APPENDIX G-3

MULIWAI SEDIMENT SAMPLING REPORT

TC K838-0402

MULIWAI SEDIMENT SAMPLING REPORT

SUPPORTING THE ENVIRONMENTAL IMPACT STATEMENT ON MILITARY TRAINING ACTIVITIES

MAKUA MILITARY RESERVATION O'AHU, HAWAI'I

Contract Number GS-10F-0268K
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US Army Corps of Engineers
Honolulu District
Environmental & Special Projects Branch
Building 252
CEPOH-PP-E
Fort Shafter, Hawai'i 96858-5440

Prepared by:

Tetra Tech, Inc.
820 Mililani Street, Suite 700
Honolulu, Hawai'i 96813

TABLE OF CONTENTS

Section Page

EXECUTIVE SUMMARY **ES-1**

1. INTRODUCTION **1-1**

1.1 Site Description 1-1
1.2 Site Background 1-3
1.3 Project Description 1-3
1.4 Previous Investigations 1-4
1.5 Objectives and Scope of Work 1-5
1.5.1 Objectives 1-5
1.5.2 Scope of Work 1-5

2. SAMPLING OVERVIEW **2-1**

2.1 Muliwai Sediment Sampling Strategy 2-1
2.2 Sample Locations 2-3
2.2.1 Muliwai Pond Sampling 2-3
2.2.2 Background Sampling 2-12
2.3 Analytical Procedures 2-13

3. ANALYTICAL RESULTS **3-1**

3.1 Analytical Results 3-1
3.2 Metals Results (USEPA Methods 6010B and 7471A) 3-1
3.2.1 Aluminum 3-4
3.2.2 Antimony 3-4
3.2.3 Arsenic 3-4
3.2.4 Barium 3-8
3.2.5 Cadmium 3-8
3.2.6 Chromium 3-8
3.2.7 Cobalt 3-12
3.2.8 Copper 3-12
3.2.9 Lead 3-15
3.2.10 Mercury 3-15
3.2.11 Selenium 3-16
3.2.12 Silver 3-18
3.2.13 Vanadium 3-18
3.2.14 Zinc 3-19
3.2.15 Metals Summary 3-21
3.3 Energetics Results (USEPA Methods 314.0, 8330, and 8332) 3-21
3.4 Petroleum Hydrocarbon Results (USEPA Method 8021B) 3-23
3.4.1 Benzene 3-23
3.4.2 Toluene 3-23
3.4.3 Ethylbenzene 3-24
3.4.4 Xylenes 3-24
3.4.5 Petroleum Hydrocarbon Summary 3-24
3.5 OC Pesticide Results (USEPA Method 8081A) 3-24
3.6 Chlorinated Herbicide Results (USEPA Method 8151A) 3-24
3.7 Semivolatile Organic Compound Results (USEPA Method 8270C) 3-25

TABLE OF CONTENTS *(continued)*

Section Page

3.8	Dioxin and Furan Results (USEPA Method 8280A)	3-26
3.9	Other Analytical Results (USEPA Methods 335.2, 354.1, and SM4500)	3-27
3.10	Analytical Results Summary	3-27
4.	**CONCLUSIONS**	**4-1**
5.	**REFERENCES**	**5-1**

LIST OF FIGURES

Figure Page

1-1	Site Location Map	1-2
2-1	Muliwai Location Map	2-2
2-2	North Muliwai Sample Location Map	2-4
2-3	South Muliwai Sample Location Map	2-5
2-4	Dry Muliwai Sample Location Map	2-6
2-5	North Background Sample Location Map	2-7
2-6	South Background Sample Location Map	2-8
3-1	Aluminum Sample Frequency Graph	3-5
3-2	Antimony Sample Frequency Graph	3-6
3-3	Arsenic Sample Frequency Graph	3-7
3-4	Barium Sample Frequency Graph	3-9
3-5	Cadmium Sample Frequency Graph	3-10
3-6	Chromium Sample Frequency Graph	3-11
3-7	Cobalt Sample Frequency Graph	3-13
3-8	Copper Sample Frequency Graph	3-14
3-9	Lead Sample Frequency Graph	3-16
3-10	Mercury Sample Frequency Graph	3-17
3-11	Selenium Sample Frequency Graph	3-19
3-12	Vanadium Sample Frequency Graph	3-20
3-13	Zinc Sample Frequency Graph	3-22

LIST OF TABLES

Table Page

2-1	Muliwai Sampling Location Data	2-9
2-2	Muliwai Sediment Type Data	2-10
2-3	Muliwai Total Organic Carbon (TOC) and Nitrate Data	2-12
2-4	Muliwai Analytical Procedures	2-14
2-5	Muliwai Sample Location and Analyses Matrix	2-15
3-1	Summary of Analytical Results	3-2
3-2	Summary of Metals Results	3-3

LIST OF APPENDICES

A Site Photographs
B Sample Logs
C Analytical Data Tables
D Sieve Analysis Results
E Contract Laboratory Reports

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Full Phrase
ASTM	American Society for Testing and Materials
BTEX	benzene, toluene, ethylbenzene, and xylenes
CALFEX	combined arms live fire exercises
CFR	Code of Federal Regulations
CIH	certified industrial hygienist
COC	chain-of-custody
EIS	environmental impact statement
FONSI	finding of no significant impact
GPS	global positioning system
HED	Honolulu Engineering District
ICP	inductively coupled plasma (spectrometry)
kg	kilogram
µg	microgram
mg	milligram
MDL	method detection limit
MMR	Mākua Military Reservation
NIOSH	National Institute for Occupational Safety and Health
OB/OD	open burn/open detonation
OC	organochlorine
OCDD	octachlorinated dibenzo-p-dioxin
OE	ordnance and explosives
PAH	polycyclic aromatic hydrocarbon
ppb	parts per billion
PCDD	polychlorinated dibenzodioxin
PCDF	polychlorinated dibenzofuran
PM	project manager
PRG	preliminary remediation goal
QA	quality assurance
QC	quality control
SEA	supplemental environmental assessment
SAP	sampling and analysis plan
SSHO	site safety and health officer

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Full Phrase
SSHP	site safety and health plan
SVOC	semivolatile organic compound
TCDD	tetrachlorinated dibenzo-p-dioxin
TEQ	toxicity equivalent
TOC	total organic carbon
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency

EXECUTIVE SUMMARY

Tetra Tech conducted an investigation to determine if sediments in muliwai at the mouths of three streams draining Mākua Valley show evidence of contamination that may be related to past military activities at Mākua Military Reservation (MMR) or other sources. *Muliwai* is the Hawaiian word for pond that sometimes develops naturally during periods of low stream flow in the back-beach depression near the mouth of a stream. Under natural conditions, as a result of storm runoff, the water level in a muliwai rises until a breach develops in the sand dune, after which the pond rapidly drains and the stream discharges directly to the sea. As stream flow decreases, the sand berm builds again and stream water again fills the pond. Depending on the amount of stream flow or recharge from groundwater, the pond may either persist, or dry up entirely, until the next storm event. In some areas of Hawaii, muliwai have been improved and maintained for aquaculture. It is not known if or when the muliwai at Mākua Beach were used for aquaculture.

