a new human health assessment that is based on accurate data regarding area residents' consumption of marine resources, circulate that new assessment for public review, and incorporate the results of the new assessment in the final EIS for MMR.

Thank you for your attention to these comments. Please feel free to contact me if you have any questions or concerns.

Sincerely,

David L. Henkin

DLH\tt
Enclosures

Earthjustice
223 S. King Street #400
Honolulu HI 96813-4501

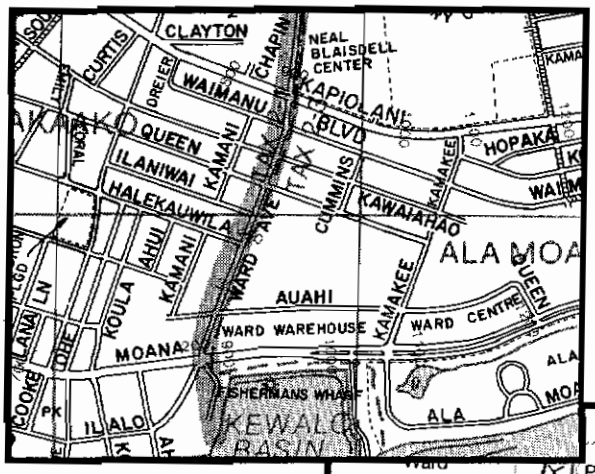
BRYAN'S

Annual Bestseller

Sectional Maps

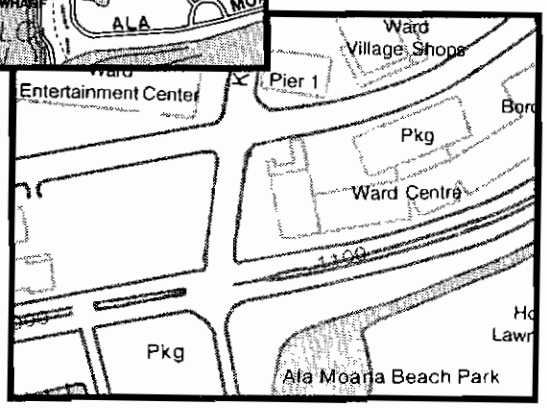
O'AHU

2005 ENLARGED EDITION



Sectional Maps

- -Latest street info
- -Zip Code areas
- -Subdivisions
- -Military Bases
- -Address numbers
- -Hiking/surfing areas
- -Freeway exits
- -Points of interest

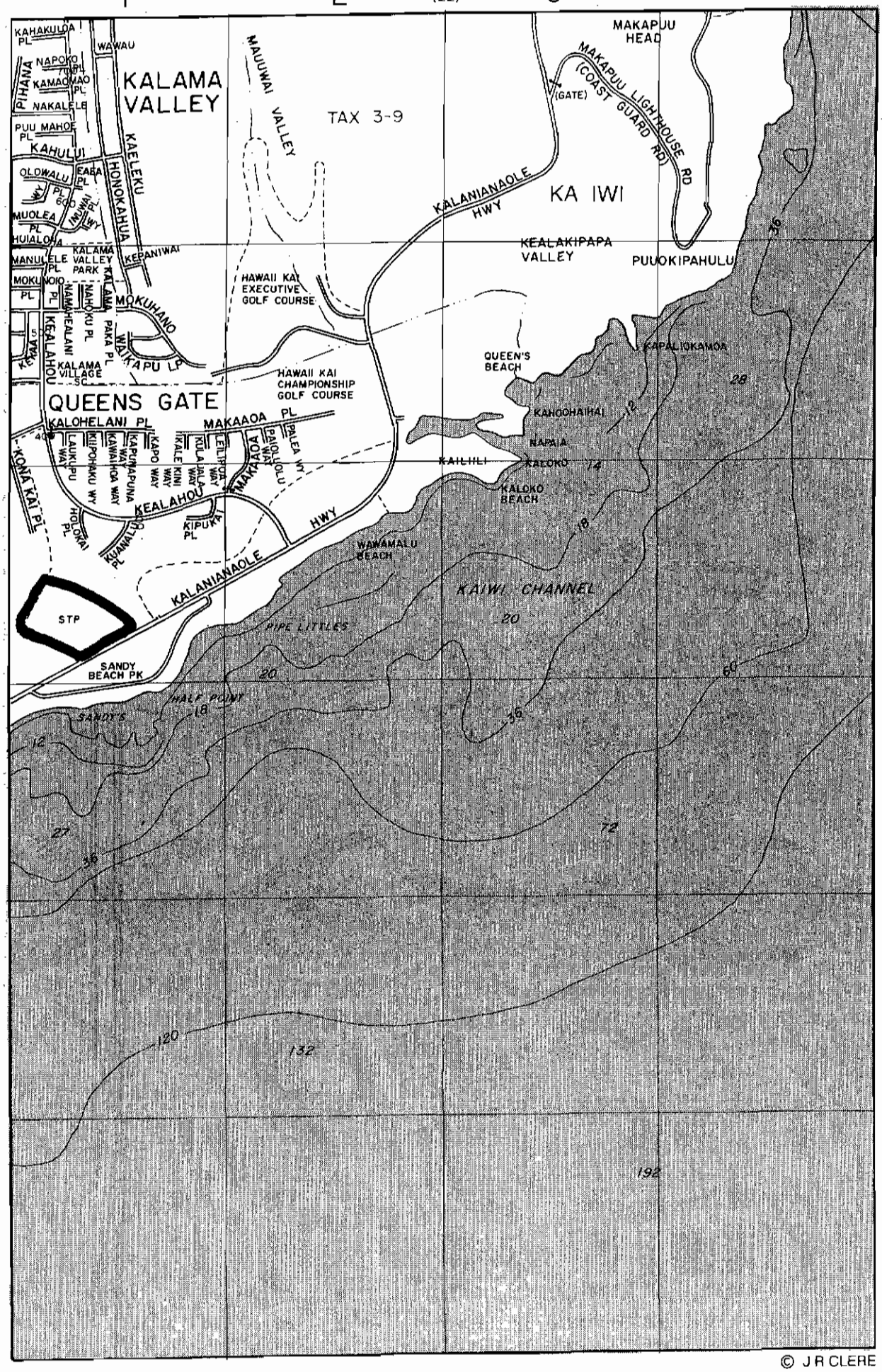


Detailed Maps

- -Large scale
- -Iwilei to Waikiki
- -Building locations
- -Hotels/condos
- -Address numbers
- -One-way streets
- -Points of interest

12.60

62nd year of publication


1
2
(22)
3
4
A
B
C
D
E
F
KALAMA VALLEY
TAX 3-9
MAUUWAI VALLEY
MAKAPUU HEAD
MAKAPUU LIGHTHOUSE RD (COAST GUARD RD)
(GATE)
KA IWI
KALANIANAOLE HWY
KEALAKIPAPA VALLEY
PUUOKIPAHULU
HAWAII KAI EXECUTIVE GOLF COURSE
HAWAII KAI CHAMPIONSHIP GOLF COURSE
QUEEN'S BEACH
KAPALIOKAMOA
KAHOOHAIHAI
NAPAIA
KALOKO
KALOKO BEACH
KAILIILI
QUEENS GATE
KALOHELANI PL
MAKAAOA PL
KEALAHOU
KONA KAI PL
HOLOKAI PL
KUANALOO PL
KIPUKAI PL
WAWAMALU BEACH
KAIWI CHANNEL
STP
PIPE LITTLES
SANDY BEACH PK
HALF POINT
SANDY'S
KAHAKULOA PL
WAWAU
NAPOKO PL
KAMAOMAO PL
NAKALELE
PUU MAHOE PL
KAHULUI
OLDWALU PL
MUOLEA PL
HUIALOHA
MANULELE PL
MOKUNOIO PL
KALAMA VALLEY PARK
KEPANIWAI
MOKUHANO
WAIKAPU LP
KALAMA VILLAGE SC
KAELEKU
HONOKAHUA
PIHANA
36
28
12
72
60
20
18
40
27
120
132
192

© J R CLERE

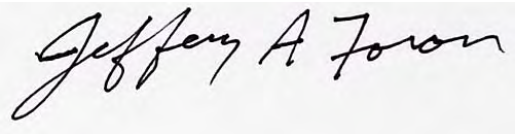
Comments on the

Final Marine Resources Study Sampling and Analysis Plan (SAP),
Mäkua Military Reservation (MMR), O‘ahu, Hawai‘i

and the

Draft Marine Resources Study, Volume 1
Field Sampling Results and Risk Assessment
Mäkua Military Reservation (MMR), O‘ahu, Hawai‘i

18 April 2007



Jeffery A. Foran, Ph.D.
ESHI, LLC
5005 N. Palisades Rd.
Whitefish Bay, WI 53217

Introduction

These comments address the final *Marine Resources Study Sampling and Analysis Plan* (hereafter SAP), and the draft *Marine Resources Study* (hereafter MRS), *Volume 1, Field Sampling Results and Risk Assessment,* for the Mäkua Military Reservation (MMR), O‘ahu, Hawai‘i (Tetra Tech 2007).

Final Marine Resources Study Sampling and Analysis Plan (SAP) Mäkua Military Reservation (MMR), O‘ahu, Hawai‘i

Overview

The Final SAP incorporates some of the recommendations that were provided in our comments on the draft SAP (Tetra Tech 2005) dated 5 April 2006 addressing selection of target chemicals, selection of species of interest, ecological impacts, and decision criteria. Questions remain regarding whether the Final SAP is structured to accomplish its stated objectives and whether and how some of the substantive issues are to be incorporated into the Draft Marine Resources Study.

Selection of Target Chemicals

The draft SAP indicated that target chemicals for evaluation in the study would be limited to explosive compounds, including nitroaromatic and nitramine explosive/energetic compounds such as TNT, RDX, and HMX. Our 5 April 2006 comments indicated that these compounds have relatively low potential to accumulate in the tissues of fish and other aquatic animals, and that the draft SAP’s narrow focus on these chemicals would bias the study toward finding no detectable contamination in fish and other aquatic animals. We recommended inclusion of chemicals with potential to bioaccumulate in

aquatic animals and plants (Table 1) identified in the Muliwai Sediment Sampling Report and the Hydrogeologic Investigation Report (USACOE 2005). These chemicals were included in the Final SAP (Table 1).

The Final SAP classifies substances in Table 1 as chemicals of potential concern (COPC), as they may result in adverse health effects upon exposure. It indicates that separate sets of COPCs will be identified for each environmental medium sampled, and all organic compounds detected in environmental samples will be identified as COPCs. However, the Final SAP indicates that only metals that occur at concentrations significantly elevated over background will be classified as chemicals of potential concern (CPOC) for purposes of human health or ecological risk assessment. Metals not identified as COPCs in sediments or surface water would not be identified as COPCs in tissue samples and would not be included in risk assessments.

The Final SAP indicates that comparison and background samples will be collected from

> the immediate vicinity of MMR [and] will also be collected from the same or similar biota from similar environments outside of the MMR region. Background muliwai will be located on the Waianae Coast within watersheds that are not subjected to military activity.

This approach may not provide suitable conditions to assess background concentrations where, for example, a site is contaminated from non-military sources. Rather, the Final SAP should determine background concentrations of contaminants from pristine sites in Hawaii or from comparable regional sites that are truly indicative of contaminant concentrations in pristine marine systems.

Selection of Species of Interest

Three fish, one mollusk, one crustacean, and one plant species were proposed for inclusion as species of interest (SOI) in the draft SAP. These species were selected for inclusion as they are "commonly collected as food sources near Makua Beach" and to represent a range of trophic levels and feeding niches. We commented on 5 April 2006 that there was no quantitative support for selection of these species based on their value to sport or commercial anglers, to local residents, or to subsistence fish consumers. We recommended that the Final SAP must select SOIs based on statistically supportable quantitative data that accurately represent collection and consumption by anglers and local residents, including subsistence fish consumers. We also commented that the draft SAP lacked discussion of SOI selection based on trophic level and feeding niche, or on the potential of some fish species to accumulate contaminants of concern based on their position in the local food chain, their lipid content, and other factors.

The Final SAP indicates that Species of Interest were identified through "discussions with regional commercial fishers, local recreational fishers, area divers and spear fishers, and local residents from the Waianae coast." Target species were prioritized where they are food sources for humans; spend part of their life cycle in or near brackish or freshwater (e.g., muliwai); and represent a variety of trophic levels and feeding niches. The Final SAP identifies several fish species that may be assessed during the study; however, it does not provide any additional support for the selection of SOIs nor does it include an objective, quantitative, survey-based approach to consumer harvest and consumption preferences for selection of SOIs. The Final SAP also fails discuss why

benthic species were excluded from the list of SOIs. Benthic species accumulate contaminants in their tissues and, therefore, play an important role in the transport of toxicants throughout the food chain. They are also critical in an assessment of adverse ecological effects. Therefore, the Final SAP appears to be inadequate and should be revised to provide scientific rationale for the selection of species of interest based on consumer preference, trophic level, feeding niche, and ecological criteria.

Evaluation of Ecological Impacts

The draft SAP indicated that the objective of the Marine Resources Study was to determine whether additional studies of human exposure were warranted based on the occurrence of target chemicals in SOIs. We commented on 5 April 2006 that the draft SAP's proposed target chemicals (explosives) as well as the broader array of chemical contaminants transported by surface water from MMR may pose significant and substantial risks to ecological systems, even where some of these compounds (e.g., explosives) do not bioaccumulate in tissues of fish and other marine animals. Therefore, we recommended that the SAP should be revised to include a sampling and analysis plan that will address and evaluate potential ecological effects in and near the MMR, and that an ecological analysis (Ecological Risk Assessment – ERA) should follow the U.S. EPA's Guidelines for Ecological Risk Assessment (EPA 1998). We also pointed out that the Hazard Quotient (HQ) approach to ERA should be used with caution; that toxicity of chemicals with similar modes of action should be assessed for additive and synergistic effects, and that a comprehensive ERA must include an assessment of the effects of multiple stressors after Foran and Ferenc (1999) and Ferenc and Foran (2000).

The Introduction to Section 1 of the Final SAP indicates that data collected during the study will be used to conduct human health and screening level ecological risk assessments. However, the ecological risk assessment and approaches to gather data for it are generally lacking in the Final SAP. Section 1.4.1 (Objectives) of the Final SAP states that

> the objective of the marine resources study at MMR is to investigate whether constituents primarily associated with military training are present in samples of selected species of fish and limu found in the Makua muliwai and nearshore Makua Beach and relied on for subsistence by area residents. An evaluation of the risks to human health will be conducted based on the data and information collected during this study, as well as on published results from earlier studies undertaken in the area.

No mention of an ecological risk assessment is made in Section 1.4.1. Section 2.1 mentions an ERA and indicates that ecological exposure will be evaluated for sediment dwelling invertebrates, fish, and invertebrates exposed to surface water, and algae exposed to surface water. However, there is no mention of sampling for ecological exposures in the remainder of Section 2, including section 2.2 – Marine Resources Sampling Strategy, or in Section 3 of the Final SAP. Approaches to environmental sampling for the purpose of conducting an ERA may be very different than approaches to sampling for human health risk assessment. Yet, there is little description of how sampling will be conducted for ERA purposes. Therefore, it is impossible to determine whether the sampling plan based on the Final SAP will provide data that are adequate to conduct a screening level ecological risk assessment.

Decision Criteria

The primary objective articulated in the draft SAP was to determine whether additional studies of human exposure were warranted, based on an analysis of chemical contaminants in the tissues of SOIs. We commented that a revised SAP should include specific, detailed discussion of the development and use of risk-based criteria to determine whether additional studies of human health and ecological impacts should be pursued. We also provided comments on components of risk-based criteria development.

The Final SAP provided a new objective – to investigate whether constituents associated with military training are present in samples of selected species of fish and limu found in the Makua muliwai and nearshore Makua Beach and relied on for subsistence by area residents. Human health and screening-level ecological risk assessments have been conducted in pursuit of this objective.

We recommended that development of risk-based criteria, or conduct of human health and ecological risk assessments, should incorporate methods to assess fish consumption rates among local populations, multiple exposure routes and sources, and concurrent exposure to multiple contaminants. A human health risk assessment should also include consideration of issues such as the value of fish and other species to local customs and traditions, and the decline in value and adverse impacts on customs and traditions where fish and other species are contaminated. The Final SAP makes no mention of these issues and whether or how they are to be incorporated into the human health and screening level ecological risk assessment.

