APPENDIX G-1

HYDROGEOLOGIC INVESTIGATION REPORT

HYDROGEOLOGIC INVESTIGATION REPORT FOR MAKUA MILITARY RESERVATION

By

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SECTION 1: TASK SUMMARIES

1.1 Purpose and Scope

This hydrogeologic investigation report presents information on soil, surface water, and groundwater studies performed as part of the Environmental Impact Statement (EIS) for resumption of live-fire training at Makua Military Reservation (MMR). The workplan prepared for this hydrogeologic investigation was finalized in October 2002 and is available for public viewing on the world wide web site: www.MakuaEIS.com. The Final Sampling and Analysis Plan incorporated changes to the original scope of work based on recommendations and comments received from the public and consultants hired by Malama Makua, made from June to August 2002. Changes to the Sampling and Analysis Plan were added if they were evaluated to be reasonable based on the recommendations of experts, as well as considering the standards of the industry at this time.

The MMR hydrogeologic investigation incorporated soil, sediment, surface water, groundwater, and environmental sampling. The sampling program, summarized in this report, evaluated the potential for compounds associated with present and historic training to be transported beyond the boundaries of Makua Valley. Compounds potentially introduced by Army training operations might be discharged from Makua Military Reservation, and could potentially impact the Muliwai Ponds, or marine resources or wildlife on or near Makua Beach. The work included obtaining samples of surface soils, streambed materials, subsurface soils, water from intermittent stream flows, suspended sediment from intermittent stream flows, and groundwater and comparing these compound levels to current environmental standards and background levels. The work also included collection of additional parameters to refine the general hydrologic site conceptual model of the Makua Valley.

This Appendix outlining the results of the MMR investigation is included as part of the Makua EIS document. It is not intended to be a stand-alone document, so further background on the Makua site will be found in the main body of this EIS document.

This report was prepared by the Engineer Research and Development Center, its contractor DIMCO, Inc., and Environet, Inc., at the direction of the Schofield Barracks DPW Environmental Office and the U.S. Army Corps of Engineers Honolulu District for the use of the U.S. Department of the Army (Army). No other party should rely on the information contained in this report, except for the intended purpose of evaluating the impacts of Army training on soil, groundwater, and surface water within the Makua Valley. This report and the interpretations, conclusions, and recommendations within are based on information in other cited and referenced documents. Therefore, this report is subject to the limitations and qualifications presented in the referenced documents.