The most recent storm event large enough to cause the streams that discharge from Mākua Valley to breach the beach dunes occurred on February 14 and 15, 2003. There is no record of the maximum size of the muliwai prior to breaching, but it is known that the streams eventually breached the dunes and discharged unimpeded to the sea during the February storm event.

Recent aerial photographs of Mākua Beach confirm that ponds form at the mouths of each of the three streams that drain Mākua Valley: Punapahaku Stream (designated as the "dry muliwai" in this report), Mākua Stream (designated as the "north muliwai" in this report), and the stream emanating from Kaiahi Gulch (designated as the "south muliwai" in this report). The aerial photographs were used to delineate the areas in which sediment samples were to be collected, as described in the sampling plan prepared for the investigation (Tetra Tech 2003). At the time the field work for this investigation was performed, from May 19 through May 21, 2003, the muliwai had receded and the beach dune had reformed. The approximate extent of the muliwai ponds at the time of sampling were superimposed on the historic aerial photographs.

The largest pond at the time of sampling was the south muliwai. The north muliwai contained water, but was smaller than the south muliwai. The dry muliwai did not contain any water.

Sediment samples were also collected and analyzed from near the mouths of streams draining the watersheds immediately north and south of Mākua Valley, for comparison to the sediments collected from the muliwai. No other muliwai outside of Mākua Valley were identified in reconnaissance of the project region. The north and south background sampling sites were chosen because the depositional environments would be similar to the muliwai, but in watersheds where there has not been recent military training activity. The same stream sediment locations were used as reference sites in a previous study of muliwai sediments conducted by the US Environmental Protection Agency (USEPA).

A total of 49 sediment samples were collected from the muliwai and the two background locations. Twenty-two samples were collected from the north muliwai, 17 from the south muliwai, four samples were collected from the dry muliwai, and three samples each were collected from the north background location and the south background location. In addition, five duplicate samples were collected. All of the samples were analyzed for metals and energetic compounds (explosives). Ten samples and two duplicates were analyzed for an extended suite of analyses that included benzene, toluene, ethylbenzene, total xylenes (BTEX), organochlorine (OC) pesticides, chlorinated herbicides, semivolatile organic compounds (SVOCs), dioxins and furans, nitrate, nitrite, cyanide, perchlorate, total organic carbon (TOC), and particle size.

The samples were collected at depths ranging from 0-12 inches to as deep as 44-inches. Depth-integrated composites were prepared in the field by mixing the soil manually and then collecting subsamples of the composited soil for submittal to contract laboratories. The field geologist logged the sampled sediment in the field according the Unified Soil Classification System. Sample locations were identified in the field using a geographic positioning system (GPS) instrument accurate to about three meters, and the positions were confirmed visually from comparison to the aerial photographs of the site.

Based all of the field observations and the analytical results of the muliwai sediment sampling program the following conclusions were made:

- A wide range of sediment types, in terms of grain size and TOC content, were encountered in the three muliwai and two background areas. No correlation was observed between the grain size, the locations or depths of the samples, and the TOC or nitrate concentrations.
- Concentrations of metals detected in the muliwai were within the ranges found in the background samples.
- Arsenic and chromium were detected at concentrations above USEPA Region IX soil preliminary remediation goals (PRGs), but within background concentration ranges.

- All of the twelve samples that were analyzed for BTEX contained one or more of these compounds at trace concentrations. All of the concentrations of the BTEX chemicals in these samples were far lower than respective USEPA Region IX residential soil PRGs.
- Six of twelve sediment samples analyzed for the full suite of organic compounds contained one or more of the chemicals of concern, (with the exception of BTEX, which was detected more frequently). One sample contained one of the explosive compounds, and one sample contained one OC pesticide compound. Three chlorinated herbicides and three SVOCs were found in four samples. The detected concentrations were far below USEPA Region IX residential soil PRGs.
- Trace concentrations of two dioxin isomers were detected in two of the twelve muliwai sediment samples analyzed for dioxins and furans. The 2,3,7,8-TCDD isomer was detected at a concentration above the USEPA Region IX industrial soil PRG in one sample from the south muliwai, collected at a depth of 2.5 feet. The toxicity equivalent of the octa-CDD isomer found in the other sample, from the north muliwai, did not exceed the USEPA Region IX residential soil PRG.
- The results were also compared to U.S. EPA Generic Soil Screening Levels for protection of groundwater, to Hawaii Tier I Soil Action Levels, and to U.S. EPA Region 5 Ecological Screening Levels, in accordance with the Sampling and Analysis Plan. While some of these comparison values were exceeded in some of the samples, careful scrutiny of the specific exceedances revealed no additional basis for further investigation or study that was not already suggested by comparison to the U.S. EPA Region IX soil PRGs.