Draft Marine Resources Study, Volume 1 - Field Sampling Results and Risk Assessment, Mäkua Military Reservation (MMR), O‘ahu, Hawai‘i

Overview

The draft MRS reports sampling results for a set of organic and inorganic compounds in fish tissues and limu (seaweed). It uses sampling results to evaluate the human health risks associated with exposure to a set of organic and inorganic compounds (Contaminants of Potential Concern – COPC) via consumption of fish and limu.

The draft MRS is poorly written and contains numerous errors and oversights. For example, data reported in Tables 3-1, 3-2, and 4-2 lack units (subsequent comments are based on my assumption that all data are reported in mg/kg wet weight). The report is flawed in its assumptions regarding the forms of arsenic (inorganic vs organic) in fish and limu; the selection and use of “background” contaminant concentrations from the reference (“clean”) sites; and assumptions and approaches used to estimate human exposure and risk.

Arsenic Concentrations in Fish and Limu

Arsenic concentrations in fish and limu are significantly elevated, although the draft MRS assumes that arsenic occurs in fish tissue as the organic form, which is less toxic than inorganic arsenic. Arsenic in limu is reported as the inorganic form and resultant cancer risk estimates associated with consumption of limu are significantly elevated (greater than 1×10^{-3} – the equivalent of smoking a pack of cigarettes each day). However, arsenic speciation was not conducted for either fish or limu. The report

assumes, possibly incorrectly, that arsenic in fish tissue occurs entirely as the less toxic organic form and indicates that there is no arsenic-associated health risk from consuming fish. The report suggests that some of the arsenic in limu occurs in the organic form and, therefore, that cancer risk estimates are overestimated. Because of the elevated concentrations of arsenic in both fish and limu, and because of the significantly elevated cancer risks of consuming arsenic-contaminated fish and limu, speculation regarding the form of arsenic in biological samples is inappropriate and should be replaced by analytical data that clearly quantify the concentrations of both inorganic and organic arsenic in fish and limu.

Selection of Background Site and Samples

Fish were collected at Makua North Muliwai, Makua South Muliwai, Nanakuli Muliwai, Sandy Beach, and the near shore waters of Makua, while limu was gathered in near shore waters of Makua. Fish samples were collected at Sandy Beach and Nanakuli Muliwai for the purposes of determining "background" concentrations of contaminants. The rationale for selection of sites to provide information on background concentrations of contaminants is not described in the Final SAP or the draft MRS; therefore, it is impossible to determine whether samples collected from these sites provide data that are representative of background contaminant concentrations in fish. However, the location of a discharge outfall from the East Honolulu Wastewater Treatment Plant offshore at Sandy Beach may significantly influence contaminant loads and contaminant tissue burdens at this site. Nanakuli muliwai, which is located in the middle of an urban area and downstream from Lualualei Naval Magazine, may also be subject to significant

contaminant loadings. As a result, samples collected from these sites would not represent true background (uncontaminated) conditions.

Data collected from background sites are used in the draft MRS to determine contaminant concentrations (or health hazards) from military operations at MMR by subtracting "background" contaminant concentrations (or quantitative estimates of hazard associated with exposure to contaminants) from MMR contaminant concentrations (or hazard estimates). The draft MRS suggests that this approach provides an estimate of contamination or risk originating from MMR. This approach ignores the fact that reference sites are impacted from local activities, are not pristine, and do not represent true background conditions. In this case, contamination from MMR would be "excused" simply because it occurs at a level similar to another contaminated site. The approach also fails to incorporate the effects of vast differences in the physical structure of the sites on the fate and transport of contaminants derived from local sources. Use of reference sites to determine background concentrations without addressing differing fate and transport phenomena will lead to an inaccurate assessment of the extent, nature, and impact of contamination at the MMR site.

Human Health Risk Assessment

The draft MRS (Volume 1) presents cancer and non-cancer risk estimates associated with exposure to contaminants via consumption of fish and limu. Risk estimates are presented for subsistence anglers, recreational anglers, and harvesters of limu based on "likely" and

“worst case” fish or limu consumption rates and mean and maximum contaminant concentrations in fish tissue and limu.

The draft MRS presents cancer risk estimates for subsistence fish consumers that range from 1×10^{-5} (one excess death from cancer associated with consumption of contaminated fish from the MMR in every 100,000 exposed individuals) for “likely” consumption rates and mean contaminant concentrations in fish tissue, to 4×10^{-4} for “worst case” consumption rates and maximum contaminant concentrations in fish tissue. Lower cancer risk estimates for recreational consumers result from the use of lower fish consumption rates in risk calculations.

The draft MRS presents non-cancer risk estimates via a Hazard Index ($HI = \sum HQ$, where HQ, the hazard quotient, is the ratio of contaminant exposure from fish or limu consumption to exposure that poses a minimal risk of adverse effects for a single contaminant). Hazard Indices greater than 1.0 indicate that exposure to contaminants in fish or limu is greater than a level that poses minimal risks, and health risks increase as Hazard Indices increase about 1.0. HI’s for subsistence consumers of fish from the muliwai at Makua range from 19 for “likely” consumption rates and mean contaminant concentrations in fish tissue, to 102 for “worst case” consumption rates and maximum contaminant concentrations in fish tissue. Hazard Indices for recreational consumers are lower based on assumptions of lower fish consumption rates.

Cancer risk estimates for contaminant exposure associated with subsistence consumption of limu range from 8 X 10^{-3} to 1 X 10^{-2}, and Hazard Indices range from 56 to 92. Risk estimates are lower for recreational consumption of limu.

The cancer and non-cancer risk estimates presented in the draft MRS are, in many cases, well above levels considered acceptable or tolerable. Typically, cancer risk estimates greater than 1 X 10^{-5} or Hazard Indices greater than 1.0 are considered unacceptable and trigger steps to remediate risks. Cancer risk estimates above 1 X 10^{-4} or Hazard Indices above 10 require immediate remediation efforts or significant and immediate exposure reduction efforts (Travis et al.1987, Barnes and Dourson 1988, USDOE 1996).

The draft MRS manipulates (attempts to minimize) the magnitude of risk by subtracting risk estimates derived for reference sites from risk estimates associated with consumption of fish and limu from the MMR. As discussed previously, the selection of sites to quantify contaminant background concentrations is flawed; thus, risk estimates associated with exposure to contaminants at these sites are not accurate depictions of "background risk." Regardless of the approach to assess contaminant background concentrations, however, the assessment of risk from reference sites and reduction of MMR-associated risk by subtracting reference-site risk is inappropriate. Cancer risk estimates associated with consumption of seafood gathered from Makua are calculated and expressed as "excess risk" (risk above background). These are site-specific estimates of cancer risk above those associated with all other exposure sources and stressors such as exposure to radionuclides in drinking water, overexposure to sunlight, exposure to contaminants in

food, and including exposure to contaminants at reference sites. Calculations of risk at reference sites produces estimates of excess cancer risk that are specific to those sites and in excess of all other cancer risks, including risks associated with MMR. Therefore, subtracting "reference site risk" from "MMR risk" is effectively subtracting excess risk from excess risk, an exercise that is conceptually and mathematically unsound.

A more appropriate approach to determine the culpability for environmental contamination at MMR would be to conduct a comprehensive fate and transport analysis of contaminants at and near the site. While the analysis would not (and should not) allow an adjustment of contaminant associated health risks at MMR, it may provide an indication of the sources and extent of responsibility for on- and off-site contamination associated with military activities at the site.

Risk estimates presented in the draft MRS are highest for subsistence fish and limu consumers, and are lower for recreational consumers. However, flaws in the risk calculation result in underestimation of health risks to both recreational and subsistence anglers. Cancer and non cancer risk estimates are based on exposure to contaminants that result from consumption of fish and limu. To estimate contaminant intake, the draft MRS uses consumption rate (CR) and exposure frequency (EF) data in the numerator of the intake equation (Page 4-5). The MRS selects rates of 242 g/day for subsistence consumers and 100.6 g/day for recreational consumers as "worst case" scenarios, and 100.6 g/day and 34 g/day as "likely" fish consumption rates for subsistence and

recreational anglers. Consumption rates for limu are set at 18.2 g/day for subsistence consumption and 5.2 g/day for recreational consumption.

These rates represent average daily consumption for populations studied by Sechena et al. (2003) and Sharma et al. (2003). However, the draft MRS adjusts these rates by multiplying by the exposure frequency (EF), which is set at 350 (out of 365) days for subsistence consumers and 48 (out of 365) days for recreational consumers. This adjustment is incorrect, as consumption rate data from Sechena et al. (2003) and Sharma et al. (2003) are annualized rates and already incorporate consideration of fish consumption that may not occur each day of the year. That is, estimates of consumption rate (such as 242 g/day) reflect the number of meals eaten during a year and the size (mass) of each meal. Therefore, the appropriate factor for EF is 365 days (which simply provides a unit conversion in the calculation of intake), not 350 days for subsistence consumers and 48 days for recreational consumers.

The effect on intake (and ultimately estimates of risk) of setting EF at less than 365 is relatively minor for subsistence consumers (where EF = 350). However, for recreational consumers, the use of this adjustment results in an inappropriate reduction in contaminant intake and the risk estimate by nearly a factor of 8; that is, contaminant intake and risks are underestimated by approximately a factor of 8 for recreational consumers in the draft MRS. This inappropriate reduction in intake and resultant underestimate of risk is compounded by the use of exposure duration (ED) of 24 years to establish intake via the equation on page 4-5, which results in a further underestimation of intake and risk by a

factor of 2.9 (compared with an ED of 70 years). The assumption of partial life intake (24 years rather than 70 years) is unlikely to be representative of consumption and exposure among subsistence fish consumers (and potentially among recreational anglers, particularly those who share their catch with family members). Therefore, the draft MRS should assume that exposure duration (ED) in the equation on page 4-5 is 70, unless data demonstrate clearly that an ED less than 70 more accurately represents gathering and consumption of seafood from Makua. Risk estimates for consumers of fish and limu in the draft MRS may, therefore, be underestimated by more than a factor of 20 because of these calculation and assumption errors.

Risk estimates for subsistence and recreational consumers may be underestimated further as exposure assumptions used in risk calculations may not represent "most likely" or "worst-case" scenarios for individuals consuming fish and limu from the MMR. The draft MRS draws heavily on Sharma et al. (2003) and Sechena et al. (2003) to generate fish consumption rates for the risk assessment. While data from these studies provide fish consumption rate information for a variety of ethnic groups, the draft MRS does not provide evidence that these rates are representative of individuals harvesting or consuming fish from MMR contaminated sites. As a result, contaminant intake and attendant health risks will be underestimated where consumption rates of fish from MMR contaminated sites are underestimated.

Accurate evaluation of fish and limu consumption and contaminant intake in the local population requires a comprehensive survey of local consumers. In the absence of such a

survey, worst case estimates of consumption should be based on consumption from traditional diets such as those reconstructed by Smith (2003), where rates for some populations were nearly 400 g/day. Any seasonal differences in consumption rates should also be acknowledged and incorporated in estimates of intake and risk, such as those by Loranger et al. (2002) who found that daily fish intake rates were 6 to 10 times higher for recreational anglers in the James Bay Territory of Canada at the end of the fishing season compared to a group that reported fish consumption on an annualized basis.

Finally, the draft MRS suggests that risk calculations may be overestimated as contaminant concentrations in whole fish were analyzed. (Concentrations of organic contaminants, excluding methyl mercury, in skin-off fillets may be lower than concentrations in whole fish as some organic contaminants concentrate disproportionately in fatty tissue.) The final SAP and draft MRS do not thoroughly describe methods to prepare fish for contaminant analysis. However, many fish from MMR contaminated sites are eaten whole (including head, skin, and bones) and in some cases internal organs are consumed as well (Vince Dodge, personal communication). Therefore, assumptions that contaminant analysis of whole fish results in overestimates of risk are not accurate or appropriate.

Conclusions

The Final Marine Resources Study Sampling and Analysis Plan for the Mäkua Military Reservation addresses several of the comments and recommendations that we provided on 5 April 2006. However, there remain deficiencies in the Final SAP including:

Inadequate description of and rationale for SOI selection;

Inappropriate or inadequate proposals for the determination of contaminant background concentrations;

Inadequate description of sampling and analysis plans to generate data for the screening level ecological risk assessment.

The Human Health Risk Assessment in the draft MRS (volume 1), presents elevated cancer and non-cancer risks for individuals consuming fish and limu from the MMR. However, these risks – which, even as reported, in many cases warrant immediate remediation efforts or exposure reduction efforts – may underestimate true risks for several reasons:

Arsenic in fish is assumed to be completely in the organic (less toxic) form, although there are no analytical data to support this assumption. Any inorganic arsenic in fish would pose considerably elevated health risks to both subsistence and recreational anglers. The only way accurately to assess these risks is to quantify the concentrations of both inorganic and organic arsenic.

Cancer and non-cancer risk estimates associated with exposure to contaminants at MMR are reduced by purported background contaminant concentrations established from inappropriate sites. Reduction of health risk estimates for MMR by subtracting “background” risks is also mathematically and conceptually inappropriate.

Improper use of exposure frequency (EF) data in the calculation of contaminant intake results in considerable underestimates of intake and risk, particularly for recreational consumers.

Poor or inappropriate approaches to the selection of likely and worst case exposure assumptions may result in further underestimates of adverse health risks.

Suggestions that health risks are overestimated because contaminant concentrations were analyzed in whole fish are inappropriate, as there is ample evidence that individuals consume fish muscle tissue, bones, head, and in some cases organs.

Health risks associated with consumption of fish and limu at MMR may be underestimated by more than a factor of 20 as a result of calculation errors and inappropriate assumptions.

Table 1. Selection of chemicals for the Mäkua Resources SAP.

Column A – Contaminants recommended for inclusion in the final SAP.
Column B – Chemicals of Potential Concern (CPOC) included in the Final SAP.

Chemical	A	B	Notes
HpCDD	Y	Y	
HpCDF	Y	Y	
HxCDF	Y	Y	
OCDD	Y	Y	
OCDF	Y	Y	
TCDD	Y	Y	
Ethylbenzene	Y	Y	
M-xylene	Y	Y	
P-xylene	Y	Y	
O-xylene	Y	Y	
Toluene	Y	Y	
Aluminum	Y	Y	1
Beryllium	Y	Y	1
Chromium	Y	Y	1
Iron	Y	Y	1
Lead	Y	Y	1
Manganese	Y	Y	1
Thallium	Y	Y	1
Vanadium (cmpds)	Y	Y	1
Antimony	Y	Y	1
Arsenic	Y	Y	1
Barium	Y	Y	1
Cadmium	Y	Y	1
Cobalt	Y	Y	1
Copper	Y	Y	1
Mercury	Y	Y	1,2
Selenium	Y	Y	1
Silver	Y	Y	1
Zinc	Y	Y	1
Aldrin	Y	Y	
Alpha-BHC	Y	Y	

Beta-BHC	Y	Y	
Delta-BHC	Y	Y	
(Lindane)	Y	Y	
Heptachlor	Y	Y	
Hept. Epoxide	Y	Y	
4,4-DDT	Y	Y	
Pentachlorophenol	Y	N	3
Styrene	Y	Y	
1,2,4-Trimethylbenz.	Y	Y	
Phthalate	Y	Y	
Pyrene	Y	Y	
Perchlorate	Y	Y	

Notes

1. Metals will be identified as COPC if they occur at concentrations above background.

2. Elemental and organic (methyl) mercury will be assessed, although it is assumed (but not stated) that elemental mercury will be treated as a metal (see note 1) and methyl mercury will be treated as an organic compound and automatically included as a COPC.

3. Not included in the Final SAP but included (although not detected) in analyses reported in Volume 1 of the Marine Resources Study

Literature Cited

Barnes, D.G. and M. Dourson. 1988. Reference Dose (RfD): Description and use in health risk assessments. *Reg. Toxicol. Pharmacol*. 8(4):471-486.

EPA. 1998. Guidelines for Ecological Risk Assessment. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC, EPA/630/R095/002F, and available at Federal Register: May 14, 1998 Volume 63, Number 93, pages 26845-26924

Ferenc, S.A. and J.A. Foran. 2000. *Multiple Stressors in Ecological Risk and Impact Assessment: Approaches to Risk Estimation*. SETAC Press, Pensacola, FL. 251pp.

Foran, J.A. and S.A. Ferenc. 1999. *Multiple Stressors in Ecological Risk and Impact Assessment*. SETAC Press, Pensacola, FL. 100pp.

