FINAL Environmental Study

Ordnance Reef (HI-06)
Wai‘anae, O‘ahu, Hawai‘i

Prepared For:

U.S. Army Corps of Engineers

July 2014

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Prepared by:
UH

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List of Acronyms and Symbols

ADCP	acoustic Doppler current profiler
AEL	Adverse Effects Level
Am	amino
ATL	acceptable tissue level
ATSDR	Agency for Toxic Substances and Disease Registry
C&C	City and County
CAMIP	Coral Avoidance and Minimization of Injury Plan
CBD	Center for Biological Diversity
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
CM	conceptual model
COC	chain-of-custody
CON	control
COPC	constituent of potential concern
COPEC	constituent of potential ecological concern
CSM	conceptual site model
CTD	conductivity, temperature, depth
CTL	critical tissue level
DLNR	State of Hawai‘i Department of Land and Natural Resources
DMM	discarded military munitions
DNB	dinitrobenzene
DNT	dinitrotoluene
DO	dissolved oxygen
DOBOR	State of Hawai‘i Division of Boating and Ocean Recreation
DoD	Department of Defense
DOH	State of Hawai‘i Department of Health
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ESA	Endangered Species Act
FA	factor analysis
ft	feet
ft/s	feet per second
FDA	U.S. Food and Drug Administration
FR	Federal Register
FSP	Field Sampling Plan
GIS	geographic information system
g/mL	grams per milliliter
GPS	global positioning system
HAR	Hawai‘i Administrative Rules
HELCOM	Helsinki Commission

HHRA	human health risk assessment
HI	Hazard Index
HI-06 ERA	Ordnance Reef (HI-06) ecological risk assessessment
HI-06 HHRA	Ordnance Reef (HI-06) human health risk assessment
HMX	high melting explosive (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)
HPLC	high performance liquid chromatography
HQ	Hazard Quotient
ICP-MS	inductively coupled plasma mass spectroscopy
ICP-OES	inductively coupled plasma optical emission spectrophotometer
ID	identification
IDW	investigation-derived waste
in	inch
IUCN	International Union for Conservation of Nature
kg	kilograms
km	kilometers
K_{oc}	organic carbon partition coefficient
K_{ow}	octanol-water partition coefficient
lbs/gal	pounds per gallon
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LCU	landing craft utility
m	meters
MB	method blank
MC	munitions constituents
MDL	method detection limit
mi	statute miles
MI	multi-incremental
mg	milligram
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mm	millimeter
m/s	meters per second
MS	matrix spike
MSD	matrix spike duplicate
NMFS	National Marine Fisheries Service
nmi	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effect level
NPDES	National Pollutant Discharge Elimination System
NPS	non-point source
NRDC	Natural Resources Defense Council
NRWQC	National Recommended Water Quality Criteria
NT	nitrotoluene
ORCC	Ordnance Reef Coordinating Council
ORP	oxidation-reduction potential
PARCC	precision, accuracy, representativeness, comparability, and completeness
PCA	principal components analysis
PELCR	Potential Excess Lifetime Cancer Risks

PETN	pentaerythritol tetranitrate
pH	hydrogen potential
ppm	parts per million
ppt	parts per thousand
psi	pounds per square inch
QA	quality assurance
QC	quality control
QAPP	Quality Assurance Project Plan
RDX	royal demolition explosive (hexahydro-1,3,5-trinitro-1,3,5-triazine)
RI	remedial investigation
RL	reporting limit
ROUMRS	Remotely Operated Underwater Munitions Recovery System
RPD	relative percentage difference
RSL	Regional Screening Level
SAA	small arms ammunition
SAP	Sampling and Analysis Plan
SBE	Sea-Bird Electronics
SCAR	Special Operations Forces Combat Assault Rifle
SCUBA	self-contained underwater breathing apparatus
SONAR	sound navigation and ranging
SQuiRT	Screening Quick Reference Tables
SRM	standard reference material
SV	screening value
SVOC	semi-volatile organic compound
SW	solid waste
TEL	Threshold Effects Level
TNB	trinitrobenzene
TNT	trinitrotoluene
UCL	upper confidence limit
UH	University of Hawai‘i
U.S.	United States
USACE	U.S. Army Corps of Engineers
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine (now Public Health Command)
USATCES	U.S. Army Technical Center for Explosives Safety
UXO	unexploded ordnance
WQS	Water Quality Standards
WWTP	wastewater treatment plant
µg/g	micrograms per gram
µg/L	micrograms per liter
µm	micrometer
°C	degrees Celsius
°F	degrees Fahrenheit
%	percent

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Executive Summary

The University of Hawai‘i (UH) was contracted by the United States (U.S.) Army Corps of Engineers (USACE) to conduct an environmental study for the Department of Defense (DoD) at sea disposal site Hawai‘i 6 (HI-06) (locally known as Ordnance Reef). This site (hereafter referred to as Ordnance Reef (HI-06)) is located off the Wai‘anae Coast of O‘ahu, Hawai‘i. By agreement between the Department of the Army, the U.S. Environmental Protection Agency (EPA) and the State of Hawai‘i Department of Health (DOH), this study was conducted as a research project (environmental study) authorized by Section 314 of the John Warner National Defense Authorization Act for Fiscal Year 2007, Public Law 109-364, (Oct. 17, 2006). The Army found the Comprehensive Environmental Response, Compensation, and Liability Act's (CERCLA) methods for sampling and analysis during remedial investigations (RI) useful in carrying out this environmental study. The Army's use of CERCLA's methods and RI processes does not mean that this environmental study is either a CERCLA response or that CERCLA regulations are applicable to Ordnance Reef (HI-06). The Army, as a matter of convenience only, uses CERCLA-related terminology and concepts throughout this report.

The purpose of this environmental study was to determine whether discarded military munitions (DMM) at Ordnance Reef (HI-06) might have an impact on human health or the ocean environment. Ordnance Reef (HI-06) covers an area approximately 1 nautical mile (nmi) in length by 0.5 nmi in width and lies in approximately 33 to 230 feet (ft) (10 to 70 meters (m)) of water. It is directly offshore of several O‘ahu communities (e.g., Wai‘anae, Nānākuli, Mā‘ili) that rely on the area for recreation, subsistence, and perpetuation of local culture. A summary of the study's findings and conclusions is provided briefly below.

Community Participation

This study involved the participation of many key individuals and groups, and their interest and involvement enabled the team to ensure that the primary concerns of the community were being considered throughout the study: from planning to fieldwork to conducting interviews for the Ordnance Reef (HI-06) human health risk assessment (HI-06 HHRA). This participation brought a wealth of local knowledge and fishing expertise to the study team that otherwise would have been lacking. The study team is particularly grateful for this assistance, which improved the overall quality of study.

Sample Site Selection

The primary focus of sample site selection was to target the collection of biota and sediment samples in close proximity to specific types of DMM. The Army consulted with the U.S. Environmental Protection Agency (EPA) in making decisions on prioritization of sample sites. Considering the anticipated difficulties of finding specific biota at DMM and other sites, Wai‘anae fishermen who were contracted to collect biota, were remarkably successful in collecting biota samples near designated DMM. Biota and sediment samples were successfully recovered near all of the DMM types (small arms ammunition, 20-millimeter (mm) rounds, 105-mm projectiles, and 6- and 8-inch (in) naval rounds). Sample sites were selected to reflect

anticipated worst-case conditions (i.e., sites likely to have the highest concentrations of contaminants present) at Ordnance Reef (HI-06).

Sample Collection and Analysis

The study's sample collection goal was exceeded. As a result, the study team was able to collect and analyze biota from three different trophic levels at all four strata. The exception was Kona crabs that could only be collected from three strata in April 2009 and two strata in September to October 2009 where sand channels, their normal habitat, were present. The study involved an extensive effort to evaluate the applicability of the previously developed EPA 8330 method (applicable to soil and groundwater) for Hawai'i-specific biota types, and modify them as necessary to allow reliable analysis of the munitions constituents (MC) of potential concern in these matrices. This effort was a multi-year undertaking that involved close coordination between UH, Environet, EPA, and the commercial laboratory selected to perform the method detection limit (MDL) study. Results of the MDL study led to a modified method 8330 for quantitative analysis of the majority of energetics in marine biota. This method can now be applied reliably to other similar studies worldwide.

Nature and Extent of Contamination

There were no detections of energetics and one detection of phthalates and pyrene in the seawater samples collected during this study. Three energetic compounds were detected at low concentrations in sediments: 2,4-dinitrotoluene (DNT), 2,6-DNT, and 1,3,5-trinitrobenzene (TNB). There was no clear and consistent correlation evident between the concentration of energetic compounds and the distance from the target DMM. Because of the low concentrations of the three energetics detected in this study, and because it is unlikely for people to come into regular contact with sediments, energetics in sediment are not considered a human health risk.

Several energetic compounds were detected in biota samples collected from Ordnance Reef (HI-06): 2,4-DNT, high melting explosive (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) (HMX), 2-nitrotoluene (NT), 4-NT, royal demolition explosive (hexahydro-1,3,5-trinitro-1,3,5-triazine) (RDX), tetryl, and 1,3,5-TNB. Detections occurred primarily in fish (weke) samples, although one octopus and one crab also contained at least one energetic compound. These data were carefully considered in both the HI-06 HHRA and the Ordnance Reef (HI-06) ecological risk assessment (HI-06 ERA). Additionally, although not considered constituents of potential concern (COPCs), there were a few detections of 3,5-dinitroaniline and 2-nitrophenol at low concentrations in several fish samples.

Samples collected from the DMM stratum typically showed higher abundances of copper and lead than those collected from the other strata, while concentrations of arsenic were higher in sediments from the control (CON) area (CON stratum) than from other strata. As with energetics, there was no clear and consistent correlation evident between the concentration of metals in sediment and the distance from the target DMM.

In general, metals were detected at similar levels in all biota from all strata. Notable exceptions to this finding were copper and zinc, which were considerably enriched in seaweed collected in the DMM stratum. Concentrations of arsenic in biota were remarkably similar across the various strata. Furthermore, the overwhelming majority (approximately 99 percent (%)) of arsenic was

present in the less toxic organic form in crab, octopus, and fish. Metals in biota were carefully considered in both the HI-06 HHRA and the HI-06 ERA.

Principal Components Analysis

A blend of principal components analysis (PCA) and factor analysis (FA) using the software SPSS® (Shaw, 2003), hereafter simply referred to as PCA, was applied to elemental composition data to evaluate elemental associations and variations that could indicate individual sources of the various elements including metals. The results of these statistical treatments demonstrate that there are three factors describing sediment element variations and associations. Factor 1 (including arsenic) represents metals which do not have considerable anthropogenic (human) contributions and whose concentrations are likely derived from land-based geologic sources. Factor 2 (zinc, copper, and lead) represents anthropogenic enrichments of these metals and the DMM stratum sediment composition and variability is representative of enrichment of copper and lead, both COPC, from the deterioration and transport of DMM. Factor 3 (calcium and strontium) represents the natural marine contribution to sediment composition.

It is important to note that marine carbonates dominate the sediment composition for Ordnance Reef (HI-06) and thus all four strata. Therefore, the natural marine components of the sediments contribute relatively little to the variance of the compositional data set as analyzed by PCA. With this in mind, the small contribution of DMM derived material (at the DMM stratum) or terrestrial petrogenic material (at the CON stratum) actually contributes to a larger variability in composition of the sediments. Hence, the factors associated with DMM and terrestrial petrogenic materials account for a greater fraction of the variance of the entire data set.

PCA of the biota data indicate that none of the metal COPC correlate with each other. The COPC copper and non-COPC zinc do correlate strongly in the biota samples. This is most likely due to copper-based hemocyanin and copper- and/or zinc-based enzymes in these organisms. This suggests that metal COPC present in these organisms are likely of natural origin and that enrichment occurs via bioaccumulation. The elemental compositions of octopus, fish, and crab tissue samples do not show any correlation with the variations observed in the sediments from the different sites or the presence of DMM. The concentrations of COPC in biotic tissues do vary between species, but are essentially identical within a given type of organism between the different strata. In simple terms, because the concentrations of metal COPC in the organisms collected from different areas (strata) are similar and generally low, there is no evidence that DMM have contributed to the observed concentrations of trace metals in the food items.

Risk Assessments

Human Health Risk Assessment

Supplemental carcinogenic risk characterization estimates for the "high-end" seafood consumer (e.g., an individual who consumes a very large amount of seafood compared to the typical resident of the area) in the DMM and non-point source (NPS) strata were within the acceptable regulatory risk range, while carcinogenic risks at the wastewater treatment plant (WWTP) and CON strata were below the EPA and DOH point of departure of 1E-06. The point of departure (i.e., a one in a million chance of developing cancer) was established as it is essentially a level at which an individual has a zero chance of developing cancer during their lifetime. Non-carcinogenic hazards for the "high-end" seafood consumer exceeded the regulatory level of

concern at the DMM and WWTP strata. Under the “average” seafood consumer scenario, carcinogenic risk was 4E-06 at the DMM stratum (within the EPA and DOH regulatory risk range but near the point of departure risk values of 1E-06). All other strata exhibited risk below the EPA and DOH point of departure. Non-carcinogenic hazards did not exceed the regulatory level of concern at any stratum.

In summary, the risk associated with consumption of seafood from the DMM stratum is similar to those of other strata within Ordnance Reef (HI-06) except for “high-end” seafood consumer, with the assumption that the “high-end” seafood consumer eats seafood collected exclusively from the DMM stratum. This scenario is not considered plausible because it assumes a level of harvest from the area that is not likely to be sustainable. Nonetheless, this scenario was chosen to assess the worstcase scenario for seafood consumption along the Wai‘anae coast. Even under such a consumption habit, however, it is highly likely that the benefits of consuming seafood (as opposed to a high fat content diet, for example) far outweigh the risk associated with seafood from the DMM stratum. For the average Wai‘anae community consumer, whose seafood consumption habits are greater than most Hawai‘i residents and far greater than considered typical of U.S. citizen consumption, there is no significant risk associated with consuming seafood from the DMM or other strata of Ordnance Reef (HI-06). It should be kept in mind the U.S. Food and Drug Administration (FDA) has routinely recommended moderate seafood consumption in order to limit ingestion of mercury that is associated with certain high-end predatory fish found throughout the world’s oceans. A similar recommendation is likely warranted here.

Ecological Risk Assessment

The results of the HI-06 ERA indicate that no risk from energetic compounds was found for sediments. Potential risks to ecological receptors from exposure to lead and zinc in sediment were low and are probably negligible. Although the Hazard Quotient (HQ) for copper in sediment was elevated, no overt signs of reef community impairment have been observed at the DMM stratum (USACHPPM, 2007) despite more than 50 years of exposure to this metal. The potential for risk to piscivorous seabirds feeding at the DMM stratum are insignificant. HMX and five other energetics were observed to occur in the fall at detectable levels in fish muscle tissue but they were not detected in the spring samples. The source or exposure pathway for these energetics is not known, but it does not appear to be related to water or sediment concentrations or from the food chain. A significant area of uncertainty in the HI-06 ERA is whether those increases in energetics in tissue pose a risk to the fish of the reef community. Observations of the reef community made during the National Oceanic and Atmospheric Administration (NOAA) 2006 survey did not indicate signs of significant adverse effects and much of the DMM of Ordnance Reef (HI-06) was in the process of being encrusted by corals. Because the DMM at Ordnance Reef (HI-06) have been in place for over 50 years, decisions about whether to recover or otherwise address these munitions based on a potential risk to some organisms should be balanced by the potential harm of the action to the reef community as a whole, given its current condition.

Section 1
Introduction

This document presents the results of an environmental study by the University of Hawai‘i (UH) at the Department of Defense (DoD) sea disposal site Hawai‘i 6 (HI-06) (locally known as Ordnance Reef), which is off the Wai‘anae Coast of O‘ahu, Hawai‘i (hereafter referred to as Ordnance Reef (HI-06)). This environmental study was conducted under the United States (U.S.) Army Corps of Engineers (USACE) contract N00024-08-D-6323. By agreement between the Department of the Army, the U.S. Environmental Protection Agency (EPA) and the State of Hawai‘i Department of Health (DOH), this study was conducted as a research project (environmental study) authorized by Section 314 of the John Warner National Defense Authorization Act for Fiscal Year 2007, Public Law 109-364, (Oct. 17, 2006). The Army found the Comprehensive Environmental Response, Compensation, and Liability Act's (CERCLA) methods for sampling and analysis during remedial investigations (RI) useful in carrying out this environmental study. The Army's use of CERCLA's methods and RI processes does not mean that this environmental study is either a CERCLA response or that CERCLA of its implementing regulations are applicable to Ordnance Reef (HI-06). The Army, as a matter of convenience only, uses CERCLA-related terminology and concepts throughout this report.

The purpose of this environmental study was to determine whether discarded military munitions[1] (DMM) at the site might have an impact on human health or the ocean environment. This study is a follow-on investigation to a screening-level survey at Ordnance Reef (HI-06) that the National Oceanic and Atmospheric Administration (NOAA) in 2006 (NOAA, 2007) conducted for the Army. The current environmental study focused on filling data gaps the Army identified upon review of the 2006 report. The Army's planning process included consultation with and consideration of comments received from affected O‘ahu communities and regulatory agencies. To obtain the data required to fill the data gaps, the study team conducted sampling during two seasons of the year, and collected and analyzed samples from human food item biota (fish, invertebrates, and seaweed), sediment, and seawater. This study was limited to investigating the presence or absence of DMM-related contamination in sediment and biota at Ordnance Reef (HI-06) and using the data collected to assess the potential impacts to human health and the ocean environment.

Ordnance Reef (HI-06) covers an area approximately 1 nautical mile (nmi) (1.8 kilometers (km)) in length by 0.5 nmi (0.9 km) in width and lies in approximately 33 to 230 feet (ft) (10 to 70 meters (m)) of water. The nearest cities are Wai‘anae, approximately 3 statute miles (mi) (5 km) to the northeast, and Mā‘ili, approximately 5 mi (8 km) to the east. The geographic boundaries of NOAA's 2006 survey (Figure 1-1) encompassed an area approximately 3 nmi (5.6 km) by 1.5 nmi (2.8 km) (3,810 acres or 1,540 hectares) which includes a fish haven and the Wai‘anae

[1] **Discarded Military Munitions (DMM)**. Military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal. The term does not include unexploded ordnance, military munitions that are being held for future use or planned disposal, or military munitions that have been properly disposed of, consistent with applicable environmental laws and regulations. (10 U.S.C. 2710(e)(2))

wastewater treatment plant (WWTP) outfall area. This environmental study occurred in much the same area as NOAA's 2006 survey (Figure 1-1), with the addition of a representative control area described below.

Data from NOAA's 2006 survey of the area were used to plan this study. This study was confined to depths in the range typically used by self-contained underwater breathing apparatus (SCUBA) divers 120 ft (approximately 37 m). Depths beyond 120 ft are not commonly accessible to most ocean users, and were thus not considered applicable for this study that was focused on potential impacts to human health. Much of the fishing at Ordnance Reef (HI-06) is conducted at these depths and the ability of local fishermen to collect biota in close proximity to munitions was important in the experimental design.

1.1 Purpose

The study's primary objective was defined as:

> **Independently collect data to fill gaps identified in NOAA's 2006 survey of DMM at Ordnance Reef (HI-06), and determine whether the presence of the DMM may have an impact on human health or the ocean environment.**

Specific study components designed to accomplish the primary objective included:

- Collecting samples of sediment, seawater, and biota from Ordnance Reef (HI-06) during two seasons of the year, and analyzing samples for munitions constituents[2] (MC).
- Performing principal components analysis (PCA) on the samples and using available information to determine whether any constituents detected are attributable to DMM, or whether they are attributable to other sources.
- Evaluating the data to determine whether any MC detected in the samples pose an unacceptable impact on human health or the environment.
- Conducting a human health risk assessment (HHRA) using data collected during this study and applicable data from prior studies.
- Conducting all aspects of the study in a transparent manner and informing communities of the findings.

The study team's planning considered other possible environmental impacts to the area such as the Wai'anae WWTP outfall at the southeast corner of the survey area, and areas of coastal non-point source (NPS) discharge via channels/canals (Figure 1-1). The sampling approach was thus designed in a stratified manner to attempt to separate out these potential sources of contamination from those attributable to DMM (refer to Section 2.1 for a more detailed discussion).

[2] **Munitions Constituents (MC)**. Any materials originating from unexploded ordnance (UXO), discarded military munitions (DMM), or other military munitions, including explosive and non-explosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions. (10 U.S.C. 2710(e)(3)).

1.2 Limitations of this Study

Several issues of local concern do not fall within the scope of either a traditional RI or this environmental study. These tasks and the justification for their exclusion are presented in this section.

1.2.1 Propellant Grains

During preliminary consultation with representatives from several regulatory agencies, the representatives requested this environmental study include an assessment of the propellant grains that have been reported washing ashore near the Mā‘ili Beach area (south of Ordnance Reef (HI-06) addressed by this study). The study team considered this recommendation, but after review and discussion, the study team decided that propellant grains should not be included for several reasons. First, the relative mass of propellant grains reported at Ordnance Reef (HI-06) is much lower than the mass of DMM present. According to NOAA's March 2011 Coral Avoidance and Minimization of Injury Plan (CAMIP), there are approximately 21,199[3] DMM present at Ordnance Reef (HI-06); the majority of these are small arms ammunition[4] (SAA) (NOAA, 2011). In contrast, as of October 2011, about 1,370 propellant grains (each measuring approximately 1 inch (in) in length (approximately 25 mm), have been recovered within Ordnance Reef (HI-06). Because the total mass of propellant appears to be small, the contribution to site risk is believed to be negligible. The 2007 U.S. Army Technical Center for Explosives Safety (USATCES) Risk Assessment conducted for Ordnance Reef (HI-06) noted that, despite reports that a high quantity of propellant is present at Ordnance Reef (HI-06), the Army has been unable to verify these reports (USATCES, 2007). Second, the propellant associated with 1940s era munitions is considered very stable. Finally, the Army established a 4-year program to immediately remove any propellant grains reported at Ordnance Reef (HI-06). Upon receiving a report that propellant grains have been discovered, a team is deployed within a matter of days to visit the site and properly remove and dispose of the propellants. Because there was already a removal action in place for propellant grains, they were not a top priority for assessment or investigation.

1.2.2 Physical Hazards

This study focused on assessing whether DMM present at Ordnance Reef (HI-06) might have an impact on human health and the ocean environment, from MC contamination. It is not focused on examining whether DMM pose a physical (explosive) hazard. USATCES assessed the explosives hazard in their assessment report (USATCES, 2007). Additionally, in July 2010, the Army conducted a demonstration at Ordnance Reef (HI-06) of a remotely operated underwater munitions recovery system (ROUMRS) in waters approximately 120 ft (37 m) deep adjacent to Wai‘anae during which 74 large munitions and about 2,300 SAA were recovered and subsequently destroyed at sea. During the demonstration, the Army noted that many of the

[3] NOAA estimated its count of DMM present, including SAA, individually rather that by packages, clusters or groupings of munitions. Previous surveys made no attempt to estimate SAA, and addressed packages, clusters and groupings collectively.

[4] **Small Arms Ammunition (SAA)**. Ammunition, without projectiles that contain explosives (other than tracers), that is 0.50 caliber or smaller, or for shotguns.

DMM present were encrusted to the sea floor and were difficult to remove without specialized equipment. This means that, although human disturbance or recovery of many of the DMM present would be possible, it would be highly improbable without a concerted effort.

1.2.3 Community Concerns

The Army established the Ordnance Reef Coordinating Council (ORCC) in 2007. The ORCC, which in addition to representatives from the Army, EPA, NOAA, and state agencies, includes members of the Wai‘anae and Nānākuli Neighborhood Boards, has been continuously involved with this study effort. In addition, USACE, on the Army's behalf, kept the Neighborhood Boards informed of the study's progress through outreach efforts. Results of this study are available to the public following review by the Army and regulatory agencies.

1.2.4 Integration with Other Ordnance Reef (HI-06) Studies

Several other studies are being conducted at Ordnance Reef (HI-06). These include the ROUMRS technology demonstration to remotely remove some DMM from Ordnance Reef (HI-06), the NOAA "Predictive Modeling Study of Two Sea-Disposed Military Munitions Sites in Hawai‘i" (NOAA, 2012), and the NOAA CAMIP study. This environmental study will be a useful component of the Army's overall goal of achieving a better, scientific understanding of the potential impact of the DMM present at Ordnance Reef (HI-06) on the environment and those that use it. This study does not rely on the other studies of Ordnance Reef (HI-06) or act as a decision point for them. While the study's results may support the other actions, it is designed to be a standalone study. Nonetheless, this and the Army's other efforts at Ordnance Reef (HI-06) will advance DoD's understanding of the potential impact of both underwater munitions (i.e., DMM) on the ocean environment and those that use it and the ocean environment on underwater munitions.

1.2.5 Screening for Ecological Health

The primary objective of this environmental study was to assess whether the DMM present at Ordnance Reef (HI-06) may have an impact on human health. The assessment of the potential impacts on the environment are also important, but to a lesser degree than assessing impacts to human health. To that end, this study has been designed to provide screening-level data for ecological impacts. For many of the compounds being assessed, the lack of marine ecological toxicity data prevents a definitive determination about whether DMM impact the environment. The study team addressed this limitation, to the extent practicable, by the sampling design described in Section 2.

1.3 Site Description

1.3.1 Site Background

During a benthic survey of the Wai‘anae WWTP ocean outfall in 1992, the City and County (C&C) of Honolulu, Department of Wastewater Management's oceanographic team discovered DMM between about 0.25 and 0.5 nmi (0.5 and 1 km) northwest of the existing municipal

sewage outfall's diffuser. The C&C's oceanographic team also discovered DMM south of the WWTP outfall and just west of the State of Hawaiʻi-designated fish haven.

At the request of USACE, the Explosive Ordnance Disposal Detachment MIDPAC (UIC-32082) from Pearl Harbor, Hawaiʻi, conducted a diver survey to determine the various amounts and types of munitions in Pōkaʻī Bay on the western coast of Oʻahu, Hawaiʻi, in July 2002. The search area was divided into three sections. The largest section was 1 nmi by 1 nmi (1.8 km by 1.8 km) with depths ranging from approximately 15 to 700 ft (5 to 213 m). The deepest section of the box was not searched due to depth. The second search area was the inner area of Pōkaʻī Bay. This was primarily searched by snorkelers. A third box was added to the survey in the attempt to find the boundary of the DMM disposal area. It was limited in size to the area with depths accessible with standard SCUBA diving equipment (an area approximately 1,500 by 900 ft (457 by 274 m) with a depth range of 60 to 130 ft (18 to 40 m). This was deemed sufficient for a general evaluation of the overall search area. Bounce dives were conducted on the deepest section just outside of the third box to try to determine the extent of the DMM disposal area. Observed DMM were reported and marked using a global positioning system (GPS).

The study team for this current project used a summary of DMM found at Ordnance Reef (HI-06), which was generated from the 2002 survey, in designing the study (Appendix A, Table A-1). The DMM observed between the 60 and 160 ft (18 and 49 m) depths included clipped 0.50 caliber rounds, 2-in Special Operations Forces Combat Assault Rifle (SCAR) munitions, 105-millimeter (mm) shells, 155-mm shells, mines, mortars, naval artillery projectiles, and other munitions. Most of the munitions found were described as live and unfired (i.e., DMM). The locations and approximate depths of the underwater military munitions at Ordnance Reef (HI-06) were documented during USACE's 2002 and NOAA's 2006 surveys. Based on these surveys, the Army estimated that approximately 2,000 munitions were present within the site boundaries at 160 ft (49 m) or shallower (DoD, 2010). Munitions are also present at depths beyond those surveyed.

During NOAA's development of the CAMIP for the Army's ROUMRS technology demonstration, NOAA completed the most comprehensive survey of munitions at Ordnance Reef (HI-06). NOAA photographed, visually identified, and categorized munitions into three general categories: SAA, small to medium caliber munitions (munitions above 0.50 caliber to and including 105 mm), and large caliber and other munitions (munitions larger than 105 mm, bombs, rockets, etc.). NOAA indicated that 64 percent (%) of the munitions at Ordnance Reef (HI-06) are SAA (NOAA, 2011). The estimate of the total number of munitions present is much higher than the 2002 estimate because (a) NOAA's divers were using nitrox, allowing more time underwater, and (b) NOAA had access to the previous surveys, allowing it to focus on areas where munitions were concentrated. In addition, NOAA attempted to count individual munitions, including SAA, rather than count them as clusters or groupings of munitions as was done previously. Prior surveys made no attempt to estimate SAA and addressed clusters and groupings collectively. Appendix A, Table A-2 summarizes munitions documented by NOAA during their 2010 survey. NOAA estimated that 21,199 DMM lie within three designated Ordnance Reef (HI-06) technology demonstration work areas.

The munitions present at Ordnance Reef (HI-06) appear to be DMM, not unexploded ordnance[5] (UXO). As such they are considered less hazardous, because they have not been through their arming sequence. Records detailing the disposal of munitions at this location have not been uncovered despite extensive research efforts. It is presumed that the munitions date from the activities associated with World War II.

1.3.1.1 Previous Environmental Investigations and Data Gaps

From May 2006 to June 2006, NOAA and UH conducted a screening-level survey of Ordnance Reef (HI-06) to determine the environmental implications of the DMM. Side-scan sound navigation and ranging (SONAR) was used to survey 71 linear nmi (131 linear km) at depths ranging from about 23 to 300 ft (7 to 91 m) and discrete samples of sediments (96) and fish (49) were analyzed for major, minor, and trace elements and energetics. Based on available documentation, NOAA's study team identified the following compounds as their target analytes: energetic compounds – trinitrotoluene (TNT), royal demolition explosive (hexahydro-1,3,5-trinitro-1,3,5-triazine) (RDX), and element target compounds – the metalloid arsenic and the metals copper, and lead. The analytical suite, however, included a large number of other elements selected based on their potential to identify individual source contribution and included calcium, cadmium, cobalt, chromium, iron, magnesium, nickel, strontium, uranium, vanadium, and zinc. To represent a "worst-case" scenario, whole-fish-homogenized samples were analyzed. All fish samples and a portion of the sediment samples were analyzed for a standard list of 13 different energetic related compounds including RDX and TNT. The trace metal enrichment of the sediment samples from Ordnance Reef (HI-06) was found to be low, suggesting that little contamination is derived from DMM. The survey did find high levels of metals in sediments near the Wai'anae WWTP outfall, and in areas of natural drainage off the island. Dinitrotoluene (DNT) was the only explosive-related compound found in the sediment, and only in four of the 96 samples. No energetics were found in the fish samples. The observations of NOAA's 2006 survey suggested that the DMM in the area are not a risk to human health.

In subsequent independent reviews of NOAA's report, the Agency for Toxic Substances and Disease Registry (ATSDR) and the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM, now Public Health Command) concurred that, based on the data collected, there were no indications that the presence of the DMM would impact human health or the environment (ATSDR, 2007; USACHPPM, 2007).

The USACHPPM health risk evaluation also included an ecological evaluation, and noted that no overt signs of stress or ecological impact were evident at Ordnance Reef (HI-06). Based on this observation, USACHPPM stated that a full ecological risk assessment (ERA) would not be necessary at Ordnance Reef (HI-06) (USACHPPM, 2007).

A risk assessment of the explosive safety considerations due to DMM at Ordnance Reef (HI-06) was conducted by USATCES (2007) following NOAA's 2006 survey. The USATCES risk

[5] **Unexploded Ordnance (UXO)**. Military munitions that (A) have been primed, fuzed, armed, or otherwise prepared for action; (B) have been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material; and (C) remain unexploded whether by malfunction, design, or any other cause. (10 U.S.C. 101(e)(5)(A) through (C)))

assessment summarized various levels of explosives risk for activities categories assumed to take place in the area. A summary of risks was as follows: Risk associated with removal of munitions (extremely high); Recreation, Commercial and Miscellaneous Risk (high); Shipping/Boating Risk (moderate); and Fishing and Emergency Services Risk (low). Based on the results of this assessment, USATCES recommended a public education program on the hazards associated with DMM and UXO, restricting some activities from Ordnance Reef (HI-06) waters, and leaving the munitions where they currently lie. The explosives risks are all associated with activities that would disturb the munitions. USACE has a contract in place to provide the public education recommended, and has undertaken a number of efforts to distribute information to the public (visit the study's website at www.denix.osd.mil for more details on the public outreach component).

Although NOAA's 2006 survey did not identify significant threats to human health or the environment, several data gaps were identified by the Army in its discussions with regulatory and natural resource agencies and affected O‘ahu communities. This study focused on addressing the following data gaps:

- A lack of seasonal sampling (NOAA's 2006 survey only collected samples during the summer season, and thus did not involve sampling during the high wave action winter months).
- Inclusion of additional analytes, specifically nitroglycerin and ammonium picrate (as picric acid).
- Analysis of fish fillet samples, to be more representative of the diet of the Wai‘anae community (the previous survey looked solely at homogenized whole fish, and the community felt that this did not accurately represent local consumption habits).
- Collection of human food-item biota, such as goatfish (weke), octopus (he‘e), Kona crab, and seaweed (limu). NOAA's 2006 survey collected fish species that were not felt to represent local human consumption, and this was identified as a data gap by the Wai‘anae community.
- Application of a modified analytical method for energetics in biological tissue samples, as opposed to the use of the standard EPA method 8330, which was designed for soil and water. The study team identified a commercial laboratory, TestAmerica West Sacramento, which was equipped to conduct a series of method detection limit (MDL) studies to modify the EPA 8330 method for tissue analysis. To ensure the applicability of the analytical method for this study, the MDL study was performed on biota types collected from O‘ahu: fish, crab, octopus, and seaweed.
- To determine whether metals and trace elements detected in samples collected from Ordnance Reef (HI-06) are attributable to land-based sources as opposed to munitions casings, all elemental concentrations have been evaluated based on partitioning into their principal components (i.e., primary sources). This statistically based evaluation method is known as PCA.
- The Health Risk Evaluation completed by USACHPPM noted that the reported arsenic levels were a source of uncertainty, because arsenic was not speciated into

inorganic and organic forms. This study included speciation of arsenic to minimize this uncertainty.

- The ATSDR health consultation determined that, although fish tissue analyses of some inorganic compounds were reported as non-detect values in NOAA's 2006 survey, the laboratory detection limits were higher than the health-based comparison values used to determine adverse health effects. Low-level amounts of these compounds may have been present in fish samples collected during NOAA's 2006 survey, but not detected by the laboratory. Regardless, because these compounds were not detected in NOAA's 2006 survey, they are not considered MC of potential concern (COPCs).

State of Hawai'i and Federal agencies identified a few issues that were not addressed during this study. The rationale for these decisions are presented below:

- DOH recommended that multi-incremental (MI) sampling of sediment be performed at the four strata. This was not a practical approach in this instance, for a number of reasons. Primary among them is the relative dearth of sediment at a majority of the strata. MI sampling requires a minimum of 30 increments of sediment, and at many of the strata sample sites, there was an insufficient volume of sediment to allow MI sampling. To maintain consistency amongst all samples, the sampling design focused on collecting discrete sediment samples at all strata sample sites, with sufficient sediment volumes present at the sites to permit statistical comparison.
- The DOH also recommended inclusion of some additional COPCs as part of this study, specifically semi-volatile organic compounds (SVOCs). The SVOCs specifically requested included phthalates, diphenylamine, and N-nitroso-diphenylamine, and pyrene. These compounds are associated with some military gun propellants. However, these compounds are also present in a large number of other man-made products, and are commonly found in marine and terrestrial environments. If these compounds were detected in any of the samples collected from Ordnance Reef (HI-06), they could not be attributed exclusively to DMM. As stated before, only a relatively small mass of propellant has been collected and little was observed during NOAA's 2006 survey. Thus, the mass of these compounds present at Ordnance Reef (HI-06) is thought to be small and to have a very limited contribution to total site risk. This type of analysis was thus not considered a priority for the study. As a compromise, the study team included analysis of phthalates and pyrene in seawater samples collected during the second round of sampling only.
- EPA requested that screening of sediment toxicity be included. The study team considered this request during the study-planning phase, but concluded that it was unnecessary. The study team based this on observations made during NOAA's 2006 survey that did not indicate a significant impact on ecological resources and the sediments were heterogeneously distributed. The sediments were collected in close proximity to the munitions due to the heterogeneity and levels of COPC to represent "worst-case" concentrations and are not representative of a large area of the seafloor in the study area. Because this study is focused on human health and the previous investigation did not find significant ecological impacts, project resources are more heavily weighted towards sampling human food-item biota, and analyzing for

concentrations of COPCs in biota, sediment and water to which human receptors could be exposed.

- ATSDR noted that clusters of military munitions have been reported outside the site boundary of NOAA’s 2006 report, and that the criteria for determining the site boundaries were unclear. In this study, the intent is to sample a representative subset of shallow sites within the DMM stratum to determine whether their presence poses a threat to human health or the environment. This limited scope does not include the intent to assess the location of all DMM, and thus there are areas of DMM disposal that fall outside the boundaries of this study.

1.3.1.2 Study Area Description

This study focused on the area previously studied by USACE in 2002, and NOAA and UH in 2006 (see Section 1.3.1). Because this study was focused on assessing potential threats to human health, the depth range of the study area has been defined as extending from approximately 33 to 120 ft (10 to 37 m), as this is the depth range that most area users, including SCUBA divers, would frequent. This study area includes DMM and areas where previous investigations found elevated concentrations of metals, other trace elements and energetics. As discussed in Section 2.1, the study area was divided into four “strata” (zones) for purposes of this investigation. Discrete sample sites were chosen from within each of the four strata, and, with the exception of the DMM stratum where sample locations were selected to represent the likely highest concentrations of MC present, are considered to be representative of the overall study area.

1.3.2 Physical Characteristics of the Site

The following section describes the physical characteristics of Ordnance Reef (HI-06).

1.3.2.1 Climate

Northeasterly trade winds prevail over O‘ahu approximately 80% of the time, with average wind speeds ranging from 10 to 15 mi per hour (16 to 24 km per hour). The trade winds blow most strongly and consistently from April through November. Southerly or “Kona” winds most frequently occur during the months of December through March. The northeasterly trade winds carry a large quantity of moisture from the Pacific Ocean to the island. Orographic lifting as the trade winds encounter the Ko‘olau mountain range causes the air temperature to decrease and moisture to precipitate. The windward side of the island generally experiences more rainfall than the leeward side. However, during Kona wind conditions, the relative humidity tends to rise, and the southern side of the island may experience periods of intense rainfall. Due to the impact of the rain shadow on storms driven by the trade winds, Wai‘anae is one of the driest areas on the island. The average annual rainfall in Wai‘anae is 22 in (560 millimeters (mm)), less than half of the average for O‘ahu as a whole (NOAA, 2006).

Temperatures at the surface of the study area are generally mild and fluctuate very little throughout the year. The mean annual temperature is approximately 77 degrees Fahrenheit (°F) (25 degrees Celsius (°C)); temperature extremes range from 54 to 95°F (12 to 35°C). The mean daily temperature during the winter is 74°F (23°C), while the mean daily temperature in the hottest summer month (August) is 80°F (27°C) (Western Regional Climate Center, 2004).

1.3.2.2 Geology and Geomorphology

Like all regions of the Hawaiian Islands, the geology and geomorphology of Wai‘anae are based on its individual volcanic origins and history. The island of O‘ahu was formed by two volcanoes, the Wai‘anae and Ko‘olau, beginning approximately four million years ago (Stearns and Vaksvik, 1935). Soils in the Wai‘anae moku (District) are a result of its volcanic history, as well as recent erosion processes. Volcanic eruption deposited lava flows and pyroclastics that built the main mass of the Wai‘anae volcano, which has since gradually eroded to its current physical characteristics.

The Wai‘anae mountain range is approximately 22 mi (35 km) long, with narrow ridges and steep slopes as the predominant features. Most of these features were formed through erosion before the Ko‘olau mountain range rose high enough to intercept the prevailing trade winds and rainfall. The maximum rainfall at Mount Ka‘ala, the highest point in the Wai‘anae range and on O‘ahu at 4,025 ft (1,227 m), is approximately 100 in (2,540 mm) per year.

The Wai‘anae mountain range has been significantly eroded by the rain, sea waves, and landslides, resulting in amphitheater valleys including Lualualei and Mākua to the west. The striking features of the range are the great flat-floored valleys that slope up to the steep pali (cliffs) that join the back of the valleys.

Volcanic rocks of the Hawaiian Islands are basaltic in composition and have a trace element composition that differs widely from those encountered in continental settings (e.g., granite or limestone). Consequently, the occurrence of high concentrations of certain elements, most notably, chromium, cobalt, copper, nickel and to a lesser extent zinc, in marine sediments predominantly composed of calcium carbonate is not necessarily a result of environmental contamination but may simply reflect the presence of detrital volcanic matter carried into the ocean by stream or overland runoff (De Carlo et al., 2004, 2005).

1.3.2.3 Soils

Current surface soils in Wai‘anae exist as a result of millions of years of erosional processes, including rain, stream action, waves, and landslides. Surface soils in the Wai‘anae moku can generally be grouped into three predominant associations (U.S. Department of Agriculture, 1971):

- Lualualei Series, Fill Land, and ‘Ewa Series Association
- Tropohumults-Dystrandepts Association
- Rock Land and Stony Steep Land Association

Other soil types and associations exist within Wai‘anae, including the Kemo‘o, Mahana, Mokulē‘ia, and Pūlehu series. In addition, rock outcrops are present at various locations throughout the moku (Figure 2-4, from NOAA, 2006).

1.3.2.4 Coastal Waters

All Hawai‘i State marine waters are classified as Class A or Class AA. Class A waters have strict pollution discharge regulations to protect them for recreational and aesthetic enjoyment. Class AA waters have regulations against discharge to maintain the waters in a natural pristine

state. The Wai‘anae coast is designated Class A waters from Barbers Point at the southern end to Mākua Beach near the northern end; the waters from Mākua Beach to Ka‘ena Point are designated Class AA.

Water quality studies along the Wai‘anae coast describe a pristine, unperturbed coastal region. Temperature and salinity values indicate that the region is well flushed and minimally affected by surface runoff of terrestrial sediments (Bienfang and Brock, 1980; Koch et al., 2004, Natural Resources Defense Council (NRDC) 2004). Although these studies described excellent water quality, two concerns regarding pollution have been cited. First, the water quality appears more compromised in the southernmost part of the coast. This appears to be related to runoff associated with development at Barbers Point and even pollution from Pearl and Honolulu Harbors during strong storm events (Bienfang and Brock, 1980). These more turbid waters have been seen moving northward along the coast during falling tide conditions. Second, there is some indication that groundwater percolation may be occurring along the shoreline. Groundwater in Wai‘anae has approximately 1,000-fold more dissolved nitrate than does the adjacent marine waters due to leaching from fertilization of agricultural lands. This problem has led to significant algal blooms in other coastal waters around Hawai‘i, although no intense or persistent algal blooms have been documented in Wai‘anae. Another potential source of water enriched in nutrients is the Wai‘anae WTTP.

1.3.2.4.1 Nutrients

Nutrients are taken up by marine plants, phytoplankton, and marine algae for primary production. Nutrients commonly measured in seawater include silica and inorganic and organic forms of nitrogen (nitrate and nitrite, and dissolved organic nitrogen) and phosphorus (phosphate, dissolved organic phosphorus). Nutrient concentrations in seawater off the Wai‘anae coast are likely to vary with the time of year and location as observed in other coastal waters of Hawai‘i (Ringuet and Mackenzie, 2005; De Carlo et al., 2007).

Land-based sources of nutrients from streams and surface water runoff cause localized increases in nutrient concentrations in coastal waters. The uptake of nutrients by marine plants and decomposition of marine life in the sea also contribute to variation in nutrient concentrations found in the water column. In general, open ocean surface waters near the Hawaiian Islands are oligotrophic (i.e., nutrient poor); this is particularly true off dry leeward sides of the islands such as Wai‘anae, where nutrient concentrations are extremely low. Primary production is generally considered to be limited by the availability of nitrogen and micronutrients such as iron (Ringuet and Mackenzie, 2005).

1.3.2.4.2 Coastal Water Quality

Land-based sources of materials, such as sediment, nutrients, and other contaminants, are one of several factors threatening water quality and coral reef ecosystems in Hawai‘i. These pollutants are transported in surface water runoff and, to a lesser extent, by groundwater seepage into coastal waters. While the complex interrelationship between land-based sources of pollution, water quality, and the health and integrity of coral reef ecosystems is not well understood, enough is known to require management policies that minimize polluted surface water runoff.

1.3.2.4.3 Stream Discharge

Many of the streams of the Wai‘anae moku have been channelized through the urban areas. This causes water to reach the ocean much more quickly, potentially increasing levels of trash, nutrients and other pollutants entering the coastal water. In spite of this, only one stream, Kaupuni Stream, was on the 2004 list of impaired waters in Hawai‘i (Koch et al., 2004). Of the 70 streams in the report, Kaupuni Stream is considered a medium priority listing with nutrients, turbidity and trash as the primary pollutants.

1.3.2.4.4 Wai‘anae Wastewater Treatment Plant

The C&C of Honolulu’s conservation district use permit for installation of the WWTP outfall pipe at Wai‘an‘ae, O‘ahu, Hawai‘i, was approved in November, 1983. The Wai‘anae WWTP outfall pipeline was installed in 1986 and extends 1.1 mi (1.8 km) offshore into 108 ft (33 m) of water. In 1996, the WWTP was converted from a primary to a secondary WWTP, which discharges 3.4 million gallons (12.9 million liters) per day of mainly domestic wastewater through the outfall offshore. The diffuser is 530 ft (162 m) long and discharges approximately 1.5 ft (0.5 m) above the seafloor through vertical risers. The long-term monitoring program at the diffuser reported an immediate drop in levels of suspended particles and nutrients from its wastewater from 1995 through 2000, in accordance with the terms of its National Pollutant Discharge Elimination System (NPDES) permits (C&C of Honolulu, 2001).

1.3.2.4.5 Stream Flow

The majority of Wai‘anae’s perennial streams flow consistently only in the upper elevations. The absence of perennial streams in the lower elevations is a reflection of the Wai‘anae region’s arid climate and alluvial soils. Because of the general sandy qualities of these soils, surface water percolates down into them, creating “underflow” that either flows through the subsurface to the ocean, or enters the water table.

Streams in Hawai‘i react quickly to storms, often reaching their maximum flow rates in less than one hour (e.g., Tomlinson and De Carlo, 2003). These high stream flows can transport large amounts of sediment, nutrients, trash, and other debris to the ocean and have a severe impact on coastal areas. Corals and intertidal fish nurseries are prone to injury from sedimentation, particularly in the presence of chemical contaminants.

1.3.2.4.6 Currents and Tides

Hawai‘i’s semi-diurnal tidal cycle is characterized by two high waters and two low waters of each tidal day. Along the Wai‘anae coast, this tidal regime results in changing current patterns. During normal trade wind conditions on a rising or flood tide, current flow is from the northwest toward the southeast, parallel to the coastline, with a velocity of about 1 knot (0.5 meters per second (m/s)) (Bienfang and Brock 1980). This current reverses during falling or ebb tide conditions, flowing from the southeast to northwest at somewhat higher velocities, about 1.5 knots (0.8 m/s).

The mass of the Hawaiian Islands interacts with large-scale trade-wind conditions and ocean currents. This interaction causes winds and currents to slow and create calmer areas on the leeward sides of each island, known as Hawai‘i’s wake. Water movement along the Wai‘anae coast is influenced by these regional oceanographic phenomena, which create eddies, or swirls of

water, where marine larvae and fish tend to concentrate. The existence of a warm-water countercurrent flowing from Asia toward the Hawaiian Islands has been attributed to Hawai‘i’s wake, resulting from the interaction between the islands and regional current and trade-wind conditions.

NOAA and the UH deployed acoustic Doppler current profilers (ADCPs) for a year in the vicinity of Ordnance Reef (HI-06) to better characterize ocean circulation in the area. The data collected by the ADCPs indicates that the primary circulation along the west coast of O‘ahu is along-shore because of the dominance of the semi-diurnal and diurnal tides (NOAA, 2012). Particles in this system are moved north and south along the coast, with weak on- and off-shore motion as the tides change from ebb to flood. During periods of mesoscale activity, current flow is primarily along-shore (clockwise-flowing eddies impinging on the shore will push particles along-shore towards the south). This summary matches the general understanding of currents and tides previously accepted to hold true in the vicinity of Ordnance Reef (HI-06).

1.3.2.4.7 Water Column Profile

The water column profile for the area off Kahe Point was studied extensively in the 1980s as part of the proposed, but never built 40-megawatt Ocean Thermal-Energy Conversion plant. Although Kahe Point is just outside the southern extent of the Wai‘anae moku, information and data collected at Kahe Point can be considered relevant to the Wai‘anae coast.

The mixed layer of the ocean off the Wai‘anae coast extends from the surface to depths of about 98 to 197 ft (30 to 60 m). In the mixed layer, temperature is nearly uniform with depth. Below the mixed layer is the thermocline, the layer in which seawater temperature decreases rapidly with depth. In the thermocline, seawater temperature decreases from about 75°F (24°C) at a depth of 197 ft (60 m) to 59°F (15°C) at over 656 ft (200 m). Below this depth, temperature decreases gradually. At 2,953 ft (900 m) depth, seawater temperature off Kahe Point is about 39°F (4°C).

Surface water salinity off Kahe Point is about 34.8 parts per thousand (ppt), typical of the Pacific central water mass. This low-salinity warm surface layer grades into the underlying Pacific intermediate water mass, which is characterized by a maximum salinity of 35.1 ppt at 591 ft (180 m) and minimum of 34.2 ppt at 1,509 ft (460 m). At 2,953 ft (900 m) depth, seawater salinity off Kahe Point is about 34.4 ppt.

1.3.2.5 Marine Ecosystems

Wai‘anae’s coastal and marine ecosystems are characterized by rocky intertidal zones, coral reefs, and offshore pelagic and deep-sea marine environments. Intertidal zones provide rocky habitat to marine invertebrates and plants that are specifically adapted to constantly changing levels of exposure to waves and seawater. Coral reefs are found on the more protected leeward exposure of the Wai‘anae coast but are subject to infrequent but severe Kona storms. Offshore pelagic and deep-sea ecosystems off the Wai‘anae coast are vast and support large marine animals like dolphins, whales, sea turtles, and the occasional endangered Hawaiian monk seal. Threats to coastal and marine ecosystems along the Wai‘anae coast include land-based and sea-based human activities, natural disturbances from storms, and large-scale global climate change phenomena such as sea level rise and increased sea surface temperature.

Most reefs on the inhabited islands of Hawai‘i are known as fringing reefs, growing near the shoreline. Fringing reefs are the first type of reef to form around young volcanic islands, such as Hawai‘i, Maui, O‘ahu, and Kaua‘i. These reefs form in areas of low rainfall runoff, primarily along the leeward shores such as the Wai‘anae coast of O‘ahu. Typical reef zonation consists of:

- Reef flat zone (0 to 7 ft (0 to 2 m)),
- Reef bench zone (7 to 33 ft (2 to 10 m)),
- Reef slope zone (33 to 98 ft (10 to 30 m)), and
- Rubble zone (98 to 131 ft (30 to 40 m)) (AECOS, Inc., 2002).

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Section 2
Investigation Methods and Procedures

The study team designed the field sampling program and associated laboratory analysis program to collect data to support both an HHRA and a screening-level ERA.

2.1 Stratified Sampling Approach

During the study, the study team collected sediment, water column, and biological samples in four different strata (Figure 2-1):

- WWTP stratum: adjacent to the municipal sewage outfall of the WWTP;
- NPS stratum: nearshore coastal NPS discharge area near Mā‘ili‘ili Stream Channel;
- DMM stratum: natural reef area with DMM; and
- CON stratum: natural reef area, without DMM, located near Maunalahilahi.

The study team selected strata to assess areas with and without DMM that had a potential for non-DMM anthropogenic sources of contamination (e.g., NPS discharge points).

Within the WWTP, NPS and CON strata, four sample sites were randomly selected. This was the minimum number of sample sites required to meet the data quality objectives (DQOs) set out in the Quality Assurance Project Plan (QAPP). The study team initially considered using a random approach for selecting sample sites within the DMM stratum, but dismissed this idea due to the low number of sites and the non-uniform distribution of DMM across this stratum. The sample site selection process is described in more detail in Section 2.1.1 below. The location of each sample was documented using a GPS receiver with meter to sub-meter accuracy and illustrated in the field notes/drawings and geographic information system (GIS) product.

Sample Site Selection

The study team, in consultation with and consideration of EPA input, determined sample site locations within the DMM stratum. DoD provided EPA with a listing of the munitions tentatively identified as DMM at Ordnance Reef (HI-06) and many of the MC related to munitions of those classes. EPA offered a ranked listing of its recommendations for sampling near DMM within Ordnance Reef (HI-06). The rankings were grouped along three different tracks with three to four sites of decreasing priority located along each of the three tracks. The Army considered the EPA rankings when setting site priorities, which were assigned based on the type and amount of DMM present at a given location. The goal during the field program was to visit the site with the highest priority on a given track and assess whether it would be possible to sample at that site. Because collecting biota, which the community consumes, in close proximity to DMM was the ideal sampling situation and of paramount importance for the study effort, a primary consideration in selecting sampling sites was whether such biota could be collected at the site. If a target organism was present, sampling would proceed. If not, the study’s field team would move to the next highest ranked site along the same track and conduct

the same assessment (refer to Appendix B for the narrative and data table provided by the EPA to assist with sample site selection).

Fishermen from the community who are very familiar with the area were used to conduct the biota sampling effort. The study team, on a separate vessel, led the fishermen to a potential sample site and provided a description of the DMM type being targeted. The fishermen then dove the site to search for the DMM and collect the targeted biota. If the targeted biota was found in close proximity to the DMM the study team described, the fisherman collected sediment (see Section 2.2 for additional details), and returned to the surface to transfer the sediment and/or biota samples to the study's field team. At this point, the study's field team took a GPS reading, queried the fishermen to determine the type munitions at which the fishermen collected samples, and recorded relevant details on field sampling or note sheets (Appendix C).

The study's field team documented the location of each sample site within approximately a 30-ft (10-m) accuracy using a diver placed float and handheld GPS. GPS readings are actually rough estimates of the actual sampling location. This is true because of inherent GPS errors and the fact that, given currents, divers (the fishermen) are not able to maintain a position directly over a sample site as they surface. Nevertheless, the approximate recording of sample site location allowed the sampling results to be correlated with the results from NOAA's 2006 survey and will facilitate future sampling, if necessary. Table 2-1 lists the samples collected during the April 2009 and September to October 2009 sampling events and provides information such as collection site, date, time, depth, and coordinates.

Within the three remaining strata (CON, NPS, and WWTP), sample sites were randomly selected based on presence of biota and/or sediment. Similar to the approach used at the DMM stratum, the study's field team would lead the fishermen to the stratum being targeted, and then the fishermen would dive and look for a target invertebrate (octopus or crab) in an area with sufficient sediment for sampling. Within the CON, NPS, and WWTP strata, the fishermen surveyed the area prior to sample collection to ensure that no DMM were within approximately 100 ft (30.5 m) of the sample location. Once the fishermen selected an appropriate location, they would conduct the sampling and return to the surface to transfer the samples to the study's field team as described above.

The currents within Ordnance Reef (HI-06) were an important aspect of stratum selection. The study team consulted with local fishing experts and others familiar with the area prior to finalizing the sampling design. Anecdotal reports from those consulted indicated that the currents in Ordnance Reef (HI-06) run mostly northwest to southeast, with wide variations in the strength of the currents associated with changing tides. This information validated the selection of the control area (CON stratum) to the north of all the other strata, a location where it was unlikely to be downcurrent of the high concentration of DMM (i.e., the DMM stratum). Subsequent to the start of the environmental study, NOAA deployed four ADCPs at Ordnance Reef (HI-06) roughly at the corners of study area to model the currents within the area. NOAA's preliminary assessment of data collected by the ADCP generally confirm the observations of local experts that currents at Ordnance Reef (HI-06) run predominantly from northwest to southeast (NOAA, 2012).

2.2 Sampling Procedures

2.2.1 Analyte and COPC Selection

2.2.1.1 Energetics

The study team based its initial selection of COPCs for the Ordnance Reef (HI-06) environmental study on the results of previous surveys and studies. The COPCs are specific MC and associated MC-degradation products that are related to DMM reported at Ordnance Reef (HI-06) that were considered a potential source of COPCs. The Army identified the following energetic compounds as COPCs prior to the start of the April 2009 sampling event:

- picric acid
- nitroglycerin
- 2-amino (Am)-4,6-DNT
- 4-Am-2,6-DNT
- 2,4-DNT
- 2,6-DNT
- RDX
- 2,4,6-TNT

Upon review of the sampling results from the April 2009 sampling, the Army consulted with EPA and decided, in consultation with the study team, to include two additional energetic compounds in the list of COPCs for sediments. The two COPCs added for sediments collected during the second round of sampling (September to October 2009) were:

- 2,4-dinitrophenol
- picramic acid

2.2.1.2 Phthalates and Pyrene

The EPA requested that biota and seawater samples be analyzed for phthalates and pyrene. These compounds are associated with some propellants; however, they are also known to be present in a number of other man-made products. The Army, in consultation with the study team, determined that analysis for these compounds would not constitute an effective use of limited resources. The Army based this determination on the fact that the relatively small mass of propellant present in most munitions would not significantly contribute to any contamination present, and phthalate compounds are very commonly found in marine and terrestrial environments. Ultimately, the Army decided to include analysis of the following compounds (present in the largest quantity within propellants) in biota samples during a single (April 2009) sampling event:

- bis(2-ethylhexyl)phthalate
- di-n-butyl phthalate
- diethyl phthalate

- dimethyl phthalate
- di-n-octyl phthalate
- pyrene

Following analysis of the April 2009 samples, the Army, in consultation with the study team, decided to analyze the above compounds in seawater for the second round of sampling.

2.2.1.3 Metals

This study also evaluated the potential effect of munitions casings on the composition of sediment and biota consumed by local residents by analyzing for selected heavy metals specifically associated with munitions casings. These metals can be released to the surrounding environment through the corrosion and decomposition of such casings. To attempt to distinguish metals from munitions, from those present within the DMM stratum due to other anthropogenic activities (e.g., delivered to the ocean through NPS pollution or WWTP outfalls) or from geologic materials, the list of elements analyzed was expanded beyond the dominant COPCs listed below. Given the amount of coastal pollution generally reported as present in O‘ahu’s nearshore areas, and the pollution that NOAA’s 2007 report documented as being present at O‘ahu’s Wai‘anae Coast, the study team considered it likely that metals from sources other than DMM may be present in the sediments and biota at Ordnance Reef (HI-06).

The study team determined it easiest to assign an attribution of COPC to DMM where samples were collected very close to individual munitions or larger groups of small caliber DMM. Metals typically associated with large munitions include iron and copper, although small amounts of lead may also be present. Iron, which is one of the most abundant elements on Earth, has extremely low toxicity and is an essential element for life. As iron does not present a significant hazard to human health and the environment, it was not included as a COPC for this study. A variety of other elements, often in varying amounts, are present within munitions; however, such elements are typically present in much lower quantities than iron.

The elemental COPC in sediment and biota for the Ordnance Reef (HI-06) environmental study are the following:

- arsenic (speciated into inorganic versus organic forms),
- copper, and
- lead.

Although arsenic, an essential element in the human diet for stimulating metabolism (Emsley, 1989; ATSDR, 2000), is a toxic element on EPA’s priority pollutant list, arsenic is not found in conventional munitions except in trace amounts. Trace amounts of arsenic are also found in most other earth substances and human products. The Army included arsenic as a COPC in this study because of the local community’s deep-seated concern regarding its potential to pose a health hazard. Other elements, including a number of heavy metals, were selected for analysis in sediment samples based on USACE’s historical records and previous environmental studies performed at the WWTP and other locations on O‘ahu (e.g., De Carlo et al., 2004; De Carlo et al., 2005). With this in mind, zinc is also discussed extensively along with the elemental COPC, owing to its potential to help elucidate elemental sources and associations.

Sediment samples were, therefore, analyzed for a suite of major, minor, and trace elements that the Army and study team selected based on their potential to help identify individual contributions from munitions, terrestrial run-off (NPS) pollution, WWTP effluents, and natural terrigenous (volcanic) materials and marine carbonates to the overall composition of sediment at Ordnance Reef (HI-06). The elements analyzed included aluminum, arsenic, barium, calcium, cadmium, cobalt, copper, chromium, iron, magnesium, nickel, lead, strontium, titanium, uranium, vanadium, and zinc.

Seawater samples collected during this study were not analyzed for metals because a large body of work has demonstrated that heavy metals are extremely particle reactive and will typically partition into the solid phase (i.e., sediment and suspended particulate matter) at seawater hydrogen potential (pH); therefore, will be present at negligible concentrations in seawater (see for example: Davis and Hayes, 1978; Bruland 1983). De Carlo et al. (2004) and Bienfang et al. (2009) have also reported extremely low concentrations of a variety of trace elements and heavy metals in marine waters of Hawai'i, even in heavily polluted settings such as the Ala Wai Canal and other harbor environments. Owing to the very low abundances of heavy metals in seawater, the COPC metals are extremely unlikely to be present in seawater at concentrations sufficient to cause any potential health hazard.

2.2.2 Screening Levels

Table 2-2 summarizes screening levels, criteria and benchmarks for environmental and ecological considerations for sediments and marine organisms. These were used to help establish reporting level needs and for screening of compounds to be considered for carrying forward in the evaluation of risk.

2.2.2.1 Sediment

There are no chemical screening values for sediments available for the exposure scenario for human receptors. USACHPPM (now Public Health Command), in its 2007 health risk evaluation for Ordnance Reef (HI-06) (USACHPPM, 2007), used EPA Region 3 Risk Based Concentration values for direct contact with soil as a screening level criteria. This risk screening was highly conservative and not entirely appropriate for evaluating contact with marine sediments. The survey compared concentrations of COPCs in marine sediments to the risk-based screening levels for direct contact with residential soils, assuming contact 350 days per year and an ingestion rate of 200 milligrams per day (mg/day). This scenario is not plausible due to site accessibility and availability of sediment.

To enable a comparison of this study's data with NOAA's 2006 survey data, this study looked at both residential soil screening levels and ecological toxicity values for sediment as the appropriate action levels for sediments. In 2008, EPA consolidated its Region 3's Risk Based Concentration values with similar risk-based screening levels used by its Regions 6 and 9 into a single table: "Regional Screening Levels (RSLs) for Chemical Contaminants at Superfund Sites." This study conservatively considers the consolidated RSLs screening criteria for exposure to sediment (Section 6 and Appendix G). As discussed in the previous paragraph, the RSLs are based upon a scenario that assumes 350 days per year of contact with sediments and a daily ingestion of 200 mg of sediment, both of which are not plausible for Ordnance Reef (HI-06) sediments. Therefore, the two estimated detections of energetics in sediment samples

collected from Ordnance Reef (HI-06) in 2009 that met or exceeded the RSLs are not considered a human health risk.

Similarly, criteria appropriate for screening risks to ecological receptors do not exist. For metals, this study uses the marine sediment screening levels that NOAA compiled in the Screening Quick Reference Tables or SQuiRT (Buchman, 2008) as criteria for screening potential ecological risks. The NOAA benchmarks, which are either the Threshold Effects Level (TEL) or the Adverse Effects Level (AEL), are considered levels of sediment contamination that can be tolerated by the majority of benthic organisms over long periods of exposure. For energetic compounds, the sediment benchmarks were from multiple government compilations and databases, including ecological screening levels from EPA Regions 3 and 6, Los Alamos National Laboratory (2010), and Oak Ridge National Laboratory (published as Talmage et al., 1999).

2.2.2.2 Aquatic Food Items (Crab and Fish)

The U.S. Food and Drug Administration (FDA) has developed chemical-specific benchmarks for seafood consumption; however, these were not used since FDA's jurisdiction in setting screening criteria or action levels is limited and their applicability to the consumers of seafood from Ordnance Reef (HI-06) is limited. Additionally the FDA screening criteria do not define action levels for many of the MC (e.g., explosive or energetic residue) included in the HI-06 HHRA (Appendix G). The methodology FDA uses in establishing screening criteria or action levels addresses only health risks from the consumption of environmental contaminants in fish and shellfish that are bought and sold in interstate commerce rather than in locally harvested fish and shellfish (Bolger et al., 1990).

EPA has developed a methodology to calculate Fish Advisories Screening Values (SVs) for environmental contaminants in fish tissue. EPA calculates Fish Advisories SVs based on the non-carcinogenic and carcinogenic effects of the environmental contaminant (EPA, 2000).

While the current assessment generally follows EPA's approach, EPA Fish Advisories SVs were not used for the HI-06 HHRA because they are not expressly applicable to Ordnance Reef's (HI-06) site-specific conditions. Many of the exposure assumptions used to calculate EPA Fish Advisories SVs differ from actual exposure in the populations of interest evaluated in the HI-06 HHRA. Additionally, these SVs are not available for many of the MC (e.g., explosive or energetic residue) and media (e.g., crab, seaweed and octopus) evaluated in the HI-06 HHRA (Appendix G).

For consumption of marine prey by seabirds, acceptable tissue levels (ATLs) for prey species were calculated based on ingestion models that the Oak Ridge National Laboratory developed (Sample et al., 1996). The benchmarks of toxicity used in these derivations were chemical (contaminant)-specific no-observed-adverse-effect levels (NOAELs) from Sample et al. (1996) in the case of metals, or from USACHPPM in the case of energetic compounds.

2.2.2.3 Surface Seawater

DOH has set Water Quality Standards (WQS) (DOH, 2004) for surface water. The study team identified the National Recommended Water Quality Criteria (NRWQC) as benchmarks for seawater exposures (EPA, 2004). Ultimately, the study team did not use either the DOH WQS or NRWQC because of the lack of MC detections in seawater samples. For potential ecological

effects, the surface water screening benchmarks were from multiple government compilations and databases, including ecological screening levels from EPA Regions 3, 4, and 5; Los Alamos National Laboratory; Oak Ridge National Laboratory (published as Talmage et al., 1999); and NOAA. Seawater media was not carried forward into the quantitative risk assessment.

2.2.3 Mobilization

Mobilization included preparing for each of the study team's field activities, determination of, gathering and checking of necessary materials and equipment, and organizing and assembling trained field personnel. The study team assembled and checked (e.g., calibrated, checked batteries) equipment and materials prior to transferring it to Ordnance Reef (HI-06). All field personnel received site-specific health and safety training and familiarization with Ordnance Reef (HI-06) prior to commencing work.

The Army's approval of the study's sampling plan followed early and continuous consultation with and consideration of regulatory and community concerns. Demobilization occurred with the same attention to detail and continuous coordination that was applied to the mobilization process.

2.2.4 Sediment Sampling

A total of 59 sediment samples were collected and sent to the laboratory for energetic analysis; however, the analysis of nine samples (ORD017S, ORD019S, ORD023S, ORD027S, ORD028S, ORD103S, ORD106S, ORD109S, and ORD112S) were held pending the results of other samples, and four samples (ORD001S, ORD002S, ORD003S, and ORD004S) were determined invalid due to improper sample preparation (i.e., samples were not sieved). Of the 59 sediment samples collected, 34 (ORD001S through ORD034S) were collected during the April 2009 sampling, with the remaining 25 samples (ORD101S through ORD125S) collected during the September to October 2009 sampling. Additionally, 76 total samples were collected and analyzed for elements. The sample information and field activities are documented in Appendix C, Field Collection Sheets; Appendix D, Photo Log; and Table 2-1.

The collection of sediment samples using a Ponar grab sampler was only marginally successful on reefs, reef flats and other hard substrate where sediment tends to only accumulate in depressions or as a thin veneer. When use of the Ponar was not successful, the fisherman contracted to collect biota were instructed to collect sediment samples by scooping sediment from the top 0.8 to 1.6 in (2 to 4 centimeter (cm)) of the substrate directly into pre-labeled gallon-sized plastic storage bags. Samples within the DMM stratum were collected from three locations associated with specific DMM.

When possible, given bottom conditions and the presence of an adequate amount of sediment for analyses, samples were collected directly adjacent to, approximately 3 ft (1 m) away from, and approximately 6 ft (2 m) away from specific DMM. In some cases, the distances from the DMM where sediment samples were collected were slightly different than described above. In such cases, the fishermen noted the distances, which the study team subsequently recorded in the field notes. The study team ensured that the fishermen could keep track of the sediments collected at each of the three sample locations by using pre-labeled sampling bags. The bags were pre-labeled A, B, and C, with A always designated as the sample collected closest to the DMM. Fishermen carried the bags to the surface and handed them to the field sampling team. Sampling

locations were individually documented using a handheld GPS (refer to Section 2.2 for further detail).

On recovery of the Ponar or the plastic storage bag, the individual sediment samples were placed onto decontaminated plastic trays and the visual characteristics of the sediments were noted. Each sediment sample was then transferred into laboratory-supplied sample containers and clean plastic storage bags using a decontaminated plastic spoon. Sample containers were labeled according to the procedures established in the Field Sampling Plan (FSP), then immediately cooled to 39°F (4°C) for preservation. The coolers containing the samples were removed from the boat upon completion of each day's work. The sample containers were then returned to the laboratory, stored, chilled, and subsequently shipped, under chain-of-custody (COC), to the appropriate laboratory for analysis (see Appendix E for a compilation of laboratory report COC forms).

2.2.5 Seawater Sampling

A total of 18 water samples, which included primary and duplicate samples, were collected and analyzed. There were eight primary samples and a duplicate sample collected during each seasonal sampling effort. The sample information and field activities are documented in Appendix C Field Collection Sheets, Appendix D Photo Log, and Table 2-1.

Water column sampling was carried out using pre-cleaned Niskin bottles modified for trace element work. The 2.5-liter modified Niskin bottles used during the study were equipped with a triggering mechanism constructed with epoxy-coated springs and silicone O-rings. The fishermen collected the water column samples after being instructed on how to operate the bottle's triggering mechanism.

Water sampling was intended to collect seawater samples close to the seafloor and directly above sampling locations, but prior to collection of sediment samples, to produce a water sample that could be collocated with a sediment sample. To accomplish this, the contract fishermen deployed Niskin bottles that the study field team had secured in the "open" position. When a sediment sample location was selected, the fishermen suspended the Niskin bottle less than one foot (<0.3 m) above the sediment sampling location and triggered the closing mechanism. At DMM stratum sample sites, seawater samples were collected from the sediment sampling location closest to the DMM. To minimize the amount of suspended sediment in water column samples, the fishermen collected water column samples prior to collecting the sediment sample from the selected sample location. The fisherman then returned the closed Niskin bottle to the study's field team and described where they had collected the sample. The study team recorded the information provided on the field sampling sheets, along with other critical information about the site (Appendix C).

Seawater aliquots were partitioned using trace metal clean methods into labeled sample containers for analyses. Seawater samples were submitted to TestAmerica West Sacramento where they were analyzed for energetics using EPA method 8330 and for phthalates and pyrene using EPA method 8270.

Profiles of water column properties were obtained through hydrocasts with a Sea-Bird Electronics (SBE) conductivity, temperature, depth (CTD) sonde (Appendix F). The SBE19*plus* V2 SEACAT® CTD system provided water column profiles of conductivity, temperature, depth,

salinity, dissolved oxygen (DO), fluorescence (a proxy for chlorophyll-a, chl-a), and turbidity during both sampling periods. The study team took profiles at times that coincided with sediment, water, and biota sampling. The following provides the hydrocasting procedure used.

- The SBE 19*plus* V2 SEACAT® CTD (mounted in a stainless steel frame) is secured to the winch line with two small (3/4 in (1.91 cm)) shackles (redundant attachment for safety) that are also doubly secured with a short length of "spectra" line. Instrument protective caps (e.g., FLNTUS cover) are removed and appropriately stowed. The automatic on/off slide switch is slid into the "on" position, which automatically creates a new internal data file with a sequentially increased numerical identifier and activates the CTD to begin logging upon contact with saltwater until the switch is deactivated or the instrument is removed from saltwater. The date, time, GPS position of the hydrocast and the water depth are recorded in the field notebook. This information is used when downloading the data files created by the SBE software, which does not provide all of this information and can only be recognized by the date/time stamp.
- The CTD stainless steel frame is lowered overboard until the instrument sensors are below the surface of the water (to trigger the data logging) and held at about the 3-ft (1-m) depth for approximately one minute to allow the sensors to equilibrate with seawater.
- The CTD frame is then lowered through the water column at the desired rate (the lowering speed is varied from approximately 1.0 ft per second (ft/s) to 1.6 ft/s (0.3 m/s to 0.5 m/s) for shallow water casts to approximately 3.3 ft/s (1 m/s)) for deeper water casts until it reaches the bottom, then raised back to the surface.
- The winch is stopped when the instrument reaches the water surface.
- The CTD frame is carefully raised out of the water (this automatically stops data logging) and brought back onboard the vessel, where it is then disconnected from the winch line, and stowed after the slide switch is returned to the "off" position. Any protective caps that were removed prior to the CTD casts are replaced on the sensors for storage.
- The process is repeated for subsequent hydrocasts.
- After the final CTD cast of the day and return to shore, the instrument sensors and frame are thoroughly rinsed with freshwater.
- Data download is achieved through connection either to the SBE deck box or through appropriate serial cables attached to a computer equipped with the SBE software.

The water column profiles obtained are provided in Appendix F, Water Column Profiles, with hydrocast locations shown on Figures 2-2 and 2-3, and the coordinates provided on Table 2-1. There were 10 profiles acquired during the April 2009 sampling event and eight acquired during the September to October 2009 sampling event. In general, the water column property profiles share the trends indicated below. These profiles differ between seasons (spring versus summer) predominantly in water temperature profile, which is higher during the September to October 2009 sampling event when compared to the April 2009 sampling event profiles (see Figure 2-4).