1.2 Data Objectives

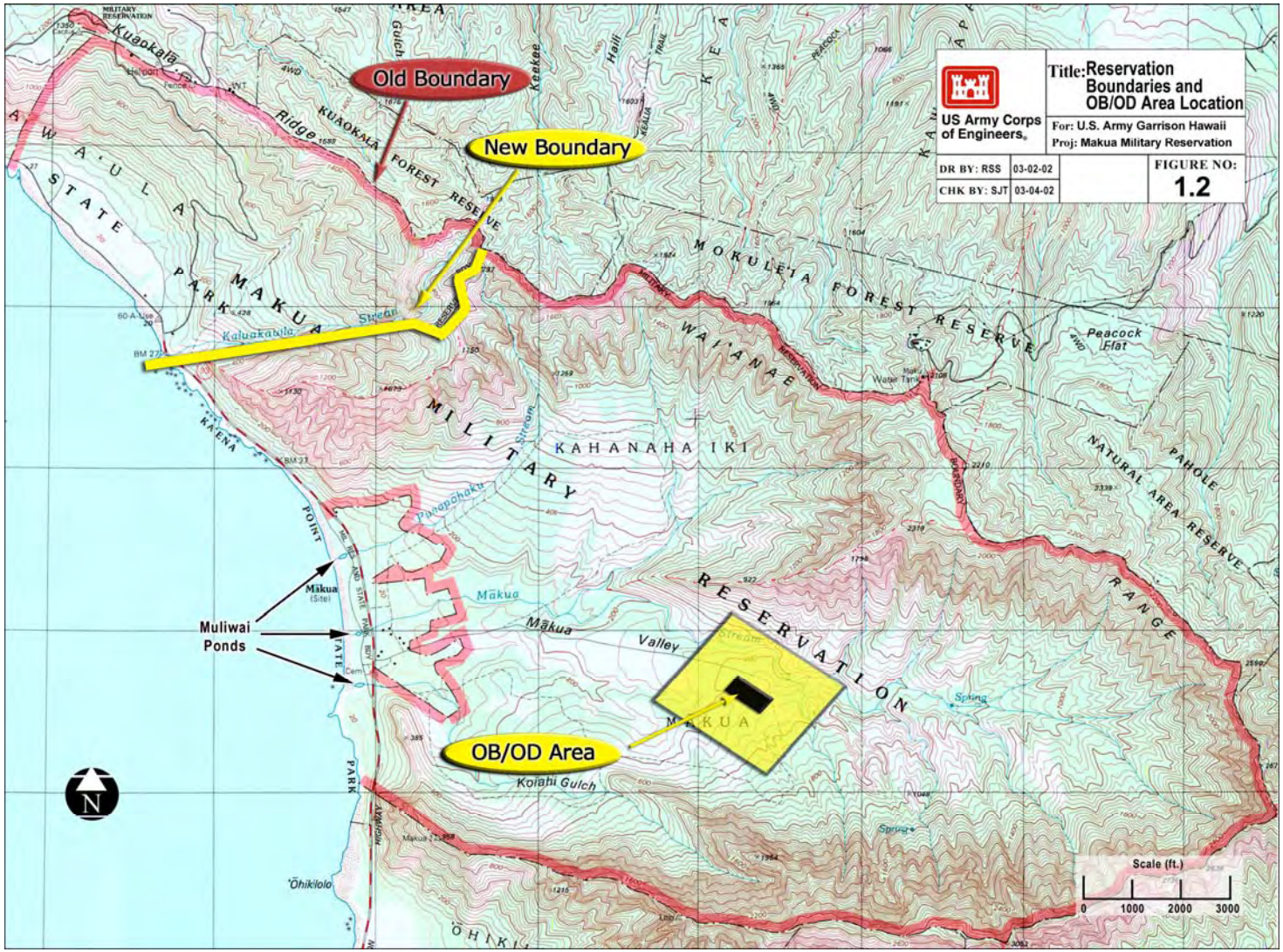
Figure 1.1 shows the location of the Makua Military Reservation on O`ahu, Hawai`i. Figure 1.2 shows the boundaries of the site, and the location of the former Open Burning/Open Detonation Area.

Specific objectives that will be met by the data reported in this document are summarized below:

a. Assess potential sources, types, and the overall degree of potential contamination (defined as compounds associated with military training) within the Open Burn/Open Detonation (OB/OD) area and other areas of MMR, including the PFC Pililaau Range Complex.
b. Evaluate whether contamination from the OB/OD area or the Range Complex has migrated, is currently migrating, or has the potential to migrate off the Makua Military Reservation.
c. Acquire data to be used by the EIS contractor (TetraTech, Inc) in evaluating potential pathways of exposure to off-site receptors.
d. Refine the hydrogeologic site conceptual model for the Makua Military Reservation.
e. Evaluate the potential for erosion of soils, and subsequent discharge of soil particles off-site during large rainfall events in the Makua Valley.

Figure 1.1 Makua Military Reservation Location

Figure 1.2 Reservation Boundaries and OB/OD Area Location



1.3 Tasks Completed

Listed below is a summary of the scope-of-work. The general time period when these tasks were completed is shown in parentheses ( ):

a. Drill two (2) boreholes and collect soil samples from the OB/OD area to depths of approximately 50 feet, and one borehole at the junk car pit to approximately 20 feet, and collect soil samples at 5-foot intervals. Install vadose zone sampling equipment in boreholes at the OB/OD area and the junk car pit (February 2003).

b. Collect four (4) sets of soil samples from streambeds at varying depths of 6, 12, and 18 inches (March 2003).

c. Collect up to three (3) rounds of stream water samples from Makua Streams if the streams flow (February 14, 2003; January 23, 2004; February 27, 2004).