Loranger S., Schetagne R., Dumont, D., Plante M. 2002. Development of a questionnaire-based method to estimate methylmercury exposure of recreational anglers in Matagami (Quebec, Canada). Abstract No 136. 23rd Ann. Soc. Environ. Toxicol. Chem. (SETAC) North Am. Meeting, Salt Lake City, UT, USA, November 16-20, 2002.

Sechena, R., S. Liao, R. Lorenzana, C. Nakano, N. Polissar, and R. Fenske. 2003. Asian American and Pacific Islander seafood consumption – A community-based study in King County, Washington. *J. Exp. Anal. Environ. Epi.* 13:256-266.

Sharma, S., S. Murphy, L. Wilkens, L. Shen, J. Hankin, B. Henderson, and L. Kolonel. 2003. Adherence to the food guide pyramid recommendations among Japanese Americans, native Hawaiians, and whites. Results from the multiethnic cohort study. *J. Am. Dietetic Assoc.* 103:1195-1198.

Smith, B.A. 2003 From venison to salt pork: reconstructing the costs to Anishinabe families in 19th century Wisconsin. Presented at the American Anthropological Association annual meeting. Chicago, Illinois. November 22.

Tetra Tech. 2005. Marine Resources Study, Sampling and Analysis Plan (Draft). Mäkua Military Reservation O`ahu, Hawai`i. Contract No. GS-10F-0268K for US Army Corps of Engineers, Honolulu District. Prepared by Tetra Tech Inc. Honolulu Hawai`i.

Tetra Tech. 2007. Marine Resources Study, Sampling and Analysis Plan (Final). Mäkua Military Reservation O`ahu, Hawai`i. Contract No. GS-10F-0268K for US Army Corps of Engineers, Honolulu District. Prepared by Tetra Tech Inc. Honolulu Hawai`i.

Travis, C.C., S.A. Richter, E.A. Crouch, R. Wilson, E.D. Klima. 1987. Cancer risk management. *Environ. Sci. Technol*. 21:415.

USACOE. 2005 Hydrogeologic Investigation Report for Makua Military Reservation. Prepared by Geotechnical and Structures Laboratory, Waterways Experiment Station, Environet, Inc., and US Army Corps of Engineers Engineer Research and Development

Center. Prepared for Honolulu Engineer District, Environmental Division and the US Army Garrison – Hawai‘i, Directorate of Public Works. February 2005.

U.S. Department of Energy (USDOE). 1996. Criteria for establishing de minimis levels of radionuclides and hazardous chemicals in the environment. Report # ES/ER/TM0187. U.S. DOE, Office of Environmental Management, Washington, DC.

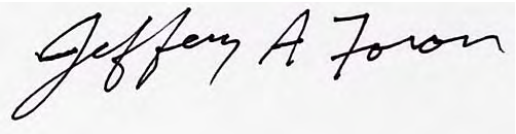
Comments on the

Final Marine Resources Study Sampling and Analysis Plan (SAP),
Mäkua Military Reservation (MMR), O‘ahu, Hawai‘i

and the

Draft Marine Resources Study, Volume 1
Field Sampling Results and Risk Assessment
Mäkua Military Reservation (MMR), O‘ahu, Hawai‘i

18 April 2007



Jeffery A. Foran, Ph.D.
ESHI, LLC
5005 N. Palisades Rd.
Whitefish Bay, WI 53217

Introduction

These comments address the final *Marine Resources Study Sampling and Analysis Plan* (hereafter SAP), and the draft *Marine Resources Study* (hereafter MRS), *Volume 1, Field Sampling Results and Risk Assessment,* for the Mäkua Military Reservation (MMR), O‘ahu, Hawai‘i (Tetra Tech 2007).

Final Marine Resources Study Sampling and Analysis Plan (SAP) Mäkua Military Reservation (MMR), O‘ahu, Hawai‘i

Overview

The Final SAP incorporates some of the recommendations that were provided in our comments on the draft SAP (Tetra Tech 2005) dated 5 April 2006 addressing selection of target chemicals, selection of species of interest, ecological impacts, and decision criteria. Questions remain regarding whether the Final SAP is structured to accomplish its stated objectives and whether and how some of the substantive issues are to be incorporated into the Draft Marine Resources Study.

Selection of Target Chemicals

The draft SAP indicated that target chemicals for evaluation in the study would be limited to explosive compounds, including nitroaromatic and nitramine explosive/energetic compounds such as TNT, RDX, and HMX. Our 5 April 2006 comments indicated that these compounds have relatively low potential to accumulate in the tissues of fish and other aquatic animals, and that the draft SAP’s narrow focus on these chemicals would bias the study toward finding no detectable contamination in fish and other aquatic animals. We recommended inclusion of chemicals with potential to bioaccumulate in

aquatic animals and plants (Table 1) identified in the Muliwai Sediment Sampling Report and the Hydrogeologic Investigation Report (USACOE 2005). These chemicals were included in the Final SAP (Table 1).

The Final SAP classifies substances in Table 1 as chemicals of potential concern (COPC), as they may result in adverse health effects upon exposure. It indicates that separate sets of COPCs will be identified for each environmental medium sampled, and all organic compounds detected in environmental samples will be identified as COPCs. However, the Final SAP indicates that only metals that occur at concentrations significantly elevated over background will be classified as chemicals of potential concern (CPOC) for purposes of human health or ecological risk assessment. Metals not identified as COPCs in sediments or surface water would not be identified as COPCs in tissue samples and would not be included in risk assessments.

The Final SAP indicates that comparison and background samples will be collected from

> the immediate vicinity of MMR [and] will also be collected from the same or similar biota from similar environments outside of the MMR region. Background muliwai will be located on the Waianae Coast within watersheds that are not subjected to military activity.

This approach may not provide suitable conditions to assess background concentrations where, for example, a site is contaminated from non-military sources. Rather, the Final SAP should determine background concentrations of contaminants from pristine sites in Hawaii or from comparable regional sites that are truly indicative of contaminant concentrations in pristine marine systems.

Selection of Species of Interest

Three fish, one mollusk, one crustacean, and one plant species were proposed for inclusion as species of interest (SOI) in the draft SAP. These species were selected for inclusion as they are "commonly collected as food sources near Makua Beach" and to represent a range of trophic levels and feeding niches. We commented on 5 April 2006 that there was no quantitative support for selection of these species based on their value to sport or commercial anglers, to local residents, or to subsistence fish consumers. We recommended that the Final SAP must select SOIs based on statistically supportable quantitative data that accurately represent collection and consumption by anglers and local residents, including subsistence fish consumers. We also commented that the draft SAP lacked discussion of SOI selection based on trophic level and feeding niche, or on the potential of some fish species to accumulate contaminants of concern based on their position in the local food chain, their lipid content, and other factors.

The Final SAP indicates that Species of Interest were identified through "discussions with regional commercial fishers, local recreational fishers, area divers and spear fishers, and local residents from the Waianae coast." Target species were prioritized where they are food sources for humans; spend part of their life cycle in or near brackish or freshwater (e.g., muliwai); and represent a variety of trophic levels and feeding niches. The Final SAP identifies several fish species that may be assessed during the study; however, it does not provide any additional support for the selection of SOIs nor does it include an objective, quantitative, survey-based approach to consumer harvest and consumption preferences for selection of SOIs. The Final SAP also fails discuss why

benthic species were excluded from the list of SOIs. Benthic species accumulate contaminants in their tissues and, therefore, play an important role in the transport of toxicants throughout the food chain. They are also critical in an assessment of adverse ecological effects. Therefore, the Final SAP appears to be inadequate and should be revised to provide scientific rationale for the selection of species of interest based on consumer preference, trophic level, feeding niche, and ecological criteria.

Evaluation of Ecological Impacts

The draft SAP indicated that the objective of the Marine Resources Study was to determine whether additional studies of human exposure were warranted based on the occurrence of target chemicals in SOIs. We commented on 5 April 2006 that the draft SAP's proposed target chemicals (explosives) as well as the broader array of chemical contaminants transported by surface water from MMR may pose significant and substantial risks to ecological systems, even where some of these compounds (e.g., explosives) do not bioaccumulate in tissues of fish and other marine animals. Therefore, we recommended that the SAP should be revised to include a sampling and analysis plan that will address and evaluate potential ecological effects in and near the MMR, and that an ecological analysis (Ecological Risk Assessment – ERA) should follow the U.S. EPA's Guidelines for Ecological Risk Assessment (EPA 1998). We also pointed out that the Hazard Quotient (HQ) approach to ERA should be used with caution; that toxicity of chemicals with similar modes of action should be assessed for additive and synergistic effects, and that a comprehensive ERA must include an assessment of the effects of multiple stressors after Foran and Ferenc (1999) and Ferenc and Foran (2000).

The Introduction to Section 1 of the Final SAP indicates that data collected during the study will be used to conduct human health and screening level ecological risk assessments. However, the ecological risk assessment and approaches to gather data for it are generally lacking in the Final SAP. Section 1.4.1 (Objectives) of the Final SAP states that

> the objective of the marine resources study at MMR is to investigate whether constituents primarily associated with military training are present in samples of selected species of fish and limu found in the Makua muliwai and nearshore Makua Beach and relied on for subsistence by area residents. An evaluation of the risks to human health will be conducted based on the data and information collected during this study, as well as on published results from earlier studies undertaken in the area.

No mention of an ecological risk assessment is made in Section 1.4.1. Section 2.1 mentions an ERA and indicates that ecological exposure will be evaluated for sediment dwelling invertebrates, fish, and invertebrates exposed to surface water, and algae exposed to surface water. However, there is no mention of sampling for ecological exposures in the remainder of Section 2, including section 2.2 – Marine Resources Sampling Strategy, or in Section 3 of the Final SAP. Approaches to environmental sampling for the purpose of conducting an ERA may be very different than approaches to sampling for human health risk assessment. Yet, there is little description of how sampling will be conducted for ERA purposes. Therefore, it is impossible to determine whether the sampling plan based on the Final SAP will provide data that are adequate to conduct a screening level ecological risk assessment.

Decision Criteria

The primary objective articulated in the draft SAP was to determine whether additional studies of human exposure were warranted, based on an analysis of chemical contaminants in the tissues of SOIs. We commented that a revised SAP should include specific, detailed discussion of the development and use of risk-based criteria to determine whether additional studies of human health and ecological impacts should be pursued. We also provided comments on components of risk-based criteria development.

The Final SAP provided a new objective – to investigate whether constituents associated with military training are present in samples of selected species of fish and limu found in the Makua muliwai and nearshore Makua Beach and relied on for subsistence by area residents. Human health and screening-level ecological risk assessments have been conducted in pursuit of this objective.

We recommended that development of risk-based criteria, or conduct of human health and ecological risk assessments, should incorporate methods to assess fish consumption rates among local populations, multiple exposure routes and sources, and concurrent exposure to multiple contaminants. A human health risk assessment should also include consideration of issues such as the value of fish and other species to local customs and traditions, and the decline in value and adverse impacts on customs and traditions where fish and other species are contaminated. The Final SAP makes no mention of these issues and whether or how they are to be incorporated into the human health and screening level ecological risk assessment.

Draft Marine Resources Study, Volume 1 - Field Sampling Results and Risk Assessment, Mäkua Military Reservation (MMR), O‘ahu, Hawai‘i

Overview

The draft MRS reports sampling results for a set of organic and inorganic compounds in fish tissues and limu (seaweed). It uses sampling results to evaluate the human health risks associated with exposure to a set of organic and inorganic compounds (Contaminants of Potential Concern – COPC) via consumption of fish and limu.

The draft MRS is poorly written and contains numerous errors and oversights. For example, data reported in Tables 3-1, 3-2, and 4-2 lack units (subsequent comments are based on my assumption that all data are reported in mg/kg wet weight). The report is flawed in its assumptions regarding the forms of arsenic (inorganic vs organic) in fish and limu; the selection and use of “background” contaminant concentrations from the reference (“clean”) sites; and assumptions and approaches used to estimate human exposure and risk.

Arsenic Concentrations in Fish and Limu

Arsenic concentrations in fish and limu are significantly elevated, although the draft MRS assumes that arsenic occurs in fish tissue as the organic form, which is less toxic than inorganic arsenic. Arsenic in limu is reported as the inorganic form and resultant cancer risk estimates associated with consumption of limu are significantly elevated (greater than 1×10^{-3} – the equivalent of smoking a pack of cigarettes each day). However, arsenic speciation was not conducted for either fish or limu. The report

assumes, possibly incorrectly, that arsenic in fish tissue occurs entirely as the less toxic organic form and indicates that there is no arsenic-associated health risk from consuming fish. The report suggests that some of the arsenic in limu occurs in the organic form and, therefore, that cancer risk estimates are overestimated. Because of the elevated concentrations of arsenic in both fish and limu, and because of the significantly elevated cancer risks of consuming arsenic-contaminated fish and limu, speculation regarding the form of arsenic in biological samples is inappropriate and should be replaced by analytical data that clearly quantify the concentrations of both inorganic and organic arsenic in fish and limu.

Selection of Background Site and Samples

Fish were collected at Makua North Muliwai, Makua South Muliwai, Nanakuli Muliwai, Sandy Beach, and the near shore waters of Makua, while limu was gathered in near shore waters of Makua. Fish samples were collected at Sandy Beach and Nanakuli Muliwai for the purposes of determining "background" concentrations of contaminants. The rationale for selection of sites to provide information on background concentrations of contaminants is not described in the Final SAP or the draft MRS; therefore, it is impossible to determine whether samples collected from these sites provide data that are representative of background contaminant concentrations in fish. However, the location of a discharge outfall from the East Honolulu Wastewater Treatment Plant offshore at Sandy Beach may significantly influence contaminant loads and contaminant tissue burdens at this site. Nanakuli muliwai, which is located in the middle of an urban area and downstream from Lualualei Naval Magazine, may also be subject to significant

contaminant loadings. As a result, samples collected from these sites would not represent true background (uncontaminated) conditions.

Data collected from background sites are used in the draft MRS to determine contaminant concentrations (or health hazards) from military operations at MMR by subtracting "background" contaminant concentrations (or quantitative estimates of hazard associated with exposure to contaminants) from MMR contaminant concentrations (or hazard estimates). The draft MRS suggests that this approach provides an estimate of contamination or risk originating from MMR. This approach ignores the fact that reference sites are impacted from local activities, are not pristine, and do not represent true background conditions. In this case, contamination from MMR would be "excused" simply because it occurs at a level similar to another contaminated site. The approach also fails to incorporate the effects of vast differences in the physical structure of the sites on the fate and transport of contaminants derived from local sources. Use of reference sites to determine background concentrations without addressing differing fate and transport phenomena will lead to an inaccurate assessment of the extent, nature, and impact of contamination at the MMR site.

Human Health Risk Assessment

The draft MRS (Volume 1) presents cancer and non-cancer risk estimates associated with exposure to contaminants via consumption of fish and limu. Risk estimates are presented for subsistence anglers, recreational anglers, and harvesters of limu based on "likely" and

“worst case” fish or limu consumption rates and mean and maximum contaminant concentrations in fish tissue and limu.

The draft MRS presents cancer risk estimates for subsistence fish consumers that range from 1×10^{-5} (one excess death from cancer associated with consumption of contaminated fish from the MMR in every 100,000 exposed individuals) for “likely” consumption rates and mean contaminant concentrations in fish tissue, to 4×10^{-4} for “worst case” consumption rates and maximum contaminant concentrations in fish tissue. Lower cancer risk estimates for recreational consumers result from the use of lower fish consumption rates in risk calculations.

The draft MRS presents non-cancer risk estimates via a Hazard Index ($HI = \sum HQ$, where HQ, the hazard quotient, is the ratio of contaminant exposure from fish or limu consumption to exposure that poses a minimal risk of adverse effects for a single contaminant). Hazard Indices greater than 1.0 indicate that exposure to contaminants in fish or limu is greater than a level that poses minimal risks, and health risks increase as Hazard Indices increase about 1.0. HI’s for subsistence consumers of fish from the muliwai at Makua range from 19 for “likely” consumption rates and mean contaminant concentrations in fish tissue, to 102 for “worst case” consumption rates and maximum contaminant concentrations in fish tissue. Hazard Indices for recreational consumers are lower based on assumptions of lower fish consumption rates.

Cancer risk estimates for contaminant exposure associated with subsistence consumption of limu range from 8 X 10^{-3} to 1 X 10^{-2}, and Hazard Indices range from 56 to 92. Risk estimates are lower for recreational consumption of limu.