- A decrease in temperature with increasing depth from a surface maximum,

- A very slight increase in the chl-a concentration with increasing depth, and
- A slight increase in the concentration of DO with increasing depth.

2.2.6 Biological Sampling

The study team selected biota species to be collected based on discussions with local community members. Consulation with community members allowed the study team to prioritize the species according to the importance of the species as food to the residents of O'ahu's Wai'anae Coast. The species targeted for this study included fish, invertebrates, and seaweed (see Table 2-3).

A total of 179 biota samples were collected during this study. This number does not include duplicate samples. Of the 179 samples collected, 79 were fish, 36 were octopus, 28 were crab, and 36 were seaweed. Of the 36 seaweed samples collected, one (ORD106L) was not analyzed due to insufficient sample volume (see Table 2-1 and Table 2-4). All of the other biota samples were analyzed.

The goal for biota sampling in the DMM stratum included collection, at each sample site, of at least one of each type fish, one invertebrate, and one seaweed sample. The goal for the non-munitions strata included collection, at each sample site, of one fish, one invertebrate, and one seaweed sample.

Octopus were caught by the tactical spearing technique, Kona crab were caught in bottom traps, and seaweed was harvested by hand. Because fish are transient and foraging organisms, the spatial goal for fish collection was modified slightly. Fish were trapped in nets, which the fishermen left in place overnight, at prime collection spots within each stratum. The fish collected were considered representative of fish that would spend time in proximity of the stratum in which they were caught. As an example, fish caught in the DMM stratum were considered representative of fish that had spent time in proximity to DMM. Seaweed was not abundant and was difficult to locate at any given sample site. Because of this, seaweed was often harvested over a larger geographic area in the vicinity of a given sample site until a sufficient mass was collected to enable laboratory analysis.

Invertebrate sampling was intended to collect the same type of invertebrate at all sample sites. Oversampling occurred throughout each sampling event, and at the end of fieldwork. The species harvested in the greatest abundance at sample sites from all four strata were submitted to the laboratory for analysis. For sample sites where the "prevalent" species could not be collected, the next most prevalent species collected was submitted for analysis. This approach was largely successful.

Octopus were always collected from all four strata, while Kona crabs, which were only found in sandy channels, were only caught within the DMM and WWTP strata. One crab was, however, caught at the NPS stratum during the April 2009 sampling event, but none were collected during the September to October 2009 sampling event (Table 2-4). The original Sampling and Analysis Plan (SAP) only called for analysis of the octopus samples because octopus had been caught across all four strata. The study team, however, decided to analyze all biota sample types collected to provide a larger database for the study. Therefore, Kona crab samples were

submitted for analysis even though Kona crabs were only collected at two strata. The data for Kona crab were examined in a different context than biota collected from all four strata.

A secondary goal of biota sampling was to attempt to collect fish and invertebrate samples of relatively similar size or mass (i.e., within 10% to 20%, if possible). This would allow the comparison of biota of approximately the same age or stage of development. For the majority of the samples this was achieved. Approximately 80% of octopus samples were within roughly 10% of mass. Crab samples were the most uniform in size, with dimensions of approximately 3.5 to 4.0 in (8.9 to 10.2 cm) in width and approximately 6.0 to 7.0 in (15.2 to 17.8 cm) in length. The size difference between crabs was within 20% for all samples. The fish samples collected by netting displayed the greatest variation in size. The length of white weke ranged from 9.0 to 14.0 in (22.9 to 35.6 cm) and that of red weke range from 7.0 to 11.0 in (17.8 to 27.9 cm). Approximately 80% of the fish samples were within a difference of 20%. Contract fishermen collected a representative number of white weke and red weke within the DMM stratum and each non-munitions stratum.

UH field personnel shadowed the fishermen in a separate surface vessel to both ensure accurate documentation of the locations where biota samples were collected and take custody of the biota samples. Sampling locations were recorded using a GPS, as described in Section 2.1.1. Samples, which were packaged in trace metal clean plastic bags, were stored on ice until return to the laboratory. Storage and handling of the biota samples followed procedures that the FSP outlined. A summary of the number of biota samples collected by stratum, season, and biota type are presented in Table 2-4.

Following the 2006 NOAA survey, the community expressed concerns regarding the procedures used for the analysis of fish samples. During NOAA's survey, whole fish were analyzed for COPC providing a "worst-case" scenario analysis regarding the potential health hazards associated with consumption of these fish (certain COPC concentrate preferentially in selected organs that are not usually consumed). The community, however, suggested that only edible portions of the biota collected be analyzed. This, they believed, would provide a better representation of the potential exposure the community would experience by the consumption of the types of biota collected.

To accomplish this, each specimen of fish was filleted, the meat was extracted from the body and appendages of each specimen of crab, and the ink sac and beak were removed from each specimen of octopus in a Class 100 laminar flow hood at UH. Limu specimens, which were also rinsed in a Class 100 laminar flow hood to remove sediment particles, were submitted intact to the laboratory. A ceramic knife used for filleting the fish and processing the octopus, and all the plasticware used for sample storage, handling, and processing were scrupulously cleaned by a series of acid washing steps that exceed EPA recommendations, as previously described by Spencer et al. (1995) and De Carlo and Spencer (1997). These cleaning procedures were originally developed to minimize trace metal contamination prior to analysis but were equally applicable to prevention of contamination of any type during sample processing. After sample preparation of fish and crab tissue, all biota samples were stored in a freezer at -22°F (-30°C) and subsequently shipped to the contract laboratory for analysis on ice packs to maintain the sample temperature near 32°F (0°C) and prevent thawing. To preserve sample integrity and preparation consistency, the contract analytical laboratory was responsible for subsequent preparation and analysis of all biota tissue. All analyses for trace elements and energetics were conducted at TestAmerica West Sacramento. Tissue samples were analyzed for heavy metals using EPA

Methods 6010B and 7471A and energetics using EPA method 8330. Arsenic speciation was performed by Brooks Rand Laboratories on aliquots of tissue prepared by TestAmerica West Sacramento. Arsenic speciation was conducted on roughly 10% of the biota samples to estimate the percent inorganic arsenic versus the percent organic arsenic in each biota type. Brooks Rand conducted the arsenic speciation by analyzing for inorganic arsenic using a modified EPA method 1632 and total arsenic using a modified EPA method 1638.

2.2.7 Sample Numbering and Labeling

Sampling procedures required that all samples collected be labeled with a field identification (ID) number as soon after collection as practical. Samples to be submitted to the laboratory for analysis were also assigned a sample ID number to facilitate data tracking and storage (see Table 2-1). The format for sample ID numbers was:

xxxyyyz

where

xxx Project description (ORD)

yyy Chronological number, starting with 001 in April 2009 and starting with 101 in September to October 2009

z letter indicating matrix type (s = sediment; w = water; f = fish; o = octopus; c = crab; l = limu (seaweed)).

(Note: sediment metal samples were provided with ID numbers in a different format than described above. In most cases, the ID number consisted of a combination of the site and field ID number (see Table 2-1).

2.3 Equipment Decontamination Procedures

Sampling equipment used at each strata included the Ponar grab sampler and the Niskin water sampler. Previous oceanographic research has shown that samples can be collected without contamination using Niskin bottles on a conventional rosette and cable (e.g., Sanderson et al., 1995; Measures and Vink, 1999, 2000, 2001). The study team decontaminated equipment between each use by a triple seawater rinse over the side of the vessel complemented by nylon brush scrubbing to remove any adhering material. Because sediment in the study area is composed largely of sand-sized particles with minor to trace amounts of clay/silt-sized particles, there was usually no adhesion of sediment to the Ponar grab surfaces after the first seawater rinse. Additionally, the Niskin water sampler was carried underwater to each sampling location in the 'open' position, with seawater flowing freely through the sampler until the time when it was triggered to collect a sample. Other sample handling materials used during the study included laboratory-supplied sampling containers, disposable plastic spoons, and nitrile gloves, which were only used once and then discarded. No decontamination was required for these materials.

2.4 Investigation-Derived Waste Management

Investigation-derived waste (IDW) is defined as any solid or liquid material used or generated during the study's field investigation. Solid IDW generated during this study was limited to nitrile gloves, plastic spoons, and paper towels. There was no liquid IDW generated during this study. Based on knowledge of Ordnance Reef (HI-06), the waste generator determined that all IDW were non-hazardous solid waste allowing it to be disposed of offsite. Biota samples were processed in their entirety at the UH laboratory to remove non-edible portions of each specimen. Again, based on knowledge of the site, the waste generator determined tissue parts removed from each animal were a non-hazardous solid waste and they were disposed of offsite.

2.5 Field Quality Assurance and Quality Control

2.5.1 Sample Collection and Management

Sample collection and handling procedures were designed to ensure that study team personnel were able to collect, label, preserve, and transport all required samples in a consistent manner to maintain sample integrity. The study team conducted field activities per the FSP. Evaluation and quality control (QC) assessment of field activities included oversight of procedures for field sampling activities, instrument calibration, and daily tailgate meetings, where discussions included a review of the day's activities, proper sampling, site safety, and a preview of upcoming activities.

2.5.2 Field QC Samples

Study field QC samples consisted of collection of field duplicate samples. Equipment rinsate blanks, trip blanks, and temperature blanks were not necessary for this study.

2.5.2.1 Quality Assurance and Field Duplicate Samples

Field duplicate samples were collected in the field from the same time and locations as their respective primary samples to gain precision information on homogeneity, handling, shipping, storage and preparation, and analysis. Precision characterizes the amount of variability and bias inherent in a data set. It also describes the reproducibility of measurements of the same parameter for a sample under the same or similar conditions. Field duplicates, which are referred to in data validation reports as replicates, were collected at a rate of approximately 10% of study samples.

For sediment samples, of the 46 samples analyzed by the laboratory for energetics, four samples (ORD016S, ORD030S, ORD032S, and ORD116S) were field duplicate samples. Sediment field duplicate samples were assigned a unique ID number in sequence with the primary samples to ensure their independent analysis. Sediment field duplicate samples, which were sent to the contract laboratory as blind samples, were analyzed for the same parameters as the primary samples (see Appendix E). There were no sediment metal duplicate samples.

For biota samples, specimens were sent to the laboratory either intact (octopus and limu) or as prepared tissue samples (fish fillets and crab meat), thus the laboratory was responsible for preparing splits of a subset of the samples. Of the 178 samples analyzed by the laboratory,

22 were split and assigned as a duplicate sample (e.g., ORD001O (DUP) (Table 2-1). Duplicate samples were analyzed for energetics, phthalates, and pyrene.

Standard COC protocols were adhered to during sample collection, management, and shipment to the analytical laboratories. COC forms were maintained for each day's samples. The laboratories followed their internal COC process once the samples arrived. The COC forms for the samples collected during this study are found in Appendix E.

2.5.3 Field Instrument Calibration/Documentation

The only field instruments used during the study were sensors on the SBE19*plus* V2 SEACAT® CTD system. These sensors, which are factory calibrated, do not require user calibration either in the laboratory or the field. Upon annual factory maintenance and calibration, the manufacturer provides new calibration coefficients. New calibration coefficients, which the manufacturer entered into SBE proprietary software, were used to calculate field data values (e.g., concentrations) for relevant parameters upon downloading of raw CTD files from the instrument. This approach is standard oceanographic practice. No field calibrations were carried out as the design characteristics of SBE systems do not permit operator/field calibrations

2.6 Chemical Analysis

TestAmerica West Sacramento analyzed all samples, with the exception of elements (including metals) in sediment, which were analyzed by Dr. De Carlo's UH laboratory. All analyses were performed using EPA or equivalent methods. High Performance Liquid Chromatography (HPLC) methods employed for this study included second column confirmation of positive detections.

All sediment samples intended for element analysis were processed in Dr. De Carlo's UH laboratory. Sediment samples were dried in an induction oven at 104°F (40°C) to a constant weight and homogenized with a tungsten-carbide ball and mill. Splits (approximately 0.007 ounces (200 milligrams (mg))) of the sample powders were digested in closed Teflon® containers using concentrated minerals acids and subsequently analyzed by atomic spectrometry for their elemental composition using methods previously used in Dr. De Carlo's laboratory (e.g., Wen et al., 1997; De Carlo et al., 2004; De Carlo et al., 2005). These digestion procedures and analyses are comparable to those described in EPA solid waste (SW) 846 (e.g., Method 3050, 3051 or 3052) followed by inductively coupled plasma optical emission spectroscopy (ICP-OES) Method 6010, and inductively coupled plasma mass spectroscopy (ICP-MS) analysis Method 6020. Standard quality assurance (QA) and QC procedures were undertaken during the course of sample preparation and analysis. These include the preparation and analysis of reagent and procedural blanks, replicate sample analyses, duplicate digested solution analysis, analysis of spiked solutions, and analysis of certified reference materials. Sediment samples submitted to TestAmercia West Sacramento were analyzed for energetics using EPA method 8330.

Tissue samples were analyzed for elements using EPA methods 6010B and 7471A and energetics using EPA method 8330. Arsenic speciation was performed by Brooks Rand Laboratories on aliquots of tissue prepared by TestAmerica West Sacramento. Brooks Rand

conducted the arsenic speciation by analyzing for inorganic arsenic using a modified EPA method 1632 and total arsenic using a modified EPA method 1638.

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Section 3
Area Use

3.1 Ocean Recreation and Tourism

Wai‘anae’s location on the leeward side of the Wai‘anae Mountain Range, from Ka‘ena Point in the north to Kahe Point in the south, provides beautiful coastal landscapes, natural white sand beaches, and majestic mountain ridges. On the coast and at sea, Wai‘anae offers diverse ocean water sports, including off-shore fishing, sailing, surfing, snorkeling, spearfishing, canoe paddling, and ocean swimming at numerous public beach parks (NOAA, 2007).

3.1.1 Swimming and Beach Recreation

About 18 mi (29 km) of the Wai‘anae coast is made up of beach parks and community recreation areas. These beach parks enable public access for swimming, snorkeling, or surfing. Some of the notable beach parks along the Wai‘anae coast known for excellent swimming and beach conditions in the summer include Mākaha Beach Park, Nānākuli Beach Park, and Mā‘ili Beach Park. In the winter season, however, strong currents can exist at these parks, and the surf can be extremely dangerous. Pōka‘ī Bay offers excellent swimming year round since it is well protected from the surf, even during the winter surf season. Unlike other reefs along the Wai‘anae coast, Pōka‘ī Bay’s coral reef slopes gradually away from shore, thereby reducing riptide effects (NOAA, 2007). Most of the children of the Wai‘anae coast learn to swim in the sheltered waters of Pōka‘ī Bay.

3.1.2 Surfing

He‘e nalu (wave sliding, aka surfing) was practiced by kings and queens and the men and women of Hawai‘i long before 1500 AD (SurfArt.com, 2000). Wai‘anae’s coast has played a significant role in the contemporary sport and business of surfing. Wai‘anae was home to the first international surfing contest, held in 1953 at Mākaha Beach.

Most surf in Hawai‘i is generated from ocean swells that come from the north, south, and west directions. O‘ahu’s North Shore, or “Country,” is famous for its waves that originate from the north and northwest in the late fall and winter. The South Shore, or “Town,” is famous for its southern waves, which normally occur during the late spring, summer, and early fall. The Wai‘anae coast generates surf conditions from a westerly swell, but it also has the perfect orientation to pick up waves from the north and south as well, making it a year-round surf location. Mākaha Beach is known as one of the premier surf locations in Hawai‘i and the world. Its unique orientation and semi-reef-break conditions enable the spot to pick up powerful surf from swells that originate from the north, west, or south (State of Hawai‘i Division of Boating and Ocean Recreation (DOBOR), 2009; NOAA, 2007).

3.1.3 Ocean Tours, Sightseeing, Snorkeling, and Fishing

Several commercial companies operate out of the Wai‘anae Small Boat Harbor to provide access to ocean sports along the Wai‘anae coast. Through specialty tours, visitors fish, snorkel, sail, kayak, and watch spinner dolphins and humpback whales in their natural habitat. Spinner dolphins are frequent visitors to bays and beaches along the northwest coastline toward Ka‘ena Point. Humpback whales are often seen 0.5 to 3.1 mi (0.8 to 5 km) offshore, primarily from January through April. The waters around the main Hawaiian Islands of Kaua‘i, O‘ahu, Hawai‘i, Maui, Moloka‘i, Lāna‘i, and Kaho‘olawe constitute one of the world's most important North Pacific humpback whale habitats and the only place in the U.S. where humpbacks reproduce (NOAA, 2011).

3.1.4 Diving

There are numerous diving sites located along the Wai‘anae coast. Some of the better known dive sites in the area include Ka‘ena Point, Kealoa Stars (Land of Oz), Mākaha Caverns, Ulua Cave, Airplane Canyon, M/V Mahi, Electric Beach, Black Rock, Black Rock Arches, 29 Down, Landing Craft Utility (LCU) Wreck, and Twin Caves. The M/V Mahi, Airplane Canyon, 29 Down, and LCU wreck were plane and boats that were intentionally sunk to serve as artificial reefs. These dive sites are frequented by the diving tour boats operating out of the Wai‘anae Small Boat Harbor and the Ko‘olina Marina (DOBOR, 2009; O‘ahu Dive Sites; Ocean Concepts O‘ahu Dive Sites).

3.2 Fishing

People from all over the island of O‘ahu come to fish off the Wai‘anae coast. Participants are primarily part of the small vessel pelagic troll fishery. These are vessels between 16 and 30 ft (5 and 9 m) long, fishing for species that feed in the upper layers of the water column and dragging or drifting bait or artificial lures behind the boat (Glazier, 1999). The State-owned Wai‘anae Small Boat Harbor is the island’s primary small vessel harbor and ramp access point, affording quick access to the ocean via a sometimes very busy seven ramp launch area. The harbor facility was constructed in 1972. The harbor has berthing spaces for 146 vessels (DOBOR, 2009). It is the center of fishing activity along the Wai‘anae coast.

The annual Ahi Fever Fishing Tournament has occurred every June since 1997. It is the largest fishing tournament in Hawai‘i, based on total number of anglers and boats registered (NOAA, 2007). Additionally there is considerable fishing activity along the coastline by local residents as well as spearfishing activities by both snorkelers on shallow reef and sandy bottom areas and by SCUBA divers.

Pelagic fishing and inshore fishing are described separately below. Pelagic, or open fish, are caught farther from shore and would not be representative of fish that had spent much of their life history in the vicinity of Ordnance Reef (HI-06). Inshore fishing, by contrast, would be centered directly around the site itself.

3.2.1 Pelagic Fisheries

Commercial fisheries data from the State Division of Aquatic Resources ranks the waters off the Wai‘anae coast first or second for total pounds of all species landed. According to the State of Hawai‘i Department of Land and Natural Resources (DLNR) landings off the Wai‘anae coast totaled 885,949 pounds (401,860 kilograms (kg)), or approximately 15% of the total landings in main Hawaiian Island waters in 2009 (DLNR, 2009). It should be noted that much of this fishing activity is conducted significantly farther offshore than the study site although certain local fishermen conduct commercial fishing operations within a distance from shore corresponding to the Ordnance Reef (HI-06) study site.

Skipjack tuna or aku (*Katsuwonus pelamis*) is the top species landed in this district, and the small fleet of aku pole and line fishery (currently three vessels) lands approximately 702,193 pounds (318,509 kg) of fish from Hawaiian waters (DLNR, 2008) (note: data were not available for 2009 landings). Yellowfin (*Thunnus albacares*) and bigeye ‘ahi (*Thunnus obesus*), akule (*Selar crumenophthalmus*) and blue marlin (*Makaira mazara*) are also caught in greater numbers than at most places in the state (DLNR, 2009). This is due mostly to the comfort of fishing in the calm leeward coast of the island and the convenience of deep waters close to shore.

3.2.2 Inshore Fisheries

Although far fewer inshore reef fish are caught in Wai‘anae than in other sites around the islands, goatfish or weke (*Mulloidichthys spp.*) and the introduced blue-lined snapper or taape (*Lutjanus kasmira*) are taken in fairly large numbers (DLNR, 2009). Shore casting and spear fishing on the reef are common activities up and down the coast. Most of these anglers will keep their catch, either for self-consumption or to distribute to friends and family (DOBOR, 2009; NOAA, 2007). Other organisms caught for consumption include Kona crabs, octopus, and seaweed such as limu kohu, as discussed in the 2009 SAP.

3.2.3 Fishing Regulations

Pōka‘ī Bay Fishery Management Area. The only Wai‘anae-specific fishing regulations occur in the Pōka‘ī Bay Fishery Management Area (Figure 3-1, from NOAA, 2006). Numerous regulations are intended to reduce the amount of fish, crabs, shrimp, and baitfish taken in this area. Anglers may use only one fishing line with no more than two hooks to catch fish. They may use a maximum of ten nets with a 2-ft (0.6-m) diameter to take crabs, and may use only hand nets for shrimp. They must have a bait license or be a licensed pond owner to take baitfish or young mullet (pua), respectively. All other net fishing is illegal in this area (DLNR, 2003). No biological, sediment or water column sampling was conducted within the Fishery Management area (Figure 3-1).

Ka‘ena Point to Mākua Bottomfish Restricted Fishing Area. The bottomfish restricted fishing area off the Wai‘anae coast was established to promote recruitment and minimize overfishing of bottomfish species in the area. The shallow side of this restricted fishing area follows the 600-ft (183-m) isobath, the contour of the seafloor at 600 ft (183 m). It is illegal to catch bottomfish in the restricted fishing area using a trap, trawl, bottomfish longline, or net (DLNR, 2003).

3.3 Conceptual Models

The primary purpose of the conceptual model (CM) for ecological (i.e., non-human) receptors (Figure 3-2) and the conceptual site model (CSM) for human receptors (Figure 3-3) is to identify the potential pathways for exposure to metals and energetics that may have leached out of or been released from sea-disposed military munitions at Ordnance Reef (HI-06). These models help define a source area, present potential routes of transport and fate, identify media and routes of exposure, and most importantly, the endpoint receptors. CMs are useful in planning for the collection and interpretation of environmental data (including a site-specific risk characterization and impact assessment) within an ecosystem, understanding potential risks to receptors, and communicating project specifics. The CMs consolidate information relevant to a given site or problem to identify key elements for incorporation into the DQO development process.

The uniqueness of Ordnance Reef (HI-06) is critical to the development of the site models. Little guidance or previous examples exist for developing models related to sea-disposed military munitions. This study, which involved, in part, the collection of site-specific data including concentrations of MC in specific media (e.g., biota, seawater, and sediment) sought to relate the detected COPCs and their concentrations to human and ecological impacts at Ordnance Reef (HI-06) in a quantitative manner. Several confounding factors present compromised the study team's ability to draw definitive conclusions. First is the ability to attribute unequivocally any detected COPC to munitions. Although the explosive COPC are military-unique, metals and other compounds (e.g., pyrene, phthalate esters) can originate from a number of sources. This study effort was aimed at characterizing the study area from the perspective of the inputs to the environment that were associated uniquely with the DMM. Nonetheless, the study team understood that explanation of other potential COPC sources and contaminants would be beneficial to the study's overall objective.

A noteworthy confounding factor influencing an ecological assessment is that some human food item biota are transitory by nature. By way of example, many species of fish may travel considerable distances as part of their natural behavior; thus there is considerable uncertainty whether fish observed or captured at any given stratum have only been exposed to the COPCs within that particular stratum. To address this possibility, reef fish which have a more limited range were selected as target species for this study. Commonly-occurring invertebrates (e.g., crabs, octopus), however, have a much smaller home range than many fish species, spend a considerably greater amount of time in close association with the seafloor, and will likely be more representative of species exposed to the COPCs for a greater duration of their life cycle.

Models can assist in assessing potential exposures and identifying receptors; however, they remain conceptual in nature and are inherently characterized by a number of limitations and uncertainties. It is necessary to continuously evaluate their validity and update the models and study approaches as the understanding of the study area grows. Because of the general nature of the CSM and CM, all exposure pathways and receptors that are exposed to the MC in the strata may not be identified.

3.3.1 Sources, Release Mechanisms, and Transport Media

3.3.1.1 Sources

As discussed previously, the primary source of MC and the related COPCs at Ordnance Reef (HI-06) was the sea disposal of conventional munitions. Other possible sources of metals, pyrene, and phthalates include the WWTP outfall, coastal NPS discharge points and geologic materials. Secondary sources include sediment and water impacted by past or ongoing releases of COPCs from the DMM and, unless controlled, any recovery of munitions or MC that occur (Figure 3-2 and Figure 3-3).

3.3.1.2 Release Mechanisms

Primary Release Mechanism

The primary potential release mechanisms for the COPCs from the DMM to the environment include the instantaneous release of MC at the time of disposal and an incremental release of MC over time due to corrosion (deterioration) causing failure of munition bodies or casings. Deteriorating munitions bodies and casings would incrementally release metals from DMM. Additionally, over time, deterioration could cause bodies or casings to perforate, exposing or releasing fill materials (e.g., energetic, such as RDX); thereby, introducing COPCs to sediments and near bottom seawater (Figure 3-2 and Figure 3-3).

In evaluating release of COPCs from DMM, it is important to consider the nature of the release events. These events include not only the period of initial release of COPCs from individual munitions, but also the period of release and solubilization and/or reaction for all COPCs at the DMM stratum. Nevertheless, there are numerous factors (e.g., sea currents, condition at time of disposal, degree of burial in the sediment) that affect when an individual munition might fail and begin to release its contents. Unbreached underwater munitions potentially take decades to breach and release, and each have their own corrosion rate and breach and release time frame. Given the random distribution and density of the DMM, they can be described as widely scattered about in a pattern with variable distances from one another. As a result, the amount of sediment contamination is limited to the immediate site surrounding the leaking DMM, if any is detected at all.

There are three likely periods of release from sea-disposed DMM. The first is an initial release of a DMM's contents due to material defects or damage caused during or by the disposal process. This release would be followed by a dormant period, during which deterioration of DMM would occur with little or no release of MC. Finally, there is the period of primary release that begins with the development of pinholes followed by corrosive disintegration during which the contents are released into the environment (MEDEA, 1997) (Figure 3-4).

Another possible release mechanism could be attributed to DMM corrosion and dissolution, due to current and wave action, which would result in exposure of more material for diffusion and dispersion. However, this release mechanism is unlikely to occur at the site. Many DMM were observed to be corroded, some even to a point at which much of their thin metal casings were missing, although none of the items were observed to be broken or crumbling. A significant fraction of the items were instead encrusted and the explosives seemed to be essentially intact. Additionally, given the depth of the sites, significant movement of the DMM by current or wave

action, except in extreme conditions, is minimal.The solubility of a given material plays a significant role in its release as corrosion progresses. Pinholes in sea-disposed military munitions may initially allow some COPCs to be released at very low rates (MEDEA, 1997). If the contents are soluble, they may diffuse from the container (i.e., munitions) into the seawater, while seawater will diffuse in the opposite direction through cracks formed from corrosion. The initial rate of COPC outflow will be low, allowing the COPCs to diffuse in the water column and hydrolyze. It is possible for dilution, photolysis, and hydrolysis to effectively reduce some COPC concentrations at a rate comparable to the rate of release, to harmless levels. If this occurs, then there will be no biological harm. If releases are rapid, then the COPC release could be considered an instantaneous release, although this is unlikely for the constituents expected at the study location. In either event, releases can occur only as long as the given materials remain in the munitions.

Secondary Release Mechanisms

Secondary release mechanisms involve the accumulation of contaminants into surrounding media. These may include accumulation of MC in sediment, the suspension of contaminated sediment in the water column, dissolution in the water column, and uptake of the COPCs by biota.

Secondary release mechanisms also may include releases during any recovery of DMM or MC that occurs. Exposures during recovery of DMM may be possible due to the relatively shallow nature of Ordnance Reef (HI-06) (a large part of the study area is accessible to recreational SCUBA divers), and its use for recreational and commercial fishing. Recovery of DMM was considered as a possible exposure route. Recovery of sediments is not considered to be a likely occurrence due to the scarcity of sediments at Ordnance Reef (HI-06) and the infrequency of human contact with the benthos. It is recognized that MC have been released to both the sediment and water column, with the releases occurring post-disposal and at the seafloor. Reasonably, some MC may be both present in the immediate vicinity of DMM and sequestered in the sediments at those specific points. Through the action of naturally-occurring currents at the seafloor, wave action, or human activities (e.g., anchoring, fishing), once sequestered, MC may become dislodged from the sediments. It is likely that, since disposal, MC have been slowly diffusing into the aquatic environment, either from the sediments or as the munitions deteriorate.

Transport Media

Transport mechanisms for COPCs at Ordnance Reef (HI-06) can be associated with natural and anthropogenic activities, including seasonal currents, storm events, human disturbances of the MC, point source (e.g., WWTP effluent release), NPS discharges (e.g., discharge from vessels in transit) and/or aerial fallout or deposition. The diversity of point and NPS can result in inputs of complex mixtures of not only parent COPCs, but also degradation products and metabolites. Additionally, metal COPCs in sediment can reflect inputs from present-day (e.g., NPS discharge, WWTP outfall) and historical sources.

3.3.2 Human Health Conceptual Site Model

The human health CSM identifies the likely contaminant source areas, exposure pathways, and potential human receptors (Figure 3-3). For any contaminant to pose a risk to human health, a

complete exposure pathway must exist between the source (e.g., breached munitions) and receptor. If a complete exposure pathway does not exist, a receptor has an acceptable (i.e., low) risk because it will not be exposed to the contaminant being MC in the Ordnance Reef's (HI-06) case. The identified potential exposure routes for human health exposures include, ingestion of contaminated media (biota, sediment, and seawater) and dermal contact with contaminated sediment and seawater.

3.3.2.1 Potential Human Receptors

This study evaluated current and future recreational or subsistence fishermen, and recreational divers as potential receptors. Additionally, should a response be determined necessary, future response workers were also evaluated as potential receptors. Each of these receptors was first evaluated qualitatively. As necessary, receptors were carried forward into a quantitative HHRA.

3.3.2.2 Potential Human Health Pathways and Exposure Routes

Ingestion of Contaminated Biota

Human exposure to MC by ingestion could occur if contaminated fish, shellfish, seaweed, or other marine organisms are consumed by human receptors. This pathway is considered complete because of the frequent use of the area by recreational and commercial fishermen. MC have the potential to be present in the human food chain at several trophic levels, including seaweed, invertebrates, and fish. For ingestion pathways through the food chain, bioaccumulation of MC by lower trophic level species followed by ingestion of those animals by upper trophic level species could possibly result in the biomagnification of MC. The organic MC (i.e., energetic compounds) have a low potential for bioaccumulation (see discussion in Section 4.1).

Discussions with members of the Wai'anae community identified several biota that are regularly harvested and consumed by local residents. These biota are listed below.

Biota Considered for Exposure Assessment

Common Name	Biota Type
White weke	Fish
Red weke	Fish
Octopus	Invertebrate
Kona crab	Invertebrate
Limu Kohu	Seaweed

Weke were selected as the target fish species after consultation with local fishermen. Weke feed on worms, crustaceans, small mollusks, and heart urchins living in rubble and sand habitats. They are reported as reef-associated, inhabiting sandy bottom reef flat areas, with depth ranges of 16 to 371 ft (5 to 113 m) (www.fishbase.org). These species are relatively stationary, high-end predators that are important local food fish and that might show evidence of biomagnification of contaminants (NOAA, 2007). According to Rainbow (2002), however, "[t]race metal concentrations are not as a rule biomagnified along food chains, the concentration at each trophic level being determined by the trace metal accumulation pattern of the particular species at each trophic level."

The Hawaiian octopus (heʻe) was selected as one of two possible invertebrates targeted for sampling. It is a small species that is found on shallow reef flats and down to depths of 151 ft (46 m) (www.waquarium.org). Octopus are active during the day, feed on reef crustaceans, mollusks, and fish, and are consumed locally.

The Kona crab (pāpaʻi kua loa) is a carnivorous species that lies buried in the sand waiting for prey or food particles (www.swfsc.noaa.gov). The Kona crab, which is also locally consumed, was selected as the second possible invertebrate targeted for sampling, based on its relatively sedentary life history and abundance in the area.

Limu kohu is the algal species selected for sampling. It is one of the most popular species of algae to eat (www.hawaii.edu/reefalgae) and has been reported by community members as being present throughout Ordnance Reef (HI-06). This species is found on the edges of the reef in areas of constant water motion.

Direct Exposure to Sediment and Seawater

The shallow nature of Ordnance Reef (HI-06) makes possible direct exposure to sediment and seawater (through swimming and diving activities) a potentially complete exposure pathway. Sediment and seawater were sampled and evaluated in the HI-06 HHRA. However, based on the lack of analyte detections in the water column samples and because sediments at Ordnance Reef (HI-06) are limited in areal extent and exist in patches, direct exposures to sediment and seawater were ultimately considered to provide an insignificant contribution to total site risk. Sediment and seawater were not included in the quantitative HI-06 HHRA (Appendix G).

3.3.3 Ecological Conceptual Model

The study team developed the Ordnance Reef (HI-06) CM based on EPA's guidance on ERA. EPA's guidance was specifically developed for EPA's Superfund Program (EPA, 1997; EPA, 1998). In the absence of guidance specifically directed at ecosystem risk assessment concerns related to sea-disposed military munitions, the below CM definitions, which were drawn from the above references, were considered appropriate to this study. A CM:

- Describes and depicts predicted relationships between ecological entities and the stressors to which they may be exposed.
- Describes a working hypothesis of how the stressor might affect ecological components. It describes the ecosystem or ecosystem components potentially at risk, and the relationships between measurement and assessment endpoints and exposure scenarios.

3.3.3.1 Potential Ecological Receptors

The shallow nature of Ordnance Reef (HI-06) makes direct exposure, disturbance, and remobilization of MC potential opportunities for exposure. Leakage of MC could lead to direct exposures by benthic and sessile animals, and mobile pelagic species that spend significant time near the seafloor. Direct dermal exposure to MC, gill exposure and uptake, and ingestion of MC are of primary concern for exposed species (Figure 3-2).

Bioconcentration of COPCs by lower trophic level species followed by ingestion of those animals by upper trophic level species could possibly result in the biomagnification of MC; however, as stated previously, trace elements are not, as a rule, biomagnified (Rainbow, 2002). Migration of exposed fish species is also a possibility due to the potential mobility of these species and their predators. These predators may include shore-based seabirds. Ultimate release, transport, exposure, and bioavailability of MC, however, depend greatly on the physical state of the source of contamination. It also depends on both the state of the seafloor where DMM lie (e.g., current, sediment type, grain size, temperature, species present), and the chemical form and nature of the specific environmental contaminant. The chemical form and nature determine a contaminant's potential for uptake, accumulation, biomagnification, and both its propensity for biotic and abiotic degradation or transformation. (None of the MC at Ordnance Reef (HI-06) is considered bioaccumulative, see Section 4.1.)

3.3.3.2 Potential Ecological Pathways and Exposure Routes

Exposure of the biota to MC can occur through a number of pathways. For MC that do not become a part of a long-term repository, leaching and transport to the marine environment may occur. There, exposure of benthic, sessile, and/or non-sedentary organisms may occur. Primary exposure pathways include, but may not be limited to, direct dermal exposure, gill exposure, and ingestion through the food chain. It is expected that food chain pathways will be limited due to the physical and chemical properties of the MC. The primary barriers to exposure include adhesion to sediment (long-term settling flux) and burial, and the potential for the munitions to remain intact keeping the MC contained and not bioavailable, although as noted earlier there is considerable likelihood that some degree of breaching of the DMM has occurred.

Ecological receptors may come into contact with MC *in situ*. Biological receptors that could be in contact with the MC include those living on or near the seafloor. Infauna (organisms such as worms living in the sediment) and epifauna (organisms such as shrimp living on the surface of the sediment) are the primary examples, although higher-level organisms such as bottom fish or reef fish could also come into direct contact with COPCs.

Exposure routes to MC in sediment, seawater, and biota include direct exposure through ingestion or physical contact (e.g., direct contact by infauna) and indirect exposure through food web bioaccumulation. Due to the shallow nature of Ordnance Reef (HI-06), direct contact with contaminated sediment and/or seawater is a possible exposure route for many species associated with the reef. Ingestion of contaminated media by biological receptors can occur by direct ingestion of the MC, or ingestion of contaminated sediment, seawater, or biota. COPCs can dissolve in seawater or sorb (adsorb or absorb) to marine sediments. Ingestion of sediment or exposure to seawater containing COPCs could occur primarily for the epifauna, macroinfauna, infauna, and demersal fish in the vicinity of the site.

The final possibility is the dispersion and diffusion of released COPCs through the water column to the surface. Given the wave regime and currents in the area, and the chemical and physical characteristics (e.g., solubility limit, rate of hydrolysis) of the MC, contact with or ingestion of contaminated water at the surface will not be at a level of concern for ecological receptors.

3.4 Biological Resources

Water Quality and Sediments

Marine waters in Hawai‘i are divided into Class A and Class AA waters under Chapter 11-54-03 Hawai‘i Administrative Rules (HAR) (DOH, 2004). The objective of Class AA waters is to preserve them “in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality of any human-caused source or actions.” The objective of Class A waters is to ensure that their use for recreational and aesthetic enjoyment is protected. The Wai‘anae coast is designated Class A waters from the southern end of Barbers Point to the northern end of Mākua Beach (Wil Chee, 2011). The waters from Mākua Beach to Ka‘ena Point are designated Class AA.

Wai‘anae’s coastal waters receive nutrient inputs from the land, and both physical processes as well as biological activity alter the concentrations of nutrients. Nutrient values fluctuate seasonally and by location causing fluctuations of water quality in the water column. Generally, the open waters of the Hawaiian Islands are nutrient poor (Wil Chee, 2011), i.e., oligotrophic.

Benthic Habitat and Coral Reefs

Wai‘anae’s coastal waters are characterized by rocky intertidal zones, coral reefs, and offshore pelagic and deep-sea marine environments. Intertidal zones provide rocky habitat to marine invertebrates and plants that are specifically adapted to constantly changing levels of exposure to waves and seawater. Pelagic and deep-sea ecosystems off the Wai‘anae coast are vast and support large marine animals like dolphins, whales, sea turtles, and occasionally, the endangered Hawaiian monk seal (NOAA, 2007). Sand, macroalgae, uncolonized hardbottom, and unknown are the four major benthic habitat types found in the marine environment of Ordnance Reef (HI-06). Approximately 50% of benthic habitat is macroalgae. Red algae are the most commonly occurring algae in Hawai‘i, representing four of the five most common species. Green and brown algal species are found in most reefs in smaller numbers (Brainard et. al, 2002; NOAA, 2007).

Coral reefs and hardbottom habitats are found along the length of the Wai‘anae coast and provide food and shelter for reef fish and invertebrates. These areas are fairly heterogeneous with sections of uncolonized hardbottom and sand, and low to high coral cover. Most of the seafloor is uncolonized pavement—a flat hardbottom of volcanic or limestone rock, interspersed with sand channels. However, corals thrive on the artificial reefs and on the armor rock at the inshore WWTP outfall pipeline probably because of artificial topographical relief (Harrison, 1987; Russo, 1997).

Although NOAA (2011) did not conduct a quantitative assessment of coral resources of the Ordnance Reef (HI-06) area, a brief overview of their findings is presented here to provide updated, site-specific information on corals in the area. According to NOAA (2011), “[w]hile a detailed survey of coral species was not conducted, common coral species encountered included: *Pocillopora meandrina*, *P. eydouxi*, P*orites lobata*, *P. evermanni*, *P. duerdeni*, *Leptastrea* sp., and *Montipora* sp.” *Pocillopora eydouxi* was identified by NOAA (2011) as a particularly important species because “…it provides a relatively large amount of three-dimensional structures to the habitat (contributing both to ecological diversity and increased risk of injury).”

Reef Fish

The Wai‘anae coast has few locations with complex habitat. Thus, most of the reef along the coast has low species diversity and biomass. The Wai‘anae coast in general offers relatively few fish species and low numbers of fish; however, there are exceptions where large schools of reef fish have been documented. They include the three artificial reefs—Pōka‘ī Bay Artificial Shoal (created with old cars, concrete pipes and a steel barge in 1963), the Mahi shipwreck (sunk in 1982) and the seaplane wreck (sunk in 1986); the outfall pipe of the WWTP in Wai‘anae town; and the thermal outfall of the Kahe power plant just south of Wai‘anae (Kanenaka, 1991; Harrison, 1987).

The weke (yellowstripe goatfish; *Mulloidichthys flavolineatus*), na‘ena‘e (surgeonfish; *Acanthurus dussumieri*), ‘ū‘ū (menpachi; *Myripristis berndti*), and the saddleback wrasse (*Thalassoma duperrey*) occur in large schools at these sites. Also common are the brown surgeonfish (*Acanthurus nigrofuscus*), Pacific Gregory (*Stegastes fasciolatus*), goldring surgeonfish (*Ctenochaetus strigosus*), and the blackfin chromis (*Chromis vanderbilti*). Moray eels belong in the family Muraenidae in the genus Gymnothorax. These eels are common apex predators with 38 species of morays found on Hawaiian reefs. Individuals are resident to specific reef areas, and feed on a wide range of reef-associated fish and invertebrates (NOAA, 2007).

Protected Species

Several protected marine species occur within the main Hawaiian Islands and in the vicinity of Ordnance Reef (HI-06):

Marine Mammals

Humpback whales are an endangered species protected under both the Marine Mammal Protection Act and the Endangered Species Act (ESA). Humpback whales appear in Hawaiian waters between November and April, which is when they socialize, mate, and give birth. When engaged in singing, nursing, or competition for mates, whales can become very vulnerable to human hazards because their attention is focused on these reproductive activities (NOAA, 2007). The Hawaiian Islands Humpback Whale National Marine Sanctuary boundary is the largest protected breeding ground for these whales and does not include Ordnance Reef (HI-06) nor the Wai‘anae coast (Wil Chee, 2011).

Spinner dolphins (*Stenella longirostris longirostris*) are found around all of the main Hawaiian Islands and are also found at some of the Northwest Hawaiian Islands; however, in contrast to the Northwest Hawaiian Islands, the main Hawaiian Islands are large and offer many potential resting areas for spinner dolphins (NOAA, 2010).

The Hawaiian monk seal (*Monachus schauinslandi*), a Federally listed endangered species, most commonly inhabits the Northwestern Hawaiian Islands. Nonetheless, monk seals are occasionally sighted around the main Hawaiian Islands, including off of Mākua Beach on the Wai‘anae coast. Prominent threats to monk seal populations include entanglement in fishing gear; disturbance by humans, which can cause seals to abandon haul-out areas and their pups; and predation by sharks (NOAA, 2007). Because Hawaiian monk seals were known to be potentially present at Ordnance Reef (HI-06), field sample collection efforts were designed to minimize disturbance or impact to this and other species.

Sea Turtles

The green sea turtle (*Chelonia mydas*), considered the most abundant sea turtle in Hawaiian waters, is listed as a threatened species under the Federal ESA. These turtles can be seen in the waters off Wai‘anae. Threats to green sea turtles occur from land-based and sea-based activities, such as the loss of nesting habitat due to development, nest predation, boat collisions, entanglement in fishing gear, and ingestion of marine pollution (NOAA, 2007).

Hawksbill turtles are distributed throughout the tropics, generally occurring at latitudes from 30 degrees north to 30 degrees south latitude within the Atlantic, Pacific, and Indian Oceans and associated bodies of water. In Hawai‘i, hawksbills nest only on main Hawaiian Island beaches, primarily along the east coast of the island of Hawai‘i. The hawksbill turtle is listed as endangered throughout its range. In the Pacific, this species is rapidly approaching extinction due to a number of factors, but the intentional harvest of the species for meat, eggs, shell, and stuffed curio trade is of greatest impact (NOAA, 2007).

Because endangered hawksbill turtles, threatened loggerhead turtles, and threatened green sea turtles were known to be potentially present at Ordnance Reef (HI-06), field sample collection efforts were designed to minimize disturbance or impact to all of these species.

Corals

At this time, coral species are not protected under the ESA. Nevetheless, pursuant to a petition filed by the Center for Biological Diversity on October 20, 2009, the National Marine Fisheries Service (NMFS) is currently reviewing the candidacy of 82 species of coral for listing as threatened or endangered under the ESA. A Notice of 90-Day Finding on the subject petition was published by the NMFS in the Federal Register (FR) on February 10, 2010 (FR, 2010).

The species petitioned are all corals identified by the International Union for Conservation of Nature (IUCN) as vulnerable, threatened, endangered, or critically endangered. Of the 82 species under consideration, the IUCN has classified 75 as vulnerable, six as endangered, and one as critically endangered. Of these species, 75 occur in the Indo-Pacific and seven occur in the Caribbean-Atlantic region. All of the coral species can be found in the U.S. and its territories; however, many occur more frequently in other countries (CBD, 2009).

Of the 75 corals species occurring in the Indo-Pacific region, nine species are found in the Hawaiian Islands. These are: *Acropora paniculata*, *Cyphastrea agassizi*, *Cyphastrea ocellina*, *Leptoseris incrustans*, *Montipora dilatata*, *Montipora flabellata*, *Montipora patula*, *Pocillopora elegans*, and *Psammocora stellata;* however, of these nine species found in Hawai‘i, none are known to occur within Ordnance Reef (HI-06) or along the Wai‘anae coast (Wil Chee, 2011).

Section 4
Nature and Extent of Contamination

This study focused on identifying the nature and extent of potential contaminant impacts to sediment, seawater, and biota from the presence of DMM at Ordnance Reef (HI-06). The following subsections present a discussion of the fate and transport of the COPCs, and the contaminant results from the sediment, seawater, and biota samples collected at Ordnance Reef (HI-06) (Figures 4-1 through 4-11). The last subsection presents a QA/QC summary. The analytical data are reviewed in the text with respect to applicable standards. A discussion of these results is presented in Section 5. The laboratory analytical reports are provided in Appendix H and the analytical data are summarized on tables provided in Appendix I. Table 4-1 (a through c) provides a summary of sample collection and detections. The results of each analyte groups in each matrix are discussed in detail below. Table 4-2 provides a list of the sites within the DMM stratum sampled based on EPA prioritization, and indicates what DMM types were present, which types of samples were collected, and the proximity of the samples to the DMM at Ordnance Reef (HI-06).

4.1 Fate and Transport

Primary factors affecting transport of COPCs include ambient temperature, solubility (in sea water), density, and available transport methods within a given medium once COPCs are dissolved, suspended, or deposited. Bottom temperatures within the study area are in the range of 75 to 77°F (24 to 25°C), which affect the solubility, rate of chemical reactions, and the physical state. The primary factors affecting fate are chemical degradation mechanics, biouptake, transport through the food chain, and/or sequestration by natural means. Table 4-3 provides a summary of COPCs along with parameters important to their fate and transport in the marine ecosystem. The octanol-water partition coefficient (K_{ow}) and organic carbon partition coefficient (K_{oc}) give indications of the potential for bioaccumulation and possible biomagnification of constituents, including MC, in an ecosystem.

Bioaccumulation is the process by which chemicals are taken up by an organism either from direct exposure to a contaminated medium or through the consumption of food containing the chemical. Bioaccumulation occurs when a chemical is taken up and stored faster than it is eliminated (i.e., metabolized, transformed, and/or excreted) (Corl, 2001). According to Rainbow (2002), trace elements accumulate in two distinct categories: (1) elements in metabolically available forms, and (2) elements that have been detoxified by the organism. In both cases, metallothioneins (a type of protein) are thought to play a role in metabolic regulation of essential elements like copper and zinc and in the detoxification of excess amounts of these essential elements as well as non-essential elements such as cadmium and mercury (Amiard et al., 2006).

Among the more important aspects of bioaccumulation is the process of biomagnification. Biomagnification occurs when the concentration of a chemical increases at each successive level in the food chain. Because an organism at each higher trophic level theoretically consumes many organisms in the level below it, the consumer effectively becomes exposed to the amount of a chemical from all trophic levels below it (Corl, 2001); however, as stated previously, trace

elements are not, as a rule, biomagnified (Rainbow, 2002), and trace element concentrations at each trophic level are "… determined by the trace metal accumulation pattern of the particular species."

Once-released, COPCs may be deposited on the seafloor as free product, dissolved in the water column, or sorbed to sediment particles. COPCs sorbed to suspended particles may settle from the water column and accumulate in sediment. Therefore, sediment can act as the ultimate sink for COPCs from DMM and other sources. The behavior and effect of chemicals in the marine environment depends on their chemical and physical properties and external factors. The properties include water solubility, tendency to transform or degrade (e.g., a compound's half-life), and chemical affinity for solids or organic matter (partition coefficient).

Predictions regarding the fate and transport of chemicals, including MC, and any breakdown products require detailed information about the integrity of the munitions or containers (relates to rate and duration of release), impurities present, temperature, pH, oxidation-reduction potential (ORP), degree of burial in sediment, currents at the disposal site, and on the physical and chemical nature of the chemicals themselves (Helsinki Commission (HELCOM), 1994). Density is a determining factor as to whether a compound will sink or rise to the surface when released (U.S. Army, 2005). Seawater has a density of approximately 8.61 pounds per gallon (lbs/gal) (1.03 grams per milliliter (g/mL)). Because all of the COPCs are denser than seawater, they are expected to sink; however, when dissolved in seawater, the COPCs will diffuse and disperse throughout the water column.

The K_{ow} is the ratio of the concentration of a chemical in octanol and in water at equilibrium and at a specified temperature. This measure indicates the affinity of the compound to accumulate in fatty tissue and is used to help determine the fate of chemicals in the environment. The greater the partitioning to octanol (i.e., the greater the K_{ow}), the greater the potential for bioaccumulation. A compound with a K_{ow} greater than 1,000 (or a log K_{ow} greater than 3) would be expected to accumulate in the food chain in fatty tissue, while a compound with a K_{ow} of less than 500 (or a log K_{ow} of less than 2.70) is not expected to bioaccumulate (Daugherty, 1998).

K_{ow} is typically determined at a temperature of 68 or 77°F (20 or 25°C) and at standard atmospheric pressure. The Ordnance Reef (HI-06) study area is approximately 33 to 121 ft (10 to 37 m) deep, resulting in pressures of 14 to 59 pounds per square inch (psi) (one to four atmospheres) or more and temperatures of approximately 75 to 77°F (24 to 25°C). It is not known how pressure at the study site alters the effective K_{ow} and hence bioaccumulation.

None of the Ordnance Reef (HI-06) COPC has a log K_{ow} greater than 2.5 at standard temperature and pressure. In shallow conditions, none of the constituents is anticipated to significantly bioaccumulate or biomagnify in living tissue. As reported in the USCHPPM Health Risk Evaluation (USACHPPM, 2007), past research has indicated that explosives are rapidly biotransformed even in worst-case laboratory studies and it would be unlikely to detect them in fish tissue. As reported in Lotufo and Lydy (2005) explosives and related compounds have low potential to bioconcentrate in aquatic organisms as expected given their weak hydrophobicity.

Similarly, the K_{oc} is a measure of the degree to which a contaminant in water will adsorb to organic carbon in the environment. Often this leads to sequestration of the contaminant in sediments containing high concentrations of organic carbon.

The degree of risk associated with leaking munitions or MC (e.g., explosives, metals) that leach into seawater depends on numerous factors. The potential for harm is a function of the rates of release, degradation or sequestration, the extent to which a constituent is diluted, toxicity, dose and the duration of exposure.

4.1.1 Energetics

The study evaluated the potential effect of conventional munitions on the composition of sediment, seawater, and human food item biota by analyzing for energetics (i.e., explosives and propellants) and their degradation products. The corrosion of the metal casings of conventional munitions and consequential leakage of the fill can release energetics and their degradation products to the environment. The fate and transport processes believed most applicable to energetics in sediment and marine environments are biotic transformation, oxidation or reduction, covalent bonding, and sorption to sediment substrates. Most conventional MC (energetics) are relatively polar, but have low solubility in water and low vapor pressure (Table 4-3).

Commonly occurring conventional MC include explosives, propellants, impurities, and degradation compounds. As a group, military explosives have relatively low water solubilities and are relatively immobile in water. The degradation and dissolution of these materials may be slowed by the physical structure and composition of blended explosives (e.g., in Composition B, the dissolution rate of RDX controls the dissolution rate of TNT).

The TNT transforms via a sequential reduction of its nitro groups (Yost et al., 2007). It has been noted that dissolution rates of TNT are somewhat slower in saline water than in fresh water. TNT is rapidly removed from solution in sediment slurries with half-lives ranging from 2.8 to 7.3 hours in both fresh and saline solutions. Formation of the TNT transformation products 2-Am-DNT and 4-Am-DNT was noted in the sediments tested (Brannon et al., 2005). A rapid drop in aqueous concentration appears related to the sorption of the compounds to sediment. The rate is related to the cation exchange capacity (CEC), organic carbon content, and particle size (Brannon et al., 2005).

Experiments on the fate and effects of MC (TNT) on fish and invertebrates in field studies showed no significant impacts on body indices, hematological variables, hepatic detoxification, and antioxidant enzyme activities in fish (Ek et al., 2006). In the same study, no detectable levels of TNT or degradates thereof were found in sediments, bile, and blood plasma of fish, and hepatopancreas of mussels (Ek et al., 2006). Dissolution rates of TNT from munitions casings appeared to be relatively slow, with no continuous increase in acute sediment toxicity over time (Ek et al., 2006). Laboratory studies of rainbow trout exposed to TNT indicated that these fish were able to detoxify and excrete TNT (Ek et al., 2005).

A study of microbial degradation of MC (RDX) in tropical marine sediments collected in Hawai'i indicated that cyclic nitramine contaminants are likely to be degraded upon release from munitions into tropical marine sediment (Bhatt et al., 2005), suggesting natural attenuation *in situ*.

The MC explosive D, ammonium picrate, is an ammonium salt of picric acid and under normal aqueous conditions will dissociate to ammonium and picrate ions. In sediment slurry tests, picric acid was found to remain in the aqueous phase with little partitioning to the sediments.

Transformation to picramic acid was limited (Yost, et al, 2007). It is likely that the ions would transform further depending on the ORP conditions. For this study, picric acid was included in the list of COPCs as a conservative measure.

The MC (nitroglycerin) is a common energetic material used in double base (nitroglycerin and nitrocellulose) gun propellants, and will leach out of the nitrocellulose matrix in double base gun propellants. Nitroglycerin has a moderate range of aqueous solubility, with a half-life range of 37 to 96 days at pH 9 (Mirecki et al., 2006). The predominant products of nitroglycerin via hydrolysis are calcium nitrate and calcium nitrite. Nitroglycerin has a low log K_{ow} value, suggesting hydrophilic behavior and a low log K_{oc} value, indicating limited sorption, thus mobile in soil environments. Nitroglycerin has been documented to transform via microbial mediation in both aerobic and anaerobic conditions, ultimately forming glycerol (Mirecki et al., 2006).

4.1.2 Trace Elements/Metals

The trace elements and metals of potential concern have relatively low solubility and are likely to accumulate in sediment and due to their elemental nature – may oxidize or react with other materials but will not break down.

Metal concentrations in sediments vary in relation to grain size and primary mineralogy. The sediment fraction under 7.87×10^{-5} in (2 micrometers (μm)) is a major sink for contaminants introduced into natural waters, due to the high surface available for adsorption, and the associated coatings of organic material and iron and manganese oxyhydroxide precipitates. These substances scavenge dissolved trace metals from the water column and deposit them with the sediments (Stumm and Morgan, 1996).

4.1.2.1 Arsenic

The sediment characteristics, namely pH, organic matter content, clay content, iron oxide content, aluminum oxide content, and CEC, have an effect on the adsorption of arsenic. Arsenic may adsorb from water onto sediments or soils, especially clays, iron oxides, aluminum hydroxides, manganese compounds, and organic material. Iron content has a significant influence on arsenic adsorption; however, arsenic that adsorbs onto iron and manganese oxides may be released under reducing conditions (ATSDR, 2007). Transport and partitioning of arsenic in water depends upon the chemical form (oxidation state and presence of complexing agent ions) of the arsenic and on interactions with other materials present. One source of arsenic in the water column can be re-suspended sediment. While arsenic bioaccumulates in animals, biomagnification in aquatic food chains does not appear to be significant (ATSDR, 2007).

4.1.2.2 Copper

In sediment, copper is generally associated with mineral matter or is tightly bound to organic material. Copper is usually associated with fine as opposed to coarse sediment. The fate of copper in the aquatic environment is determined by the formation of complexes, sorption to hydrous metal oxides and organic matter. The formation of complexes with organic ligands modifies the solubility and precipitation behavior of copper. Between a pH 5 and 6, adsorption is the primary process for removing copper from the water column; above pH 6, precipitation becomes dominant (World Health Organization, 2003). Typically, seawater is about pH 8 thus, copper is expected to precipitate at Ordnance Reef (HI-06).

4.1.2.3 Lead

Sorption sequesters the concentration of soluble lead in water. The tendency for lead to form complexes with organic matter increases its adsorptive affinity for clays and mineral surfaces. Benthic microbes can methylate lead to a volatile and more toxic form. Lead in its inorganic form does not tend to biomagnify (http://www.epa.gov/R5Super/ecology/html/toxprofiles.htm).

4.2 Results of Phthalates and Pyrene Analysis (Seawater and Biota Only)

4.2.1 Phthalates and Pyrene in Seawater

There were no detections of phthalates or pyrene in any of the seawater samples collected during the September to October 2009 sampling event, with one exception (Table 4-4 and Appendix I, Table I-1). Bis(2-ethylhexyl)phthalate was detected in a single seawater sample (ORD107W) collected from the WWTP stratum at a concentration of 1.4 micrograms per liter (µg/L), estimated, i.e., exceeding the MDL but less than the reporting limit (RL). This value is thus flagged as an estimated value in Table 4-4 (note that bis(2-ethylhexyl)phthalate is also a common laboratory artifact).

4.2.2 Phthalates and Pyrene in Biota

Neither phthalates nor pyrene were detected in any of the biota samples collected in either sampling event with one exception (ORD004F DUP). In this sample, di-n-butyl phthalate was detected at an estimated concentration of 1.2 mg per kilogram (mg/kg), but it was not detected in the corresponding primary sample (Appendix I, Table I-2).

4.3 Results of Energetics (MC) Analysis

4.3.1 Energetics in Seawater

Energetics were not detected in any of the seawater samples analyzed as part of this study (Appendix I, Table I-3).

Seawater samples collected during the September and October 2009 sampling event were also analyzed for additional 8330 energetics (i.e., 3,5-dinitroaniline, 2-nitrophenol, 4-nitrophenol, 2,4-dinitrophenol, and picramic acid). Although these energetic are not considered COPCs for seawater, the data are presented in the laboratory reports (see Appendix H) and the results are summarized on Table I-6. There were no energetics detected in the seawater samples.

Due to low laboratory control sample (LCS) recoveries, samples ORD005W through ORD009W (SDG G9D140192 amended) were re-extracted outside of the seven-day hold time along with a new set of QC (see laboratory reports in Appendix H). All associated samples were non-detects and were flagged "UJ" by they validator (see validation reports in Appendix K). The analytical results presented in the data summary tables are those of the original samples, with the appropriate validation qualifiers, that were extracted within the required hold times (see Appendix I, Table I-3).

4.3.2 Energetics in Sediment

The MC compounds 2,4-DNT, 2,6-DNT, and 1,3,5-trinitrobenzene (TNB) were the only energetics detected in the sediment samples collected in either sampling event (Table 4-4; Appendix I, Table I-4 and Table 4-1a for the frequency of detections). Compounds 2,4-DNT and 2,6-DNT were detected in a total of 12 primary samples and a single duplicate. All but two of these samples were collected from the DMM stratum. The other two samples were collected from the WWTP stratum. MC compound 1,3,5-TNB was detected in a total of six primary samples and a single duplicate sample. The primary sample associated with the the duplicate, which contained a detection of 1,3,5-TNB, did not contain a detection. Of the samples that contained detections of 1,3,5-TNB, two were collected from the NPS stratum, two were collected from the CON stratum, two were collected from the DMM stratum, and one was collected from the WWTP stratum. All detections of energetics were below the screening levels, except in two sediment samples, which were collected in the September to October 2009 sampling event. These samples contained estimated concentrations of 2,4-DNT that met or exceeded the EPA Residential Soil Screening Level of 1.6 mg/kg or parts per million (ppm). The estimated concentrations were 3.30 mg/kg in a sample collected at site DMM11 and 1.60 mg/kg in a sample collected from sample site DMM13 (Table 4-4; Appendix I, Table I-4). There is no available ecological toxicity screening level for 2,4-DNT.

All detections occurred in samples that were collected near naval and/or 0.50 caliber rounds, except ORD024S. A propellant grain was collected with this sediment sample. Sampling distances were either 0 or 4 ft (0 or 1.2 m) away from the DMM. Samples collected at further distances were not analyzed (i.e., samples were sent to the laboratory, but were held pending the results of other samples). There were five sampling sites (DMM1, DMM3, DMM10, DMM11, and DMM13) that exhibited detections in both the 0 and 4 ft (0 and 1.2 m) distance samples. With the exception of DMM3, the detections in the 4 ft (1.2 m) distance samples were higher than those at 0 ft (0 m) (Table 4-2; Table 4-4; Appendix I, Table I-4).

Sediment samples collected during the September and October 2009 sampling event were also analyzed for additional 8330 energetics (i.e., 3,5-dinitroaniline, 2-nitrophenol, and 4-nitrophenol). Although these energetics are not considered COPCs, the data are presented in the laboratory reports (see Appendix H) and the results are summarized on Appendix I, Table I-6. There were no energetics detected in the sediment samples.

Picric acid was re-analyzed in samples ORD005S through ORD016S (SDG G9D160182 amended 2) and ORD017S through ORD034S (SDG G9D160175 amended) due to failed QC in the initial analysis (see Appendix H). The re-analysis results for picric acid are presented in Appendix I, Table I-3.

4.3.3 Energetics in Biota

Several energetics compounds (2,4-DNT, high melting explosive (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) (HMX), 2-nitrotoluene (NT), 4-NT), RDX, tetryl, and 1,3,5-TNB were detected in biota samples collected from Ordnance Reef (HI-06). These detections occurred primarily in fish samples, although one octopus and one crab also contained at least one energetic compound (both marked as estimated values) (Table 4-4; Appendix I, Table I-5 and Table 4-1a for the frequency of detections).

Biota samples were also analyzed for additional 8330 energetics (e.g., 3,5-dinitroaniline, 2-nitrophenol, and 4-nitrophenol). Although these energetics are not considered COPCs, the data are presented in the laboratory report (see Appendix H) and the results are summarized on Appendix I, Table I-6. Two energetic compounds (3,5-dinitroaniline and 2-nitrophenol) were detected in fish samples collected from Ordnance Reef (HI-06). There were detections of 3,5-dinitroaniline in three samples (ORD128F, ORD133F, and ORD134F) and a detection of 2-nitrophenol in a single sample (ORD120F). All detections were at estimated values.

4.3.3.1 Energetics in Octopus

MC (HMX) was detected at a concentration exceeding the MDL, but not exceeding the RL, in a single octopus sample (ORD012O) that was collected from the DMM stratum during the April 2009 sampling event (Table 4-4; Appendix I, Table I-5). This sample, which was collected at site DMM8, was collected 4 ft (1.2 m) away from two projectiles and 8 ft (2.4 m) away from two other projectiles (Table 4-2; Appendix C). There were no other detections during either season of sampling.

4.3.3.2 Energetics in Crab

MC (1,3,5-TNB) was detected at a concentration exceeding the MDL, but not exceeding the RL, in a single crab sample (ORD005C) that was collected from the WWTP stratum during the April 2009 sampling event (Table 4-4; Appendix I, Table I-5 and Table 4-1a for the frequency of detections). The sample was not collected in proximity to any DMM. No other detections occurred during either season of sampling.

4.3.3.3 Energetics in Fish

MC (1,3,5-TNB) was detected at a concentration exceeding the MDL, but not exceeding the RL, in a single fish sample (ORD014F) that was collected from the control stratum during the April 2009 sampling event. There were 16 primary fish samples and a single duplicate sample collected during the September to October 2009 sampling event that contained detectable levels of one or more energetics compounds. These included three fish samples from the NPS stratum and 13 primary fish samples and a single duplicate sample from the DMM stratum. Of the three fish samples from the NPS stratum, two contained quantifiable amounts of HMX, while the third contained 2,4-DNT. The 14 fish samples collected from the DMM stratum contained one or more of the following: 2,4-DNT, HMX, 2-NT, 4-NT, RDX, and tetryl (Appendix I, Table I-5 for a summary of results and Table 4-1a for the frequency of detections).

Although not considered COPCs, 3,5-dinitroaniline, 2-nitrophenol, and 4-nitrophenol were detected in fish samples collected during the September to October 2009 sampling event. There were detections of 3,5-dinitroaniline in three samples (ORD128F, ORD133F, and ORD134F) and a detection of 2-nitrophenol in a single sample (ORD120F). All detections were at estimated values (Appendix I, Table I-6 for a summary of the results and Table 4-1a for the frequency of detections).

4.3.3.4 Energetics in Seaweed

There were no energetics detected in the seaweed samples analyzed (Appendix I, Table I-5 and Table 4-1a).

4.4 Results of Elemental Analysis (Sediment and Biota only)

4.4.1 Grain Size Fraction Analysis

Sediment samples from four strata (CON, DMM, WWTP, and NPS) and from the two sampling events (April 2009 and September to October 2009) were sieved into three grain-size fractions. These grain size categories were: a) clay-silt (less than 63 µm), (b) sand (between 63 µm and 2 mm), and (c) gravel (greater than 2 mm)). On average, the WWTP and DMM strata contained about 45% sand. Sediment from the DMM and WWTP strata averaged slightly more than 50% gravel. The WWTP stratum displayed the greatest variability in the abundance of both sand and gravel fractions. The study team noted that during sample processing some of the gravel-size fraction of the DMM sediments included fragments of DMM casings. The sediments from the CON and NPS strata contained very little gravel (7.1% and 0.21%, respectively), which consisted primarily of coral rubble or volcanic rock. Sediments collected from the NPS stratum consisted overwhelmingly of the sand fraction (98.4%).

Sediments collected during the September to October 2009 sampling event had slightly different size distributions than those collected in April 2009 of that year. Sediments collected during the September to October 2009 sampling event all had less than 1.5% silt and clay. Samples from the WWTP stratum had the highest proportion of clay-silt (1.5%), followed by the CON stratum (0.94%). Sediments from the DMM and NPS strata exhibited a slightly lower mean clay-silt content (0.7% and 0.6%, respectively) than CON and WWTP strata. Sediments from the second sampling round collected at the other three strata (NPS, WWTP and DMM) contained, on average, about 70% sand with a corresponding decrease in the abundance of the gravel fraction, compared to sediments collected during the first round sampling. Sediments from the CON stratum displayed the greatest variability in the abundance of both the sand and gravel fractions. The size distributions between each season are slightly different with more similar size distributions between sample sites observed during the September to October 2009 (second) sampling event (Appendix J-Figure 5).

4.4.2 Elemental Composition of Sediment Samples (Non-COPC Elements)

Summaries of the representative major and minor (aluminum, calcium, iron, magnesium, manganese, strontium, silicon) and trace elemental composition (vanadium, chromium, cobalt, nickel, copper, zinc, arsenic, cadmium, barium, lead, and uranium) of the combined fractions of clay-silt and sand sediment samples from each of the four strata (CON, DMM, WWTP, and NPS) and both April 2009 and September to October 2009 sampling events are presented in Table 4-5. Included in Appendix I is a summary table of individual sediment metal results that were used in creating Table 4-5 Compiled Sediment Metal Results (Appendix I, Table I-7). The complete validated reports are provided in Appendix K. Table 2 of Appendix J, also presents a summary of statistics of the elemental composition of the clay/silt and sand fractions of sediments collected during the 2009 sampling events. The elemental composition of the gravel fraction was not determined as visual examination during sample processing indicated this size fraction consisted primarily of larger coral rubble and fragments and volcanic pebbles, neither of which were expected to be important carriers of metal COPCs. The averaged sediment compositional data from Table 4-5 are the focus for the discussion of results below. The chemical composition of sediments is characterized by substantial variability between the different strata as well as between samples from various sites within each specific stratum.

4.4.3 Trace Elements in Sediment

Although trace elements (heavy metals and arsenic) were detected in sediment samples from all strata, the majority of samples had concentrations of COPC elements that were below the screening levels (Table 4-5). In combining both sampling events (April 2009 and September to October 2009), 1 of 17 samples collected from the CON stratum; 24 of 27 samples collected from the DMM stratum; and 5 of 16 samples collected in the WWTP stratum contained copper at concentrations that exceeded the screening level. For arsenic, 15 of 17 samples collected from the CON stratum; 1 of 27 samples collected from the DMM stratum; and 1 of 16 samples collected in the NPS stratum contained arsenic at concentrations that exceeded the screening level. No WWTP samples had arsenic concentrations above the screening level. For lead, 1 of 17 samples collected from the CON stratum; 4 of 27 samples collected from the DMM stratum; 2 of 16 samples collected in the WWTP stratum; and none of the 16 NPS samples collected contained lead at a concentration that exceeded the screening level (Table 4-5).

For copper, during the April 2009 sampling event, 1 of 12 samples collected from the CON stratum; 12 of 15 samples collected from the DMM stratum; and 3 of 12 samples collected from the WWTP stratum contained copper at concentrations that exceeded the screening level. During the September to October 2009 sampling event, all 12 samples collected from the DMM stratum; and 2 of 4 samples collected from the WWTP stratum contained copper at concentrations that exceeded the screening level. None of the samples collected from the CON stratum during the September to October 2009 sampling event, and none of the samples collected from the NPS stratum in both the April 2009 and September to October 2009 sampling events contained copper at concentrations that exceeded the screening level (Table 4-5).

For arsenic, during the April 2009 sampling event, all 12 samples collected from the CON stratum and 1 of 12 samples collected from the NPS stratum contained arsenic at concentrations that exceeded the screening level. During the September to October 2009 sampling event, 3 of 5 samples collected from the CON stratum; and 1 of 12 samples collected from the DMM stratum contained arsenic at concentrations that exceeded the screening level. None of the samples collected from the DMM stratum during the April 2009 sampling event, none of the samples collected from the NPS stratum during the September to October sampling event, and none of the samples collected from the WWTP stratum in both sampling events contained arsenic at concentrations that exceeded the screening level (Table 4-5).

For lead, during the April 2009 sampling event, 1 of 12 samples collected from the CON stratum; 4 of 15 samples collected from the DMM stratum; and 2 of 12 samples collected from the WWTP stratum contained lead at concentrations that exceeded the screening level. None of NPS samples collected during the April 2009 sampling event, and none of the CON, DMM, NPS, and WWTP samples collected during the September to October 2009 sampling event contained lead at concentrations that exceeded the screening level (Table 4-5).

The CON stratum sediment samples contained the highest concentrations of arsenic. The DMM stratum sediment samples contained the highest concentrations of lead and copper.

Although not considered a heavy metal COPC, chromium was found in concentrations greater than the screening level (37.3 mg/kg) in 15 of 17 CON stratum site samples combining the April 2009 and September to October 2009 sampling events, with the highest sample concentration at 112.9 mg/kg. There were no DMM or NPS samples from either sampling period that had

chromium at concentrations greater than the screening level. While 6 of 12 April 2009 WWTP samples had chromium at concentrations greater than screening level, none of the September to October 2009 samples had chromium at concentrations greater than the screening level.

4.4.4 Trace Elements in Biota

The biota samples were analyzed for the three COPCs (arsenic, copper, lead) and a suite of other elements not considered to be COPCs (barium, cadmium, chromium, cobalt, mercury, nickel, vanadium, and zinc). Arsenic was also speciated into organic and inorganic forms (Appendix I, Table I-8). During the September to October 2009 sampling event, an analysis was also conducted on additional analytes (i.e., aluminum, calcium, iron, magnesium, manganese, and titanium). Although these metals/trace elements are not considered COPCs, the data is presented in the laboratory reports. The results of the additional metal analyses are presented in Appendix I, Table I-9 Additional Metals and Other Trace Elements in Biota. The elemental composition of each type of biological sample is given in Appendix J, Section IV. For the majority of samples, most (approximately 99%) of the arsenic is present in the organic or less toxic form (organic arsenic is calculated as the difference between total arsenic and inorganic arsenic) in crab, octopus, and fish.

4.4.4.1 Trace elements in he'e (octopus)

Concentrations of trace elements in octopus tissue are given in Appendix J, Section IV, Figure 10. The average concentrations of arsenic in octopus that was collected during the April 2009 and September to October 2009 sampling events span a relatively narrow range from 29.8 mg/kg to 22.5 mg/kg. Concentrations of zinc were between 9.0 mg/kg and 24.0 mg/kg, except for an octopus (ORD006O) caught next to multiple 0.50 caliber rounds at the DMM2 sampling location, which contained 51.6 mg/kg of zinc. The concentrations of copper in octopus varied more widely than those of arsenic or zinc among octopus and between the two sampling periods. In April 2009, the range in the concentration of copper was from a low of 6.8 mg/kg in octopus captured in the CON stratum to 90.3 mg/kg in an octopus from the DMM stratum. During the April 2009 sampling event, the averages were: 15.7 mg/kg of copper in the NPS stratum, 16.1 mg/kg in the WWTP stratum, 17.3 mg/kg in the CON stratum, and 44.6 mg/kg in the DMM stratum. During the September to October 2009 sampling event, the range of concentrations within and between sites was not as broad. The overall range was from 2.6 to 12.7 mg/kg of copper with averages of 4.7 mg/kg of copper in octopi from the CON stratum to 7.4 mg/kg in octopi from the DMM stratum. Concentrations of most other elements, including cobalt, chromium, mercury, nickel, lead, selenium, vanadium in octopus tissue were all low, ranging from undetected to only 0.6 mg/kg. The concentrations of cadmium, however, displayed a wider range from undetected to 3.5 mg/kg across the four strata.