d. Rehabilitate the existing well (SP-7)(September 2002).

e. Install two additional wells (35 feet deep) adjacent to intermittent streams (September to October 2002).

f. Install four deeper monitoring wells (approximately 60-100 feet deep) to sample groundwater chemistry along groundwater flow paths. (October to December 2002)

g. Collect background soil samples for dioxin/furans and metal compounds (February and September 2003).

h. Perform fate and transport calculations using both surface water and groundwater computer models (May to September 2003).

i. Collect 102 soil samples from 18 areas of concern, 19 additional surface soil samples, and 10 background samples from outlying areas of Makua Military Reservation (September 2002 to February 2003).

j. Drill one deep monitoring well between the OB/OD areas and the ocean (December 2002).

k. Install and monitor rainfall measurement equipment in Makua Valley (September 2002 to September 2003).

l. Collect six (6) quarterly rounds of groundwater samples from the monitoring wells (December 2002 to December 2003).

SECTION 2.0: EXPLANATION OF TASKS COMPLETED

2.1 Unexploded Ordnance Clearance

There was the potential for encountering unexploded ordnance (UXO) throughout the MMR, so precautions were taken during all investigative work to avoid UXO. During the duration of the fieldwork, only limited pieces of ordnance were encountered. This included remnants of fuses and metal shrapnel at the OB/OD area.

2.2 Shallow Soil Samples

This section of the Work Plan describes the overall approach that was used to collect soil samples at Makua Military Reservation (MMR). Detonation of ordnance has the potential to release compounds to the surface soils in the Makua Valley. To evaluate this, eighteen areas of concern in the training areas have been identified (Table 2.1) and shallow soils within those areas were sampled. A total of 102 discrete soil samples were collected from these areas of concern. An additional 22 soil samples were collected outside of the central training areas of MMR. The objective of the soil sampling was to evaluate if concentrations of potential contaminants within the surface soils are present at detectable levels at MMR.

The samples were collected as discrete samples biased toward visual observations. The sampling focused on areas of obvious or suspected contamination and runoff pathways. Field discretion has been used to refine the soil sampling locations and provide for representativeness of the areas of concern being investigated. This method maximizes the potential for compounds to be found by the shallow soil-sampling task.

2.2.1 Soil Sampling Procedure

Soil sampling locations were chosen to be representative of the areas of concern to be investigated. Each surface soil sample was collected as a discrete sample within an area of concern that may have been impacted by military operations. The sample locations were biased toward any visible signs of surficial or point-source contamination, or areas that exhibited either enhanced or retarded vegetation growth. These locations also included the target berms that are

used to stop mostly small arms projectiles (mainly caliber 223, 5.5 mm, 7.62 mm and caliber 50) or depressions caused by larger projectiles such as 105mm.

Each surface soil sample collected and submitted for analysis was a discrete sample located within a training area that had the potential to be impacted by military operations. This was done to meet the requirement of Region IX U.S. EPA, which does not endorse or permit composite sampling, but rather prefers discrete sampling. Composite sampling is thought to dilute the sample and mask potential detections. Prior to sampling, surface vegetation, rocks, pebbles, leaves, and twigs were cleared from the sampling point to allow collection of a representative material. In the case of an obstacle, the sample point was shifted off the nearest edge of the obstacle and the soil sample collected. For UXO, which during this exercise consisted of metal fragments, the sampling point was shifted to the nearest cleared point. Sampling equipment was decontaminated away from the sampling point. Decontamination procedures include cleaning the sampling device with a non-phosphate surfactant, a distilled water rinse, and finally another distilled water rinse.

Each shallow sampling interval was exposed and the sample taken using a pre-cleaned disposable plastic sampling device or a decontaminated metal sampling scoop. Once the sample was obtained, it was field screened with a GR-110 Exploranium Gamma Ray Scintillometer for gamma radiation. This instrument records gamma radiation. Radioactive contamination from an alpha or a beta source will occur in conjunction with a gamma source, so that measuring for gamma is a very good tool for screening for radioactive contamination. As part of this study, it was necessary to evaluate site-specific background levels of radiation at MMR, and also to perform a separate evaluation of off-site background levels. Measurements obtained in the field were compared to these background levels, as explained in Section 3.6. Background radiation levels were determined by surveying several areas across O`ahu.