The cancer and non-cancer risk estimates presented in the draft MRS are, in many cases, well above levels considered acceptable or tolerable. Typically, cancer risk estimates greater than 1 X 10^{-5} or Hazard Indices greater than 1.0 are considered unacceptable and trigger steps to remediate risks. Cancer risk estimates above 1 X 10^{-4} or Hazard Indices above 10 require immediate remediation efforts or significant and immediate exposure reduction efforts (Travis et al.1987, Barnes and Dourson 1988, USDOE 1996).

The draft MRS manipulates (attempts to minimize) the magnitude of risk by subtracting risk estimates derived for reference sites from risk estimates associated with consumption of fish and limu from the MMR. As discussed previously, the selection of sites to quantify contaminant background concentrations is flawed; thus, risk estimates associated with exposure to contaminants at these sites are not accurate depictions of "background risk." Regardless of the approach to assess contaminant background concentrations, however, the assessment of risk from reference sites and reduction of MMR-associated risk by subtracting reference-site risk is inappropriate. Cancer risk estimates associated with consumption of seafood gathered from Makua are calculated and expressed as "excess risk" (risk above background). These are site-specific estimates of cancer risk above those associated with all other exposure sources and stressors such as exposure to radionuclides in drinking water, overexposure to sunlight, exposure to contaminants in

food, and including exposure to contaminants at reference sites. Calculations of risk at reference sites produces estimates of excess cancer risk that are specific to those sites and in excess of all other cancer risks, including risks associated with MMR. Therefore, subtracting "reference site risk" from "MMR risk" is effectively subtracting excess risk from excess risk, an exercise that is conceptually and mathematically unsound.

A more appropriate approach to determine the culpability for environmental contamination at MMR would be to conduct a comprehensive fate and transport analysis of contaminants at and near the site. While the analysis would not (and should not) allow an adjustment of contaminant associated health risks at MMR, it may provide an indication of the sources and extent of responsibility for on- and off-site contamination associated with military activities at the site.

Risk estimates presented in the draft MRS are highest for subsistence fish and limu consumers, and are lower for recreational consumers. However, flaws in the risk calculation result in underestimation of health risks to both recreational and subsistence anglers. Cancer and non cancer risk estimates are based on exposure to contaminants that result from consumption of fish and limu. To estimate contaminant intake, the draft MRS uses consumption rate (CR) and exposure frequency (EF) data in the numerator of the intake equation (Page 4-5). The MRS selects rates of 242 g/day for subsistence consumers and 100.6 g/day for recreational consumers as "worst case" scenarios, and 100.6 g/day and 34 g/day as "likely" fish consumption rates for subsistence and

recreational anglers. Consumption rates for limu are set at 18.2 g/day for subsistence consumption and 5.2 g/day for recreational consumption.

These rates represent average daily consumption for populations studied by Sechena et al. (2003) and Sharma et al. (2003). However, the draft MRS adjusts these rates by multiplying by the exposure frequency (EF), which is set at 350 (out of 365) days for subsistence consumers and 48 (out of 365) days for recreational consumers. This adjustment is incorrect, as consumption rate data from Sechena et al. (2003) and Sharma et al. (2003) are annualized rates and already incorporate consideration of fish consumption that may not occur each day of the year. That is, estimates of consumption rate (such as 242 g/day) reflect the number of meals eaten during a year and the size (mass) of each meal. Therefore, the appropriate factor for EF is 365 days (which simply provides a unit conversion in the calculation of intake), not 350 days for subsistence consumers and 48 days for recreational consumers.

The effect on intake (and ultimately estimates of risk) of setting EF at less than 365 is relatively minor for subsistence consumers (where EF = 350). However, for recreational consumers, the use of this adjustment results in an inappropriate reduction in contaminant intake and the risk estimate by nearly a factor of 8; that is, contaminant intake and risks are underestimated by approximately a factor of 8 for recreational consumers in the draft MRS. This inappropriate reduction in intake and resultant underestimate of risk is compounded by the use of exposure duration (ED) of 24 years to establish intake via the equation on page 4-5, which results in a further underestimation of intake and risk by a

factor of 2.9 (compared with an ED of 70 years). The assumption of partial life intake (24 years rather than 70 years) is unlikely to be representative of consumption and exposure among subsistence fish consumers (and potentially among recreational anglers, particularly those who share their catch with family members). Therefore, the draft MRS should assume that exposure duration (ED) in the equation on page 4-5 is 70, unless data demonstrate clearly that an ED less than 70 more accurately represents gathering and consumption of seafood from Makua. Risk estimates for consumers of fish and limu in the draft MRS may, therefore, be underestimated by more than a factor of 20 because of these calculation and assumption errors.

Risk estimates for subsistence and recreational consumers may be underestimated further as exposure assumptions used in risk calculations may not represent "most likely" or "worst-case" scenarios for individuals consuming fish and limu from the MMR. The draft MRS draws heavily on Sharma et al. (2003) and Sechena et al. (2003) to generate fish consumption rates for the risk assessment. While data from these studies provide fish consumption rate information for a variety of ethnic groups, the draft MRS does not provide evidence that these rates are representative of individuals harvesting or consuming fish from MMR contaminated sites. As a result, contaminant intake and attendant health risks will be underestimated where consumption rates of fish from MMR contaminated sites are underestimated.

Accurate evaluation of fish and limu consumption and contaminant intake in the local population requires a comprehensive survey of local consumers. In the absence of such a

survey, worst case estimates of consumption should be based on consumption from traditional diets such as those reconstructed by Smith (2003), where rates for some populations were nearly 400 g/day. Any seasonal differences in consumption rates should also be acknowledged and incorporated in estimates of intake and risk, such as those by Loranger et al. (2002) who found that daily fish intake rates were 6 to 10 times higher for recreational anglers in the James Bay Territory of Canada at the end of the fishing season compared to a group that reported fish consumption on an annualized basis.

Finally, the draft MRS suggests that risk calculations may be overestimated as contaminant concentrations in whole fish were analyzed. (Concentrations of organic contaminants, excluding methyl mercury, in skin-off fillets may be lower than concentrations in whole fish as some organic contaminants concentrate disproportionately in fatty tissue.) The final SAP and draft MRS do not thoroughly describe methods to prepare fish for contaminant analysis. However, many fish from MMR contaminated sites are eaten whole (including head, skin, and bones) and in some cases internal organs are consumed as well (Vince Dodge, personal communication). Therefore, assumptions that contaminant analysis of whole fish results in overestimates of risk are not accurate or appropriate.

Conclusions

The Final Marine Resources Study Sampling and Analysis Plan for the Mäkua Military Reservation addresses several of the comments and recommendations that we provided on 5 April 2006. However, there remain deficiencies in the Final SAP including:

Inadequate description of and rationale for SOI selection;

Inappropriate or inadequate proposals for the determination of contaminant background concentrations;

Inadequate description of sampling and analysis plans to generate data for the screening level ecological risk assessment.

The Human Health Risk Assessment in the draft MRS (volume 1), presents elevated cancer and non-cancer risks for individuals consuming fish and limu from the MMR. However, these risks – which, even as reported, in many cases warrant immediate remediation efforts or exposure reduction efforts – may underestimate true risks for several reasons:

Arsenic in fish is assumed to be completely in the organic (less toxic) form, although there are no analytical data to support this assumption. Any inorganic arsenic in fish would pose considerably elevated health risks to both subsistence and recreational anglers. The only way accurately to assess these risks is to quantify the concentrations of both inorganic and organic arsenic.

Cancer and non-cancer risk estimates associated with exposure to contaminants at MMR are reduced by purported background contaminant concentrations established from inappropriate sites. Reduction of health risk estimates for MMR by subtracting “background” risks is also mathematically and conceptually inappropriate.

Improper use of exposure frequency (EF) data in the calculation of contaminant intake results in considerable underestimates of intake and risk, particularly for recreational consumers.

Poor or inappropriate approaches to the selection of likely and worst case exposure assumptions may result in further underestimates of adverse health risks.

Suggestions that health risks are overestimated because contaminant concentrations were analyzed in whole fish are inappropriate, as there is ample evidence that individuals consume fish muscle tissue, bones, head, and in some cases organs.

Health risks associated with consumption of fish and limu at MMR may be underestimated by more than a factor of 20 as a result of calculation errors and inappropriate assumptions.

Table 1. Selection of chemicals for the Mäkua Resources SAP.

Column A – Contaminants recommended for inclusion in the final SAP.
Column B – Chemicals of Potential Concern (CPOC) included in the Final SAP.

Chemical	A	B	Notes
HpCDD	Y	Y	
HpCDF	Y	Y	
HxCDF	Y	Y	
OCDD	Y	Y	
OCDF	Y	Y	
TCDD	Y	Y	
Ethylbenzene	Y	Y	
M-xylene	Y	Y	
P-xylene	Y	Y	
O-xylene	Y	Y	
Toluene	Y	Y	
Aluminum	Y	Y	1
Beryllium	Y	Y	1
Chromium	Y	Y	1
Iron	Y	Y	1
Lead	Y	Y	1
Manganese	Y	Y	1
Thallium	Y	Y	1
Vanadium (cmpds)	Y	Y	1
Antimony	Y	Y	1
Arsenic	Y	Y	1
Barium	Y	Y	1
Cadmium	Y	Y	1
Cobalt	Y	Y	1
Copper	Y	Y	1
Mercury	Y	Y	1,2
Selenium	Y	Y	1
Silver	Y	Y	1
Zinc	Y	Y	1
Aldrin	Y	Y	
Alpha-BHC	Y	Y	

Beta-BHC	Y	Y	
Delta-BHC	Y	Y	
(Lindane)	Y	Y	
Heptachlor	Y	Y	
Hept. Epoxide	Y	Y	
4,4-DDT	Y	Y	
Pentachlorophenol	Y	N	3
Styrene	Y	Y	
1,2,4-Trimethylbenz.	Y	Y	
Phthalate	Y	Y	
Pyrene	Y	Y	
Perchlorate	Y	Y	

Notes

1. Metals will be identified as COPC if they occur at concentrations above background.

2. Elemental and organic (methyl) mercury will be assessed, although it is assumed (but not stated) that elemental mercury will be treated as a metal (see note 1) and methyl mercury will be treated as an organic compound and automatically included as a COPC.

3. Not included in the Final SAP but included (although not detected) in analyses reported in Volume 1 of the Marine Resources Study

Literature Cited

Barnes, D.G. and M. Dourson. 1988. Reference Dose (RfD): Description and use in health risk assessments. *Reg. Toxicol. Pharmacol*. 8(4):471-486.

EPA. 1998. Guidelines for Ecological Risk Assessment. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC, EPA/630/R095/002F, and available at Federal Register: May 14, 1998 Volume 63, Number 93, pages 26845-26924

Ferenc, S.A. and J.A. Foran. 2000. *Multiple Stressors in Ecological Risk and Impact Assessment: Approaches to Risk Estimation*. SETAC Press, Pensacola, FL. 251pp.

Foran, J.A. and S.A. Ferenc. 1999. *Multiple Stressors in Ecological Risk and Impact Assessment*. SETAC Press, Pensacola, FL. 100pp.

Loranger S., Schetagne R., Dumont, D., Plante M. 2002. Development of a questionnaire-based method to estimate methylmercury exposure of recreational anglers in Matagami (Quebec, Canada). Abstract No 136. 23rd Ann. Soc. Environ. Toxicol. Chem. (SETAC) North Am. Meeting, Salt Lake City, UT, USA, November 16-20, 2002.

Sechena, R., S. Liao, R. Lorenzana, C. Nakano, N. Polissar, and R. Fenske. 2003. Asian American and Pacific Islander seafood consumption – A community-based study in King County, Washington. *J. Exp. Anal. Environ. Epi.* 13:256-266.

Sharma, S., S. Murphy, L. Wilkens, L. Shen, J. Hankin, B. Henderson, and L. Kolonel. 2003. Adherence to the food guide pyramid recommendations among Japanese Americans, native Hawaiians, and whites. Results from the multiethnic cohort study. *J. Am. Dietetic Assoc.* 103:1195-1198.

Smith, B.A. 2003 From venison to salt pork: reconstructing the costs to Anishinabe families in 19th century Wisconsin. Presented at the American Anthropological Association annual meeting. Chicago, Illinois. November 22.

Tetra Tech. 2005. Marine Resources Study, Sampling and Analysis Plan (Draft). Mäkua Military Reservation O`ahu, Hawai`i. Contract No. GS-10F-0268K for US Army Corps of Engineers, Honolulu District. Prepared by Tetra Tech Inc. Honolulu Hawai`i.

Tetra Tech. 2007. Marine Resources Study, Sampling and Analysis Plan (Final). Mäkua Military Reservation O`ahu, Hawai`i. Contract No. GS-10F-0268K for US Army Corps of Engineers, Honolulu District. Prepared by Tetra Tech Inc. Honolulu Hawai`i.

Travis, C.C., S.A. Richter, E.A. Crouch, R. Wilson, E.D. Klima. 1987. Cancer risk management. *Environ. Sci. Technol*. 21:415.

USACOE. 2005 Hydrogeologic Investigation Report for Makua Military Reservation. Prepared by Geotechnical and Structures Laboratory, Waterways Experiment Station, Environet, Inc., and US Army Corps of Engineers Engineer Research and Development

Center. Prepared for Honolulu Engineer District, Environmental Division and the US Army Garrison – Hawai‘i, Directorate of Public Works. February 2005.

U.S. Department of Energy (USDOE). 1996. Criteria for establishing de minimis levels of radionuclides and hazardous chemicals in the environment. Report # ES/ER/TM0187. U.S. DOE, Office of Environmental Management, Washington, DC.

Response And Comments To The DEIS on Military Training Activities at MMR, HI

1. Draft EIS on Training in Makua, needs to include all alternative locations for training including those for short term as well as long term use. Therefore, incorporate the congressionally mandated report on all possible alternate sites to Makua.

2. It is important and necessary to include the effect and relationship of the proposed Stryker Brigade on proposed training in Makua.

3. Archeological study: this is apparently an inadequate study. Please refer to Malama Makua's consultant's report.

4. Draft Marine Resources Study
   a. Original S & A plan was flawed. Most recommendations by community and our consultants were not followed.
   b. Nanakuli muliwae (known to local people as "stink pond") is a poor and unacceptable choice for the control muliwae. It's in an urban drainage area (e.g. from a four lane heavily used highway) as well as gets drainage from Nanakuli Ranch. Therefore it is obviously contaminated. This goes also for Sandy Beach. The area was used for military training in the past. You should have a better control muliwai, even if you have to go to an outer island - one where there is no history of military training, ranch, or urban area runoff. .
   c. Limu study found high levels of arsenic. The next obvious test was not done, i.e., to determine percentage of inorganic (toxic) vs. percentage of organic (safe) levels. Will you do it ?
      All limu samples need to be identified-- not only by scientific but also by local names. The limu sample was too small. Needs to be larger.

   d. Were the field notes redone to be clearly legible? Were all tables and information included in the appendices?
   e. Re fish catch: didn't include eels (puhi) which was strongly recommended in scopings. Need to do night fishing as well as diving both day and night. Fish sample was too small, only 34 gms. EPA recommends 258 gms. Analysis of fish samples should be segregated by species.
   f. Molluscs (shellfish) and crustaceans are supposed to be included in this study; e.g. crabs in muliwai and urchins near shore and benthic organisms. Please do it.
   g. "There was a potential hazard to benthic invertebrates from 2,3,7,8-TCDD in sediments in the south muliwai" (Page 6-3 near the bottom).
      It is unlikely that dioxin found in the muliwai came from "burning of household waste." More likely, is the burning that occurred in the former OB/OD site. Please refer to my testimony on February 24, 2007 and the photo I took of the OB/OD site in 1979 and exhibited at that meeting. That information should be included in the revision.

Dioxin/furans were also found in the "Halliburton" study of the OB/OD site (1994, I believe). This is important information regarding the cumulative effects which are supposed to be included in the EIS. Please so note in your revised report.

h. Re: Draft Marine Resources Study (page 6-2) you state "there is no obvious pattern of deposition of explosive related chemicals." Yet you stated that perchlorate was found in surface water and detected in six samples of fish from the muliwai. That appears to be a pattern to me. The dioxin/furans may not show "obvious pattern" but were widely distributed" in the environment tested. Therefore, there could be a less obvious and more subtle pattern.
You reported that xylene was detected in fish samples. This is disturbing and again raises more questions.
Your study has raised more questions than it has answered.
The critique by our consultants goes into more detail and needs to be addressed.

i. I quote from your Appendix C page 7 paragraph C.4.1:

"A significant number of organochlorine data were disqualified because They could not be accurately quantified. Additionally, nitroglycerine and RDX data from three samples were disqualified. This resulted in a reduced number of valid data with which to use in the project assessment".