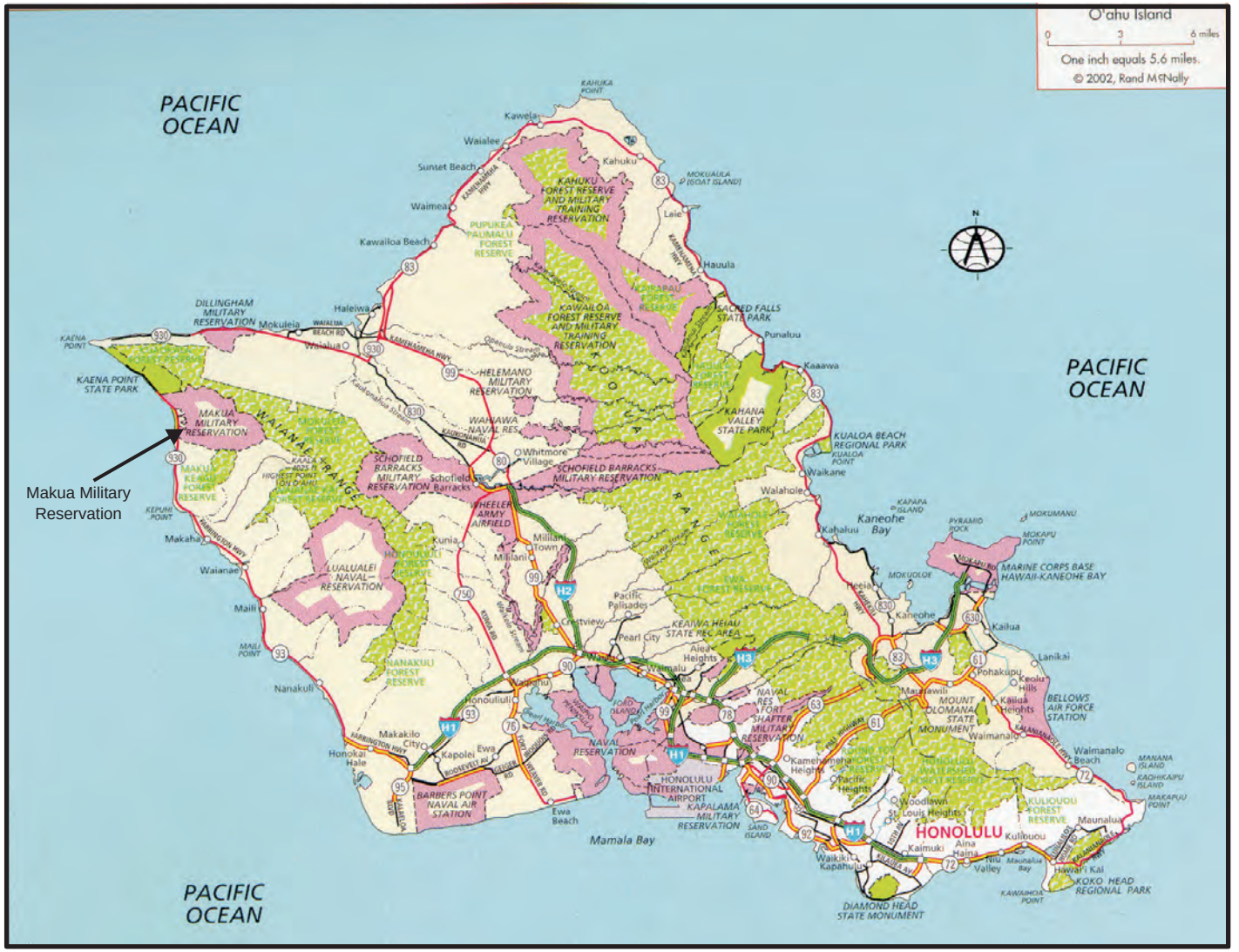
SECTION 1
INTRODUCTION

Muliwai is the Hawaiian word for a stream mouth that is isolated from the sea. Analytical data of the sediments in the muliwai adjacent to the Mākua Military Reservation (MMR, the site), on Oʻahu, Hawaiʻi, were determined to be a data gap for the environmental impact statement (EIS) for military training activities at the reservation. This muliwai sediment sampling report presents the purpose, scope of work, strategy, methodology, field changes to the methodology, and the results and findings of the sampling program to fill this data gap. Tetra Tech, Inc., is preparing the EIS under contract number GS-10F-0268K, delivery order number DACA83-02-F-0002 for the United States Army Corps of Engineers (USACE), Pacific Ocean Honolulu Engineer District (HED).

1.1 SITE DESCRIPTION

MMR is approximately 38 miles northwest of Honolulu, on the western shore of Oʻahu, near Kaʻena Point, and is in the adjoining Mākua and Kahanahāiki valleys (Figure 1-1). MMR is bordered on the west by the Pacific Ocean and is surrounded by the Waiʻanae Mountains on the north, east, and south. MMR borders Farrington Highway and extends west from the Waiʻanae Mountains ridgeline to the Pacific Ocean; Mākaha, the nearest township, is approximately three miles south. The installation encompasses almost 4,190 acres and is arid, with annual rainfall ranging from about 50 inches towards the head of the valley, to less than 15 inches at the mouth of the valley. The high, precipitous valley walls surrounding the installation reach heights of 2,100 to 2,900 feet. The broad range in rainfall and topography results in a diversity of vegetation types within the valley.

Of the total acreage at MMR, the US Army owns 170 acres in fee simple and 1.64 acres by license, leases 782.35 acres from the state of Hawaiʻi, and has the use of 3,236.48 acres of ceded lands. These are lands that were originally controlled by the Kingdom of Hawaiʻi and were transferred to the US in 1898, when Hawaiʻi was annexed as a territory. These ceded lands were subsequently granted to Hawaiʻi in 1959 upon



Source: Rand McNally 2002

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Site Location Map

Mākua Military Reservation
O´ahu, Hawai´i

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Figure 1-1

statehood. In 1964 a series of real estate actions resulted in the current 4,190-acre mixture of leased, ceded, and fee-simple land holdings. The State of Hawai'i lease, which expires in 2029 and includes the 782.35-acre parcel along Farrington Highway, requires the US Army to allow employees of the Hawai'i Board of Land and Natural Resources to enter the leased premises when necessary. Additionally, it grants the right to develop public use of Kāneana Cave, including a foot trail and parking area associated with the cave. The terms of the lease also allow public access to Mākua Beach, which lies between Farrington Highway and the shoreline.

The muliwai that were sampled for this task are within the Mākua Beach area. Water flows over Mākua Valley only during heavy rainfall. Water flowing from Mākua Valley or from incoming high tides collects in muliwai ponds located just inland along the beach. Typically, muliwai ponds are completely flushed each year by heavy rainfall.

1.2 SITE BACKGROUND

Use of Mākua Valley by US armed forces dates back to the 1920s when three parcels on the upper Mākua Valley floor were purchased for howitzer emplacements. After the bombing of Pearl Harbor in 1941, the Army used its authority under martial law to take over the entire Mākua-Ka'ena Point area for security and training. In 1942, the Army issued a real estate directive for 6,600 acres of land at Mākua that were already being used. Private parcels within the property were taken by condemnation, whereas territorial lands were conferred by the territorial governor's consent. In 1943, the territorial government granted a revocable permit for the military to use 6,600 acres "to assist in the present war effort extending for the duration of the present war and six months thereafter." The site was used extensively for bombing and infantry training, but no records of ordnance expended on Mākua were kept; it has remained under Army control ever since. After Hawai'i was granted statehood in 1959, the federal government exercised its option to set aside lands for its continued use.

In September 1998, the Army temporarily suspended training at MMR due to several wildland fires that burned outside the southern firebreak road. The Army then began an extensive investigation into the potential effects of wildland fires on the environment and reevaluated its fire management plan and training procedures. The Army consulted with the US Fish and Wildlife Service, pursuant to Section 7 of the Endangered Species Act, and discussed ways to identify, evaluate, and reduce the impact of Army activities on threatened and endangered species. Fish and Wildlife ultimately issued an opinion that the Army's resumption of modified training at MMR would not jeopardize endangered and threatened species.

1.3 PROJECT DESCRIPTION

In 1998, Earthjustice filed a lawsuit on behalf of Mālama Mākua seeking to compel preparation of an EIS addressing all of the Army's training and related operations at MMR. In 2000, the Army announced the completion of its supplemental environmental assessment (SEA) and finding of no significant impact (FONSI). In December 2000, Mālama Mākua sued the Army and challenged the SEA and FONSI and the Army's decision not to prepare an EIS for the resumption of training. In July 2001, the US

District Court for the District of Hawai'i granted a preliminary injunction enjoining the Army from training at MMR until the court issued its decision on the merits of the lawsuit. Following the events of September 11, 2001, a settlement agreement and stipulated order between Mālama Mākua and the US Department of Defense was issued in October 2001. The agreement allowed the Army to return to a limited number of training exercises until an EIS is completed and the record of decision is published in the *Federal Register,* no later than October 2004. The US Army will be permitted to carry out combined live arms fire exercises at MMR in the three years immediately following court approval of the agreement.