The collected shallow soil sample was homogenized in a pre-cleaned stainless steel bowl. The sample was then placed in a certified clean wide-mouth jar and sealed with a Teflon-lined

lid. Twenty-five (25) of the discrete soil samples were analyzed for soil moisture content, grain size analysis and soil salinity. These data provided additional information for estimating erosion of soils and were utilized in the fate and transport analysis (Section 3.9).

2.2.2 Objective Deer

Objective Deer training area, located in the central portion of Makua Valley, consists of 17 target positions in the trench legs (as "pop-up" targets) and eight target positions (berms) in the center of the trench system. Because this large and relatively topographically flat site is one of the more heavily used objectives, randomly selected discrete soil samples were collected with a bias toward visible or point sources of surface impacts, including bare areas or areas of visible distressed vegetation. A total of 15 soil samples were collected at Objective Deer (Figure 2.1). Eight discrete soil samples were collected from the pop-up target positions within the various trench legs, and seven were collected from the target positions in the center of the trench systems (Figure 2.1).

2.2.3 Objective Coyote

This training area consists of 22 target positions (berms) on a topographic high that projects slightly into Makua Valley (Figure 2.2). A total of eight discrete soil samples were collected from the berms located on the east and west sides of the service road (four on the east side and four on the west side of the service road; Figure 2.2) that runs through the site. Mainly small arms projectiles (caliber 223, 5.5 mm, and 7.6 mm) were observed associated with the berms. Samples were biased towards any concentrations of projectiles or associated bare/bald areas.