Your honesty is appreciated—I would expect nothing less. However, this appears to be a "significant" gap and deficiency in your data. This study needs to be redone!!!

We need more information and answers.

Sincerely,

Frederick A. Dodge, MD and Karen GS Young, NP
86-024 Glenmonger Street
Wai'anae, Hawaii 96792
Phone 696-4677

PUBLIC COMMENT MEETING
MARINE RESOURCE STUDY -
ARCHAEOLOGICAL SUBSURFACE SURVEY - DEIS
FEBRUARY 24, 2007
WAIANAE, WAIANAE DISTRICT PARK

BEFORE: RITA KING, RPR, CSR #373
Court Reporter, State of Hawaii

I N D E X

FACILITATOR: Annelle Amaral

SPEAKERS: Page

Shermaih K. Iaea, Jr.	3
Bill Prescott	8
Adrian Silva, Jr.	12
Pat Patterson	13
David Henkin	15
William Aila	22
Albert Silva	35
Vince Dodge	38
Jonathan Deenik	44
David Henkin	47
Fred Dodge	66

SHERMAIH IAEA, JR.: Aloha kakou. If I knew that I was going to be invited up here to speak when I signed in, I would have my wife sign in because I'm not an eloquent speaker, but I'm here, basically, because during the last meeting they asked for verification of the lineage that we have, family lineage in Makua, and we do have family lineage, very big family lineage in Makua.

I have a paper here from Dr. Reverand Kaleo Patterson who wrote this for me, and he says that he's the grandson, he's the great, great, great grandson of Kamakea, which is part of our lineage, and I am the great, great grandson of Kamakea and Issac Iaea.

This is a very brief description of family relationship in Makua Valley and surrounding area that is documented to Mahele records. In the Mahele Claims for Kawailoa, you will find Kamakea LCA2896, Iaea LCA3454-B, and Moo LCA3703, these names are all related to ohana, and these are the names you find related to LCA6092 in Makua Valley, Kahanahaiki, two parcels under Kamakea and the Iaea. Other names are also related as you will find listed in Kawailoa Mahele. Oral history consists of fishing and seasonal camping, family

4

burial areas in the area and connection with Waialua and Kawailoa. For more information on genealogy on Kamakea, Iaea and Moo, and others, see Anahulu Volumes I and II by Patrick V. Kirch and Marshall Sahlins.

Many Iaea-Kamakea family members still live in Makaha and on the Waianae Coast. Very little knowledge of Makua since displacement most family connection related to Kawailoa/Waialua, written by Kaleo Patterson. This is the documentation of the families, all families on Makua. So, I'm through with that. That was what I was told to bring, but I have other things to say.

I'm a very angry military guy. I spent a good part of my life in the military, and when I find that Hawaiians are up in arms and trying to protest what we are trying to do right by protesting our training, by saying we can't do this and we can't do that, it just hurts me.

I really don't know what you're protesting about our training in little Makua, about the fish, about the bones, you know, our land is sacred, all land is sacred, where I live, where you live now, not just Makua. What are you protesting? You protesting against our gods or

5

your god? You protesting the violence? What are you protesting, the animals, the plants? There are plants up there, there's plenty goats up there, too, eating the plants, why don't you protest them? It doesn't make any sense, it doesn't make any sense one bit. There's a law that should be passed, and I wish we had martial law because we are at war, whether you like it or not.

I remember during the Second World War, I was 10 years old at the time, I lived in Kalihi at that time, right up the road about two blocks away they had an Army camp, I used to go with the guys up there and go to the mess hall and eat with them, so I've been a military guy for a long time. When they were here at that time they can do anything they wanted because there was a war going on. Well, what the hell, the war's going on now. What can we do now? We run into protest after protest.

I don't understand that, I don't understand anything about the limu, the fish, the water or the bones, all I know is all my relatives in heaven, they're not in Makua, all my people are in heaven. So is the land sacred? Yes, all land is sacred. If there was a way that we can, I would award everyone in the protest group, if there's any way

6

we can do something, to get them for treason, that's what it is, treason. Thank you.

ANNELLE AMARAL: Thank you, Mr. Iaea. Mahalo.

Our next speaker is Debra Gregory and following Debra is Bill Prescott.

DEBRA GREGORY: Hi, my name's Debra Gregory. I don't have too much to say right now, I just got the report and I briefly reviewed it, and I'm shocked, my intelligence is so insulted and this is why. You're supposed to do 350, you did 350 probes, that's what you call them, probes, 350 probes, 50 were done in area one, am I correct, or was that area three? You should know, right?

ANNELLE AMARAL: This is the time that you get to make a statement, not ask questions.

DEBRA GREGORY: Okay. Well, I got nothing really much to say right now except that I'm really, I'm really flabbergasted, this is so insulting, I can't believe you guys put this in here. I mean, why do a subsurface survey in an area where it's highly unlikely that you will

uncover anything archeological, like in a lava field where the rocks are like 20 feet thick, so

7

thick, in fact, that you had to put -- what is it called -- AraGas. So 200 probes done by gas in an area where it's highly unlikely, and you even said so yourself, highly unlikely that you will find any archeological remains of anything. Okay, so you did 150, you did 150 subsurface probes in areas where you were actually supposed to have done them, that's good, but then the 200 in an area where you weren't supposed to have done them, took it upon yourself to change the plan entirely, so this is totally unacceptable, I won't qualify it, I won't quantify it, and you can kiss my ass.

ANNELLE AMARAL: Mahalo.

If you haven't had a chance to read the document and you want to read it, then put in your testimony at a later time. As has already been indicated, that can be done by the website.

Again, I'm going to repeat, we have some strong feelings one way or the other about the subject matter, and it is wonderful to hear your mana'o, there is no need to be rude, there is no need to be disagreeable, so if we can sort of manage ourselves and temper ourselves, I'd appreciate it. Mahalo.

Our next speaker is Mr. Prescott, and

8

after that Adrian Silva.

Aloha, Mr. Prescott.

BILL PRESCOTT: Aloha kakou, my name is Bill Prescott, I'm Bill Punini Prescott, I want you all to know that I am a native Hawaiian. You know, back in those days, my mother's days, the Hawaiian's tended to marry haoles who had some money, you know, like Bernice Pauahi married Charles Bishop and Lydia Dominis -- how many of you know Lydia Dominis?

ANNELLE AMARAL: Liliuokalani.

BILL PRESCOTT: Everybody knows her by Liliuokalani. She married a haole. These guys had money, my mother married somebody that was good looking.

Anyway, to start with, having read the works that went into the marine resource study and archeological subsurface survey, I want to compliment all of you for doing a job well done. You know, at this time, I'd really like to address members of our community and say on behalf of the Waianae Veterans of Foreign Wars, we want to ask you to join us in supporting the training our soldiers will need in order to accomplish their

mission and return home safely after they deploy later this year, keeping in mind that many of these soldiers to be deployed are our own Hawaii sons and daughters. You know, we sometimes tend to forget that our soldiers are stationed in Hawaii not by choice, they're here because those that we elected to congress, Senator Dan Inouye, Akaka,

Representatives Abercrombie and Case, brought the people here, and it wasn't our soldier's decision to fight terrorism in Iraq and Afghanistan, they're there because our president and our congressional representatives, who we elected, decided to send them there, it wasn't our soldier's choice. So if you don't agree with the decision that was made, then you should take it up with those people that you elected and not our soldiers.

To those Hawaiians who believe that Makua is sacred, we, the native Hawaiians of the Waianae Veterans of Foreign Wars, want to assure you that Makua is no more sacred than the grounds on which this building now sits. Anyone who has studied Hawaiian culture knows that there was a time when mana, or spiritual power, existed in people, in plants, animals, yes, and even stones, and that mana controlled all aspects of Hawaiian life. This

spiritual power came from the gods and those closest to the gods had the most mana, people had more mana than the plants, than the rocks. The kahunas had more spiritual power than the people, and the Alii, because they could trace their lineage back to the gods, had even more mana, spiritual power.

The kapu protected the mana and helped to maintain order. Breaking a kapu could have terrible consequences, the gods could get angry and vengeful causing volcanos to erupt, tidal waves to form, earthquakes to devastate the land, and,

13 therefore, anyone breaking the kapu had to be put
14 to death, and those were our Hawaiian cultural
15 practices in those days. However, in 1819 all of
16 that changed when Liholiho, Kamehameha II, sat and
17 dined with some noble women, including his mother,
18 Queen Keopuolani. By doing so, the King himself
19 openly violated one of the most sacred of all
20 kapus, that which prohibited men and women from
21 eating together.
22 You know, shortly thereafter,
23 Kamehameha II ordered all the god images to be
24 burned, all the heiaus demolished throughout the
25 islands, all of the heiaus, these were sacred

11

1 places of worship, some of these heiaus, luakinis,
2 were used to sacrifice Hawaiians to the gods, no
3 more were they sacred, and what his orders did was
4 to bring an end to the Hawaiian religion and the
5 kapu system that supported it. Now, with the
6 arrival of Christians the following year in 1820,
7 Hawaiians were quick to embrace this religion of
8 one god, a god of love and forgiveness. With this
9 god you could break a kapu and sin against this god
10 and still be forgiven. So while Makua was
11 considered sacred in our old culture, it is not now
12 sacred in our new culture. And just as people had
13 more mana than plants and animals back in the old
14 culture, being born in the image and likeness of
15 god, sacredness of people still reign in our new
16 culture.
17 To those who oppose the military, let me

ask you, Do you oppose police officers as well, do you believe that we will ever be rid of crime and criminals on our streets, and do you believe we will ever see the end of wars and meaningless mass killing of people? Just as our police keep our families safe from harm, so, too, does our military keep our country safe from radical nations and terrorists who wish to do us harm.

12

You know, one last thought I'd like to leave you with is what Prime Minister Tony Blair said when asked why he believed in America so much, and what he said was, You know what, a simple way to measure the worth of a country is to look at how many people want in and how many people want out. He went on to say, there are only two defining forces ever offered to die for you, one was Jesus Christ, the other the American GI, one died for your soul and the other for your freedom.

Again, I ask you to join us in supporting our soldier's training needs. Thank you.

ANNELLE AMARAL: Thank you very much.

Our next speaker is Adrian Silva, Junior, followed by Pat Patterson.

Adrian Silva, Junior.

ADRIAN SILVA, JUNIOR: Aloha. You know, it's very obvious that everybody sitting in the chairs in front of me must have a child somewhere or know of a child. What I'm talking about is the word training. We know this EIS is very important,

likewise with training. How many of you have kids in high school, kids in elementary school, they're training; isn't that correct? Without training we

13

would be useless, we wouldn't be able to read, we wouldn't be able to write, that's training.

You know, most of you understand the role in the life of a soldier, he goes far off and he trains, and he tells you it's frightening, you never know when and which bullet has your name on it, but he has got to be on his very best and that's why he trains. So I don't want to be up here too long to let you know that if a GI don't train, he's not ready. EIS is important and so is a soldier's life. Thank you.

ANNELLE AMARAL: Thank you, very much.

Our next speaker is Pat Patterson, followed by David Henkin.

PAT PATTERSON: Aloha, I'm Pat Patterson, a member of the Hui Malama O Makua, the larger group that has their arms around Malama Makua. I haven't been to the library to pick up my copies of these reports but I'm very happy to see them.

Opening up the one on the archeological study, something came to me that's bothered me ever since I've been involved with Makua since 1996. All of the areas of Makua have the names of animals we don't even have in Hawaii, to me that tells me

14

people who use those names don't belong there, Badger, Fox, Dear, Deeds, Coyote, Wolf, at least we could have Hawaiian animals, and we might get used to calling them that.

I looked at the foldout map on the archeology, also Figures 15, 16 and 17, it shows the shovel test probes, but it doesn't say how deep those went, whether it was one shovel full or 10 shovels full. You know, archeological tells all across the world there are layers indicating whether there were people living there or not, and then they get covered up and covered up and covered up, I don't think shovel probes would tell very much about an area where people have lived for, perhaps, 2,000 years, I know we've got to go much, much deeper.

On page 10 I see two unrecorded archeological features, my question is, When will those unrecorded archeological features been investigated and studied? And this brings me to asking another question to Dr. Lucking, Have you yet had a chance to look at the archeological sites on the north road and above?

As far as the marine resources study, I'm very happy that this has occurred. Before, when we

only went around the edge of the muluwai and go down seven inches, we didn't learn very much. Hopefully, this study will give us a great deal more. Thank you.

ANNELLE AMARAL: Thank you very much.

Our next speaker is Mr. David Henkin.

David Henkin.

DAVID HENKIN: Aloha kakou, my name is David Henkin, I'm an attorney with Earth Justice, and since 1995 I've been working with members of this community over concerns about the effects of live fire training at Makua.

I'd like to sort of preface this by explaining what exactly I've been doing over the last 12 years. This really isn't a question about whether American soldiers are going to be able to train, it's a question about making informed decisions about the best places to do that. The purpose of the Environmental Impact Study and of the National Environmental Policy Act is to make sure that the Army and, in fact, every federal agency can make fully informed decisions about where to carry out its activities, particularly where those activities might cause significant

effects to the human environment, so we're in that equation.

So, you know, ultimately it's not about whether soldiers train or not, it's about where they should train and how they should train, an informed decision, and that's an informed decision not only that the Army needs to make but the law recognizes the importance of public information so that the public can keep an eye on its government, its elected officials, the folks who said that we

need to hold them accountable for the decisions, absolutely correct. Part of this environmental review process is to make sure that we have the information that we need to so that we can know what should be done and if we disagree with the decisions that are made by the Army, we can raise that through the Democrat process.

It's in that spirit that I offer these comments. First, a few I just want to get out of the way, a few procedural things, they're not really procedural, but they're not getting to the substance. In order to provide the public with an opportunity, really, to offer meaningful comments here, and by the public I mean lay people like myself and also experts who can really take a look

17

at these marine studies and get into the science of it, they need to have the data on which those studies are based, and I know that there was an effort to put those on the website. I did mention to the Tetra Tech folks, and I just want to put it on the record, that the field notes for the marine study are in many cases completely illegible, not suggesting anyone did anything intentional but you need to make the copies darker so one can actually read what species was collected where, and that information should be promptly provided to the public because we have a limited amount of time to comment. We have retained Ph.D.'s in this and they've just said they cannot review certain aspects of the study until they actually can look

at the data.

Same thing, there's a table B, as in boy, one that was supposed to be in appendix B that would set forth how the samples were composited, in other words, how different fish and limu species were mixed together. I couldn't find it, I looked through every page of appendix B, hundreds of pages, I couldn't find it, so, again, that information just needs to be provided. And, again, these are things that just unintentional, I'm sure,

but even the hard copies that were provided today of the document, and it's appreciated the effort, if you look at it, and I don't know what's going on with the word processing program, but look, for example, on page 4-6, there are boxes instead of numbers, so certain numbers are coming through as boxes. So, you know, for example, if you want to, you know, they say later, USEPA guidance provides a mean uncooked fish consumption rate for the general U.S. population of box, 2.59 grams per day, and, anyway, there's boxes all over the place, so you actually don't even have the numbers, so we need to correct that, and I think we need to extend the comment period, there's a 60 day comment period as required under the settlement agreement so that people can actually review the information. That information, you know, should be provided promptly, both on the website and in a hard copy to people who wanted it.

Getting to the substance of the EIS,

because this is a comment period as well on the entire Environmental Impact Statement, the draft that was put out for review last year, I think it was last year, it's been awhile, one of the questions that came up had to do with the alleged

necessity of Makua, and one of the concerns that we raised in the earlier round of comments on the draft EIS is what are the alternatives to training at Makua, where are the other places that the Army can train the soldiers to perform the tasks that they're called upon to perform?

In the original, and I say original draft because I hope that there's going to be a revised draft put out for comment, in the original draft the only location that was looked at for training of soldiers was Makua, and we were told there was going to be, alternative one was training at Makua, alternative two was more training at Makua and alternative three was yet more training at Makua, and we said there's got to be other places where you can do this training, where you can provide these opportunities. Fortunately, congress agreed with us, and my understanding is that the Army is under congressional directive to provide a report by March 1st, that's next week, of alternate locations where they can conduct the training that is currently proposed for Makua. I assume that the Army is complying with congress's demand, that there are alternatives being proposed, and those alternatives, as well as any other alternatives the

public mentioned during the comment period need to be analyzed in the Environmental Impact Statement.