4.4.4.2 Trace elements in weke (goatfish)

Trace element concentrations in weke were universally very low as can be seen in Appendix J, Section IV, Figure 11 and Table I-8. The concentrations of arsenic ranged from 4.4 to 38.8 mg/kg across the sites with the majority of the highest concentrations found in weke from the NPS and CON strata. Weke typically contained only a few mg/kg of zinc (ranging from 2.2 to 6.5 mg/kg) in weke caught during both sampling seasons and no obvious differences were observed between weke collected in the various strata, except for two (ORD015F) caught in the

CON stratum during the April 2009 sampling event (7.8 mg/kg zinc) and (ORD133F) in the DMM stratum during the September to October 2009 sampling event (an estimated 7.8 mg/kg zinc). Most of the other elements displayed concentrations below 1 mg/kg.

4.4.4.3 Trace elements in Kona crab

The Kona crabs sampled in this study were not found throughout all strata from Ordnance Reef (HI-06); none were collected from the CON strata. Additionally, only a subset of the crabs (males) caught were analyzed; all female crabs were released because they are illegal to collect. Appendix J, Section IV, Figure 12 and Table I-8 provide the results of the analysis of the trace elements in the crabs. All inorganic COPC (arsenic, copper, lead) were detected in crabs. The highest overall concentration of arsenic was found in crabs collected from the WWTP stratum (52.4 mg/kg) during the September to October 2009 sampling event and from the DMM stratum during the April 2009 sampling event (51.2 mg/kg), but were generally lower, the average for all samples was about 36.5 mg/kg, for the rest of the crabs for both seasons. The maximum zinc concentrations measured during this study was 59.2 mg/kg (ORD006C) in a crab trapped at the WWTP stratum during the April 2009 sampling event; however, concentrations in other crabs were only slightly lower and varied from about 30 to 56 mg/kg, except for two samples during the April 2009 sampling event (3.2 mg/kg and 3.6 mg/kg zinc). The concentrations of copper varied in crabs from within each stratum, with most results ranging from 5 to 15 mg/kg copper regardless of the season or the stratum. Lead was detected in a single sample (ORD107C) in the WWTP strata (2.4 mg/kg) during this study. Excepting strontium, concentrations of other elements in crab tissue were low, ranging from undetected to only 1.6 mg/kg.

4.4.4.4 Trace elements in limu kohu (seaweed)

The range of concentrations of trace elements in seaweed (Appendix J, Section IV, Figure 13 and Table I-8) was very different from those observed for the octopus, fish and crab data. The elemental concentrations were nearly identical to each other in samples collected from the various strata during the September to October 2009 sampling event. The concentrations of arsenic, however, were higher in seaweed collected during the April 2009 sampling event, with a maximum concentration observed in samples from the NPS stratum (1.5 mg/kg). However, the overall average for the April 2009 sampling event was 0.82 mg/kg, compared to the overall average of 0.97 mg/kg arsenic for seaweed collected during the September to October 2009 sampling event. One DMM stratum sample (ORD019L) differed notably from the rest, with rather high concentrations of zinc (263 mg/kg) and copper (25 mg/kg) (see Appendix I, Table I-8). The study team considers this sample to be an outlier. Because concentrations of these elements were likely derived from inclusion of sediment in the sample during processing, this sample was not included in the data analysis. The concentrations of lead in seaweed ranged from 0.12 to 1.10 mg/kg across the sites and the seasons. The concentrations of the other elements in seaweed were generally low and below levels of concern.

4.5 QA/QC Summary

4.5.1 Review of QC Data

Laboratory QC is established through the collection of specific samples and data to identify potential problems or complications that may compromise data quality. The types of samples

and data collected and the associated qualifiers resulting from the QC process are described below. For metal analysis in sediments, the QC data was generated for individual isotopes and particle sizes. The validation was conducted for these individual results (Appendix I, Table I-7; Appendix K). Precision, accuracy, representativeness, comparability, and completeness (PARCC) parameters are used to evaluate the usability of all analytical data. This is discussed in greater detail in Section 4.5.3 and Section 4.5.4. Although the paragraphs immediately following describe various anomalies with regard to the analytical data, the PARCC parameters are considered acceptable. The data are thus considered suitable for their intended use in this study and the associated HHRA and ERA.

4.5.1.1 Matrix Spike/Matrix Spike Duplicate

A matrix spike (MS) sample is an aliquot of a matrix spiked with known quanitities of specific compounds and subjected to an entire analytical procedure in order to indicate the appropriateness of the method for a particular matrix. The spiking occurs in the laboratory using a matrix sample from the site prior to sample preparation and analysis. An MS sample is used to document the bias of a method in a given sample matrix. The percent recovery for the respective compounds is then calculated. The matrix spike duplicate (MSD) is a second aliquot of the same matrix as the MS, also spiked, in order to determine the precision of the method. The spiking, which is conducted in the laboratory, occurs prior to sample preparation and analysis. The results are used to document the precision and bias of a method in a given sample matrix.

In the analysis of sediment for energetics, picric acid was found to have low recoveries in most of the MS and MSD (MS/MSD) samples. The relative percentage difference (RPD) of these MS/MSD sets, however, was within the control limit. However, due to low recoveries (LCS and MS/MSD) for picric acid in samples ORD005S through ORD016S (see Appendix H, SDG G9D160182 amended 2) and ORD017S through ORD034S (see Appendix H, SDG G9D160175 amended), the samples were re-extracted and re-analyzed outside of the hold time. The re-extracted LCS and MS again had low picric acid recoveries, which could indicate a low bias for the analyte in the associated field samples (see Appendix H, SDG G9D160182 amended 2 and SDG G9D160175 amended). Therefore, picric acid results for all associated samples were validator flagged as "UJ" (see Appendix K). Low MS/MSD recoveries were also observed in picramic acid. The RPDs for both MS/MSD sets were out of the control limit. All associated samples were validator flagged "UJ" (see Appendix K). A high recovery of 2,4-DNT was observed in one MS/MSD sample. The RPD for the 2,4-DNT MS/MSD set was also out of the control limit. Associated samples with positive 2,4-DNT results were validator flagged "J". Nitrobenzene was observed with a high recovery in one of the MS/MSD samples. All nitrobenzene results were non-detects, so no data qualification was required by the validator (see Appendix K). In the MS analysis for metal sediment samples, there were observations of MS recoveries out of control limits for each isotope in one or more analytical batches and associated samples were validator flagged (see Appendix K).

The single anomaly observed in the MS/MSD analysis for energetic analysis of water samples was 4-Am-2,6-DNT. The recoveries of this compound were slightly lower than the control limit in two of the four MS/MSD samples.

In the analysis of water samples for phthalates and pyrene, an MSD was not performed due to the limited sample volume. The limited sample volume resulted when a bottle cap cracked during

shipment causing some MS/MSD water sample volume to be lost. The MS sample that was analyzed met the QC requirements.

In the analysis of biota samples for energetics the recoveries of tetryl in a few fish and one crab MS/MSD samples were lower than the laboratory control limit. The RPDs of tetryl were also out of the control limit in several fish and crab samples. All associated results with failed MS/MSD were rejected by the primary data validator. However, following a secondary validation by Laboratory Data Consultants of tetryl results for SDG G0C240536 and SDG G0C240547, only the parent sample of the failed MS/MSD (ORD040F) was rejected (see Appendix K). Note, other rejected tetryl results in fish were due to other failed QC (e.g., LCS). High MS/MSD recoveries were observed for 1,3,5-TNB in octopus samples. Since all results were non-detects, no data qualification by the validator was required (see Appendix K).

In the analysis of biota samples for metals, some metals exhibited MS/MSD recoveries out of the control limit. Among these, strontium and mercury had relatively frequent low recoveries. Other metals that exhibited low recoveries included copper, lead, arsenic, antimony, cadmium, nickel, and selenium. Most of these trace elements exhibited recoveries only slightly lower than the corresponding control limits. Strontium and copper, however, exhibited high recoveries in one or two MS/MSD samples. The RPDs were all within the control limit, except for mercury in one MS/MSD sample set for fish tissue. Where MS displayed recoveries outside of control limts, associated results were validator flagged "J" or "UJ" if the percent recovery was less than the lower control limit and "J" if the the percent recovery was greater than the upper control limit (see Appendix K).

Despite these anomalies, the PARCC parameters are considered acceptable (Please refer to Section 4.5.3 and Section 4.5.4 for the PARCC parameter evaluation). The data are thus considered suitable for their intended use in this study and the associated HHRA and ERA.

4.5.1.2 Field Duplicates and Laboratory Duplicates

A field duplicate is a split sample that is collected and analyzed in a manner identical to that of the primary sample. These samples, which were submitted to the primary laboratory (TestAmerica), serve as "blind" duplicates. The results of "blind duplicates" are used to evaluate the sampling procedures and precision of the laboratory analyses. Laboratory duplicates are different aliquots of the same sample prepared in the laboratory. They are analyzed to evaluate the precision of the laboratory's performance. Results of both field duplicates and laboratory duplicates are expressed as the RPD between analytical results for the duplicate and the original sample. The RPD is affected by the sample matrix homogeneity. It is expected that solid matrices will have a greater variance than the aqueous matrices due to the difficulty in homogenizing the solid samples.

Field duplicate sediment and water samples were collected and analyzed for energetics. Field duplicate seawater samples were collected and analyzed for phthalates and pyrene. There were no anomalies observed in the field duplicates regarding RPDs. For the sediment metal analysis, the RPDs of laboratory duplicates were found outside of the control limits for chromium-53, cobalt-59, cadmium-111, zinc-66, zinc-68, and uranium-238 in one or more batches.

It was not feasible to collect field duplicates for the biota samples. However, the laboratory prepared laboratory duplicates to evaluate performance. Most of the results for the energetic

duplicates were non-detects. However, the RPDs for those detects were within the control limits, with the exception of HMX, which had a high RPD in one fish sample duplicate (ORD104F DUP).

For the phthalates and pyrene duplicates, most of the results were non-detects. The only anomaly observed in RPDs was for di-n-butyl phthalate. This was observed in fish samples, with the primary result a non-detect and the field duplicate with an estimated value.

In biota metal analysis, quite a few metal duplicates had RPDs outside of the control limits. These metals include barium, strontium, copper, selenium, vanadium, cobalt, chromium, mercury, nickel, lead, cadmium, and zinc. Barium, strontium, copper, selenium and vanadium had relatively more frequent high RPDs. The observation is not unexpected due to the heterogeneity of the biota tissues.

4.5.1.3 Method Blank

Method blank (MB) is an analytical control consisting of all reagents, which may include internal standards and surrogates, and is carried through the entire analytical procedure. The MB data is used to evaluate any laboratory contamination during analysis.

For the biota analysis, the laboratory prepared the MB for the energetics analysis from tissues, which were assumed to be clean, that were obtained from a local Hawai'i fish market. Similar, tissues were used in the MDL study. For phthalates, pyrene and metal analysis, the laboratory prepared two sets of MB samples. One set was the aforementioned blank tissues; the other was prepared from the laboratory standard solid components.

There were no anomalies observed in the MBs for energetics in the sediment samples. Negative and positive blank results were observed in some batches in sediment metal analysis. There were no anomalies observed in the MBs for energetics, and phthalates and pyrene analysis in water samples.

There were no anomalies observed in the MBs for energetics, and phthalates and pyrene in biota samples; however, multiple metals were detected in the MBs. Among them, only a few were detected once or twice in the laboratory standard MBs. These metals included chromium, copper, vanadium, mercury, and zinc. The metals that were detected in blank tissues included barium, chromium, cobalt, cadmium, copper, selenium, strontium, nickel, lead, mercury, arsenic, vanadium, and zinc. Among these metals, arsenic, barium, copper, selenium, strontium, and zinc were observed in almost all the tissue blanks. This finding is reasonable because metals were expected to be present in the biota tissues. The arsenic concentrations detected in the tissue blank samples were relatively high. This is possibly due to Hawai'i's high arsenic background.

An important note for biota MBs are that, although the laboratory called the biota tissue from the fish market a "blank," it is closer to "background" for this study. For the energetics, and phthalates and pyrene "tissue blanks," because no anomalies were observed, the tissue blanks were treated as MBs. The metal "tissue blanks," however, were finally treated as a "background" during the data validation because, as described above, many metals were observed in the blanks.

4.5.1.4 Laboratory Control Samples and Surrogate Samples

LCSs are well-characterized sample MS with compounds representative of the target analytes that are used to document laboratory performance during analysis. LCSs are used to monitor the accuracy of the analytical process independent of project sample matrix and identify potential background interference or contamination of the analytical system. LCSs were analyzed and reported for each analytical batch. Laboratory control sample duplicates (LCSDs) are internal laboratory splits of the LCSs. Accuracy and batch precision can be determined using LCS/LCSD recoveries. Similar to the MBs, the laboratory prepared LCS for the energetic from the blank tissues, and two sets of LCS for the phthalates, pyrene and metals. One set was from the blank tissues and the other set was from laboratory standard solid components.

Surrogate samples are organic compounds that are not likely to be detected in the field samples, but behave similarly to the target analytes. Surrogate compounds are spiked in each sample within a batch and the recoveries are used to determine the efficiency of sample preparation and analysis.

In the energetic analysis for the sediment samples, picric acid had slightly low recoveries in the LCS, while nitrobenzene had several slightly high recoveries. There were no other anomalies observed. In the sediment metal analysis, metal isotopes were observed with recoveries out of control limits in some of the batches.

In the energetics analysis for the water samples, there were several compounds that had marginally low recoveries in one or two of the LCS. These compounds include 4-Am-2,6-DNT, 1,3-dinitrobenzene (DNB), 2,4 –DNT, 2,6-DNT, nitrobenzene, 3-NT, 4-NT, and 2,4,6-TNT. The RPDs for the LCS/LCSD were all within the control limits. There were no anomalies observed in LCS analysis for phthalates and pyrene.

In the energetics analysis for the biota samples, all the compounds had the LCS recoveries within the control limit, except for tetryl, which had low recoveries in some fish LCS. There were no anomalies observed in LCS analysis for phthalates and pyrene.

In the metal analysis for the biota samples, the recoveries of all the target metals in the laboratory standard LCS were within the control limits. Several metals showed high recoveries in the blank tissue LCS. These metals include arsenic, copper, strontium, antimony, and zinc. Arsenic was the one with high recoveries in all types of tissues except for seaweed. The high recoveries were very likely the result of the presence of the associated metals in the blank tissues. As described in Section 4.5.1.3, these findings are reasonable.

A few low recoveries of the surrogate were observed in the analysis of water and biota samples for phthalates and pyrene. There were two water samples (ORD107W and ORD108W), five seaweed samples (ORD001L, ORD003L, ORD011L, ORD014L, and ORD017L), four octopus samples (ORD011O, ORD015O, ORD017O, and ORD018O), one crab sample (ORD002C), and one fish sample (ORD005F) impacted. The energetic surrogates in all matrices had recoveries within the control limits.

4.5.2 Data Validation

The data validation was conducted based on the current version of the EPA National Functional Guidelines for Organic Data Review (2008) and for Inorganic Data Review (2010). The

guidelines were modified to incorporate elements and specifications of the actual methods employed. The modifications used were largely taken from SW-846, Test Methods for Evaluating Solid Wastes. TestAmerica West Sacramento, further modified the guidelines per guidance in the SW-846 Manual (i.e., control charting) to incorporate project-specific acceptance criteria.

The metals data for sediments were generated using a non-standard method of ICP-MS analysis. To the fullest extent possible, the same verification procedures were applied to those data. However, a number of more routinely encountered QCs (e.g., ICS A and ICS AB) were not included as part of the work. The data were reviewed for initial and continuing calibrations, indicators of accuracy (i.e., standard reference material (SRM) analysis and blank spike analysis); matrix accuracy (i.e., MS) and precision (i.e., duplicates). Both field and laboratory blanks were also evaluated. All of the analytical data were validated at Level IV. Data qualifiers were applied to cases where the data do not meet the required QC criteria, or where special consideration of the data was required. The data validation reports can be found in Appendix K.

Through the data validation processes, the rejection qualifier "R" was applied to 38 fish samples due to its critically low LCS recoveries. Tetryl samples belonging to laboratory reports GC240536 and G0C240547 were re-validated by Laboratory Data Consultants, Inc. (Appendix K report number 27100) due to results being incorrectly rejected during the initial data validation. Three sediment metal results for uranium-238 were rejected due to the critically low recoveries of SRM/LCS. Two sediment metal results for vanadium-51, two sediment metal results for chromium-53, and one sediment metal results for nickel-60, were rejected due to the significantly low recoveries in the continuing calibration. The other data that did not meet the QC requirements as described in Section 4.5.1, but were with minor impacts, were qualified as estimated value "J" (only for metals whose results were above the MDL but below the limit of quantitation), non-detects "U," or non-detects with estimated detection limits "UJ" according to the validation guidelines.

4.5.3 PARCC Parameters

PARCC parameters are used to evaluate the usability of all analytical data. PARCC parameters are evaluated as part of the data validation report. Summaries of the PARCC parameters are provided below.

4.5.3.1 Precision

Precision is a measure of agreement among repeated measurements of the same property under identical or substantially similar conditions. Precision was evaluated using the RPDs of the MS/MSD, LCS/LCSD, field duplicates, or laboratory duplicates. Data Quality Assessment Tables for some measures are provided in Appendix L while others are in the validation reports Appendix K.

The precision for energetics is generally acceptable in sediment samples, except for picramic acid because its RPDs for both MS/MSD sets were outside of the control limit. The precision for energetics in water samples are within the acceptable range. The precision for energetics in biota samples is good, except for tetryl in some crab and fish samples. In those samples, tetryl had RPDs for MS/MSD outside of the control limit.

The precision for phthalates and pyrene in water samples is difficult to assess due to a lack of MSD analysis and all non-detect results in the field duplicates. However, according to the validator, the impact on data usability is small. The precision for phthalates and pyrene in biota samples is generally good. One RPD of sample duplicates for di-n-butyl phthalate was out of the control limit. Because all the other RPDs for this compound met the QC criteria, this anomaly has small impact to the usability of the data.

The precision for metals in sediment samples was evaluated from laboratory duplicates. The RPDs for reported duplicates were within the control limits, except for chromium-53, cobalt-59, cadmium-111, zinc-66, zinc-68, and uranium-238 in one or more batches. The precision of metals in sediments is considered acceptable. For the metals in biota samples, only one RPD (mercury) for MS/MSD was out of the control limit; however, RPDs for quite a few metals in laboratory duplicates were out of the control limits. Considering the heterogeneity of the tissue samples the precision for biota metals is acceptable.

Overall, the precision for energetics, phthalates, and pyrene is considered acceptable in all sample matrices, except for the precision of tetryl in fish tissues. The metal precision is considered acceptable in both sediment and biota samples.

4.5.3.2 Accuracy

Accuracy is a measure of the overall agreement of a measurement to a known value. It includes the combination of random error (precision) and systematic error (bias). The evaluation of random error is described in the precision section above and the systematic error is evaluated by the recoveries of LCS/LCSD, surrogates, and MS/MSD. Instrument calibrations were also reviewed for accuracy assessment.

The accuracy of analysis for energetics in the sediments was acceptable, except for picric acid, picramic acid, and 2,4-DNT. The observation of low recoveries in most of LCS and MS/MSD samples for picric acid indicates that the results were low biased. For picramic acid, the fact that the MS/MSD recoveries were low, while the LCS recoveries were within the control limit, indicates a possible matrix effect. The results of picramic acid may also be low biased. The high recovery of 2,4-DNT in one of the MS samples indicates that the associated results may be high biased. A few detections of 2,4-DNT were thus qualified with "J" (estimated value). The high recoveries of nitrobenzene indicate that the result may be biased high; however, nitrobenzene was not detected in any of the sediment samples. Thus, the quality of results was not impacted by the high recoveries.

The accuracy of analysis for energetics in the water was good, except for 4-Am-2,6-DNT, which had low recoveries in LCS and MS/MSD; and 1,3-DNB, 2,4-DNT, 2,6-DNT, nitrobenzene, 3-NT, 4-NT, and 2,4,6-TNT, which had slightly low recoveries in one LCS. All of these compounds may have low bias in the associated results.

The accuracy of analysis for energetics in the biota tissues was acceptable except for tetryl. The critically low recoveries of tetryl in LCS and MS/MSD resulted in the rejection of the data in 42 fish samples. The continuing calibration for energetics in seaweed showed the percent differences were over the control limits for a few contaminants (HMX, 2-NT, and 2,4,6,-TNT) and the corresponding results were qualified as estimated non-detect (UJ). The high recoveries

for 1,3,5-TNB in MS/MSD in octopus did not impact the data quality because all the results for octopus were non-detects.

The accuracy of analysis for phthalates and pyrene in the water and biota tissues is considered acceptable. No anomalies were observed for the recoveries of the QC samples, except for low recoveries of several surrogates in some water and tissue samples. The low surrogate recoveries indicate possible low bias in the associated results.

Less accuracy was observed for analysis of metals in the sediment samples. This was due to the fact that the recoveries of SRM/LCS and continuing calibration were out of the control limits for quite a few metal isotopes. As a result, 17 metal data were rejected. However, the accuracy of analysis for metals in the sediment is considered acceptable because the rejected data was only a small part (0.7%) of the whole data record, and most of the results that had been qualified are still usable.

The accuracy of analysis for metals in the biota samples is considered acceptable. The low recoveries of MS/MSD observed for strontium, mercury, copper, lead, arsenic, antimony, cadmium, nickel, and selenium indicate possible low bias for these metal results. Although the high recoveries of a few metals were observed in a LCS that was prepared from tissue blanks, the observation may be due to the natural presence of the metals in biota tissues rather than poor performance of the lab. Overall, the accuracy is considered acceptable for all analyte groups in all sample matrices.

4.5.3.3 Representativeness

Representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population. Representativeness can be assessed through evaluation of holding times and MBs.

The holding time requirements for sediment and water samples were all met. The holding time requirements for biota samples were also met, except for seaweed energetics, which were analyzed about two years after the collection, and some metal samples, which were prepared or analyzed slightly outside the one year requirement. In both cases, the samples were stored under -4°F (-20°C) during this period. The one year holding time was generally applied to frozen tissues; however, there are no promulgated, scientifically-based holding time criteria for energetics and metals in tissues. Very likely, the metals results were not impacted by the holding time because the analysis took place just a few days outside the one year period. Given difficulties in method development for seaweed energetics, the analysis of seaweed was not conducted until two years later. The representativeness of energetics in seaweed may be impacted. However, EPA concurred with the study team's opinion that sample results would not be impacted. No energetic, phthalates, and pyrene were observed in the MBs for all sample matrices.

Metal isotopes were observed in some sediment MBs. There were a large number of negative results in the MBs too. The 5X (five times) rule (i.e., for positive blank values, if the sample results were less than 5X of the MB results, the data were considered non-detects). For the negative blanks, if the sample results were less than 5X of the absolute value of the blank, the data were considered estimates) was applied.

In the tissue metal analysis, a few metals were observed in the laboratory standard MBs while many more metals were frequently observed in the "tissue blanks." As described in Section 4.5.1.3., detecting metals in the blank tissues is not unexpected and the "tissue blank" should be treated as the "background" for this study. Therefore, the data were qualified based on results of laboratory standard MBs. Overall, the results of all analytical compounds are considered representative for all sample matrices.

4.5.3.4 Comparability

Comparability expresses the measure of confidence that one data set can be compared to another and can be combined for the decisions to be made. Comparability can be assessed through evaluation of sample collection and handling methods, and sample preparation and analytical procedures.

In this study, the samples were collected during two seasons – wet season (April) and dry season (September). During the two sampling events, the sampling methods, sample storage, biota sample pretreatment were all comparable. The samples were sent to the same laboratory for analysis. The laboratory sample preparation and analysis procedures were all same for the two sets of samples. Therefore, the data obtained from two seasons are considered comparable and can be combined for decision making.

4.5.3.5 Completeness

Completeness is the degree to which the data set provides sufficient number of data points to perform the specified data analyses, under the actual condition of sampling and analysis compared to the assumptions of the project planning process. It is evaluated by comparing the number of valid data with those required by the study's quality criteria or total data obtained during this study.

Among the approximately 11,514 data obtained and validated for this study, 72 results were rejected. The rejected data include 42 results of tetryl for fish tissues, 21 results for 2,4-dinitrophenol for limu samples, and 9 results of several metal isotopes for sediment samples. The overall completeness is 99%, which meets the completeness requirement for this study. The information about the numbers of total data records, rejected data, and completeness in each matrix for each analyte group is listed in Appendix L, Table L-6 (seawater), Table L-7 (biota), and Table L-8 (sediment).

4.5.4 QA/QC Summary and Conclusions for Sediment

The QA/QC results for energetics analysis in the sediment samples showed that there was low bias in picric acid and picramic acid results, and there may be high bias in some 2,4-DNT results. A few 2,4-DNT detections were, therefore, qualified as estimated values. Among the total 887 data records, none of the analytical results were rejected. The completeness was 100% (see Appendix L, Table L-8). The PARCC parameters were thus considered acceptable.

The QA/QC results for metal analysis in the sediment samples showed low accuracy in the results. A large number of data were impacted due to low/high SRM/LCS recoveries, calibration anomaly, and negative/positive results in MBs. Among the total 1,806 data records, 9 were

rejected. The completeness was 99.5% (see Appendix L, Table L-8). Since the most impacted data were still usable, the PARCC parameters were considered acceptable.

4.5.5 QA/QC Summary and Conclusions for Seawater

The QA/QC results for energetic analysis in the water samples showed that there may be low bias in some results for 4-Am-2,6-DNT, 1,3-DNB, 2,4-DNT, 2,6-DNT, nitrobenzene, 3-NT, 4-NT, and 2,4,6-TNT. There was no data rejected from the total 351 data records. The completeness was 100% (see Appendix L, Table L-6). The PARCC parameters were considered acceptable.

The QA/QC results for phthalates and pyrene analysis in the water samples showed that there might be low bias for the target MC in two samples. There was no data rejected from the total 54 data records. The completeness was 100% (see Appendix L, Table L-6). The PARCC parameters were considered acceptable.

4.5.6 QA/QC Summary and Conclusions for Biota

The QA/QC results for energetic analysis in the biota samples showed that there was low bias in the tetryl results for some fish tissues. In fact, the recoveries of tetryl in the associated QC samples were so low that the non-detect results were rejected. Additionally, the LCS associated with the limu samples, had no reportable recovery for 2,4-dinitrophenol. Therefore, the results for 2,4-dinitrophenol in limu samples were "NR" (not reportable). Among the total 3,792 data records, 63 were rejected (42 results of tetryl for fish tissues, 21 results of 2,4-dinitrophenol for limu samples). The completeness was 98% (see Appendix L, Table L-7). The PARCC parameters were considered acceptable.

The QA/QC results for phthalates and pyrene analysis in the biota samples showed that there may be low bias for the target compounds in four samples. There was no data rejected from the total 1,188 samples. The completeness was 100% (see Appendix L, Table L-7). The PARCC parameters were considered acceptable.

The QA/QC results for metal analysis in biota samples showed that there may be low bias in arsenic, cadmium, copper, lead, mercury, nickel, selenium and strontium in some of the samples. In addition, some data were qualified due to the detections of the laboratory standard MB and high recoveries of LCS. There was no data rejected from the total 3,436 data records. The completeness was 100% (see Appendix L, Table L-7). The PARCC parameters were considered acceptable.

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Section 5
Discussion

5.1 Phthalates and Pyrene (Seawater and Biota Only)

During this study, a single phthalate detection, bis-2-ethylhexl phthalate, occurred in a seawater sample (ORD107W) collected from the WWTP stratum. The concentration detected was well below the proposed acute and chronic screening levels for this constituent for ecological receptors (Buchman, 2008). A di-n-butyl phthalate detection occurred in a biota sample (ORD004F DUP). In this sample, di-n-butyl phthalate was detected at an estimated concentration, but it was not detected in the corresponding primary sample. There were no other phthalates or pyrene detections in any of the seawater or biota samples collected.

5.2 Energetics

5.2.1 Energetics in Seawater

There were no detections of energetics in seawater. This is unsurprising given the likelihood of rapid dilution and transformations of energetic in seawater.

5.2.2 Energetics in Sediment

NOAA's 2006 survey detected concentrations of (a) 2,4-DNT in sediment samples ranging from 3.1 ppm to 21.0 ppm, and (b) 2,6-DNT in sediment samples at 0.60 ppm and 1.4 ppm. NOAA's 2006 survey compared these detections to EPA's risk-based concentrations for direct contact with surface soil, assuming a residential exposure scenario. EPA's screening level for 2,4-DNT is 160 ppm, with its screening levels for 2,6-DNT at 78 ppm. This highly conservative screening concluded that the concentrations of energetics in sediment that NOAA reported in 2006 did not pose a direct exposure risk. In subsequent independent reviews of NOAA's 2006 survey, ATSDR and USACHPPM (now Public Health Command) concurred with this conclusion. Based on the data collected, ATSDR and USACHPPM concluded that there was no indication that the presence of the DMM posed an unacceptable threat to human health or the environment.

The two energetic compounds (2,4-DNT and 2,6-DNT) that NOAA detected in sediments during its 2006 survey are the same compounds detected during the April 2009 and September to October 2009 sampling events. During this study, 2,4-DNT was detected in 12 primary sediment samples and one duplicate sample. The maximum concentration of 2,4-DNT detected during this study was an estimated 3.30 mg/kg. This concentration was found in a sample collected at site DMM11. The next highest concentration 1.60 mg/kg estimated was found in a sample collected from sample site DMM13 (see Table 4-4; Appendix I, Table I-4). This range of concentrations of 2,4-DNT (estimated as 0.03 to 3.30 mg/kg) is at the low end of the range reported in NOAA's 2006 survey (3.1 mg/kg to 21.0 mg/kg). The two 2,6-DNT detections in sediment samples, which occurred in samples collected from the DMM stratum, were

0.098 (estimated) mg/kg and 0.38 mg/kg (Table 4-4). These detections are below those reported in NOAA's 2006 survey (0.60 mg/kg and 1.4 mg/kg).

The risk screening conducted for NOAA's 2006 survey was highly conservative and not entirely appropriate for evaluating contact with marine sediments. The survey compared concentrations of COPCs in marine sediments to the risk-based screening levels for direct contact with residential soils, assuming contact 350 days per year and an ingestion rate of 200 mg/day. This comparison provided an upper bound on possible risk, even though such a scenario is improbable given the amount of sediment present and the fact that access to it is very limited. To allow a comparison of NOAA's 2006 data with this study's data, this study looked at both residential-soil screening levels and ecological toxicity values for sediment as appropriate action levels for sediments.

During the September to October 2009 sampling event, two sediment samples collected contained estimated concentrations of 2,4-DNT that met or exceeded the EPA Resident Soil Screening Level of 1.6 mg/kg (Table 4-4). The estimated concentrations were 3.30 mg/kg in a sample from DMM11 and 1.60 mg/kg in a sample from DMM13. These two detections are not considered a human health risk because: (a) these low-level concentrations are estimated values that are either at or slightly above the EPA Resident Soil Screening Level; and (b) it is highly unlikely that a resident or worker would both (1) come into contact with sediments at Ordnance Reef (HI-06) 350 days per year and (2) ingest 200 mg of sediment per day.

5.2.3 Energetics in Biota

Several energetic compounds were detected in biota samples collected from Ordnance Reef (HI-06): 2,4-DNT, HMX, 2-NT, 4-NT, RDX, tetryl and 1,3,5-TNB. These detections occurred primarily in fish samples, although one octopus and one crab sample also contained at least one energetic compound (both marked as estimated values). These data were carefully considered in both the HI-06 HHRA and the HI-06 ERA. For further discussion of potential human health risks see Section 6. Addtionally, although not considered COPCs, 3,5-dinitroaniline and 2-nitrophenol were detected in four fish samples at estimated concentrations.

5.3 Elemental Analysis

5.3.1 Major and Trace Elements in Sediment

Based on the concentrations of major constituents measured in the sediments collected from Ordnance Reef (HI-06), sediments from the study area can be classified primarily as marine carbonates. These sediments are derived mainly from natural coral reef and seashell materials to which are added lesser but relatively variable contributions from natural terrestrial runoff. Superimposed upon these two primary natural sources of materials are what appear to be signatures of anthropogenic contributions derived from either land-based runoff or from DMM. The following paragraphs provide some details to place the elemental data in context of these general observations.

Overall, concentrations of most trace elements were broadly similar within sediment samples from all strata. The COPC, however, are exceptions to this general rule. Samples collected from the DMM stratum typically showed higher average abundances of copper and lead than those

collected from the other strata (Appendix J, Chapter III, Tables 2, 3, and 4, Figures 6 through 9). These findings are not surprising, considering the abundance of these elements in DMM and the fact that sampling in the DMM stratum specifically targeted munitions. It is interesting, however, that the average concentration of lead was elevated in sediments collected from the DMM stratum during the April 2009 sampling event relative to sediments from other strata. Samples collected during the September to October 2009 period (Appendix J-Figure 8); however, did not show such an enrichment of lead in sediments from the DMM stratum. The reason for this discrepancy is largely due to a single outlier (549 mg/kg) during the April sampling round.

A particularly interesting observation made during the study was that concentrations of arsenic were considerably higher in sediments from the CON stratum than in sediments from other strata (Appendix J-Figure 8). Although there has been significant community concern expressed with respect to arsenic, this element is not found in conventional munitions, hence, it was not expected that arsenic would be abundant in sediments from the DMM stratum. The findings of the study are consistent with this hypothesis, although the observation of more elevated concentrations of arsenic in sediments from the CON stratum compared to the other three strata is somewhat surprising. Results of PCA (Section 5.3.3) suggest that this element is derived from land-based geologic source input through runoff, although the ultimate source of arsenic cannot be determined from this statistical technique. Elemental associations and the elucidation of sources are explained in greater detail in the PCA discussion (Section 5.3.3). The observation of the second highest average concentration of arsenic in sediments collected from the NPS stratum is also consistent with the hypothesis that the arsenic derives from terrestrial runoff, as the NPS sample sites are closest to shore and receive land-based runoff through the channelized Maʻiliʻili drainage channel.

Within the DMM stratum, the average copper, lead, and zinc concentrations exceeded those found in sediments from the CON stratum (as well as the NPS and WWTP strata). The averages, however, were biased largely to the occurrence of a few highly enriched sediment samples in the DMM stratum, whereas many others showed concentrations of these elements that are more similar to the range observed in the other three strata. As observed with the energetic compounds, no clear and consistent correlation was evident between the concentration of COPC metals and distance from the target DMM. This lack of correlation may result in part from the movement of small arms ammunition and corroded fragments thereof across the seafloor due to wave and current activity. A significant number of samples from the DMM stratum was collected in areas where small arms ammunition were distributed broadly across the sampling area and corroded fragments of these munitions would likely also be distributed widely.

Overall, only copper, lead, and zinc exhibited concentrations in sediment that appear related to the presence of DMM at Ordnance Reef (HI-06). The lack of lead enrichment during the second season of sampling (September to October 2009) is more difficult to explain if all three metals are assumed to derive from a DMM source. If this element were associated exclusively with other DMM-related metals such as copper and zinc found in casings, it should also have been enriched in sediments collected during the fall sampling, since some of the latter were indeed highly enriched in copper. It should also be noted that a significant fraction of the sediment samples collected within the DMM stratum do not show strong enrichments of metal COPC relative to sediments from the three other strata, indicating that metal contamination within the

DMM stratum itself is not widespread and is limited to the proximity of only selected DMM items.

The observations made during this study are largely consistent with the results of NOAA's 2006 survey (NOAA, 2007). NOAA's screening-level survey showed that, among the trace elements, copper and zinc showed a significant enrichment over natural trends that could be attributed to human influences (either NPS runoff pollution or the presence of DMM). By focusing sampling in the DMM stratum to individual DMM during this study, it became apparent that DMM are responsible for the highest enrichment of copper and zinc in the sediment. However, a significant number of sediment samples collected within the DMM stratum have compositions that are not statistically different from those of sediments collected in other strata of Ordnance Reef (HI-06). This is an especially encouraging finding in light of the fact that overall metal concentrations in sediments, except for a few samples, are not particularly elevated when compared to sediments from other coastal environments in Hawaiʻi as discussed in the following paragraphs. Thus, the overall impact of DMM on metals concentrations at Ordnance Reef (HI-06) appears relatively limited and suggests that no widespread environmental contamination has resulted from the DMM.

It is also interesting to compare the concentrations of trace elements in general, and COPC in particular, between sediments from the four strata of this study and other areas around Oʻahu and throughout other regions. Table 5-1 is a compilation of selected trace element data in sediments from Ordnance Reef (HI-06). Showing both the NOAA 2006 survey data and the data from this study, other coastal areas of Hawaiʻi and some other locations in the United States and in other countries. Examination of this compilation immediately reveals that a broad range of concentrations of trace elements exists throughout various coastal areas of Hawaiʻi. Some of these areas are clearly heavily polluted from NPS runoff (e.g., the Ala Wai canal as described by De Carlo and colleagues (1995, 1997, 2002)). Others are slightly contaminated (e.g., southern Kāneʻohe Bay), with some (e.g., Kahana Bay and Honolua Bay) environments that are relatively free of urban and other NPS contamination, yet contain concentrations of trace elements that, at least for selected trace elements, are not largely different from those at Ordnance Reef (HI-06). In some cases, these areas exhibit rather elevated concentrations of trace elements. These observations indicate that a large extent of variability exists within the Hawaiian environment, depending upon the sources of materials to each respective area.

Common sources that influence the trace element composition of sediment include natural volcanic minerals (e.g., olivine and pyroxene), particularly abundant components in the sediments from Honolua Bay (De Carlo and Dollar, 2007; Hedouin et al., 2011). These minerals can lead to very high concentrations of cobalt, chromium, nickel, vanadium and, to a lesser extent, copper that, in other geologic settings, might be easily considered to be pollutant inputs. Contributions from these volcanic minerals, however, can be highly variable as evidenced by the wide range of concentrations of these elements observed in the studies of Hedouin et al (2011) and De Carlo and Dollar (2007). A volcanic source invoked as contributing to the elevated concentrations of these elements in sediments from Honolua Bay and other Oʻahu locations (Spencer et al., 1995; De Carlo and Anthony, 2002; De Carlo et al., 2004, 2005) is also most likely responsible for enrichments in sediments collected from the CON stratum, although one might have also anticipated that sediments from the NPS stratum would also be similarly affected by natural land sources. Visual examination of the sediments from this study, however, revealed a much greater abundance of dark-colored grains in sediments from the CON stratum

than from the NPS stratum. This is consistent with a greater abundance of volcanic minerals in the CON stratum. The calcium carbonate dominated sediments of Hawaiʻi display concentrations of cobalt, chromium, nickel, and vanadium that are somewhat elevated relative to results reported by Gough et al. (1996) and Caccia et al. (2004) for sediments from the Bahamas and Florida, two other coral reef and calcium carbonate dominated areas. The latter, however, are not subject to any input of volcanic minerals, so it is not surprising that sediments collected in those locations do not contain high concentrations of cobalt, chromium, nickel, or vanadium. Regardless, it is quite evident that enrichment of these particular trace elements in Hawaiian marine sediments are attributable to volcanic inputs rather than anthropogenic contamination.

A more mixed picture exists for the COPCs copper and lead. These elements appear to show wide variability in the various environments depicted in Table 5-1. NPS runoff, which can contribute high concentrations of copper, lead, and zinc (e.g., De Carlo et al., 2004, 2005 and references therein) is a well-known source of these elements to coastal sediments in Hawaiʻi and elsewhere. Concentrations of these elements ranging from a few tens to multiple hundreds of mg/kg in sediments of the Ala Wai canal and in southern Kāneʻohe Bay clearly reveal the influence of NPS as do the data for sediments from the NPS stratum of NOAA's 2006 survey of Ordnance Reef (HI-06).

This study's data exhibit much lower concentrations of copper, lead, and zinc in sediments from the NPS stratum than observed in NOAA's 2006 survey, largely reflecting the much lower rainfall in 2009 than in 2006, a particularly wet year, during which unusually large amounts of rain fell across Oʻahu during the period of February to April 2006.

What is slightly more surprising, however, is the occurrence of up to 136 mg/kg lead in sediments from the CON stratum, as this area would have been anticipated to be more representative of background conditions along the Waiʻanae coast. The lack of commensurately high copper and zinc concentrations may be a clue that a separate source of lead to this area exists, possibly lead weights from fishing activities, or some unidentified materials that do not have the copper and zinc association that is typical of urban (automotive-derived) runoff (e.g., De Carlo et al., 2004, 2005 and references therein). The upper range of the copper concentrations observed in sediments from the DMM stratum is similar to that found in NOAA's 2006 survey, clearly pointing to a DMM source, especially considering that sampling was targeted to areas immediately adjacent to munitions, some of which were observed to be deteriorating as evidenced by fragments of shell casings in the collected sediment. The higher lead concentrations in the DMM stratum are also consistent with a DMM source. The average at Ordnance Reef (HI-06) is also comparable to other Oʻahu locations such as Maunalua Bay (Hawaiʻi Kai), Kahana Bay, or Waikīkī, although all data from these areas are from several decades ago, when lead was typically more abundant in sediments owing to its widespread use as a fuel additive, which was later discontinued. Many continental sites in the United States (e.g., Biscayne Bay, Florida; Galveston Bay, Texas; and the Southern California Bight) show markedly higher concentrations of copper, lead, and zinc than found at Ordnance Reef (HI-06), although each of these areas is also known to be subject to contamination from NPS runoff.

In the case of lead and zinc, sediments from Chi-Ku Lagoon, in southwestern Taiwan, also show remarkably similar ranges of concentrations as observed at Ordnance Reef (HI-06), although concentrations of copper in Chi-Ku Lagoon are more comparable to those of sediments collected during this study from the WWTP stratum. Copper and zinc concentrations in coastal sediments from Spain are also considerably enriched relative to those observed here, except for the few

highly enriched samples collected from the DMM stratum. Various other sites in Florida and other areas of the Gulf of Mexico, not considered particularly contaminated, reveal concentration ranges for copper, lead, and zinc that are broadly similar to those observed throughout the Ordnance Reef (HI-06) strata, again excluding the inordinately enriched sediment samples that targeted specific DMM. Refer to Figures 30 through 32 of Appendix J, which are element-element plots displaying high concentrations of arsenic, copper, zinc, and lead in samples collected from the DMM stratum relative to samples collected from other strata.

Natural sources of lead in Hawai'i should only contribute very small amounts of this element to the environment. For example, the lead content of mafic and ultramafic rocks is always below 10 mg/kg (Spencer et al., 1995; Frey et al., 1994). This value is of the same order of magnitude as found in sediments from the NPS stratum, but lower than the averages observed in sediments from the CON, DMM, and WWTP strata. Typically, concentrations of lead above a few mg/kg in sediments from Hawai'i reflect contributions from human activity (Spencer et al., 1995; De Carlo and Spencer, 1997). Thus, except for the sediments from the NPS, which display the lowest average lead concentrations in this study and are also considerably less enriched than observed during NOAA's 2006 survey, sediments from the other three strata display some human-derived contamination. Nonetheless, the minimum lead concentrations observed in each of these strata are consistent with what would be expected for uncontaminated carbonate dominated sediments.

Concentrations of arsenic from the various locations listed in Table 5-1 fall within the range of less than one microgram per gram (µg/g) (one ppm) to nearly 60 µg/g. The dataset, unfortunately is rather limited with only a few values available for sites outside of Hawai'i. Sediments from Ordnance Reef (HI-06) fall within the broad range of values observed elsewhere in Hawai'i, with low values observed in the sediments from the DMM, NPS, and WWTP strata and the higher values observed in sediments from the CON stratum. It appears, however, that many other areas of Hawai'i are characterized by relatively high concentrations of this element when compared to the global average for carbonates (Kabata-Pendias and Pendias, 2001). This potentially reflects a widespread use of arsenical pesticides in Hawai'i during the post-World War II era and its subsequent runoff into the marine environment. Unfortunately, fewer data are available from elsewhere for arsenic in other areas with predominantly carbonate sediments than for the other metal COPC. It is quite encouraging to note that even the most arsenic-enriched sediments from the CON stratum of Ordnance Reef (HI-06) display concentrations comparable to those observed in sediments from Chi-Ku Lagoon in southwestern Taiwan. As mentioned briefly before, the source of arsenic in sediments of the CON stratum cannot be unequivocally identified from this study's results. Circumstantial evidence, however, points to a human source that is not munitions related.

5.3.2 Trace Element COPC in Biota

Before proceeding with a discussion of trace elements in biota, it is important to remember that "[a]ny meaningful comparison of relative concentrations in aquatic invertebrates should be *intraspecies, and certainly not between families* [emphasis added] (e.g. between mussels and oysters), or higher systematic divisions such as between decapod and cirripede crustaceans" (Rainbow, 2002). That being said, concentrations of individual trace elements in biota shown in Table 5-2 vary widely between the different biota types, but the ranges of concentrations of individual elements were generally similar in any given species of biota at all four strata. The

two notable exceptions to this finding were higher concentrations of both copper and zinc in one seaweed sample collected in the DMM stratum, and a high concentration of these elements in a single octopus from the DMM stratum. Both of these samples were collected in April 2009. There were no samples from subsequent sampling rounds that exhibited such high concentrations. This suggests that these particular samples may be outliers.

In the case of the seaweed sample, retention of even a small amount of sediment in the seaweed and carrying of this material through the laboratory processing steps would be sufficient to cause elevation of the concentrations of these two elements. No post collection processing other than rinsing of samples with water was undertaken before sending the samples to a contract laboratory for analysis. The anomalously high copper concentration in the single octopus sample is, however, more difficult to explain, although one might invoke a similar source of these elements. Yet, the preparation process for the octopus sample carried out prior to sending the sample to the contract laboratory involved dissection under a laminar flow hood, specifically designed to minimize any possible contamination. Processing of these samples for analysis by the contract laboratory is assumed to have been carried out with due care, but some contamination at this stage cannot be ruled out. The lack of high values in all of the other biota samples analyzed as part of this study, however, suggest that post sample collection laboratory contamination is not an issue.

Concentrations of arsenic in biota were remarkably similar across the various strata. This is consistent with the observations for fish collected as part of the 2006 NOAA study, although the maximum values observed in fish during this study are approximately one third of those found in 2006. This most likely reflects the analysis of whole fish during the NOAA study whereas only fish fillet (muscle) were analyzed during this study. A finding of greater interest, however, is that the overwhelming majority (approximately 99%) of arsenic was present in the less toxic organic form in crab, octopus, and fish. A considerably larger fraction (approximately 6% to 50%) of the arsenic found in seaweed was present in the inorganic form, although total concentrations of arsenic in seaweed were the lowest of all biota. It is not entirely surprising that a greater fraction of the arsenic is present in the inorganic form in seaweed. The chemical form of arsenic common in seawater is arsenate, which is structurally identical to that of phosphorous (present as phosphate), an essential nutrient for the growth of plant material. It is therefore, hypothesized that seaweed may incorporate arsenate because it is substituted for phosphate.

Octopus and Kona crab display tighter ranges of concentrations of arsenic than fish, which exhibit a full order of magnitude range between the low and high values. Because the former species are bottom dwellers, it might be expected that they incorporate higher concentrations of trace elements from prey whose own trace element composition may reflect inputs from sediment. Yet, the upper end of the concentration range for arsenic in all animal species is quite similar, and without specific understanding of the mechanism for bioaccumulation of trace elements in each species, it is difficult to draw any conclusions from the data. It remains clear, however, that all animals contain more total arsenic than the sediments in the respective areas but all animals contain very low concentrations of inorganic arsenic, which is the more toxic form. It thus appears that these species do not represent a source of toxic arsenic to upper level predators or humans that consume them.

For copper, it is again the crab and octopus samples that display the highest concentrations. This is not altogether surprising given that crab and octopus both have copper-based hemocyanin in their blood. Moreover, according to White and Rainbow (1985), "… metabolically functional

copper and zinc [see below] often make up significant proportions of the total content of these metals in molluscs [e.g., octopus] and crustaceans [e.g., Kona crab] from non-polluted environments, especially the open ocean." For example, White and Rainbow (1985) calculated that the total theoretical metabolic and respiratory requirements for copper in cephalopod molluscs and decapod crustaceans was 91.8 and 83.7 ppm-dry weight, respectively.

According to Kumar et al. (2014), "[c]opper serves as an essential component in metabolic processes of algae [as well as animals], playing vital functions in the electron transport and various enzyme systems (e.g., amineoxidase, cytochrome c oxidase), and particularly works as a prosthetic group of the chloroplastic antioxidant enzyme Cu/Zn superoxide dismutase [Cu/Zn-SOD]." According to Mallick and Mohn (2000), "… SOD consists of a group of metalloisoenzymes that neutralize the very reactive superoxide radicals (O_2^-) into oxygen (O_2) and hydrogen peroxide (H_2O_2).

$$O^- \quad H \xrightarrow{O} O \quad H \quad O$$

In plant systems, three types of SOD are normally distinguished. The first is a copper-zinc-containing protein, sensitive to CN^- [cyanide ion] and predominantly associated with the chloroplast (Cu-Zn-metalloprotein)." Paradoxically, excess copper and zinc (and other heavy metals) can induce oxidative stress (Mellado et al., 2012).

Excluding the one outlier octopus sample, the ranges of concentrations of copper are similar across the various strata, suggesting that DMM do not contribute significantly to the body burden of this element in these animals. The fact that all copper concentrations were below the theoretical limit in the octopus and crab (White and Rainbow, 1985) was most likely due to the fact that the Ordnance Reef Environmental Study reported concentrations as parts per million – wet weight, whereas White and Rainbow (1985) report the trace element concentrations as parts per million – dry weight. The fact that not the entire organism was analyzed during the Ordnance Reef Environmental Study may also explain the observed concentrations that were below the theoretical metabolic requirement. Excluding the outlier octopus sample, the range of concentrations of copper is similar in the CON, DMM, and NPS strata with samples from the WWTP showing up to 50% enrichment of this element over those found in octopus from the other strata, possibly reflecting an additional source of copper from the WWTP outfall pipe. All fish samples contained very low concentrations of copper with no obvious trend between strata. Concentrations of copper in seaweed are also extremely low, although a greater enrichment of this element is evident in the DMM stratum, which might reflect direct uptake of this element from the sediment by the plant.

Lead is an element of high public concern owing to its toxicity. The concentrations of this element are uniformly low across all biota types. Although, crab collected near the WWTP appear to contain at least ten times more lead than those collected in the DMM stratum.

Finally, although zinc is not generally considered a potentially toxic metal and is in actuality an essential element for life, biota samples from Ordnance Reef (HI-06) also show remarkably similar concentrations in biota samples across the various strata, excluding the outlier octopus and seaweed samples discussed previously. As with other COPC trace elements, the crab and octopus samples generally display higher levels than found in fish or seaweed. As stated above, zinc, along with copper, is a key component of many enzymes particularly carbonic anhydrase in the case of zinc (White and Rainbow, 1985; Rainbow, 2002). According to Creighton (1999),

carbonic anydrase "… catalyses the reversible hydration of carbon dioxide to bicarbonate and a proton, using a catalytic zinc ion bound at the active site" and it "… plays roles in respiration, photosynthesis, and CO_2 fixation." In addition, both copper and zinc are found in the ubiquitous enzyme Cu/Zn-SOD.

The concentrations of trace element COPC in biota from Ordnance Reef (HI-06) are compared to those measured in biota from other locations in Table 5-2. Almost universally, concentrations observed here are comparable or lower than found in the same biota items elsewhere. Of particular note are the much lower concentrations of arsenic, lead, and zinc found in fish from the Wai'anae area compared to those from the French Frigate shoals area. A similar argument can be made for crab from these respective areas. Goatfish from Honolua Bay, Maui, however, appear to have remarkably similar concentrations of all trace elements as observed at Ordnance Reef (HI-06). Goatfish from the Philippines appear to contain slightly greater amounts of copper and zinc than those from Wai'anae, whereas octopus from Spain show considerable enrichment in both arsenic and zinc relative to those studied at Ordnance Reef (HI-06). The potential human health implications of trace element enrichment in biota are discussed in detail in the HI-06 HHRA (Section 6).

5.3.3 Principal Components Analysis – Sediments

A blend of principal components analysis (PCA) and factor analysis (FA) using the software SPSS® (Shaw, 2003), hereafter simply referred to as PCA, was applied to elemental composition data to determine relationships between elemental components of the silt-clay, sand, and combined sand-silt-clay fractions of sediments. All tables and figures generated as part of the PCA are included in Appendix J. The derived correlations shown in Appendix J, Chapter III, Section VI establish the relationships between interrelated elemental concentrations. PCA is particularly useful because it reduces a large number of variables, such as the elemental abundances in the current data set, to a smaller number of components (or factors) that represent some linear combination of the original variables. These variables are grouped into several factors, which account for a significant portion of variance (i.e., eigenvalues) of the original variables. Extracted factors can, in turn, be interpreted based on the meaning of variables clumped within. Thus, through the application of PCA, a large number of quantitative variables can be condensed into a few factors. The first component represents the best linear combination of the variables, the second component, the next best linear combination, and so on. There are, however, limitations to using PCA, especially if the technique is going to be used to explain geochemical processes. Even with these potential limitations, however, PCA remains a powerful multivariate tool used broadly by the research community to look for patterns in the data and it was found to be quite useful for this study.

Although laboratory analysis and PCA of these data were performed on the silt-clay, sand, and combined sand-silt-clay fractions, the results of PCA will be limited to the silt-clay fraction. Typically, the finer silt-clay-sized sediments contain greater concentrations of trace elements. According to Horowitz (1991), "[t]here is a very strong positive correlation between decreasing grain size and increasing trace element concentrations. This correlation results from a combination of both physical (e.g., surface area) and chemical factors (e.g., geochemical substrates)."

PCA of element data in sediments extracted three component factors for the samples (Appendix J, Chapter III, Section V). The first three factors explained 86.3% of the variance of

the silt-clay fraction of sediments (Appendix J, Chapter III, Section V, p. 52). The first component (Factor 1) grouped chromium, vanadium, cobalt, nickel, arsenic, barium, aluminum, iron, manganese, and titanium (Appendix J, Chapter III, Section V, p. 52, Tables 7 and 8, and Figure 14, p. 53). This factor is interpreted to represent metals whose concentrations were likely derived from terrestrial petrogenic sources (volcanic minerals and their weathering products) and do not appear to have significant anthropogenic contributions (with the possible exception of arsenic). Factor 2 grouped zinc, copper and lead. The elements with high Factor 2 loadings are interpreted to represent elements with anthropogenic enrichment likely derived from NPS pollution, WWTP effluent, or from DMM. Factor 3, which grouped calcium and strontium, is interpreted to represent the contributions from marine carbonate minerals to the sediment composition. The correlation matrix using Pearson's *r* (Appendix J, pg. 51 Table 6) generally confirms what was observed in the factor loading plot (Appendix J, Figure 14), i.e., the presence of three groups of elements that correlate significantly ($\alpha = 0.05$). Nearly all of the petrogenic elements (Factor 1) correlate with Pearson's *r* values >0.800. The anthropogenic elements (Factor 2) correlate significantly at $\alpha = 0.05$ with Pearson's *r* values of 0.268 (copper and lead), 0.674 (zinc and lead), and 0.772 (copper and zinc). The factor score plots (Appendix J, Figures 15 and 16) do show a distinct separation of the DMM, NPS, and WWTP strata from the CON stratum but it is not clear if the source(s) of the anthropogenic elements copper, zinc, and lead is(are) from terrestrial runoff, WWTP effluent, or slow dissolution of the DMM.

The use of PCA to analyze silt-clay fraction of the sediments demonstrated that there are three principal factors describing sediment metal variations and associations. Factor 1 (which includes COPC arsenic) represents metals which do not have considerable anthropogenic contributions and whose concentrations are likely derived from terrestrial petrogenic sources (although a terrestrial anthropogenic source for arsenic cannot be ruled out). Factor 2 (zinc, COPC copper, and COPC lead) represents anthropogenic enrichments of these metals. The DMM sediment copper and zinc concentration and variability could be representative of copper and zinc enrichment from the deterioration and transport of military munitions. Lead, the final metal COPC, is significantly correlated with the COPC copper ($r = 0.268$) and non-COPC zinc ($r = 0.674$) at all but the CON strata and it is enriched in DMM sediment samples. While the elevated lead concentrations of DMM sediment samples are likely derived, in part, from DMM sources, it is also possible that some portion is also derived from NPS pollution. It is, however, not possible to ascertain the relative contribution of lead from NPS versus DMM as a source in the DMM sediment samples. Therefore, the close proximity to DMM of the DMM sediment samples with elevated lead concentrations is consistent with the DMM present as the primary lead source.

5.3.4 Principal Components Analysis – Biota

Results of PCA of trace element compositional data for the biota are presented in Appendix J. Each type of biota has been treated separately for the PCA analysis as each type of organism displays different concentrations ranges and different elemental distributions (refer to the beginning of Section 5.3.2).

Biota: he'e (octopus)

Results of PCA for the octopus tissue are presented in Appendix J Tables 15, 16, and 17 and Figures 21 and 22. From Table 15 (Appendix J) the strongest positive correlations are between copper and cadmium with a Pearson's $r = 0.943$; zinc and copper (0.916) – most likely due to the

presence of carbonic anhydrase and hemocyanin, respectively, and to Cu/Zn-SOD; and cobalt and cadmium (0.905). The strongest negative correlations are for vanadium and chromium (r = -0.690) and vanadium and arsenic (-0.548). Lead correlates weakly with copper (r = 0.255), mercury correlates weakly with barium (r = 0.298), and arsenic correlates with chromium (r = 0.621) and is also anti-correlated with vanadium (r = -0.548). PCA extracted two components for the octopus tissue (Appendix J-Table 16). These two factors accounted for 82.0% of the data set variance (Appendix J-Table 17) with Factor 1 accounting for 61.7% of the total variance. The factor loads from Table 16 are also shown in Figure 21 (Appendix J). The first factor groups cadmium, chromium, cobalt, copper, strontium, and zinc. Factor 2 only includes arsenic. All individual sample factor scores are shown in Figure 22 (Appendix J). The samples are shown for each site and also for both of the sampling seasons and are grouped more by season than by sample site location.

Biota: weke (goatfish)

Results of PCA for the goatfish tissue are presented in Appendix J Tables 18, 19, and 20, and Figures 23 and 24. The elements generally display weaker positive correlations than found for the octopus and sediment samples. The strongest positive correlations are between zinc and strontium (r = 0.447), strontium and barium (0.414), and finally zinc and barium (0.361). The strongest negative correlation is between vanadium and chromium (r = -0.826), which was also observed with the octopus tissue samples. Table 18 also shows that copper does not strongly correlate with any other elements. PCA extracted two components for the goatfish tissue (Appendix J - Table 19). These two factors accounted for 52.8% of the data set variance (Appendix J-Table 20) with Factor 1 accounting for 32.1% of the total variance. The factor loads from Table 19 are also shown in Figure 23 (Appendix J). Factor 1 groups barium, cobalt, lead, strontium and zinc and Factor 2 groups arsenic and chromium. All individual sample factor scores are shown in Figure 24 (Appendix J). The samples are grouped more based on sampling season than by sample site location but not to the degree observed in octopus.

Biota: Kona crab

Results of PCA for the Kona crab tissue are presented in Appendix J Tables 21, 22, and 23 and Figures 25 and 26. There are few elements with strong positive correlations. The strongest positive correlations are between strontium and barium (r = 0.759), zinc and copper (0.661) – like the octopus, probably due to carbonic anhydrase and hemocyanin, respectively, and Cu/Zn-SOD, arsenic and zinc (0.637), and finally arsenic and copper (0.505) (Appendix J Table 21). The strongest negative correlation is between zinc and mercury (r = -0.333). The PCA extracted two components for the Kona crab tissue (Appendix J-Table 22). These factors accounted for 61.0% of the data set variance (Appendix J-Table 23), with Factor 1 accounting for 39.0% of the variance. The factor loads from Table 22 are also shown in Figure 25 (Appendix J). Factor 1 groups arsenic, barium, copper, strontium and zinc and Factor 2 groups cadmium and cobalt. The individual sample factor scores are shown in Figure 26 (Appendix J). The samples are shown for each site and also for both sampling seasons with most of the samples grouped near the center of the plot.

Biota: Limu Kohu (seaweed)

Results of PCA for the limu kohu tissue are presented in Appendix J Tables 24, 25, 26, and Figures 27 and 28. From Table 24 (Appendix J), the elements that have the strongest positive

correlations are copper and zinc (r = 0.972) – carbonic anhydrase and Cu/Zn-SOD, nickel and cobalt (0.919), and strontium and chromium (0.911). The strongest, albeit very low, negative correlation is between vanadium and copper (r = -0.173). Copper and zinc only correlate with each other and arsenic does not correlate strongly with any other elements. PCA extracted two components for the limu kohu (Appendix J Table 25). These factors accounted for 86.7% of the data set variance (Appendix J-Table 26), with Factor 1 accounting for 57.8% of the variance. The factor loads from Table 24 (Appendix J) are also shown in Figure 27. The first factor groups barium, cobalt, chromium, lead and strontium and Factor 2 only includes copper and zinc. The individual sample factor scores are shown in Figure 28 (Appendix J). The samples are shown for each site and also for both sampling seasons and the limu samples appear to be distributed by seasons more than by strata.

The use of PCA to analyze the biota data indicated that none of the three metal/metalloid COPCs (copper, lead, and arsenic) are correlated within the biological samples. This lack of correlation indicates that metal COPCs present in these organisms are probably controlled by metabolic processes and not necessarily by exposure to any one particular source. The elemental compositions of octopus, fish, and crab tissue samples show no correlation with the variations observed in the sediments from the different sites or the presence of DMM. While the concentrations of metal COPCs in biotic tissues do vary between species, these concentrations are essentially identical for a given type of biota compared between the four strata.

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Section 6
Risk Assessments

This study evaluated the potential impacts to selected receptors at Ordnance Reef (HI-06) from the presence of DMM. The study team prepared both a detailed HHRA (see Appendix G) for current and future on-site human activity and a screening ERA for on-site marine environments (see Appendix M). Readers should review these appendices to gain a detailed understanding of the methodology and assumptions the study team used to prepare these assessments leading to the study's findings and recommendations. The remainder of this section provides a brief overview of the objectives of these risk assessments and the assumptions inherent in the evaluations.

6.1 Risk Assessment Overview

6.1.1 Human Health Risk Assessment Overview

The study team conducted the HI-06 HHRA to characterize the potential human health risks from exposures to biota, sediment, and seawater collected from four independent strata at Ordnance Reef (HI-06). The HI-06 HHRA, which is a follow-on assessment to a screening-level survey that NOAA conducted in 2006, provides further characterization of the potential risks at Ordnance Reef (HI-06).

This study consisted of a site-specific HHRA that evaluated the potential risks and hazards assumed to be directly attributable to the military munitions (i.e., DMM) sea disposed at Ordnance Reef (HI-06) circa WWII. The HI-06 HHRA excluded non-munitions related metals (e.g., barium, cadmium, cobalt, mercury, nickel, selenium, strontium, vanadium, and zinc) and MC that appeared to be equivalent to background (e.g., arsenic). To provide a better understanding of potential risks, the HI-06 HHRA includes a Supplemental Risk Characterization. This characterization calculated the potential risks and hazards from the DMM present at Ordnance Reef (HI-06) assuming none of the DMM present are recovered and all environmental contaminants analyzed, including MC, are related to Ordnance Reef (HI-06). Because these are highly conservative assumptions, the Supplemental Risk Characterization should be considered a worst-case scenario.

The four strata assessed included the DMM source area (DMM stratum), the Wai'anae WWTP outfall area (WWTP stratum), the coastal NPS discharge area (NPS stratum) and a control area (CON stratum) that was similar in environment to the DMM stratum, but was assumed un-impacted from the DMM present at Ordnance Reef (HI-06). The HI-06 HHRA evaluated the potential risk from exposures to media collected from each of these areas separately.

The analytes selected for this investigation were based on the types of both munitions observed in the area and compounds (i.e., MC) associated with these historic munitions. Because the specific munitions fills were not known, consideration was given to those energetic analytes associated with the general types of military munitions known to have been disposed of at

Ordnance Reef (HI-06). Also considered was the impact of corrosion and resulting releases of MC from the DMM present at Ordnance Reef (HI-06) that would logically occur.

The main energetic analytes of concern were TNT (2,4,6-TNT), cyclonite (RDX), tetryl, and ammonium picrate (as picric acid). Other energetic analytes included nitroglycerin, pentaerythritol tetranitrate (PETN), 2-Am-4,6-DNT, 4-Am-2,6-DNT, 1,3-DNT, 2,4-DNT, 2,6-DNT, HMX, nitrobenzene, 2-NT, 3-NT, 4-NT, 1,3,5-TNB, 2,4-dinitrophenol, and picramic acid. The HI-06 HHRA also evaluated the potential contributions of corroded munitions casings by analyzing for heavy metals, specifically metals associated with munitions' casings. Munitions-specific metals were identified as arsenic (speciated into organic and inorganic forms), copper, and lead. Zinc, although associated with munitions, is not a COPC nor is it considered particularly toxic to humans. Although arsenic is not expected in the munitions present at Ordnance Reef (HI-06) at significant quantities, the local community concerns relating to the historic disposal of chemical warfare materials containing arsenic in Hawaiian waters led to the inclusion of this analyte as a COPC. Although not munitions-related, a full suite of metals including antimony, barium, cadmium, cobalt, chromium, copper, lead, mercury, nickel, selenium, strontium, thallium, uranium, and vanadium, were also included in the analysis to aid in the PCA used in identifying the source metals.

The study team estimated risk for Current and Future Residents who reside near and consume seafood collected from Ordnance Reef (HI-06). To obtain a representative estimate of seafood consumption, a limited seafood consumption survey was conducted of the local population. Results of the survey indicate that the community consists of (a) those that may consume a limited amount (less) of seafood from the DMM stratum (referred to as "average" seafood consumers); and (b) those that consume large amounts of seafood (referred to as "high-end" consumers). For the risk assessment, the highly conservative (and potentially unrealistic) assumption was made that the "high-end" seafood consumer collected the seafood consumed exclusively from the DMM stratum. The "high-end" seafood consumer was included in the assessment to be health protective and provide a range of risk estimates. The study team recognizes, however, that the "high-end" seafood consumer used in the HI-06 HHRA is a hypothetical scenario. This scenario is not based on the current or reasonably foreseeable uses of the study site because the sea life in the DMM stratum is inadequate to support such a level of consumption. Nonetheless, the study team believed this scenario would provide an upper bound to the range of risks.

The four strata the study team assessed were limited in areal extent. Most of the fish consumed from these areas would theoretically be sourced from deeper water, not from reef areas where the study team collected fish samples and fishermen were assumed to catch fish for consumption. Additionally, the seafood consumption survey the study team conducted was intentionally performed to be health protective. As a result, the consumption survey may not realistically represent the relatively small number of individuals, if any, in the population that would be "high-end" seafood consumers. Therefore, the HI-06 HHRA is considered very conservative.

Interviews, which included a number of fishermen, were in large part directed by several local fishermen. As such, fishermen made up a larger proportion of people that participated in the survey. Readers of this report should consider the potential risks and hazards for the "high-end" seafood consumer to be very conservative and not representative of the potential risks and hazards to which the general population might be exposed.

Current and Future Recreational Fishermen and Future Response Workers were considered for quantitative analysis, but were excluded because exposures were assumed equivalent to the Current and Future Resident (see Section 2.2.1.2 of the HI-06 HHRA for additional discussion regarding limiting the quantitative analysis to residential scenarios only) (Appendix G). The study team eliminated exposure to seawater from the quantitative assessment because concentrations of environmental contaminants, including MC, in seawater were, in almost all cases less than laboratory detection limits. The study team also eliminated exposure to sediment as a pathway of concern because sediments in the four potential marine areas assessed were limited in areal extent and existed in patches and contact to this media would be infrequent and low.

6.1.2 Screening HI-06 Ecological Risk Assessment Overview

The HI-06 ERA is consistent with a screening-level or Tier I ERA that encompasses Steps 1 and 2 of the EPA's eight-step process for conducting ERAs at Superfund sites (EPA, 1997). The Tier I assessment relies on both existing site data and conservative assumptions to support risk management decisions. In addition, it includes a less conservative analysis that is part of the Tier II (baseline) risk assessment, commonly referred to as "Step 3a." One of the principal objectives of the Tier I HI-06 ERA is to determine whether some or all site-related environmental contaminants of concern can be eliminated from consideration as potential sources of risk to ecological receptors at Ordnance Reef (HI-06).

The HI-06 ERA assessed the same four marine areas (or strata) as the HI-06 HHRA (i.e., DMM, WWTP, NPS, and CON strata). The HI-06 ERA focused primarily on the DMM stratum and constituents of potential ecological concern (COPEC) that the Army identified as being associated with the DMM.

The 2009 investigation collected samples and data over two seasons, spring and fall. Analytes in the 2009 investigation included energetic compounds, metals, phthalate esters and pyrene. However, phthalate esters and pyrene, which were not detected in most samples, were not of concern to the HI-06 ERA. The study team also analyzed inorganic arsenic for the HI-06 HRRA, but these data were not used in the HI-06 ERA. Biota sampled as part of the 2009 investigation focused on food sources used by the local (human) population and included goatfish (weke) prepared as fillets, octopus, crabs, and seaweed.

COPECs were identified through graphic comparisons (quantile-quantile plots) of the data from the DMM disposal area to data from the control area. The study team identified a total of 11 COPECs. These included seven energetic compounds (2,4-DNT, 2,6-DNT, 2-NT, 4-NT, HMX, RDX, and tetryl) and four metals (barium, copper, lead, and zinc). Water was not found to be a potential source medium for any of the COPECs at Ordnance Reef (HI-06).

6.2 Interpretation of Results and Recommendations

6.2.1 HI-06 Human Health Risk Assessment Results and Recommendations

The HI-06 HHRA evaluated risks and hazards under multiple health-protective current and future land use scenarios. Risk managers who use this report to evaluate Ordnance Reef (HI-06) and any associated risks and hazards should consider realistic current and future land use

scenarios, the conservativeness of the HI-06 HHRA's assessment assumptions and process, and the economic and cultural importance of Ordnance Reef (HI-06) to the community.

The HI-06 HRRA calculated the Potential Excess Lifetime Cancer Risks (PELCR) and compared them to EPA and DOH regulatory risk range of 1E-06 to 1E-04. Estimated non-carcinogenic risks are presented as total site Hazard Indices (HIs). These calculations sum the Hazard Quotients (HQs) of each COPC at Ordnance Reef (HI-06) and by specific medium. A total HI of "1" was considered the regulatory level of concern (Appendix G, Table ES-1 provides the site-specific HI-06 HRRA and Supplemental Risk Characterization risk summary).

The HI-06 HHRA's results indicate that the potential risks and hazards associated with DMM at Ordnance Reef (HI-06) are acceptable, when people limit consumption to reasonable quantities and the human food items (e.g., fish, invertebrates, and seaweed) that are generally consumed by an "average" seafood consumer from the community (Appendix G, Table ES-1, the "average" seafood consumer scenario for the HI-06 HHRA). The potential carcinogenic risk was 4E-06 at the DMM stratum (within the EPA and DOH regulatory risk range and near the point of departure risk values of 1E-06). All other strata exhibited risk below the EPA and DOH point of departure. Non-carcinogenic hazards did not exceed the regulatory level of concern at any stratum.

Site-specific risk characterization estimates for the "high-end" seafood consumer in the DMM and NPS strata were within the acceptable regulatory risk range, while carcinogenic risks at the WWTP and CON strata were below the EPA and DOH point of departure of 1E-06. Non-carcinogenic hazards for the "high-end" seafood consumer exceed the regulatory level of concern at the DMM and WWTP strata.

The Supplemental Risk Characterization served as an estimate of total cumulative risk versus the initial estimates of risk for the DMM stratum that are based on site-specific COPCs. Supplemental Risk Characterization results (i.e., baseline conditions) were as follows: Carcinogenic risks for the "average" seafood consumer were within the acceptable regulatory risk range, while non-carcinogenic hazards for the "average" seafood consumer were below the regulatory level of concern of 1 at all strata.

Carcinogenic risks for the "high-end" seafood consumers in the DMM and NPS stratum assumed exposure to all environmental contaminants evaluated in this study were within the acceptable regulatory risk range, while risks at the WWTP and CON strata were below the EPA and DOH point of departure of 1E-06. Non-carcinogenic hazards for the "high-end" seafood consumer exceeded the regulatory level of concern at the DMM and WWTP strata. The reader is reminded that the "high-end" seafood consumer is a hypothetical scenario. This scenario is not based on the current or a reasonably foreseeable future use of the study site because the sea life present is inadequate to support such a consumption level. This scenario, however, provides an upper bound to the range of risks.

6.2.2 Screening HI-06 Ecological Risk Assessment Results and Recommendations

Based on the comparison of the maximum measured concentrations of the six COPECs identified in the sediment at the DMM stratum to their corresponding sediment screening levels, the potential for risk to organisms from the reef community may exist from exposures to four of

these constituents in sediment: 2,4-DNT, copper, lead, and zinc. Basing the HQs on a less conservative measure of overall sediment concentration in the DMM stratum (i.e., the 95% upper confidence limit (UCL) of the mean) reduces the HQ for 2,4-DNT to less than one, indicating that, on average, this energetic compound does not represent an unacceptable risk to communities that use Ordnance Reef (HI-06) to support subsistence and for recreational and commercial purposes as it currently exists in the sediment. The ranges of HQs for the three metals (copper, lead, and zinc) based on the ranges of their central tendency estimates (i.e., the maximum likelihood estimate represented by the arithmetic mean and the 95% UCL of the mean) indicate a low potential for risk from lead and zinc in the sediments. Although the range of HQs for copper in sediment is higher (22 to 34), no overt signs of the Ordnance Reef communities' impairment have been observed at the DMM stratum (USACHPPM, 2007) despite more than 50 years of exposure to this metal (see Appendix M). It should also be noted that sediment cover in the study area is extremely patchy, contributing to a limited exposure pathway for biota.