Figure 2.1 Objective Deer

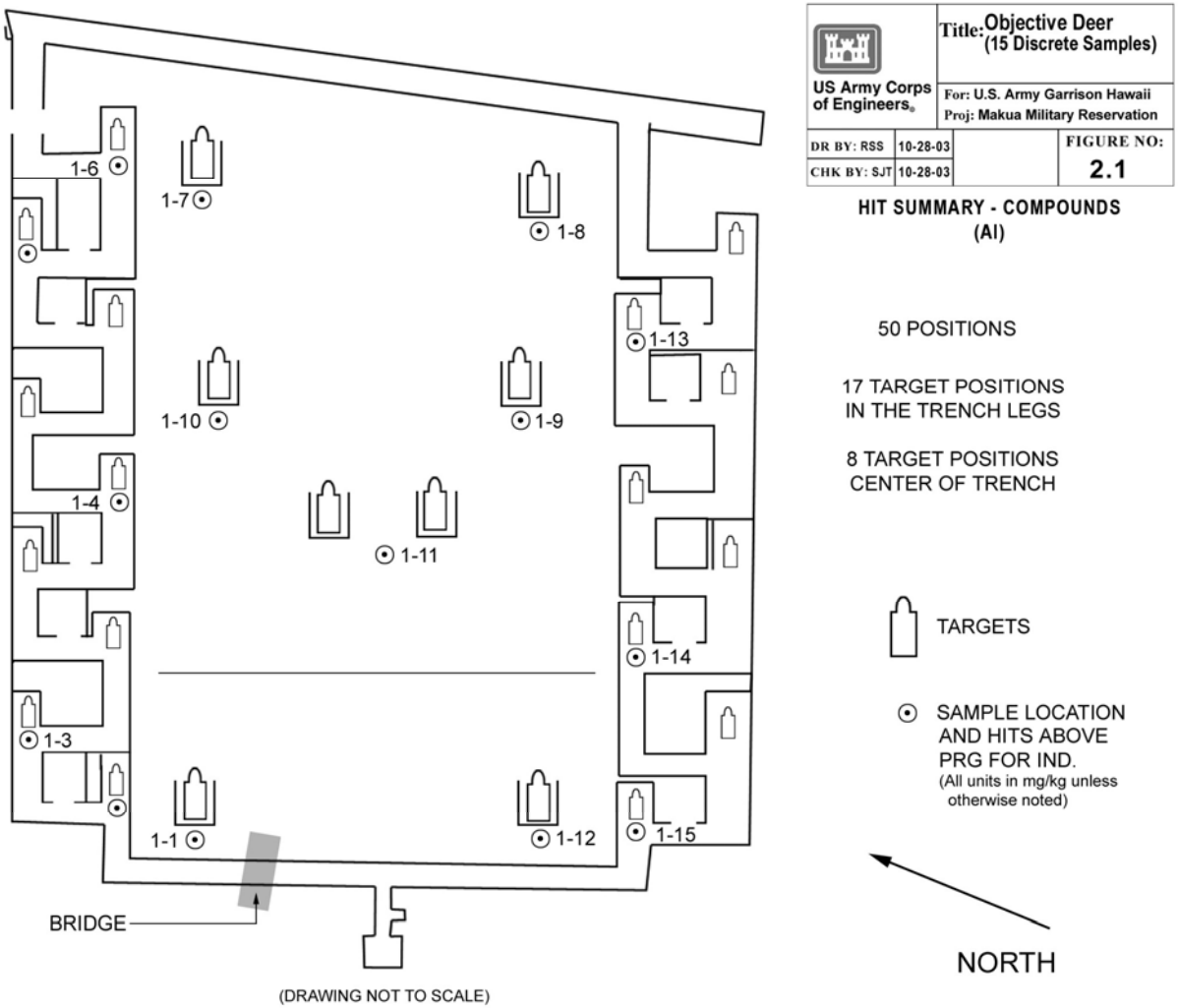


Figure 2.2 Objective Coyote

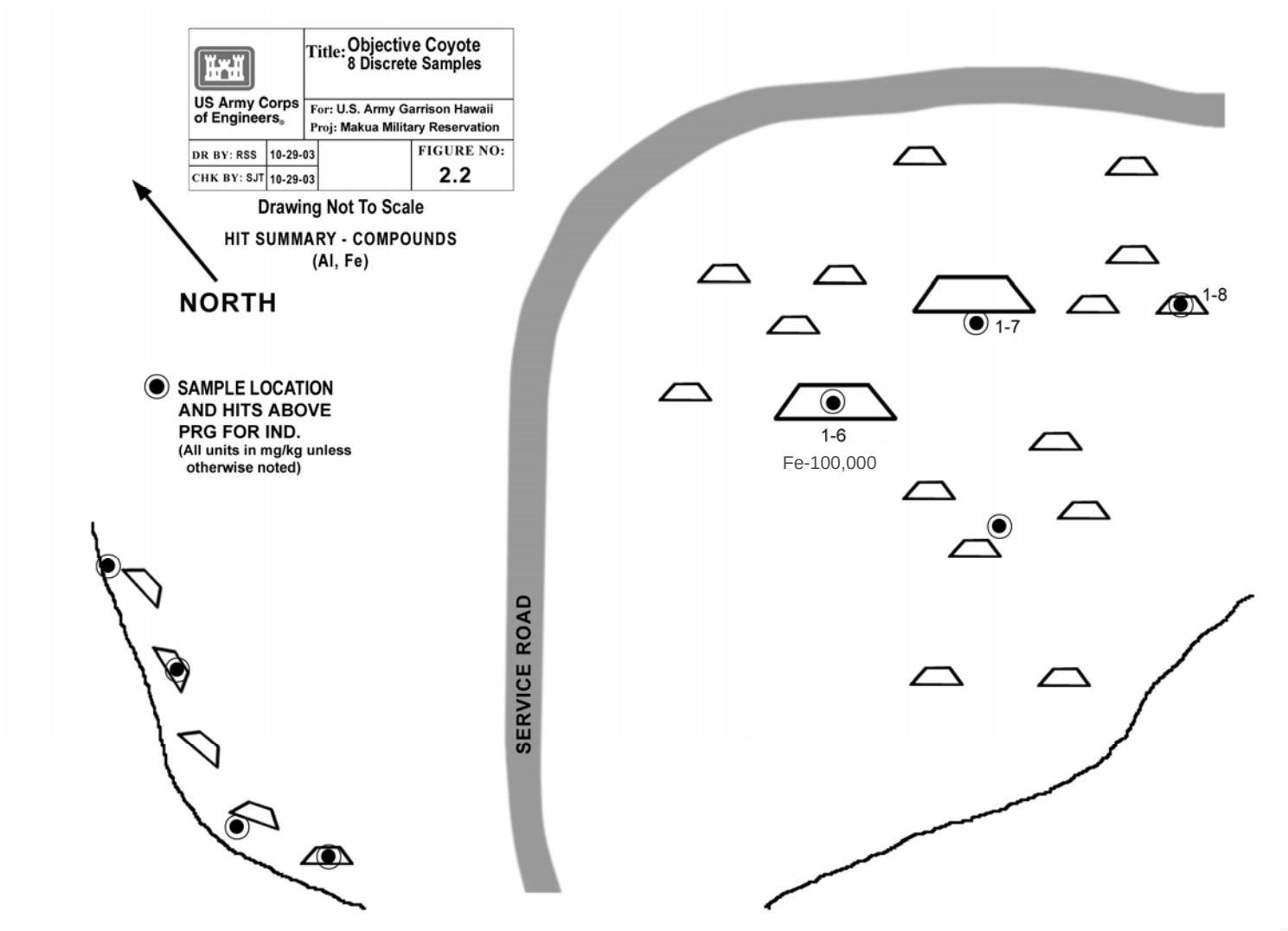


Table 2.1 Summary of Shallow Soil Sampling for Makua Military Reservation

Areas of Concern	Number of Samples to be collected
Objective Deer	15
Objective Coyote	8
Objective Fox	3
Objective Wolf	6
Objective Elk	10
Objective Deeds	3
Objective Badger	10
Objective Buffalo	6
Counter Attack Positions	14

Table 2.1 (Continued)

Summary of Shallow Soil Sampling for Makua Military Reservation

Areas of Concern	**Number of Samples to be collected**
105 Firing Area	2
Proposed Burn Pit	1
Makua Stream Firing Area	3
Weather Station Burn Pan	1
OB/OD Area	5
Demolition Pit (Area)	2
Area G	3
Misc. Training Areas	5
Deer Berms	5
Outlying Areas	22
Background Samples (metals)	10

2.2.4 Objective Fox

This training area consists of 8 target positions (berms) located in the lower elevations and parallel to the axis of Makua Valley. A total of three discrete soil samples were collected from three target positions in Objective Fox (Figure 2.3). A slight number of mostly caliber 223, 5.5 mm and 7.62 mm projectiles were observed in the berms. Soil samples were biased toward areas with a high concentration of projectiles on or within these berms.

2.2.5 Objective Wolf