When you have new alternatives, substantially new alternatives, because any new location would be, by definition, a substantially new alternative, in EIS, you need to put that back out for public comment because there may be effects associated with the alternate locations that the public needs to be able to review and comment on. It may ultimately be that Makua is the best place for this training, that's not something that I personally believe but this is not a process about my personal beliefs, this is a process about getting the information out so that people can arrive at their own decisions and the Army can make an informed decision. So if there are alternate locations where you're considering to do the training, whether it's at Schofield, whether it's elsewhere, whether it's on redesigned training ranges, all of those need to be put out for public comment in a revised draft EIS, and all of us, I think, would like to see this process come to a close where we get the information that we need to make a decision, so I would encourage the Army to do that sooner rather than later, but that needs to

be done. By definition, any alternative that's identified in the report that comes out next week is a reasonable alternative that the Army is under a legal obligation to analyze.

Now, Annelle, I'm just going to ask you because I have a lot of thoughts about this but I don't want to cut off other speakers, so I can come back. What would be best?

ANNELLE AMARAL: I have two speakers signed up, the intention was to take a break and allow more people to sign up.

DAVID HENKIN: How about this, I think to that one thought about the need to study other alternative locations, the existence of other locations, we submitted testimony the last time around that, even if the other location is not currently available, because you need to build a new range or move things around, that the Army needs to look at alternatives that involve temporary, short-term use of Makua before the alternate range is available, those would clearly cause less environmental impact, less cultural impact on the resources at Makua than long-term permanent training there, so those are reasonable alternatives that need to be looked at. I'll get

into some issues related to the marine study and the archeological study, but for now I want to let other people talk, so, mahalo.

ANNELLE AMARAL: Mahalo.

As I had indicated, what I'm going to do is I'm going to call on the next speaker, the next speaker is William Aila, to make his comments on the record, and then what I'd like to do is to give you a bit of a break, those of you that have not

yet had an opportunity to sign up to speak, I'll give you the opportunity to do that then, and then we'll do the second round to allow you to make your comments on the record.

So, William, William Aila.

WILLIAM AILA: Mahalo.

Aloha kakou everybody, my name is William Aila, for the record, Johnson middle name, Junior last name, or suffix. Comments are going to be short and choppy.

Colonel Killian, very similar to the question that David asked, will the results of the study requested by Representative Abercrombie studying alternate training areas to replace Makua be included in the analysis in the draft EIS for

Makua? I think that's a reasonable thing to do, I think it would also provide you with reasonable alternatives. How much money has been spent to date for the last 10 years in maintaining and operating Makua military reservation, how much money is budgeted for the next five years for the operations of Makua military reservation, I think those are all good numbers that should be in there, also. Will the draft EIS analyze and explain how the Army units for the last, oh, I would say last six years the marine units and the National Guard units how they've been certified as trained even though they haven't been trained in Makua, there needs to be an analysis of that because if history

can demonstrate that the Army has the ability, that the Marines have the ability, that the National Guard has the ability to be certified as fit for fighting wars, as the recent history for the last six years has clearly demonstrated, clearly, clearly, clearly demonstrated, Makua has not been used, and they have fought, that needs to be analyzed, and it needs to be placed in the draft EIS. If you can find another alternative, as you have, and they've fought very, very well, then that needs to be placed in the EIS as part of the

summary.

Regarding the use of the proposed ranges in conjunction with the stryker brigade at Schofield and at Pohakuloa, my understanding from talking to, oh, he's not here today, Ron Borne, is that the design of those ranges are capable of being used for company combined assault training qualifications and, as such, are a reasonable alternative to be studied to Makua, so making sure that that alternative analysis is included in the draft EIS.

Regarding the marine study, sample size is too small. The Nanakuli Muluwai, I think we told you ahead of time that that was not a good choice to use because of the past military uses in Nanakuli, so it's not like you weren't told ahead of time don't use it, and you still went ahead and used it, so the results are mixed, the results are unsubstantiated, the results have failed to comply

with our request for reasonable study. We told you not to do it and you did it, we told you why, too, and you did it anyway. There's a clear pattern going on here, very clear pattern.

A more reasonable alternative would be to look at the baseline of a pristine muluwai, that

baseline is closer to Makua 70 years ago than Nanakuli is, you're comparing apples with oranges. The baseline that we need to be looking at is the baseline that occurred before the military showed up and started bombing and started burning and started dumping and started doing OBOD disposal there, that's the baseline, not the baseline for the last 20 years, the baseline is what occurred before the military showed up and evicted people from Makua Valley, that's the baseline. That should always be the baseline, whether it's archeological, whether it's chemical, whether it's hydrological, whether it's sociological.

The marine study clearly states in several places in the executive summary about uncertainties, uncertainties of baselines by which to make comparisons, uncertainties of order of magnitude of effect, uncertainties based on assumptions which translate into risk assessment, and what we asked for was some certainty, not more uncertainty when we requested the muluwai study, we want to know with certainty, is the fish safe to eat, are the crabs safe to eat, is the limu safe to eat? That's all we asked for. We get a report

25 with all of these assumptions that based on further

26

1 assumptions which result in greater uncertainty.
2 You haven't answered the question, you
3 haven't answered the question, you've raised more
4 questions, like now, Is the arsenic organic or
5 inorganic? Gee, I don't know, maybe I should stop
6 eating the limu but until you guys tell me, because
7 if it's inorganic, then chances are I'm going to
8 die of cancer. You guys knew when you were doing
9 the study that there are two forms of arsenic, why
10 didn't you just figure out what the percentage was
11 in the limu and the fish instead of coming back
12 with our report that's full of uncertainty.
13 The choice of Sandy Beach as an alternate
14 control site, wow, who came up with that one? They
15 should have gone back and checked the records.
16 Alan Davis was used to house military folks, there
17 were military activities that occurred at Alan
18 Davis, Alan Davis is another name for Sandy Beach.
19 So you compare an area that has been used
20 for military activities with an area that is being
21 used for military activities and, guess what, the
22 difference shouldn't be that much, so does that
23 make it okay? More appropriate, and we said this
24 in our comments to you before you designed the
25 study, we said, use someplace where there's been no

27

1 military influence, use Haena on Kauai, use
2 someplace on the North Shore of Molokai, that's the

baseline, that's the appropriate baseline in which to make comparisons because you guys not going to eat the fish, you guys going to serve two years over here and you guys going to leave, but we got to eat the fish and we got to eat the limu.

So, inappropriate use of alternate sites controls, a report that's filled with uncertainty, making me even more uncertain now, it didn't answer my questions, and I thought our questions was pretty simple, and I thought when we asked our comments on the study we were pretty clear, Use appropriate baselines, you didn't. The study fails to address our concerns, the study should not be included in the DEIS, and you should answer the other questions that have been raised, otherwise your EIS is incomplete, and we all know what happens in front of judges when EIS's are incomplete. Don't go there, don't do it, just do us right by the people of Waianae, answer the questions, that's all we want to know.

And the final comment is there's so much uncertainty that has been raised by the muluwai study right now that there is a huge demand for

28

quantifying some of the questions that it came out. For example, the arsenic, for example, where did those chemicals that are associated with Heptachlore and pesticide use, agriculture pesticide use end up in fish in Makua. Now, knowing what I know now, that in the 1940s, the 1950s, the 1960s and 1970s, that anybody with

access to the key, anybody could have gone to Schofield, obtained the key, gone up to Makua and done open burn and open destination dumping of whatever, we don't know what's there, just like we didn't know there was depleted uranium at Schofield. You know, we don't know until we know, so what's wrong with us asking the questions. If it's treasonous to ask questions, I'm guilty, I'll tell you right now, I'm proud to be guilty because I can look my grandkids in the eyes and I can tell them I tried.

So, let's do the task at hand, let's look at reasonable alternatives to training at Makua, let's look at the impact of 60 plus years of military use in Makua with questionable recordkeeping, very questionable recordkeeping, very questionable disposal techniques in those open burn and open destination pits, just bring the

29

stuff over here, it's too old, no more than 10 percent never go off, so pile them up, bring them over here. You know what, we get some contaminated jet fuel, we get some contaminated diesel we got to get rid of, dig the hole, throw them inside, set them on fire. Oh, by the way, we never keep all the records. So we really don't know what's up there, we don't really know what the source is of those Heptachlore related compounds that's found in the fish at Makua, something that I wouldn't consider, but now I consider and I put two plus two together, Oh, no record keeping, they could have

13 put anything in those pits for all those years,
14 maybe some guy in the pineapple company wanted to
15 get rid of some Heptachlore, he says, Hey, brah,
16 you guys get access to Makua, how about you take my
17 truck up there and you pour them in those pits and
18 dispose of them for us, no record keeping, no
19 record keeping of depleted uranium at Schofield.
20 Very scary. You try to get me to feel
21 comfortable, you try to build trust and then we
22 find these things. Initially, no report on any
23 kind of chemicals disposed of in Makua, then we
24 find this U.H. report, then we follow the
25 bibliography, and then we find all kinds of other

30

1 things. Like I said, we had to find that stuff,
2 nobody when I first approached the staff at Makua
3 was willing to tell me. Oh, and by the way, we
4 found some more evidence in some reports of a
5 crater bomb dump. Gee, nobody told us, they knew
6 it was there, we asked to do sampling around there,
7 all of a sudden we find, oh, magical, the stuff get
8 cleaned up, all hauled out, the cars that was in
9 there, the wires that was in there all disappeared,
10 no analysis. You like us trust you, you're asking
11 me to trust him?
12 A VOICE: Sure, why not?
13 WILLIAM AILA: I don't think I can, based
14 upon everything that I've been exposed to. You can
15 trust me because I tell the truth, I tell the
16 truth. I went over the treason part. I'm glad
17 we're having this discussion because I want to give

you a little Hawaiian, since you gave some Hawaiian culture, I want to give you just a little bit more.

Our Kapuna, our Kapuna wasn't cannibal savages and all-around bad guys, that if you broke a kapu you were destined to die, come on, we had compassionate Kapuna, we come from them. Brother no mention about Puulalula, you can go up there and be absolved. Brother no mentioned that chiefs had

31

the ability to pardon people, so I just want to provide some additional Hawaiian culture to some people who I don't want to misconstrue the chiefs and the kapu system was all bad. You know what, we don't have no kapu system today, guess what, we have no more fish, we have no more limu, all that stuff went. If the kapu system was around today, I don't think we would get drug use.

The other reason why alternatives to Makua have to be completely analyzed is because a promise was made, you can no make believe was there, it's in the lease, you can go back and look, it's in the palapala, the promise was made six months after World War II, Makua is to be returned, not just to the families that live there, because the majority, the vast majority of the land at Makua which was illegally taken under the guise of an illegal martial law declaration, you can go to the Supreme Court and find out that later on martial law in Hawaii was declared to be unconstitutional, go do a little bit more research. That promise that was made has not been kept to

today. The majority of the lands in Makua Valley are crown lands which became illegal ceded lands to the United States of America, which they were

32

illegally ceded back to the State of Hawaii, which are illegally leased to the U.S. Army, so maybe I not such treasonous after all, maybe I just honoring the right government. Thank you.

I have two things that I would like you to translate for the record. One is part of a chant, okay.

E iho ana o luna
E pii ana o lalo
E hui ana na moku
E ku ana ka paia

That's my hookupu to all the veterans in the audience, and the guys that know their culture, hoi no ai i kou kahu. Thank you.

ANNELLE AMARAL: What I'm going to do here for a moment is I only have one person registered to speak, and he wanted to be the last speaker, so I'm going to give you all an opportunity, those of you that came late, to go and sign up so that you have an opportunity to get onto the record or go and get something to eat and drink, which you can also do, and we'll come back in five minutes, and we'll take whoever else has signed up to speak, and then we'll be pau.

(The proceedings were at recess.)

33

ANNELLE AMARAL: I have four people that

have signed up to speak, so I would imagine that, and, actually, David Henkin's going to come back a second time, so there will be five speakers, and then after that we're going to bring this to a close.

I didn't have the chance, it slipped my mind, I'm getting old, to tell you there is another transcriber, and she's located in the back room there, so if you didn't want to speak on the record here in front of everyone, you can easily go to that back room and the transcriber will take your testimony there for the record. We will tell you, also, that this is not your last opportunity to comment, pick up a copy of the report, and you can send your comments in writing to the website that is on one of those displays.

And I want to give Kehau another opportunity to come up and once again make the announcement about elelo Hawaii.

KEHAU PUU NAPUELUA: Aloha, I'm Kehau Napuelua, and I will be here on the side, I'm the Hawaiian language translator today, and I'll be here on the side for those of you wishing to give testimony in Hawaiian. Please come and see me so

we can discuss a process for that. Mahalo.

ANNELLE AMARAL: Mahalo. All right. Here we go now. So just a reminder again, the ground rules are you wait to be recognized before you speak. I'll be calling the speakers in the order that they signed up, we're here talking to

one another, let's listen well, let's speak well, let's treat one another with respect. It's understood that not everyone agrees on issues in this room, we will disagree with one other, but it's not necessary for us to be disagreeable with one another, so let us say our peace, our mana'o, accept it for what it is, and pau. Let's not engage one another, speak your truth, we hear it, it's on the record, that should be sufficient. I will interrupt anyone who tries to interrupt the speaker, and we will not proceed until that speaker can proceed uninterrupted.

And, finally, the most important rule is be kind to the facilitator and the facilitator will be kind to you, I promise.

Our next speaker is Mr. Albert Silva followed by Mr. Vince Dodge.

Mr. Silva, aloha.

35

ALBERT SILVA: Aloha everyone. It gives me a chance to speak on, say, my behalf and my ohana, you might not know, but my lineage runs on the Waianae Coast for at least 200 years. I am the first male since it got in the hands of the wahines, and we know that the wahines are like the beautiful flower and the kane is like the bee, that's our analogy of life or our existence.

My efforts today is to give you or share with you not so much criticisms in any negative way but to bring to you a message from the way I've

experienced my life here on the Waianae Coast.

I was born here, like I said, I was born here September 15th, 1929. I grew up going to Makua from Waianae from when I first can remember, it was a dirt road and lots of ohiki, ohiki the crab, thousands of them at Ohikilolo. Fortunately, I've lived long enough to witness a lot, a lot that I was always concerned about, and it's part of me, my interest, my way of life, the hills, the mountains, the bush, the water, the wind, the rain, the ocean, but Makua in particular was my favorite place as a child, like I repeat, maybe at around four years old, as I can recall, opening the gate at Ohikilolo that I thought I could do but my

36

mother insisted that I couldn't and she was right, I tried to pick up that gate and open it so we could drive through, and I think I was around five years old, at least, at that time.

But, Makua, the place where like only the hermits maybe wanted to live, there was that church there, the graveyard, they talk about the muluwai, yeah, my brother went in that muluwai and caught a lot of fish in there, net, and the paipai -- the cowboys, he was a cowboy on the ranch, the cowboys would paipai the fish into the net and plenty fish, plenty kaukau. If you wanted meat, then go on up the hill with a 22 and got a goat, whenever they wanted meat.

But then times were not like the way it is now. I am sad to say the way Makua was at my

beginnings was very rough, lots of brush, opala, blue bushes, lantana, and the pipi, the cattle, weren't fat like they are now, there wasn't the grasses. The grasses right now is just like, go down to the best golf course you have here on this coast and the grass there is growing that thick, although these grasses out there is heartier, it can take the drought. The grasses we had before was simple foxtails that stuck to your pants when

37

you went walking through it, now, it just changed so much, and I tell you what, 90 percent of the change, the beauty, the so pretty valley that you can see, that you notice, is all because the care that the U.S. Army has done. They send people up there not only to protect the plants but to take care of the aina. Hey, tell me who can take care of the aina like the Army does here at Makua. If we are not grateful for the way they take care of the aina, that all the people around in the community here that have beautiful little yards, maybe five feet from their house around the yard, but that's all they can afford to take care of, but the Army takes care of a few hundred acres. Aren't we fortunate, aren't we lucky? Somebody might think, you know, no, we're not lucky, but the point is how beautiful Makua is now compared to the way it was when I was a keiki, and this is something that we all should be thanking the Army for, trying to make this effort, not only to train our soldiers but to maintain the aina, stewards of the land.