In support of the settlement agreement, the USACE HED contracted with Tetra Tech to prepare an EIS addressing, among other things, the potential direct, indirect, and cumulative environmental impacts associated with the proposal to continue military training activities at MMR. The EIS development process will be conducted in accordance with the aforementioned settlement agreement. The EIS areas of interest for evaluation will be the environmental, cultural, and socioeconomic effects at MMR and the adjacent community. For the cumulative impacts analysis portion of the EIS, Tetra Tech will assess existing conditions and trends in surrounding ecosystems and landscapes, privately owned lands, and the surrounding communities within the region of influence. In general, Tetra Tech's on-site activities at MMR will be noninvasive, consisting primarily of field testing, monitoring, and evaluating cultural, historical, and natural resources.

1.4 PREVIOUS INVESTIGATIONS

A number of studies have been performed relating to MMR, including, but not limited to the Halliburton NUS study (1994), The Mākua SEA (Onyx 2001), the muliwai sampling conducted by the US Environmental Protection Agency during 1999 (USEPA 1999a). In addition, a few studies have been performed along the leeward coast that include or apply to Mākua Valley, including US Geological Survey Professional Paper 1412B (Hunt 1996) and Hydrologic Investigation HA-358 (Takasaki 1971). Two recent reports to the Earthjustice Legal Defense Fund completed by consultants are also available that critiqued the SEA and the Halliburton report; these are "The Geohydrologic Setting of Mākua Valley and Contaminant Transport from Mākua Military Reservation by Overland Flow and via the Ground Water System," by William Meyer (Meyer 2001), and "Review of the Supplemental Environmental Assessment for Routine Training at Mākua Military Reservation and PFC Pililā'au Range Complex, Hawai'i, including the Potential for Off-Site Transport of Contaminants," by Eric De Carlo (De Carlo 2001).

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

1.5 OBJECTIVES AND SCOPE OF WORK

1.5.1 Objectives

The primary objectives of Tetra Tech's muliwai sediment sampling program at MMR include the following:

- To determine if inorganic and organic contaminants, primarily explosives and metals, are present in the muliwai sediments;
- To assess if contamination from the open burn/open detonation (OB/OD) area or the range complex at MMR has migrated off-site; and
- To provide data necessary to comply with the terms of the September 11, 2001 settlement agreement, and to support preparation of Tetra Tech's EIS.

1.5.2 Scope of Work

The proposed scope of work was performed to meet the objectives of the sampling program and includes the following elements:

- ***Preliminary activities.*** Tetra Tech reviewed the findings of the previous studies and assessments available for the muliwai ponds at MMR and related military training sites. Tetra Tech also obtained basic information (e.g., maps, soil data, munitions compositions, and historic site activities) and obtained permission to enter MMR and the adjacent properties.
- ***Sampling and analysis plan.*** Tetra Tech assessed detectable muliwai sediment quality impacts from military training activities at MMR by preparing and implementing a site-specific sampling and analysis plan (SAP). Identifying potential impacts at MMR could assist in complying with the requirements of federal and state statutes and rules, Hawai'i Revised Statutes and Hawai'i Administrative Rules.
- ***Site safety and health plan.*** Tetra Tech followed the site safety and health plan (SSHP) during on-site sampling (Tetra Tech 2002b). The SSHP was implemented in compliance with 29 Code of Federal Regulations (CFR) 1910.120 and USACE guidance document, Safety and Health Requirements Manual (EM 385-1-1), to address the potential for hazardous materials that could be encountered during field work at the muliwai ponds.
- ***Site visits.*** Tetra Tech visited the site, under authorization of MMR personnel, to locate and map appropriate sampling locations at the muliwai ponds.
- ***Sample collection and analysis.*** Tetra Tech collected muliwai sediment samples, in accordance with quality control (QC) requirements of the SAP (Tetra Tech 2003), and arranged for the samples to be delivered to certified contract laboratories for analysis.

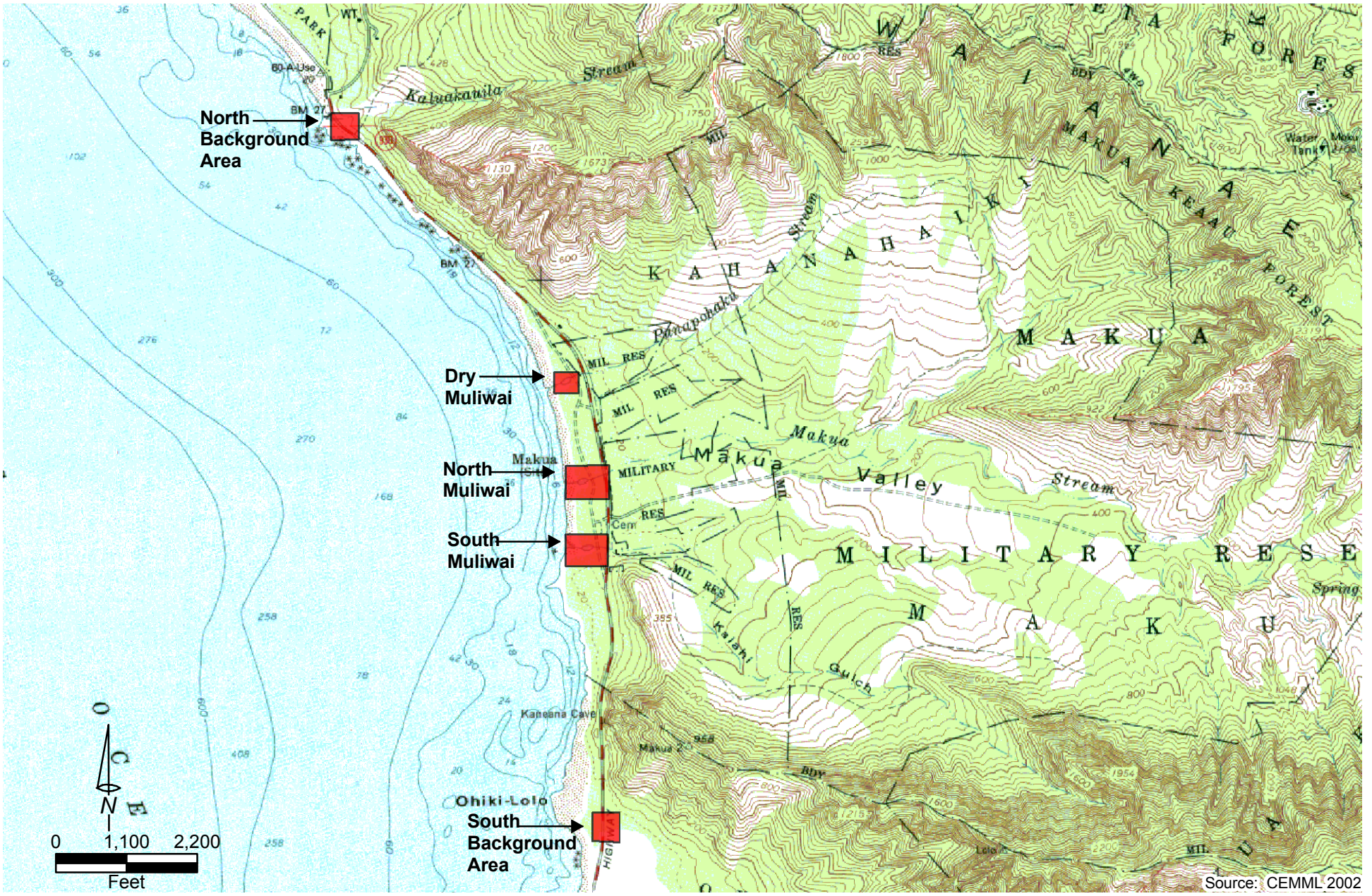
- ***Muliwai sediment sampling report.*** Tetra Tech has prepared this muliwai sediment sampling report, based on an evaluation of site conditions and on the results of laboratory analyses. The report includes a description of the methods and procedures used to collect and analyze the samples, along with the results and observations of the sampling and analysis.