The comparisons of tissue concentrations to available ATLs indicate that of the COPECs for which ATLs were available, the potential for risk to seabirds consuming prey at the DMM is very low. None of the concentrations in the fish tissue exceeded the corresponding ATL. Only the zinc concentrations in octopus and crab exceeded to ATL for that metal. However, the maximum HQ for zinc (based on the crab) was less than two.

Although both octopus and crab showed significantly high concentrations of barium, copper, and zinc in their tissues than did fish, these taxa will represent only a small percentage (if any) of the diet of the piscivorous seabirds due to their tendencies to stay near the sea floor rather than be exposed to avian predation near the surface. Although it could be argued that fish are similarly unlikely to be taken by seabirds, the fish are used in the HI-06 ERA to conservatively represent all fish, including more pelagic fish that would be found closer to the surface.

The comparisons of fish tissue concentrations to available critical tissue levels (CTLs) also indicated no potential risk to fish from lead, 4-NT, and RDX at the DMM stratum. It is acknowledged, however, that these CTLs represent only a fraction of the COPECs detected in biota at Ordnance Reef (HI-06) and that potential risk may exist to one or more receptors in fish from the reef community that is not recognized due to the absence of appropriate screening levels at this time.

Finally, it is an open question how certain receptors (specifically the fish) are being exposed to energetic compounds at Ordnance Reef (HI-06). In the sediment, only 2,4- and 2,6-DNT were detected, with no detections made of any energetics in the water column. Lesser detections of 2,4-DNT were made in the sediment at the WWTP stratum than at the DMM stratum. Although there was one detection of HMX in an octopus sample collected in spring (April 2009 sampling event), there were no other detections of energetics in fish during this sampling event. In the fall (September to October 2009), 61% of the fish samples showed detectable levels of HMX, with some also showing detectable levels of RDX, tetryl, 2,4-DNT, and 2- and 4-NT.

None of these energetic compounds is expected to be especially bioaccumulative or persistent in tissues, and the fact they appear to exhibit seasonality in their occurrence indicates that, if they persist at all in muscle tissue, they do not do so for any longer than than six months. The seaweed, crab, and octopus data do not show a similar pattern; therefore, do not support a hypothesis of food-chain transfer and biomagnification. Instead, it appears that there may be a

more direct exposure of fish to energetics occurring on a seasonal basis. Possible explanations for this may include seasonal changes that cause MC released to the environment to be more available or that brings fish into more direct contact with DMM allowing for exposed explosives in deteriorating DMM. It is noted that HMX and 2,4-DNT were also detected in a few fish from the NPS stratum from samples collected during the fall (September to October 2009). The concentrations detected were much lower than those of the DMM stratum. It is possible, however, that these fish may have migrated from the DMM stratum to the NPS stratum after exposure at the DMM stratum.

Given the lack of CTLs for most of these energetics, it cannot be determined whether seasonally high concentrations of these compounds in fish collected during this study represent varying levels of potential risk to fish or whether other fish species might show similar patterns of accumulation. Observations of fish from the reef community do not indicate any overt signs of impairment (USACHPPM, 2007).

6.3 Summary of Risk Assessment Results

HI-06 HHRA's results indicate that the potential risks and hazards associated with DMM at Ordnance Reef (HI-05) are acceptable when people limit consumption to reasonable quantities and to the human food items (e.g., fish, invertebrates, and seaweed) that are generally consumed by an "average" resident from the community. For "high-end" seafood consumers, the results of sampling in the DMM stratum exceeded the regulatory level of concern for non-carcinogenic hazards. The "high-end" seafood consumer is a hypothetical scenario that is not based on the current or reasonably foreseeable future uses of the study site because the sea life at the study site is inadequate to support this use. The potential risks and hazards for the "high-end" seafood consumer are not indicative of the potential risks and hazards for the general population, but represent a hypothetical upper bound for risk.

The results of the HI-06 ERA indicate that there were no risks from energetic compounds and barium found for sediments. Potential risks to ecological receptors from exposure to lead and zinc in sediment were low and are probably negligible. Although the range of HQs for copper in sediment is higher, no overt signs of impairment were observed in fish from the reef community at the DMM stratum (USACHPPM, 2007) despite more than 50 years of exposure to this metal.

The potential for risk to piscivorous seabirds feeding at the DMM stratum is insignificant, although insufficient toxicity data are available to assess this pathway for four of the six energetic compounds detected in fish fillets (2- and 4-NT, HMX, and tetryl). The concentrations of COPECs in fish samples did not exceed CTLs for fish when such values were available; however, tissue-based screening levels were only available for three of the 10 COPECs detected in the fish samples (4-NT, RDX, and lead). There were no CTLs found for the COPECs detected in the other biota specific to those taxa.

Although detectable levels of HMX and five other energetics were observed in fish muscle tissue collected in the fall (September to October 2009), they were not detected in the spring (April 2009) samples. The source or exposure pathway for these energetics is not known, but it does not appear to be related to water or sediment concentrations or from the food chain. A significant area of uncertainty in the HI-06 ERA is whether those increases in energetics in tissue pose a risk to fish of the reef community. Observations of fish from the reef community made

during the 2006 investigation did not indicate signs of significant adverse effects and much of the DMM at Ordnance Reef (HI-06) was in the process of being encrusted by corals.

Section 7
Conclusions

7.1 Community Participation

This study involved the participation of many key individuals and groups, and their interest and involvement enabled the team to ensure that the primary concerns of the community were identified and could be considered during the planning phase of the study. The study team was able to continue involving community members during the fieldwork phase of the study by incorporating the aid of local fishermen to collect biota samples and assist in the collection of sediments and seawater. This participation provided assurance to the local community that appropriate types of biota were being collected in close proximity to DMM, and it also brought a wealth of local knowledge and fishing expertise to the study team that otherwise would have been lacking. The study team is particularly grateful for this assistance, which improved the overall quality of the study.

Progress of the fieldwork was regularly communicated to community members via informal briefings as well as ORCC meetings and presentations at special neighborhood board meetings.

Community participation was critical for the HI-06 HHRA. The study team developed a seafood consumption questionnaire based on input from members of the Waiʻanae and Nānākuli communities. Therefore, the HI-06 HHRA is believe to be representative of local consumption habits, as opposed to the default mainland U.S. seafood consumption habits typically used for HHRAs. Because the seafood consumption values used for the risk assessment are several orders of magnitude higher than industry-standard values, the HI-06 HHRA presents a much more conservative assessment of potential human health impacts associated with consuming seafood from Ordnance Reef (HI-06).

7.2 Sample Site Selection

To address community and regulatory agency concerns regarding NOAA's 2006 survey and sampling design, the primary focus of sample site selection was to target the collection of biota and sediment samples in close proximity to specific DMM items as prioritized by EPA. Considering the anticipated difficulties of finding specific biota at DMM and other sites, the Waiʻanae fishermen were remarkably successful in collecting biota samples near DMM items. Biota and sediment samples were successfully recovered near all of the DMM types targeted by the EPA (small arms ammunition, 20-mm rounds, 105-mm projectiles, and 6- and 8-in naval rounds). Sample sites were selected to reflect anticipated worst-case conditions (e.g., sites likely to have the highest concentrations of contaminants present) at Ordnance Reef (HI-06). This approach results in a highly conservative estimate of potential risk given the concentrations are likely to over estimate the average across the DMM stratum.

7.3 Sample Collection and Analysis

The study's sample collection goal was exceeded. As a result, the study was able to collect and analyze biota from three different trophic levels. Octopi were collected at all four strata, although Kona crabs were collected principally from two strata (WWT and DMM) where sand channels, the normal habitat for these organisms, were present.

Sample analyses for this study were rigorous and thorough. This study involved an extensive effort to evaluate the applicability of the previously developed EPA 8330 method (applicable to soil and groundwater) for Hawai'i-specific biota types, and modify them as necessary to allow for reliable analysis of the COPCs in these matrices. This effort was a multi-year undertaking that involved close coordination between the Army, UH, Environet, EPA, and the commercial laboratory selected to perform the MDL study. Results of the MDL study led to a modified method 8330 that is sufficient to quantitatively analyze for the majority of energetics in marine biota. This method can now be applied reliably to other similar studies worldwide.

7.4 Nature and Extent of Contamination

There was only a single detection of phthalates, pyrene, or energetics in the seawater samples collected during this study. The compound bis(2-ethylhexyl)phthalate was detected at an estimated concentration of 1.4 µg/L in a single sample from the WWT stratum. This is unsurprising considering the rapid dilution that would be anticipated for any COPC released into seawater at Ordnance Reef (HI-06), but it should still assure the community that seawater at Ordnance Reef (HI-06) is not contaminated as a result of the presence of DMM.

There were three energetic compounds detected in sediments: 2,4-DNT, 2,6-DNT, and 1,3,5-TNB. Two compounds (2,4-DNT and 2,6-DNT) are the same that were detected during NOAA's 2006 survey. Concentrations detected in 2009 were much lower than those detected in 2006. These detections occurred in primarily the DMM stratum, although at least one also occurred in the WWT stratum. There was no clear and consistent correlation evident between the concentration of energetic compounds detected and the distance from the target DMM. Neither compound was present at concentrations exceeding study action limits. Because of the low concentrations of energetics detected during this study and the fact it is unlikely that members of the communities that use Ordnance Reef (HI-06) for subsistence as well as for recreational and commercial purposes will come into regular contact with sediments, energetics in sediment are not considered a human health risk.

Several energetic compounds were detected in biota samples collected from Ordnance Reef (HI-06). These included 2,4-DNT, HMX, 2-NT, 4-NT, RDX, tetryl and 1,3,5-TNB. Detections occurred primarily in fish samples, although one octopus and one crab also contained at least one energetic compound (values are flagged as estimated). These data were carefully considered in both the HI-06 HHRA and the HI-06 ERA. Additionally, although not considered COPCs, there were a few detections of 3,5-dinitroaniline and 2-nitrophenol at low concentrations in several fish samples.

Samples collected from the DMM stratum typically showed higher abundances of copper, lead and zinc than those collected from the other strata, whereas concentrations of arsenic were higher in sediments from the CON stratum than from other strata. Although there is community

concern with respect to arsenic, this element is not found in any quantity in conventional munitions; therefore, arsenic would not be expected to be abundant in sediments from the DMM stratum. The finding of arsenic in sediments from the CON stratum indicates that this element is derived from land-based source input through runoff. As with energetics, there was no clear and consistent correlation evident between the concentration of metals in sediment and the distance from the target DMM.

In general, metals were detected at similar levels in all biota from all strata. Notable exceptions to this finding were copper and zinc, which were considerably enriched in seaweed collected in the DMM stratum. Concentrations of arsenic in biota were remarkably similar across the various strata. Furthermore, the overwhelming majority (approximately 99%) of arsenic was present in the less toxic organic form in crab, octopus, and fish. Metals in biota were carefully considered in both the HI-06 HHRA and the HI-06 ERA.

7.5 Principal Components Analysis

PCA is useful for finding patterns of variance and elemental associations both within and between large and diverse data sets. There is considerable variation in concentrations of metals (both COPC and non-COPC) detected in sediments and biota for the four strata. PCA was applied to elemental composition data to evaluate elemental associations and variations that could indicate individual sources of the metals.

The PCA sediment results demonstrate there are three principal factors describing sediment metal variations and associations.

- Factor 1 (vanadium, chromium, cobalt, nickel, arsenic, barium, aluminum, iron, manganese, and titanium) represent metals which do not have considerable anthropogenic contributions. Elevated concentrations of these elements are likely derived from terrestrial petrogenic sources such as volcanic minerals and their weathering products, which are mainly aluminosilicate minerals, iron oxyhydroxides, and hydrous aluminum oxides. Arsenic, as one of the three metal COPC, is grouped into this first factor with the terrestrial elements. Unlike the other elements, the source of arsenic may be anthropogenic. It is not, however, associated with anthropogenic elements related to DMM (Factor 2 below). Arsenic has been commonly observed elsewhere in Hawai'i and the source could be the result of past or current agricultural activities. Comparing the four strata, the CON stratum appears to be most strongly influenced by sources of materials derived from weathering of geologic materials

- Factor 2 (zinc, copper, and lead) represents anthropogenic enrichments of these metals, but cannot distinguish readily between land based anthropogenic inputs and DMM. Clearly, however, the sediment composition and variability in the DMM stratum is representative of enrichment of copper, a COPC, from the deterioration and transport of military munitions. The other primary source is thought to be land runoff of non-point source pollution, especially associated with wear of automotive parts such as brakes and tires.

- Factor 3 (calcium and strontium) represents the influence of marine biogenic sediments. The WWTP and NPS strata show stronger variability and composition controls by marine biogenic sediments compared to the DMM and CON strata.

It is important to note that marine carbonates dominate the sediment composition for Ordnance Reef (HI-06) and thus all four strata. Therefore, the overwhelming predominance of natural marine carbonates with a highly homogenous chemical composition in the sediments contributes relatively little to the variance of the compositional data set as analyzed by PCA. With this in mind, the small contribution of DMM derived material (at the DMM stratum) or terrestrial petrogenic material (at the CON stratum) actually contributes to a larger variability in composition of the sediments. For this reason , the factors associated with DMM and terrestrial materials account for a greater fraction of the variance of the entire data set.

PCA of the biota data indicate that none of the COPC correlate with each other. This lack of correlation indicates that metal COPCs present in these organisms are probably controlled by metabolic processes and not necessarily by exposure to any one particular source. The elemental compositions of octopus, fish, and crab tissue samples do not show any correlation with the variations observed in the sediments from the different sites or the presence of discarded munitions. The concentrations of COPC in biotic tissues do vary between species, but are essentially identical for a given type of biota between sites.

7.6 Risk Assessments

7.6.1.1 Human Health Risk Assessment

Supplemental carcinogenic risk characterization estimates for the "high-end" seafood consumer (e.g., an individual consumer who eats seafood collected exclusively from the DMM stratum) in the DMM and NPS strata were within the acceptable regulatory risk range, while carcinogenic risks at the WWTP and CON strata were below the EPA and DOH point of departure of 1E-06. Non-carcinogenic hazards for the "high-end" seafood consumer exceeded the regulatory level of concern at the DMM and WWTP strata. Under the "average" seafood consumer scenario, carcinogenic risk was 4E-06 at the DMM stratum (within the EPA and DOH regulatory risk range but near the point of departure risk values of 1E-06). All other strata exhibited risk below the EPA and DOH point of departure. Non-carcinogenic hazards did not exceed the regulatory level of concern at any stratum.

In summary, the risk associated with consumption of seafood from the DMM stratum is similar to those of other strata within Ordnance Reef (HI-06) except for the "high-end" seafood consumer, with the assumption that the "high-end" seafood consumer eats seafood collected exclusively from the DMM stratum. The "high-end" seafood consumer is a hypothetical scenario that is not based on the current or reasonably foreseeable future uses of the study site because the sea life at the study site is inadequate to support this level of consumption. This scenario provided an upper bound to the range of risks and was chosen to assess the worst-case scenario for seafood consumption along the Wai'anae coast. In reality, it is highly unlikely that Ordnance Reef (HI-06) could support the ingestion rate for the "high-end" seafood consumer used in the HI-06 HHRA. Ordnance Reef (HI-06) is limited in areal extent and most of the fish consumed in the area would theoretically be sourced from deeper water and not the reef area where fish sampling was conducted and where fishermen were assumed to consume fish. Even

under such a consumption habit, however, it is highly likely that the benefits of consuming seafood (as opposed to a high fat content diet, for example) far outweigh the risk associated with seafood from the DMM stratum. For the average Waiʻanae community consumer, whose seafood consumption habits are greater than most Hawaiʻi residents and far greater than considered typical of U.S. citizen consumption, there is no significant risk associated with consuming seafood from the DMM or other strata of Ordnance Reef (HI-06). It should be kept in mind, the FDA has routinely recommended a moderate seafood consumption in order to limit ingestion of mercury that is associated with certain high-end predatory fish found throughout the world's oceans. A similar recommendation is likely warranted here.

7.6.1.2 Ecological Risk Assessment

The results of the HI-06 ERA indicate no risk from either energetic compounds or barium in sediments. Potential risks to ecological receptors from exposure to lead and zinc in sediment were low and are probably negligible. Potential risk from copper in sediment was moderate.

The potential for risk to piscivorous seabirds feeding at the DMM stratum are insignificant, although insufficient toxicity data are available to assess this pathway for four of the six energetic compounds that were detected in fish fillets (2- and 4-NT, HMX, and tetryl). The concentrations of COPECs in fish samples did not exceed CTLs for fish when such values were available; however, tissue-based screening levels were only available for three of the 10 COPECs detected in the fish samples (4-NT, RDX, and lead). No tissue-based screening levels were found for the COPECs detected in the other biota specific to those taxa.

HMX and five other energetics were observed to occur in the fall at detectable levels in fish muscle tissue, but they were not detected in the spring samples. The source or exposure pathway for these energetics is not known, but it does not appear to be related to water or sediment concentrations or from the food chain. A significant area of uncertainty in the HI-06 ERA is whether those increases in energetic in tissue pose a risk to the fish of the reef community. Observations of the reef community made during the 2006 investigation did not indicate signs of significant adverse effects and much of the DMM of Ordnance Reef (HI-06) was in the process of being encrusted by corals. The DMM at Ordnance Reef (HI-06) has been in place for over 50 years, as such, decisions regarding these munitions should consider both explosives safety and the harm the action could cause to the current vibrant reef community.

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Section 8
References

AECOS, Inc., 2002. *Inventory Catalogue of Hawai'i's Coral Reefs*. Hawai'i Wildlife Fund. Accessed at <http://home.hawaii.rr.com/cPie/CoralReefBib.html>.

Amiard, J.-C., C. Amiard-Triquet, S. Barka, J. Pellerin, and P.S. Rainbow, 2006. "Metallothioneins in aquatic invertebrates: Their role in metal detoxification and their use as biomarkers." *Aquat. Toxicol*. 76(2006):160-202.

ATSDR (Agency for Toxic Substances and Disease Registry), 1995. *Toxicological Profile.* ATSDR, Atlanta, GA.

_____, 2000. *Toxicological Profile for Arsenic*. ATSDR, Atlanta, GA, 468 pp.

_____, 2007. *Health Consultation, Ordnance Reef, Wai'anae, Honolulu County, HI.* August.

Bhatt, M., Zhao, J., Monteil-Rivera, F., Hawari, J., 2005. "Biodegradation of cyclic nitramines by tropical marine sediment bacteria". *J. Ind. Microbial Biotechnol*, 32:261-267.

Bienfang, P.K., and R.E. Brock, 1980. *Predevelopment Reconnaissance of the Water Quality and Macrobiota Conditions Affronting the West Beach Coastline, Oahu, Hawaii*. Technical Report Submitted to Environmental Communications, Inc.

Bienfang, P., E.H. De Carlo, S. Christopher, S. DeFelice, and P. Moeller, 2009. "Trace element concentrations in coastal Hawaiian waters." *Mar. Chem.,* 113(3-4):149-256. <http://dx.doi.org/10.1016/j.marchem.2009.01.007>.

Bolger, P.M., M.A. Adams, L.D. Sawyer, J.A. Burke, C.E. Coker, and R.J. Scheuplein, 1990. *Risk Assessment Methodology for Environmental Contaminants in Fish and Shellfish*. U.S. Food and Drug Administration, Center for Food Safety and Applied Nutrition, Washington, D.C.

Brainard, R., D. Gulko, C. Hunter, A. Friedlander, R. Kelty, and J. Maragos, 2002. "Status of Coral Reefs in the Hawaiian Archipelago". In C.R. Wilkinson (Ed), *Status of Coral Reefs of the World*, 14.

Brannon, J., C. Price, S. Yost, C. Hayes, and B. Porter, 2005. "Comparison of environmental fate and transport process descriptors of explosives in saline and freshwater systems". *Mar. Pollut. Bull.*, 50:247-251.

Bricker, S., 1992. "The history of Cu, Pb and Zn inputs to Narragansett Bay as recorded by Rhode Island salt marsh sediments." *EOS Trans. Am. Geophys. Union,* 73: 60.

Bruland, K., 1983. "Trace elements in seawater." *Chemical Oceanography.* Ed. J.P. Riley and R. Chester. 2nd Edition, Vol. 8. 147-220.

Buchman, M.F., 2008. *NOAA Screening Quick Reference Tables (SQuiRT), NOAA OR&R Report 08-1*. Office of Response and Restoration Division, National Oceanic and Atmospheric Administration, Seattle, Washington.

Caccia, V.G., F.J. Millero, and A. Palanques, 2004. “The distribution of trace metals in Florida Bay Sediments.” *Mar. Pollut. Bull.,* 46:1420-1433.

Cantillo, A.Y., G.G. Lowenstein, T.P. OConner, and W.E. Johnson, 1999. *Status and trends of contaminant levels in biota and sediments of South Florida.* NOAA Regional Reports Series No. 2:40.

Carmody, D.J., J.B. Pearce, and W.E. Yasso, 1973. “Trace metals in sediments of New York Bight.” *Mar. Pollut. Bull.,* 4:132–135.

CBD (Center for Biological Diversity), 2009. *Petition to List 83 Coral Species Under the Endangered Species Act – Submitted Before the Secretary of Commerce and the National Oceanic and Atmospheric Administration (NOAA) through the National Marine Fisheries Service (NMFS)*. Submitted 20 October.

City and County of Honolulu, 2001. *Wai‘anae Wastewater Plant Wins National Award*. News Release. Accessed at http://www.co.honolulu.hi.us/csd/publiccom/honnews01/amsa.htm.

Corl, E., 2001. *Bioaccumulation in the Ecological Risk Assessment Process*. Atlantic Division, Naval Facilities Engineering Command.

Creighton, T.E., 1999. *Encyclopedia of Molecular Biology*. John Wiley & Sons, New York, 4,900 pp.

Daugherty, J., 1998. *Assessment of Chemical Exposures: Calculation Methods for Environmental Professionals*. Lewis Publishers, New York, 117 pp.

Davis, J.A. and K.F. Hayes, 1978. *Geochemical Processes at Mineral Surfaces*. ACS Symposium Series, Volume 323, American Chemical Society, Washington, D.C. 683 pp.

De Carlo, E.H. and K.J. Spencer, 1997. “Retrospective analysis of anthropogenic inputs of lead and other metals to the Ala Wai Canal, O‘ahu, Hawai‘i.” *Appl. Organomet. Chem.,* 11(4):415-437.

De Carlo, E.H. and S.A. Anthony, 2002. “Spatial and temporal variability of trace element concentrations in an urban subtropical watershed, Honolulu, Hawaii.” *Appl. Geochem.*, 17:475-492.

De Carlo, E.H., V.L. Beltran, and M.S. Tomlinson, 2004. “Composition of water and suspended sediment in streams of urbanized subtropical watersheds in Hawaii.” *Appl. Geochem.,* 19(7):1011-1037. doi.org/10.1016/j.apgeochem.2004.01.004<http://dx.doi.org/10.1016/j.apgeochem.2004.01.004>.

De Carlo, E.H., M.S. Tomlinson, and S.A. Anthony, 2005. “Trace elements in streambed sediments of small subtropical streams on O‘ahu, Hawai‘i: Results from the USGS NAWQA Program.” *Appl. Geochem.,* 20(12):2157-2188.

De Carlo, E.H. and S. Dollar, 2007. *An evaluation of the Chemical Composition of Sediment in Honolua Bay, West Maui*. Report submitted to Maui Land and Pine Co., Kapalua, Maui. 16 pp.

De Carlo, E.H., 2007. *Trace elements in Hawaiian sediments: Where do they come from and how do we know? Special report to DOD on studies conducted at Ordnance Reef, Waianae, Oahu, June 2006.* 26 pp.

DLNR, 2003. *Hawaii Fishing Regulations*. Division of Aquatic Resources. <http://www.hawaii.gov/dlnr/dar/fish_regs/index.htm>.

_____, 2008. *Commercial Marine Landings Summary Trend Report.* Division of Aquatic Resources. <http://www.hawaii.gov/dlnr/dar/pubs/cmlstr2008.pdf>.

_____, 2009. *Commercial Marine Landings Summary Trend Report.* Division of Aquatic Resources. <http://www.hawaii.gov/dlnr/dar/pubs/cmlstr2009.pdf>.

DOBOR (State of Hawai'i Division of Boating and Ocean Recreation), 2009. *Waianae Baselilne Environmental Study*. Prepared by Tetra Tech, Inc. February.

DoD (U.S. Department of Defense), 2010. "Chapter 10, Sea Disposal of Military Munitions." *Defense Environmental Programs Annual Report to Congress – Fiscal Year 2009.*

DOH (Hawai'i Department of Health), 2004. *Hawai'i Administrative Rules, Title 11, Chapter 54: Water Quality Standards.* August.

Ek., H., Dave, G., Sturve, J., Almroth, B., Stephensen, E., Forlin, L., and Birgersson, G., 2005. "Tentative biomarkers for 2,4,6-TNT in fish (*Oncorhynchus mykiss*)." *Aquat. Toxicol.,* 72:221-230.

Ek., H., Dave, G., Nilsson, E., Sturve, J., Birgersson, G., 2006. "Fate and Effects of 2,4,6-TNT from Dumped Ammunition in a Field Study with Fish and Invertebrates." *Arch. Environ. Contam. Toxicol*., 51:244-252.

Emsley, J., 1989. *The Elements.* Oxford University Press, New York, 292 pp.

EPA (United States Environmental Protection Agency), 1997. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological risk Assessment*. EPA 540-R-97-006. Washington, D.C.

_____, 1998. *Guidelines for Ecological Risk Assessment*. EPA/630/R-95/002F. Washington, D.C.

_____, 2000. *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories.* Office of Water, Office of Science and Technology. November.

_____, 2004. *National Recommended Water Quality Criteria: 2004*. Office of Water, Office of Science and Technology. EPA-822-R-02-047. November.

_____, 2008. *National Functional Guidelines for Organic Data Revie*w.

_____, 2010. *National Functional Guidelines for Inorganic Data Review.*

_____, 2012. *Estimation Programs Interface Suite™ for Microsoft® Windows, V4.10.* United States Environmental Protection Agency, Washington, DC.

EPA.gov. Accessed online at: http://www.epa.gov/R5Super/ecology/html/toxprofiles.htm.

FDA (Food and Drug Administration), 2011. *Fish and Fishery Products Hazards and Controls Guidance.* Department of Health and Human Services, Public Health Service Center for Food Safety and Applied Nutrition, Office of Food Safety. Fourth Edition, April.

FishBase. Accessed online at: www.fishbase.org.

FR (Federal Register), 2010. *Department of Commerce - NOAA, 50 CFR Parts 223 and 224. Endangered and Threatened Wildlife: Notice of a 90-day Finding on a Petition to List 83 Species of Corals as Threatened or Endangered Under the Endangered Species Act.* 75 (27):6616 - 6621. 10 February

Frey, F.A., M.O. Garcia, and M.F. Roden, 1994. “Geochemical characteristics of Ko‘olau Volcano: Implications of intershield geochemical differences among Hawaiian volcanoes.” *Geochim. Cosmochim. Acta,* 58:1441-1462.

Glazier, E.W., 1999. *Social Aspects of Hawaii's Small Vessel Troll Fishery.* Phase II of Joint Institute for Marine and Atmospheric Research (JIMAR) Social Aspects of Pacific Pelagic Fisheries Program, University of Hawai‘i at Mānoa. 280 pp.

Gough, L.P., R.K. Kotra, C.W. Colmes, W.H. Orem, P.L. Hageman, P.H. Briggs, A.L. Meier, and Z.A. Brown, 1996. *Regional geochemistry of metals in organic rich sediments, sawgrass and surface water, from Taylor Slough, Florida*. USGS Open File Report (OFR-00-327).

Harrison, J.T., 1987. *40-MW(e) OTEC Plant at Kahe Point, Oahu, Hawaii: A Case Study of Potential Biological Impacts*. NOAA-TM-NMFS-SWFC-68. National Oceanic and Atmospheric Administration, 105 pp.

Hedouin, L., M. Metian, and R.D. Gates, 2011. “Ecotoxicological approach for assessing the contamination of a Hawaiian coral reef ecosystem (Honolua Bay, Maui) by metals and metalloid.” *Mar. Environ. Res.,* 17:149-161.

HELCOM (Helsinki Commission), 1994. *Report on Chemical Munitions Dumped in the Baltic Sea, Report to the 15th Meeting of the Helsinki Commission 8 – 11 March 1994 from the ad hoc Working Group on Dumped Chemical Munition (HELCOM CHEMU)*. January.

Horowitz, A.J., 1991. *A Primer on Sediment-Trace Element Chemistry*. Lewis Publishers, Boca Raton, FL, 136 pp.

Kabata-Pendias, A., and H. Pendias, 2001. *Trace Elements in Soils and Plants*. CRC Press, Boca Raton, Florida, 413 pp.

Kanenaka, B.K., 1991. “Hawaii's Artificial Reef Program: Past, Present and Future.” *Proceedings of the Fifth International Conference on Aquatic Habitat Enhancement*. Long Beach, CA.

Kang, W.J., 1999. *Inputs of Sediments and Mercury to the Lower Everglades and Florida Bay: A Temporal and Spatial Perspective*. Doctoral Dissertation, Florida Institute of Technology, Florida. 122pp.

Koch, L., J. Harrigan-Lum, and K. Henderson, 2004. *Final 2004 List of Impaired Waters in Hawaii Prepared under Clean Water Act §303(d)*. Hawai'i State Department of Health, Environmental Planning Office. Accessed at <http://www.hawaii.gov/health/environmental/env-planning/wqm/wqm.html#303pcd.>

Krom, M.D., K.K. Turekian, N.H. Cutshall, 1983. "Fate of Metals in the sediments of the New York Bight." *Wastes in the Ocean.* Ed. I.W. Duedall, D.R. Kester, B.H. Ketchum, P. Kilho. Wiley. 209–234.

Kumar, K.S., H-U. Dahms, J-S. Lee, H.C. Kim, W.C. Lee, and K-H. Shin, 2014. "Algal photosynthetic responses to toxic metals and herbicides assessed by chlorophyll a fluorescence." *Ecotoxicol. Environ. Saf.* 104(2014):51–71.

Los Alamos National Laboratory (LANL) ECORISK Database Release 2.5, 2010. <http://www.lanl.gov/environment/cleanup/ecorisk.shtml>. October.

Lotufo, G.R., and M.J. Lydy, 2005. "Comparative Toxicokinetics of Explosive Compounds in Sheepshead Minnows." *Arch. Environ. Contam. Toxicol*. 49:206-214.

Mallick, N., and F.H. Mohn, 2000. "Reactive oxygen species: response of algal cells". *J. Plant Physiol*. 157(2000):183-193.

Measures, C.I. and S. Vink, 1999. "Seasonal variations in the distribution of Fe and Al in the surface waters of the Arabian Sea." *Deep Sea Res.,* 46:1597-1622.

_____, 2000. "On the use of dissolved aluminum in surface waters to estimate dust deposition to the ocean." *Global Biogeochem. Cycles*, 14:317-327.

_____, 2001. "Dissolved Fe in the upper waters of the Southern Ocean during the 1997/98 US-JGOFS cruises." *Deep Sea Res.,* 48:2787-2809.

MEDEA, 1997. *Ocean Dumping of Chemical Munitions: Environmental Effects in Arctic Seas*.

Mellado, M., R.A. Contreras, A. González, G. Dennett, and A. Moenne, 2012. "Copper-induced synthesis of ascorbate, glutathione and phytochelatins in the marine alga *Ulva compressa* (Chlorophyta)". *Plant Physiol. Biochem*. 51(2012):102-108.

Miao, X-S., L.A. Woodward, C. Swenson, and Q.X. Li, 2001. "Comparative Concentrations of Metals in Marine Species from French Frigate Shoals, North Pacific Ocean." *Mar. Pollut. Bull.,* 42:1049-1054.

Mirecki, J.E., Porter, B., Weiss, Jr., C., 2006. *Environmental Transport and Fate Process Descriptors for Propellant Compounds*. ERDC/EL TR-06-7. U.S. Army Corps of Engineers, Engineer Research and Development Center.

NOAA (National Oceanic and Atmospheric Administration), 2006. *Ordnance Reef Sampling and Analysis Plan*. May.

_____, 2007. *Remote Sensing Survey and Sampling at a Discarded Military Munitions Sea Disposal Site, Ordnance Reef, Wai'anae, HI*, *Final Report*. NMSP-07-01, March.

_____, 2010. *Spinner Dolphins in Hawaii: Biology, Abundance, and Distribution*. <www.fpir.noaa.gov/.../Spinner%20Dolphin/ BiologyAbundanceDistribution. pdf>.

_____, 2011. *Ordnance Reef (HI–06) Coral Avoidance and Minimization of Injury Plan (CAMIP)*. <http://www.ordnancereefhawaii.org/EA$20Files/04_AppendixC_CAMIP. pdf>.

_____, 2012. *Ocean Circulation and Predictive Modeling Study of Two Sea-Disposed Military Munitions Sites in Hawai'i: Ordnance Reef (HI-06) and HI-01*. June.

NOAA.gov. Accessed online at: www.swfsc.noaa.gov.

NRDC (Natural Resources Defense Council), 2004. *Testing the Waters: A Guide to Water Quality at Vacation Beaches*. Accessed at <http://www2.nrdc.org/water/oceans/ttw/sumhaw.pdf>.

Palanques, A., J.I. Diaz, M. Farran, 1995. "Contamination of heavy metals in the suspended and surface sediment of the Gulf of Cadiz, Spain: the role of sources, currents, pathways and sinks." *Oceanolog. Acta,* 18:469–477.

Porter, J.W., J.V. Barton, and C. Torres, 2011. "Ecological Radiological, and toxicological effects of naval bombardment on the coral reefs of Ilsa de Vieques, Puerto Rico". In G.E. Machlis et al. (eds.), "Warfare Ecology: A New Synthesis for Peace and Security," *NATO Science for Peace and Security Series C: Environmental Security, DOI 10.1007/978-94-007-1214-0_8,* Springer, Dordrecht, The Netherlands.

Presley, B.R., 1994. "The potential environmental impact of trace metals in the Arctic." *Arctic Res.*, 8:123–135.

Presley, B.R., R.J. Taylor, P.N. Boothe, 1992. "Trace metal concentrations in sediments of the Eastern Mississippi Bight." *Mar. Environ. Res.*, 33:267–282.

Puig, P., A. Palanques, J.A. Sanchez-Cabeza, P. Masque, 1999. "Heavy metals in particulate matter and sediments in the southern Barcelona sedimentation system (North-western Mediterranean)." *Mar. Chem.*, 63:311–329.

Rainbow, P.S., 2002. "Trace metal concentrations in aquatic invertebrates: Why and so what?" *Environ. Pollut.* 120(2002):497-507.

Ringuet, S. and F.T. Mackenzie, 2005. "Controls on nutrient and phytoplankton dynamics by storm runoff events, southern Kaneohe Bay." *Estuaries*, 28(3):327-337.

Russo, A.R., 1997. *Survey of Selected Coral and Fish Assemblages Near the Waianae Ocean Outfall, Oahu, Hawaii*. Project Report PR-97-03. Water Resource Research Center.

Sample, B.E., D.M. Opresko, G.W. Suter II., 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision*. Oak Ridge National Laboratory ES/ER/TM-86/R3.

Sanderson, M.P., C.N. Hunter, S.E. Fitzwater, R.M. Gordon, and R.T. Barber, 1995. "Primary productivity and trace-metal contamination measurements from a clean rosette system versus ultra-clean Go-Flo® bottles." *Deep Sea Res.,* 42:431-440.

Schropp, S.J., F.G. Lewis, H.L. Windom, J.D. Ryan, F.D. Calder, L.C. Burney, 1990. "Interpretation of metal concentrations in estuarine sediments of Florida using aluminum as a reference element." *Estuaries*, 13:227–235.

Seixas, S., P. Bustamante, and G. Pierce, 2005. "Accumulation of mercury in the tissues of the common octopus *Octopus vulgaris* (L.) in two localities on the Portuguese coast." *Sci. Total Environ.,* 340:113-122.

Sharma, V.K., K.B. Rhudy, R. Koening, F.G. Vazquez, 1999. "Metals in sediments of the upper Laguna Madre." *Mar. Pollut. Bull.,* 38:1221–1226.

Shaw, P.J.A., 2003. *Multivariate Statistics for the Environmental Sciences*. John Wiley & Sons, Ltd., Chicester, UK. 233 pp.

Spencer, K.J., E.H. De Carlo, and G.M. McMurtry, 1995. "Isotopic clues to the sources of natural and anthropogenic lead in sediments and soils from Oahu, Hawaii." *Pac. Sci.,* 49:492-510.

Stearns, H.T. and K.N. Vaksvik, 1935. *Geology and Ground-water Resources of the Island of Oahu, Hawaii*. Division of Hydrography Bulletin, 1:479.

Stumm, W.and J. Morgan, 1996. *Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters, Third Edition.* John Wiley & Sons, Inc., New York, 1040 pp.

Sunahara, G.I, G. Lotufo, R.G. Kuperman, J. Hawari, 2009. *Exotoxicology of Explosives*. CRC Press, New York, 325 pp.

SurfArt.com, 2000. *Hawaiian Roots of Surfing*. Accessed online at: http://www.surfart.com /surf_history/roots.html.

Talmage, S.S., D.M. Opresko, C.J. Maxwell, J.E. Welsh, M. Cretella, P.H. Reno, and F.B. Daniel, 1999. "Nitroaromatic munition compounds: Environmental effects and screening values." *Rev. Environ. Contam. Toxicol.,* 161:1-156.

Tomlinson, M.S. and De Carlo, E.H., 2003. "The need for high-resolution time series data to characterize Hawaiian streams." *J. Am. Water Resour. Assoc.*, 39(1):113-123.

Trefry, J.H., B.J. Presley, 1976. "Heavy metals in sediments from San Antonio Bay and the Northwest Gulf of Mexico." *Environ. Geol.,* 1:283–294.

University of Hawaii. *Marine Algae of Hawaii.* Accessed online at: www.hawaii.edu/reefalgae.

United States Army, 2005. *Potential Military Chemical/Biological Agents And Compounds, released as FM 3-11.9, MCRP 3-37.1B, NTRP 3-11.32, and AFTTP(I) 3-2.55*. January.

USATCES (U.S. Army Technical Center for Explosives Safety), 2007. *Risk Assessment of NOAA Ordnance Reef Survey Report, April 2007.*

USACHPPM (U.S. Army Center for Health Promotion and Preventive Medicine), 2002. *Wildlife Toxicity Assessment for 1,3,5-Trinitrohexahydro-1,3,5-triazine (RDX)*. USACHPPM Document # 39-EJ-1138-01H. July.

_____, 2006. *Wildlife Toxicity Assessment for 2,4 & 2,6-Dinitrotoluene.* USACHPPM Document # 39-EJ-1138-01D. January.

_____, 2007. *Health Risk Evaluation No. 39-EJ-06UY-07, Ordnance Reef Discarded Military Munitions Site, Wai'anae, O'ahu, HI, May 2007*.

U.S. Department of Agriculture, 1971. *Soil Survey of the State of Hawaii. Natural Resource Conservation Service*. Access at <http://www.ctahr.hawaii.edu/soilsurvey/soils.htm>

Vasquez, F.G. and V.R. Sharma, 2004. "Major and trace elements in sediments of the Campeche Sound, southeast Gulf of Mexico." *Mar. Poll. Bull.,* 48: 87-90

Waikīkī Aquarium. Accessed online at: www.waquarium.org.

Western Regional Climate Center, 2004. *Climate of Hawaii*. Accessed on line at: http://www.wrcc.dri.edu/narratives/HAWAII.htm.

Wil Chee – Planning, Inc., 2011. *Environmental Assessment and Draft Finding of No Significant Impact, Technology Demonstration of Remotely Operated Underwater Munitions Recovery System (ROUMRs) and Energetic Hazard Demilitarization System (EHDS) at Ordnance Reef (Site HI-06), Wai'anae, O'ahu, Hawai'i*. March.

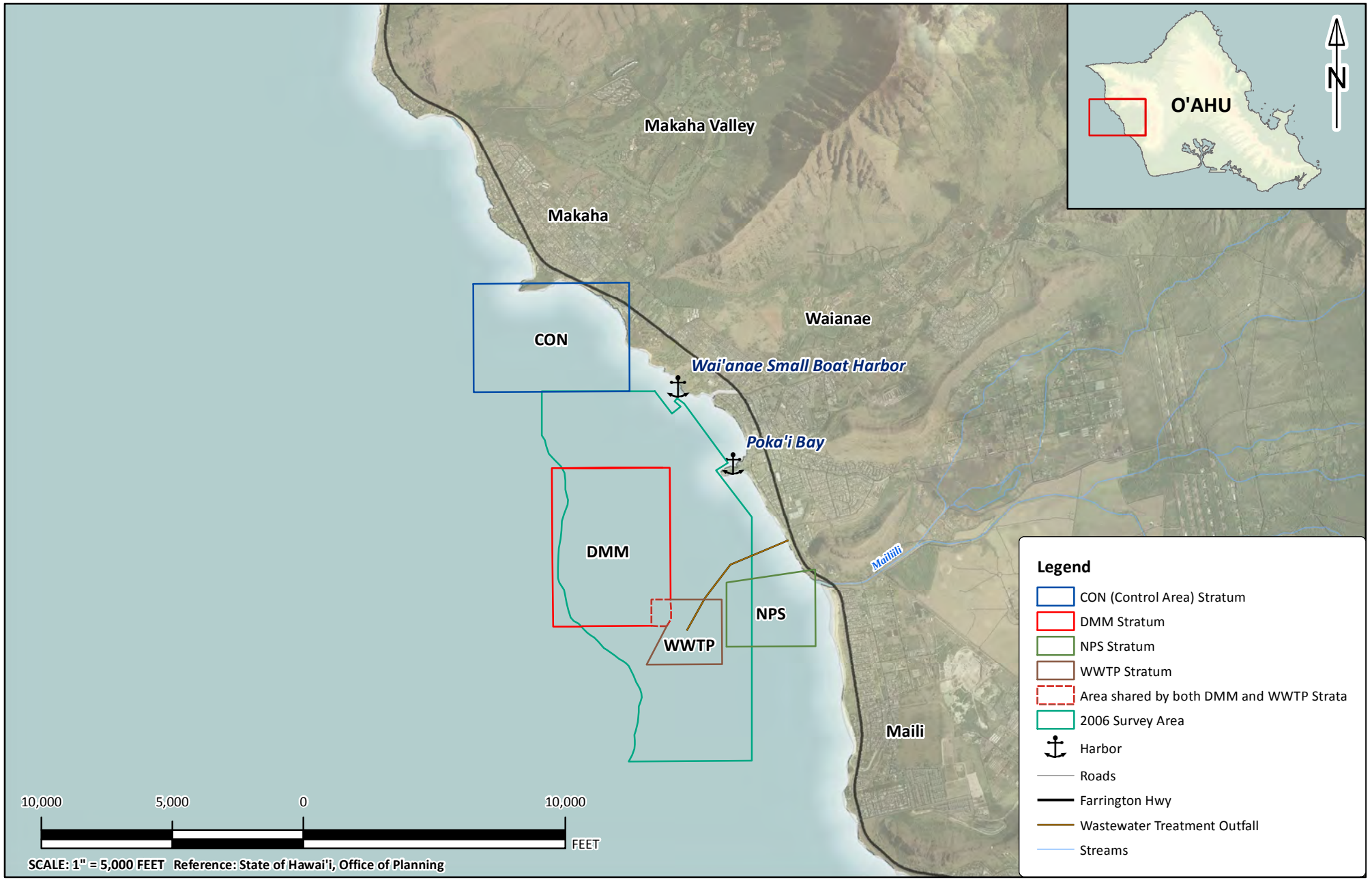
Wen, X.Y., E.H. De Carlo, and Y.H. Li, 1997. "Interelement relationships in ferromanganese crusts from the central Pacific Ocean: Their implications for crust genesis." *Mar. Geol.,* 136(3/4):277-297.

White, S.L., and P.S. Rainbow, 1985. "On the metabolic requirements for copper and zinc in molluscs and crustaceans." *Mar. Environ. Res*. 16(1985):215-229.

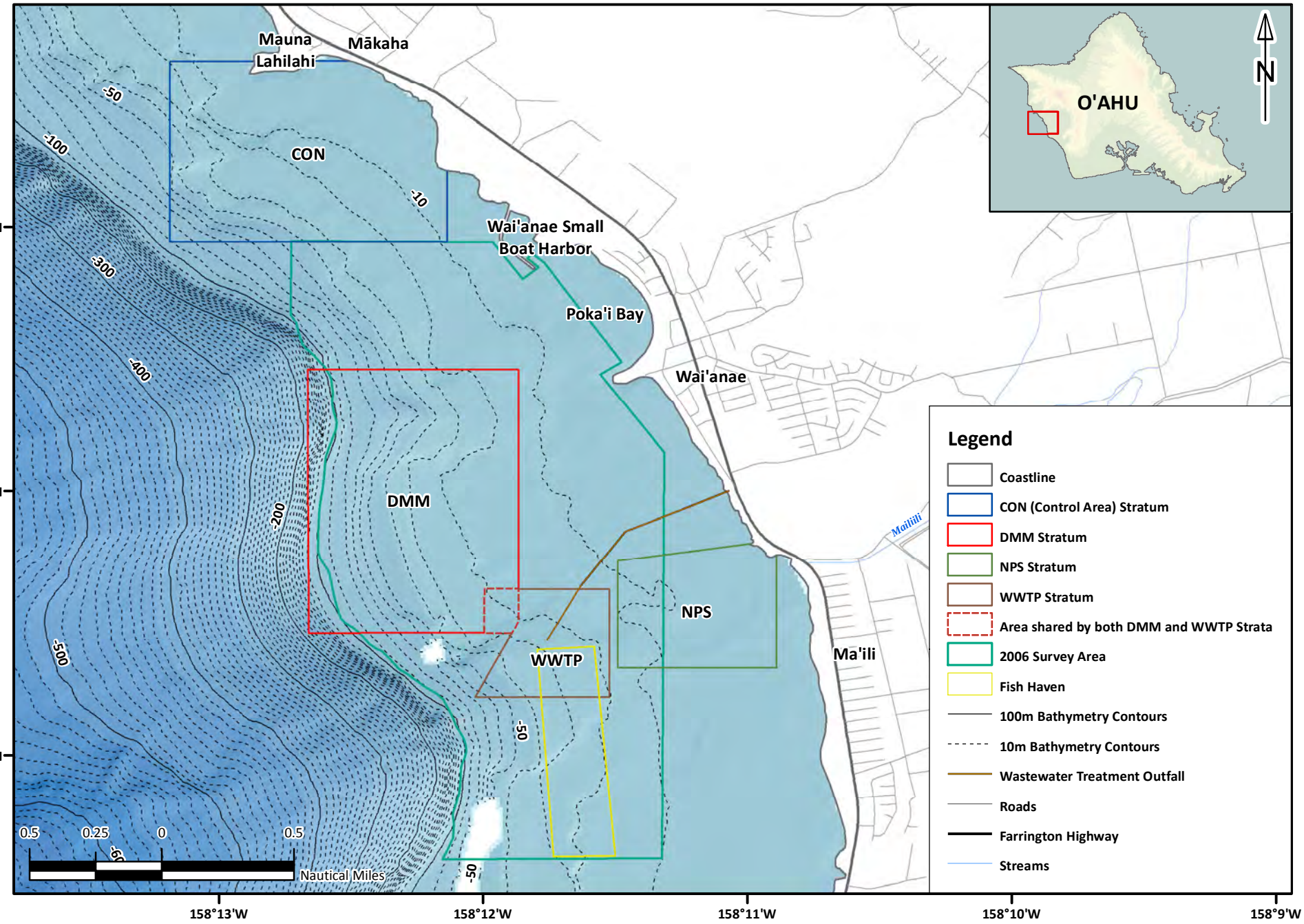
World Health Organization, 2003. *Guidelines for Drinking-Water Quality, Third Edition.* Accessed online at http://www.fsc.go.jp/senmon/tenkabutu/t-dai5/ten5-siryou2-3-4.pdf.

Yost, S., J. Pennington, J. Brannon, and C. Hayes, 2007. "Environmental process descriptors for TNT, TNT-related compounds and picric acid in marine sediment slurries". *Mar. Pollut. Bull.,* 54:1262-1266.

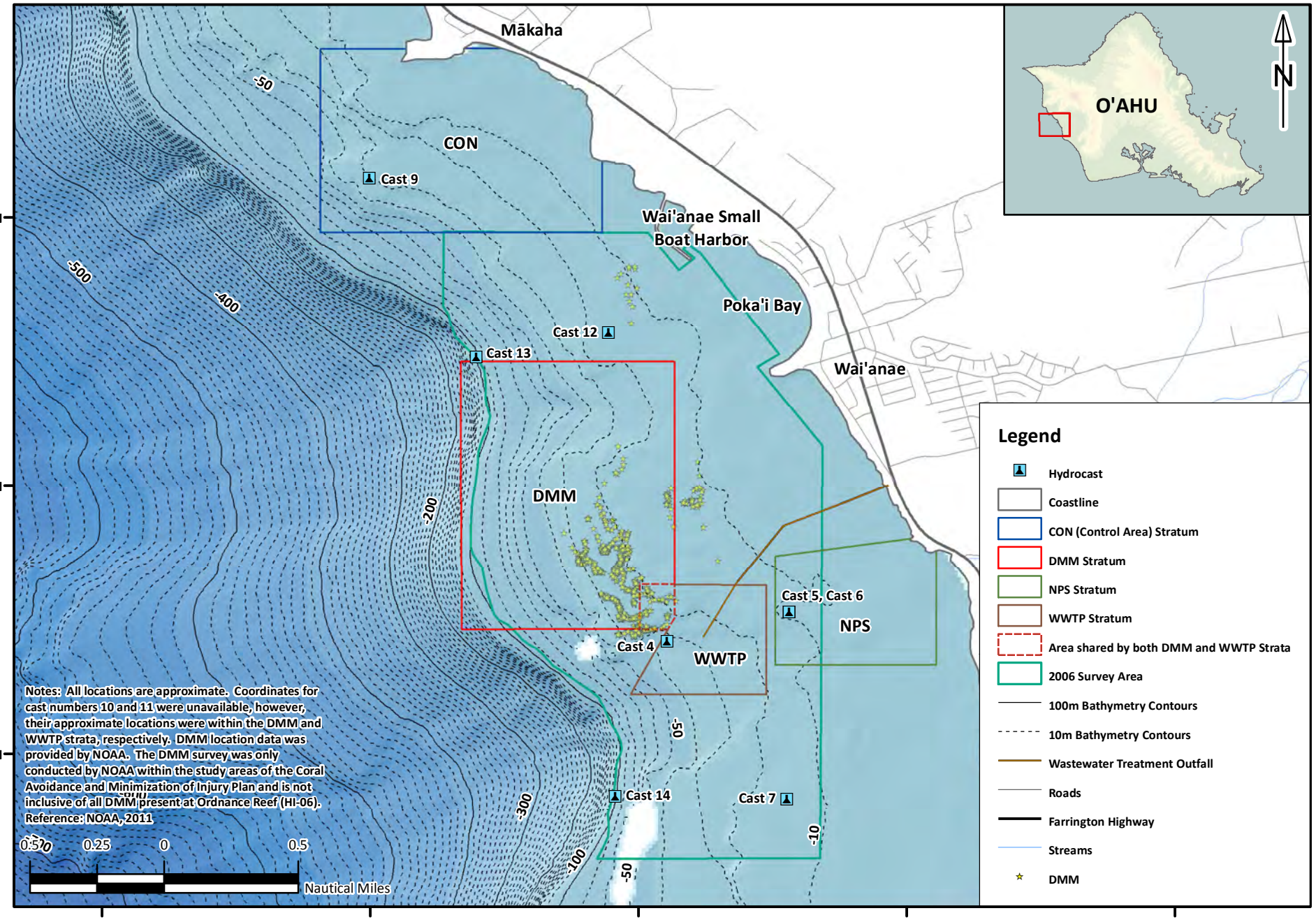
Figures



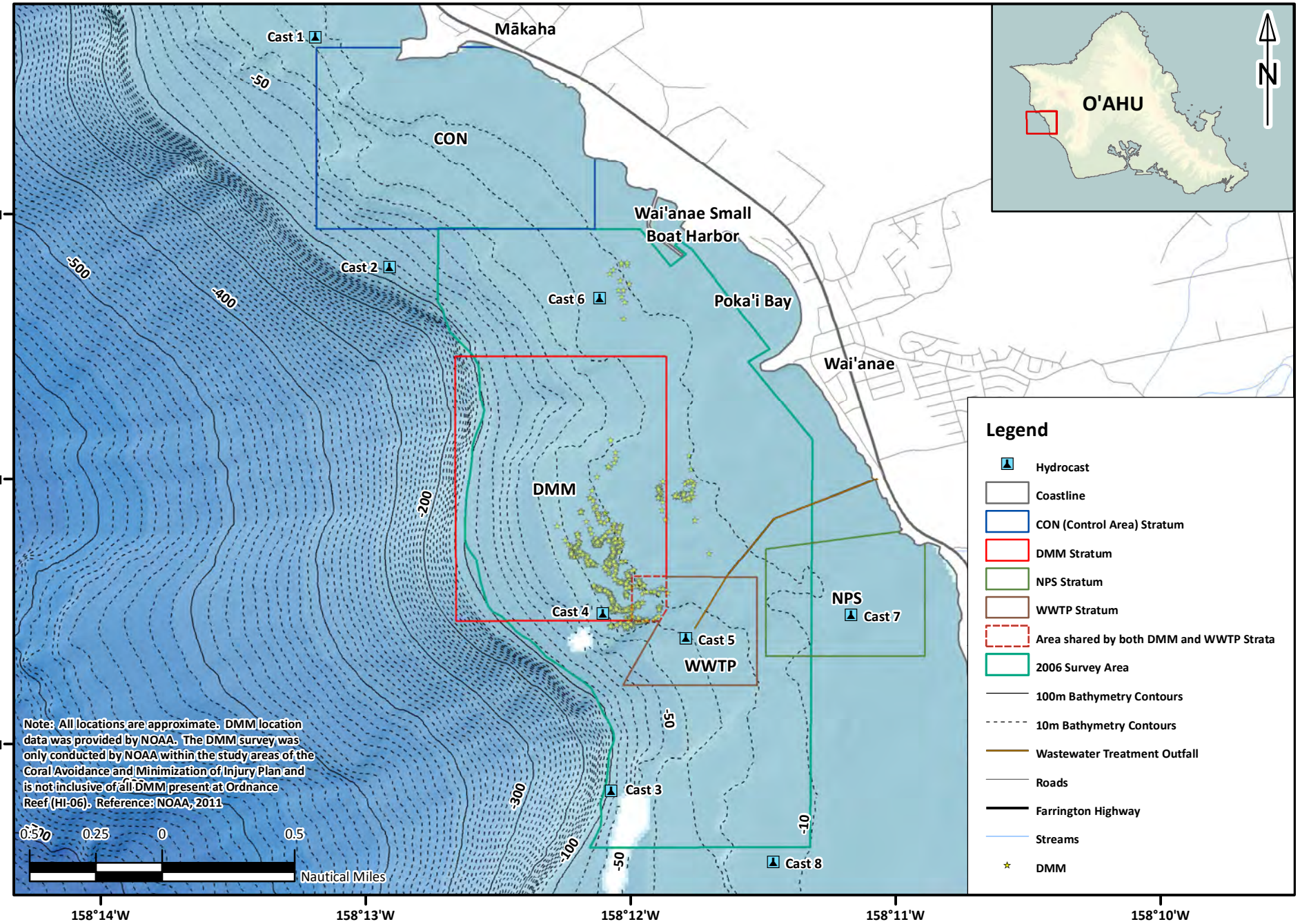
Environet, Inc.	PROJECT NO.: 1059-001	ORDNANCE REEF (HI-06)	FIGURE 1-1
	DATE: APRIL 4, 2012		
	DRAWN BY: MR/SK	SITE LOCATION MAP	
	REVIEWED BY: SS	WAI'ANAE COAST, O'AHU, HAWAI'I	



Environet, Inc.	PROJECT NO.: 1059-001	ORDNANCE REEF (HI-06)	FIGURE 2-1
	DATE: APRIL 4, 2012		
	DRAWN BY: MR/SK	STRATA LOCATION AND FISH HAVEN WAI'ANAE COAST, O'AHU, HAWAI'I	
	REVIEWED BY: SS		

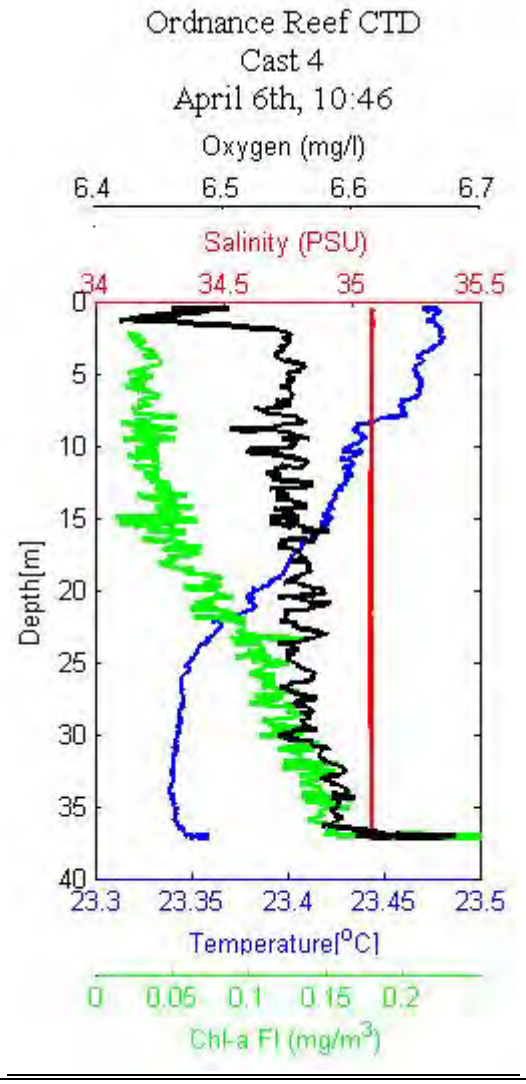
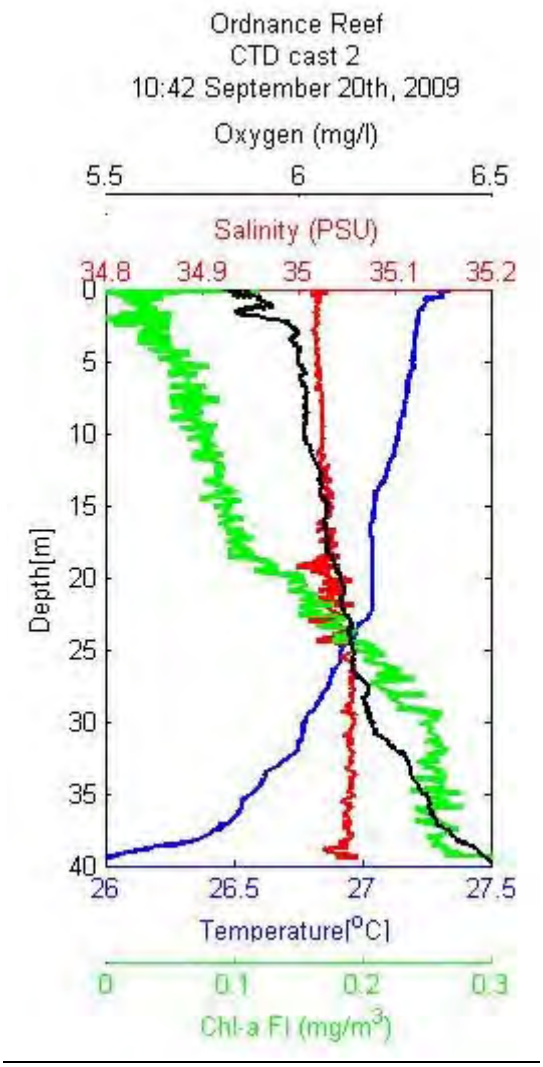


Environet, Inc.	PROJECT NO.: 1059-001	ORDNANCE REEF (HI-06)	FIGURE 2-2
	DATE: JUNE 15, 2012		
	DRAWN BY: MR/SK	APPROXIMATE APRIL HYDROCAST LOCATIONS WAI'ANAE COAST, O'AHU, HAWAI'I	
	REVIEWED BY: SS		



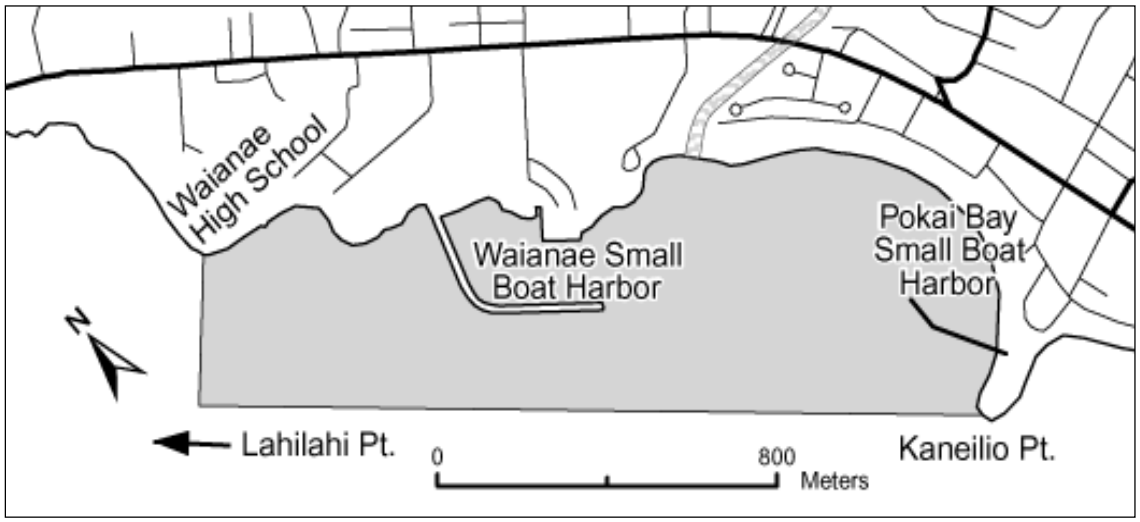
Environet, Inc.	PROJECT NO.: 1059-001	ORDNANCE REEF (HI-06)	FIGURE 2-3
	DATE: JUNE 15, 2012		
	DRAWN BY: MR/SK	APPROXIMATE SEPTEMBER HYDROCAST LOCATIONS WAI'ANAE COAST, O'AHU, HAWAI'I	
	REVIEWED BY: SS		

Figure 2-4: Comparison of April 2009 and September 2009 Water Column Profiles

(a) April 2009	(b) September 2009
	

Note: Water column profiles obtained during the April 2009 and September to October 2009 sampling events are provided in Appendix F.

Figure 3-1: Coastal Fishery Management Area in the Wai‘anae Moku



Source as cited in NOAA, 2006: Hawai‘i DLNR, Division of Aquatic Resources.

Figure 3-2: Conceptual Model for Ecological Receptors
Ordnance Reef (HI-06), O'ahu, Hawai'i

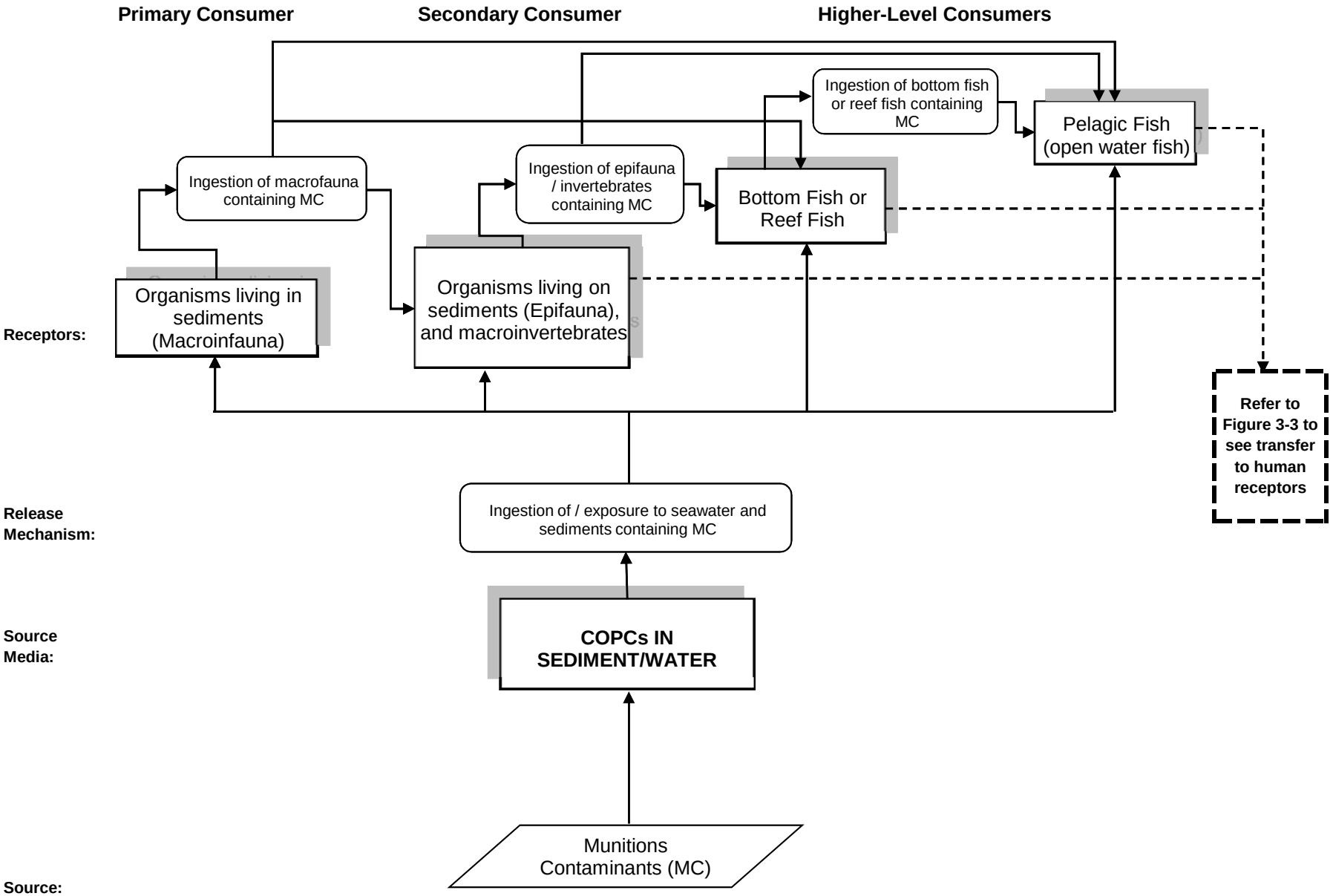
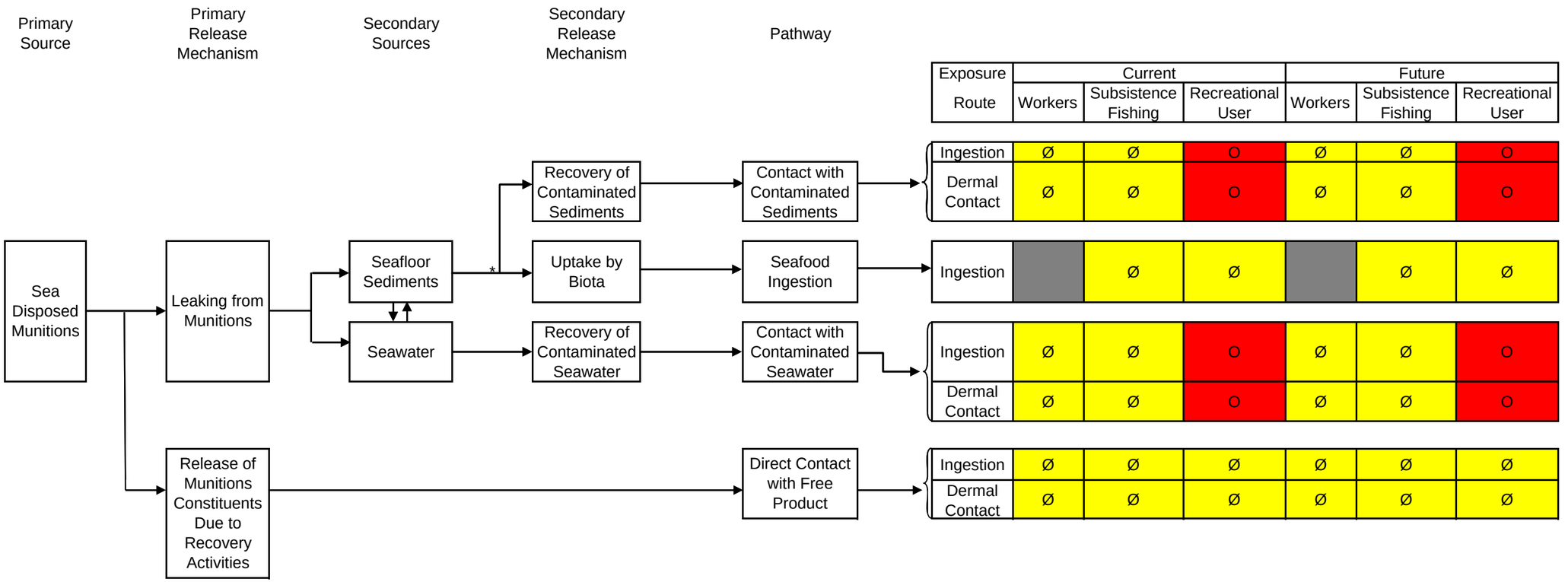


Figure 3-3
Conceptual Site Model for Human Receptors,
Ordnance Reef (HI-06), O'ahu, Hawai'i



* Note: Trophic pathways to human food items are discussed in more detail in the Ecological Conceptual Model.

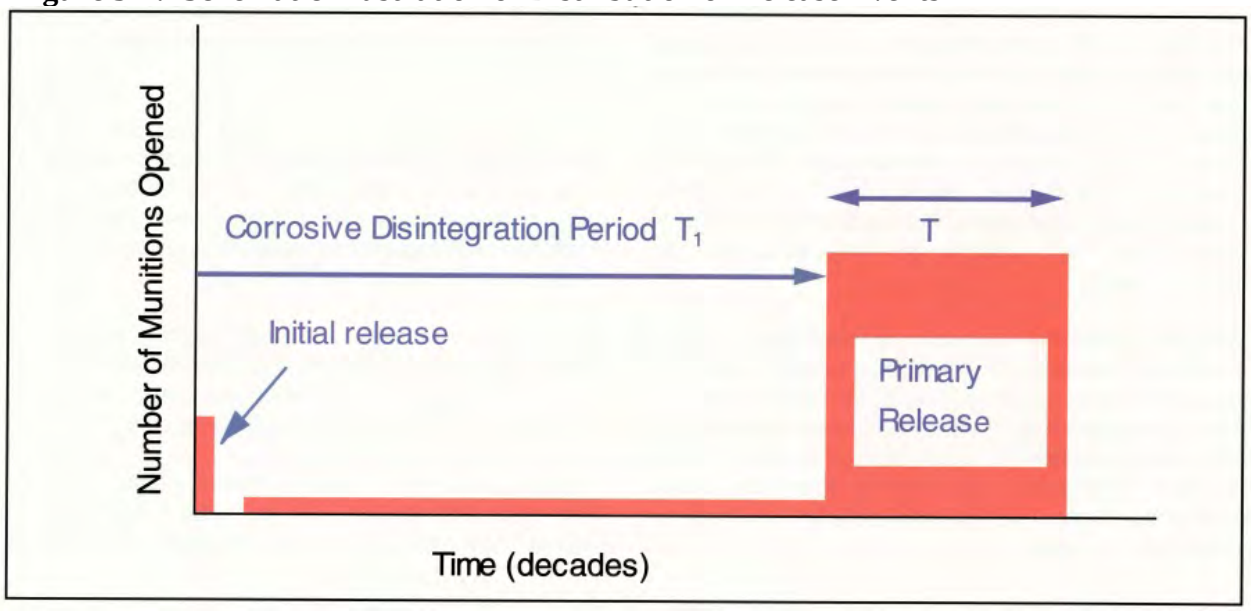
Indicates a pathway that was considered, but determined to be inapplicable to this site.