We hear about it, we want to be Hawaiians, we always say, hey, take care of the aina so the aina take care of you, but a lot of people, we should be grateful for the way the Army

38

is taking care of Makua, and they have all these scientists that know about plants, they've studied plants, they know so much about plants and even the environment, and they're not slacking. You go over there any one particular time and you will find them people are hard at work trying to maintain the Valley the best they know how, with all them scientists, all them guys with degrees, and yet we come to a place like this and we shoot them down, ungrateful, I feel.

Thank goodness we're in America, but I want to be a good American and call it like I see it, at least this Army is doing a wonderful job. Hear me and call me a liar if you want to, but show me any other large landowner that is taking care of their property like they do at Makua. Thank you.

ANNELLE AMARAL: Thank you very much.

Our next speaker is Mr. Vince Dodge followed by Jonathan Deenik.

Vince?

VINCE DODGE: Aloha Kakou, my name is Vince Dodge, it's Kanai Dodge, and mahalo for sharing that, Mr. Silva, it's really a pleasure to hear your mana'o, especially in the days of old

39

and, you know, kind of the richness of the aina.

I want to make a few comments on the marine study, and as I sit here listening to the discussion, I'm very thankful for Mr. Iaea's comment, I know his son Bula pretty well, you know, that all the land is sacred, and that's my belief, you know, our mother earth, she really does take care of us, and for the most part we treat her pretty bad, you know, I drive my truck around, I got here in an automobile, just like probably most of you, I know that's not good for our earth, and doing what I can in other departments to balance that out, but I'm part of the problem as much as anybody else here.

I've come to the conclusion recently that it's all about food, you know, I get to work with youth across the street at the intermediate school, and I got a garden growing there, I mean, food is essential to every culture, it nourishes our body, and I just had a really wonderful experience in the last couple of years spending more time growing food, especially growing food with people. It's a very rich part of my life right now, and then to eat the food that we grow, to do that with the youth, to see the way that they enjoy, you know,

40

what their efforts and Mother Nature has brought forth is also a wonderful thing to see.

And we're really fortunate we live in this country in this time. I think that, you know,

we have the opportunity to make some great changes here in our world because our world is pretty messed up when you look around, you know, when you look in Waianae, but when you look bigger globally, we've made a mess of it, you know, and we have special freedoms, I agree, and I'm grateful for those. But there's a lot of things that we're not free, and one of the things having to do with food is that we're not free to choose whether we want to eat genetically modified food or not, and this wonderful, this powerful nation of America, we're not free to do that, and it's real simple why, it's because the businesses that are promoting this type of food don't want it labeled because they don't want any accountability in case this food should turn out to be not good for us. And I think that's a major challenge for living in our world today, living in this country, is that it really is a lack of accountability kind of across-the-board, and we have institutions and people in businesses that are very powerful and that influence our lives

41

tremendously. I mean, you imagine every time you eat something with corn or soy bean in it that you might be eating, not you might, you're most likely eating something that's genetically modified unless the label says it is not, and these are foods that are concocted, which brings me back to the marine study because the marine study is about food, and I love my 'ia, I love my fish, and one of the things that I noticed is missing in that study, and Gary

from Tetra Tech was kind enough to tell me that they spent five weeks catching fish, they didn't catch too many species, they only fished in the daytime, they didn't fish early in the morning, they didn't fish at night, they didn't go diving, so their methodology and their window of, you know, trying to catch fish was pretty limited, you know, and as fishermen we know there's certain things you catch in the middle of the day and there's certain things you got to go in the morning early or you got to go at night, and you got to throw palu, you know.

Now, we're looking for good information from this marine study because many of us eat from the ocean, that's part of our ice box, and even though the ocean is pretty fished out, as William

42

said earlier, and when I look at that marine study, I'm like either these guys are not good fishermen and/or there's just no fish in the ocean anymore, but one of the things that they did not catch and they did not make any real effort to catch, was the puhi, the eel, and in the scoping meetings, as folks that live down here, as folks that fish and eat fish, you know, we strongly recommended many times that they catch puhi because the puhi is a creature that eats near shore, inshore fish and crustaceans, and he's at the top of the food chain, pretty much, you know, and he lives in the area, and he's going be to the one that if there are toxins he's going to be one that you're going to

15 find the concentration in, you're not going to find
16 concentration in oholiholi that are this big, you
17 know, moana that are like eight inches, I mean,
18 that's a fish that's maybe a year or two old,
19 that's not an old fish but a nice big puhi, one of
20 the green ones or a big white eel, that fish, that
21 fish has been around for awhile, he's eaten a lot
22 of things and we'd get some, it would be a good
23 indicator.
24 So I think that for my, you know, I'm not
25 a scientist, in my somewhat uneducated mind, you

43

1 know, looking at that marine study and saying, wow,
2 they missed the boat on this one in a really
3 important way, you know, and it's like I mentioned
4 to Gary, this is costing us taxpayers a lot of
5 money, and he's like, yeah, he's a taxpayer, too,
6 we're all in this room taxpayers, you know, like we
7 got to get effective information for the money
8 that's being spent here, wow, that's a whole other
9 conversation the way money is wasted, yeah, but I
10 won't go there today.
11 So for me, the marine study, it's not my
12 kahi, it's not giving myself, you know, and I talk
13 on behalf of my children and my grandchildren, I
14 just became a grandfather this past year, it's a
15 wonderful thing, because they didn't catch the
16 right fish, real simple, real, real simple.
17 I also, you know, want to say that for a
18 long time now I've come to the place where there is
19 no us and them, I'm not against anybody, you know,

to me we're all in this together, and the Army's made big changes, and it's going to continue to change, and part of the reason it changes is because we push on it because we got to, yeah, and Michelle, folks, and Kapua and Jobi guy that are up in the mountain taking care of the native species

and working the fences to keep the goats out and whatnot, they do an awesome job, they serve us really, really well, and I just have a deep mahalo and appreciation for what they do, and it sounds like they really enjoy their work. Mahalo.

ANNELLE AMARAL: So our next speaker is Dr. Jonathan Deenik, followed by Mr. David Henkin.

DR. JONATHAN DEENIK: Aloha kakou. Thank you for giving us the opportunity to speak today. I have just very simple, concise comments, much similar to what Mr. Aila shared before.

With addressing the concept of uncertainty or certainty that's outlined in the marine study, you know, it's very difficult to predict and gather information that can give us 100 percent certainty on a biological phenomenon, so how do we deal with that, how do we try to get an estimate of certainty or uncertainty? Well, one way is by taking many samples. So here is, I think, a basic flaw in this study is the number of samples that were gathered. Now, maybe it was constrained by money, well, that's fair enough, you know, we have to operate within a budget, but if

you were to look at this and say that decisions are

being made on four samples of limu, that's at least what's said in the paper there, well, then, of course, you're going to have a lot of uncertainty and you cannot, anybody in their right mind can't make, you know, a good prediction of what is the health hazard on four samples. So that's a pretty fundamental basic baseline.

The other important question is what are we comparing this to, so there's always in any kind of study a control group and an affected group, so Mr. Aila clearly pointed out the flaws associated with the control group. I don't think the study needed to select a control within the Waianae Coast, that was never one of our suggestions during the scoping meeting, so where do you go find an area that has not been affected by military use? Well, Oahu, it's not easy to find an area that hasn't been impacted by military activity, in fact, I still think there are two or three super fund sites associated with military activity on this island, so you're going to have to go somewhere else, Molokai, that's a fair enough comparison, same type of sediments in east Molokai as Makua, similar, at least, make a comparison. That becomes a real control, and then you can say with a little

bit more certainty, well, there is an impact or there isn't an impact.

Now, obviously, you look at the numbers

associated with this study, and I'm not an expert in all of these chemicals that they're outlining there, and we see very small concentrations, well, what does that mean, you can only get a handle of the meaning if you compare it to an unaffected area, it may have been non-detectable in the unaffected area, Lanai, I don't know, somewhere else. So those are two pretty serious flaws, and we, you know, not to blame anybody, but we discussed that these issues came up, I think, two years ago, so we just are repeating ourselves, and we get the same kind of results, and the results only raise more questions, as Mr. Aila pointed out, so we're even less certain now than we were two years ago, so those are two points I'd like to share with you folks today. And I did, I married a Hawaiian, but I wasn't like the older guys, I'm not so handsome and I don't got a lot of money, so my poor wife. Mahalo.

ANNELLE AMARAL: The last two speakers now are David Henkin followed by Dr. Fred Dodge.

47

DAVID HENKIN: Aloha, hana hou. I'm going to start by addressing one of the issues that Jonathan Deenik raised which goes to, you know, how good is the good study, and it's true in everything in life there are constraints, but in this case we have a court order, and the court order, just to make it clear for those who aren't familiar, this court order is the result of an agreement that was

ratified by the court, so it's not something the court imposed on the Army, it was something the Army voluntarily agreed to in order to address the community's concerns about issues like the ones we're addressing today, archeological studies and potential contamination of marine resources that people rely on for their subsistence or for their recreation, bringing food home to the keiki. So we don't need to, and, you know, as a taxpayer my experience has been if the Army needs the money to do a study that's required by law or hear a court order, it gets it. So, we're entitled under not one but two court orders, one that was entered into October 4th, 2001, and one that was entered just this last January, January 8th, 2007, we're entitled to a study that evaluates fish, limu and other marine resources on which area residents rely

48

for subsistence. That was the 2001 agreement which we clarified just last month, we are entitled to one or more studies to determine whether fish, limu, shell fish and other marine resources near Makua Beach and in the muluwai, on which area residents rely for subsistence, are contaminated by substances associated with the proposed training activities at Makua military reservation. So we have a court order, we're entitled to that information.

So when you do a study based on very limited sampling size such that the uncertainties are so great that you cannot say anything

14 meaningful about the potential for contamination by
15 substances associated with proposed training at
16 Makua, you haven't done what the court order said,
17 you haven't done what you agreed to do, so money in
18 this case really is not relevant, what's relevant
19 is what the Army voluntarily entered into and what
20 the court ordered. That goes to a number of
21 different issues. The emphasis here is marine
22 resources, limu, shell fish, fish on which area
23 residents rely for subsistence. That goes to the
24 point that Vince Dodge raised, people fish at
25 night, people dive, people eat a variety of things

49

1 out of the ocean, these are the things that the
2 Army agreed to and is obliged to study, and that's
3 not what we got.
4 One thing, you know, and I haven't had an
5 opportunity, these reports came out a couple weeks
6 ago, even our experts that we've retained to take a
7 look at them have only been able to get back on
8 such short notice with impressions, and we'll be
9 offering more detailed comments over the course of
10 the public comment period which I must emphasize
11 again should be extended to allow 60 days from the
12 availability of all of the data on which the
13 studies were based, but I'll give you some of the
14 things that we have noticed so far.
15 How many people here in the room ever eat
16 fish for dinner? When you eat fish, do you eat an
17 ounce size portion of fish or do you eat more than
18 that, and my guess is that the answer is going to

be more than that because an ounce is not very much. Well, the study assumed that for recreational fishermen, so people that are not subsistence, that a meal of fish is 34 grams, 28 grams is an ounce, so we're talking a little bit more than a couple of bites, that was the, obviously, how much of something you eat has a

strong correlation to the likelihood you're going to get poisoned by it or it's going to contribute to cancer rates, so if you start with an unrealistically low assumption that people take a bite of fish and that's their fish meal and that's what you're going to evaluate, you're going to get inaccurate results that are not reliable because the point of the exercise really is not to, we didn't enter into this to try and prove that marine resources at Makua are unhealthy, because that would really be damaging to this community if that were the truth, we'd like to have good data that proved that marine resources at Makua are healthy because the fact of the matter is, that healthy or unhealthy, people are going to be keep eating them.

The reason we entered into the agreement with the Army, the reason we insisted on this particular type of study is because we know the people in Waianae rely on their resources for the livelihood, for their subsistence, for their recreation, for their paina, and we want them to have good information about the likelihood that these are killing them, that's why we need good

24 information and that's why we entered into the
25 agreement. So if a good study is done and the

51

1 study reveals there's nothing to worry about, you
2 can eat the limu, you can eat the fish, you can eat
3 the shell fish, that's good for everyone, that's
4 fine, that's it, that's a fine result because I
5 think that there are some out there who assume that
6 what the community is trying to do and the groups
7 that Earth Justice represent are to say "Gotcha" to
8 the Army, to prove that something is harmful, and
9 that's not accurate, particularly in this case, all
10 we want is good information.
11 So when you do a study that assumes that
12 we only eat an ounce of fish at a meal, that
13 doesn't give us good information. When you do risk
14 assumptions, it may get you a good sound bite in
15 the media that your odds of getting cancer are less
16 than your odds of being hit by lightning -- I might
17 state for the record I've been hit by lightening,
18 so it happens, it's true, in Wisconsin, anyhow, but
19 it gives you a good sound bite, it doesn't give you
20 good information, because if you're actually going
21 to eat more than an ounce you're going to get a lot
22 more toxic loading.
23 Now, for a subsistence fisherman, now
24 this is someone who is relying on this area to
25 really survive, I mean, they're not going to the

52

1 supermarket for their fish, this is survival, they

consume 110 grams, so that's about a four ounce portion, it's a quarter pound of meat, so those who go get a quarter pounder, not very much, again. So in terms of what the experts who do this over at EPA, EPA assumes that an average fish sized meal is 227 grams, so over twice as much they consume for subsistence fishermen or about half a pound, and based on my own experience and 41 years on this earth, that's kind of more like what people tend to eat when they sit down to eat fish, so we need studies that are based on good data, and we're entitled to them.

One of the big issues that's totally unresolved in this study is the likelihood that people are eating toxic levels of arsenic. They came out in the study with extremely high levels of arsenic in the fish and the limu, the problem is they don't tell us whether the arsenic is organic arsenic, which has a lower toxicity, or inorganic arsenic, which has a very high toxicity, there's no reason for that. You can analyze a sample and determine the proportion that's organic and inorganic.

Now, I talked to the folks who are

53

putting together the study, and I mean them no personal disrespect, I'm sure they were following a plan that the Army approved and told them to carry out, they didn't analyze whether the arsenic was organic or inorganic, they looked at studies that said worldwide, most fish has organic arsenic in

it, therefore, we assume that all of the arsenic that we found is organic. Well, that doesn't follow logically because most fish aren't in a near shore area where we have surface water studies that the Army has done that inorganic arsenic is flowing in the streams into the water, so you can't just sort of assume, you know, sort of Socrates was a man, that type of logic. Unless you study the specific fish that people are going down and eating to determine whether it's organic arsenic or inorganic arsenic, you're not going to get good data. Same thing with limu, limu had very high levels of arsenic, they did not go into any analysis of whether it was organic or inorganic, that's information that we need, that's information that we're entitled to. Also, with limu, I'll get into a little bit later the references that were used for these various studies, but for limu they did not sample limu anywhere else in the Hawaiian

54

islands, in fact, anywhere else at all, they just looked at the chemical constituents that are in this limu that people are eating, people are gathering, people are eating, I've eaten it, there's no comparison, so we don't know what pristine limu would have, maybe it is that all limu in Hawaiian waters have elevated levels of arsenic, and even if you go to pristine areas on neighbor islands that are not affected not only by military activities, and I'll get into this, but by any urbanization or human input, any anthropogenic

input, maybe that's just the way our limu is, well, that would be a meaningful study, that would provide meaningful information, that this is the level arsenic that you get in limu. Sampling is one place not breaking that organic/inorganic and not having any baseline, any comparison doesn't provide information we're entitled to.

I'm going to highlight one of the parts of the marine study that is completely missing, and, again, I'm quoting from an agreement that was entered by the court on January 8th of this year: Defendant shall complete one or more studies to determine whether shell fish near Makua Beach and in the muluwai on which area residents for life for

55

subsistence are contaminated. Shell fish. There's nothing in this study about shell fish, they didn't gather shell fish, whether it's crabs in the muluwai or urchin in the inshore areas, there's no study of shell fish at all, none. So they have failed to comply with their agreement and the court order to study shell fish, they need to do that, they need to do that, they need to take these comments, they need to revise the study and also under the agreement we reached last month they need to go out and do another 60 day public comment period because it's not, you know, don't blame Earth Justice, don't blame Malama Makua, you entered into the agreement, you agreed to do certain things, and when we get the study they're not there, so if you want to know who's dragging

this process out, you have to look in the mirror because it's the decisions that the Army's making not to fulfill the black and white terms of the agreement.

I'm not singling out any individual, I'm just saying the reality is that we will insist on complete compliance with these study requirements because we want good information and we're entitled to that information because that's the agreement

56

that we have. So I think everyone on both sides of this issue hopefully can agree that when two parties who may disagree about something have nonetheless entered into an agreement, they're entitled to be held to that agreement, and there's nothing improper about doing that, and we will.