SECTION 2
SAMPLING OVERVIEW

2.1 MULIWAI SEDIMENT SAMPLING STRATEGY

Tetra Tech's sampling program was conducted to support the MMR EIS by collecting and analyzing sediment samples in the muliwai ponds downstream of MMR. Three muliwai ponds were identified for sampling as shown on Figure 2-1. These three muliwai have been identified in the work plan as the north muliwai, the south muliwai, and the dry muliwai. The north muliwai is the pond that results from runoff from Mākua Stream, the principal stream that runs through the center of MMR. The south muliwai is the pond that results from runoff from Kaiahi Gulch, which runs along the south side of MMR. Based on the topography and the drainage ditches along the MMR access road, runoff from most of the live-fire areas and the disposal areas at MMR would drain to the south muliwai. The dry muliwai was dry at the time the investigation was conducted. It is located at the mouth of Punapohaku Stream, which drains the north side of MMR.

Tetra Tech also sampled streambed sediments north and south of these muliwai for comparison. One of these background sample areas was near the mouth of the dry streambed of the Kaluakauila Stream, which drains the watershed immediately north of the Mākua Valley. Kaluakauila Stream is within the boundary of MMR, but is considered a background location because no live-fire military training activity takes place in this watershed. The USEPA collected background samples from this streambed in 1999 for metals analysis. A second background sampling area was selected at the closest drainage south of the MMR valley in the Ohikilolo Valley. The locations of the two background sediment sampling areas are shown on Figure 2-1. Background sample results are useful in evaluating ambient concentrations of chemicals of concern that may result from natural or other sources not related to activities at MMR. These background samples were analyzed for metals and explosives. Site photographs of these activities are included in Appendix A.



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Muliwai Location Map

Mākua Military Reservation
O'ahu, Hawai'i

Figure 2-1

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Forty-four primary and three field duplicate sediment samples were proposed for collection from a maximum depth of three feet below the pond floor surface at three different ponds located west of MMR (Tetra Tech 2003). An additional six sediment samples and two field duplicate samples were proposed for collection from a maximum depth of three feet below ground surface at two background sites located outside of the MMR boundary. All told, 50 primary sediment samples and five field duplicate samples (ten percent) were proposed in this sampling program. All of these planned samples were collected, however, except for one sediment sample near the center of the south Muliwai, where the water depth prevented access.

The samples were collected in compliance with the heath and safety guidelines outlined in the SSHP and the SAP (Tetra Tech 2002b and 2003). All sediment and background samples were analyzed for metals (including mercury) and explosives. In addition, twelve samples (ten sediment and two field duplicate samples) were analyzed for an extended suite of analytes, including cyanide, nitrate, nitrite, total organic carbon (TOC), perchlorate, nitroglycerine, benzene, toluene, ethylbenzene, total xylenes (BTEX), organochlorine (OC) pesticides, SVOCs, chlorinated herbicides, dioxins, and furans. Particle size/sieve analyses were also performed to characterize the set of twelve samples associated with the extended suite of analytes.