This Objective consists of 14 target positions (berms) located on a small, low relief topographic "nose." Objective Wolf is the most forward position used for training in MMR. A total of six discrete soil samples were collected adjacent to the berms located northeast of the service road (Figure 2.4). Samples were biased toward bare areas observed within this position.

2.2.6 Objective Elk

This training area consists of 15 target positions (berms) located in the southern portion of Makua Valley. The 15 positions are situated around five large "tire forts" prominently visible on a small topographic nose in the southern areas of MMR. A total of 10 discrete soil samples were collected from four sites within Objective Elk (Figure 2.5). Five of the discrete samples were collected inside each tire fort (along walls or near pop-up targets positioned inside) and five were collected from the target berms located adjacent to the tire forts (Figure 2.5). Samples were biased toward concentrations of small arms projectiles and bald areas associated with the target berms and tire forts.

2.2.7 Objective Deeds

This training area consists of three fixed target positions located east of the service road. A total of three discrete soil samples were collected from three sites within Objective Deeds (Figure 2.6). Because of the rugged location (high relief) of these target positions, the three samples were collected on the front portions of the "berms" with a bias toward areas that had concentrations of small arms projectiles (mainly caliber 223, 5.5 mm, 7.62 mm and caliber 50) or areas that appeared to have less vegetation than adjacent areas.