In terms of the sampling, the so-called background areas of the reference sites, let's talk about Nanakuli muluwai. Nanakuli muluwai has the past and present military impacts, but in addition it's in an urbanized portion of the Waianae Coast, it's in the middle of Nanakuli, it gets all of the contaminates that flows whenever people drive through on the Farrington Highway or repair their car or throw their garbage or all those things affect that muluwai, so when the Army tells us that with respect to certain contaminants the levels at Makua which, other than the Army's activities, is in a remote and formerly pristine portion of the island are similar to the level of contaminates at Nanakuli and, therefore, there is no impact from

the military, that's just wrong, it's like saying we've sampled the ash residue left at H power and it has greater levels of arsenic and heavy metals than the fish and limu in the muluwai, and,

57

therefore, the military's doing no more than society as a whole is doing. You need to look at a non-contaminated muluwai, which is what Makua would be, and determine what the background levels are.

Let's go another step further. When you're looking at an Environmental Impact Statement, the Army has an obligation to talk about cumulative impacts, so the only thing this study wants to talk about is the incremental impact of what the Army is adding to what you would otherwise find in terms of contamination near fish. Let's take it as a given, this is an assumption, that even if the Army had never trained at Makua, there would be a certain level of contamination in the fish and the limu. They didn't say, well, the only thing that we're concerned about is the extent to which we add to it incrementally. Well, under the law that's not accurate, you need to disclose in your Environmental Impact Statement the cumulative impact, which is the impact of the Army's activities on top of the impact of everyone else's activities, including nature, I mean, just what the cumulative impact is, because with respect to a lot of contaminants, a lot of poisons, you get to a point where it's the straw that broke the camel's

58

back, it would be okay if you had this level of contamination, but when you add this level of contamination, all of a sudden you've gotten to a heightened risk that goes beyond what society will accept, so you need to evaluate, you need to analyze not the incremental damage, but in addition you need to look at the cumulative effects. So even if in pristine areas you have certain levels of contamination because of global pollution, there's just no way to run because we've contaminated our environment or naturally occurring pollution like, you know, vog coming out of the volcano, if you're adding on top of that, you need to analyze that, we're entitled to that information.

Sandy Beach, there's been questions raised whether that's an appropriate background for the fish and so, in general, you need to address how you selected the locations because if they're not free of human input, if they're not pristine areas, they don't tell us what the effects are of the military being there.

Turning now to the archeological studies, and if there are other people that want -- I mean, I don't need to monopolize, does anyone else want

to jump in or I should go ahead and finish?

On the archeological studies we also have agreements on what needs to be done. Starting in 2001, we have an agreement that was substantially modified in 2007 so we'll just focus on the January

8th agreement. With respect to archeology, the defendants, in this case the Army, were supposed to complete, complete surface and subsurface archeological surveys of all areas within the company combined arms assault course. For those of you who are familiar with Makua, that's the south fire break road, except for the area that is suspected of having or that has been designated as an improved conventional munitions area, and with respect to that area the Army was supposed to secure a waiver, or if the Department of the Army would not give a waiver after good faith efforts by the 25th Infantry then they would not have to conduct the archeological surveys in those areas. Today I tried to determine, because no surveys were done within the ICM area, whether the waiver had, in fact, been granted, denied, still pending, we don't yet have information on that, we need that information because under the agreement we're supposed to be commenting after all archeological

studies are completed. So, presumably, we're going to find out what the status of the waiver is. If the waiver is still pending, this process is premature.

The requirement is to complete surface and subsurface archeological studies. When I spoke with Laurie Lucking at deposition in, I believe, November of 2005, we agreed that there was an area within the south fire break road where, outside of the ICM area but inside the fire break road that

had not yet been surface surveyed, that would be the southeast lobe, it had not yet been surveyed at that point, it needed to be surveyed, I haven't seen anything in this study to suggest that those surface surveys have been completed. If they have been completed, great, but we are supposed to have those disclosed to us so that we can also comment on those.

With respect to the subsurface archeological surveys, there are some serious problems, and all these comments are preliminary because of the short time for review, but, again, the emphasis was on complete surveys so that we would have all the information that we need in order to evaluate the impact, the effects of live

fire training at Makua, which the Army concedes and just logic dictates, has the potential to destroy cultural resources, misfired weapons, that happens, it's training, soldiers trampling, a variety of ways in which archeological resources could be lost forever, that needed to be disclosed as part of the rational analysis of whether Makua is a really good place to do the training the Army would like to carry out there.

As far as the subsurface archeology goes, there are a few problems that I've noticed. This study that we've been given to review is only a presence absence survey, in other words, they've dug some pits to determine whether subsurface deposits might be there. When they encountered

16 them, and they did encounter them in areas where
17 they didn't expect to encounter them, they weren't
18 actually characterized, so we don't know what they
19 are, and we don't know how vulnerable they are to
20 training related impacts. That's a problem
21 because, in my mind, from a common sense
22 standpoint, that survey is not complete if you
23 don't know what you've found.
24 They also only looked subsurface where
25 there were no surface features, in other words, if

1 they came across a surface feature in an area where
2 they were supposed to dig, they wouldn't dig there
3 because they knew there would be something
4 subsurface there. Well, again, the purpose of the
5 survey was to determine and characterize what types
6 of things were there, and nothing in the agreement
7 exempts an area from inquiry where you're
8 particularly likely to find something.
9 I might also note that we're talking
10 about archeological surveys in the core assault
11 course area, so this is an area where they have
12 been training, for, I believe, decades at this
13 point, 1985, I think, is when the CCAAC went in,
14 and prior to that they had been doing a lot of
15 training at Makua for decades before that. It is
16 notable that they continue to find surface
17 features, surface features, not subsurface
18 features, surface features that had not previously
19 been identified. Now, that clearly indicates that
20 there are -- and some of these features, I mean,

one of them, this is not a native Hawaiian feature, but nonetheless it's an archeological feature, was a Kiawe fence that was 150 meters long, so, you know, a distance of one-and-a-half football fields long, this is a pretty big thing, so they're still

finding things out there, and that raises concerns about the thoroughness of the surface surveys in the areas that they claim to have completed, and, in fact, in the study it notes that we may have missed some surface features along the way. Well, again, we're entitled to complete surface archeological surveys.

With respect to the subsurface surveys, the report says that the plan that they had for the probes, 350 probes that became another 200 just along some roads, that that would be inadequate to provide any meaningful information about subsurface archeological resources at Makua, well, that's not acceptable in the context of an agreement where you have to do a subsurface survey that will provide meaningful information about subsurface resources at Makua.

There was one area, area two, where 200 probes were dug, and this was an area that they had not previously surveyed, and of those 200 probes five of them came up with either surface or subsurface archeological resources, that's two-and-a-half percent within that area, it's extremely high in an area that the Army previously said they didn't expect to find anything, so we're

64

still waiting on a complete characterization of the resources there.

Another thing that concerned me is that the study makes clear that the Army would not do a subsurface hit if it found some unexploded ordnance below the surface, they would abandon that particular sampling location, it's on page 7 where they said they'd do that, that's contrary to the settlement agreement that we reached just last month, it said, quote, Defendants will make good faith efforts to clear unexploded ordnance, as necessary, to complete the subsurface archeological surveys within the south fire break road. In other words, if you hit UXO, you're supposed to clear it in order to complete the surveys. And how do we know that they didn't try? Well, it says, If safety concerns arise, the parties are supposed to meet and confer in a good faith attempt to resolve the concerns so we can determine whether there's any clearance that could take place. I'm the person they would have contacted if they had any safety concerns that would have precluded them from carrying out the unexploded ordnance clearance necessary to comply with the agreement, I didn't receive any phone calls, so there was no meeting

65

conferred as required, consequently, I have to conclude there were no safety concerns that would preclude them from complying with the agreement.

There's two problems here, why do I mention all this? I mention all this because we started down this path a long time ago to make sure that there was a thorough examination of the impacts of training at Makua and the alternatives to training at Makua, reasonable alternatives that would allow the Army to train elsewhere, satisfy its goals without impairing the unique cultural and biological resources at Makua, without continuing to impact this already heavily impacted community, and we're not there yet. But Earth Justice working together with Malama Makua, and the other community members, are committed to ensuring that we get a full disclosure of the impacts and a full discussion of the alternatives so that we can all make an informed decision about the best way forward. Mahalo.

ANNELLE AMARAL: Thank you very much. The last speaker, then, is Dr. Fred Dodge.

Dr. Dodge? As Dr. Dodge is getting ready to come up, and don't rush, we're going to replace the tape, Dr. Dodge, so that we're assured you're

66

not going to be interrupted.

DAVID HENKIN: I just have a question slash concern, when this public meeting/hearing was announced, it was announced it would run until 6 o'clock, and I'm concerned that there may be people who assume that means they can show up any time between now and 6 o'clock, and particularly, as the Army has experienced, sometimes these

meetings actually run late. So when you say he's the last speaker, I hope that if someone shows up between now and 6 o'clock, we'll have an opportunity to hear their comments.

ANNELLE AMARAL: So what David has raised is that it was announced that this meeting would go to 6 o'clock, and he's concerned should people be coming after this last speaker will we still be here to take comments. So I'm going to go over and talk to the Colonel, I thought I heard him say we will be here, so let me settle that before the end of this. Thank you.

Dr. Dodge.

DR. FRED DODGE: Aloha kakou everyone. Thank you, Annelle, Colonel, and everybody that's here, including our stenographer and our Hawaiian

67

translator, I don't think I'm going to give you much work on that.

First of all, a little bit of background, I also served in the military many, many moons ago, well over 50, I was in Korea, and I have an appreciation for the military that a lot of people may not realize I do, but I do. That appreciation isn't always shared by what our leaders do with our military people, and perhaps I shouldn't go there, but I think it's very important to elect good leaders who aren't afraid to negotiate, who wait to use war as an absolute last resort. I better quit on that note, on that particular subject.

I don't know where our other friends
went, but I was going to also mention to our
friends on the other side, concerned citizens and
so on, that I, too, appreciate the fact that
there's this give-and-take, that, you know,
Albert's reminiscence of the way Makua used to be
is really wonderful, he reminds me a great deal of
Ivanhoe Naiwi, who was born in Makua, who I got to
know and really appreciate during the Ohikilolo
struggle where the community got together and was
able to save Albert Silva's farm. I also know his
family quite well, Adrian Junior, Uncle Jay Landis,

68

a very dear friend, is another person who, along
with Ivanhoe Naiwi, who actually got me involved in
Makua, so although I'm not Hawaiian, I wasn't even
born in the islands, I came to appreciate that aina
tremendously because of these wonderful people. I
also had the pleasure of knowing and caring for
Albert's mother, Annie, who was a wonderful,
wonderful person, lived to be more than 95 years
old. And this hasn't got anything to do with it,
but I can't help but state that when she was in a
nursing home and I was making rounds, I would
sometimes bring my kids, so I brought my daughter
Summer, who is now in the mid 20s, she was five
years old then, Annie Silva was 95, and I was
looking at these two human beings, almost a century
difference in age, and I got to thinking about
life. And as I get older I think more, and I have
to agree with my son Vince, and I have wonderful

kids, but there really shouldn't be us and them, we're in this together. They eat the same fish that we do, presumably, I'm quite sure, we're all subject to the same influences, and I did want to say that at the outset. Actually, William Aila, Jonathan Deenik, Vince, my son, certainly David, have gone over much of what I wanted to, so I will

save you repetition except that I, too, would like to know what the status is on Representative Abercrombie and congress's request for a list of alternative locations to Makua, and this is supposed to be done by, I believe, the beginning of March, certainly sometime in March, and I would think that that should be included in this EIS.

I'm also concerned about the strykers, William mentioned them briefly, and we've asked this in the past, what role does a stryker brigade or would the stryker brigade play now in Makua, I've heard different scenarios, but I think this should be included. I have a map, compliments of the military, of the archeological sites in Makua, it's the red, there's a little bit larger picture in the book that Laurie Lucking brought, and, again, this is a previous request that I'm requesting again.

As you can see, a great deal of the valley is archeologically rich, and, as such, should be declared an archeological district. Dr. Lucking agreed with me in the past, and I just wondered, again, where are we in that kind of

24 request. Now, for those that feel that this might
25 interfere with military training, at least from my

1 experience in Kahoolawe, which was declared an
2 archeological district, it does not stop military
3 training. It doesn't make sense, but, basically,
4 it doesn't by present laws, to the best of my
5 understanding. So if we can try to get moving on
6 that, at least, I think that would be very
7 appropriate to declare Makua as an archeological
8 district.
9 This is my last show and tell. Now,
10 Malama Makua members, Hui Malama O Makua, you're
11 not supposed to answer this because you guys know,
12 but what is this, where is it? Give you a little
13 information on it, this was taken from Ohikilolo
14 Peak, that's the ridge between Ohikilolo Valley and
15 Makua, and it was taken in 1979, at that time I
16 wasn't involved in this, and I assumed that these
17 were craters filled with water, which they were,
18 but I assumed that they had occurred from military
19 training and use. Does anybody want to -- well,
20 this is the OBOD site, open burn, open detonation
21 site here, this is the south fire break road that
22 runs through it. And the reason I'm showing this,
23 what brought it to mind, what made me look up this
24 thing is that Tetra Tech, for all the criticisms
25 that you heard today and shortcomings of the study,

1 which does appear to be flawed, but they did find
2 quite a bit of dioxins and furans in their studies,

and then they added that these occur often with household burning. Well, as Mr. William Aila can tell you, and he's shaking his head, the OBOD site used to use old diesel fuel, gas, crates, wood, all kinds of things, I don't know how related it is to household burning things but Tripler brought materials to be burned in that area, University of Hawaii, also, and this is documented in the studies that we've been able to ascertain. And I have copies in case anybody wants, so there's a lot of opportunity for the dioxins, et cetera, to be generated in this area and find their way down into the muluwai area.

I do want to take this opportunity also to thank the good Colonel over here and our military friends. I know you have tried and, you know, we want you to get a good study, we want you to go back to the drawing board and really do it up right, but thank you very much for this opportunity, and I wish you all aloha and mahalo.

ANNELLE AMARAL: Thank you.

What we're going to do now is we're going to take a bit of a break, say about 10 minutes, it

gives you an opportunity to sign up now if you want to speak. We also have, as we mentioned earlier, a transcriber in the back room. If you want to give testimony, you know, not here but in private, that's available, so we'll take a break. And as David had questioned, we will remain here until 6 o'clock, absolutely, we will remain, the doors

will stay open, and we will receive testimony until then.

David?

DAVID HENKIN: I wanted to make clear to everyone how much I appreciate and I think it would be fair to say Earth Justice clients appreciate the efforts that were made to hold the meeting in this format. We had some dialogue about it following the stryker meeting and very much appreciated, I think it's something that works very well, particularly in this community, I think it works well in most communities, and the efforts that the Army made to accommodate that request are appreciated, and I think it's helped to generate some good comments today, so I want to say mahalo, thanks for the sensitivity to the community's concerns.

ANNELLE AMARAL: We'll take a bit of a

break, and you can sign up, get some food, there's still some food and drink.

(The proceedings were at recess.)

ANNELLE AMARAL: It looks like we're sort of picking up chairs and putting things away, so it probably would be good for us to just sort of close this off formally.

I'm wondering, Colonel Killian, do you want to say anything? No.

Then let me say something, I want to thank all of you for your conduct today, this was an excellent public hearing, I appreciate the

cooperation with which we all worked together, and I was very happy to be able to facilitate this meeting. And before we go, I think it would be good if we could just form a circle, let's do a final closing pule and then we can all go home in safety.

(The proceedings concluded at 6:00 p.m.)

CERTIFICATE

STATE OF HAWAII)
) ss.
COUNTY OF HONOLULU)

I, Rita King, RPR, CSR, Court Reporter and Notary Public, State of Hawaii, do hereby certify that on Saturday, February 24, 2007, at 2:00 p.m., that the proceedings contained herein were taken down by me in machine shorthand and was thereafter reduced to computerized transcription under my supervision; that the foregoing represents, to the best of my ability, a true and correct copy of the transcript of proceedings had in the foregoing matter.

I further certify that I am not of counsel for any of the parties hereto, nor in any way

interested in the outcome of the cause named in this caption.

Dated this 12th day of March 2007.

_____

RITA KING, RPR, CSR No. 373

Notary Public, State of Hawaii