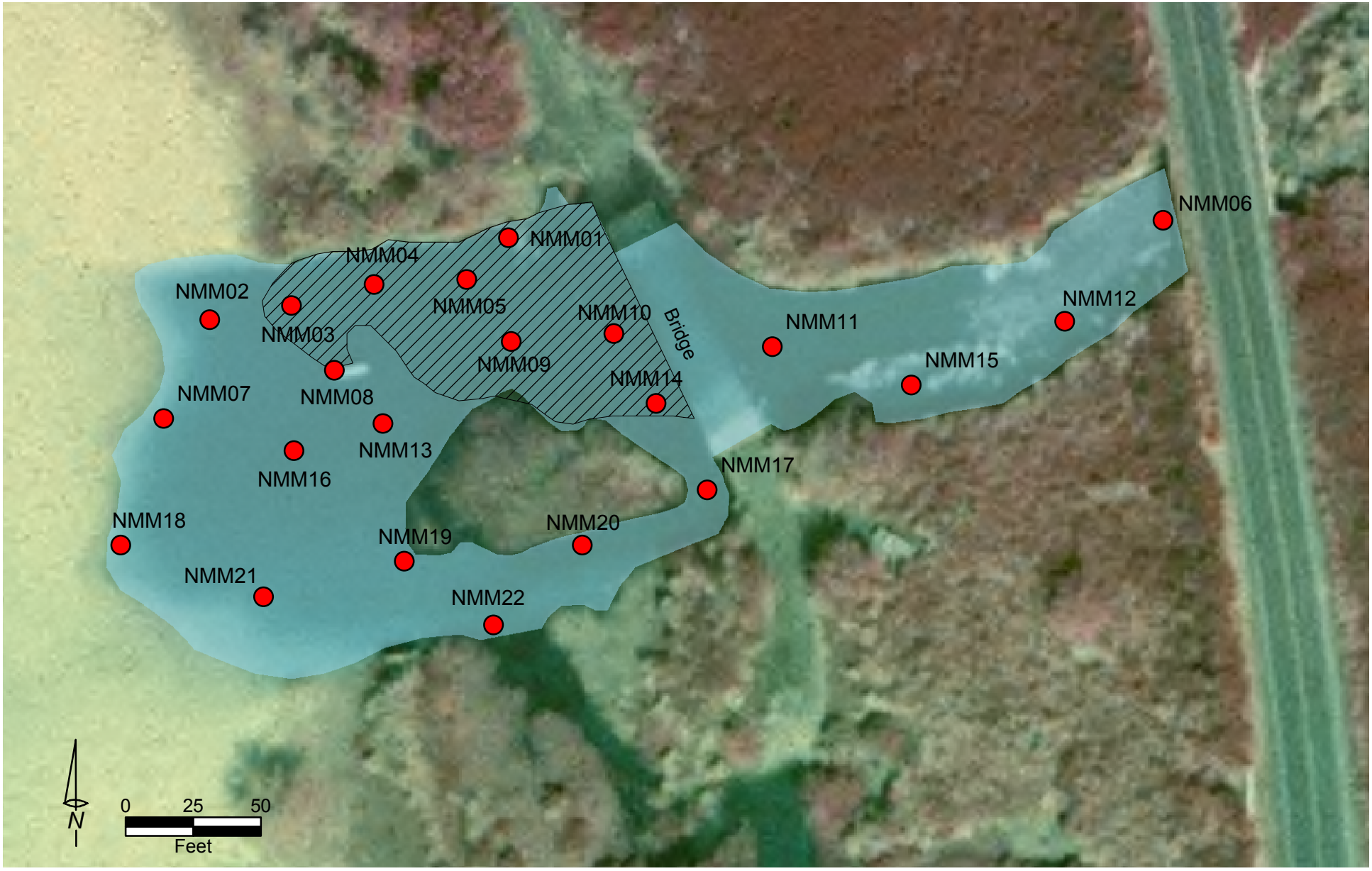
2.2 SAMPLE LOCATIONS

2.2.1 Muliwai Pond Sampling

The sampling locations for the north and south muliwai ponds, and for the dry muliwai are shown on Figures 2-2, 2-3 and 2-4, respectively. The sampling locations of the north and south background sampling sites are shown on Figures 2-5 and 2-6, respectively. The bases of these figures are registered aerial photographs of the ponds supplied by the Army, which depict a period when the ponds were full of water. The sample locations selected for investigation were identified in the field using a global positioning system (GPS) instrument and by reference to features recognizable in the photographs.

The sampling plan called for collecting these samples from an approximate triangular grid laid out over the ponds' boundaries. Twenty-two sediment samples were to be collected from the composited top one foot of the muliwai floor, and another twenty-two sediment samples were to be collected from the composited top three feet of the floor.

The sample collecting procedure was modified due to conditions encountered in the field. Although, as intended, most of the samples were collected as composite samples, the final sample depths varied depending on the location. Those sample locations that were within the high water level of the historical muliwai, but outside of the low water level area shown on the figures representing existing muliwai at the time of the sampling, were covered with wind-blown beach sand. Test pits were dug at these locations in an attempt to visually identify sediments associated with the muliwai floor; however, this sedimentary horizon was not always found. Also, where the test pit or



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Legend

- Sampling Locations
- Low Water Level - covers approx. 0.1771 acres (7,713 ft sq)
- High Water Level - covers approx. 0.8166 acres (35,570 ft sq)

North Muliwai Sample Location Map

Mākua Military Reservation
Oʻahu, Hawaiʻi

Figure 2-2

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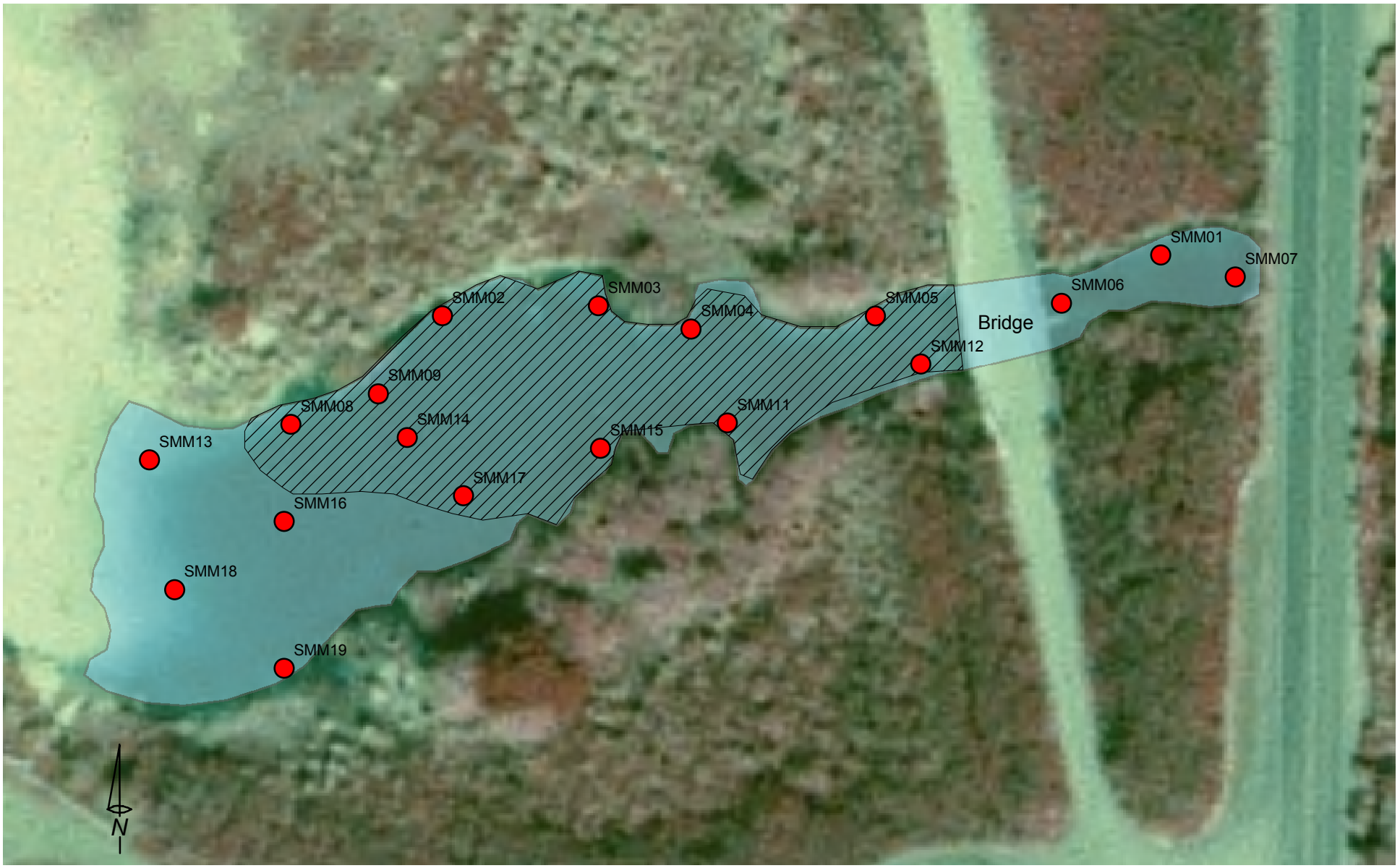

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Legend

- Sampling Locations
- Low Water Level - covers approx. 0.2498 acres (10,879 ft sq)
- High Water Level - covers approx. 0.4915 acres (21,409 ft sq)

South Muliwai Sample Location Map

Mākua Military Reservation
Oʻahu, Hawaiʻi

Figure 2-3

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Dry Muliwai Sample Location Map

Legend

- Sampling Locations

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Mākua Military Reservation
Oʻahu, Hawaiʻi

Figure 2-4

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North Background Area Sample Location Map

Legend

- Sampling Locations

Tetra Tech, Inc

Mākua Military Reservation
Oʻahu, Hawaiʻi

Figure 2-5

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South Background Area Sample Location Map

Legend

- Sampling Locations

Mākua Military Reservation
Oʻahu, Hawaiʻi

Figure 2-6

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sample boring encountered water, both inside and outside of the existing muliwai boundary, the sampling equipment was not always able to penetrate to the desired depth in a single run. Because of the saturated soils at these locations, the test pit or borehole tended to collapse, and maximum sample depths varied. Also, some sample locations were modified in the field due to water depths or obstructions at the planned sample location.