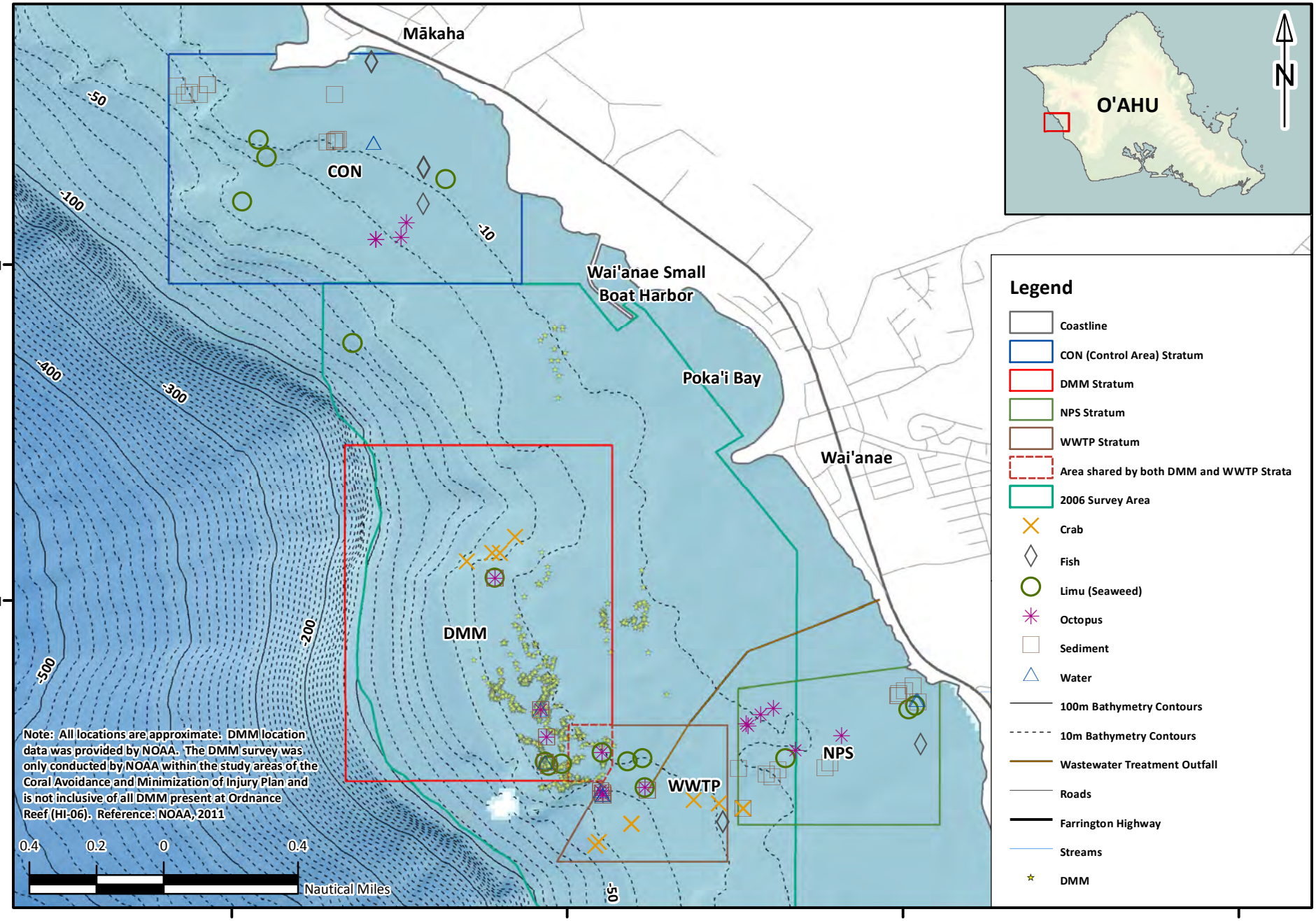
X Indicates exposure unlikely

Ø Indicates a possible exposure route

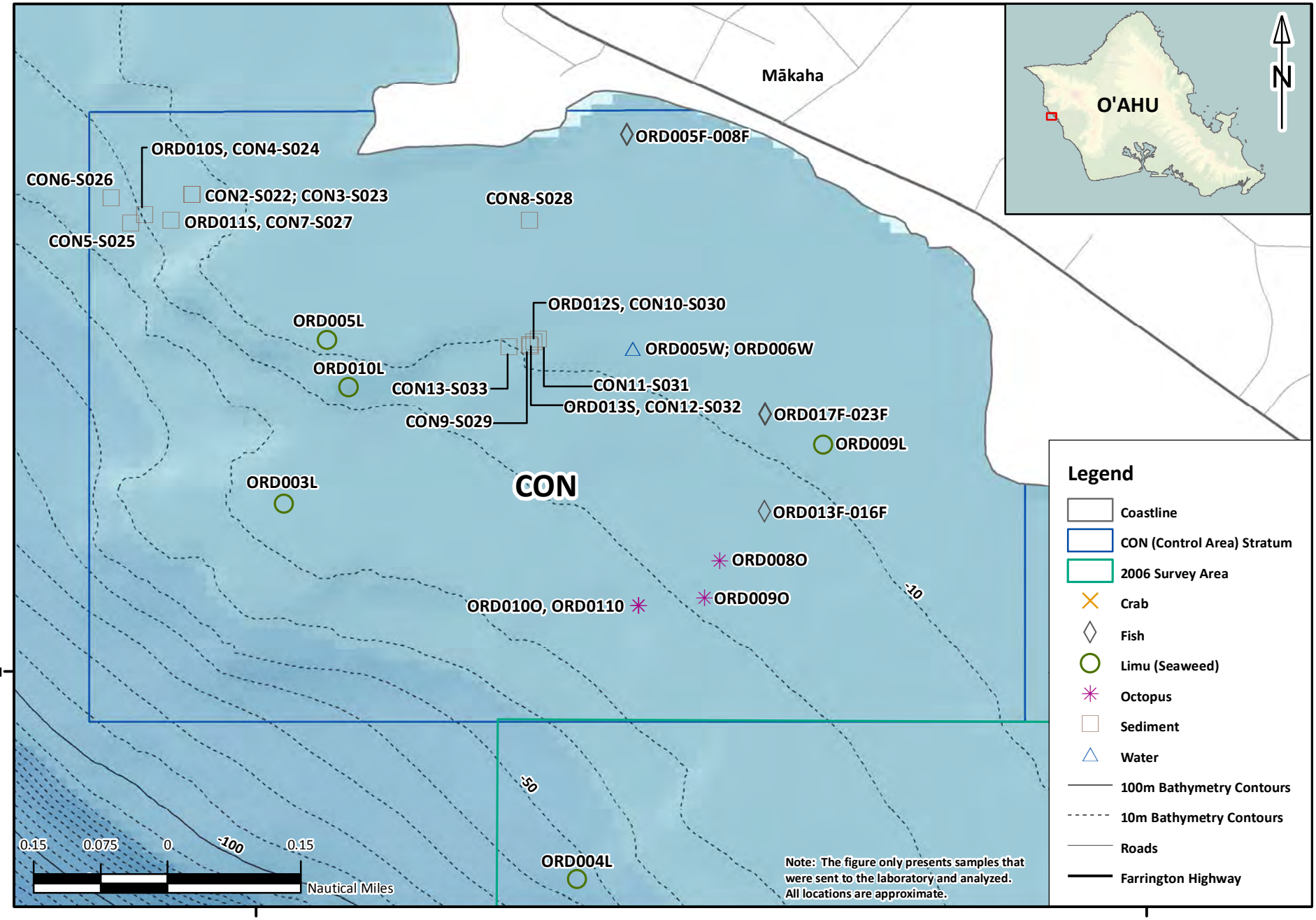
O Indicates a complete exposure pathway

Figure 3-4: Schematic Illustration of Distribution of Release Events

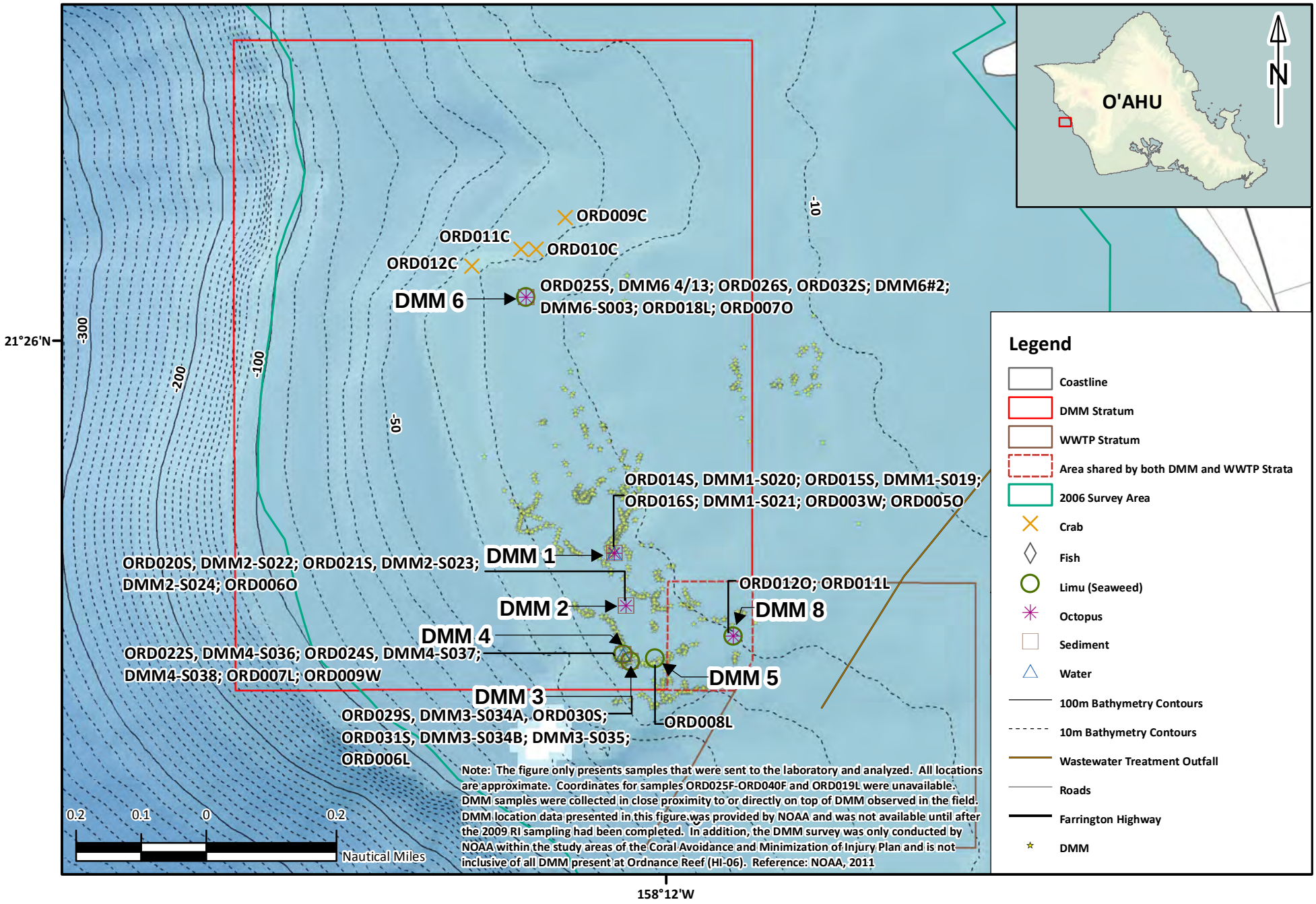




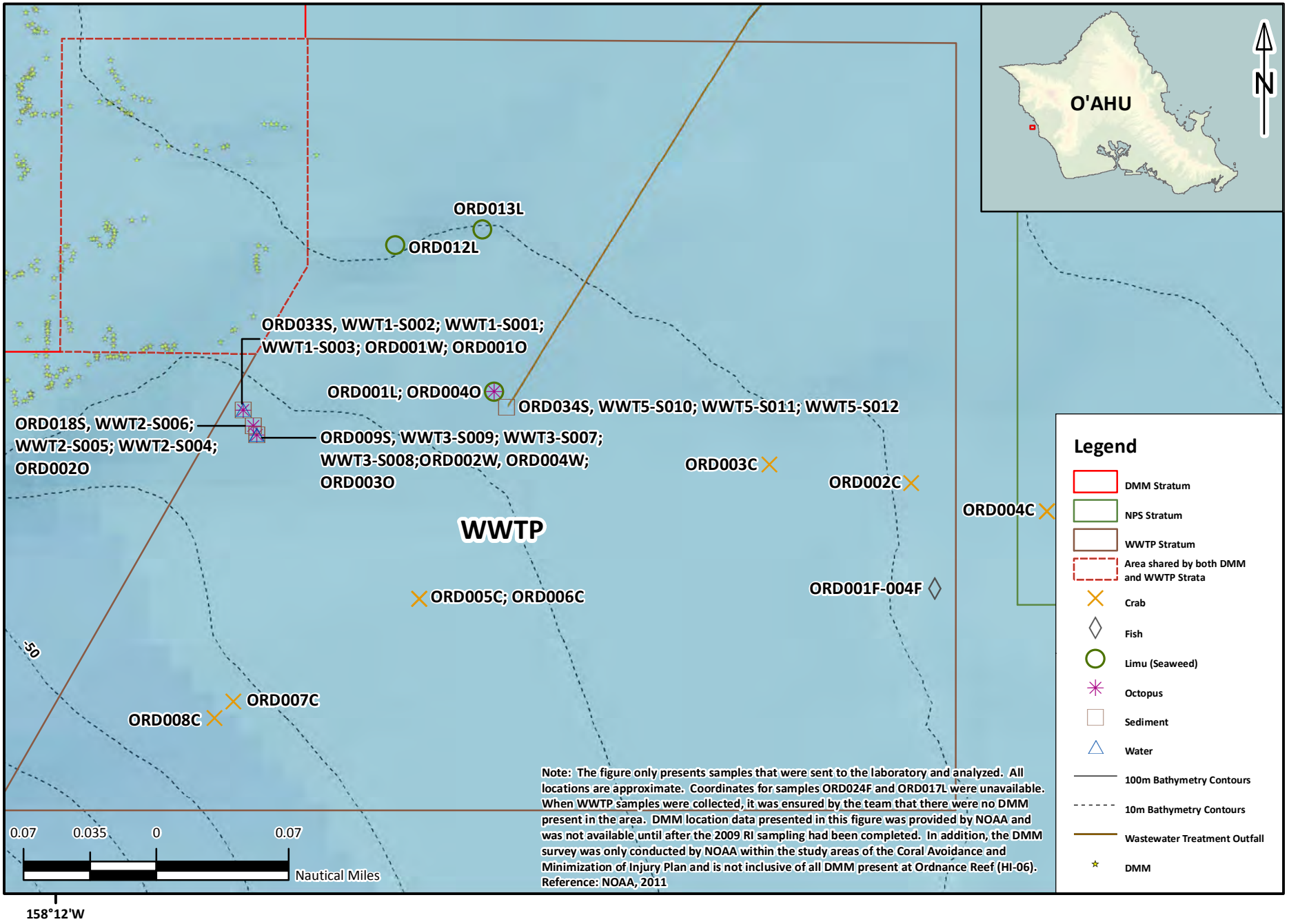
Environet, Inc.	PROJECT NO.: 1059-001	ORDNANCE REEF (HI-06)	FIGURE 4-1
	DATE: APRIL 4, 2012		
	DRAWN BY: MR/SK	APPROXIMATE APRIL SAMPLE LOCATIONS WAI'ANAE COAST, O'AHU, HAWAI'I	
	REVIEWED BY: SS		



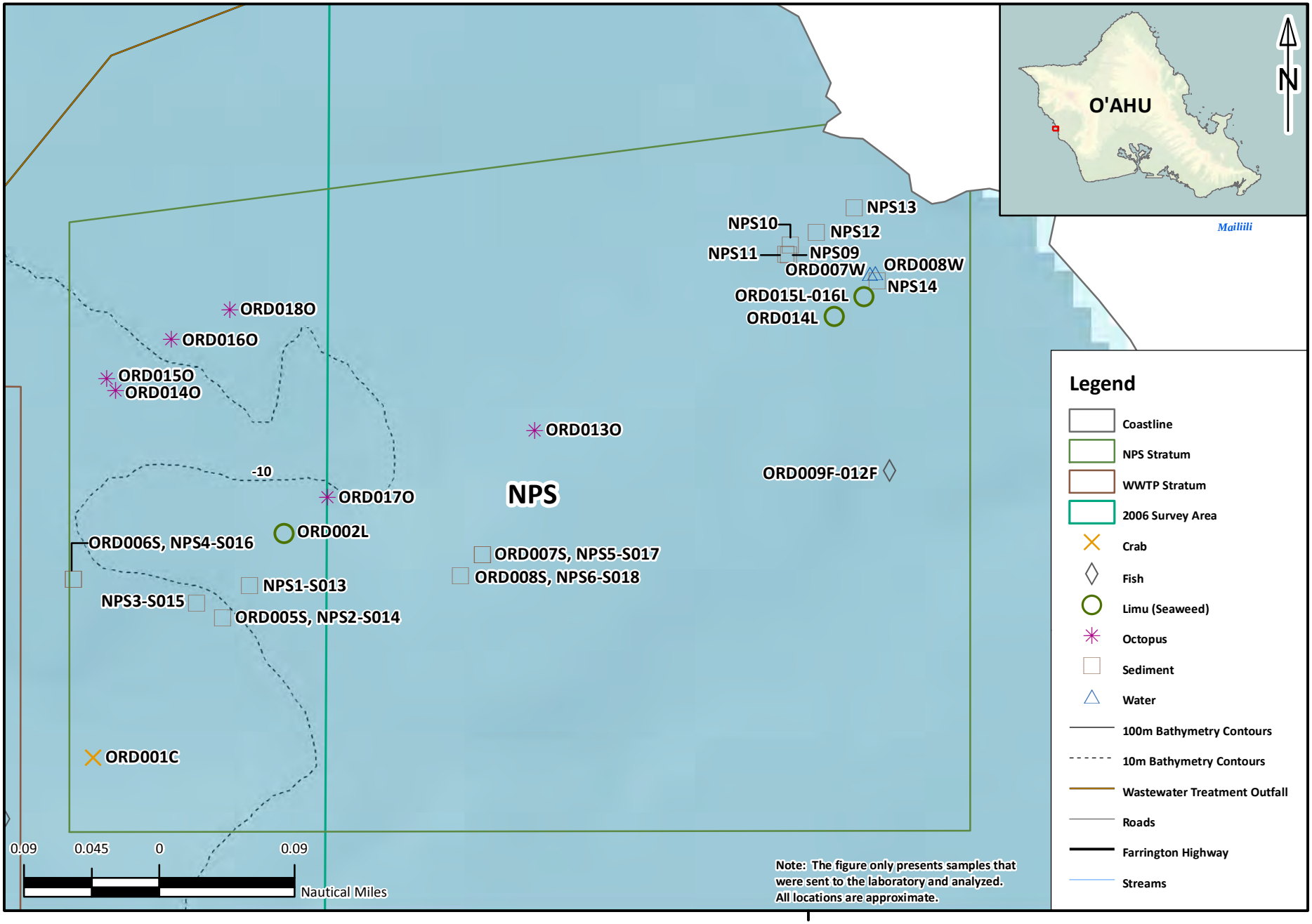
Environet, Inc.	PROJECT NO.: 1059-001 DATE: APRIL 4, 2012 DRAWN BY: MR/SK REVIEWED BY: SS	ORDNANCE REEF (HI-06) APPROXIMATE APRIL SAMPLE LOCATIONS CON STRATUM, WAI'ANAE COAST, O'AHU, HAWAI'I	FIGURE 4-2



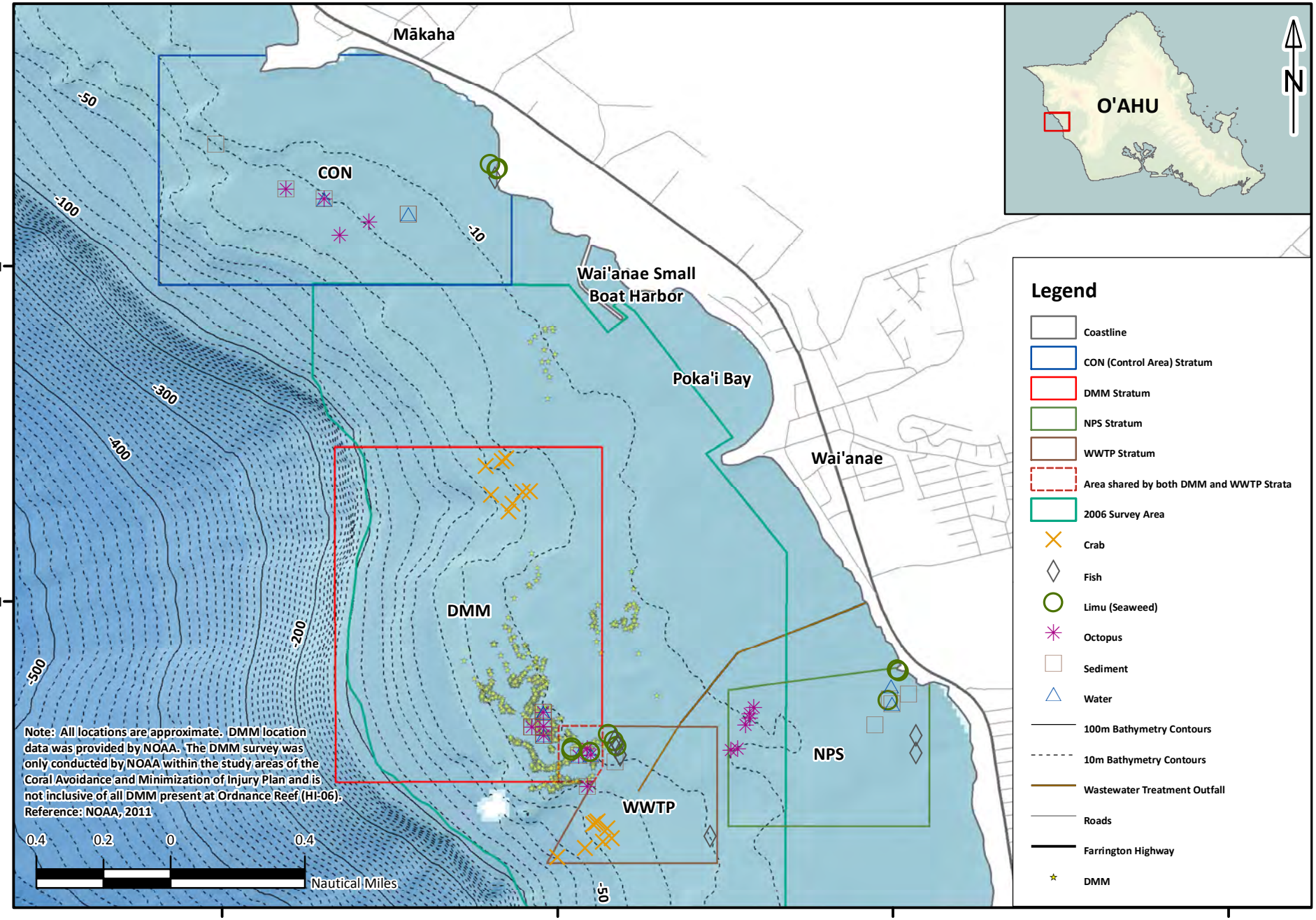
Environet, Inc.	PROJECT NO.: 1059-001	ORDNANCE REEF (HI-06)	FIGURE 4-3
	DATE: APRIL 13, 2012		
	DRAWN BY: MR/SK	APPROXIMATE APRIL SAMPLE LOCATIONS	
	REVIEWED BY: SS	DMM STRATUM, WAI'ANAE COAST, O'AHU, HAWAI'I	



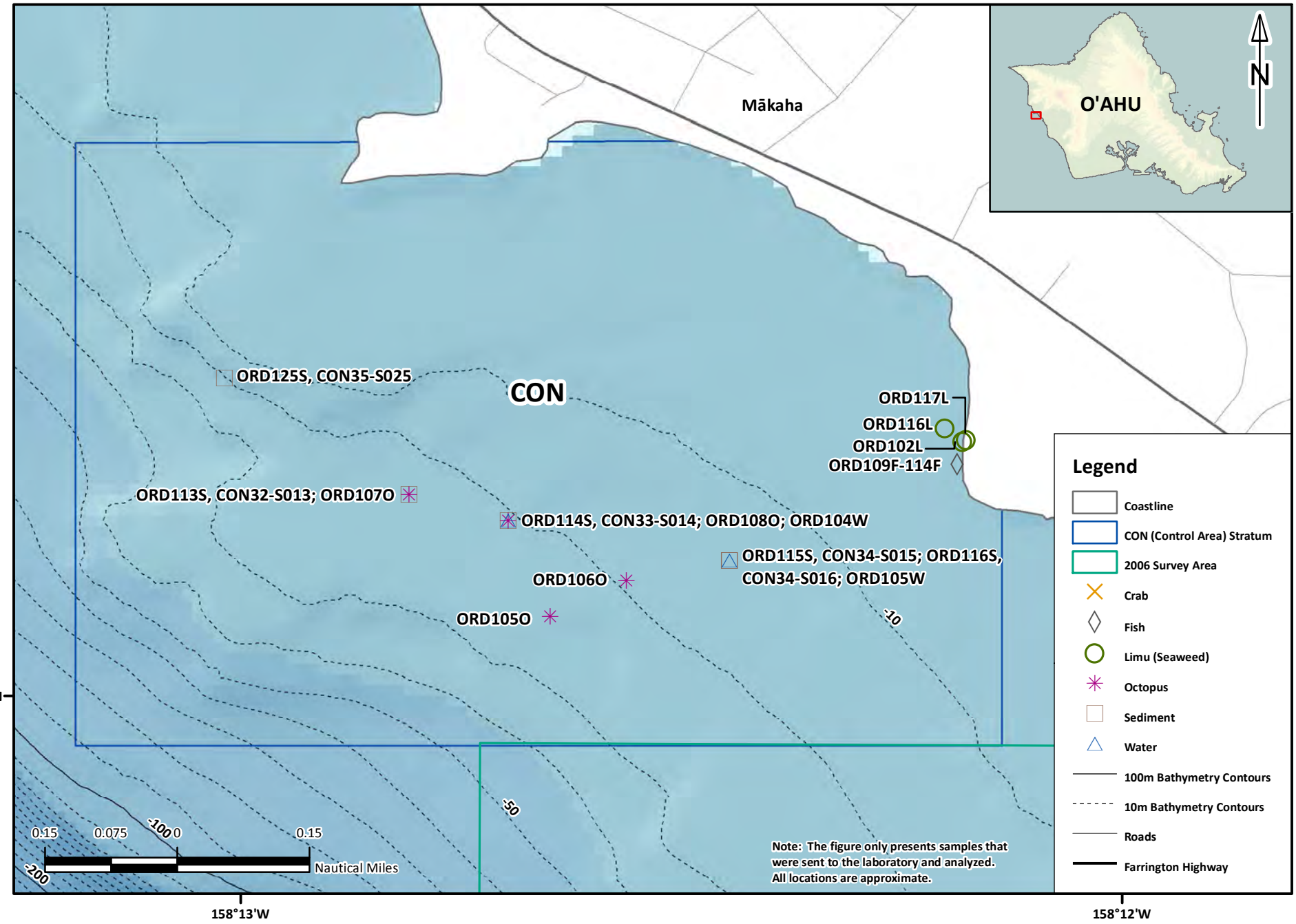
Environet, Inc.	PROJECT NO.: 1059-001 DATE: APRIL 13, 2012 DRAWN BY: MR/SK REVIEWED BY: SS	ORDNANCE REEF (HI-06) APPROXIMATE APRIL SAMPLE LOCATIONS WWTP STRATUM, WAI'ANAE COAST, O'AHU, HAWAI'I	FIGURE 4-4



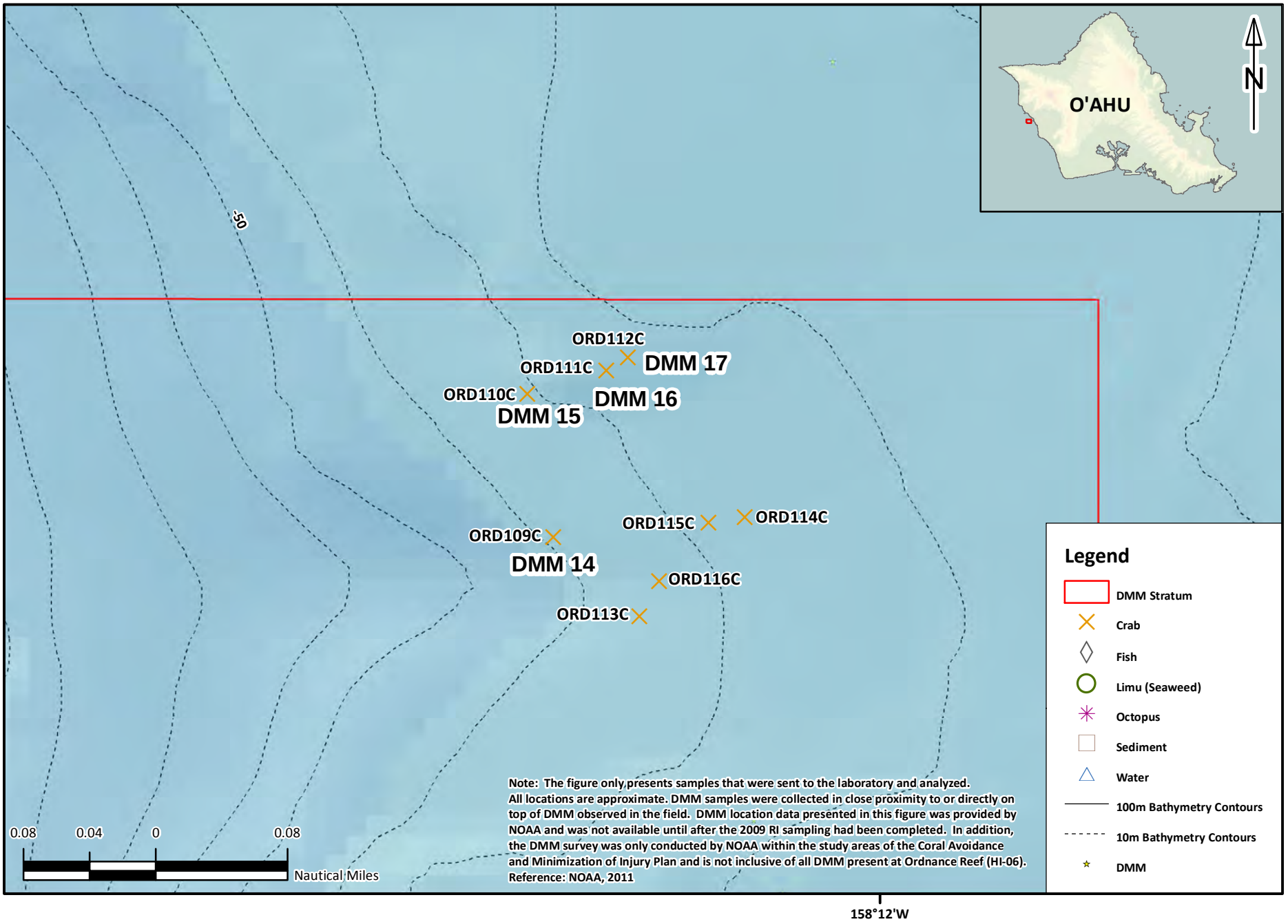
Environet, Inc.	PROJECT NO.: 1059-001	ORDNANCE REEF (HI-06)	FIGURE 4-5
	DATE: APRIL 4, 2012		
	DRAWN BY: MR/SK	APPROXIMATE APRIL SAMPLE LOCATIONS	
	REVIEWED BY: SS	NPS STRATUM, WAI'ANAE COAST, O'AHU, HAWAI'I	



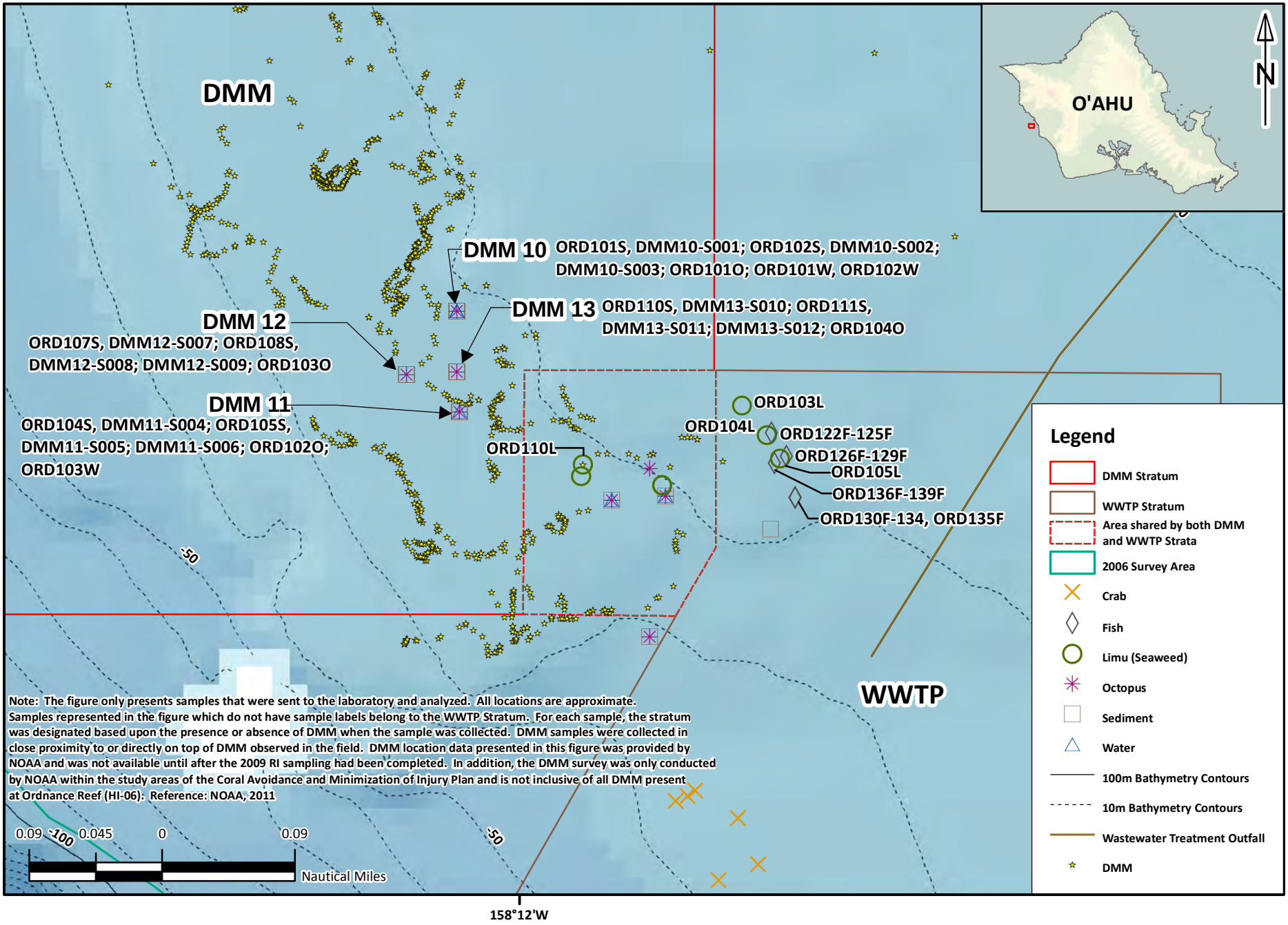
Environet, Inc.	PROJECT NO.: 1059-001	ORDNANCE REEF (HI-06)	FIGURE 4-6
	DATE: APRIL 5, 2012		
	DRAWN BY: MR/SK	APPROXIMATE SEPTEMBER SAMPLE LOCATIONS WAI'ANAE COAST, O'AHU, HAWAI'I	
	REVIEWED BY: SS		



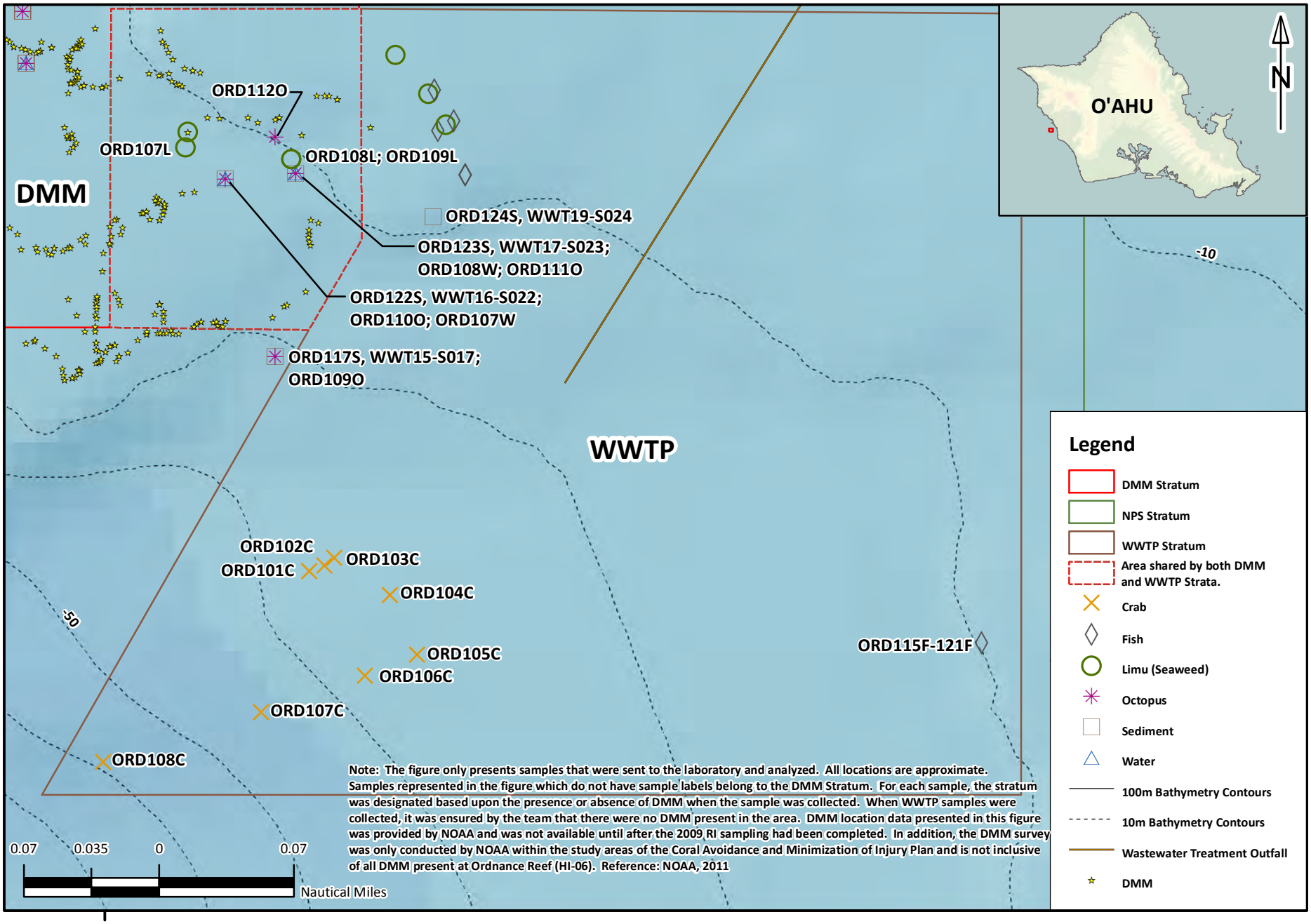
Environet, Inc.	PROJECT NO.: 1059-001	ORDNANCE REEF (HI-06)	FIGURE 4-7
	DATE: APRIL 5, 2012		
	DRAWN BY: MR/SK	APPROXIMATE SEPTEMBER SAMPLE LOCATIONS CON STRATUM, WAI'ANAE COAST, O'AHU, HAWAI'I	
	REVIEWED BY: SS		



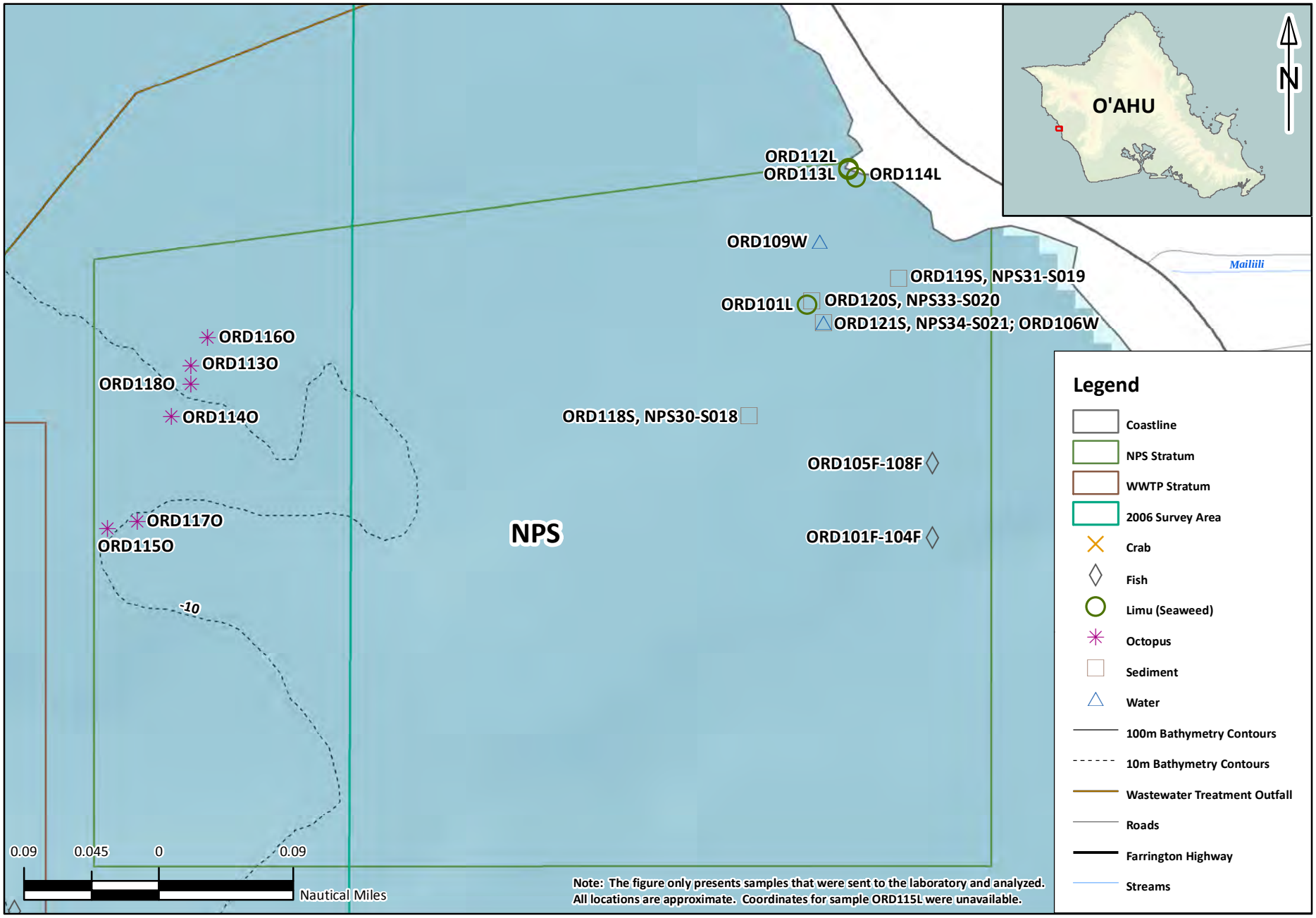
Environet, Inc.	PROJECT NO.: 1059-001 DATE: APRIL 13, 2012 DRAWN BY: MR/SK REVIEWED BY: SS	ORDNANCE REEF (HI-06) APPROXIMATE SEPTEMBER SAMPLE LOCATIONS DMM STRATUM (NORTH), WAI'ANAE COAST, O'AHU, HAWAI'I	FIGURE 4-8



Environet, Inc.	PROJECT NO.: 1059-001	ORDNANCE REEF (HI-06)	FIGURE 4-9
	DATE: APRIL 13, 2012		
	DRAWN BY: MR/SK	APPROXIMATE SEPTEMBER SAMPLE LOCATIONS DMM STRATUM (SOUTH), WAI'ANAE COAST, O'AHU, HAWAI'I	
	REVIEWED BY: SS		



Environet, Inc.	PROJECT NO.: 1059-001	ORDNANCE REEF (HI-06)	FIGURE 4-10
	DATE: APRIL 13, 2012		
	DRAWN BY: MR/SK	APPROXIMATE SEPTEMBER SAMPLE LOCATIONS WWTP STRATUM, WAI'ANAE COAST, O'AHU, HAWAI'I	
	REVIEWED BY: SS		



Environet, Inc.	PROJECT NO.: 1059-001	ORDNANCE REEF (HI-06)	FIGURE 4-11
	DATE: APRIL 5, 2012		
	DRAWN BY: MR/SK	APPROXIMATE SEPTEMBER SAMPLE LOCATIONS	
	REVIEWED BY: SS	NPS STRATUM, WAI'ANAE COAST, O'AHU, HAWAI'I	

Tables

TABLE 2-1: SAMPLE COLLECTION LIST AND DESCRIPTIONS

Lab ID	Site	Field ID	Collection Date	Collection Time	Depth (m)	Latitude	Longitude	Sample Analyzed?	Analytes	Primary (P)/ Duplicate (D)	Sediment Description
SEAWATER											
ORD001W	WWT1	W001	4/6/2009	9:30	28.8	21.42388	-158.19835	Yes	Energetics	P	N/A
ORD002W	WWT3	W002	4/6/2009	10:45	34.3	21.42366	-158.19823	Yes	Energetics	P	N/A
ORD003W	DMM1	W003	4/7/2009	11:30	24	21.42789	-158.20132	Yes	Energetics	P	N/A
ORD004W	WWT3	W002	4/6/2009	10:45	34.3	21.42366	-158.19823	Yes	Energetics	D	N/A
ORD005W	CON15	W005	4/8/2009	12:30	6	21.45604	-158.20961	Yes	Energetics	P	N/A
ORD006W	CON16	W006	4/8/2009	13:00	7	21.45604	-158.20961	Yes	Energetics	P	N/A
ORD007W	NPS15	W007	4/9/2009	13:30	3.4	21.42836	-158.18265	Yes	Energetics	P	N/A
ORD008W	NPS16	W008	4/9/2009	13:00	3.5	21.42837	-158.18259	Yes	Energetics	P	N/A
N/A	NPS17	W009	4/9/2009	13:00	3.5	21.42843	-158.18297	No	-	-	N/A
ORD009W	DMM4	W010	4/9/2009	13:00	/	21.42530	-158.20110	Yes	Energetics	P	N/A
ORD101W	DMM10	W001	9/21/2009	10:26	21.2	21.42782	-158.20071	Yes	Phthalates & Pyrene; Energetics	P	N/A
ORD102W	DMM10	W002	9/21/2009	10:26	21.2	21.42782	-158.20071	Yes	Phthalates & Pyrene; Energetics	D	N/A
ORD103W	DMM11	W003	9/21/2009	11:01	24.1	21.42668	-158.20068	Yes	Phthalates & Pyrene; Energetics	P	N/A
ORD104W	CON33	W004	9/22/2009	10:20	20.8	21.45331	-158.21161	Yes	Phthalates & Pyrene; Energetics	P	N/A
ORD105W	CON34	W005	9/22/2009	10:20	16.3	21.45256	-158.20743	Yes	Phthalates & Pyrene; Energetics	P	N/A
ORD106W	NPS34	W006	9/22/2009	14:13	5	21.42823	-158.18340	Yes	Phthalates & Pyrene; Energetics	P	N/A
ORD107W	WWT16	W007	9/24/2009	10:00	21.6	21.42568	-158.19896	Yes	Phthalates & Pyrene; Energetics	P	N/A
ORD108W	WWT17	W008	9/24/2009	10:22	21	21.42573	-158.19835	Yes	Phthalates & Pyrene; Energetics	P	N/A
ORD109W	NPS35	W009	9/24/2009	11:44	4.4	21.42913	-158.18344	Yes	Phthalates & Pyrene; Energetics	P	N/A
SEDIMENT											
ORD001S	WWT1	S001	4/6/2009	9:30	28.8	21.42388	-158.19835	No, sample not sieved	-	-	Lots of clay, some gravel, lots of sand, dark gray.
ORD002S	WWT1	S001	4/6/2009	9:30	28.8	21.42388	-158.19835	No, sample not sieved	-	-	Lots of clay, some gravel, lots of sand, dark gray.
ORD003S	WWT1	S002	4/6/2009	9:30	28.8	21.42388	-158.19835	No, sample not sieved	-	-	/
ORD004S	WWT1	S003	4/6/2009	9:30	28.8	21.42388	-158.19835	No, sample not sieved	-	-	/
ORD005S	NPS2	S014	4/6/2009	14:50	10	21.42454	-158.18983	Yes	Energetics	P	Fine sand coraline/detrital.
ORD006S	NPS4	S016	4/6/2009	15:07	7.1	21.42497	-158.19149	Yes	Energetics	P	Sand quartz/volcanic.
ORD007S	NPS5	S017	4/6/2009	15:15	5.6	21.42524	-158.18695	Yes	Energetics	P	/
ORD008S	NPS6	S018	4/6/2009	15:32	5.2	21.42501	-158.18719	Yes	Energetics	P	Fine detrital sand, light colored.
ORD009S	WWT3	S009	4/6/2009	10:45	34.3	21.42366	-158.19823	Yes	Energetics	P	Mostly sand/gravel quartz/coral mix.
ORD010S	CON4	S024	4/8/2009	9:45	16	21.45854	-158.21875	Yes	Energetics	P	Coraline sand, muddy, little gravel.
ORD011S	CON7	S027	4/8/2009	10:02	16	21.45844	-158.21826	Yes	Energetics	P	/
ORD012S	CON10	S030	4/8/2009	10:45	10	21.45616	-158.21147	Yes	Energetics	P	/
ORD013S	CON12	S032	4/8/2009	10:43	10	21.45609	-158.21153	Yes	Energetics	P	/
ORD014S	DMM1	S020	4/7/2009	11:30	24	21.42789	-158.20132	Yes	Energetics	P	Very rocky, large shells, some green flakes.
ORD015S	DMM1	S019	4/7/2009	11:30	24	21.42789	-158.20132	Yes	Energetics	P	/
ORD016S	DMM1	S019	4/7/2009	11:30	24	21.42789	-158.20132	Yes	Energetics	D	/
ORD017S	DMM1	S021	4/7/2009	11:30	24	21.42789	-158.20132	No, sample held	-	-	Coral, mostly sand & gravel, little mud/clay.
ORD018S	WWT2	S006	4/6/2009	10:00	32.8	21.42374	-158.19826	Yes	Energetics	P	Mostly sand & gravel, detrital.
ORD019S	DMM2	S024	4/7/2009	12:45	24	21.42655	-158.20102	No, sample held	-	-	/
ORD020S	DMM2	S022	4/7/2009	12:45	24	21.42655	-158.20102	Yes	Energetics	P	Shells & coral fragments.
ORD021S	DMM2	S023	4/7/2009	12:45	24	21.42655	-158.20102	Yes	Energetics	P	Little mud/clay, lots of sand & gravel, large shells.
ORD022S	DMM4	S036	4/9/2009	13:00	/	21.42530	-158.20110	Yes	Energetics	P	Coraline sand, mostly sand/gravel.
ORD023S	DMM6	DMM6#3	4/13/2009	10:00	/	21.43445	-158.20358	No, sample held	-	-	Coraline sand & gravel, little mud/clay, tan.
ORD024S	DMM4	S037	4/9/2009	13:00	/	21.42530	-158.20110	Yes	Energetics	P	Coraline sand.
ORD025S	DMM6	DMM6#1	4/13/2009	10:00	/	21.43445	-158.20358	Yes	Energetics	P	/
ORD026S	DMM6	DMM6#2	4/13/2009	10:00	/	21.43445	-158.20358	Yes	Energetics	P	Lots of gravel, mud/clay; will not settle fast, lots of $CaCO_3$.
ORD027S	DMM3	S035	4/9/2009	12:30	/	21.42512	-158.20092	No, sample held	-	-	Some mud/clay & sand, lots of gravel, light colored.
ORD028S	DMM4	S038	4/9/2009	13:00	/	21.42530	-158.20110	No, sample held	-	-	Mostly gravel and sand, some clay.
ORD029S	DMM3	S034A	4/9/2009	12:30	/	21.42512	-158.20092	Yes	Energetics	P	Mostly gravel, coral pieces.
ORD030S	DMM3	S034A	4/9/2009	12:30	/	21.42512	-158.20092	Yes	Energetics	D	Mostly gravel, coral pieces.
ORD031S	DMM3	S034B	4/9/2009	12:30	/	21.42512	-158.20092	Yes	Energetics	P	/
ORD032S	DMM6	DMM6#2	4/13/2009	10:00	/	21.43445	-158.20358	Yes	Energetics	D	Lots of gravel, mud/clay; will not settle fast, lots of $CaCO_3$.
ORD033S	WWT1	S002	4/6/2009	9:30	28.8	21.42388	-158.19835	Yes	Energetics	P	/
ORD034S	WWT5	S010	4/6/2009	11:30	27	21.42390	-158.19603	Yes	Energetics	P	Mostly gravel/sand, little mud/clay.
ORD101S	DMM10	S001	9/21/2009	10:26	21.2	21.42782	-158.20071	Yes	Energetics	P	2 gravel samples, 2 sand (light colored) samples. Little mud.
ORD102S	DMM10	S002	9/21/2009	10:26	21.2	21.42782	-158.20071	Yes	Energetics	P	Dark colored sand, "muddy," 2 gravel containers.
ORD103S	DMM10	S003	9/21/2009	10:26	21.2	21.42782	-158.20071	No, sample held	-	-	Lots of clay, dark colored, "dirty", 3 containers for gravel.
ORD104S	DMM11	S004	9/21/2009	10:55	24.1	21.42668	-158.20068	Yes	Energetics	P	Light colored sand. Very little mud.
ORD105S	DMM11	S005	9/21/2009	10:55	24.1	21.42668	-158.20068	Yes	Energetics	P	Large gravel fractions, light colored sand and clay/mud.
ORD106S	DMM11	S006	9/21/2009	10:55	24.1	21.42668	-158.20068	No, sample held	-	-	Light colored, very little mud/clay.
ORD107S	DMM12	S007	9/21/2009	12:23	23.7	21.42710	-158.20128	Yes	Energetics	P	Light colored, 3 containers of sand.
ORD108S	DMM12	S008	9/21/2009	12:23	23.7	21.42710	-158.20128	Yes	Energetics	P	Light colored sand with three samples. Lots of gravel and some mud.
ORD109S	DMM12	S009	9/21/2009	12:23	23.7	21.42710	-158.20128	No, sample held	-	-	2 sand containers, very dark, "dirty", lots of mud archived 2/3.
ORD110S	DMM13	S010	9/21/2009	12:40	23.2	21.42713	-158.20071	Yes	Energetics	P	Light colored sand, little mud/gravel. 3 sand samples.

TABLE 2-1: SAMPLE COLLECTION LIST AND DESCRIPTIONS

Lab ID	Site	Field ID	Collection Date	Collection Time	Depth (m)	Latitude	Longitude	Sample Analyzed?	Analytes	Primary (P)/ Duplicate (D)	Sediment Description
ORD111S	DMM13	S011	9/21/2009	12:40	23.2	21.42713	-158.20071	Yes	Energetics	P	Archived half. 2 gravel containers (A, B), 2 sand (A, B). Lots of mud, light colored sand.
ORD112S	DMM13	S012	9/21/2009	12:40	23.2	21.42713	-158.20071	No, sample held	-	-	Dark colored sand. Lots of mud/gravel, Archived about 1/8 of the sand.
ORD113S	CON32	S013	9/22/2009	9:52	24.3	21.45381	-158.21349	Yes	Energetics	P	Dark, coarse sand & dark mud.
ORD114S	CON33	S014	9/22/2009	10:20	20.8	21.45331	-158.21161	Yes	Energetics	P	2 sand samples, dark in color, little gravel.
ORD115S	CON34	S015	9/22/2009	10:20	16.3	21.45256	-158.20743	Yes	Energetics	P	Light colored sand with three samples. Little mud.
ORD116S	CON34	S016	9/22/2009	10:20	16.3	21.45256	-158.20743	Yes	Energetics	D	3 sand & 2 gravel samples. Light colored sand and not much mud.
ORD117S	WWT15	S017	9/22/2009	12:07	31.2	21.42414	-158.19853	Yes	Energetics	P	Dark colored sand with lots of mud/gravel. 3 sand, 3 gravel containers. Archived 1/2.
ORD118S	NPS30	S018	9/22/2009	13:11	5.7	21.42719	-158.18423	Yes	Energetics	P	Light colored sand, very little mud/gravel.
ORD119S	NPS31	S019	9/22/2009	13:50	3.5	21.42872	-158.18256	Yes	Energetics	P	Very little mud/clay, 2 containers sand, light colored, only a little bit of gravel. Archived 2/3.
ORD120S	NPS33	S020	9/22/2009	14:10	5.4	21.42847	-158.18353	Yes	Energetics	P	Lots of sand, light colored, very little gravel. Archived 3/4.
ORD121S	NPS34	S021	9/22/2009	14:13	5	21.42823	-158.18340	Yes	Energetics	P	Dark colored sand with 2 samples. Half of the sample was archived. Little gravel and mud.
ORD122S	WWT16	S022	9/24/2009	10:00	21.6	21.42568	-158.19896	Yes	Energetics	P	Lots of big gravel fractions; fine, light colored mud/clay.
ORD123S	WWT17	S023	9/24/2009	10:22	21	21.42573	-158.19835	Yes	Energetics	P	3 sand samples, 2 gravel samples. Sand samples were light. Lots of shells in the gravel samples. Lots of mud/clay.
ORD124S	WWT19	S024	9/24/2009	11:04	22.4	21.42535	-158.19716	Yes	Energetics	P	/
ORD125S	CON35	S025	9/24/2009	11:24	21.3	21.45601	-158.21698	Yes	Energetics	P	3 Sand-light, colorful gravel fractions, lots of mud/clay.
SEDIMENT METAL SAMPLES											
DMM 6 4/13	DMM6	DMM6#1	4/13/2009	10:00	/	21.43445	-158.20358	Yes	Metals	P	/
DMM 6 #2	DMM6	DMM6#2	4/13/2009	10:00	/	21.43445	-158.20358	Yes	Metals	P	Lots of gravel, mud/clay; will not settle fast, lots of $CaCO_3$.
DMM6-S003	DMM6	DMM6#3	4/13/2009	10:00	/	21.43445	-158.20358	Yes	Metals	P	Coraline sand & gravel, little mud/clay, tan.
WWT1-S001	WWT1	S001	4/6/2009	9:30	28.8	21.42388	-158.19835	Yes	Metals	P	Lots of clay, some gravel, lots of sand, dark gray.
WWT1-S002	WWT1	S002	4/6/2009	9:30	28.8	21.42388	-158.19835	Yes	Metals	P	/
WWT1-S003	WWT1	S003	4/6/2009	9:30	28.8	21.42388	-158.19835	Yes	Metals	P	/
WWT2-S004	WWT2	S004	4/6/2009	10:00	32.8	21.42374	-158.19826	Yes	Metals	P	/
WWT2-S005	WWT2	S005	4/6/2009	10:00	32.8	21.42374	-158.19826	Yes	Metals	P	/
WWT2-S006	WWT2	S006	4/6/2009	10:00	32.8	21.42374	-158.19826	Yes	Metals	P	Mostly sand & gravel, detrital.
WWT3-S007	WWT3	S007	4/6/2009	10:45	34.3	21.42366	-158.19823	Yes	Metals	P	Mostly gravel, little sand/mud/clay, tan coraline.
WWT3-S008	WWT3	S008	4/6/2009	10:45	34.3	21.42366	-158.19823	Yes	Metals	P	Muddy sample, few coral pieces & shell.
WWT3-S009	WWT3	S009	4/6/2009	10:45	34.3	21.42366	-158.19823	Yes	Metals	P	Mostly sand/gravel quartz/coral mix.
WWT5-S010	WWT5	S010	4/6/2009	11:30	27	21.42390	-158.19603	Yes	Metals	P	Mostly gravel/sand, little mud/clay.
WWT5-S011	WWT5	S011	4/6/2009	11:30	27	21.42390	-158.19603	Yes	Metals	P	Little mud/clay, some sand & gravel (coral pieces).
WWT5-S012	WWT5	S012	4/6/2009	11:30	27	21.42390	-158.19603	Yes	Metals	P	/
NPS1-S013	NPS1	S013	4/6/2009	14:45	10	21.42490	-158.18953	Yes	Metals	P	Very little mud clay.
NPS2-S014	NPS2	S014	4/6/2009	14:50	10	21.42454	-158.18983	Yes	Metals	P	Fine sand coraline/detrital.
NPS3-S015	NPS3	S015	4/6/2009	15:00	10.6	21.42470	-158.19012	Yes	Metals	P	Mostly sand, little gravel & mud, quartz/volcanic.
NPS4-S016	NPS4	S016	4/6/2009	15:07	7.1	21.42497	-158.19149	Yes	Metals	P	Sand quartz/volcanic.
NPS5-S017	NPS5	S017	4/6/2009	15:15	5.6	21.42524	-158.18695	Yes	Metals	P	/
NPS6-S018	NPS6	S018	4/6/2009	15:32	5.2	21.42501	-158.18719	Yes	Metals	P	Fine detrital sand, light colored.
DMM1-S019	DMM1	S019	4/7/2009	11:30	24	21.42789	-158.20132	Yes	Metals	P	/
DMM1-S020	DMM1	S020	4/7/2009	11:30	24	21.42789	-158.20132	Yes	Metals	P	Very rocky, large shells, some green flakes.
DMM1-S021	DMM1	S021	4/7/2009	11:30	24	21.42789	-158.20132	Yes	Metals	P	Coral, mostly sand & gravel, little mud/clay.
DMM2-S022	DMM2	S022	4/7/2009	12:45	24	21.42655	-158.20102	Yes	Metals	P	Shells & coral fragments.
CON2-S022	CON2	S022	4/8/2009	9:30	6	21.45892	-158.21786	Yes	Metals	P	Sand, coraline mix with detrital.
DMM2-S023	DMM2	S023	4/7/2009	12:45	24	21.42655	-158.20102	Yes	Metals	P	Little mud/clay, lots of sand & gravel, large shells.
CON3-S023	CON3	S023	4/8/2009	9:40	11	21.45892	-158.21786	Yes	Metals	P	Dark sand, lots of sand, no gravel.
DMM2-S024	DMM2	S024	4/7/2009	12:45	24	21.42655	-158.20102	Yes	Metals	P	/
CON4-S024	CON4	S024	4/8/2009	9:45	16	21.45854	-158.21875	Yes	Metals	P	Coraline sand, muddy, little gravel.
CON5-S025	CON5	S025	4/8/2009	9:50	18	21.45839	-158.21901	Yes	Metals	P	/
CON6-S026	CON6	S026	4/8/2009	9:56	19	21.45886	-158.21938	Yes	Metals	P	/
CON7-S027	CON7	S027	4/8/2009	10:02	16	21.45844	-158.21826	Yes	Metals	P	/
CON8-S028	CON8	S028	4/8/2009	10:26	7	21.45844	-158.21155	Yes	Metals	P	Lots of mud/clay, brown black.
CON9-S029	CON9	S029	4/8/2009	10:29	8	21.45611	-158.21155	Yes	Metals	P	Lots of sand & clay, dark colored.