Table 2-1 contains a breakdown of all muliwai samples that were collected and their associated laboratory analytical requests. The Tetra Tech field personnel determined the coordinates of all sampling locations using a GPS instrument. All soil/sediment types observed in the test pits and composite samples were logged by the Tetra Tech field geologist, as summarized in Table 2-2. Copies of the logs are presented in Appendix B.

Table 2-2 shows the sediment samples with their respective sample depth range, and the soil type that was encountered. These soils were classified according to both the visual inspection description from the geologist's logs (Appendix B), and by the contract laboratory sieve analyses, where applicable (Appendix D).

Sediment samples at all of the sampling areas were collected and composited over depth intervals ranging from of 0 to 2 inches (minimum), to 44 to 47 inches (maximum) below the ground surface. In general, the shallowest samples were collected at locations where the sediment was saturated and the walls of the test pits or borings collapsed. Some of the shallow sample intervals were also at locations where large cobbles prevented deeper excavation or drilling. The deeper sample intervals were mostly in areas outside the boundaries of the existing muliwai ponds where test pits were excavated in an attempt to remove the recently deposited aeolian beach sand so that a sediment sample could be collected from the level of the previous pond floor. As noted in Table 2-2, at some sample locations, no visible evidence of the pond floor was observed.

Table 2-1
Muliwai Sampling Location Data

Muliwai (Location[1])	Number of Sediment Samples Collected	
	Metals & Explosives Only[2]	**Full Suite of Analyses Including Metals and Explosives[2]**
North Muliwai Mākua	17 primary samples 0 duplicate samples	5 primary samples 1 duplicate sample
South Muliwai Mākua	13 primary samples 0 duplicate samples	4 primary samples 1 duplicate sample
Dry Muliwai Mākua	3 primary samples 1 duplicate sample	1 primary sample 0 duplicate sample
Background Area (North Stream)	3 primary samples 1 duplicate sample	0 primary samples 0 duplicate samples
Background Area (South Stream)	3 primary samples 1 duplicate sample	0 primary samples 0 duplicate samples

NOTES: [1]See Figures 2-2 through 2-6.
[2]See Table 2-2.

Table 2-2
Muliwai Sediment Type Data

		Visual Classification (ASTM 2488)		Sieve Analysis Classification (ASTM D422/D4464M)	
Sample Number	**Depth (inches)**	**Soil Symbol**	**Soil Type**	**Soil Symbol**	**Soil Type**
BMN-01-MX-1	12 to 14	GM	Gravel-sand-silt		
BMN-02-MX-1	18 to 20	SM	Silty sand with gravel		
BMN-03-MX-1	16 to 18	SM	Silty sand with gravel		
BMS-01-MX-2	22 to 24	CL	Clay		
BMS-02-MX-2	18 to 20	CL	Clay		
BMS-03-MX-1	12 to 14	CL	Clay		
DMM-01-FL-3	24 to 30	SP[1]	Gravelly sand	SP	Poorly-graded sand
DMM-02-MX-3	29 to 33	SP[1]	Poorly-graded sand		
DMM-03-MX-1	12 to 16	SP[1]	Poorly-graded sand		
NMM-01-MX-1	At 12	OH	Organic clay		
NMM-02-MX-1	4 to 16	SP[1]	Poorly-graded sand		
NMM-03-MX-1	9 to 12	SP	Poorly-graded sand		
NMM-04-FL-1	12 to 18	SM	Silty sand	SW	Well-graded sand
NMM-05-MX-1	9 to 12	SM	Silty sand		
NMM-06-MX-1	6 to 12	SW	Well-graded sand		
NMM-07-MX-3	30 to 36	SP[1]	Poorly-graded sand		
NMM-08-MX-1	12 to 18	SW	Well-graded sand		
NMM-09-MX-1	4 to 12	SM	Silty sand		
NMM-10-FL-1	0 to 4	SW	Well-graded sand	SW	Well-graded sand
NMM-11-MX-2	18 to 24	SW	Gravelly sand		
NMM-12-FL-3	19 to 33	SW	Gravelly sand	SW	Gravelly sand
NMM-13-MX-3	30 to 33	CL	Clay		
NMM-14-MX-1	6 to 8	CL	Clay		
NMM-15-MX-1	0 to 11	SW	Well-graded sand		
NMM-16-FL-3	38 to 44	SP[1]	Poorly-graded sand	SP	Poorly-graded sand
NMM-17-MX-2	17 to 20	SP	Poorly-graded sand		
NMM-18-MX-3	44 to 47	SP[1]	Poorly-graded sand		
NMM-19-MX-3	36 to 40	SP[1]	Poorly-graded sand		
NMM-20-FL-1	0 to 12	SP	Poorly-graded sand	SP	Poorly-graded sand

Table 2-2
Muliwai Sediment Type Data *(continued)*

		Visual Classification (ASTM 2488)		Sieve Analysis Classification (ASTM D422/D4464M)	
Sample Number	**Depth (inches)**	**Soil Symbol**	**Soil Type**	**Soil Symbol**	**Soil Type**
NMM-21-MX-3	38 to 42	SP[1]	Poorly-graded sand		
NMM-22-MX-1	At 12	CL	Clay		
SMM-01-MX-1	6 to 9	CL	Clay		
SMM-02-FL-1	0 to 6	SM	Silty sand	SM	Silty sand
SMM-03-MX-1	0 to 4	GM	Gravel-sand-silt		
SMM-04-MX-1	9 to 14	GW	Gravel-sand		
SMM-05-MX-1	0 to 4	OL	Organic silt		
SMM-06-FL-1	6 to 12	CL	Sandy clay	SC	Clayey sand
SMM-07-MX-1	8 to 12	CL	Sandy clay		
SMM-08-MX-1	22 to 24	SW	Well-graded sand		
SMM-09-MX-1	0 to 3	CL	Clay		
SMM-11-MX-1	0 to 2	CL	Clay		
SMM-12-MX-1	0 to 4	CL	Sandy clay		
SMM-13-FL-3	37 to 40	SP[1]	Poorly-graded sand	SP	Poorly-graded sand
SMM-14-FL-1	0 to 4	SM	Silty sand	SW	Well-graded sand
SMM-15-MX-1	0 to 4	SM	Silty sand		
SMM-16-MX-2	24 to 26	SP[1]	Poorly-graded sand		
SMM-17-MX-1	0 to 4	SM	Silty sand		
SMM-18-MX-2	24 to 26	SP[1]	Poorly-graded sand		
SMM-19-MX-3	34 to 38	SP[1]	Poorly-graded sand		

NOTES: [1]Sediment appeared to be aeolian beach sand.