TABLE 2-1: SAMPLE COLLECTION LIST AND DESCRIPTIONS

Lab ID	Site	Field ID	Collection Date	Collection Time	Depth (m)	Latitude	Longitude	Sample Analyzed?	Analytes	Primary (P)/ Duplicate (D)	Sediment Description
CON10-S030	CON10	S030	4/8/2009	10:45	10	21.45616	-158.21147	Yes	Metals	P	/
CON11-S031	CON11	S031	4/8/2009	10:40	10	21.45621	-158.21138	Yes	Metals	P	Detrital.
CON12-S032	CON12	S032	4/8/2009	10:43	10	21.45609	-158.21153	Yes	Metals	P	/
CON13-S033	CON13	S033	4/8/2009	10:51	11	21.45607	-158.21193	Yes	Metals	P	Black, lots of mud/clay, little gravel.
DMM3-S034A	DMM3	S034A	4/9/2009	12:30	/	21.42512	-158.20092	Yes	Metals	P	Mostly gravel, coral pieces.
DMM3-S034B	DMM3	S034B	4/9/2009	12:30	/	21.42512	-158.20092	Yes	Metals	P	/
DMM3-S035	DMM3	S035	4/9/2009	12:30	/	21.42512	-158.20092	Yes	Metals	P	Some mud/clay & sand, lots of gravel, light colored.
DMM4-S036	DMM4	S036	4/9/2009	13:00	/	21.42530	-158.20110	Yes	Metals	P	Coraline sand, mostly sand/gravel.
DMM4-S037	DMM4	S037	4/9/2009	13:00	/	21.42530	-158.20110	Yes	Metals	P	Coraline sand.
DMM4-S038	DMM4	S038	4/9/2009	13:00	/	21.42530	-158.20110	Yes	Metals	P	Mostly gravel and sand, some clay.
NPS8	NPS8	S043	4/9/2009	/	/	21.42299	-158.19127	No, sample lost	-	-	/
NPS9	NPS9	/	4/9/2009	/	/	21.42857	-158.18355	Yes	Metals	P	lots of sand (light colored), very little mud/clay, no gravel fractions.
NPS10	NPS10	/	4/9/2009	/	/	21.42868	-158.18353	Yes	Metals	P	/
NPS11	NPS11	/	4/9/2009	/	/	21.42858	-158.18358	Yes	Metals	P	/
NPS12	NPS12	/	4/9/2009	/	/	21.42882	-158.18324	Yes	Metals	P	/
NPS13	NPS13	/	4/9/2009	/	/	21.42909	-158.18282	Yes	Metals	P	/
NPS14	NPS14	/	4/9/2009	/	/	21.42828	-158.18257	Yes	Metals	P	/
DMM10-S001	DMM10	S001	9/21/2009	10:26	21.2	21.42782	-158.20071	Yes	Metals	P	2 gravel samples, 2 sand (light colored) samples. Little mud.
DMM10-S002	DMM10	S002	9/21/2009	10:26	21.2	21.42782	-158.20071	Yes	Metals	P	Dark colored sand, "muddy," 2 gravel containers.
DMM10-S003	DMM10	S003	9/21/2009	10:26	21.2	21.42782	-158.20071	Yes	Metals	P	Lots of clay, dark colored, "dirty", 3 containers for gravel.
DMM11-S004	DMM11	S004	9/21/2009	10:55	24.1	21.42668	-158.20068	Yes	Metals	P	Light colored sand. Very little mud.
DMM11-S005	DMM11	S005	9/21/2009	10:55	24.1	21.42668	-158.20068	Yes	Metals	P	Large gravel fractions, light colored sand and clay/mud.
DMM11-S006	DMM11	S006	9/21/2009	10:55	24.1	21.42668	-158.20068	Yes	Metals	P	Light colored, very little mud/clay.
DMM12-S007	DMM12	S007	9/21/2009	12:23	23.7	21.42710	-158.20128	Yes	Metals	P	Light colored, 3 containers of sand.
DMM12-S008	DMM12	S008	9/21/2009	12:23	23.7	21.42710	-158.20128	Yes	Metals	P	Light colored sand with three samples. Lots of gravel and some mud.
DMM12-S009	DMM12	S009	9/21/2009	12:23	23.7	21.42710	-158.20128	Yes	Metals	P	2 sand containers, very dark, "dirty", lots of mud. Archived 2/3.
DMM13-S010	DMM13	S010	9/21/2009	12:40	23.2	21.42713	-158.20071	Yes	Metals	P	Light colored sand, little mud/gravel. 3 sand samples.
DMM13-S011	DMM13	S011	9/21/2009	12:40	23.2	21.42713	-158.20071	Yes	Metals	P	Archived half. 2 gravel containers (A, B), 2 sand (A, B). Lots of mud, light colored sand.
DMM13-S012	DMM13	S012	9/21/2009	12:40	23.2	21.42713	-158.20071	Yes	Metals	P	Dark colored sand. Lots of mud/gravel, Archived about 1/8 of the sand.
CON32-S013	CON32	S013	9/22/2009	9:52	24.3	21.45381	-158.21349	Yes	Metals	P	Dark, coarse sand & dark mud.
CON33-S014	CON33	S014	9/22/2009	10:20	20.8	21.45331	-158.21161	Yes	Metals	P	2 sand samples, dark in color, little gravel.
CON34-S015	CON34	S015	9/22/2009	10:20	16.3	21.45256	-158.20743	Yes	Metals	P	Light colored sand with three samples. Little mud.
CON34-S016	CON34	S016	9/22/2009	10:20	16.3	21.45256	-158.20743	Yes	Metals	P	3 sand & 2 gravel samples. Light colored sand and not much mud.
WWT15-S017	WWT15	S017	9/22/2009	12:07	31.2	21.42414	-158.19853	Yes	Metals	P	Dark colored sand with lots of mud/gravel. 3 sand, 3 gravel containers. Archived 1/2.
NPS30-S018	NPS30	S018	9/22/2009	13:11	5.7	21.42719	-158.18423	Yes	Metals	P	Light colored sand, very little mud/gravel.
NPS31-S019	NPS31	S019	9/22/2009	13:50	3.5	21.42872	-158.18256	Yes	Metals	P	Very little mud/clay, 2 containers sand, light colored, only a little bit of gravel. Archived 2/3.
NPS33-S020	NPS33	S020	9/22/2009	14:10	5.4	21.42847	-158.18353	Yes	Metals	P	Lots of sand, light colored, very little gravel. Archived 3/4.
NPS34-S021	NPS34	S021	9/22/2009	14:13	5	21.42823	-158.18340	Yes	Metals	P	Dark colored sand with 2 samples. Half of the sample was archived. Little gravel and mud.
WWT16-S022	WWT16	S022	9/24/2009	10:00	21.6	21.42568	-158.19896	Yes	Metals	P	Lots of big gravel fractions; fine, light colored, mud/clay.
WWT17-S023	WWT17	S023	9/24/2009	10:22	21	21.42573	-158.19835	Yes	Metals	P	3 sand samples, 2 gravel samples. Sand samples were light. Lots of shells in the gravel samples. Lots of mud/clay.
WWT19-S024	WWT19	S024	9/24/2009	11:04	22.4	21.42535	-158.19716	Yes	Metals	P	/
CON35-S025	CON35	S025	9/24/2009	11:24	21.3	21.45601	-158.21698	Yes	Metals	P	3 Sand-light, colorful gravel fractions, lots of mud/clay.
BIOTA											
OCTOPUS											
ORD001O	WWT1	O001	4/6/2009	8:30	28.8	21.42388	-158.19835	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD001O DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD002O	WWT2	O002	4/6/2009	9:30	32.8	21.42374	-158.19826	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD003O	WWT3	O003	4/6/2009	10:00	34.3	21.42366	-158.19823	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD004O	WWT4	O004	4/6/2009	11:30	27	21.42404	-158.19614	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD005O	DMM1	O005	4/7/2009	11:30	24	21.42789	-158.20132	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD006O	DMM2	O006	4/7/2009	12:45	24	21.42655	-158.20102	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD007O	DMM6	O007	4/13/2009	10:00	/	21.43445	-158.20358	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A

TABLE 2-1: SAMPLE COLLECTION LIST AND DESCRIPTIONS

Lab ID	Site	Field ID	Collection Date	Collection Time	Depth (m)	Latitude	Longitude	Sample Analyzed?	Analytes	Primary (P)/ Duplicate (D)	Sediment Description
ORD008O	CON19	O008	4/13/2009	11:50	25.9	21.45207	-158.20799	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD009O	CON20	O009	4/13/2009	12:05	/	21.45137	-158.20827	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD010O	CON21	O010	4/13/2009	12:15	/	21.45123	-158.20950	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD011O	CON21	O011	4/13/2009	12:15	/	21.45123	-158.20950	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD011O DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD012O	DMM8	O012	4/13/2009	14:00	/	21.42576	-158.19827	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD013O	NPS	O013	4/22/2009	12:00	/	21.42662	-158.18637	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD014O	NPS	O014	4/22/2009	12:00	/	21.42707	-158.19102	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD015O	NPS	O015	4/22/2009	12:00	/	21.42720	-158.19112	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD016O	NPS	O016	4/22/2009	12:00	/	21.42763	-158.19040	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD017O	NPS	O017	4/22/2009	12:00	/	21.42588	-158.18867	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD018O	NPS	O018	4/22/2009	12:00	/	21.42797	-158.18975	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD101O	DMM10	O001	9/21/2009	10:26	21.2	21.42782	-158.20071	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD102O	DMM11	O002	9/21/2009	10:52	24.1	21.42668	-158.20068	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD102O DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD103O	DMM12	O003	9/21/2009	12:23	23.7	21.42710	-158.20128	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD104O	DMM13	O004	9/21/2009	12:40	23.2	21.42713	-158.20071	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD105O	CON30	O005	9/21/2009	13:07	23.3	21.45150	-158.21082	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD106O	CON31	O006	9/21/2009	13:26	18.4	21.45218	-158.20938	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD107O	CON32	O007	9/22/2009	9:52	24.3	21.45381	-158.21349	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD108O	CON33	O008	9/22/2009	10:20	20.8	21.45331	-158.21161	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD109O	WWT15	O009	9/22/2009	12:07	31.2	21.42414	-158.19853	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD110O	WWT16	O010	9/24/2009	10:00	21.6	21.42568	-158.19896	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD111O	WWT17	O011	9/24/2009	10:22	21	21.42573	-158.19835	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD112O	WWT18	O012	9/24/2009	10:24	19.7	21.42604	-158.19853	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD113O	NPS	O013	10/12/2009	12:00	/	21.42775	-158.19045	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD114O	NPS	O014	10/12/2009	12:00	/	21.42718	-158.19067	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD115O	NPS	O015	10/12/2009	12:00	/	21.42593	-158.19138	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD115O DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD116O	NPS	O016	10/12/2009	12:00	/	21.42807	-158.19027	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD117O	NPS	O017	10/12/2009	12:00	/	21.42602	-158.19105	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD118O	NPS	O018	10/12/2009	12:00	/	21.42755	-158.19045	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
FISH (WEKE)											
ORD001-004F	WWT6	F001-F004	4/7/2009	8:00	25	21.42231	-158.19226	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD004F DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD005F	CON18	F005	4/9/2009	8:30	/	21.46005	-158.20972	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD006F	CON18	F006	4/9/2009	8:30	/	21.46005	-158.20972	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD007F	CON18	F007	4/9/2009	8:30	/	21.46005	-158.20972	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD008F	CON18	F008	4/9/2009	8:30	/	21.46005	-158.20972	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD009-012F	NPS	F009-F012	4/13/2009	8:30	/	21.42618	-158.18243	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD012F DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD013-016F	CON	Fish extra	4/9/2009	8:30	/	21.45300	-158.20715	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD017F	CON	Fish-red	4/24/2009	16:00	/	21.45482	-158.20713	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD018F	CON	Fish-red	4/24/2009	16:00	/	21.45482	-158.20713	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD019F	CON	Fish-red	4/24/2009	16:00	/	21.45482	-158.20713	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD020F	CON	Fish-red	4/24/2009	16:00	/	21.45482	-158.20713	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD021F	CON	Fish-red	4/24/2009	16:00	/	21.45482	-158.20713	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD022F	CON	Fish-red	4/24/2009	16:00	/	21.45482	-158.20713	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD023F	CON	Fish-red	4/24/2009	16:00	/	21.45482	-158.20713	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD024F	WWT	F024	4/7/2009	8:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD025F	DMM	DMM#1W	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD025F DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD026F	DMM	DMM#2W	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD027F	DMM	DMM#3W	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD028F	DMM	DMM#4W	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD029F	DMM	DMM#1R	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD030F	DMM	DMM#2R	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD031F	DMM	DMM#3R	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD032F	DMM	DMM#4R	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD033F	DMM	DMM#5	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD034F	DMM	DMM#6	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD035F	DMM	DMM#7	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD035F DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD036F	DMM	DMM#8	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD037F	DMM	DMM center r	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD038F	DMM	DMM 2 1/2 small	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD039F	DMM	DMM 2 1/2 small	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD040F	DMM	DMM EXTRA	4/15/2009	23:00	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD101-104F	NPS	Bag #6	9/29/2009	12:00	/	21.42583	-158.18218	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD104F DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD105-108F	NPS	Bag #7	9/29/2009	12:00	/	21.42667	-158.18218	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD106F DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD109-114F	CON	/	10/9/2009	12:00	/	21.45438	-158.20312	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD115-121F	WWT	Bag # 5	9/29/2009	12:00	/	21.42167	-158.19242	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD118F DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD122-125F	DMM	Bag #8	10/12/2009	12:00	/	21.42645	-158.19715	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD126-129F	DMM	Bag #9	10/12/2009	12:00	/	21.42618	-158.19698	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD130-134F	DMM	Bag #13	10/12/2009	12:00	/	21.42572	-158.19688	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD134F DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD135F	DMM	Bag #13	10/12/2009	12:00	/	21.42572	-158.19688	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD136-139F	DMM	Bag #14	10/12/2009	12:00	/	21.42610	-158.19712	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
CRAB											
ORD001C	NPS8	C001	4/8/2009	8:30	21	21.42299	-158.19127	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD002C	WWT10	C002	4/8/2009	8:45	/	21.42323	-158.19247	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD003C	WWT11	C003	4/8/2009	8:45	/	21.42340	-158.19372	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD004C	WWT9	C004	4/8/2009	8:45	/	21.42299	-158.19127	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD005C	WWT12	C005	4/8/2009	9:00	36	21.42222	-158.19680	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD006C	WWT13	C006	4/8/2009	9:00	36	21.42222	-158.19680	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD006C DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD007C	WWT14	C007	4/8/2009	9:00	37.2	21.42132	-158.19843	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD008C	WWT15	C008	4/8/2009	9:00	41.1	21.42117	-158.19860	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD009C	DMM	C009	4/8/2009	11:15	25.9	21.43648	-158.20258	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD010C	DMM	C010	4/8/2009	11:15	27.4	21.43567	-158.20333	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD011C	DMM	C011	4/8/2009	11:15	28.3	21.43567	-158.20372	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD012C	DMM	C012	4/8/2009	11:15	36.6	21.43525	-158.20498	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD012C DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD101C	WWT20	C001	9/25/2009	9:25	32.6	21.42228	-158.19823	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD101C DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD102C	WWT21	C002	9/25/2009	9:25	32.6	21.42233	-158.19810	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD103C	WWT22	C003	9/25/2009	9:25	32.6	21.42240	-158.19802	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD104C	WWT23	C004	9/25/2009	9:25	32.6	21.42208	-158.19753	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A

TABLE 2-1: SAMPLE COLLECTION LIST AND DESCRIPTIONS

Lab ID	Site	Field ID	Collection Date	Collection Time	Depth (m)	Latitude	Longitude	Sample Analyzed?	Analytes	Primary (P)/ Duplicate (D)	Sediment Description
ORD105C	WWT24	C005	9/25/2009	9:25	32.6	21.42157	-158.19730	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD106C	WWT25	C006	9/25/2009	9:25	32.6	21.42138	-158.19775	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD107C	WWT26	C007	9/25/2009	9:25	32.6	21.42107	-158.19865	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD108C	WWT27	C008	9/25/2009	9:25	32.6	21.42063	-158.20002	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD109C	DMM14	C009	9/25/2009	10:56	39.5	21.43862	-158.20330	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD110C	DMM15	C010	9/25/2009	11:45	33.7	21.44007	-158.20357	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD111C	DMM 16	C011	9/25/2009	11:45	33.7	21.44030	-158.20277	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD112C	DMM17	C012	9/25/2009	11:45	33.7	21.44043	-158.20255	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD113C	DMM	C013	10/14/2009	12:00	/	21.43782	-158.20243	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD114C	DMM	C014	10/14/2009	12:00	/	21.43882	-158.20137	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD115C	DMM	C015	10/14/2009	12:00	/	21.43877	-158.20173	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD115C DUP (dup for Phthalates & Pyrene and Energetics only)	N/A
ORD116C	DMM	C016	10/14/2009	12:00	/	21.43817	-158.20223	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
SEAWEED (LIMU)											
ORD001L	WWT4	L001	4/6/2009	16:00	27	21.42404	-158.19614	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD001L DUP (dup for Energetics only)	N/A
ORD002L	NPS7	L002	4/6/2009	16:40	8.4	21.42548	-158.18915	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD003L	CON1	L003	4/7/2009	10:05	32	21.45313	-158.21614	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD004L	CON17	L004	4/8/2009	8:30	15.2	21.44610	-158.21065	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD004L DUP (dup for Phthalates & Pyrene only)	N/A
ORD005L	CON19	L005	4/9/2009	13:00	/	21.45620	-158.21533	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD006L	DMM3	L006	4/9/2009	13:00	/	21.42512	-158.20092	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD007L	DMM4	L007	4/9/2009	13:00	/	21.42530	-158.20110	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD008L	DMM5	L008	4/9/2009	13:00	/	21.42520	-158.20028	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD009L	CON18	L009	4/13/2009	11:20	/	21.45424	-158.20604	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD010L	CON	L010	4/13/2009	12:00	/	21.45532	-158.21493	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD011L	DMM8	L011	4/13/2009	14:00	/	21.42576	-158.19827	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD011L DUP (dup for Energetics only)	N/A
ORD012L	WWT10	L012	4/13/2009	14:15	/	21.42533	-158.19701	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD013L	WWT11	L013	4/13/2009	14:20	/	21.42547	-158.19624	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD014L	NPS20	L014	4/13/2009	14:35	/	21.42789	-158.18304	Yes	Phthalates & Pyrene; Energetics; Metals	P, ORD014L DUP (dup for Phthalates & Pyrene only)	N/A
ORD015-016	NPS21	L015	4/13/2009	14:40	/	21.42811	-158.18271	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD017L	WWT	L-WWT	4/13/2009	8:30	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD018L	DMM6	/	4/13/2009	10:00	/	21.43445	-158.20358	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD019L	DMM7	/	4/13/2009	8:30	/	/	/	Yes	Phthalates & Pyrene; Energetics; Metals	P	N/A
ORD101L	NPS32	L001	9/22/2009	14:00	5.4	21.42843	-158.18358	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD102L	CON	Bag #7	9/29/2009	12:00	/	21.45480	-158.20301	Yes	Phthalates & Pyrene; Metals	P, ORD102L DUP (dup for Phthalates & Pyrene only)	N/A
ORD103L	DMM	Bag #2	10/12/2009	12:00	/	21.42675	-158.19748	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD104L	DMM	Bag #3	10/12/2009	12:00	/	21.42642	-158.19720	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD105L	DMM	Bag #4	10/12/2009	12:00	/	21.42615	-158.19705	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD106L	WWT	Bag #5	10/14/2009	12:00	/	21.42370	-158.19883	No, insufficient sample volume	-	-	N/A
ORD107L	WWT	Bag #6	10/14/2009	12:00	/	21.42595	-158.19930	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD108L	WWT	Bag #8	10/14/2009	12:00	/	21.42585	-158.19838	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD109L	WWT	Bag #9	10/14/2009	12:00	/	21.42585	-158.19838	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD110L	DMM	Bag # 10	10/14/2009	12:00	/	21.42609	-158.19928	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD111L	Unknown	Unlabeled	10/14/2009	12:00	/	/	/	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD112L	NPS	/	10/27/2009	12:00	/	21.42995	-158.18312	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD113L	NPS	/	10/27/2009	12:00	/	21.42993	-158.18312	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD114L	NPS	/	10/27/2009	12:00	/	21.42985	-158.18303	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD115L	NPS	/	10/27/2009	12:00	/	/	/	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD116L	CON	/	10/27/2009	12:00	/	21.45505	-158.20335	Yes	Phthalates & Pyrene; Metals	P	N/A
ORD117L	CON	/	10/27/2009	12:00	/	21.45483	-158.20295	Yes	Phthalates & Pyrene; Metals	P, ORD117L DUP (dup for Phthalates & Pyrene only)	N/A

Cast ID	Site	CTD ID	Date	Time Lowered	Latitude	Longitude
HYDROCASTS						
Cast 4	WWTP Stratum	CTD 1	4/6/2009	10:46	21.42366	-158.19823
Cast 5	NPS Stratum	CTD 2	4/6/2009	15:45	21.42546	-158.19063
Cast 6	NPS Stratum	CTD 2 dup	4/6/2009	15:56	21.42546	-158.19063
Cast 7	South of WWTP & NPS Strata	CTD 3	4/7/2009	9:23	21.41384	-158.19078
Cast 9	CON Stratum	CTD 4	4/7/2009	9:59	21.45241	-158.21672
Cast 10	DMM Stratum	/	4/7/2009	10:21	/	/
Cast 11	WWTP Stratum	/	4/7/2009	12:11	/	/
Cast 12	North of DMM Stratum	CTD 5	4/7/2009	13:46	21.44282	-158.20187
Cast 13	North of DMM Stratum	CTD 6	4/7/2009	13:58	21.44131	-158.21008
Cast 14	South of DMM & WWTP Strata	CTD 7	4/7/2009	14:17	21.41401	-158.20145
Cast 1	North of CON Stratum	CTD 1	9/20/2009	10:15	21.46114	-158.21983
Cast 2	South of CON Stratum	CTD 2	9/20/2009	10:42	21.44667	-158.21517
Cast 3	South of DMM & WWTP strata	CTD 3	9/20/2009	11:19	21.41372	-158.20122
Cast 4	DMM Stratum	CTD 4	9/20/2009	11:41	21.42485	-158.20177
Cast 5	WWTP Stratum	CTD 5	9/20/2009	11:56	21.42333	-158.19653
Cast 6	Between CON & DMM strata	CTD 6	9/20/2009	12:12	21.44468	-158.20195
Cast 7	NPS Stratum	CTD 7	9/20/2009	13:07	21.42477	-158.18615
Cast 8	South of WWTP & NPS strata	CTD 8	9/20/2009	13:32	21.40923	-158.19102

Note:

/ - information not available

N/A - not applicable

TABLE 2-2: CHEMICAL (CONTAMINANT)-SPECIFIC CRITERIA AND BENCHMARKS

Criteria or Benchmark	Requirement/Description	Citation
WQS and Fish Consumption Standards	Standards used to evaluate chemicals present in surface water at concentrations that warrant further assessment.	HAR Title 11, Chapter 54; DOH, 2004
FDA Action Levels	Levels of action established for fish and crustaceans.	FDA, 2011
EPA Fish Advisories Screening Values	Screening values calculated to determine chemical concentrations in fish tissue that is of a potential public health concern.	EPA, 2000
Sediment (metals): NOAA Marine Sediment Quality Benchmarks	Whole sediment toxicity-based benchmarks used to evaluate metal concentrations in surface sediment for concentrations that warrant further assessment.	NOAA SQuiRT (Buchman, 2008)
Sediment (energetic compounds): Ecological Screening Values for Sediment	Whole sediment toxicity-based benchmarks used to evaluate energetic compound concentrations in surface sediment for concentrations that warrant further assessment.	LANL, 2010; Talmage et al., 1999; EPA Region 3; EPA Region 6
Seabird Ingestion Doses: Acceptable Tissue Levels in Prey	Screening Values calculated to determine chemical concentrations in prey tissues that are protective of foraging seabirds (based on NOAELs).	Sample et al., 1996; USACHPPM, 2002 and 2006
Surface Water: Ecological Screening Values	Toxicity-based benchmarks used to evaluate chemical concentrations in surface water for concentrations that warrant further assessment	LANL 2010; Talmage et al. 1999; EPA Region 3; EPA Region 4; EPA Region 5; NOAA SQuiRT (Buchman, 2008)
NRWQC	Criteria used to evaluate chemicals present in surface water at concentrations that warrant further assessment.	CWA; EPA, 2004

CWA	Clean Water Act
DOH	Hawai‘i Department of Health
EPA	U.S. Environmental Protection Agency
FDA	Food and Drug Administration
HAR	Hawai‘i Administrative Rules
LANL	Los Alamos National Laboratory
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effect levels
NRWQC	National Recommended Water Quality Criteria
SQuiRT	Screening Quick Reference Tables
USACHPPM	U.S. Army Center for Health Promotion and Preventative Medicine (now Public Health Command)
WQS	Water Quality Standards

TABLE 2-3: BIOTA SPECIES STUDIED IN ORDNANCE REEF (HI-06) STUDY

Common Names	Hawaiian Name	Scientific Name	Biota Type
White goatfish or yellowstripe goatfish	White weke	*Mulloidichthys flavolineatus*	Fish
Red goatfish or yellowfin goatfish	Red weke	*Mulloidichthys vanicolensis*	Fish
Octopus	He‘e	*Octopus cyanea*	Invertebrate
Kona crab	Pāpa‘i kua loa	*Ranina ranina*	Invertebrate
	Limu kohu	*Asparagopsis taxiformis*	Seaweed

TABLE 2-4: SUMMARY OF BIOTA COLLECTED BY STRATUM, SEASON, AND MATRIX

	April 2009	September to October 2009
Fish		
DMM	16	18
WWTP	5	7
NPS	4	8
Control	15	6
Octopus		
DMM	4	4
WWTP	4	4
NPS	6	6
Control	4	4
Crab		
DMM	4	8
WWTP	7	8
NPS	1	0
Control	0	0
Limu		
DMM	6	4
WWTP	4	3
NPS	4	5
Control	5	3
Unknown	0	1

Note: The counts presented on this table include only primary samples analyzed by the laboratory (i.e., the counts do not include quality control samples (e.g., duplicates) or those without sufficient volume).

TABLE 4-1a: SUMMARY OF ENERGETICS COLLECTION AND DETECTION

Compound	Strata	Detections / analyses[1]	Range of detected values	Range of reporting limits
Sediment				
Picric Acid	CON	0/9	N/A	0.98-1.0 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
Nitroglycerin	CON	0/9	N/A	0.49-0.50 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
PETN	CON	0/9	N/A	0.49-0.50 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
2-Am-4,6-DNT	CON	0/9	N/A	0.24-0.25 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
4-Am-2,6-DNT	CON	0/9	N/A	0.24-0.25 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
1,3-DNB	CON	0/9	N/A	0.24-0.25 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
2,4-DNT	CON	0/9	N/A	0.24-0.25 mg/kg
	DMM	11/21	0.041^{J}-3.30^{J} mg/kg	
	NPS	0/8	N/A	
	WWT	2/8	0.03^{J}-0.048^{J} mg/kg	
2,6-DNT	CON	0/9	N/A	0.24-0.25 mg/kg
	DMM	2/21	0.098^{J}-0.38 mg/kg	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
HMX	CON	0/9	N/A	0.24-0.25 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
Nitrobenzene	CON	0/9	N/A	0.24-0.25 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
2-NT	CON	0/9	N/A	0.24-0.25 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
3-NT	CON	0/9	N/A	0.24-0.25 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
4-NT	CON	0/9	N/A	0.24-0.25 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	

TABLE 4-1a: SUMMARY OF ENERGETICS COLLECTION AND DETECTION

Compound	Strata	Detections / analyses[1]	Range of detected values	Range of reporting limits
RDX	CON	0/9	N/A	0.24-0.25 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
Tetryl	CON	0/9	N/A	0.24-0.25 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
1,3,5-TNB	CON	2/9	0.026^{J}-0.047^{J} mg/kg	0.24-0.25 mg/kg
	DMM	2/21	0.022^{J}-0.025^{J} mg/kg	
	NPS	2/8	0.021^{J}-0.024^{J} mg/kg	
	WWT	1/8	0.033^{J} mg/kg	
2,4,6-TNT	CON	0/9	N/A	0.24-0.25 mg/kg
	DMM	0/21	N/A	
	NPS	0/8	N/A	
	WWT	0/8	N/A	
2,4-Dinitrophenol	CON	0/5	N/A	0.49-0.50 mg/kg
	DMM	0/8	N/A	
	NPS	0/4	N/A	
	WWT	0/4	N/A	
Picramic Acid	CON	0/5	N/A	0.49-0.50 mg/kg
	DMM	0/8	N/A	
	NPS	0/4	N/A	
	WWT	0/4	N/A	
3,5-Dinitroaniline	CON	0/5	N/A	0.49-0.50 mg/kg
	DMM	0/8	N/A	
	NPS	0/4	N/A	
	WWT	0/4	N/A	
2-Nitrophenol	CON	0/5	N/A	0.49-0.50 mg/kg
	DMM	0/8	N/A	
	NPS	0/4	N/A	
	WWT	0/4	N/A	
4-Nitrophenol	CON	0/5	N/A	0.49-0.50 mg/kg
	DMM	0/8	N/A	
	NPS	0/4	N/A	
	WWT	0/4	N/A	
Seawater				
Picric Acid	CON	0/4	N/A	0.95-1.4 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
Nitroglycerin	CON	0/4	N/A	0.62-0.88 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
PETN	CON	0/4	N/A	0.62-0.88 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	

TABLE 4-1a: SUMMARY OF ENERGETICS COLLECTION AND DETECTION

Compound	Strata	Detections / analyses[1]	Range of detected values	Range of reporting limits
2-Am-4,6-DNT	CON	0/4	N/A	0.19-0.27 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
4-Am-2,6-DNT	CON	0/4	N/A	0.095-0.14 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
1,3-DNB	CON	0/4	N/A	0.095-0.14 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
2,4-DNT	CON	0/4	N/A	0.095-0.14 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
2,6-DNT	CON	0/4	N/A	0.095-0.14 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
HMX	CON	0/4	N/A	0.095-0.14 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
Nitrobenzene	CON	0/4	N/A	0.095-0.14 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
2-NT	CON	0/4	N/A	0.48-0.68 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
3-NT	CON	0/4	N/A	0.48-0.68 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
4-NT	CON	0/4	N/A	0.48-0.88 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
RDX	CON	0/4	N/A	0.095-0.14 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
Tetryl	CON	0/4	N/A	0.095-0.14 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
1,3,5-TNB	CON	0/4	N/A	0.095-0.14 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	

TABLE 4-1a: SUMMARY OF ENERGETICS COLLECTION AND DETECTION

Compound	Strata	Detections / analyses[1]	Range of detected values	Range of reporting limits
2,4,6-TNT	CON	0/4	N/A	0.095-0.14 µg/L
	DMM	0/5	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
3,5-Dinitroaniline	CON	0/2	N/A	0.49-0.68 µg/L
	DMM	0/3	N/A	
	NPS	0/2	N/A	
	WWT	0/2	N/A	
2-Nitrophenol	CON	0/2	N/A	0.64-0.88 µg/L
	DMM	0/3	N/A	
	NPS	0/2	N/A	
	WWT	0/2	N/A	
4-Nitrophenol	CON	0/2	N/A	0.64-0.88 µg/L
	DMM	0/3	N/A	
	NPS	0/2	N/A	
	WWT	0/2	N/A	
2,4-Dinitrophenol	CON	0/2	N/A	0.64-0.88 µg/L
	DMM	0/3	N/A	
	NPS	0/2	N/A	
	WWT	0/2	N/A	
Picramic Acid	CON	0/2	N/A	0.64-0.88 µg/L
	DMM	0/3	N/A	
	NPS	0/2	N/A	
	WWT	0/2	N/A	
Biota-Octopus				
Picric Acid	CON	0/9	N/A	0.73-1.0 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
Nitroglycerin	CON	0/9	N/A	0.73-1.0 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
PETN	CON	0/9	N/A	0.73-1.0 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
2-Am-4,6-DNT	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
4-Am-2,6-DNT	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
1,3-DNB	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
2,4-DNT	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	

TABLE 4-1a: SUMMARY OF ENERGETICS COLLECTION AND DETECTION

Compound	Strata	Detections / analyses[1]	Range of detected values	Range of reporting limits
2,6-DNT	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
HMX	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	1/9	0.062^{J} mg/kg	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
Nitrobenzene	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
2-NT	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
3-NT	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
4-NT	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
RDX	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
Tetryl	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
1,3,5-TNB	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
2,4,6-TNT	CON	0/9	N/A	0.18-0.25 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
2,4-Dinitrophenol	CON	0/9	N/A	0.36-0.50 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
Picramic Acid	CON	0/9	N/A	0.36-0.50 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
3,5-Dinitroaniline	CON	0/9	N/A	0.36-0.50 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	

TABLE 4-1a: SUMMARY OF ENERGETICS COLLECTION AND DETECTION

Compound	Strata	Detections / analyses[1]	Range of detected values	Range of reporting limits
2-Nitrophenol	CON	0/9	N/A	0.36-0.50 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
4-Nitrophenol	CON	0/9	N/A	0.36-0.50 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
Biota-Fish				
Picric Acid	CON	0/21	N/A	0.70-1.0 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
Nitroglycerin	CON	0/21	N/A	0.70-1.0 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
PETN	CON	0/21	N/A	0.70-1.0 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
2-Am-4,6-DNT	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
4-Am-2,6-DNT	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
1,3-DNB	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
2,4-DNT	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	9/37	0.037^{J}-0.18^{J} mg/kg	
	NPS	1/15	0.046^{J} mg/kg	
	WWT	0/14	N/A	
2,6-DNT	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
HMX	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	12/37	0.037^{J}-0.42^{J} mg/kg	
	NPS	2/15	0.037^{J}-0.042^{J} mg/kg	
	WWT	0/14	N/A	
Nitrobenzene	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	

TABLE 4-1a: SUMMARY OF ENERGETICS COLLECTION AND DETECTION

Compound	Strata	Detections / analyses[1]	Range of detected values	Range of reporting limits
2-NT	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	2/37	0.046[J]-0.055[J] mg/kg	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
3-NT	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
4-NT	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	1/37	0.092[J] mg/kg	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
RDX	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	1/37	1.6[J] mg/kg	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
Tetryl	CON	0/15	N/A	0.35-0.52 mg/kg
	DMM	2/19	0.39[J]-0.85[J] mg/kg	
	NPS	0/5	N/A	
	WWT	0/6	N/A	
1,3,5-TNB	CON	1/21	0.076[J] mg/kg	0.18-0.26 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
2,4,6-TNT	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
2,4-Dinitrophenol	CON	0/21	N/A	0.35-0.52 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
Picramic Acid	CON	0/21	N/A	0.35-0.52 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
3,5-Dinitroaniline	CON	0/21	N/A	0.35-0.52 mg/kg
	DMM	3/37	0.044[J]-0.053[J] mg/kg	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
2-Nitrophenol	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	1/14	0.092[J] mg/kg	
4-Nitrophenol	CON	0/21	N/A	0.18-0.26 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
Biota-Crab				
Picric Acid	DMM	0/14	N/A	0.69-1.0 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	

TABLE 4-1a: SUMMARY OF ENERGETICS COLLECTION AND DETECTION

Compound	Strata	Detections / analyses[1]	Range of detected values	Range of reporting limits
Nitroglycerin	DMM	0/14	N/A	0.69-1.0 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
PETN	DMM	0/14	N/A	0.69-1.0 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
2-Am-4,6-DNT	DMM	0/14	N/A	0.17-0.26 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
4-Am-2,6-DNT	DMM	0/14	N/A	0.17-0.26 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
1,3-DNB	DMM	0/14	N/A	0.17-0.26 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
2,4-DNT	DMM	0/14	N/A	0.17-0.26 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
2,6-DNT	DMM	0/14	N/A	0.17-0.26 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
HMX	DMM	0/14	N/A	0.17-0.26 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
Nitrobenzene	DMM	0/14	N/A	0.34-0.51 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
2-NT	DMM	0/14	N/A	0.17-0.26 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
3-NT	DMM	0/14	N/A	0.17-0.26 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
4-NT	DMM	0/14	N/A	0.17-0.26 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
RDX	DMM	0/14	N/A	0.17-0.26 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
Tetryl	DMM	0/14	N/A	0.34-0.51 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
1,3,5-TNB	DMM	0/14	N/A	0.17-0.26 mg/kg
	NPS	0/1	N/A	
	WWT	1/17	0.067[J] mg/kg	
2,4,6-TNT	DMM	0/14	N/A	0.17-0.26 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
2,4-Dinitrophenol	DMM	0/14	N/A	0.34-0.51 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	

TABLE 4-1a: SUMMARY OF ENERGETICS COLLECTION AND DETECTION

Compound	Strata	Detections / analyses[1]	Range of detected values	Range of reporting limits
Picramic Acid	DMM	0/14	N/A	0.34-0.51 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
3,5- Dinitroaniline	DMM	0/14	N/A	0.34-0.51 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
2-Nitrophenol	DMM	0/14	N/A	0.34-0.51 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
4-Nitrophenol	DMM	0/14	N/A	0.34-0.51 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
Biota-Seaweed				
Picric Acid	CON	0/5	N/A	1.9-2.0 mg/kg
	DMM	0/7	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
Nitroglycerin	CON	0/5	N/A	1.9-2.0 mg/kg
	DMM	0/7	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
4-Am-2,6-DNT	CON	0/5	N/A	0.93-1.0 mg/kg
	DMM	0/7	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
HMX	CON	0/5	N/A	0.93-1.0 mg/kg
	DMM	0/7	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
Nitrobenzene	CON	0/5	N/A	0.93-1.0 mg/kg
	DMM	0/7	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
2-NT	CON	0/5	N/A	0.93-1.0 mg/kg
	DMM	0/7	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
4-NT	CON	0/5	N/A	0.93-1.0 mg/kg
	DMM	0/7	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
RDX	CON	0/5	N/A	0.93-1.0 mg/kg
	DMM	0/7	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
Tetryl	CON	0/5	N/A	0.93-1.0 mg/kg
	DMM	0/7	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
2,4,6-TNT	CON	0/5	N/A	0.93-1.0 mg/kg
	DMM	0/7	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	

TABLE 4-1a: SUMMARY OF ENERGETICS COLLECTION AND DETECTION

Compound	Strata	Detections / analyses[1]	Range of detected values	Range of reporting limits
3,5-Dinitroaniline	CON	0/5	N/A	0.93-1.0 mg/kg
	DMM	0/7	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
2-Nitrophenol	CON	0/5	N/A	0.93-1.0 mg/kg
	DMM	0/7	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	
4-Nitrophenol	CON	0/5	N/A	0.93-1.0 mg/kg
	DMM	0/7	N/A	
	NPS	0/4	N/A	
	WWT	0/5	N/A	

Note:

[1] The counts only include samples that were analyzed by the laboratory and produced a usable data results (i.e., the counts do not include samples that had insufficient volume, nor does it include results that were rejected or not reported (NR)).

J = data is an estimated value

mg/kg = milligrams per kilogram

µg/L = micrograms per liter

N/A = not applicable

TABLE 4-1b: SUMMARY OF PHTHALATES AND PYRENE COLLECTION AND DETECTION

Compound	Strata	Detections / analyses[1]	Range of detected values	Range of reporting limits
Water				
Bis(2-ethylhexyl) Phthalate	CON	0/2	N/A	9.4-12 µg/L
	DMM	0/3	N/A	
	NPS	0/2	N/A	
	WWT	1/2	1.4 [J] µg/L	
Di-n-butyl Phthalate	CON	0/2	N/A	9.4-12 µg/L
	DMM	0/3	N/A	
	NPS	0/2	N/A	
	WWT	0/2	N/A	
Diethyl Phthalate	CON	0/2	N/A	9.4-12 µg/L
	DMM	0/3	N/A	
	NPS	0/2	N/A	
	WWT	0/2	N/A	
Dimethyl Phthalate	CON	0/2	N/A	9.4-12 µg/L
	DMM	0/3	N/A	
	NPS	0/2	N/A	
	WWT	0/2	N/A	
Di-n-octyl Phthalate	CON	0/2	N/A	9.4-12 µg/L
	DMM	0/3	N/A	
	NPS	0/2	N/A	
	WWT	0/2	N/A	
Pyrene	CON	0/2	N/A	9.4-12 µg/L
	DMM	0/3	N/A	
	NPS	0/2	N/A	
	WWT	0/2	N/A	
Biota-Octopus				
Bis(2-ethylhexyl) Phthalate	CON	0/9	N/A	1.8-2.0 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
Di-n-butyl Phthalate	CON	0/9	N/A	1.8-2.0 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
Diethyl Phthalate	CON	0/9	N/A	1.8-2.0 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
Dimethyl Phthalate	CON	0/9	N/A	1.8-2.0 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
Di-n-octyl Phthalate	CON	0/9	N/A	1.8-2.0 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	
Pyrene	CON	0/9	N/A	1.8-2.0 mg/kg
	DMM	0/9	N/A	
	NPS	0/13	N/A	
	WWT	0/9	N/A	

TABLE 4-1b: SUMMARY OF PHTHALATES AND PYRENE COLLECTION AND DETECTION

Compound	Strata	Detections / analyses[1]	Range of detected values	Range of reporting limits
Biota-Fish				
Bis(2-ethylhexyl) Phthalate	CON	0/21	N/A	1.8-2.1 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
Di-n-butyl Phthalate	CON	0/21	N/A	1.8-2.1 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	1/14	1.2 [J] mg/kg	
Diethyl Phthalate	CON	0/21	N/A	1.8-2.1 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
Dimethyl Phthalate	CON	0/21	N/A	1.8-2.1 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
Di-n-octyl Phthalate	CON	0/21	N/A	1.8-2.1 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
Pyrene	CON	0/21	N/A	1.8-2.1 mg/kg
	DMM	0/37	N/A	
	NPS	0/15	N/A	
	WWT	0/14	N/A	
Biota-Crab				
Bis(2-ethylhexyl) Phthalate	DMM	0/14	N/A	1.9-2.1 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
Di-n-butyl Phthalate	DMM	0/14	N/A	1.9-2.1 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
Diethyl Phthalate	DMM	0/14	N/A	1.9-2.1 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
Dimethyl Phthalate	DMM	0/14	N/A	1.9-2.1 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
Di-n-octyl Phthalate	DMM	0/14	N/A	1.9-2.1 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	
Pyrene	DMM	0/14	N/A	1.9-2.1 mg/kg
	NPS	0/1	N/A	
	WWT	0/17	N/A	

TABLE 4-1b: SUMMARY OF PHTHALATES AND PYRENE COLLECTION AND DETECTION

Compound	Strata	Detections / analyses[1]	Range of detected values	Range of reporting limits
Biota- Limu				
Bis(2-ethylhexyl) Phthalate	CON	0/11	N/A	1.9-4.0 mg/kg
	DMM	0/8	N/A	
	NPS	0/10	N/A	
	WWT	0/6	N/A	
	unknown	0/1	N/A	
Di-n-butyl Phthalate	CON	0/11	N/A	1.9-4.0 mg/kg
	DMM	0/8	N/A	
	NPS	0/10	N/A	
	WWT	0/6	N/A	
	unknown	0/1	N/A	
Diethyl Phthalate	CON	0/11	N/A	1.9-4.0 mg/kg
	DMM	0/8	N/A	
	NPS	0/10	N/A	
	WWT	0/6	N/A	
	unknown	0/1	N/A	
Dimethyl Phthalate	CON	0/11	N/A	1.9-4.0 mg/kg
	DMM	0/8	N/A	
	NPS	0/10	N/A	
	WWT	0/6	N/A	
	unknown	0/1	N/A	
Di-n-octyl Phthalate	CON	0/11	N/A	1.9-4.0 mg/kg
	DMM	0/8	N/A	
	NPS	0/10	N/A	
	WWT	0/6	N/A	
	unknown	0/1	N/A	
Pyrene	CON	0/11	N/A	1.9-4.0 mg/kg
	DMM	0/8	N/A	
	NPS	0/10	N/A	
	WWT	0/6	N/A	
	unknown	0/1	N/A	

Note:

[1] The counts only include samples that were analyzed by the laboratory and produced a usable data results (i.e., the counts do not include samples that had insufficient volume, nor does it include results that were rejected).

[J] = data is an estimated value

µg/L = micrograms per liter

mg/kg = milligrams per kilogram

N/A = not applicable

TABLE 4-1c: SUMMARY OF METAL COLLECTION AND DETECTION

Compound	Strata	Detections / Analyses[1]	Range of Detected Values (mg/kg)	Range of Reporting Limits (mg/kg)
Sediment[2]				
Vanadium-51	CON	17/17	6.1-75.0	N/A
	DMM	27/27	6.5-11.2	
	NPS	16/16	5.8-16.0	
	WWT	16/16	7.7-36.2	
Chromium-53	CON	17/17	11.1-112.9	N/A
	DMM	27/27	9.4-30.7	
	NPS	16/16	1.4-30.0	
	WWT	16/16	8.0-71.9	
Cobalt-59	CON	17/17	4.2-18.9	N/A
	DMM	27/27	2.2-6.3	
	NPS	16/16	3.0-10.8	
	WWT	16/16	3.1-11.6	
Nickel-60	CON	17/17	26.2-125.0	N/A
	DMM	27/27	14.7-62.9	
	NPS	16/16	14.0-65.0	
	WWT	16/16	27.3-105.2	
Copper (average)	CON	17/17	3.0-24.3	N/A
	DMM	27/27	3.0-2500.1	
	NPS	16/16	0.7-4.2	
	WWT	16/16	3.1-95.4	
Zinc (average)	CON	17/17	8.5-49.2	N/A
	DMM	27/27	12.6-407.6	
	NPS	16/16	0.1-18.4	
	WWT	16/16	5.2-55.4	
Arsenic-75	CON	17/17	1.1-20.2	N/A
	DMM	27/27	0.1-7.6	
	NPS	14/16	1.1-8.1	
	WWT	15/16	0.2-6.8	
Cadmium-111	CON	4/17	0.1-0.4	N/A
	DMM	10/27	0.1-1.8	
	NPS	5/16	0.1-1.2	
	WWT	4/16	0.1-1.0	
Barium (average)	CON	17/17	5.3-23.9	N/A
	DMM	27/27	1.8-14.3	
	NPS	16/16	2.5-11.3	
	WWT	16/16	0.1-24.7	
Lead (average)	CON	17/17	2.7-136.0	N/A
	DMM	27/27	1.7-549.3	
	NPS	16/16	1.2-11.0	
	WWT	16/16	0.5-109.7	
Uranium-238	CON	17/17	0.4-1.8	N/A
	DMM	22/27	0.2-1.2	
	NPS	14/16	0.1-1.7	
	WWT	16/16	0.1-1.6	
Biota-Octopus				
Aluminum	CON	0/4	N/A	5.0
	DMM	1/4	5.2[J]	
	NPS	0/6	N/A	
	WWT	1/4	16.7[J]	
Antimony	CON	0/8	N/A	0.20
	DMM	0/8	N/A	
	NPS	0/12	N/A	
	WWT	0/8	N/A	
Arsenic Total	CON	8/8	20.3-32.5	0.20
	DMM	8/8	20.2[J]-32.4	
	NPS	12/12	18.7-35.3	
	WWT	8/8	19.9-37.8[J]	

TABLE 4-1c: SUMMARY OF METAL COLLECTION AND DETECTION

Compound	Strata	Detections / Analyses[1]	Range of Detected Values (mg/kg)	Range of Reporting Limits (mg/kg)
Arsenic (total)*	CON	3/3	30.4-36.8	0.15-0.16
	DMM	3/3	25.8-29.7	
	WWT	1/1	36.4	
Arsenic (inorganic)*	CON	0/3	N/A	0.009-0.010
	DMM	0/3	N/A	
	WWT	0/1	N/A	
Barium	CON	1/8	0.097[J]	0.10
	DMM	6/8	0.12-0.23	
	NPS	4/12	0.12-1.9	
	WWT	1/8	0.17	
Calcium	CON	4/4	228-299	30.0
	DMM	4/4	188-244	
	NPS	6/6	214-282	
	WWT	4/4	201-230	
Cadmium	CON	4/8	0.31[J]-1.4[J]	0.10
	DMM	4/8	0.71[J]-3.5[J]	
	NPS	6/12	0.083[J]-1.1[J]	
	WWT	4/8	0.27[J]-0.75[J]	
Chromium	CON	2/8	0.12[J]-0.14[J]	0.20
	DMM	3/8	0.10[J]-0.69[J]	
	NPS	7/12	0.19[J]-1.0[J]	
	WWT	3/8	0.11[J]-0.21	
Cobalt	CON	5/8	0.011[J]-0.18[J]	0.10
	DMM	4/8	0.038[J]-0.23[J]	
	NPS	7/12	0.012[J]-0.13[J]	
	WWT	4/8	0.026[J]-0.14[J]	
Copper	CON	8/8	2.6[J]-23.2	0.20
	DMM	8/8	5.9[J]-90.3[J]	
	NPS	12/12	3.4[J]-22.5	
	WWT	8/8	3.0[J]-33.4	
Iron	CON	1/4	3.2[J]	5.0
	DMM	0/4	N/A	
	NPS	0/6	N/A	
	WWT	1/4	2.7[J 3]	
Lead	CON	2/8	0.073[J]-0.083[J]	0.10
	DMM	1/8	0.063[J]	
	NPS	2/12	0.073[J]-0.20	
	WWT	1/8	0.090[J 3]	
Magnesium	CON	4/4	655-725	5.0
	DMM	4/4	585-705	
	NPS	6/6	594-739	
	WWT	4/4	619-654	
Manganese	CON	4/4	0.23-0.35	0.20
	DMM	4/4	0.27-0.33	
	NPS	6/6	0.27-0.62	
	WWT	4/4	0.25-0.33	
Mercury	CON	2/8	0.034[J]-0.050[J]	0.048-0.120
	DMM	0/8	N/A	
	NPS	1/12	0.046[J 3]	
	WWT	0/8	N/A	
Nickel	CON	0/8	N/A	0.20
	DMM	2/8	0.13[J]-0.16[J]	
	NPS	1/12	0.12[J]	
	WWT	1/8	0.11[J]	

TABLE 4-1c: SUMMARY OF METAL COLLECTION AND DETECTION

Compound	Strata	Detections / Analyses[1]	Range of Detected Values (mg/kg)	Range of Reporting Limits (mg/kg)
Selenium	CON	8/8	0.15[J]-0.35	0.20
	DMM	8/8	0.18[J]-0.59	
	NPS	12/12	0.18[J]-0.34	
	WWT	8/8	0.16[J]-0.44	
Strontium	CON	8/8	3.4-4.9	0.50
	DMM	8/8	2.9[J]-5.9	
	NPS	12/12	3.1[J]-7.0	
	WWT	8/8	3.0[J]-4.0[J]	
Titanium	CON	0/4	N/A	0.50
	DMM	0/4	N/A	
	NPS	0/6	N/A	
	WWT	0/4	N/A	
Thallium	CON	0/8	N/A	0.10
	DMM	0/8	N/A	
	NPS	0/12	N/A	
	WWT	0/8	N/A	
Uranium	CON	0/8	N/A	0.50
	DMM	0/8	N/A	
	NPS	0/12	N/A	
	WWT	0/8	N/A	
Vanadium	CON	0/8	N/A	1.0
	DMM	1/8	0.36[J]	
	NPS	0/12	N/A	
	WWT	0/8	N/A	
Zinc	CON	8/8	9.0[J]-17.7	1.0
	DMM	8/8	10.3[J]-51.6	
	NPS	12/12	11.5[J]-19.3[J]	
	WWT	8/8	12.8[J]-16.5	
Biota-Fish				
Aluminum	CON	0/6	N/A	5.0
	DMM	1/18	17.3[J]	
	NPS	0/8	N/A	
	WWT	0/7	N/A	
Antimony	CON	0/21	N/A	0.20
	DMM	0/34	N/A	
	NPS	0/12	N/A	
	WWT	0/12	N/A	
Arsenic Total	CON	21/21	6.0-38.8	0.20
	DMM	34/34	4.4-24.9	
	NPS	12/12	5.9-38.1	
	WWT	12/12	6.5-21.2[J]	
Arsenic (total)*	CON	1/1	14.2	0.15-0.16
	DMM	3/3	12.6-25.3	
	NPS	1/1	18.2	
	WWT	1/1	25.4	
Arsenic (inorganic)*	CON	0/1	N/A	0.009-0.010
	DMM	0/3	N/A	
	NPS	0/1	N/A	
	WWT	0/1	N/A	
Barium	CON	10/21	0.091[J]-0.22[J]	0.10
	DMM	21/34	0.093[J]-0.42	
	NPS	6/12	0.11[J]-0.22[J]	
	WWT	5/12	0.095[J]-0.17	

TABLE 4-1c: SUMMARY OF METAL COLLECTION AND DETECTION

Compound	Strata	Detections / Analyses[1]	Range of Detected Values (mg/kg)	Range of Reporting Limits (mg/kg)
Calcium	CON	6/6	83.8-1340^{J}	30.0
	DMM	18/18	92.9-2530^{J}	
	NPS	8/8	74.9-2230^{J}	
	WWT	7/7	98.3-1280^{J}	
Cadmium	CON	0/21	N/A	0.10
	DMM	0/34	N/A	
	NPS	0/12	N/A	
	WWT	0/12	N/A	
Chromium	CON	17/21	0.25-0.77	0.20
	DMM	22/34	0.11^{J}-0.86^{J}	
	NPS	10/12	0.19^{J}-0.68	
	WWT	9/12	0.26-0.75^{J}	
Cobalt	CON	7/21	0.01^{J}-0.018^{J}	0.10
	DMM	3/34	0.01^{J}-0.012^{J}	
	NPS	8/12	0.011^{J}-0.036^{J}	
	WWT	0/12	N/A	
Copper	CON	21/21	0.17^{J}-0.70	0.20
	DMM	34/34	0.19^{J}-1.1^{J}	
	NPS	12/12	0.16^{J}-0.89^{J}	
	WWT	12/12	0.13^{J}-0.28	
Iron	CON	2/6	3.6^{J}-4.4^{J}	5.0
	DMM	10/18	2.6^{J}-5.2	
	NPS	6/8	2.6^{J}-8.8^{J}	
	WWT	4/7	2.6^{J}-4.3^{J}	
Lead	CON	5/21	0.06^{J}-0.092^{J}	0.10
	DMM	9/34	0.061^{J}-0.14	
	NPS	3/12	0.072^{J}-0.12	
	WWT	4/12	0.066^{J}-0.31	
Magnesium	CON	6/6	246^{J}-300^{J}	5.0
	DMM	18/18	299-371	
	NPS	8/8	255^{J}-373^{J}	
	WWT	7/7	262^{J}-329^{J}	
Manganese	CON	4/6	0.12^{J}-0.28	0.20
	DMM	12/18	0.10^{J}-0.34^{J}	
	NPS	6/8	0.11^{J}-0.41^{J}	
	WWT	4/7	0.13^{J}-0.26	
Mercury	CON	17/21	0.039^{J}-0.14	0.050-0.120
	DMM	30/34	0.044^{J}-0.15^{J}	
	NPS	12/12	0.055-0.17	
	WWT	10/12	0.062^{J}-0.11	
Nickel	CON	0/21	N/A	0.20
	DMM	0/34	N/A	
	NPS	5/12	0.13^{J}-0.80	
	WWT	1/12	0.13^{J}	
Selenium	CON	20/21	0.13^{J}-1.2	0.20
	DMM	33/34	0.11^{J}-0.43^{J}	
	NPS	11/12	0.29-0.81	
	WWT	12/12	0.29-0.42	
Strontium	CON	21/21	0.24^{J}-15.2^{J}	0.50
	DMM	34/34	0.24^{J}-15.2^{J}	
	NPS	12/12	0.31^{J}-12.6^{J}	
	WWT	12/12	0.41^{J}-9.7^{J}	

TABLE 4-1c: SUMMARY OF METAL COLLECTION AND DETECTION

Compound	Strata	Detections / Analyses[1]	Range of Detected Values (mg/kg)	Range of Reporting Limits (mg/kg)
Thallium	CON	0/21	N/A	0.10
	DMM	0/34	N/A	
	NPS	0/12	N/A	
	WWT	0/12	N/A	
Titanium	CON	0/6	N/A	0.50
	DMM	3/18	0.29[J]-0.50	
	NPS	1/8	0.36[J]	
	WWT	1/7	0.32[J]	
Uranium	CON	0/21	N/A	0.50
	DMM	0/34	N/A	
	NPS	0/12	N/A	
	WWT	0/12	N/A	
Vanadium	CON	0/21	N/A	1.0
	DMM	10/34	0.32[J]-0.67[J]	
	NPS	1/12	0.61[J]	
	WWT	0/12	N/A	
Zinc	CON	21/21	2.4-7.8	1.0
	DMM	34/34	2.5-7.8[J]	
	NPS	12/12	2.2-4.4	
	WWT	12/12	2.2-4.6	
Biota-Crab				
Aluminum	WWT	7/8	4.2[J]-9.0	5.0
	DMM	6/8	4.4[J]-11.8	
Antimony	DMM	0/12	N/A	0.20
	NPS	0/1	N/A	
	WWT	0/15	N/A	
Arsenic Total	DMM	12/12	27.1-51.2	0.20
	NPS	1/1	37.9	
	WWT	15/15	14.9-52.4	
Arsenic (total)*	DMM	3/3	34.7-53.8	0.16
	WWT	3/3	30.3-47.3	
Arsenic (inorganic)*	DMM	2/3	0.004[J 4]-0.007[J 4]	0.009-0.010
	WWT	1/3	0.007[J 4]	
Barium	DMM	8/12	0.10-0.27	0.10
	NPS	0/1	N/A	
	WWT	11/15	0.093[J]-1.6	
Calcium	WWT	8/8	782[J]-2370[J]	30.0
	DMM	8/8	610[J]-1630[J]	
Cadmium	DMM	4/12	0.10-0.18	0.10
	NPS	0/1	N/A	
	WWT	5/15	0.057[J]-0.51	
Chromium	DMM	12/12	0.48[J]-0.71	0.20
	NPS	1/1	0.50[J]	
	WWT	15/15	0.44-0.71	
Cobalt	DMM	12/12	0.011[J]-0.11	0.10
	NPS	0/1	N/A	
	WWT	8/15	0.012[J]-0.04[J]	
Copper	DMM	12/12	4.8[J]-16.8[J]	0.20
	NPS	1/1	3.3	
	WWT	15/15	0.3-13.8[J]	
Iron	WWT	8/8	6.3-12.7	5.0
	DMM	8/8	5.0-15.1	
Lead	DMM	0/12	N/A	0.10
	NPS	0/1	N/A	
	WWT	1/15	2.4	
Magnesium	WWT	8/8	546-863	5.0
	DMM	8/8	550-708	

TABLE 4-1c: SUMMARY OF METAL COLLECTION AND DETECTION

Compound	Strata	Detections / Analyses[1]	Range of Detected Values (mg/kg)	Range of Reporting Limits (mg/kg)
Manganese	WWT	8/8	0.13^{J}-0.17^{J}	0.20
	DMM	8/8	0.12^{J}-0.23	
Mercury	DMM	6/12	0.032^{J}-0.14^{J}	0.056-0.110
	NPS	1/1	0.055^{J}	
	WWT	8/15	0.05^{J}-0.10^{J}	
Nickel	DMM	0/12	N/A	0.20
	NPS	0/1	N/A	
	WWT	0/15	N/A	
Selenium	DMM	12/12	0.17^{J}-0.52	0.20
	NPS	1/1	0.29	
	WWT	15/15	0.16^{J}-0.57	
Strontium	DMM	12/12	2.7-18.6	0.50
	NPS	1/1	25.4	
	WWT	15/15	0.36^{J}-66.5	
Titanium	WWT	8/8	0.98-1.4	0.50
	DMM	8/8	0.85-2.0	
Thallium	DMM	0/12	N/A	0.10
	NPS	0/1	N/A	
	WWT	0/15	N/A	
Uranium	DMM	0/12	N/A	0.50
	NPS	0/1	N/A	
	WWT	0/15	N/A	
Vanadium	DMM	0/12	N/A	1.0
	NPS	0/1	N/A	
	WWT	0/15	N/A	
Zinc	DMM	12/12	40.5-54.9	1.0
	NPS	1/1	39.2	
	WWT	15/15	3.2-59.2	
Biota-Seaweed				
Aluminum	CON	3/3	41.1^{J}-56.2^{J}	5.0
	DMM	4/4	123^{J}-182^{J}	
	NPS	1/5	248^{J}	
	WWT	3/3	141^{J}-239^{J}	
	unknown	1/1	191^{J}	
Antimony	CON	0/8	N/A	0.20
	DMM	0/10	N/A	
	NPS	0/9	N/A	
	WWT	0/7	N/A	
	unknown	0/1	N/A	
Arsenic Total	CON	8/8	0.16^{J}-1.3	0.20
	DMM	9/10	0.34-1.2	
	NPS	8/9	0.47^{J}-1.5	
	WWT	7/7	0.51-1.4	
	unknown	1/1	1.2	
Arsenic (total)*	CON	2/2	1.16-1.56	0.15-0.16
	DMM	3/3	1.29-1.77	
	NPS	3/3	1.27-2.23	
Arsenic (inorganic)*	CON	2/2	0.108-0.832	0.010-0.102
	DMM	3/3	0.329-0.89	
	NPS	3/3	0.078-1.3	
Barium	CON	8/8	0.26-1.6	0.10
	DMM	10/10	0.43-2.1	
	NPS	9/9	0.21^{J}-8.0	
	WWT	7/7	0.45-2.2	
	unknown	1/1	0.67	

TABLE 4-1c: SUMMARY OF METAL COLLECTION AND DETECTION

Compound	Strata	Detections / Analyses[1]	Range of Detected Values (mg/kg)	Range of Reporting Limits (mg/kg)
Cadmium	CON	0/8	N/A	0.10
	DMM	0/10	N/A	
	NPS	0/9	N/A	
	WWT	0/7	N/A	
	unknown	0/1	N/A	
Calcium	CON	3/3	1170[J]-2070[J]	30.0-150
	DMM	4/4	10600[J]-32200[J]	
	NPS	5/5	730[J]-19200[J]	
	WWT	3/3	16400[J]-32200[J]	
	unknown	1/1	11400[J]	
Chromium	CON	8/8	0.2-1.7	0.20
	DMM	9/10	0.78-1.7	
	NPS	8/9	0.30-2.7	
	WWT	7/7	0.56-2.1	
	unknown	1/1	1.1	
Cobalt	CON	8/8	0.027[J]-0.28	0.10
	DMM	9/10	0.052[J]-0.15	
	NPS	8/9	0.012[J]-0.42	
	WWT	7/7	0.062[J]-0.19	
	unknown	1/1	0.1	
Copper	CON	6/8	0.16[J]-0.62[J]	0.20
	DMM	10/10	0.62-25[J]	
	NPS	8/9	0.15[J]-0.99[J]	
	WWT	6/7	0.45-1.3[J]	
	unknown	1/1	0.65	
Iron	CON	3/3	66.4-89.4	5.0
	DMM	4/4	245-380	
	NPS	5/5	15.0-409[J]	
	WWT	3/3	238-389	
	unknown	1/1	316	
Lead	CON	7/8	0.12-0.52	0.10
	DMM	9/10	0.31-0.69	
	NPS	8/9	0.14-1.1[J]	
	WWT	7/7	0.18-0.80	
	unknown	1/1	0.49	
Magnesium	CON	3/3	432[J]-774[J]	5.0
	DMM	4/4	1310[J]-2060[J]	
	NPS	5/5	655[J]-2370[J]	
	WWT	3/3	1730[J]-2510[J]	
	unknown	1/1	1770[J]	
Manganese	CON	0/3	N/A	0.20
	DMM	1/4	4.8[J]	
	NPS	0/5	N/A	
	WWT	1/3	3.6	
	unknown	0/1	N/A	
Mercury	CON	1/8	0.031[J]	0.040-0.120
	DMM	1/10	0.028[J]	
	NPS	0/9	N/A	
	WWT	0/7	N/A	
	unknown	0/1	N/A	
Nickel	CON	8/8	0.17[J]-1.7	0.20
	DMM	9/10	0.48-1.0	
	NPS	8/9	0.26-2.5	
	WWT	7/7	0.36-1.6	
	unknown	1/1	0.68	

TABLE 4-1c: SUMMARY OF METAL COLLECTION AND DETECTION

Compound	Strata	Detections / Analyses[1]	Range of Detected Values (mg/kg)	Range of Reporting Limits (mg/kg)
Selenium	CON	0/8	N/A	0.20-0.30
	DMM	3/10	0.12^{J}-0.14^{J}	
	NPS	4/9	0.22^{J}-0.91	
	WWT	3/7	0.3-0.44	
	unknown	0/1	N/A	
Strontium	CON	8/8	10.9-152^{J}	0.50
	DMM	10/10	7.2-280^{J}	
	NPS	9/9	7.7^{J}-445^{J}	
	WWT	7/7	77.8^{J}-252^{J}	
	unknown	1/1	108^{J}	
Titanium	CON	3/3	4.7-6.8	0.50
	DMM	4/4	19.4-31.3	
	NPS	5/5	0.75-33.3^{J}	
	WWT	3/3	20.2-35.7	
	unknown	1/1	26.3	
Thallium	CON	0/8	N/A	0.10
	DMM	0/10	N/A	
	NPS	0/9	N/A	
	WWT	0/7	N/A	
	unknown	0/1	N/A	
Uranium	CON	0/8	N/A	0.50
	DMM	1/10	0.11^{J}	
	NPS	4/9	0.17^{J}-0.21^{J}	
	WWT	1/7	0.1^{J}	
	unknown	0/1	N/A	
Vanadium	CON	8/8	0.31^{J}-2.1	1.0
	DMM	9/10	0.46^{J}-3.0	
	NPS	7/9	0.34^{J}-6.6^{J}	
	WWT	7/7	0.6^{J}-3.0	
	unknown	1/1	1.9	
Zinc	CON	3/8	0.84^{J}-1.6	1.0
	DMM	6/10	1.3-263	
	NPS	3/9	0.98^{J}-1.3	
	WWT	4/7	0.66^{J}-3.1	
	unknown	0/1	N/A	

Note:

[1] The counts only include samples that were analyzed by the laboratory and produced a usable data results (i.e., the counts do not include samples that had insufficient volume, nor does it include results that were rejected or not reported (NR)).

[2] Sediment metal data presented on this table are based on the "representative data" that were compiled on Table 4-5 Compiled Sediment Metal Results.

[3] The qualifier is shown as "J" in this table for consistency, although it was presented as "B" in the validation report. The qualifier "B" is defined by the laboratory as an indication that the result is between the method detection limit (MDL) and the reporting limit, therefore is an estimated value; which is the same as a "J" qualifier by the validator.

[4] The qualifier is shown as "J" in this table for consistency, although it was presented as "B" in the laboratory report (note: these results were not validated, thus they had not been provided validation qualifiers). The qualifier "B" is defined by the laboratory as an indication that the result is between the MDL and the reporting limit, therefore is an estimated value.

*: the data come from Brooks Rand other than TestAmerica; the corresponding qualifiers come from the lab (Brooks Rand) other than the validator

^{J} = data is an estimated value

mg/kg = milligrams per kilogram

N/A = not applicable

TABLE 4-2: MUNITIONS FOUND AND SAMPLES COLLECTED WITHIN THE DMM STRATUM

Site Name	Date	Ordnance Present	Depth	Sample Collected	Sample Distance to Ordnance	Sample Observation
DMM1	4/7/2009	6 inch Naval Rounds; 50 Cal in vicinity	~79 ft (24 m)	ORD015S, ORD016S(dup), & DMM1-S019	0 ft	6 inch naval round at the octopus location which was 5 ft from the center of the site
				ORD014S & DMM1-S020	4 ft (1.2 m)	
				ORD017S* & DMM1-S021	8 ft (2.4 m)	
				ORD003W	0 ft	
				ORD005O	0 ft	
DMM2	4/7/2009	50 Cal Rounds	~79 ft (24 m)	ORD020S & DMM2-S022	0 ft	
				ORD021S & DMM2-S023	4 ft (1.2 m)	
				ORD019S* & DMM2-S024	8 ft (2.4 m)	
				ORD006O	0 ft	
DMM3	4/9/2009	Naval Round	~92 ft (28 m)[1]	ORD029S, ORD030S(dup), & DMM3-S034A	0 ft	
				ORD031S & DMM3-S034B	4 ft (1.2 m)	
				ORD027S* & DMM3-S035	8 ft (2.4 m)	
				ORD006L	0 ft	Collected on a naval round
DMM4	4/9/2009	/	~92 ft (28 m)[1]	ORD022S & DMM4-S036	0 ft	
				ORD024S & DMM4-S037	4 ft (1.2 m)	Propellant grain in baggie
				ORD028S* & DMM4-S038	8 ft (2.4 m)	Partial casing in baggie
				ORD009W	/	
				ORD007L	/	
DMM5	4/9/2009	/	~89 ft (27 m)[1]	ORD008L	/	
DMM6	4/13/2009	50 Cal Rounds; Projectile in Vicinity	~82 ft (25 m)[1]	ORD025S & DMM6 4/13	0 ft	
				ORD026S, ORD032S(dup), & DMM6#2	4 ft (1.2 m)	
				ORD023S* & DMM6-S003	8 ft (2.4 m)	
				ORD007O	/	
				ORD018L	/	
DMM7	4/13/2009	/	/	ORD019L	/	
DMM8	4/13/2009	Four projectiles Small arms	~66 ft (20 m)[1]	ORD012O	4 ft (1.2 m) from two projectiles and 8 ft (2.4 m) from two more projectiles	
				ORD011L	on bomb	
DMM10	9/21/2009	50 Cal; Naval Rounds and other munitions	~70 ft (21.2 m)	ORD101S & DMM10-S001	0 ft	
				ORD102S & DMM10-S002	4 ft (1.2 m)	
				ORD103S* & DMM10-S003	8 ft (2.4 m)	
				ORD101W & ORD102W(dup)	0 ft	
				ORD101O	0 ft	
DMM11	9/21/2009	50 Cal; Naval Rounds	~79 ft (24.1 m)	ORD104S & DMM11-S004	0 ft	
				ORD105S & DMM11-S005	4 ft (1.2 m)	
				ORD106S* & DMM11-S006	6 ft (1.8 m)	
				ORD103W	0 ft	
				ORD102O	0 ft	
DMM12	9/21/2009	50 Cal Rounds	~78 ft (23.7 m)	ORD107S & DMM12-S007	0 ft	
				ORD108S & DMM12-S008	4 ft (1.2 m)	
				ORD109S* & DMM12-S009	8 ft (2.4 m)	
				ORD103O	0 ft	
DMM13	9/21/2009	Naval Round; 50 Cal	~76 ft (23.2 m)	ORD110S & DMM13-S010	0 ft	
				ORD111S & DMM13-S011	4 ft (1.2 m)	
				ORD112S* & DMM13-S012	8 ft (2.4 m)	
				ORD104O	0 ft	
DMM14	9/25/2009	/	~130 ft (39.5 m)	ORD109C	/	
DMM15	9/25/2009	/	~111 ft (33.7 m)	ORD110C	/	
DMM16	9/25/2009	/	~111 ft (33.7 m)	ORD111C	/	
DMM17	9/25/2009	/	~111 ft (33.7 m)	ORD112C	/	
DMM[2]	4/8/2009	/	~108 ft (33 m)[1]	ORD009C	/	
DMM[2]	4/8/2009	/	~108 ft (33 m)[1]	ORD010C	/	
DMM[2]	4/8/2009	/	~108 ft (33 m)[1]	ORD011C	/	
DMM[2]	4/8/2009	/	~115 ft (35 m)[1]	ORD012C	/	
DMM[2]	4/15/2009	/	/	ORD025F-ORD040F	/	
DMM[2]	10/12/2009	/	~61 ft (18.5 m)[1]	ORD122F-ORD0125F	/	
DMM[2]	10/12/2009	/	~61 ft (18.5 m)[1]	ORD126F-ORD0129F	/	
DMM[2]	10/12/2009	/	~62 ft (19 m)[1]	ORD130F-ORD0135F	/	

TABLE 4-2: MUNITIONS FOUND AND SAMPLES COLLECTED WITHIN THE DMM STRATUM

Site Name	Date	Ordnance Present	Depth	Sample Collected	Sample Distance to Ordnance	Sample Observation
DMM[2]	10/12/2009	/	~61 ft (18.5 m)[1]	ORD136F-ORD0139F	/	
DMM[2]	10/12/2009	/	~61 ft (18.5 m)[1]	ORD103L-ORD105L	/	
DMM[2]	10/14/2009	/	~115 ft (35 m)[1]	ORD113C	/	
DMM[2]	10/14/2009	/	~89 ft (27 m)[1]	ORD114C	/	
DMM[2]	10/14/2009	/	~95 ft (29 m)[1]	ORD115C	/	
DMM[2]	10/14/2009	/	~112 ft (34 m)[1]	ORD116C	/	
DMM[2]	10/14/2009	/	~69 ft (21 m)[1]	ORD110L	/	

Note:
/ = information not available
* = Samples were not analyzed. The samples were submitted to the laboratory but placed on hold pending the results of other samples.
[1] = Depths were estimated based on sample location coordinates. All other depths were recorded in the field.
[2] = Samples were collected from various locations within the DMM stratum.

TABLE 4-3: PROPERTIES OF COPCS

COPC	CAS No.	MW (g/mol)	Density (g/mL)	Melting Point (°C)	Log K_{ow}	K_{oc} (mL/g)	Vapor Pressure (mm Hg at 25°C)	S (mg/L)	References
Energetics									
2,4,6-trinitrotoluene (TNT)	118-96-7	227.13	1.654	80.8	1.86	1.1E+3	8.02E-6	130@20°C	Administrative Record and Information Repository, 2008; ATSDR, 1995; Kohler, J. and Meyer, R., 1993; Syracuse Research Corporation, 2008; The Risk Assessment Information System, 2008; United States National Library of Medicine, 2008; Walsh, et al., 1995
Dinitrotoluene (DNT)	25321-14-6	182.15	1.32@71°C	71	2.18	587.4	3.97E-4	270	EPA, 2012; Syracuse Research Corporation, 2008; www.osha.gov; www.sciencelab.com, Sunahara et al., 2009
1,3,5-trinitroperhydro-1,3,5-triazine (Royal Demolition Explosive (RDX))	121-82-4	222.1	1.82	204	0.86	89.07	4.1E-9	42@20°C	ATSDR, 1995; Kohler, J. and Meyer, R., 1993; Syracuse Research Corporation, 2008; Walsh, et al., 1995
Explosive D (Ammonium Picrate)	131-74-8	246.14	1.72	280	-1.40	5363	3.37E-11	1.6E+5 @25°C	EPA, 2012; Kohler, J. and Meyer, R., 1993; Syracuse Research Corporation, 2008; United States National Library of Medicine, 2008; Walsh, et al., 1995

TABLE 4-3: PROPERTIES OF COPCS

COPC	CAS No.	MW (g/mol)	Density (g/mL)	Melting Point (°C)	Log K_{ow}	K_{oc} (mL/g)	Vapor Pressure (mm Hg at 25°C)	S (mg/L)	References
Nitroglycerin	55-63-0	227.09	1.6	13.2	1.62	115.8	4E-4	1800 @ 25°C	EPA, 2012; Sunahara et al., 2009; Syracuse Research Corporation, 2008; www.osha.gov
Metals									
Arsenic	7440-38-2	74.9	1.97-5.75	>615	0.68	13.22	2.51E-9	3.47E+4 @25° C	CRC, 2006-2007; EPA, 2012; Ernest Orlando Lawrence Berkeley National Laboratory: Environment, Health and Safety Division, 2008; Syracuse Research Corporation, 2008; United States National Library of Medicine, 2008
Copper	7440-50-8	63.55	8.96	1083	-0.57	13.22	4.24E-9	4.21E+5@25° C	CRC, 2006-2007; EPA, 2012; Syracuse Research Corporation, 2008
Lead	7439-92-1	207.2	11.3	327.5	0.73	13.22	3.02E-9	9580@25°C	CRC, 2006-2007; EPA, 2012; Syracuse Research Corporation, 2008

Notes: Composition B is a mixture of TNT and RDX, Torpex is a mixture of TNT, RDX and aluminum, and amatol is a mixture of ammonium nitrate and TNT.
Arsenic is a possible carcinogen by the United States Occupational Safety and Health Administration (OSHA), IARC, and the NTP.

° C	degrees Celsius	mL/g	milliliter per gram
CAS	Chemical Abstract Service	mg/L	milligram per liter
COPC	constituent of potential concern	mm HG	millimeters of mercury
g/mL	grams per milliliter	MW	molecular weight
g/mol	grams per mole	ND	no data
IARC	International Agency for Research on Cancer	NTP	National Toxicology Program
K_{ow}	octanol-water partition coefficient	S	Water Solubility
K_{oc}	organic carbon partition coefficient		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Sample ID / Analyte	Result	Units	Location	Sampling Date
SEAWATER				
ORD107W			*WWT16*	*24-Sep-09*
Bis(2-ethylhexyl) phthalate	1.4 J	µg/L		
SEDIMENT				
ORD007S			*NPS5*	*6-Apr-09*
1,3,5-TNB	0.024 J1	mg/kg		
ORD008S			*NPS6*	*6-Apr-09*
1,3,5-TNB	0.021 J1	mg/kg		
ORD009S			*WWT3*	*6-Apr-09*
1,3,5-TNB	0.033 J1	mg/kg		
ORD012S			*CON10*	*8-Apr-09*
1,3,5-TNB	0.026 J1	mg/kg		
ORD013S			*CON12*	*8-Apr-09*
1,3,5-TNB	0.047 J1	mg/kg		
ORD014S			*DMM1*	*7-Apr-09*
1,3,5-TNB	0.025 J1	mg/kg		
ORD016S (duplicate of ORD015S)			*DMM1*	*7-Apr-09*
1,3,5-TNB	0.022 J1	mg/kg		
ORD024S			*DMM4*	*9-Apr-09*
2,4-DNT	0.041 J	mg/kg		
ORD029S			*DMM3*	*9-Apr-09*
2,4-DNT	0.16 J	mg/kg		
ORD030S (duplicate of ORD029S)			*DMM3*	*9-Apr-09*
2,4-DNT	0.14 J	mg/kg		
ORD031S			*DMM3*	*9-Apr-09*
2,4-DNT	0.12 J	mg/kg		
ORD101S			*DMM10*	*21-Sep-09*
2,4-DNT	0.12 J	mg/kg		
ORD102S			*DMM10*	*21-Sep-09*
2,4-DNT	0.56 J2	mg/kg		
ORD104S			*DMM11*	*21-Sep-09*
2,4-DNT	0.27 J2	mg/kg		
ORD105S			*DMM11*	*21-Sep-09*
2,4-DNT	**3.30** J2	mg/kg		
2,6-DNT	0.38	mg/kg		
ORD107S			*DMM12*	*21-Sep-09*
2,4-DNT	0.043 J	mg/kg		
ORD110S			*DMM13*	*21-Sep-09*
2,4-DNT	0.033 J2	mg/kg		
ORD111S			*DMM13*	*21-Sep-09*
2,4-DNT	1.60 J2	mg/kg		
2,6-DNT	0.098 J	mg/kg		
ORD122S			*WWT16*	*24-Sep-09*
2,4-DNT	0.048 J	mg/kg		
ORD123S			*WWT17*	*24-Sep-09*
2,4-DNT	0.03 J	mg/kg		
BIOTA--OCTOPUS				
ORD001O			*WWT1*	*6-Apr-09*
Arsenic Total	34.3	mg/kg		
Cadmium	0.27 J	mg/kg		
Cobalt	0.026 J	mg/kg		
Copper	7.7	mg/kg		
Nickel	0.11 J	mg/kg		
Selenium	0.20	mg/kg		
Strontium	3.2	mg/kg		
Zinc	13.5	mg/kg		
ORD002O			*WWT2*	*6-Apr-09*
Arsenic Total	37.8 J	mg/kg		
Cadmium	0.33 J	mg/kg		
Cobalt	0.043 J	mg/kg		
Copper	8.6 J	mg/kg		
Selenium	0.20 J	mg/kg		
Strontium	4.0 J	mg/kg		
Zinc	14.5 J	mg/kg		
ORD003O			*WWT3*	*6-Apr-09*
Arsenic Total	37.3	mg/kg		
Arsenic Total*	36.4	mg/kg		
Cadmium	0.75 J	mg/kg		
Cobalt	0.14 J	mg/kg		
Copper	33.4	mg/kg		
Lead	0.090 J3	mg/kg		
Selenium	0.44	mg/kg		
Strontium	3.7	mg/kg		
Zinc	16.5	mg/kg		
ORD004O			*WWT4*	*6-Apr-09*
Arsenic Total	27.9	mg/kg		
Barium	0.17	mg/kg		
Cadmium	0.53 J	mg/kg		
Cobalt	0.079 J	mg/kg		
Copper	14.5	mg/kg		
Selenium	0.27	mg/kg		
Strontium	3.2	mg/kg		
Zinc	14.7	mg/kg		
ORD005O			*DMM1*	*7-Apr-09*
Arsenic Total	21.3	mg/kg		
Barium	0.12	mg/kg		
Cadmium	0.71 J	mg/kg		
Cobalt	0.038 J	mg/kg		
Copper	24.6	mg/kg		
Lead	0.063 J	mg/kg		
Selenium	0.21	mg/kg		
Strontium	5.9	mg/kg		
Zinc	14.4	mg/kg		
ORD006O			*DMM2*	*7-Apr-09*
Arsenic Total	20.2	mg/kg		
Arsenic Total*	25.8	mg/kg		
Barium	0.19	mg/kg		
Cadmium	3.5 J	mg/kg		
Cobalt	0.23 J	mg/kg		
Copper	90.3 J	mg/kg		
Nickel	0.16 J	mg/kg		
Selenium	0.54	mg/kg		
Strontium	4.5	mg/kg		
Vanadium	0.36 J	mg/kg		
Zinc	51.6	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD007O			*DMM6*	*13-Apr-09*
Arsenic Total	32.4	mg/kg		
Barium	0.23	mg/kg		
Cadmium	1.9 J	mg/kg		
Chromium	0.69 J	mg/kg		
Cobalt	0.21 J	mg/kg		
Copper	38	mg/kg		
Nickel	0.13 J	mg/kg		
Selenium	0.59	mg/kg		
Strontium	4.7	mg/kg		
Zinc	24	mg/kg		
ORD008O			*CON19*	*13-Apr-09*
Arsenic Total	27.6	mg/kg		
Cadmium	0.91 J	mg/kg		
Cobalt	0.15 J	mg/kg		
Copper	20.4	mg/kg		
Selenium	0.22	mg/kg		
Strontium	4.9	mg/kg		
Zinc	17.1	mg/kg		
ORD009O			*CON20*	*13-Apr-09*
Arsenic Total	29.8	mg/kg		
Arsenic Total*	36.8	mg/kg		
Barium	0.097 J	mg/kg		
Cadmium	0.31 J	mg/kg		
Cobalt	0.045 J	mg/kg		
Copper	6.8	mg/kg		
Mercury	0.034 J	mg/kg		
Selenium	0.18 J	mg/kg		
Strontium	3.4	mg/kg		
Zinc	15.7	mg/kg		
ORD010O			*CON21*	*13-Apr-09*
Arsenic Total	32.5	mg/kg		
Cadmium	1.2 J	mg/kg		
Cobalt	0.18 J	mg/kg		
Copper	18.8	mg/kg		
Selenium	0.35	mg/kg		
Strontium	3.7	mg/kg		
Zinc	17.7	mg/kg		
ORD011O			*CON21*	*13-Apr-09*
Arsenic Total	32.5	mg/kg		
Cadmium	1.4 J	mg/kg		
Cobalt	0.14 J	mg/kg		
Copper	23.2	mg/kg		
Selenium	0.20	mg/kg		
Strontium	3.7	mg/kg		
Zinc	13.7	mg/kg		
ORD012O			*DMM8*	*13-Apr-09*
HMX	0.062 J	mg/kg		
Arsenic Total	29.1	mg/kg		
Cadmium	0.76 J	mg/kg		
Cobalt	0.06 J	mg/kg		
Copper	25.5	mg/kg		
Selenium	0.29	mg/kg		
Strontium	3.9	mg/kg		
Zinc	17.8	mg/kg		
ORD013O			*NPS*	*22-Apr-09*
Arsenic Total	30.4	mg/kg		
Cadmium	0.59 J	mg/kg		
Cobalt	0.11 J	mg/kg		
Copper	22.5	mg/kg		
Lead	0.073 J	mg/kg		
Selenium	0.34	mg/kg		
Strontium	4.3	mg/kg		
Zinc	17.2	mg/kg		
ORD014O			*NPS1*	*22-Apr-09*
Arsenic Total	25.9	mg/kg		
Cadmium	1.1 J	mg/kg		
Chromium	1.0 J	mg/kg		
Cobalt	0.13 J	mg/kg		
Copper	21.4	mg/kg		
Nickel	0.12 J	mg/kg		
Selenium	0.27	mg/kg		
Strontium	7.0	mg/kg		
Zinc	17.1	mg/kg		
ORD015O			*NPS2*	*22-Apr-09*
Arsenic Total	21.2	mg/kg		
Cadmium	0.28 J	mg/kg		
Cobalt	0.035 J	mg/kg		
Copper	7.5	mg/kg		
Selenium	0.18 J	mg/kg		
Strontium	3.9	mg/kg		
Zinc	13.2	mg/kg		
ORD016O			*NPS3*	*22-Apr-09*
Arsenic Total	35.3	mg/kg		
Cadmium	0.72 J	mg/kg		
Cobalt	0.12 J	mg/kg		
Copper	21.5	mg/kg		
Selenium	0.27	mg/kg		
Strontium	4.0	mg/kg		
Zinc	16.2	mg/kg		
ORD017O			*NPS4*	*22-Apr-09*
Arsenic Total	27.9	mg/kg		
Barium	1.9	mg/kg		
Cadmium	0.69 J	mg/kg		
Cobalt	0.095 J	mg/kg		
Copper	14.1	mg/kg		
Selenium	0.23	mg/kg		
Strontium	4.1	mg/kg		
Zinc	16.3	mg/kg		
ORD018O			*NPS5*	*22-Apr-09*
Arsenic Total	33.1	mg/kg		
Barium	1.4	mg/kg		
Cadmium	0.083 J	mg/kg		
Cobalt	0.024 J	mg/kg		
Copper	7.1	mg/kg		
Mercury	0.046 J3	mg/kg		
Selenium	0.19 J	mg/kg		
Strontium	4.4	mg/kg		
Zinc	13.1	mg/kg		
ORD101O			*DMM10*	*21-Sep-09*
Arsenic Total	20.2 J	mg/kg		
Barium	0.15 J	mg/kg		
Calcium	207 J	mg/kg		
Copper	5.9 J	mg/kg		
Magnesium	618 J	mg/kg		
Manganese	0.28 J	mg/kg		
Selenium	0.18 J	mg/kg		
Strontium	3.2 J	mg/kg		
Zinc	11.5 J	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD102O			*DMM11*	*21-Sep-09*
Aluminum	5.2 J	mg/kg		
Arsenic Total	21.0	mg/kg		
Arsenic Total*	26.1	mg/kg		
Barium	0.14	mg/kg		
Calcium	199	mg/kg		
Copper	8.7 J	mg/kg		
Magnesium	625	mg/kg		
Manganese	0.27	mg/kg		
Selenium	0.21	mg/kg		
Strontium	3.1 J	mg/kg		
Zinc	10.3 J	mg/kg		
ORD103O			*DMM12*	*21-Sep-09*
Arsenic Total	27.0	mg/kg		
Barium	0.21	mg/kg		
Calcium	244	mg/kg		
Chromium	0.20	mg/kg		
Copper	6.2 J	mg/kg		
Magnesium	705	mg/kg		
Manganese	0.33	mg/kg		
Selenium	0.25	mg/kg		
Strontium	3.6 J	mg/kg		
Zinc	13.6 J	mg/kg		
ORD104O			*DMM13*	*21-Sep-09*
Arsenic Total	21.6	mg/kg		
Arsenic Total*	29.7	mg/kg		
Calcium	188	mg/kg		
Chromium	0.10 J	mg/kg		
Copper	8.6 J	mg/kg		
Magnesium	585	mg/kg		
Manganese	0.28	mg/kg		
Selenium	0.21	mg/kg		
Strontium	2.9 J	mg/kg		
Zinc	14.9 J	mg/kg		
ORD105O			*CON30*	*21-Sep-09*
Arsenic Total	24.3	mg/kg		
Arsenic Total*	33.2	mg/kg		
Calcium	228	mg/kg		
Copper	2.9 J	mg/kg		
Lead	0.073 J	mg/kg		
Magnesium	670	mg/kg		
Manganese	0.23	mg/kg		
Selenium	0.28	mg/kg		
Strontium	3.5 J	mg/kg		
Zinc	11.9 J	mg/kg		
ORD106O			*CON31*	*21-Sep-09*
Arsenic Total	20.3	mg/kg		
Calcium	279	mg/kg		
Cobalt	0.011 J	mg/kg		
Copper	8.7 J	mg/kg		
Lead	0.083 J	mg/kg		
Magnesium	725	mg/kg		
Manganese	0.29	mg/kg		
Mercury	0.050 J	mg/kg		
Selenium	0.15 J	mg/kg		
Strontium	4.5 J	mg/kg		
Zinc	9.0 J	mg/kg		
ORD107O			*CON32*	*22-Sep-09*
Arsenic Total	23.3	mg/kg		
Arsenic Total*	30.4	mg/kg		
Calcium	299	mg/kg		
Chromium	0.12 J	mg/kg		
Copper	4.4 J	mg/kg		
Iron	3.2 J	mg/kg		
Magnesium	655	mg/kg		
Manganese	0.31	mg/kg		
Selenium	0.21	mg/kg		
Strontium	4.0 J	mg/kg		
Zinc	11.9 J	mg/kg		
ORD108O			*CON33*	*22-Sep-09*
Arsenic Total	28.3	mg/kg		
Calcium	236	mg/kg		
Chromium	0.14 J	mg/kg		
Copper	2.6 J	mg/kg		
Magnesium	682	mg/kg		
Manganese	0.35	mg/kg		
Selenium	0.19 J	mg/kg		
Strontium	3.8 J	mg/kg		
Zinc	14.5 J	mg/kg		
ORD109O			*WWT15*	*22-Sep-09*
Aluminum	16.7 J	mg/kg		
Arsenic Total	24.8	mg/kg		
Calcium	201	mg/kg		
Chromium	0.15 J	mg/kg		
Copper	7.2 J	mg/kg		
Magnesium	626	mg/kg		
Manganese	0.33	mg/kg		
Selenium	0.18 J	mg/kg		
Strontium	3.1 J	mg/kg		
Zinc	13.8 J	mg/kg		
ORD110O			*WWT16*	*24-Sep-09*
Arsenic Total	22.5	mg/kg		
Calcium	206	mg/kg		
Chromium	0.21	mg/kg		
Copper	5.0 J	mg/kg		
Iron	2.7 J3	mg/kg		
Magnesium	627	mg/kg		
Manganese	0.25	mg/kg		
Selenium	0.23	mg/kg		
Strontium	3.0 J	mg/kg		
Zinc	12.8 J	mg/kg		
ORD111O			*WWT17*	*24-Sep-09*
Arsenic Total	22.1	mg/kg		
Calcium	209	mg/kg		
Chromium	0.11 J	mg/kg		
Copper	7.0 J	mg/kg		
Magnesium	619	mg/kg		
Manganese	0.31	mg/kg		
Selenium	0.28	mg/kg		
Strontium	3.1 J	mg/kg		
Zinc	14.0 J	mg/kg		
ORD112O			*WWT18*	*24-Sep-09*
Arsenic Total	19.9	mg/kg		
Calcium	230	mg/kg		
Copper	3.0 J	mg/kg		
Magnesium	654	mg/kg		
Manganese	0.28	mg/kg		
Selenium	0.16 J	mg/kg		
Strontium	3.4 J	mg/kg		
Zinc	15.5 J	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD113O			*NPS*	*12-Oct-09*
Arsenic Total	25.0	mg/kg		
Barium	0.12	mg/kg		
Calcium	261	mg/kg		
Chromium	0.20	mg/kg		
Cobalt	0.012 J	mg/kg		
Copper	12.7 J	mg/kg		
Magnesium	739	mg/kg		
Manganese	0.61	mg/kg		
Selenium	0.32	mg/kg		
Strontium	4.0 J	mg/kg		
Zinc	19.3 J	mg/kg		
ORD114O			*NPS*	*12-Oct-09*
Arsenic Total	22.3	mg/kg		
Calcium	244	mg/kg		
Chromium	0.26	mg/kg		
Copper	6.0 J	mg/kg		
Magnesium	672	mg/kg		
Manganese	0.43	mg/kg		
Selenium	0.32	mg/kg		
Strontium	3.4 J	mg/kg		
Zinc	12.6 J	mg/kg		
ORD115O			*NPS*	*12-Oct-09*
Arsenic Total	20.8	mg/kg		
Calcium	282	mg/kg		
Chromium	0.21	mg/kg		
Copper	5.8 J	mg/kg		
Magnesium	626	mg/kg		
Manganese	0.27	mg/kg		
Selenium	0.21	mg/kg		
Strontium	4.0 J	mg/kg		
Zinc	13.4 J	mg/kg		
ORD116O			*NPS*	*12-Oct-09*
Arsenic Total	19.7	mg/kg		
Barium	0.13	mg/kg		
Calcium	243	mg/kg		
Chromium	0.19 J	mg/kg		
Copper	4.9 J	mg/kg		
Lead	0.20	mg/kg		
Magnesium	711	mg/kg		
Manganese	0.62	mg/kg		
Selenium	0.19 J	mg/kg		
Strontium	3.6 J	mg/kg		
Zinc	13.4 J	mg/kg		
ORD117O			*NPS*	*12-Oct-09*
Arsenic Total	22.4	mg/kg		
Calcium	231	mg/kg		
Chromium	0.24	mg/kg		
Copper	9.1 J	mg/kg		
Magnesium	662	mg/kg		
Manganese	0.33	mg/kg		
Selenium	0.29	mg/kg		
Strontium	3.3 J	mg/kg		
Zinc	13.1 J	mg/kg		
ORD118O			*NPS*	*12-Oct-09*
Arsenic Total	18.7	mg/kg		
Calcium	214	mg/kg		
Chromium	0.18 J	mg/kg		
Copper	3.4 J	mg/kg		
Magnesium	594	mg/kg		
Manganese	0.29	mg/kg		
Selenium	0.26	mg/kg		
Strontium	3.1 J	mg/kg		
Zinc	11.5 J	mg/kg		
BIOTA--FISH				
ORD001F			*WWT6*	*7-Apr-09*
Arsenic Total	18.3	mg/kg		
Barium	0.17 J	mg/kg		
Chromium	0.49	mg/kg		
Copper	0.23	mg/kg		
Lead	0.31	mg/kg		
Mercury	0.075 J	mg/kg		
Selenium	0.40	mg/kg		
Strontium	9.7 J	mg/kg		
Zinc	4.4	mg/kg		
ORD002F			*WWT6*	*7-Apr-09*
Arsenic Total	21.2 J	mg/kg		
Arsenic Total*	25.4	mg/kg		
Chromium	0.54 J	mg/kg		
Copper	0.27 J	mg/kg		
Lead	0.066 J	mg/kg		
Mercury	0.11	mg/kg		
Nickel	0.13 J	mg/kg		
Selenium	0.42 J	mg/kg		
Strontium	0.41 J	mg/kg		
Zinc	3.0 J	mg/kg		
ORD003F			*WWT6*	*7-Apr-09*
Arsenic Total	18.7	mg/kg		
Barium	0.10 J	mg/kg		
Chromium	0.51	mg/kg		
Copper	0.22	mg/kg		
Mercury	0.072	mg/kg		
Selenium	0.42	mg/kg		
Strontium	6.2 J	mg/kg		
Zinc	3.5	mg/kg		
ORD004F			*WWT6*	*7-Apr-09*
Arsenic Total	12.8	mg/kg		
Chromium	0.63	mg/kg		
Copper	0.24	mg/kg		
Lead	0.069 J	mg/kg		
Selenium	0.34	mg/kg		
Strontium	1.3	mg/kg		
Zinc	3.7	mg/kg		
ORD004F DUP			*WWT6*	*7-Apr-09*
Di-n-butyl Phthalate	1.2 J	mg/kg		
ORD005F			*CON18*	*9-Apr-09*
Arsenic Total	35.3	mg/kg		
Chromium	0.67	mg/kg		
Cobalt	0.013 J	mg/kg		
Copper	0.23	mg/kg		
Lead	0.092 J	mg/kg		
Mercury	0.07 J	mg/kg		
Selenium	0.55	mg/kg		
Strontium	0.32 J	mg/kg		
Zinc	3.1	mg/kg		
ORD006F			*CON18*	*9-Apr-09*
Arsenic Total	10.4	mg/kg		
Chromium	0.65	mg/kg		
Copper	0.25	mg/kg		
Selenium	0.43	mg/kg		
Strontium	0.41 J	mg/kg		
Zinc	3.5	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD007F			*CON18*	*9-Apr-09*
Arsenic Total	38.8	mg/kg		
Chromium	0.65	mg/kg		
Cobalt	0.01 J	mg/kg		
Copper	0.26	mg/kg		
Mercury	0.11	mg/kg		
Selenium	0.51	mg/kg		
Strontium	1.2	mg/kg		
Zinc	4.0	mg/kg		
ORD008F			*CON18*	*9-Apr-09*
Arsenic Total	10.6	mg/kg		
Chromium	0.60	mg/kg		
Copper	0.27	mg/kg		
Lead	0.06 J	mg/kg		
Mercury	0.066 J	mg/kg		
Selenium	0.45	mg/kg		
Strontium	0.36 J	mg/kg		
Zinc	4.2	mg/kg		
ORD009F			*NPS*	*13-Apr-09*
Arsenic Total	38.1	mg/kg		
Barium	0.12 J	mg/kg		
Chromium	0.68	mg/kg		
Cobalt	0.036 J	mg/kg		
Copper	0.26	mg/kg		
Lead	0.12	mg/kg		
Mercury	0.10	mg/kg		
Selenium	0.68	mg/kg		
Strontium	7.6 J	mg/kg		
Zinc	4.4	mg/kg		
ORD010F			*NPS*	*13-Apr-09*
Arsenic Total	20.6	mg/kg		
Chromium	0.68	mg/kg		
Cobalt	0.019 J	mg/kg		
Copper	0.32	mg/kg		
Mercury	0.11	mg/kg		
Nickel	0.13 J	mg/kg		
Selenium	0.69	mg/kg		
Strontium	0.40 J	mg/kg		
Zinc	3.5	mg/kg		
ORD011F			*NPS*	*13-Apr-09*
Arsenic Total	27.2	mg/kg		
Chromium	0.60	mg/kg		
Copper	0.19 J	mg/kg		
Mercury	0.055	mg/kg		
Selenium	0.54	mg/kg		
Strontium	0.66	mg/kg		
Zinc	3.7	mg/kg		
ORD012F			*NPS*	*13-Apr-09*
Arsenic Total	33.6	mg/kg		
Barium	0.17 J	mg/kg		
Chromium	0.68	mg/kg		
Cobalt	0.013 J	mg/kg		
Copper	0.19 J	mg/kg		
Mercury	0.14	mg/kg		
Selenium	0.81	mg/kg		
Strontium	0.31 J	mg/kg		
Zinc	2.8	mg/kg		
ORD013F			*CON*	*9-Apr-09*
Arsenic Total	11.6	mg/kg		
Barium	0.13 J	mg/kg		
Chromium	0.77	mg/kg		
Copper	0.21	mg/kg		
Selenium	1.2	mg/kg		
Strontium	0.24 J	mg/kg		
Zinc	3.3	mg/kg		
ORD014F			*CON*	*9-Apr-09*
1,3,5-TNB	0.076 J	mg/kg		
Arsenic Total	10.5	mg/kg		
Barium	0.11 J	mg/kg		
Chromium	0.66	mg/kg		
Copper	0.24	mg/kg		
Mercury	0.039 J	mg/kg		
Selenium	0.30	mg/kg		
Strontium	0.30 J	mg/kg		
Zinc	4.9	mg/kg		
ORD015F			*CON*	*9-Apr-09*
Arsenic Total	9.7	mg/kg		
Barium	0.22 J	mg/kg		
Chromium	0.47	mg/kg		
Cobalt	0.01 J	mg/kg		
Copper	0.21	mg/kg		
Lead	0.067 J	mg/kg		
Selenium	0.40	mg/kg		
Strontium	15.2 J	mg/kg		
Zinc	7.8	mg/kg		
ORD016F			*CON*	*9-Apr-09*
Arsenic Total	6.0	mg/kg		
Barium	0.095 J	mg/kg		
Chromium	0.55	mg/kg		
Copper	0.37	mg/kg		
Mercury	0.045 J	mg/kg		
Selenium	0.41	mg/kg		
Strontium	0.32 J	mg/kg		
Zinc	3.4	mg/kg		
ORD017F			*CON*	*24-Apr-09*
Arsenic Total	15.7	mg/kg		
Chromium	0.53	mg/kg		
Copper	0.23	mg/kg		
Mercury	0.065 J	mg/kg		
Selenium	0.23	mg/kg		
Strontium	0.29 J	mg/kg		
Zinc	3.3	mg/kg		
ORD018F			*CON*	*24-Apr-09*
Arsenic Total	22.5	mg/kg		
Barium	0.091 J	mg/kg		
Chromium	0.67	mg/kg		
Cobalt	0.013 J	mg/kg		
Copper	0.70	mg/kg		
Mercury	0.078 J	mg/kg		
Selenium	0.36	mg/kg		
Strontium	0.77	mg/kg		
Zinc	3.8	mg/kg		
ORD019F			*CON*	*24-Apr-09*
Arsenic Total	12.7	mg/kg		
Arsenic Total*	14.2	mg/kg		
Barium	0.11 J	mg/kg		
Chromium	0.54	mg/kg		
Copper	0.26	mg/kg		
Mercury	0.14	mg/kg		
Selenium	0.24	mg/kg		
Strontium	0.61	mg/kg		
Zinc	3.2	mg/kg		
ORD020F			*CON*	*24-Apr-09*
Arsenic Total	18.5	mg/kg		
Barium	0.11 J	mg/kg		
Chromium	0.56	mg/kg		
Copper	0.18 J	mg/kg		
Mercury	0.085 J	mg/kg		
Selenium	0.22	mg/kg		
Strontium	0.28 J	mg/kg		
Zinc	2.8	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD021F			*CON*	*24-Apr-09*
Arsenic Total	24.7	mg/kg		
Barium	0.11	mg/kg		
Chromium	0.76 J	mg/kg		
Cobalt	0.015 J	mg/kg		
Copper	0.34	mg/kg		
Selenium	0.24	mg/kg		
Strontium	4.9 J	mg/kg		
Zinc	5.0	mg/kg		
ORD022F			*CON*	*24-Apr-09*
Arsenic Total	20.6 J	mg/kg		
Barium	0.12 J	mg/kg		
Cobalt	0.018 J	mg/kg		
Copper	0.43 J	mg/kg		
Lead	0.09 J	mg/kg		
Mercury	0.046 J	mg/kg		
Selenium	0.24 J	mg/kg		
Strontium	0.48 J	mg/kg		
Zinc	5.1 J	mg/kg		
ORD023F			*CON*	*24-Apr-09*
Arsenic Total	27.5	mg/kg		
Chromium	0.76 J	mg/kg		
Cobalt	0.016 J	mg/kg		
Copper	0.24	mg/kg		
Lead	0.073 J	mg/kg		
Mercury	0.044 J	mg/kg		
Selenium	0.19 J	mg/kg		
Strontium	0.48 J	mg/kg		
Zinc	4.0	mg/kg		
ORD024F			*WWT*	*7-Apr-09*
Arsenic Total	12.9	mg/kg		
Barium	0.095 J	mg/kg		
Chromium	0.75 J	mg/kg		
Copper	0.24	mg/kg		
Lead	0.088 J	mg/kg		
Mercury	0.078 J	mg/kg		
Selenium	0.38	mg/kg		
Strontium	0.92	mg/kg		
Zinc	3.3	mg/kg		
ORD025F			*DMM*	*15-Apr-09*
Arsenic Total	10	mg/kg		
Cobalt	0.012 J	mg/kg		
Copper	0.31	mg/kg		
Lead	0.073 J	mg/kg		
Mercury	0.15 J	mg/kg		
Selenium	0.37	mg/kg		
Strontium	0.40 J	mg/kg		
Zinc	3.5	mg/kg		
ORD026F			*DMM*	*15-Apr-09*
Arsenic Total	13.5	mg/kg		
Barium	0.10	mg/kg		
Chromium	0.82 J	mg/kg		
Cobalt	0.01 J	mg/kg		
Copper	0.35	mg/kg		
Lead	0.099 J	mg/kg		
Mercury	0.094 J	mg/kg		
Selenium	0.36	mg/kg		
Strontium	2.9	mg/kg		
Zinc	4.7	mg/kg		
ORD027F			*DMM*	*15-Apr-09*
Arsenic Total	6.5	mg/kg		
Barium	0.15	mg/kg		
Chromium	0.78 J	mg/kg		
Copper	0.49	mg/kg		
Lead	0.077 J	mg/kg		
Mercury	0.082 J	mg/kg		
Selenium	0.32	mg/kg		
Strontium	1.0	mg/kg		
Zinc	3.2	mg/kg		
ORD028F			*DMM*	*15-Apr-09*
Arsenic Total	15.5	mg/kg		
Chromium	0.77 J	mg/kg		
Copper	0.22	mg/kg		
Mercury	0.11 J	mg/kg		
Selenium	0.34	mg/kg		
Strontium	0.48 J	mg/kg		
Zinc	3.5	mg/kg		
ORD029F			*DMM*	*15-Apr-09*
Arsenic Total	17.0	mg/kg		
Barium	0.25	mg/kg		
Chromium	0.86 J	mg/kg		
Copper	0.34	mg/kg		
Lead	0.063 J	mg/kg		
Mercury	0.057 J	mg/kg		
Selenium	0.24	mg/kg		
Strontium	0.39 J	mg/kg		
Zinc	3.3	mg/kg		
ORD030F			*DMM*	*15-Apr-09*
Arsenic Total	13.1	mg/kg		
Barium	0.13	mg/kg		
Chromium	0.74 J	mg/kg		
Copper	0.33	mg/kg		
Selenium	0.19 J	mg/kg		
Strontium	0.39 J	mg/kg		
Zinc	3.4	mg/kg		
ORD031F			*DMM*	*15-Apr-09*
Arsenic Total	12.3	mg/kg		
Arsenic Total*	12.6	mg/kg		
Barium	0.14	mg/kg		
Chromium	0.84 J	mg/kg		
Copper	0.45	mg/kg		
Lead	0.11	mg/kg		
Mercury	0.078 J	mg/kg		
Selenium	0.22	mg/kg		
Strontium	0.45 J	mg/kg		
Zinc	3.3	mg/kg		
ORD032F			*DMM*	*15-Apr-09*
Arsenic Total	10.4	mg/kg		
Barium	0.42	mg/kg		
Copper	0.59	mg/kg		
Mercury	0.098 J	mg/kg		
Selenium	0.23	mg/kg		
Strontium	7.6	mg/kg		
Zinc	4.9	mg/kg		
ORD033F			*DMM*	*15-Apr-09*
Arsenic Total	17.9	mg/kg		
Chromium	0.84 J	mg/kg		
Copper	0.31	mg/kg		
Lead	0.061 J	mg/kg		
Mercury	0.08 J	mg/kg		
Selenium	0.24	mg/kg		
Strontium	2.0	mg/kg		
Zinc	3.3	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD034F			*DMM*	*15-Apr-09*
Arsenic Total	17.2	mg/kg		
Barium	0.13	mg/kg		
Chromium	0.86 J	mg/kg		
Copper	0.25	mg/kg		
Mercury	0.13 J	mg/kg		
Selenium	0.24	mg/kg		
Strontium	0.37 J	mg/kg		
Zinc	2.9	mg/kg		
ORD035F			*DMM*	*15-Apr-09*
Arsenic Total	8.8	mg/kg		
Barium	0.37	mg/kg		
Chromium	0.83 J	mg/kg		
Copper	0.24	mg/kg		
Mercury	0.098 J	mg/kg		
Selenium	0.22	mg/kg		
Strontium	0.35 J	mg/kg		
Zinc	3.1	mg/kg		
ORD036F			*DMM*	*15-Apr-09*
Arsenic Total	13.2	mg/kg		
Chromium	0.75 J	mg/kg		
Copper	0.29	mg/kg		
Mercury	0.13 J	mg/kg		
Selenium	0.20	mg/kg		
Strontium	0.34 J	mg/kg		
Zinc	3.00	mg/kg		
ORD037F			*DMM*	*15-Apr-09*
Arsenic Total	15.2	mg/kg		
Chromium	0.75 J	mg/kg		
Copper	0.30	mg/kg		
Mercury	0.097 J	mg/kg		
Selenium	0.20	mg/kg		
Strontium	0.29 J	mg/kg		
Zinc	3.1	mg/kg		
ORD038F			*DMM*	*15-Apr-09*
Arsenic Total	12.8	mg/kg		
Barium	0.16	mg/kg		
Copper	0.33	mg/kg		
Selenium	0.14 J	mg/kg		
Strontium	11.2 J	mg/kg		
Zinc	4.7	mg/kg		
ORD039F			*DMM*	*15-Apr-09*
Arsenic Total	15.0	mg/kg		
Chromium	0.79 J	mg/kg		
Copper	0.29	mg/kg		
Mercury	0.044 J	mg/kg		
Selenium	0.15 J	mg/kg		
Strontium	0.44 J	mg/kg		
Zinc	3.5	mg/kg		
ORD040F			*DMM*	*15-Apr-09*
Arsenic Total	18.7	mg/kg		
Chromium	0.82 J	mg/kg		
Copper	0.23	mg/kg		
Mercury	0.11 J	mg/kg		
Selenium	0.24	mg/kg		
Strontium	0.26 J	mg/kg		
Zinc	2.9	mg/kg		
ORD101F			*NPS*	*29-Sep-09*
HMX	0.042 J	mg/kg		
Arsenic Total	5.9	mg/kg		
Barium	0.16 J	mg/kg		
Calcium	95	mg/kg		
Chromium	0.56 J	mg/kg		
Copper	0.46 J	mg/kg		
Iron	5.8 J	mg/kg		
Magnesium	355	mg/kg		
Manganese	0.41 J	mg/kg		
Mercury	0.15 J	mg/kg		
Nickel	0.80	mg/kg		
Selenium	0.37	mg/kg		
Strontium	0.37 J	mg/kg		
Titanium	0.36 J	mg/kg		
Zinc	3.4	mg/kg		
ORD102F			*NPS*	*29-Sep-09*
Arsenic Total	15.6 J	mg/kg		
Calcium	697 J	mg/kg		
Copper	0.30 J	mg/kg		
Iron	8.2 J	mg/kg		
Magnesium	373 J	mg/kg		
Manganese	0.21 J	mg/kg		
Mercury	0.15 J	mg/kg		
Nickel	0.22	mg/kg		
Selenium	0.47 J	mg/kg		
Strontium	6.5 J	mg/kg		
Vanadium	0.61 J	mg/kg		
Zinc	3.4 J	mg/kg		
ORD103F			*NPS*	*29-Sep-09*
2,4-DNT	0.046 J	mg/kg		
Arsenic Total	14.9	mg/kg		
Arsenic Total*	18.2	mg/kg		
Calcium	114	mg/kg		
Chromium	0.32 J	mg/kg		
Cobalt	0.014 J	mg/kg		
Copper	0.21 J	mg/kg		
Iron	3.1 J	mg/kg		
Magnesium	359	mg/kg		
Manganese	0.11 J	mg/kg		
Mercury	0.064 J	mg/kg		
Strontium	0.40 J	mg/kg		
Zinc	3.9	mg/kg		
ORD104F			*NPS*	*29-Sep-09*
HMX	0.037 J	mg/kg		
Arsenic Total	16.1	mg/kg		
Barium	0.22 J	mg/kg		
Calcium	1440 J	mg/kg		
Chromium	0.33 J	mg/kg		
Cobalt	0.011 J	mg/kg		
Copper	0.89 J	mg/kg		
Iron	8.8 J	mg/kg		
Lead	0.10 J	mg/kg		
Magnesium	353	mg/kg		
Manganese	0.28 J	mg/kg		
Mercury	0.17	mg/kg		
Nickel	0.15 J	mg/kg		
Selenium	0.52	mg/kg		
Strontium	8.7 J	mg/kg		
Zinc	4.3	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD105F			*NPS*	*29-Sep-09*
Arsenic Total	25.0 J	mg/kg		
Barium	0.11 J	mg/kg		
Calcium	308 J	mg/kg		
Chromium	0.30 J	mg/kg		
Cobalt	0.013 J	mg/kg		
Copper	0.17 J	mg/kg		
Lead	0.072 J	mg/kg		
Magnesium	277 J	mg/kg		
Manganese	0.18 J	mg/kg		
Mercury	0.066	mg/kg		
Nickel	0.42	mg/kg		
Selenium	0.40 J	mg/kg		
Strontium	1.4 J	mg/kg		
Zinc	3.0 J	mg/kg		
ORD106F			*NPS*	*29-Sep-09*
Arsenic Total	20.5	mg/kg		
Barium	0.12	mg/kg		
Calcium	2230 J	mg/kg		
Chromium	0.19 J	mg/kg		
Cobalt	0.013 J	mg/kg		
Copper	0.24	mg/kg		
Iron	3.6 J	mg/kg		
Magnesium	299 J	mg/kg		
Manganese	0.17 J	mg/kg		
Mercury	0.14	mg/kg		
Selenium	0.34	mg/kg		
Strontium	12.6 J	mg/kg		
Zinc	3.7	mg/kg		
ORD107F			*NPS*	*29-Sep-09*
Arsenic Total	17.0	mg/kg		
Calcium	74.9	mg/kg		
Copper	0.16 J	mg/kg		
Magnesium	255 J	mg/kg		
Mercury	0.11	mg/kg		
Selenium	0.29	mg/kg		
Strontium	0.32 J	mg/kg		
Zinc	2.2	mg/kg		
ORD108F			*NPS*	*29-Sep-09*
Arsenic Total	12.3	mg/kg		
Calcium	105	mg/kg		
Chromium	0.32	mg/kg		
Cobalt	0.015 J	mg/kg		
Copper	0.20	mg/kg		
Iron	2.6 J	mg/kg		
Magnesium	296 J	mg/kg		
Mercury	0.075	mg/kg		
Selenium	0.44	mg/kg		
Strontium	0.37 J	mg/kg		
Zinc	3.3	mg/kg		
ORD109F			*CON*	*9-Oct-09*
Arsenic Total	12.8	mg/kg		
Calcium	438	mg/kg		
Chromium	0.45	mg/kg		
Copper	0.35	mg/kg		
Iron	4.4 J	mg/kg		
Magnesium	296 J	mg/kg		
Manganese	0.24	mg/kg		
Mercury	0.10	mg/kg		
Selenium	0.18 J	mg/kg		
Strontium	2.6 J	mg/kg		
Zinc	4.5	mg/kg		
ORD110F			*CON*	*9-Oct-09*
Arsenic Total	15.3	mg/kg		
Calcium	231	mg/kg		
Copper	0.19 J	mg/kg		
Magnesium	276 J	mg/kg		
Manganese	0.28	mg/kg		
Mercury	0.067	mg/kg		
Selenium	0.44	mg/kg		
Strontium	1.1 J	mg/kg		
Zinc	4.8	mg/kg		
ORD111F			*CON*	*9-Oct-09*
Arsenic Total	9.6	mg/kg		
Calcium	83.8	mg/kg		
Copper	0.17 J	mg/kg		
Magnesium	246	mg/kg		
Mercury	0.072 J	mg/kg		
Selenium	0.18 J	mg/kg		
Strontium	0.28 J	mg/kg		
Zinc	2.4	mg/kg		
ORD112F			*CON*	*9-Oct-09*
Arsenic Total	9.8	mg/kg		
Calcium	112	mg/kg		
Chromium	0.25	mg/kg		
Copper	0.17 J	mg/kg		
Magnesium	260 J	mg/kg		
Manganese	0.12 J	mg/kg		
Mercury	0.082 J	mg/kg		
Strontium	0.51 J	mg/kg		
Zinc	2.9	mg/kg		
ORD113F			*CON*	*9-Oct-09*
Arsenic Total	10.7	mg/kg		
Calcium	1340 J	mg/kg		
Chromium	0.31	mg/kg		
Copper	0.19 J	mg/kg		
Iron	3.6 J	mg/kg		
Magnesium	300 J	mg/kg		
Manganese	0.20	mg/kg		
Mercury	0.080	mg/kg		
Selenium	0.23	mg/kg		
Strontium	7.1 J	mg/kg		
Zinc	4.0	mg/kg		
ORD114F			*CON*	*9-Oct-09*
Arsenic Total	11.7	mg/kg		
Barium	0.12	mg/kg		
Calcium	114	mg/kg		
Copper	0.17 J	mg/kg		
Magnesium	294 J	mg/kg		
Mercury	0.063 J	mg/kg		
Selenium	0.13 J	mg/kg		
Strontium	0.49 J	mg/kg		
Zinc	4.5	mg/kg		
ORD115F			*WWT*	*29-Sep-09*
Arsenic Total	17.8	mg/kg		
Calcium	517 J	mg/kg		
Copper	0.13 J	mg/kg		
Magnesium	281 J	mg/kg		
Manganese	0.26	mg/kg		
Mercury	0.069	mg/kg		
Selenium	0.33	mg/kg		
Strontium	2.7 J	mg/kg		
Zinc	2.2	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD116F			*WWT*	*29-Sep-09*
Arsenic Total	10.2	mg/kg		
Calcium	121	mg/kg		
Chromium	0.41	mg/kg		
Copper	0.28	mg/kg		
Iron	4.3 J	mg/kg		
Magnesium	262 J	mg/kg		
Manganese	0.13 J	mg/kg		
Mercury	0.10	mg/kg		
Selenium	0.38	mg/kg		
Strontium	0.74 J	mg/kg		
Titanium	0.32 J	mg/kg		
Zinc	3.4	mg/kg		
ORD117F			*WWT*	*29-Sep-09*
Arsenic Total	6.5	mg/kg		
Barium	0.17	mg/kg		
Calcium	1280 J	mg/kg		
Chromium	0.30	mg/kg		
Copper	0.15 J	mg/kg		
Magnesium	329 J	mg/kg		
Mercury	0.062	mg/kg		
Selenium	0.29	mg/kg		
Strontium	6.4 J	mg/kg		
Zinc	3.7	mg/kg		
ORD118F			*WWT*	*29-Sep-09*
Arsenic Total	11.6	mg/kg		
Calcium	98.3	mg/kg		
Copper	0.23	mg/kg		
Iron	3.1 J	mg/kg		
Magnesium	270 J	mg/kg		
Mercury	0.084	mg/kg		
Selenium	0.34			
Strontium	0.58 J	mg/kg		
Zinc	2.7	mg/kg		
ORD119F			*WWT*	*29-Sep-09*
Arsenic Total	10.9	mg/kg		
Barium	0.096 J	mg/kg		
Calcium	109	mg/kg		
Chromium	0.27	mg/kg		
Copper	0.16 J	mg/kg		
Iron	3.6 J	mg/kg		
Magnesium	270 J	mg/kg		
Manganese	0.13 J	mg/kg		
Mercury	0.11	mg/kg		
Selenium	0.29	mg/kg		
Strontium	0.58 J	mg/kg		
Zinc	2.8	mg/kg		
ORD120F			*WWT*	*29-Sep-09*
2-Nitrophenol	0.092 J	µg/L		
Arsenic Total	13.4	mg/kg		
Calcium	121	mg/kg		
Chromium	0.26	mg/kg		
Copper	0.14 J	mg/kg		
Iron	2.6 J	mg/kg		
Magnesium	276 J	mg/kg		
Selenium	0.31	mg/kg		
Strontium	0.63 J	mg/kg		
Zinc	4.6	mg/kg		
ORD121F			*WWT*	*29-Sep-09*
Arsenic Total	8.1	mg/kg		
Calcium	99.5	mg/kg		
Copper	0.14 J	mg/kg		
Magnesium	265 J	mg/kg		
Manganese	0.20	mg/kg		
Mercury	0.10	mg/kg		
Selenium	0.31	mg/kg		
Strontium	0.70 J	mg/kg		
Zinc	2.2	mg/kg		
ORD122F			*DMM*	*12-Oct-09*
Arsenic Total	18.4	mg/kg		
Calcium	107	mg/kg		
Copper	0.19 J	mg/kg		
Magnesium	313 J	mg/kg		
Mercury	0.064 J	mg/kg		
Selenium	0.20	mg/kg		
Strontium	0.35 J	mg/kg		
Zinc	3.6	mg/kg		
ORD123F			*DMM*	*12-Oct-09*
Arsenic Total	24.9	mg/kg		
Barium	0.28	mg/kg		
Calcium	2530 J	mg/kg		
Chromium	0.42	mg/kg		
Cobalt	0.010 J	mg/kg		
Copper	0.21	mg/kg		
Iron	5.2	mg/kg		
Lead	0.14	mg/kg		
Magnesium	341 J	mg/kg		
Manganese	0.30	mg/kg		
Mercury	0.10	mg/kg		
Selenium	0.41	mg/kg		
Strontium	15.2 J	mg/kg		
Titanium	0.50	mg/kg		
Zinc	4.2	mg/kg		
ORD124F			*DMM*	*12-Oct-09*
Arsenic Total	19.9	mg/kg		
Arsenic Total*	25.3	mg/kg		
Barium	0.12	mg/kg		
Calcium	867 J	mg/kg		
Chromium	0.36	mg/kg		
Copper	0.20	mg/kg		
Iron	3.1 J	mg/kg		
Lead	0.072 J	mg/kg		
Magnesium	321 J	mg/kg		
Manganese	0.14 J	mg/kg		
Mercury	0.046 J	mg/kg		
Selenium	0.43	mg/kg		
Strontium	4.2 J	mg/kg		
Titanium	0.33 J	mg/kg		
Zinc	4.5	mg/kg		
ORD125F			*DMM*	*12-Oct-09*
HMX	0.045 J	mg/kg		
Arsenic Total	8.8	mg/kg		
Calcium	95.2	mg/kg		
Copper	0.57 J	mg/kg		
Iron	4.0 J	mg/kg		
Magnesium	299	mg/kg		
Manganese	0.13 J	mg/kg		
Mercury	0.091	mg/kg		
Selenium	0.34	mg/kg		
Strontium	0.44 J	mg/kg		
Vanadium	0.60 J	mg/kg		
Zinc	4.2	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD126F			*DMM*	*12-Oct-09*
HMX	0.040 J	mg/kg		
Arsenic Total	18.5	mg/kg		
Barium	0.11 J	mg/kg		
Calcium	1410 J	mg/kg		
Chromium	0.30 J	mg/kg		
Copper	0.22 J	mg/kg		
Magnesium	364	mg/kg		
Manganese	0.12 J	mg/kg		
Mercury	0.078	mg/kg		
Selenium	0.30	mg/kg		
Strontium	7.0 J	mg/kg		
Zinc	3.7	mg/kg		
ORD127F			*DMM*	*12-Oct-09*
2,4-DNT	0.085 J	mg/kg		
HMX	0.076 J	mg/kg		
2-NT	0.055 J	mg/kg		
4-NT	0.092 J	mg/kg		
Arsenic Total	15.9	mg/kg		
Calcium	727 J	mg/kg		
Chromium	0.41 J	mg/kg		
Copper	0.25 J	mg/kg		
Iron	2.6 J	mg/kg		
Magnesium	356	mg/kg		
Manganese	0.17 J	mg/kg		
Mercury	0.077	mg/kg		
Selenium	0.20	mg/kg		
Strontium	3.3 J	mg/kg		
Titanium	0.29 J	mg/kg		
Zinc	3.2	mg/kg		
ORD128F			*DMM*	*12-Oct-09*
2,4-DNT	0.13 J	mg/kg		
HMX	0.13 J	mg/kg		
Tetryl	0.39 J	mg/kg		
3,5-Dinitroaniline	0.045 J	µg/L		
Arsenic Total	18.4	mg/kg		
Calcium	109	mg/kg		
Chromium	0.11 J	mg/kg		
Copper	0.20 J	mg/kg		
Magnesium	364	mg/kg		
Mercury	0.076 J	mg/kg		
Selenium	0.23	mg/kg		
Strontium	0.33 J	mg/kg		
Vanadium	0.60 J	mg/kg		
Zinc	3.7	mg/kg		
ORD129F			*DMM*	*12-Oct-09*
2,4-DNT	0.065 J	mg/kg		
Arsenic Total	15.0	mg/kg		
Barium	0.093 J	mg/kg		
Calcium	92.9	mg/kg		
Copper	0.54 J	mg/kg		
Iron	2.9 J	mg/kg		
Magnesium	346	mg/kg		
Manganese	0.14 J	mg/kg		
Mercury	0.058 J	mg/kg		
Strontium	0.24 J	mg/kg		
Vanadium	0.63 J	mg/kg		
Zinc	2.7	mg/kg		
ORD130F			*DMM*	*12-Oct-09*
Arsenic Total	4.4	mg/kg		
Barium	0.10 J	mg/kg		
Calcium	101	mg/kg		
Chromium	0.25 J	mg/kg		
Copper	0.48 J	mg/kg		
Iron	4.8 J	mg/kg		
Magnesium	309	mg/kg		
Manganese	0.11 J	mg/kg		
Mercury	0.057 J	mg/kg		
Selenium	0.22	mg/kg		
Strontium	0.43 J	mg/kg		
Zinc	2.8	mg/kg		
ORD131F			*DMM*	*12-Oct-09*
Arsenic Total	4.4	mg/kg		
Barium	0.10 J	mg/kg		
Calcium	368 J	mg/kg		
Chromium	0.33 J	mg/kg		
Copper	0.63 J	mg/kg		
Iron	2.8 J	mg/kg		
Magnesium	359	mg/kg		
Manganese	0.13 J	mg/kg		
Mercury	0.072 J	mg/kg		
Selenium	0.19 J	mg/kg		
Strontium	1.5 J	mg/kg		
Vanadium	0.32 J	mg/kg		
Zinc	3.2	mg/kg		
ORD132F			*DMM*	*12-Oct-09*
2,4-DNT	0.047 J	mg/kg		
HMX	0.052 J	mg/kg		
2-NT	0.046 J	mg/kg		
Arsenic Total	11.6	mg/kg		
Calcium	145	mg/kg		
Copper	0.22 J	mg/kg		
Magnesium	339	mg/kg		
Selenium	0.13 J	mg/kg		
Strontium	0.53 J	mg/kg		
Vanadium	0.65 J	mg/kg		
Zinc	2.6	mg/kg		
ORD133F			*DMM*	*12-Oct-09*
2,4-DNT	0.086 J	mg/kg		
3,5-Dinitroaniline	0.053 J	µg/L		
Arsenic Total	9.6	mg/kg		
Barium	0.25 J	mg/kg		
Calcium	96	mg/kg		
Copper	0.39 J	mg/kg		
Iron	3.7 J	mg/kg		
Magnesium	371	mg/kg		
Manganese	0.11 J	mg/kg		
Mercury	0.051 J	mg/kg		
Selenium	0.26	mg/kg		
Strontium	0.35 J	mg/kg		
Vanadium	0.67 J	mg/kg		
Zinc	7.8 J	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD134F			*DMM*	*12-Oct-09*
2,4-DNT	0.093 J	mg/kg		
HMX	0.069 J	mg/kg		
3,5-Dinitroaniline	0.044 J	µg/L		
Aluminum	17.3 J	mg/kg		
Arsenic Total	14.4	mg/kg		
Barium	0.21 J	mg/kg		
Calcium	169	mg/kg		
Chromium	0.37 J	mg/kg		
Copper	1.1 J	mg/kg		
Iron	4.4 J	mg/kg		
Lead	0.065 J	mg/kg		
Magnesium	357	mg/kg		
Manganese	0.34 J	mg/kg		
Mercury	0.099	mg/kg		
Selenium	0.12 J	mg/kg		
Strontium	0.65 J	mg/kg		
Zinc	4.0 J	mg/kg		
ORD134F DUP			*DMM*	*12-Oct-09*
2,4-DNT	0.096 J	mg/kg		
HMX	0.092 J	mg/kg		
ORD135F			*DMM*	*12-Oct-09*
HMX	0.041 J	mg/kg		
Arsenic Total	14.1	mg/kg		
Barium	0.11 J	mg/kg		
Calcium	136	mg/kg		
Copper	0.23 J	mg/kg		
Magnesium	330	mg/kg		
Mercury	0.057 J	mg/kg		
Selenium	0.11 J	mg/kg		
Strontium	0.55 J	mg/kg		
Vanadium	0.61 J	mg/kg		
Zinc	2.9	mg/kg		
ORD136F			*DMM*	*12-Oct-09*
2,4-DNT	0.037 J	mg/kg		
HMX	0.037 J	mg/kg		
Arsenic Total	19.9	mg/kg		
Barium	0.11 J	mg/kg		
Calcium	94.4	mg/kg		
Copper	0.30 J	mg/kg		
Magnesium	325	mg/kg		
Selenium	0.12 J	mg/kg		
Strontium	0.26 J	mg/kg		
Vanadium	0.66 J	mg/kg		
Zinc	2.8	mg/kg		
ORD137F			*DMM*	*12-Oct-09*
HMX	0.086 J	mg/kg		
Arsenic Total	16.2	mg/kg		
Arsenic Total*	19.7	mg/kg		
Barium	0.12 J	mg/kg		
Calcium	1050 J	mg/kg		
Chromium	0.36 J	mg/kg		
Copper	0.34 J	mg/kg		
Iron	3.0 J	mg/kg		
Magnesium	363	mg/kg		
Manganese	0.21 J	mg/kg		
Mercury	0.051 J	mg/kg		
Selenium	0.15 J	mg/kg		
Strontium	4.6 J	mg/kg		
Zinc	6.5	mg/kg		
ORD138F			*DMM*	*12-Oct-09*
HMX	0.068 J	mg/kg		
Arsenic Total	12.7	mg/kg		
Calcium	104	mg/kg		
Copper	0.28 J	mg/kg		
Magnesium	358	mg/kg		
Manganese	0.10 J	mg/kg		
Mercury	0.078	mg/kg		
Selenium	0.14 J	mg/kg		
Strontium	0.36 J	mg/kg		
Vanadium	0.64 J	mg/kg		
Zinc	2.5	mg/kg		
ORD139F			*DMM*	*12-Oct-09*
2,4-DNT	0.18 J	mg/kg		
HMX	0.42 J	mg/kg		
RDX	1.6 J	mg/kg		
Tetryl	0.85 J	mg/kg		
Arsenic Total	16.1	mg/kg		
Barium	0.14 J	mg/kg		
Calcium	113	mg/kg		
Copper	0.24 J	mg/kg		
Magnesium	332	mg/kg		
Mercury	0.051 J	mg/kg		
Selenium	0.16 J	mg/kg		
Strontium	0.34 J	mg/kg		
Vanadium	0.61 J	mg/kg		
Zinc	3.4	mg/kg		
BIOTA--CRAB				
ORD001C			*NPS8*	*8-Apr-09*
Arsenic Total	37.9	mg/kg		
Chromium	0.50 J	mg/kg		
Copper	3.3	mg/kg		
Mercury	0.055 J	mg/kg		
Selenium	0.29	mg/kg		
Strontium	25.4	mg/kg		
Zinc	39.2	mg/kg		
ORD002C			*WWT10*	*8-Apr-09*
Arsenic Total	35.7 J	mg/kg		
Chromium	0.49 J	mg/kg		
Copper	3.3 J	mg/kg		
Mercury	0.05 J	mg/kg		
Selenium	0.28 J	mg/kg		
Strontium	9.4 J	mg/kg		
Zinc	40.2 J	mg/kg		
ORD003C			*WWT11*	*8-Apr-09*
Arsenic Total	29.7	mg/kg		
Arsenic Total*	30.3	mg/kg		
Arsenic Inorg*	0.007 J4	mg/kg		
Chromium	0.52 J	mg/kg		
Copper	5.3	mg/kg		
Mercury	0.052 J	mg/kg		
Selenium	0.49	mg/kg		
Strontium	5.5	mg/kg		
Zinc	41.9	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD004C			*WWT9*	*8-Apr-09*
Arsenic Total	14.9	mg/kg		
Chromium	0.59 J	mg/kg		
Copper	0.32	mg/kg		
Mercury	0.061 J	mg/kg		
Selenium	0.36	mg/kg		
Strontium	0.86	mg/kg		
Zinc	3.2	mg/kg		
ORD005C			*WWT12*	*8-Apr-09*
1,3,5-TNB	0.067 J	mg/kg		
Arsenic Total	48.2	mg/kg		
Barium	0.11	mg/kg		
Cadmium	0.057 J	mg/kg		
Chromium	0.57 J	mg/kg		
Cobalt	0.015 J	mg/kg		
Copper	11.9	mg/kg		
Mercury	0.058 J	mg/kg		
Selenium	0.48	mg/kg		
Strontium	31.6	mg/kg		
Zinc	52	mg/kg		
ORD006C			*WWT13*	*8-Apr-09*
Arsenic Total	39.4	mg/kg		
Barium	0.18	mg/kg		
Cadmium	0.10	mg/kg		
Chromium	0.57 J	mg/kg		
Cobalt	0.022 J	mg/kg		
Copper	12	mg/kg		
Mercury	0.056 J	mg/kg		
Selenium	0.57	mg/kg		
Strontium	46.1	mg/kg		
Zinc	59.2	mg/kg		
ORD007C			*WWT14*	*8-Apr-09*
Arsenic Total	43.4	mg/kg		
Arsenic Total*	47.3	mg/kg		
Barium	1.6	mg/kg		
Chromium	0.49 J	mg/kg		
Cobalt	0.013 J	mg/kg		
Copper	13.6	mg/kg		
Selenium	0.34	mg/kg		
Strontium	66.5	mg/kg		
Zinc	46.8	mg/kg		
ORD008C			*WWT15*	*8-Apr-09*
Arsenic Total	14.9	mg/kg		
Chromium	0.52 J	mg/kg		
Copper	0.30	mg/kg		
Mercury	0.10 J	mg/kg		
Selenium	0.29	mg/kg		
Strontium	0.36 J	mg/kg		
Zinc	3.6	mg/kg		
ORD009C			*DMM*	*8-Apr-09*
Arsenic Total	45.4	mg/kg		
Cadmium	0.18	mg/kg		
Chromium	0.48 J	mg/kg		
Cobalt	0.021 J	mg/kg		
Copper	8.1	mg/kg		
Mercury	0.057 J	mg/kg		
Selenium	0.37	mg/kg		
Strontium	6.2	mg/kg		
Zinc	43.6	mg/kg		
ORD010C			*DMM*	*8-Apr-09*
Arsenic Total	48.2	mg/kg		
Cadmium	0.14	mg/kg		
Chromium	0.52 J	mg/kg		
Cobalt	0.028 J	mg/kg		
Copper	14.9	mg/kg		
Mercury	0.072 J	mg/kg		
Selenium	0.36	mg/kg		
Strontium	5.0	mg/kg		
Zinc	46.5	mg/kg		
ORD011C			*DMM*	*8-Apr-09*
Arsenic Total	51.2	mg/kg		
Arsenic Total*	53.8	mg/kg		
Arsenic Inorg*	0.004 J 4	mg/kg		
Chromium	0.55 J	mg/kg		
Cobalt	0.011 J	mg/kg		
Copper	6.5	mg/kg		
Mercury	0.14 J	mg/kg		
Selenium	0.28	mg/kg		
Strontium	13.2	mg/kg		
Zinc	44.4	mg/kg		
ORD012C			*DMM*	*8-Apr-09*
Arsenic Total	45.3	mg/kg		
Cadmium	0.13	mg/kg		
Chromium	0.51 J	mg/kg		
Cobalt	0.015 J	mg/kg		
Copper	7.7	mg/kg		
Mercury	0.057 J	mg/kg		
Selenium	0.33	mg/kg		
Strontium	2.7	mg/kg		
Zinc	42.8	mg/kg		
ORD101C			*WWT20*	*25-Sep-09*
Aluminum	9.0	mg/kg		
Arsenic Total	42.2	mg/kg		
Barium	0.15	mg/kg		
Cadmium	0.38	mg/kg		
Calcium	1270 J	mg/kg		
Chromium	0.44	mg/kg		
Cobalt	0.04 J	mg/kg		
Copper	13.0 J	mg/kg		
Iron	12.7	mg/kg		
Magnesium	644	mg/kg		
Manganese	0.13 J	mg/kg		
Selenium	0.37	mg/kg		
Strontium	12.9	mg/kg		
Titanium	1.4	mg/kg		
Zinc	46.2	mg/kg		
ORD102C			*WWT21*	*25-Sep-09*
Aluminum	4.3 J	mg/kg		
Arsenic Total	30.5 J	mg/kg		
Barium	0.15 J	mg/kg		
Calcium	1290 J	mg/kg		
Chromium	0.67 J	mg/kg		
Copper	9.7 J	mg/kg		
Iron	7.6 J	mg/kg		
Magnesium	621 J	mg/kg		
Manganese	0.14 J	mg/kg		
Selenium	0.16 J	mg/kg		
Strontium	14.1 J	mg/kg		
Titanium	1.1 J	mg/kg		
Zinc	45.6 J	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD103C			*WWT22*	*25-Sep-09*
Arsenic Total	34.4	mg/kg		
Arsenic Total*	32.7	mg/kg		
Barium	0.13	mg/kg		
Calcium	1020 J	mg/kg		
Chromium	0.64	mg/kg		
Copper	6.9 J	mg/kg		
Iron	6.3	mg/kg		
Magnesium	546	mg/kg		
Manganese	0.17 J	mg/kg		
Selenium	0.23	mg/kg		
Strontium	10.6	mg/kg		
Titanium	0.98	mg/kg		
Zinc	55.8	mg/kg		
ORD104C			*WWT23*	*25-Sep-09*
Aluminum	6.2	mg/kg		
Arsenic Total	33.6	mg/kg		
Barium	0.12	mg/kg		
Calcium	1060 J	mg/kg		
Chromium	0.64	mg/kg		
Cobalt	0.021 J	mg/kg		
Copper	13.8 J	mg/kg		
Iron	9.9	mg/kg		
Magnesium	739	mg/kg		
Manganese	0.13 J	mg/kg		
Selenium	0.29	mg/kg		
Strontium	11.1	mg/kg		
Titanium	1.2	mg/kg		
Zinc	50.5	mg/kg		
ORD105C			*WWT24*	*25-Sep-09*
Aluminum	4.2 J	mg/kg		
Arsenic Total	52.4	mg/kg		
Barium	0.093 J	mg/kg		
Calcium	862 J	mg/kg		
Chromium	0.71	mg/kg		
Copper	9.7 J	mg/kg		
Iron	7.2	mg/kg		
Magnesium	573	mg/kg		
Manganese	0.16 J	mg/kg		
Mercury	0.077 J	mg/kg		
Selenium	0.32	mg/kg		
Strontium	8.8	mg/kg		
Titanium	1.1	mg/kg		
Zinc	49.4	mg/kg		
ORD106C			*WWT25*	*25-Sep-09*
Aluminum	5.9	mg/kg		
Arsenic Total	31.0	mg/kg		
Barium	0.11	mg/kg		
Cadmium	0.51	mg/kg		
Calcium	1060 J	mg/kg		
Chromium	0.58	mg/kg		
Cobalt	0.036 J	mg/kg		
Copper	7.9 J	mg/kg		
Iron	10.7	mg/kg		
Magnesium	653	mg/kg		
Manganese	0.15 J	mg/kg		
Selenium	0.34	mg/kg		
Strontium	10.8	mg/kg		
Titanium	1.1	mg/kg		
Zinc	51.5	mg/kg		
ORD107C			*WWT26*	*25-Sep-09*
Aluminum	4.6 J	mg/kg		
Arsenic Total	36.1	mg/kg		
Barium	0.11	mg/kg		
Cadmium	0.19	mg/kg		
Calcium	2370 J	mg/kg		
Chromium	0.54	mg/kg		
Cobalt	0.038 J	mg/kg		
Copper	6.3 J	mg/kg		
Iron	8.7	mg/kg		
Lead	2.4	mg/kg		
Magnesium	863	mg/kg		
Manganese	0.13 J	mg/kg		
Selenium	0.22	mg/kg		
Strontium	28.0	mg/kg		
Titanium	1.1	mg/kg		
Zinc	29.8	mg/kg		
ORD108C			*WWT27*	*25-Sep-09*
Aluminum	4.7 J	mg/kg		
Arsenic Total	31.1	mg/kg		
Barium	0.10	mg/kg		
Calcium	782 J	mg/kg		
Chromium	0.62	mg/kg		
Cobalt	0.012 J	mg/kg		
Copper	7.5 J	mg/kg		
Iron	7.5	mg/kg		
Magnesium	586	mg/kg		
Manganese	0.15 J	mg/kg		
Mercury	0.062 J	mg/kg		
Selenium	0.36	mg/kg		
Strontium	8.7	mg/kg		
Titanium	1.1	mg/kg		
Zinc	47.3	mg/kg		
ORD109C			*DMM14*	*25-Sep-09*
Aluminum	11.1	mg/kg		
Arsenic Total	34.9	mg/kg		
Arsenic Total*	34.7	mg/kg		
Arsenic Inorg*	0.007 J4	mg/kg		
Barium	0.14	mg/kg		
Calcium	1030 J	mg/kg		
Chromium	0.71	mg/kg		
Cobalt	0.017 J	mg/kg		
Copper	5.4 J	mg/kg		
Iron	15.1	mg/kg		
Magnesium	618	mg/kg		
Manganese	0.20	mg/kg		
Selenium	0.17 J	mg/kg		
Strontium	10.2	mg/kg		
Titanium	2.0	mg/kg		
Zinc	44.0	mg/kg		
ORD110C			*DMM15*	*25-Sep-09*
Aluminum	7.3	mg/kg		
Arsenic Total	36.8	mg/kg		
Arsenic Total*	37.2	mg/kg		
Barium	0.10	mg/kg		
Calcium	1510 J	mg/kg		
Chromium	0.70	mg/kg		
Cobalt	0.013 J	mg/kg		
Copper	4.8 J	mg/kg		
Iron	11.1	mg/kg		
Magnesium	564	mg/kg		
Manganese	0.19 J	mg/kg		
Selenium	0.35	mg/kg		
Strontium	15.6	mg/kg		
Titanium	1.4	mg/kg		
Zinc	49.3	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD111C			*DMM16*	*25-Sep-09*
Aluminum	5.8	mg/kg		
Arsenic Total	36.7	mg/kg		
Barium	0.11	mg/kg		
Calcium	883 J	mg/kg		
Chromium	0.50	mg/kg		
Cobalt	0.014 J	mg/kg		
Copper	9.1 J	mg/kg		
Iron	9.2	mg/kg		
Magnesium	575	mg/kg		
Manganese	0.17 J	mg/kg		
Selenium	0.32	mg/kg		
Strontium	9.3	mg/kg		
Titanium	1.1	mg/kg		
Zinc	48.7	mg/kg		
ORD112C			*DMM17*	*25-Sep-09*
Aluminum	4.4 J	mg/kg		
Arsenic Total	37.8	mg/kg		
Barium	0.27	mg/kg		
Calcium	835 J	mg/kg		
Chromium	0.60	mg/kg		
Cobalt	0.015 J	mg/kg		
Copper	11.5 J	mg/kg		
Iron	7.0	mg/kg		
Magnesium	590	mg/kg		
Manganese	0.16 J	mg/kg		
Selenium	0.32	mg/kg		
Strontium	8.8	mg/kg		
Titanium	1.0	mg/kg		
Zinc	54.9	mg/kg		
ORD113C			*DMM*	*14-Oct-09*
Aluminum	5.3	mg/kg		
Arsenic Total	36.5	mg/kg		
Barium	0.13	mg/kg		
Calcium	859 J	mg/kg		
Chromium	0.65	mg/kg		
Cobalt	0.013 J	mg/kg		
Copper	13.1 J	mg/kg		
Iron	7.8	mg/kg		
Magnesium	570	mg/kg		
Manganese	0.23	mg/kg		
Selenium	0.24	mg/kg		
Strontium	8.9	mg/kg		
Titanium	1.2	mg/kg		
Zinc	45.4	mg/kg		
ORD114C			*DMM*	*14-Oct-09*
Arsenic Total	27.1	mg/kg		
Barium	0.13	mg/kg		
Cadmium	0.10	mg/kg		
Calcium	883 J	mg/kg		
Chromium	0.51	mg/kg		
Cobalt	0.11	mg/kg		
Copper	6.0 J	mg/kg		
Iron	6.5	mg/kg		
Magnesium	708	mg/kg		
Manganese	0.14 J	mg/kg		
Selenium	0.52	mg/kg		
Strontium	9.6	mg/kg		
Titanium	0.85	mg/kg		
Zinc	40.5	mg/kg		
ORD115C			*DMM*	*14-Oct-09*
Arsenic Total	31.7	mg/kg		
Barium	0.15	mg/kg		
Calcium	1630 J	mg/kg		
Chromium	0.64	mg/kg		
Cobalt	0.014 J	mg/kg		
Copper	16.8 J	mg/kg		
Iron	5.0	mg/kg		
Magnesium	675	mg/kg		
Manganese	0.12 J	mg/kg		
Mercury	0.032 J	mg/kg		
Selenium	0.48	mg/kg		
Strontium	18.6	mg/kg		
Titanium	0.88	mg/kg		
Zinc	48.8	mg/kg		
ORD116C			*DMM*	*14-Oct-09*
Aluminum	11.8	mg/kg		
Arsenic Total	34.9	mg/kg		
Barium	0.12	mg/kg		
Calcium	610 J	mg/kg		
Chromium	0.70	mg/kg		
Cobalt	0.012 J	mg/kg		
Copper	7.8 J	mg/kg		
Iron	5.7	mg/kg		
Magnesium	550	mg/kg		
Manganese	0.16 J	mg/kg		
Mercury	0.060 J	mg/kg		
Selenium	0.31	mg/kg		
Strontium	6.6	mg/kg		
Titanium	1.0	mg/kg		
Zinc	40.5	mg/kg		
BIOTA--SEAWEED (LIMU)				
ORD001L			*WWT4*	*6-Apr-09*
Arsenic Total	0.51	mg/kg		
Barium	0.45	mg/kg		
Chromium	0.56	mg/kg		
Cobalt	0.062 J	mg/kg		
Lead	0.18	mg/kg		
Nickel	0.36	mg/kg		
Strontium	77.8 J	mg/kg		
Vanadium	0.60 J	mg/kg		
Zinc	0.66 J	mg/kg		
ORD002L			*NPS7*	*6-Apr-09*
Barium	0.21 J	mg/kg		
Strontium	7.7 J	mg/kg		
ORD003L			*CON1*	*7-Apr-09*
Arsenic Total	0.55	mg/kg		
Arsenic Total*	1.56	mg/kg		
Arsenic Inorg*	0.832	mg/kg		
Barium	0.57	mg/kg		
Chromium	0.91	mg/kg		
Cobalt	0.14	mg/kg		
Copper	0.38 J	mg/kg		
Lead	0.21	mg/kg		
Nickel	0.74	mg/kg		
Strontium	107 J	mg/kg		
Vanadium	1.5	mg/kg		
Zinc	1.0	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD004L			*CON17*	*8-Apr-09*
Arsenic Total	0.47	mg/kg		
Barium	0.48	mg/kg		
Chromium	0.95	mg/kg		
Cobalt	0.13	mg/kg		
Copper	0.40 J	mg/kg		
Lead	0.23	mg/kg		
Nickel	0.73	mg/kg		
Strontium	36	mg/kg		
Vanadium	1.3	mg/kg		
Zinc	0.84 J	mg/kg		
ORD005L			*CON19*	*9-Apr-09*
Arsenic Total	0.16 J	mg/kg		
Barium	0.41	mg/kg		
Chromium	0.20	mg/kg		
Cobalt	0.036 J	mg/kg		
Nickel	0.19 J	mg/kg		
Strontium	10.9	mg/kg		
Vanadium	0.31 J	mg/kg		
ORD006L			*DMM3*	*9-Apr-09*
Arsenic Total	0.84	mg/kg		
Barium	0.70	mg/kg		
Chromium	0.78	mg/kg		
Cobalt	0.071 J	mg/kg		
Copper	1.2 J	mg/kg		
Lead	0.31	mg/kg		
Nickel	0.48	mg/kg		
Strontium	90.4 J	mg/kg		
Vanadium	1.2	mg/kg		
Zinc	1.3	mg/kg		
ORD007L			*DMM4*	*9-Apr-09*
Arsenic Total	0.88	mg/kg		
Arsenic Total*	1.60	mg/kg		
Arsenic Inorg*	0.890	mg/kg		
Barium	1.0	mg/kg		
Chromium	1.7	mg/kg		
Cobalt	0.11	mg/kg		
Copper	2.8 J	mg/kg		
Lead	0.60	mg/kg		
Nickel	1.0	mg/kg		
Selenium	0.12 J	mg/kg		
Strontium	212 J	mg/kg		
Vanadium	1.6	mg/kg		
Zinc	2.7	mg/kg		
ORD008L			*DMM5*	*9-Apr-09*
Arsenic Total	1.0	mg/kg		
Barium	0.91	mg/kg		
Chromium	1.2	mg/kg		
Cobalt	0.14	mg/kg		
Copper	1.5 J	mg/kg		
Lead	0.52	mg/kg		
Nickel	0.91	mg/kg		
Selenium	0.14 J	mg/kg		
Strontium	201 J	mg/kg		
Vanadium	2.1	mg/kg		
Zinc	2.9	mg/kg		
ORD009L			*CON18*	*13-Apr-09*
Arsenic Total	1.1	mg/kg		
Barium	0.75	mg/kg		
Chromium	1.7	mg/kg		
Cobalt	0.28	mg/kg		
Copper	0.62 J	mg/kg		
Lead	0.38	mg/kg		
Nickel	1.7	mg/kg		
Strontium	152 J	mg/kg		
Vanadium	2.1	mg/kg		
Zinc	1.6	mg/kg		
ORD010L			*CON*	*13-Apr-09*
Arsenic Total	0.26	mg/kg		
Barium	0.33	mg/kg		
Chromium	0.70	mg/kg		
Cobalt	0.061 J	mg/kg		
Lead	0.12	mg/kg		
Mercury	0.031 J	mg/kg		
Nickel	0.45	mg/kg		
Strontium	20.7	mg/kg		
Vanadium	0.48 J	mg/kg		
ORD011L			*DMM8*	*13-Apr-09*
Arsenic Total	0.97	mg/kg		
Barium	0.99	mg/kg		
Chromium	0.97	mg/kg		
Cobalt	0.099 J	mg/kg		
Copper	1.0 J	mg/kg		
Lead	0.31	mg/kg		
Nickel	0.74	mg/kg		
Strontium	108 J	mg/kg		
Vanadium	1.1	mg/kg		
Zinc	1.6	mg/kg		
ORD012L			*WWT10*	*13-Apr-09*
Arsenic Total	0.88	mg/kg		
Barium	1.2	mg/kg		
Chromium	1.8	mg/kg		
Cobalt	0.16	mg/kg		
Copper	0.92 J	mg/kg		
Lead	0.59	mg/kg		
Nickel	1.4	mg/kg		
Selenium	0.30	mg/kg		
Strontium	237 J	mg/kg		
Vanadium	1.9	mg/kg		
Zinc	1.7	mg/kg		
ORD013L			*WWT11*	*13-Apr-09*
Arsenic Total	0.84	mg/kg		
Barium	1.5	mg/kg		
Chromium	2.1	mg/kg		
Cobalt	0.17	mg/kg		
Copper	0.74 J	mg/kg		
Lead	0.58	mg/kg		
Nickel	1.6	mg/kg		
Selenium	0.33	mg/kg		
Strontium	243 J	mg/kg		
Uranium	0.10 J	mg/kg		
Vanadium	1.9	mg/kg		
Zinc	1.6	mg/kg		
ORD014L			*NPS20*	*13-Apr-09*
Arsenic Total	0.86	mg/kg		
Barium	8.0	mg/kg		
Chromium	2.7	mg/kg		
Cobalt	0.42	mg/kg		
Copper	0.99 J	mg/kg		
Lead	0.72	mg/kg		
Nickel	2.5	mg/kg		
Selenium	0.52	mg/kg		
Strontium	445 J	mg/kg		
Uranium	0.21 J	mg/kg		
Vanadium	2.4	mg/kg		
Zinc	0.98 J	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD015L			*NPS21*	*13-Apr-09*
Arsenic Total	1.3	mg/kg		
Barium	3.4	mg/kg		
Chromium	2.1	mg/kg		
Cobalt	0.22	mg/kg		
Copper	0.53 J	mg/kg		
Lead	0.69	mg/kg		
Nickel	1.5	mg/kg		
Selenium	0.91	mg/kg		
Strontium	385 J	mg/kg		
Uranium	0.19 J	mg/kg		
Vanadium	2.2	mg/kg		
Zinc	1.3	mg/kg		
ORD016L			*NPS21*	*13-Apr-09*
Arsenic Total	1.5	mg/kg		
Arsenic Total*	2.23	mg/kg		
Arsenic Inorg*	1.30	mg/kg		
Barium	5.9	mg/kg		
Chromium	2.2	mg/kg		
Cobalt	0.25	mg/kg		
Copper	0.62 J	mg/kg		
Lead	0.72			
Nickel	1.8	mg/kg		
Selenium	0.77	mg/kg		
Strontium	401 J	mg/kg		
Uranium	0.20 J	mg/kg		
Vanadium	2.3	mg/kg		
Zinc	1.2	mg/kg		
ORD017L			*WWT*	*13-Apr-09*
Arsenic Total	1.4	mg/kg		
Barium	1.1	mg/kg		
Chromium	2.0	mg/kg		
Cobalt	0.19	mg/kg		
Copper	1.3 J	mg/kg		
Lead	0.80	mg/kg		
Nickel	1.6	mg/kg		
Selenium	0.44	mg/kg		
Strontium	226 J	mg/kg		
Vanadium	3.0	mg/kg		
Zinc	3.1	mg/kg		
ORD018L			*DMM6*	*13-Apr-09*
Barium	0.43	mg/kg		
Copper	6.4 J	mg/kg		
Strontium	7.2	mg/kg		
Zinc	8.4	mg/kg		
ORD019L			*DMM7*	*13-Apr-09*
Arsenic Total	0.34	mg/kg		
Barium	2.1	mg/kg		
Chromium	1.6	mg/kg		
Cobalt	0.052 J	mg/kg		
Copper	25 J	mg/kg		
Lead	0.44	mg/kg		
Nickel	0.85	mg/kg		
Strontium	78.8 J	mg/kg		
Vanadium	0.46 J	mg/kg		
Zinc	263	mg/kg		
ORD101L			*NPS32*	*22-Sep-09*
Aluminum	248 J	mg/kg		
Arsenic Total	0.47 J	mg/kg		
Barium	1.3 J	mg/kg		
Calcium	19200 J	mg/kg		
Chromium	1.6 J	mg/kg		
Cobalt	0.19 J	mg/kg		
Copper	0.63 J	mg/kg		
Iron	409 J	mg/kg		
Lead	1.1 J	mg/kg		
Magnesium	2370 J	mg/kg		
Nickel	0.78 J	mg/kg		
Selenium	0.22 J	mg/kg		
Strontium	202 J	mg/kg		
Titanium	33.3. J	mg/kg		
Uranium	0.17 J	mg/kg		
Vanadium	6.6 J	mg/kg		
ORD102L			*CON*	*29-Sep-09*
Aluminum	48.6 J	mg/kg		
Arsenic Total	0.57	mg/kg		
Arsenic Total*	1.16	mg/kg		
Arsenic Inorg*	0.108	mg/kg		
Barium	0.26	mg/kg		
Calcium	1350 J	mg/kg		
Chromium	0.42	mg/kg		
Cobalt	0.027 J	mg/kg		
Copper	0.16 J	mg/kg		
Iron	76.9	mg/kg		
Lead	0.21	mg/kg		
Magnesium	432 J	mg/kg		
Nickel	0.17 J	mg/kg		
Strontium	13.2	mg/kg		
Titanium	6.8	mg/kg		
Vanadium	0.33 J	mg/kg		
ORD103L			*DMM*	*12-Oct-09*
Aluminum	156 J	mg/kg		
Arsenic Total	0.80	mg/kg		
Barium	0.88	mg/kg		
Calcium	21300 J	mg/kg		
Chromium	1.2	mg/kg		
Cobalt	0.11	mg/kg		
Copper	0.74	mg/kg		
Iron	311	mg/kg		
Lead	0.54	mg/kg		
Magnesium	1310 J	mg/kg		
Nickel	0.50	mg/kg		
Strontium	177 J	mg/kg		
Titanium	24.3	mg/kg		
Vanadium	1.3	mg/kg		
ORD104L			*DMM*	*12-Oct-09*
Aluminum	182 J	mg/kg		
Arsenic Total	1.2	mg/kg		
Arsenic Total*	1.77	mg/kg		
Arsenic Inorg*	0.644	mg/kg		
Barium	2.1	mg/kg		
Calcium	32200 J	mg/kg		
Chromium	1.5	mg/kg		
Cobalt	0.15	mg/kg		
Copper	0.87	mg/kg		
Iron	380	mg/kg		
Lead	0.69	mg/kg		
Magnesium	2060 J	mg/kg		
Manganese	4.8 J	mg/kg		
Nickel	0.82	mg/kg		
Strontium	280 J	mg/kg		
Titanium	31.3	mg/kg		
Uranium	0.11 J	mg/kg		
Vanadium	3.0	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD105L			*DMM*	*12-Oct-09*
Aluminum	123	mg/kg		
Arsenic Total	0.61	mg/kg		
Arsenic Total*	1.29	mg/kg		
Arsenic Inorg*	0.329	mg/kg		
Barium	1.1	mg/kg		
Calcium	22300 J	mg/kg		
Chromium	1.1	mg/kg		
Cobalt	0.10	mg/kg		
Copper	0.62	mg/kg		
Iron	245	mg/kg		
Lead	0.44	mg/kg		
Magnesium	1600 J	mg/kg		
Mercury	0.028 J	mg/kg		
Nickel	0.48	mg/kg		
Strontium	204 J	mg/kg		
Titanium	21.0	mg/kg		
Vanadium	1.5	mg/kg		
ORD107L			*WWT*	*14-Oct-09*
Aluminum	196 J	mg/kg		
Arsenic Total	0.84	mg/kg		
Barium	2.2	mg/kg		
Calcium	18500 J	mg/kg		
Chromium	1.4	mg/kg		
Cobalt	0.13	mg/kg		
Copper	0.58	mg/kg		
Iron	303	mg/kg		
Lead	0.52	mg/kg		
Magnesium	2510 J	mg/kg		
Nickel	0.70	mg/kg		
Strontium	175 J	mg/kg		
Titanium	28.0	mg/kg		
Vanadium	2.6	mg/kg		
ORD108L			*WWT*	*14-Oct-09*
Aluminum	141 J	mg/kg		
Arsenic Total	1.1	mg/kg		
Barium	0.67	mg/kg		
Calcium	16400 J	mg/kg		
Chromium	0.78	mg/kg		
Cobalt	0.090 J	mg/kg		
Copper	0.45	mg/kg		
Iron	238	mg/kg		
Lead	0.34	mg/kg		
Magnesium	1730 J	mg/kg		
Nickel	0.61	mg/kg		
Strontium	133 J	mg/kg		
Titanium	20.2	mg/kg		
Vanadium	1.6	mg/kg		
ORD109L			*WWT*	*14-Oct-09*
Aluminum	239 J	mg/kg		
Arsenic Total	0.81	mg/kg		
Barium	0.99	mg/kg		
Calcium	32200 J	mg/kg		
Chromium	1.7	mg/kg		
Cobalt	0.17	mg/kg		
Copper	0.71	mg/kg		
Iron	389	mg/kg		
Lead	0.53	mg/kg		
Magnesium	2510 J	mg/kg		
Manganese	3.6	mg/kg		
Nickel	0.73	mg/kg		
Strontium	252 J	mg/kg		
Titanium	35.7	mg/kg		
Vanadium	2.6	mg/kg		
ORD110L			*DMM*	*14-Oct-09*
Aluminum	133 J	mg/kg		
Arsenic Total	0.99	mg/kg		
Barium	1.0	mg/kg		
Calcium	10600 J	mg/kg		
Chromium	1.1	mg/kg		
Cobalt	0.085 J	mg/kg		
Copper	1.4	mg/kg		
Iron	245	mg/kg		
Lead	0.60	mg/kg		
Magnesium	1950 J	mg/kg		
Nickel	0.48	mg/kg		
Selenium	0.12 J	mg/kg		
Strontium	114 J	mg/kg		
Titanium	19.4	mg/kg		
Vanadium	1.0	mg/kg		
ORD111L			*unknown*	*14-Oct-09*
Aluminum	191 J	mg/kg		
Arsenic Total	1.2	mg/kg		
Barium	0.67	mg/kg		
Calcium	11400 J	mg/kg		
Chromium	1.1	mg/kg		
Cobalt	0.10	mg/kg		
Copper	0.65	mg/kg		
Iron	316	mg/kg		
Lead	0.49	mg/kg		
Magnesium	1770 J	mg/kg		
Nickel	0.68	mg/kg		
Strontium	108 J	mg/kg		
Titanium	26.3	mg/kg		
Vanadium	1.9	mg/kg		
ORD112L			*NPS1*	*27-Oct-09*
Arsenic Total	1.2	mg/kg		
Arsenic Total*	1.72	mg/kg		
Arsenic Inorg*	0.141	mg/kg		
Barium	0.54	mg/kg		
Calcium	880 J	mg/kg		
Chromium	0.30	mg/kg		
Cobalt	0.016 J	mg/kg		
Copper	0.20	mg/kg		
Iron	20.5	mg/kg		
Lead	0.15	mg/kg		
Magnesium	711 J	mg/kg		
Nickel	0.26	mg/kg		
Strontium	9.5	mg/kg		
Titanium	1.4	mg/kg		
Vanadium	0.37 J	mg/kg		
ORD113L			*NPS2*	*27-Oct-09*
Arsenic Total	1.2	mg/kg		
Barium	0.36	mg/kg		
Calcium	730 J	mg/kg		
Chromium	0.31	mg/kg		
Cobalt	0.014 J	mg/kg		
Copper	0.17 J	mg/kg		
Iron	17.0	mg/kg		
Lead	0.14	mg/kg		
Magnesium	655 J	mg/kg		
Nickel	0.43	mg/kg		
Strontium	8.2	mg/kg		
Titanium	0.90	mg/kg		
Vanadium	0.36 J	mg/kg		

TABLE 4-4: DETECTION SUMMARY FOR SEAWATER, SEDIMENT, AND BIOTA PHTHALATES AND PYRENE, ENERGETICS, AND METALS (BIOTA METALS ONLY)

Analyte	Result	Units	Location	Sampling Date
ORD114L			*NPS3*	*27-Oct-09*
Arsenic Total	1.0	mg/kg		
Arsenic Total*	1.27	mg/kg		
Arsenic Inorg*	0.078	mg/kg		
Barium	0.32	mg/kg		
Calcium	829 J	mg/kg		
Chromium	0.30	mg/kg		
Cobalt	0.012 J	mg/kg		
Copper	0.15 J	mg/kg		
Iron	18.7	mg/kg		
Lead	0.19	mg/kg		
Magnesium	659 J	mg/kg		
Nickel	0.33	mg/kg		
Strontium	9.4	mg/kg		
Titanium	1.1	mg/kg		
ORD115L			*NPS4*	*27-Oct-09*
Arsenic Total	1.1	mg/kg		
Barium	0.22	mg/kg		
Calcium	1110 J	mg/kg		
Chromium	0.32	mg/kg		
Cobalt	0.012 J	mg/kg		
Copper	0.15 J	mg/kg		
Iron	15.0	mg/kg		
Lead	0.17	mg/kg		
Magnesium	751 J	mg/kg		
Nickel	0.29	mg/kg		
Strontium	10.7	mg/kg		
Titanium	0.75	mg/kg		
Vanadium	0.34 J	mg/kg		
ORD116L			*CON*	*27-Oct-09*
Aluminum	41.1 J	mg/kg		
Arsenic Total	1.3	mg/kg		
Barium	1.6	mg/kg		
Calcium	1170 J	mg/kg		
Chromium	0.40	mg/kg		
Cobalt	0.034 J	mg/kg		
Copper	0.26	mg/kg		
Iron	66.4	mg/kg		
Lead	0.38	mg/kg		
Magnesium	639 J	mg/kg		
Nickel	0.31	mg/kg		
Strontium	12.2	mg/kg		
Titanium	4.7	mg/kg		
Vanadium	0.45 J	mg/kg		
ORD117L			*CON*	*27-Oct-09*
Aluminum	56.2 J	mg/kg		
Arsenic Total	1.2	mg/kg		
Barium	0.77	mg/kg		
Calcium	2070 J	mg/kg		
Chromium	0.46	mg/kg		
Cobalt	0.046 J	mg/kg		
Copper	0.26	mg/kg		
Iron	89.4	mg/kg		
Lead	0.52	mg/kg		
Magnesium	774 J	mg/kg		
Nickel	0.35	mg/kg		
Strontium	20.3	mg/kg		
Titanium	6.6	mg/kg		
Vanadium	0.58 J	mg/kg		

Note:

*: the data come from Brooks Rand other than TestAmerica; the corresponding qualifiers come from the lab (Brooks Rand) other than the validator

[1] The analytical results presented in the laboratory reports differed from the validation reports (i.e., results were ND in the laboratory reports). The results from the validation reports are presented in this table.