For the 49 primary sediment samples listed in Table 2-2, a variety of sediment or soil types were collected. Sixteen of the samples were poorly graded sand (SP), twelve of the samples were clay (CL), nine of the samples were silty sand (SM), seven of the samples were well graded sand (SW), three of the samples were either well graded gravel (GW) or silt-sand-gravel (GM), and two of the samples were either organic clay (OL) or organic silt (OH). Therefore, the analytical data represent a variety of depositional conditions.

As another indicator of sediment type and depositional setting, TOC analyses were performed on the "full suite" samples. Table 2-3 presents the TOC concentrations and the respective soil types. Based on this small data set, the soil type and TOC

concentrations appear to be poorly correlated. Furthermore, the TOC concentrations do not correlate well with the existing pond footprint. Samples collected inside the pond outline (Figures 2-2 and 2-3) contain both the highest TOC concentration and non-detect concentrations, while samples collected outside of the existing pond footprint also contained a range of detectable and also some non-detect concentrations of TOC.

All of the samples listed in Table 2-3 contained detectable concentrations of nitrate. These concentrations ranged from 3.9 to 19.5 mg/kg. As with the TOC concentrations, there does not appear to be any obvious correlation between the nitrate concentrations and the sediment type or location from which the sample was collected.

Table 2-3
Muliwai Total Organic Carbon (TOC) and Nitrate Data

Sample Number	Depth (inches)	Soil Symbol	Soil Type	TOC (Walkley Black) (mg/kg)	Nitrate (mg/kg)
DMM-01-FL-3	24 to 30	SP	Gravelly sand /Poorly-graded sand	<170	10.1
NMM-04-FL-1	12 to 18	SM/SW	Silty sand/Well-graded sand	<170	19.5
NMM-10-FL-1	0 to 4	SW	Well-graded sand	1,990	12.6
NMM-12-FL-3	19 to 33	SW	Gravelly sand	510	12.9
NMM-16-FL-3	38 to 44	SP[1]	Poorly-graded sand	<170	3.9
NMM-20-FL-1	0 to 12	SP	Poorly-graded sand	1,200	11
SMM-02-FL-1	0 to 6	SM	Silty sand	3,270	13
SMM-06-FL-1	6 to 12	CL/SC	Sandy clay /Clayey sand	<170	12.1
SMM-13-FL-3	37 to 40	SP[1]	Poorly-graded sand	620	4.1
SMM-14-FL-1	0 to 4	SM/SW	Silty sand /Well-graded sand	720	12

NOTES: [1]Sediment appeared to be aeolian beach sand.

2.2.2 Background Sampling

To assess the ambient concentrations of the analytes of concern near MMR, two areas were selected for background sediment sampling ("north stream" and "south stream"). No other muliwai ponds were identified near Mākua Valley. These two background areas were selected as locations where sediments are derived from similar source rocks, but are not likely to have been affected by military activities. The north stream location is at the mouth of the Kaluakauila Stream, approximately 1.3 miles north of the MMR main gate. This streambed was the site used for background sampling during the 1999 USEPA muliwai sampling (USEPA 1999a). The south stream is an unnamed streambed approximately 1.6 miles south of the MMR main gate (Figure 2-1). Both streams were dry at the time of sampling.

Sampling locations at the background sites were selected where the streambeds appear to be relatively flat and the sediments are likely the thickest. Three sediment samples were collected at each of the two background sampling sites, comprising the composited upper one foot of streambed sediment. Table 2-1 lists the background samples that were collected and their associated laboratory analyses.

2.3 ANALYTICAL PROCEDURES

Chemical parameters and analytes of interest included in this sampling project were selected based on the following sources and references and in accordance with the approved SAP for this project:

- Previous investigation results;
- Third-party technical expert review comments;
- Interviews with MMR range personnel;
- Hydrogeologic data from MMR (WES 2004);
- Final Report, RCRA Facility Assessment for MMR (SAIC 1992);
- Federal Facility Preliminary Assessment/Site Inspection Review for MMR (University of Hawai'i, undated);
- Critique of the "Halliburton Study" dated Feb 17, 1999 (Masters 2001); and
- Heavy Metals Survey in Mākua (Char 1977).

Table 2-4 lists the analytes included in each of the analytical methods used in this study. Table 2-5 lists the analytical methods performed for each of the samples submitted. All samples were shipped to the APCL Laboratory in Chino, California. Note that the analysis for dioxins (Method 8280A) was performed by Triangle Laboratories in Triangle Park, New Jersey, and that the particle size analysis (ASTMD1140) was performed by PTS Laboratories in Santa Fe Springs, California.

Table 2-4
Muliwai Analytical Procedures

No.	Parameter	Method	Analyte(s)
1.	**Metals**	USEPA 6010B[1]	Aluminum, Antimony, Arsenic, Barium, Cadmium, Chromium, Cobalt, Copper, Lead, Selenium, Silver, Vanadium, and Zinc
2.	**Mercury**	USEPA 7471A[1]	Mercury
3.	**Cyanide**	USEPA 335.2[2]	Cyanide
4.	**Nitrite**	USEPA 354.1[2]	Nitrite
5.	**Nitrate**	SM 4500D[3]	Nitrate
6.	**TOC**	Walkley Black[4]	Total Organic Carbon
7.	**Perchlorate**	USEPA 314.0[5]	Perchlorate
8.	**Explosives & Energetics**	USEPA 8330[1]	Includes full suite of nitroaromatic and nitramine explosive compounds (e.g., TNT, RDX and HMX), as well as relevant breakdown compounds.
9.	**Nitroglycerine**	USEPA 8332[1]	Nitroglycerine
10.	**BTEX**	USEPA 8021B[1]	Benzene, toluene, ethylbenzene, and xylenes.
11.	**OC Pesticides**	USEPA 8081A[1]	Includes full suite of organochlorine pesticides (e.g., DDT, chlordane, aldrin and dieldrin) as well as relevant breakdown isomers.
12.	**SVOCs**	USEPA 8270C[1]	Includes full suite of semivolatile compounds, including polycyclic aromatic hydrocarbons (PAHs), phthalates, and phenolic compounds.
13.	**Chlorinated herbicides**	USEPA 8151A[1]	Includes full suite of chlorinated herbicides, including phenoxy-acid herbicides (e.g., 2,4-D and 2,4,5-T).
14.	**Dioxins/Furans**	USEPA 8280A[1]	Includes 17 isomers and congeners of tetra through octa chlorine-substituted dibenzo-p-dioxins and dibenzofurans (PCDDs and PCDFs)
15.	**Particle Size**	ASTM D-1140[6]	Particle size/sieve analysis: amount of material in soils finer than the #200 sieve.

NOTES:
[1]Test Methods for Evaluating Solid Waste (SW-846), Final Update IIIB (USEPA 1998).
[2]Methods for Chemical Analysis of Waters and Wastes (USEPA 1983).
[3]Standard Methods for the Examination of Water and Wastewater (APHA/AWWA 1998).
[4]Walkley Black (Soil Science 37:29-37, 1934).
[5]Methods for the Determination of Organic and Inorganic Compounds in Drinking Water (USEPA 2000b).
[6]Standard Test Methods – Book of Standards (Volume 04.08, ASTM).