[2] The analytical result is an estimated value (J-flagged) even though the result exceeds the reporting limit, because the matrix spike recovery was outside of the specified window.

[3] The qualifier is shown as "J" in this table for consistency, although it was presented as "B" in the validation report. The qualifier "B" is defined by the laboratory as an indication that the result is between the method detection limit (MDL) and the reporting limit, therefore is an estimated value; which is the same as a "J" qualifier by the validator.

[4] The qualifier is shown as "J" in this table for consistency, although it was presented as "B" in the laboratory report (note: these results were not validated, thus they had not been provided validation qualifiers). The qualifier "B" is defined by the laboratory as an indication that the result is between the MDL and the reporting limit, therefore is an estimated value.

DNT = dinitrotoluene
HMX = high melting explosive (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine);
TNB = trinitrobenzene
µg/L = micrograms per liter
mg/kg = milligrams per kilogram

J = Estimated value. The analytical result is higher than the MDL but lower than the reporting limit.
bold = result is above the screening level
Compiled sediment metal results are provided in Table 4-5.

TABLE 4-5: COMPILED SEDIMENT METAL RESULTS

Field Sample ID	Site label	Type	Sample Lab IDs	ICP MS Run on	51V	53Cr	59Co	60Ni	63Cu	65Cu	Cu (average)	66Zn	68Zn	Zn (average)	75As	111Cd	136Ba	137Ba	Ba (average)	206Pb	207Pb	208Pb	Pb (average)	238U
				Unit:	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
				Analytical Method:	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS
				Screening Level:	NA	37.3	NA	15.9	NA	NA	18.7	NA	NA	123	7.24	0.6	NA	NA	NA	NA	NA	NA	30.2	NA
First Round Sampling, April 2009																								
CON 2 - S022	CON 2	CON	OR1 46-1 / OR1 46-2		41.6	43.8	8.7	48.2	7.2[a]	10.1	8.6	26.5[a]	24.1[a]	25.3	16.9	ND	17.7	17.9	17.8	4.8[a]	5.0[a]	4.9[a]	4.9	1.1
CON 3 - S023	CON 3	CON	OR1 52-4 / OR1 52-5		50.9	79.2	16.9	86.2	11.5	17.2	14.3	36.8	29.6	33.2	20.2	0.1	22.3	22.4	22.3	8.8	8.9	9[a]	8.9	1.1
CON 4 - S024	CON 4	CON	53-1 / 53-2		75.0	112.9	18.6	103.3	14.0	17.3	15.7	34.1	30.3	32.2	17.2	0.4	23.9	24.0	23.9	8.1	8.3	8.0	8.1	1.5
CON 5 - S025	CON 5	CON	31-13/ 31-14		59.5	91.1	18.9	125.0	12.7	18.1	15.4	39.5	32.4	35.9	16.8	ND	18.6	18.7	18.7	2.6	2.9	2.7[a]	2.7	0.4
CON 6 - S026	CON 6	CON	29-7 / 29-8		50.7	91.1	18.0	98.6	12.5	18.9	15.7	40.3	31.2	35.8	19.1	ND[a]	20.4	20.7	20.5	25.4[a]	25.8[a]	25.8[a]	25.7	1.4
CON 7 - S027	CON 7	CON	53-4 / 53-5		53.9	83.3	17.5	87.9	14.0	20.1	17.1	40.7	32.8	36.7	20.1	ND[a]	22.9	22.7	22.8	6.8	7.1	6.9	6.9	1.3
CON 8 - S028	CON 8	CON	50-4 / 50-5		48.3[a]	65.5[a]	11.6	61.0	13.0	18.2	16.4	49.0	43.5[a]	46.2	17.1	ND	20.5	20.9	20.7	24.5[a]	24.9[a]	24.8[a]	24.7	1.8[a]
CON 9 - S029	CON 9	CON	47-7 / 47-8		39.5	60.1	13.2	67.0	2.1[a]	18.5	18.1	32.9	26.3	29.6	16.2	0.1[a]	17.7[a]	17.6	17.7	4.9	5.0	4.9	4.9	1.6
CON 10 - S030	CON 10	CON	29-1 / 29-2		28.4	42.6	10.1	56.2	8.0	12.2	10.1	28.3	24.6	26.4	13.6	ND	12.2	12.2	12.2	4.3	4.4	4.3	4.3	1.5[a]
CON 11 - S031	CON 11	CON	51-5 / 51-6		39.9	47.8	11.1	57.1	10.8	15.9	14.5	32.5	27.4	29.9	16.5	ND	19.4	19.5[a]	19.4	11.1	11.3	11.3	11.2	1.4
CON 12 - S032	CON 12	CON	31-1 / 31-2	HUM 09-09D / OR 1-10C	69.8	99.5	17.4	87.6	22.4	26.3	24.3	53.4	45.0	49.2	14.2	ND	22.7	23.7	23.2	50.7	137.5	134.6	136.0	0.6
CON 13 - S033	CON 13	CON	49-4 / 49-5		36.5	50.2	11.5	82.3	11.4	15.6	13.5	28.2	24.3	26.3	15.9	ND	12.5	13.2	12.8	15.7[a]	16.1[a]	15.9[a]	15.9	0.4
Avg					49.5	72.3	14.5	80.0	11.6	17.4	15.3	36.9	31.0	33.9	17.0	0.0	19.2	19.4	19.3	14.0	21.4	21.1	21.2	1.2
Std Dev					13.7	23.8	3.8	22.8	4.8	4.0	3.9	8.3	6.9	7.6	2.0	0.1	3.8	3.8	3.8	13.8	37.4	36.6	37.0	0.5
DMM 1 - S019	DMM 1	DMM	49-1 / 49-2		8.8	14.0	3.3	45.5	1446.2[a]	1437.9[a]	1442.1	214.5[a]	195.1[a]	204.8	4.0	ND	3.8	5.7	4.7	17.4	29.3	29.2	29.2	0.2[a]
DMM 1 - S020	DMM 1	DMM	50-1 / 50-2	OR 12-09A / OR 10-09B	10.1	14.4	2.2	25.0	921.7[a]	731.1[a]	826.4	184.7[a]	183.5[a]	184.1	5.8	ND	6.8	7.0	6.9	95.0	97.1	46.0	95.7	0.9[a]
DMM 1 - S021	DMM 1	DMM	38-4 / 38-5		11.2	17.5	4.0	42.4	692.7[a]	803.6[a]	748.1	220.2[a]	205.1[a]	212.6	6.3	ND[a]	4.8	5.0	4.9	546.3[a]	555.8[a]	545.8[a]	549.3	1.0[a]
DMM 2 - S022	DMM 2	DMM	47-1 / 47-2		8.2[a]	13.1[a]	2.5	30.0	105.9[a]	115.2[a]	110.5	117.9[a]	113.6[a]	115.8	3.1[a]	ND	4.3	4.3[a]	4.3	9.5	9.7	8.9	9.7	0.4[a]
DMM 2 - S023	DMM 2	DMM	48-1 / 48-2		7.0	9.9	3.4	27.7	149.0	147.8	148.4	135.4	125.8	130.6	2.2	0.2	3.0	4.7	3.9	11.1	11.8	11.9	11.9	1.0
DMM 2 - S024	DMM 2	DMM	45-3 / 45-4		7.5	26.0	4.4	52.6	316.3[a]	310.0[a]	313.1	147.1[a]	134.8[a]	141.0	3.2	ND[a]	2.7	3.8	3.2	9.4	9.6	9.4	9.5	ND[a]
DMM 3 - S034A	DMM 3	DMM	40-4 / 40-5	OR 2-10A / OR 11-09A	9.0	11.9	3.1	29.3	610.5[a]	591.1[a]	600.8	226.6[a]	205.9[a]	216.2	3.9	0.1	0.6	4.3	2.5	0.8	6.4	6.4	6.4	0.9
DMM 3 - S034B	DMM 3	DMM	48-4 / 48-5	OR 1-10B / OR 10-09E	7.0	10.2	2.2	26.2	175.5[a]	181.0[a]	178.3	240.2[a]	228.8[a]	234.5	4.2[a]	ND[a]	3.7[a]	3.8[a]	3.8	8.0[a]	8.3[a]	8.0[a]	8.1	0.6[a]
DMM 3 - S035	DMM 3	DMM	47-4 / 47-5		8.7[a]	10.7[a]	2.7	30.7	256.5[a]	252.6[a]	254.6	255.6[a]	234.5[a]	245.1	5.2	0.7[a]	3.8	4.0[a]	3.9	88.2[a]	93.7[a]	90.0[a]	90.6	0.2[a]
DMM 4 - S036	DMM 4	DMM	40-1 / 40-2		8.5	11.2	2.5	25.5	291.4[a]	292.5[a]	291.9	220.1[a]	200.0[a]	210.1	5.9	0.2	1.9	5.3	3.6	2.4[a]	12.7[a]	12.7[a]	12.7	0.9
DMM 4 - S037	DMM 4	DMM	52-1 / 52-2		9.0	11.2	5.0	58.5	135.5[a]	138.5[a]	137.0	147.6[a]	134.2[a]	140.9	4.4	ND	2.5	3.8	3.2	19.0	18.7	18.4	18.7	ND[a]
DMM 4 - S038	DMM 4	DMM	43-7 / 43-8		9.3	11.8	2.8	51.6	328.2[a]	329.4[a]	328.8	417.6[a]	397.6[a]	407.6	5.1	ND	13.6	14.8	14.2	192.9	200.9	196.8[a]	196.8	ND
DMM 6 4/13	DMM 6	DMM	49-7 / 49-8		9.5	17.5	2.5	28.0	1.9	4.0	3.0	19.6	20.1	19.9	5.3	ND	5.2	5.4	5.3	1.7	1.8	1.6	1.7	0.8[a]
DMM 6 #2	DMM 6	DMM	45-6 / 45-7		7.9	17.0	4.4	38.8	2.3	5.7	4.0	14.2	13.6	13.9	4.6	ND	4.4	4.6	4.5	1.7	1.8	1.7	1.7	1.0[a]
DMM 6 - S003	DMM 6	DMM	38-7 / 38-8		7.9	18.7	4.2	62.9	2.0	5.0	3.5	12.3	13.0	12.6	4.0	ND[a]	1.3	2.3	1.8	12.0[a]	12.4[a]	12.3[a]	12.2	ND
Avg					8.6	14.3	3.3	38.3	362.4	356.4	359.4	171.6	160.4	166.0	4.5	0.0	4.2	5.3	4.7	67.7	71.3	66.6	70.3	0.5
Std Dev					1.1	4.4	0.9	13.0	402.2	390.4	395.2	107.1	100.5	103.8	1.1	0.2	3.0	2.8	2.9	142.7	144.7	142.0	142.9	0.4
NPS 1 - S013	NPS 1	NPS	51-3 / 51-4		12.7	30.0	5.8	58.3	0.1	1.5	1.5	4.2	3.6	3.9	5.3	ND	3.6	5.3	4.5	3.7	3.8	3.8	3.8	1.1[a]
NPS 2 - S014	NPS 2	NPS	46-4 / 46-5		10.3	22.7	5.1	55.5	0.1	1.7	1.7	2.6	0.2	1.4	4.8	ND	2.9	4.5	3.7	4.1	4.1	4.2	4.1	1.1
NPS 3 - S015	NPS 3	NPS	39-4 / 39-5		9.8	24.3	4.6	65.0	1.3	4.6	3.0	17.0	16.8	16.9	4.7	ND	3.7	4.5	4.1	9.3	9.7	9.4	9.5	0.6
NPS 4 - S016	NPS 4	NPS	39-1 / 39-2		10.8	26.6	4.5	50.3	ND	1.4[a]	1.4	6.6	6.1	6.4	6.3	ND	4.3	5.9	5.1	1.1	1.1	1.4[a]	1.2	1.1[a]
NPS 5 - S017	NPS 5	NPS	31-16 / 31-17		9.4	17.3	4.7	50.2	0.8	3.6	2.2	9.9[a]	9.3[a]	9.6	5.6	ND	4.6	5.0	4.8	1.8	2.0	1.9	1.9	0.5
NPS 6 - S018	NPS 6	NPS	45-1 / 45-2		8.9	16.7	7.7	59.8	1.2	4.4	2.8	11.1[a]	10.0[a]	10.5	4.8	ND	6.3	6.3	6.3	3.2[a]	3.3[a]	0.3[a]	3.2	0.2
NPS 9	NPS 9	NPS	51-1 / 51-2		13.5	20.5	3.5	29.2	2.0	4.0	3.0	15.9	16.2	16.0	8.1	ND	7.4	7.6	7.5	5.3	5.4	5.2	5.3	1.5
NPS 10	NPS 10	NPS	31-4 /31-5		16.0[a]	15.6	8.8	53.3	1.9	5.1	3.5	18.0[a]	17.2[a]	17.6	6.5	ND	11.3	11.3	11.3	3.7	3.8	3.4[a]	3.6	0.1[a]
NPS 11	NPS 11	NPS	31-7 / 31-8		13.9	24.6	10.8	62.9	2.5	5.8	4.2	12.8[a]	11.7[a]	12.3	6.8	0.1[a]	8.3	8.3	8.3	3.6	3.8	3.5[a]	3.6	0.1
NPS 12	NPS 12	NPS	31-10 / 31-11		10.0	17.9	4.8	63.6	1.2	4.5	2.9	18.7	18.2	18.4	5.6	ND	3.3	4.0	3.7	3.5	3.8	3.7	3.7	0.3
NPS 13	NPS 13	NPS	29-4 / 29-5		5.8	12.4	3.3	55.6	1.7	4.5	3.1	15.2[a]	15.1[a]	15.2	1.9	ND	2.1	2.9	2.5	9.6[a]	9.9[a]	9.7[a]	9.7	ND
NPS 14	NPS 14	NPS	27-13 / 27-14		11.0	17.7	4.6	51.8	0.1	0.8	0.7	2.8	2.1	0.1	4.6	ND	1.8	3.6	2.7	2.7	2.8	2.9	2.8	0.7
Avg					11.0	20.5	5.7	54.6	1.1	3.5	2.5	11.2	10.6	10.7	5.4	0.0	5.0	5.8	5.4	4.3	4.5	4.1	4.4	0.6
Std Dev					2.7	5.2	2.3	9.5	0.9	1.7	1.0	6.0	6.4	6.5	1.5	0.0	2.8	2.3	2.6	2.6	2.7	2.9	2.7	0.5
WWT 1 - S001	WWT 1	WWT	44-1 / 44-2		36.2	71.9	11.6	105.2	32.8[a]	36.0	34.4	41.8[a]	37.4[a]	39.6	3.2	ND	24.1	25.4	24.7	6.9	7.1	7.1	7.0	0.3[a]
WWT 1 - S002	WWT 1	WWT	27-4 / 27-5		22.3	45.2	6.8	59.9	18.2	20.4	19.3	29.4	27.9	28.7	3.5	ND	18.0	18.1	18.0	2.6	2.7	2.5	2.6	1.0
WWT 1 -S003	WWT 1	WWT	44-5 / 44-6		27.0	47.0	9.8	80.9	86.5	104.4	95.4	31.1	27.5	29.3	3.0	ND	19.6	19.9	19.7	1.4	2.2	2.0[a]	2.1	0.9
WWT 2 - S004	WWT 2	WWT	27-10 / 27-11		13.6	26.5	4.0	39.5	9.3	7.2	9.8	18.6	16.2	17.4	1.7	ND	4.1	7.1	5.6	2.7	4.4	4.4	4.4	1.0
WWT 2 - S005	WWT 2	WWT	27-1 / 27-2		14.6	26.7	5.1	68.7	11.3	14.4	12.8	45.4	43.1	44.3	1.8	ND[a]	7.2	7.0	7.1	108.8	111.6	108.7	109.7	0.2[a]
WWT 2 - S006	WWT 2	WWT	41-7 / 41-8		12.4[a]	25.5[a]	3.3[a]	30.9[a]	6.2	8.1	7.2	44.6	44.4	44.5	3.2	ND	6.8	6.8	6.8	18.1	18.4	18.0	18.2	1.5
WWT 3 - S007	WWT 3	WWT	38-1 /38-2		20.6	41.4	11.4	76.8	15.7	19.3	17.5	29.5	26.3	27.9	1.9	0.1	14.3	14.5	14.4	66.9[a]	67.8[a]	66.3[a]	67.0	0.1
WWT 3 - S008	WWT 3	WWT	41-4 /41-5		15.0	28.3	4.0	33.2	13.2	15.0	14.1	26.0	25.3	25.7	2.4	ND	9.5	9.5	9.5	4.7	4.9	4.8	4.8	1.6
WWT 3 - S009	WWT 3	WWT	41-1 /41-2		13.4	41.2	5.3	59.0	1.7[a]	4.5	3.1	7.0	5.6	6.3	1.4	ND	4.1	5.6	4.9	3.2	3.2	3.4	3.3	0.7[a]
WWT 5 - S010	WWT 5	WWT	43-1 / 43-2		11.8	34.7	3.1	27.3	2.7	4.5	3.6	15.3	16.1	15.7	4.7	ND	8.3	8.3	8.3	7.7	7.9[a]	7.7[a]	7.8	1.5
WWT 5 - S011	WWT 5	WWT	43-4 / 43-4		12.0	28.3	7.2	61.4	2.4	5.7	4.0	10.7	9.0	9.9	3.4	ND	9.0	8.9[a]	9.0	1.2	1.2	0.1	0.5	0.9
WWT 5 - S012	WWT 5	WWT	27-7 / 27-8		12.0	38.3	6.2	48.7[a]	3.0	6.5[a]	4.7	13.4	12.1	12.7	3.5	ND	8.3	8.4	8.3	1.1	1.2	0.3	1.2	1.2
Avg					17.6	37.9	6.5	57.6	16.9	20.5	18.8	26.1	24.3	25.2	2.8	0.0	11.1	11.6	11.4	18.8	19.4	18.8	19.0	0.9
Std Dev					7.6	13.2	3.0	23.3	23.7	28.0	25.7	13.3	12.9	13.1	1.0	0.0	6.4	6.3	6.4	33.8	34.4	33.7	33.9	0.5
Second Round Sampling, Sept 2009																								
CON 32 - S013	CON32	CON	89-36 / 89-17		25.5[a]	48.5	6.1	40.1	4.6	6.7	5.6	9.8	7.3	8.5	11.4	ND	7.2	8.5	7.9	7.3	14.5[a]	14.6[a]	14.5	1.4
CON 33 - S014	CON33	CON	89-23 / 90-12		33.0	80.7	8.7	48.4[a]	3.8	0.9	3.8	17.5[a]	18.8[a]	18.1	8.9	ND	12.1	11.7	11.9	21.4	21.7	21.6	21.6	1.4
CON34-S015	CON34	CON	90-19 / 90-11		33.7	43.3[a]	6.8	26.2[a]	5.5	ND	5.5	17.9[a]	16.4[a]	17.1	17.0	ND[a]	12.1	12.1	12.1	8.5	8.7	8.6	8.6	1.5
CON34-S016	CON34	CON	89-21 / 90-10		13.2	20.3	4.6	39.6	3.0	0.6	3.0	14.8	14.0	14.4	3.4	ND	6.5	6.8	6.7	12.9	13.0	13.0	13.0	1.0
CON35-S025	CON35	CON	89-39 / 90-7		6.1	11.1	4.2	32.3	2.5	5.4	4.0	12.6	12.4	12.5	1.1[a]	0.1	5.0	5.6	5.3	5.4[a]	5.4	5.4	5.4	1.4
Avg					22.3	40.8	6.1	37.3	3.9	2.7	4.4	14.5	13.8	14.1	8.3	0.0	8.6	8.9	8.8	11.1	12.7	12.6	12.6	1.3
Std Dev					12.2	27.2	1.8	8.4	1.2	3.1	1.1	3.4	4.4	3.8	6.3	0.0	3.3	2.9	3.1	6.4	6.2	6.2	6.2	0.2

Field Sample ID	Al (ppm)	Al %	Ca (ppm)	Ca %	Fe (ppm)	Fe %	Mg (ppm)	Mg %	Mn (ppm)	Sr (ppm)	Ti (ppm)
First Round Sampling, April 2009											
CON 2 - S022	9461.8	0.95	322635.4	32.3	11988.7	1.20	21800.3	2.18	189.1	2839.5	1902.8
CON 3 - S023	13724.3	1.37	301884.2	30.2	19358.0	1.94	24693.2	2.47	265.4	2904.2	2989.9
CON 4 - S024	14584.1	1.46	293255.7	29.3	22244.9	2.22	26519.9	2.65	289.8	2923.0	3476.7
CON 5 - S025	13189.1	1.32	304026.7	30.4	19204.5	1.92	24712.9	2.47	247.7	2970.3	2943.9
CON 6 - S026	13484.0	1.35	291649.1	29.2	19586.9	1.96	24944.3	2.49	246.4	2971.0	3026.5
CON 7 - S027	15141.1	1.51	294932.7	29.5	21621.0	2.16	25236.5	2.52	282.6	2946.1	3395.1
CON 8 - S028	14517.8	1.45	313910.7	31.4	16430.7	1.64	16480.6	1.65	197.8	3984.2	2593.1
CON 9 - S029	12500.6	1.25	293753.7	29.4	14878.4	1.49	16612.2	1.66	197.4	3775.0	2388.6
CON 10 - S030	7894.6	0.79	259115.1	25.9	7888.7	0.79	16311.1	1.63	159.4	3303.3	1503.8
CON 11 - S031	14715.7	1.47	307386.0	30.7	16382.9	1.64	15903.1	1.59	191.6	3924.3	2617.9
CON 12 - S032	10285.7	1.03	279881.0	28.0	11848.9	1.18	17940.9	1.79	159.0	3521.9	1933.8
CON 13 - S033	10169.4	1.02	320971.0	32.1	12153.6	1.22	17995.7	1.80	178.8	3669.4	1838.8
Avg	12472.4	1.25	298616.8	29.9	16132.3	1.61	20762.6	2.08	217.1	3311.0	2550.9
Std Dev	2412.2	0.24	17718.2	1.8	4475.1	0.45	4236.1	0.42	46.8	439.1	645.3
DMM 1 - S019	955.3	0.10	330027.5	33.0	2743.3	0.27	25211.4	2.52	26.8	2461.4	296.0
DMM 1 - S020	875.5	0.09	317646.0	31.8	2443.0	0.24	25289.2	2.53	26.1	2418.9	309.2
DMM 1 - S021	1464.3	0.15	334009.2	33.4	2909.2	0.29	24565.7	2.46	31.4	2601.8	388.9
DMM 2 - S022	711.0	0.07	324265.6	32.4	1931.7	0.19	17887.8	1.79	21.9	2739.5	226.1
DMM 2 - S023	734.4	0.07	339033.7	33.9	2079.9	0.21	21419.9	2.14	17.9	2595.7	210.5
DMM 2 - S024	616.2	0.06	287468.4	28.7	1742.8	0.17	15266.3	1.53	20.9	2280.0	266.5
DMM 3 - S034A	1067.0	0.11	323899.6	32.4	3143.7	0.31	20951.6	2.10	22.6	2590.8	270.3
DMM 3 - S034B	675.9	0.07	271422.6	27.1	2199.7	0.22	20439.1	2.04	26.3	2463.7	250.6
DMM 3 - S035	1018.7	0.10	319586.7	32.0	2629.7	0.26	21286.7	2.13	21.9	2346.6	253.4
DMM 4 - S036	922.4	0.09	325776.1	32.6	4713.6	0.47	19187.8	1.92	24.5	2755.4	277.5
DMM 4 - S037	1240.6	0.12	367642.1	36.8	3209.6	0.32	21288.3	2.13	26.4	2686.5	255.3
DMM 4 - S038	1149.9	0.11	342358.3	34.2	4159.0	0.42	19271.4	1.93	25.4	2813.9	281.2
DMM 6 4/13	1143.9	0.11	339431.8	33.9	2076.0	0.21	18668.8	1.87	31.5	3106.0	327.7
DMM 6 #2	972.5	0.10	316838.0	31.7	1720.3	0.17	19670.0	1.97	27.7	2869.9	322.4
DMM 6 - S003	963.9	0.10	264557.5	26.5	1430.7	0.14	14494.4	1.45	28.2	2557.2	306.3
Avg	967.4	0.10	320264.2	32.0	2608.8	0.26	20326.6	2.03	25.3	2619.2	282.8
Std Dev	229.5	0.02	27228.8	2.7	915.5	0.09	3174.3	0.3	3.8	217.0	44.6
NPS 1 - S013	3378.9	0.34	331360.9	33.1	3278.3	0.33	15702.2	1.57	64.3	3571.0	472.1
NPS 2 - S014	2421.7	0.24	285734.4	28.6	2264.4	0.23	14017.2	1.40	52.3	3554.1	430.8
NPS 3 - S015	2438.8	0.24	300702.5	30.1	2606.3	0.26	14885.4	1.49	52.6	3528.7	465.9
NPS 4 - S016	2477.9	0.25	294041.4	29.4	2219.0	0.22	15819.0	1.58	56.3	3260.8	420.6
NPS 5 - S017	1433.6	0.14	331680.6	33.2	1468.7	0.15	17479.8	1.75	46.7	3177.8	320.3
NPS 6 - S018	1133.8	0.11	264157.4	26.4	1453.7	0.15	16575.6	1.66	47.6	3036.7	312.6
NPS 9	1819.6	0.18	319715.4	32.0	3001.9	0.30	16890.0	1.69	73.8	3092.2	435.4
NPS 10	1500.4	0.15	333143.2	33.3	2526.3	0.25	17300.7	1.73	66.5	3181.0	373.3
NPS 11	2527.2	0.25	343372.7	34.3	3379.4	0.34	17249.3	1.72	74.7	3136.5	489.5
NPS 12	1597.8	0.16	308413.0	30.8	2120.0	0.21	15891.9	1.59	69.8	3057.9	353.5
NPS 13	402.6	0.04	233186.0	23.3	1437.4	0.14	14102.9	1.41	57.3	2365.1	313.9
NPS 14	1487.6	0.15	337800.0	33.8	2487.1	0.25	17552.3	1.76	63.0	2928.0	342.7
Avg	1885.0	0.19	306942.3	30.7	2353.5	0.24	16122.2	1.61	60.4	3157.5	394.2
Std Dev	794.8	0.08	33391.8	3.3	671.0	0.07	1268.6	0.1	9.7	328.6	65.6
WWT 1 - S001	8035.5	0.80	311684.2	31.2	10915.0	1.09	21686.1	2.17	129.0	2518.0	1977.0
WWT 1 - S002	4512.8	0.45	283135.1	28.3	5172.1	0.52	14283.7	1.43	89.3	1839.0	1202.2
WWT 1 -S003	5339.8	0.53	290894.5	29.1	6859.6	0.69	14319.1	1.43	104.0	1618.2	1347.4
WWT 2 - S004	3137.3	0.31	297400.3	29.7	4225.2	0.42	16533.5	1.65	57.4	2845.1	903.2
WWT 2 - S005	3720.8	0.37	328497.5	32.8	4570.8	0.46	15873.6	1.59	67.3	2884.0	973.7
WWT 2 - S006	2083.6	0.21	293904.4	29.4	2550.9	0.26	15583.0	1.56	40.9	3109.7	610.1
WWT 3 - S007	4480.7	0.45	334760.6	33.5	6176.3	0.62	15279.8	1.53	88.7	2906.2	1234.7
WWT 3 - S008	1019.9	0.10	191059.9	19.1	1071.0	0.11	10145.7	1.01	33.7	2461.6	334.4
WWT 3 - S009	2328.9	0.23	339130.6	33.9	3028.9	0.30	16916.4	1.69	46.2	3193.2	552.7
WWT 5 - S010	1754.0	0.18	219863.5	22.0	1367.9	0.14	14786.5	1.48	61.5	3017.0	616.0
WWT 5 - S011	2700.2	0.27	313045.3	31.3	2560.5	0.26	15355.9	1.54	57.6	3479.7	538.3
WWT 5 - S012	2231.0	0.22	287498.2	28.7	2696.2	0.27	16603.9	1.66	62.0	3409.4	585.8
Avg	3445.4	0.34	290906.2	29.1	4266.2	0.43	15613.9	1.56	69.8	2773.4	906.3
Std Dev	1928.6	0.19	44439.2	4.4	2762.6	0.28	2605.46	0.26	27.88	576.60	467.41
Second Round Sampling, Sept 2009											
CON 32 - S013	2900.3	0.29	325083.5	32.5	5145.5	0.51	24799.0	2.48	88.4	2614.0	758.3
CON 33 - S014	5782.8	0.58	321489.9	32.1	8643.2	0.86	19241.7	1.92	133.4	3175.3	1376.0
CON34-S015	8698.4	0.87	317575.5	31.8	9957.5	1.00	17563.7	1.76	119.1	3457.7	1581.9
CON34-S016	2512.2	0.25	333556.3	33.4	3110.2	0.31	20019.7	2.00	56.8	2899.9	557.8
CON35-S025	1060.5	0.11	339275.3	33.9	875.4	0.09	15891.0	1.59	27.9	4009.0	326.0
Avg	4190.9	0.42	327396.1	32.7	5546.4	0.55	19503.0	1.95	85.1	3231.2	920.0
Std Dev	3046.9	0.30	8884.5	0.9	3773.7	0.38	3361.2	0.34	43.5	536.2	537.6

TABLE 4-5: COMPILED SEDIMENT METAL RESULTS

Field Sample ID	Site label	Type	Sample Lab IDs	ICP MS Run on	51V	53Cr	59Co	60Ni	*63Cu*	*65Cu*	Cu (average)	*66Zn*	*68Zn*	Zn (average)	75As	111Cd	*136Ba*	*137Ba*	Ba (average)	*206Pb*	*207Pb*	*208Pb*	Pb (average)	238U	*Al (ppm)*	*Al %*	*Ca (ppm)*	*Ca %*	*Fe (ppm)*	*Fe %*	*Mg (ppm)*	*Mg %*	*Mn (ppm)*	*Sr (ppm)*	*Ti (ppm)*
				Unit:	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	*(mg/kg)*	*(mg/kg)*	(mg/kg)	*(mg/kg)*	*(mg/kg)*	(mg/kg)	(mg/kg)	(mg/kg)	*(mg/kg)*	*(mg/kg)*	(mg/kg)	*(mg/kg)*	*(mg/kg)*	*(mg/kg)*	(mg/kg)	(mg/kg)											
				Analytical Method:	ICP-MS	ICP-MS	ICP-MS	ICP-MS	*ICP-MS*	*ICP-MS*	ICP-MS	*ICP-MS*	*ICP-MS*	ICP-MS	ICP-MS	ICP-MS	*ICP-MS*	*ICP-MS*	ICP-MS	*ICP-MS*	*ICP-MS*	*ICP-MS*	ICP-MS	ICP-MS											
				Screening Level:	NA	37.3	NA	15.9	*NA*	*NA*	18.7	*NA*	*NA*	123	7.24	0.6	*NA*	*NA*	NA	*NA*	*NA*	*NA*	30.2	NA											
DMM10-S001	DMM10	DMM	90-23 / 90-26		6.5[a]	10.0[a]	2.9[a]	**29.9[a]**	*264.0[a]*	*16.9[a]*	**264.0**	*204.0[a]*	*195.0[a]*	**199.5**	0.3[a]	ND[a]	*4.1[a]*	*4.5[a]*	4.3	*6.3[a]*	*8.2[a]*	*8.2[a]*	8.2	0.7[a]	*769.0*	*0.08*	*327814.8*	*32.8*	*1115.8*	*0.11*	*25747.7*	*2.57*	*23.4*	*2334.0*	*233.8*
DMM 10 - S002	DMM10	DMM	89-7 / 90-28		10.8	30.7[a]	6.3	**33.2**	*890.1*	*14.7*	**890.0**	*116.8*	*113.1*	114.9	3.0	ND	*14.2*	*14.5*	14.3	*10.1*	*11.2*	*11.1*	11.1	1.1	*1766.6*	*0.18*	*334122.2*	*33.4*	*8984.4*	*0.90*	*20985.8*	*2.10*	*37.8*	*2658.8*	*411.3*
DMM-10 -S003	DMM10	DMM	90-13 / 89-3		9.0[a]	14.5[a]	2.5[a]	**22.9[a]**	*2523.3[a]*	*2347.1[a]*	**2500.1**	*209.8[a]*	*194.3[a]*	**202.0**	5.4	0.3	*2.4*	*5.6*	4.0	*12.0*	*12.6*	*12.0*	12.2	ND	*1098.3*	*0.11*	*333530.0*	*33.4*	*1943.4*	*0.19*	*23347.9*	*2.33*	*31.1*	*2499.3*	*336.5*
DMM 11 - S004	DMM11	DMM	89-38 / 90-25		7.6	9.8	3.9	**35.4**	*107.4[a]*	*106.8[a]*	**107.1**	*98.5*	*90.5*	94.5	**7.6[a]**	ND[a]	*3.6[a]*	*5.9[a]*	4.8	*ND*	*10.3*	*10.2*	10.3	0.9	*969.9*	*0.10*	*335736.3*	*33.6*	*1703.8*	*0.17*	*19797.3*	*1.98*	*26.9*	*2760.9*	*297.8*
DMM 11 - S005	DMM11	DMM	89-24 / 89-16		9.9	16.8	3.2	**24.2**	*220.2*	*219.7*	**220.0**	*238.0*	*219.7*	**228.8**	5.5	0.2	*3.9*	*5.3*	4.6	*1.2*	*17.9*	*17.6*	17.7	1.2	*1294.2*	*0.13*	*340593.1*	*34.1*	*2194.6*	*0.22*	*19988.1*	*2.00*	*28.9*	*2942.5*	*353.8*
DMM 11 - S006	DMM11	DMM	90-1 / 89-6		8.5[a]	11.8[a]	3.0[a]	15.1[a]	*147.1[a]*	*146.6[a]*	**146.8**	*96.2[a]*	*85.5[a]*	90.9	2.9[a]	0.1[a]	*3.2[a]*	*5.1[a]*	4.1	*ND[a]*	*10.3[a]*	*10.5[a]*	10.4	1.0[a]	*898.4*	*0.09*	*340351.9*	*34.0*	*1449.9*	*0.14*	*22747.0*	*2.27*	*22.7*	*2666.2*	*288.8*
DMM 12 - S007	DMM12	DMM	90-4 / 90-8		7.2	10.7[a]	3.0	**25.9**	*106.4*	*4.7*	**106.4**	*118.8[a]*	*113.0*	115.9	2.0	ND	*4.5*	*4.5*	4.5	*10.4*	*11.4*	*11.2*	11.3	0.9	*860.0*	*0.09*	*331460.9*	*33.1*	*1234.0*	*0.12*	*23616.9*	*2.36*	*25.4*	*2432.9*	*268.2*
DMM 12 - S008	DMM12	DMM	89-2 / 90-20		8.8[a]	11.9[a]	2.9[a]	**28.1[a]**	*191.8[a]*	*13.4[a]*	**125.5**	*109.8[a]*	*108.8[a]*	109.3	2.6[a]	ND[a]	*7.4[a]*	*7.7*	7.5	*13.1*	*17.4[a]*	*17.1[a]*	17.2	0.9	*1078.5*	*0.11*	*335895.4*	*33.6*	*1991.0*	*0.20*	*21449.1*	*2.14*	*22.3*	*2634.5*	*324.1*
DMM 12 - S009	DMM12	DMM	89-10 / 90-2		7.9[a]	9.4[a]	4.8[a]	**34.7[a]**	*714.1[a]*	*712.5[a]*	**713.3**	*92.5[a]*	*86.9[a]*	89.7	0.1[a]	**1.8[a]**	*4.2[a]*	*4.9[a]*	4.6	*7.9[a]*	*10.1[a]*	*9.8[a]*	9.8	1.0[a]	*924.4*	*0.09*	*341479.3*	*34.1*	*1420.2*	*0.14*	*19954.2*	*2.00*	*23.7*	*2668.6*	*280.3*
DMM 13 - S010	DMM13	DMM	90-22 / 90-17		8.1	14.0[a]	5.2	**31.9**	*18.1*	*20.5*	**19.6**	*35.3*	*33.5*	34.4	0.9[a]	ND[a]	*4.9*	*5.3*	5.1	*7.7*	*9.7*	*9.6[a]*	9.6	1.0	*991.1*	*0.10*	*338584.9*	*33.9*	*1475.0*	*0.15*	*19732.1*	*1.97*	*28.0*	*2824.6*	*293.6*
DMM 13 - S011	DMM13	DMM	89-20 / 90-14		7.9	11.7	4.2	**35.8**	*76.6*	*8.5*	**76.5**	*121.6*	*113.6*	117.6	1.5[a]	**0.8**	*3.4*	*5.6*	4.5	*1.4*	*11.3*	*11.3*	11.3	1.1	*1140.2*	*0.11*	*341266.4*	*34.1*	*1969.0*	*0.20*	*18690.1*	*1.87*	*26.2*	*2943.8*	*307.1*
DMM 13 - S012	DMM13	DMM	89-14 / 89-28		10.7	20.0	4.4	14.7	*214.1*	*216.5*	**215.3**	*64.8*	*64.9*	64.9	0.1	**0.8**	*6.2*	*7.1*	6.7	*11.0*	*14.7*	*14.7*	14.7	1.2	*952.5*	*0.10*	*342823.1*	*34.3*	*1604.6*	*0.16*	*20320.2*	*2.03*	*23.5*	*2775.8*	*294.9*
Avg					8.6	14.3	3.9	27.6	*456.1*	*319.0*	448.7	*125.5*	*118.2*	121.9	2.7	0.3	*5.2*	*6.3*	5.8	*6.8*	*12.1*	*11.9*	12.0	0.9	*1061.9*	*0.11*	*336971.5*	*33.7*	*2257.2*	*0.23*	*21364.7*	*2.14*	*26.7*	*2678.5*	*307.5*
Std Dev					1.3	6.0	1.2	7.3	*702.2*	*669.1*	698.4	*60.9*	*56.4*	58.6	2.4	0.5	*3.1*	*2.7*	2.9	*4.9*	*3.0*	*3.0*	3.0	0.3	*262.2*	*0.03*	*4641.8*	*0.5*	*2143.9*	*0.21*	*2078.6*	*0.21*	*4.4*	*188.6*	*45.3*
NPS 30 - S018	NPS30	NPS	90-3 / 89-26		12.5	23.6	4.7	14.0	*1.2*	*4.1*	2.7	*4.2[a]*	*5.4[a]*	4.8	ND	0.4	*6.9*	*7.6*	7.3	*4.2*	*4.8*	*4.8*	4.8	1.7	*6.0*	*0.00*	*330.6*	*0.0*	*7.9*	*0.00*	*48.8*	*0.00*	*0.1*	*3.8*	*2.0*
NPS 31 - S019	NPS31	NPS	89-9 / 89-35		11.3	1.4[a]	3.0	**29.0**	*1.5*	*3.2*	2.4	*4.9[a]*	*5.3[a]*	5.1	5.5	0.4[a]	*6.2[a]*	*5.8[a]*	6.0	*0.6*	*9.0*	*8.5*	8.7	ND	*1409.0*	*0.14*	*342123.8*	*34.2*	*2084.1*	*0.21*	*16904.3*	*1.69*	*60.9*	*2954.6*	*385.0*
NPS 33 - S020	NPS33	NPS	89-13 / 90-33		10.7	13.4	4.6	**33.5**	*1.9[a]*	*0.1*	1.9	*1.8*	*0.1*	1.8	ND	**1.2**	*5.4*	*7.2*	6.3	*ND*	*5.5*	*5.4*	5.4	1.4	*1700.4*	*0.17*	*341895.1*	*34.2*	*2143.9*	*0.21*	*16627.4*	*1.66*	*55.8*	*3258.8*	*429.8*
NPS 34 - S021	NPS34	NPS	89-1 / 90-32		9.3	12.4	4.2	**31.5**	*2.5*	*0.4*	2.5	*12.4*	*12.4[a]*	12.4	1.1	0.4	*6.0*	*6.4[a]*	6.2	*6.5*	*11.0*	*11.0*	11.0	1.2	*1498.4*	*0.15*	*337571.8*	*33.8*	*1706.6*	*0.17*	*16662.8*	*1.67*	*57.2*	*3202.0*	*364.8*
Avg					11.0	12.7	4.1	27.0	*1.8*	*1.9*	2.4	*5.8*	*5.8*	6.0	1.7	0.6	*6.1*	*6.7*	6.4	*2.8*	*7.6*	*7.4*	7.5	1.1	*1153.5*	*0.12*	*255480.3*	*25.5*	*1485.6*	*0.15*	*12560.8*	*1.26*	*43.5*	*2354.8*	*295.4*
Std Dev					1.3	9.1	0.8	8.9	*0.6*	*2.0*	0.3	*4.6*	*5.1*	4.5	2.6	0.4	*0.6*	*0.8*	0.6	*3.1*	*2.9*	*2.9*	2.9	0.8	*774.6*	*0.08*	*170112.7*	*17.0*	*1004.0*	*0.10*	*8342.2*	*0.83*	*29.0*	*1572.9*	*197.5*
WWT 15 - S017	WWT15	WWT	89-33 / 89-25		16.5	27.6	4.5	**37.3**	*19.2*	*20.6*	**19.9**	*57.2*	*53.6*	55.4	6.8	0.2	*11.6*	*11.4*	11.5	*5.7[a]*	*5.7*	*5.8*	5.7	1.3	*3043.4*	*0.30*	*333578.6*	*33.4*	*3780.0*	*0.38*	*20035.5*	*2.00*	*50.9*	*2726.8*	*765.9*
WWT 16 - S022	WWT16	WWT	89-37 / 90-15		9.3	10.5	4.0	**36.9**	*11.4*	*0.8*	11.4	*50.6*	*47.0*	48.8	1.6[a]	ND	*5.3*	*6.2*	5.8	*1.3*	*5.5*	*5.6*	5.5	1.0	*1372.7*	*0.14*	*334338.0*	*33.4*	*2039.9*	*0.20*	*18332.3*	*1.83*	*38.9*	*2828.9*	*403.1*
WWT 17 - S023	WWT17	WWT	90-16 / 90-16		7.7	8.0	4.4	**34.3**	*35.6[a]*	*ND*	**35.6**	*18.0*	*14.6*	16.3	ND	**0.8**	*3.6*	*5.2*	4.4	*ND*	*13.7*	*13.7*	13.7	1.0	*1446.6*	*0.14*	*330995.9*	*33.1*	*2029.9*	*0.20*	*15874.0*	*1.59*	*38.1*	*3124.8*	*410.3*
WWT 19 - S024	WWT19	WWT	89-34 / 90-29		9.0[a]	13.3	4.6	**37.2**	*4.1*	*1.5*	4.1	*5.4*	*1.8*	5.2	0.2	**1.0**	*3.9*	*5.7*	0.1	*2.6*	*5.3*	*5.3*	5.3	1.1	*1532.3*	*0.15*	*333493.7*	*33.3*	*1557.3*	*0.16*	*14557.5*	*1.46*	*36.4*	*3229.9*	*406.1*
Avg					10.6	14.9	4.4	36.4	*17.6*	*5.7*	17.8	*32.8*	*29.2*	31.4	2.2	0.5	*6.1*	*7.1*	5.4	*2.4*	*7.6*	*7.6*	7.6	1.1	*1848.8*	*0.18*	*333101.6*	*33.3*	*2351.8*	*0.24*	*17199.8*	*1.72*	*41.1*	*2977.6*	*496.4*
Std Dev					4.0	8.8	0.2	1.4	*13.5*	*9.9*	13.5	*25.0*	*25.0*	24.4	3.2	0.5	*3.7*	*2.9*	4.7	*2.4*	*4.1*	*4.1*	4.1	0.1	*799.1*	*0.08*	*1454.2*	*0.1*	*978.4*	*0.10*	*2453.8*	*0.25*	*6.6*	*238.3*	*179.7*

Note:
This table was populated with "representative data," not averages of all validated data. A summary table of individual validated sediment metal results is presented in Appendix I. Complete validation reports are located in Appendix K.
[a] Result is based on data that had not been validated
bold = result is above the screening level
ND = not detected above 0.0 mg/kg

TABLE 5-1: COMPARISON OF TRACE ELEMENTS AT VARIOUS LOCATIONS, SEDIMENTS

Element	As	Cd	Co	Cr	Cu	Ni	Pb	V	Zn	Reference
Units	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
Ordnance Reef (HI-06) Environmental Study										
CON Stratum										
Minimum	1.1	ND	4.2	11.1	3.0	26.2	2.7	6.1	8.5	Ordnance Reef (HI-06) Environmental Study
Maximum	20.2	0.4	18.9	112.9	24.3	125.0	136.0	75.0	49.2	
Average	14.4	0.04	12.0	63.0	12.1	67.5	18.7	41.5	28.1	
Standard Deviation	5.4	0.1	5.1	28.2	6.1	27.9	31.1	18.1	11.4	
NPS Stratum										
Minimum	ND	ND	3.0	1.4	0.7	14.0	1.2	5.8	0.1	Ordnance Reef (HI-06) Environmental Study
Maximum	8.1	1.2	10.8	30.0	4.2	65.0	11.0	16.0	18.4	
Average	4.5	0.2	5.3	18.6	2.5	47.7	5.1	11.0	9.5	
Standard Deviation	2.4	0.3	2.1	6.9	0.9	15.3	3.0	2.4	6.3	
DMM Stratum										
Minimum	0.1	ND	2.2	9.4	3.0	14.7	1.7	6.5	12.6	Ordnance Reef (HI-06) Environmental Study
Maximum	7.6	1.8	6.3	30.7	2500.1	62.9	549.3	11.2	407.6	
Average	3.7	0.2	3.5	14.3	399.1	33.6	44.4	8.6	146.4	
Standard Deviation	2.0	0.4	1.0	5.1	540.9	12.0	108.9	1.2	88.1	
WWTP Stratum										
Minimum	ND	ND	3.1	8.0	3.1	27.3	0.5	7.7	5.2	Ordnance Reef (HI-06) Environmental Study
Maximum	6.8	1.0	11.6	71.9	95.4	105.2	109.7	36.2	55.4	
Average	2.64	0.13	5.96	32.2	18.6	52.3	16.2	15.8	26.7	
Standard Deviation	1.7	0.31	2.7	15.8	22.9	22.1	29.6	7.4	15.9	
2006 NOAA Ordnance Reef Survey										
Minimum	9.8	0.00	0.2	2.4	0.3	0.8	0.0	0.9	1.5	NOAA (2007)
Maximum	29.4	0.56	23.0	158	2147	211	61.7	91.6	162	
Average	10.3	0.23	2.6	19.1	56.4	10.4	6.7	10.7	25.0	
Standard Deviation	4.6	0.10	3.3	21.9	258	26.2	10.3	12.6	31.6	
Ala Wai, Oʻahu										
Minimum	6.2	0.08	12.8	86	40	47	0.1	70	35	De Carlo and Spencer (1997), Spencer et al. (1995), De Carlo and Anthony (2002)
Maximum	23.4	2.20	138	506	291	340	759	254	711	
Southern Kāneʻohe Bay, Oʻahu										
Minimum	11.5	0.20	10.9	45.8	17	33.7	2.0	49.1	35.4	DeCarlo, Unpublished results
Maximum	58.1	7.30	15.6	76.0	1120	184	37.4	83.3	165	
Average	16.8	0.64	13.8	65.1	55	53.6	5.7	68.4	64.7	
Standard Deviation	7.7	1.20	1.3	7.9	188	24.4	7.0	8.4	25.3	
Pearl Harbor SE, Oʻahu										
Minimum	n/a	1.04	n/a	64.0	110	57	82	n/a	172	Naval Civil Engineering Laboratory (1973)
Maximum	n/a	1.38	n/a	76.0	146	68	110	n/a	223	
Average	n/a	1.20	n/a	70.0	127	62	95	n/a	196	
Pearl Harbor NW, Oʻahu										
Minimum	n/a	0.42	n/a	91	57	106	20	n/a	122	Naval Civil Engineering Laboratory (1973)
Maximum	n/a	0.57	n/a	116	74	149	24	n/a	148	
Average	n/a	0.49	n/a	103	65	126	22	n/a	135	
Kahana Bay, NE Oʻahu										
Minimum	n/a	1.52	n/a	13.0	7	33	24	n/a	10	Water Resources Research Center (1973)
Maximum	n/a	1.78	n/a	17.0	9	39	27	n/a	13	
Average	n/a	1.64	n/a	15.0	8	36	26	n/a	11	
Waikīkī Beach (Māmala Bay)										
Minimum	n/a	0.59	n/a	15.0	3.3	36	35	n/a	5.4	Water Resources Research Center (1973)
Maximum	n/a	0.71	n/a	17.0	4.0	40	38	n/a	6.6	
Average	n/a	0.65	n/a	16.0	3.6	38	37	n/a	6.0	
Hawaiʻi Kai (Maunalua Bay)										
Minimum	n/a	1.58	n/a	35	26	88	30	n/a	39	Water Resources Research Center (1973)
Maximum	n/a	2.09	n/a	43	35	103	33	n/a	49	
Average	n/a	1.82	n/a	39	30	95	32	n/a	44	
Honolua Bay, Maui										
Minimum	12.4	0.04	24.0	359	8	158	1.0	38.0	23.0	De Carlo and Dollar (2007)
Maximum	21.0	0.07	41.0	658	13	354	1.9	67.0	49.0	
Average	16.2	0.05	35.0	524	11.8	286	1.5	55.8	43.0	
Standard Deviation	3.6	0.01	7.8	125	2.5	88	0.4	13.7	15.2	
Sand Island, Oʻahu	n/a	n/a	n/a	n/a	8	n/a	90.0	n/a	25.0	City and County of Honolulu (1971)
Honolua Bay, Maui										
Minimum	24.0	n/a	2.71	13.9	5.25	9.93	14.6	89.4	6.52	Hedouin et al. (2011)
Maximum	42.5	n/a	48.4	95.9	17.1	481	36.2	346	54.9	
Average	35.0	n/a	26.2	61.0	10.8	236	26.1	221	32.3	
Standard Deviation	8.07	n/a	20.3	40.4	5.60	202	10.9	111	22.9	
Hokuanui Bay, Maui										
Average	34.8	n/a	3.6	16.7	6.0	17.7	17.6	108.3	10.7	Hedouin et al. (2011)
Standard Deviation	3.2	n/a	0.6	0.4	0.2	3.7	0.6	7.6	2.2	
Honokeana Cove, Maui										
Average	27.0	n/a	5.4	21.3	7.5	22.6	20.7	103.2	16.7	Hedouin et al. (2011)
Standard Deviation	0.4	n/a	0.5	1.0	0.2	2.4	0.7	4.4	2.5	

TABLE 5-1: COMPARISON OF TRACE ELEMENTS AT VARIOUS LOCATIONS, SEDIMENTS

Element	As	Cd	Co	Cr	Cu	Ni	Pb	V	Zn	Reference
Units	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
Līpoa Point, Maui										
Average	25.7	n/a	2.7	14.7	6.1	10.3	15.9	94.4	6.7	Hedouin et al. (2011)
Standard Deviation	0.5	n/a	0.2	0.9	0.5	1.7	0.8	3.8	0.6	
Honokōhau Point, Maui										
Average	56.2	n/a	45.5	73.1	17.1	373.9	35.3	343.0	51.2	Hedouin et al. (2011)
Standard Deviation	1.4	n/a	3.2	5.1	1.0	43.9	1.7	27.0	2.1	
Mokulēʻia Bay, Maui										
Average	48.1	n/a	19.9	47.3	9.4	144.6	26.1	190.6	25.1	Hedouin et al. (2011)
Standard Deviation	1.4	n/a	2.1	5.7	0.7	28.4	0.9	13.1	2.4	
Upper Laguna Madre, SE Texas										
Minimum	n/a	n/a	n/a	n/a	0.6	3.0	7.5	n/a	4.1	Sharma et al. (1999)
Maximum	n/a	n/a	n/a	n/a	18.5	24.5	27.5	n/a	69.8	
Average	n/a	n/a	n/a	n/a	3.1	8.1	80.5	n/a	21.4	
Gulf of Mexico Estuaries and Bays	n/a	n/a	n/a	n/a	12	n/a	18.0	n/a	75.0	Presley (1994)
Mississipi Bight										
Minimum	n/a	n/a	n/a	n/a	1	1.0	0.1	n/a	2.0	Presley et al. (1992)
Maximum	n/a	n/a	n/a	n/a	25	43.0	40.0	n/a	154	
Average	n/a	n/a	n/a	n/a	9.3	14.6	13.6	n/a	56.0	
Campeche Sound, Gulf of Mexico										
Minimum	n/a	n/a	n/a	n/a	4	68.0	0.1	n/a	47.0	Vazquez and Sharma (2004)
Maximum	n/a	n/a	n/a	n/a	27	126	19.0	n/a	111	
Average	n/a	n/a	n/a	n/a	18.8	104	11.1	n/a	75.2	
Tampa Bay, W Florida										
Minimum	n/a	n/a	n/a	22.6	0	0.0	0.0	n/a	0.0	Cantillo et al. (1999)
Maximum	n/a	n/a	n/a	45.3	10	10.0	20.0	n/a	19.9	
Flamingo, Florida										
Minimum	n/a	n/a	n/a	45.3	10	0.0	5.0	n/a	19.9	Cantillo et al. (1999)
Maximum	n/a	n/a	n/a	67.8	20	10.0	10.0	n/a	39.9	
Joe Bay, Florida										
Minimum	n/a	n/a	n/a	22.6	0	0.0	0.0	n/a	0.0	Cantillo et al. (1999)
Maximum	n/a	n/a	n/a	45.3	10	10.0	5.0	n/a	19.9	
Florida Bay										
Minimum	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	5.3	Kang (1999)
Maximum	n/a	n/a	n/a	n/a	n/a	n/a	2.2	n/a	10.1	
Taylor Slought (Everglades)										
Minimum	n/a	n/a	n/a	5.7	1.97	3.0	6.0	2.0	5.0	Gough et al. (1996)
Maximum	n/a	n/a	n/a	47.6	14.0	14.0	51.8	37.0	47.0	
Bahamas	n/a	n/a	n/a	2.6	0.30	0.4	0.4	1.3	0.5	Caccia (2004)
Florida Bay										
Zones as defined by V.G. Caccia										
Maximum [c] zone Min	n/a	n/a	0.2	7.8	0.95	1.2	1.7	2.1	1.7	Caccia (2004)
Max	n/a	n/a	0.6	18.0	2.03	3.2	3.3	5.6	2.0	
Minimum [c] zone Min	n/a	n/a	0.0	3.1	0.44	0.3	0.6	1.7	0.4	
Max	n/a	n/a	0.2	6.8	0.79	0.9	1.2	5.1	1.6	
Average	n/a	n/a	0.3	8.4	0.95	1.2	1.7	5.8	1.1	
Narragansett Bay, Rhode Island										
Sediments	n/a	n/a	n/a	n/a	506	n/a	585	n/a	160	Bricker (1992)
Suspended matter	n/a	n/a	n/a	n/a	655	n/a	446	n/a	n/a	
Miami River & Biscayne Bay, Florida										
Minimum	n/a	n/a	n/a	n/a	n/a	n/a	500	n/a	n/a	Schropp et al. (1990)
Maximum	n/a	3.5	n/a	n/a	300	10.0	600	n/a	500	
Galveston Bay, Texas										
Minimum	n/a	0.2	n/a	n/a	n/a	0.6	5.0	n/a	9.8	Trefry et al. (1976)
Maximum	n/a	4.9	n/a	n/a	35156	58.0	50.0	n/a	141.0	
New York Bight	n/a	n/a	n/a	310	390	35.2	n/a	n/a	1500	Carmody et al. (1973)
South California Bight	n/a	n/a	n/a	510	280	64.0	n/a	n/a	730	Krom et al. (1983)
Gulf of Cadiz	n/a	n/a	n/a	11.9	158	25.8	n/a	n/a	n/a	Palanques et al. (1995)
Mississippi Bight	n/a	n/a	n/a	87.8	24.8	42.8	n/a	n/a	154	Presley et al. (1992)
Llobregat Continental Shelf, Spain	n/a	n/a	n/a	167	82.0	54.0	n/a	n/a	278	Puig et al. (1999)
Isla de Vieques, Puerto Rico										
Rosa Alcatraz (Site 3, min)	1.3	n/a	n/a	n/a	n/a	n/a	<2.4	n/a	n/a	Porter et al. (2011)
Rosa Alcatraz (Site 3, max)	1.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Hatillo, PR (control, single value)	4.2	n/a	n/a	n/a	n/a	n/a	32.3	n/a	n/a	

Note: n/a = not applicable

ND = not detected above 0.0 mg/kg

TABLE 5-2: COMPARISON OF TRACE ELEMENTS AT VARIOUS LOCATIONS, BIOTA

Element	As	Cu	Pb	Zn	Reference
Units	ppm	ppm	ppm	ppm	
2006 NOAA Ordnance Reef Survey					
Fish (whole fish)					
Control Area					
Minimum	13.0	n/a	ND	12.0	NOAA (2007)
Maximum	80.0	n/a	ND	110.0	
Outfall Area [1]					
Minimum	33.0	n/a	ND	22.0	NOAA (2007)
Maximum	110.0	n/a	ND	50.0	
Munitions Area					
Minimum	15.0	n/a	13.0	13.0	NOAA (2007)
Maximum	110.0	n/a	16.0	100.0	
2009 Ordnance Reef Environmental Study					
Octopus					
DMM Stratum					
Minimum	20.2	5.9^{J}	ND^{U}	10.3^{J}	Ordnance Reef (HI-06) Environmental Study
Maximum	32.4	90.3	0.06^{J}	51.6	
Average*	24.1	26.0	0.05	19.8	
Standard Deviation*	4.7	28.5	0.005	13.5	
CON Stratum					
Minimum	20.3	2.6^{J}	ND^{U}	9.0^{J}	Ordnance Reef (HI-06) Environmental Study
Maximum	32.5	23.2	0.083^{J}	17.7	
Average*	27.3	11.0	0.057	13.9	
Standard Deviation*	4.4	8.5	0.013	2.9	
NPS Stratum					
Minimum	18.7	3.4^{J}	ND^{U}	11.5^{J}	Ordnance Reef (HI-06) Environmental Study
Maximum	35.3	22.5	0.20	19.3^{J}	
Average*	25.2	11.3	0.06	14.7	
Standard Deviation*	5.4	7.0	0.04	2.4	
WWTP Stratum					
Minimum	19.9	3.0^{J}	ND^{U}	12.8^{J}	Ordnance Reef (HI-06) Environmental Study
Maximum	37.8	33.4	0.09^{J}	16.5	
Average*	28.3	10.8	0.06	14.4	
Standard Deviation*	7.2	9.7	0.01	1.2	
Fish (filets only)					
DMM Stratum					
Minimum	4.4	0.19	ND^{U}	2.5	Ordnance Reef (HI-06) Environmental Study
Maximum	24.9	1.1^{J}	0.14	7.8^{J}	
Average*	14.1	0.4	0.06	3.7	
Standard Deviation*	4.5	0.2	0.02	1.1	
CON Stratum					
Minimum	6.0	0.17^{J}	ND^{U}	2.4	Ordnance Reef (HI-06) Environmental Study
Maximum	38.8	0.70	0.092^{J}	7.8	
Average*	16.4	0.27	0.056	4.0	
Standard Deviation*	8.8	0.12	0.013	1.2	
NPS Stratum					
Minimum	5.9	0.16^{J}	ND^{U}	2.2	Ordnance Reef (HI-06) Environmental Study
Maximum	38.1	0.89^{J}	0.12	4.4	
Average*	20.6	0.30	0.06	3.5	
Standard Deviation*	9.1	0.20	0.02	0.6	
WWTP Stratum					
Minimum	6.5	0.13^{J}	ND^{U}	2.2	Ordnance Reef (HI-06) Environmental Study
Maximum	21.2^{J}	0.28	0.31	4.6	
Average*	13.5	0.20	0.08	3.3	
Standard Deviation*	4.6	0.05	0.07	0.8	
Crab					
DMM Stratum					
Minimum	27.1	4.8^{J}	ND^{U}	40.5	Ordnance Reef (HI-06) Environmental Study
Maximum	51.2	16.8^{J}	ND^{U}	54.9	
Average*	38.9	9.3	0.5	45.8	
Standard Deviation*	7.1	3.9	0.0	4.1	
CON Stratum [2]					
Minimum	n/a	n/a	n/a	n/a	Ordnance Reef (HI-06) Environmental Study
Maximum	n/a	n/a	n/a	n/a	
Average	n/a	n/a	n/a	n/a	
Standard Deviation	n/a	n/a	n/a	n/a	
NPS Stratum					
One specimen only	37.9	3.3	ND^{U}	39.2	Ordnance Reef (HI-06) Environmental Study
WWTP Stratum					
Minimum	14.9	0.3	ND^{U}	3.2	Ordnance Reef (HI-06) Environmental Study
Maximum	52.4	13.8^{J}	2.4	59.2	
Average*	34.5	8.1	0.2	41.5	
Standard Deviation*	10.4	4.5	0.6	16.9	

TABLE 5-2: COMPARISON OF TRACE ELEMENTS AT VARIOUS LOCATIONS, BIOTA

Element	As	Cu	Pb	Zn	Reference
Units	ppm	ppm	ppm	ppm	
Seaweed					
DMM Stratum					
Minimum	ND[U]	0.62	ND[UJ]	ND[U]	Ordnance Reef (HI-06) Environmental Study
Maximum	1.2	25[J]	0.69	263	
Average*	0.8	4.2	0.45	28.2	
Standard Deviation*	0.3	7.5	0.19	82.5	
CON Stratum					
Minimum	0.16[J]	ND[UJ]	ND[UJ]	ND[U]	Ordnance Reef (HI-06) Environmental Study
Maximum	1.3	0.62[J]	0.52	1.6	
Average*	0.7	0.3	0.3	0.7	
Standard Deviation*	0.4	0.2	0.2	0.4	
NPS Stratum					
Minimum	ND[U]	ND[UJ]	ND[UJ]	ND[U]	Ordnance Reef (HI-06) Environmental Study
Maximum	1.5	0.99[J]	1.1[J]	1.3	
Average*	1.0	0.4	0.4	0.7	
Standard Deviation*	0.4	0.3	0.4	0.3	
WWTP Stratum					
Minimum	0.51	ND[UJ]	0.18	ND[U]	Ordnance Reef (HI-06) Environmental Study
Maximum	1.4	1.3[J]	0.80	3.1	
Average*	0.9	0.7	0.5	1.2	
Standard Deviation*	0.3	0.4	0.2	1.0	
Unknown					
One specimen only	1.2	0.65	0.49	ND[U]	Ordnance Reef (HI-06) Environmental Study
French Frigate Shoals, North Pacific Ocean					
Goatfish					
Average	121.0	30.0	20.0	273.0	Hedouin, L.; Metian, M; Gates, R.D. (2011)
French Frigate Shoals, North Pacific Ocean					
Crab					
Average	52.0	245.0	33.0	232.0	Miao, X-S, Woodward, L, Swenson, C, et al. (2001)
Damselfish					
Average	26.0	63.0	19.0	159.0	Miao, X-S, Woodward, L, Swenson, C, et al. (2001)
Squirrelfish					
Average	33.0	63.0	12.0	204.0	Miao, X-S, Woodward, L, Swenson, C, et al. (2001)
Honolua Bay, Maui, Hawai'i					
Goatfish (muscle)					
Average	39.9	0.9	1.5	10.3	Hedouin, L.; Metian, M; Gates, R.D. (2011)
Standard Deviation	10.7	0.2	0.4	1.9	
Alga-Honolua location					
Average	15.8	4.0	8.7	2.6	
Standard Deviation	5.6	1.5	3.1	0.6	
Manila Bay, Phillipines					
Goatfish					
Average	n/a	2.12	0.10	66.1	Hedouin, L.; Metian, M; Gates, R.D. (2011)
New Caledonia					
Fish liver					
Minimum	8.0	n/a	n/a	n/a	Meitan, M. (unpublished results)
Maximum	44.0	n/a	n/a	n/a	
Fish muscle					
Minimum	7.0	n/a	n/a	n/a	Meitan, M. (unpublished results)
Maximum	38.0	n/a	n/a	n/a	
Octopus muscle					
Average	144.0	n/a	n/a	n/a	Meitan, M. (unpublished results)
Standard Deviation	27.0	n/a	n/a	n/a	Meitan, M. (unpublished results)
Octopus heart					
Average	61.0	n/a	n/a	n/a	Meitan, M. (unpublished results)
Standard Deviation	25.0	n/a	n/a	n/a	Meitan, M. (unpublished results)
Portuguese Coast					
Octopus vulgaris					
Minimum Average	34.0	7.9	2.9	40.0	Seixas, S.; Bustamante, P.; Pierce, G.J. (2005)
Standard Deviation	14.0	2.9	0.2	24.0	
Maximum Average	133.0	81.0	4.0	142.0	
Standard Deviation	49.0	68.0	1.0	92.0	

Notes:

[1] The 2006 NOAA Ordnance Reef Survey's "outfall area" corresponds with the WWTP stratum of the 2009 study.

[2] No crab specimen were collected from the CON Stratum.

* For average and standard deviation calculations, ND results were represented as half the reporting limit.

n/a = not applicable

ND = not detected at or above the method detection limit (MDL)

[J] = Estimated value. The analytical result is higher than the MDL but lower than the reporting limit.

[U] = The analytical result is qualified as non-detected at or above the MDL.

[UJ] = The analytical result is qualified as non-detected, but the MDL is an estimated value.