Figure 2.3 Objective Fox

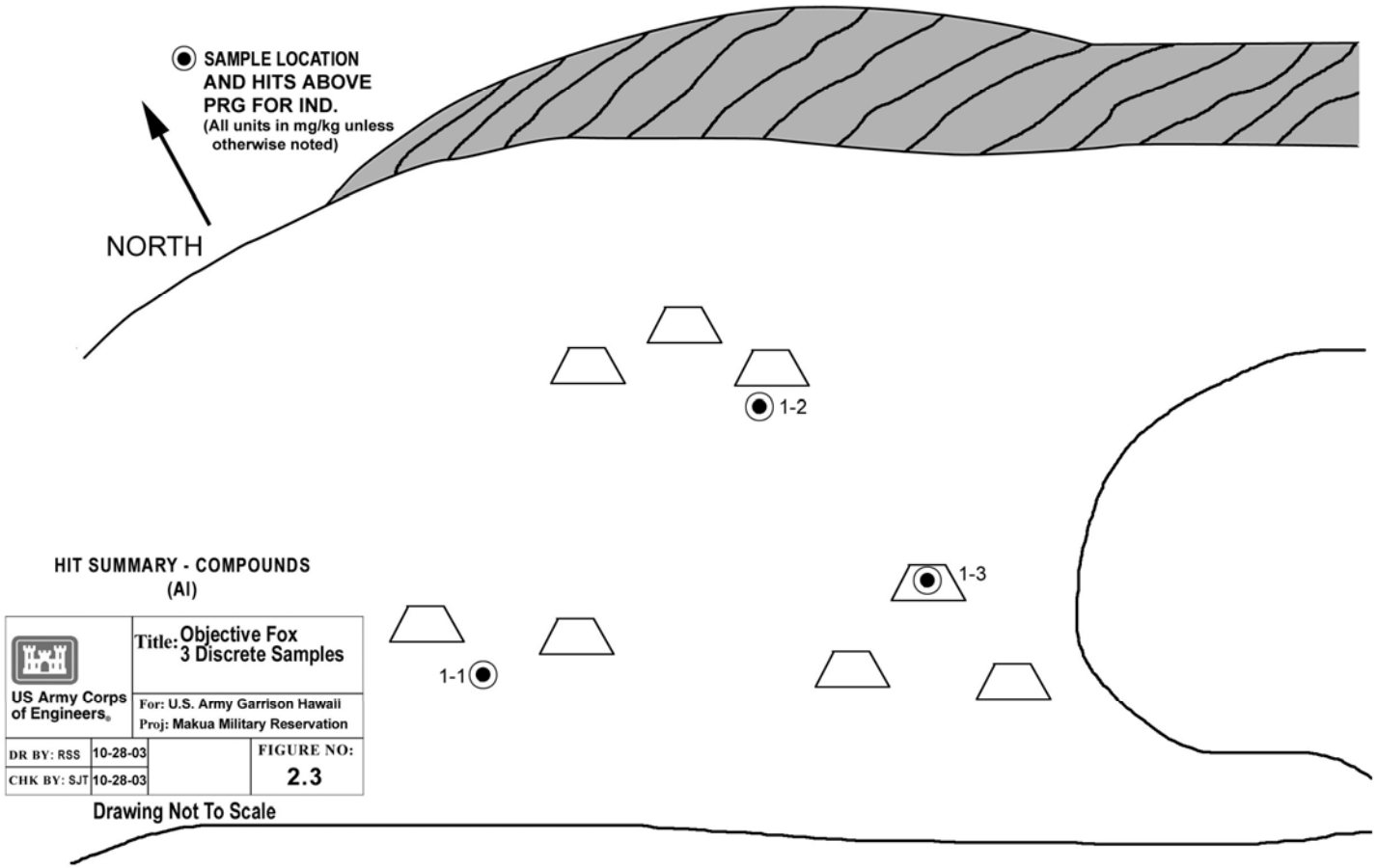


Figure 2.4 Objective Wolf

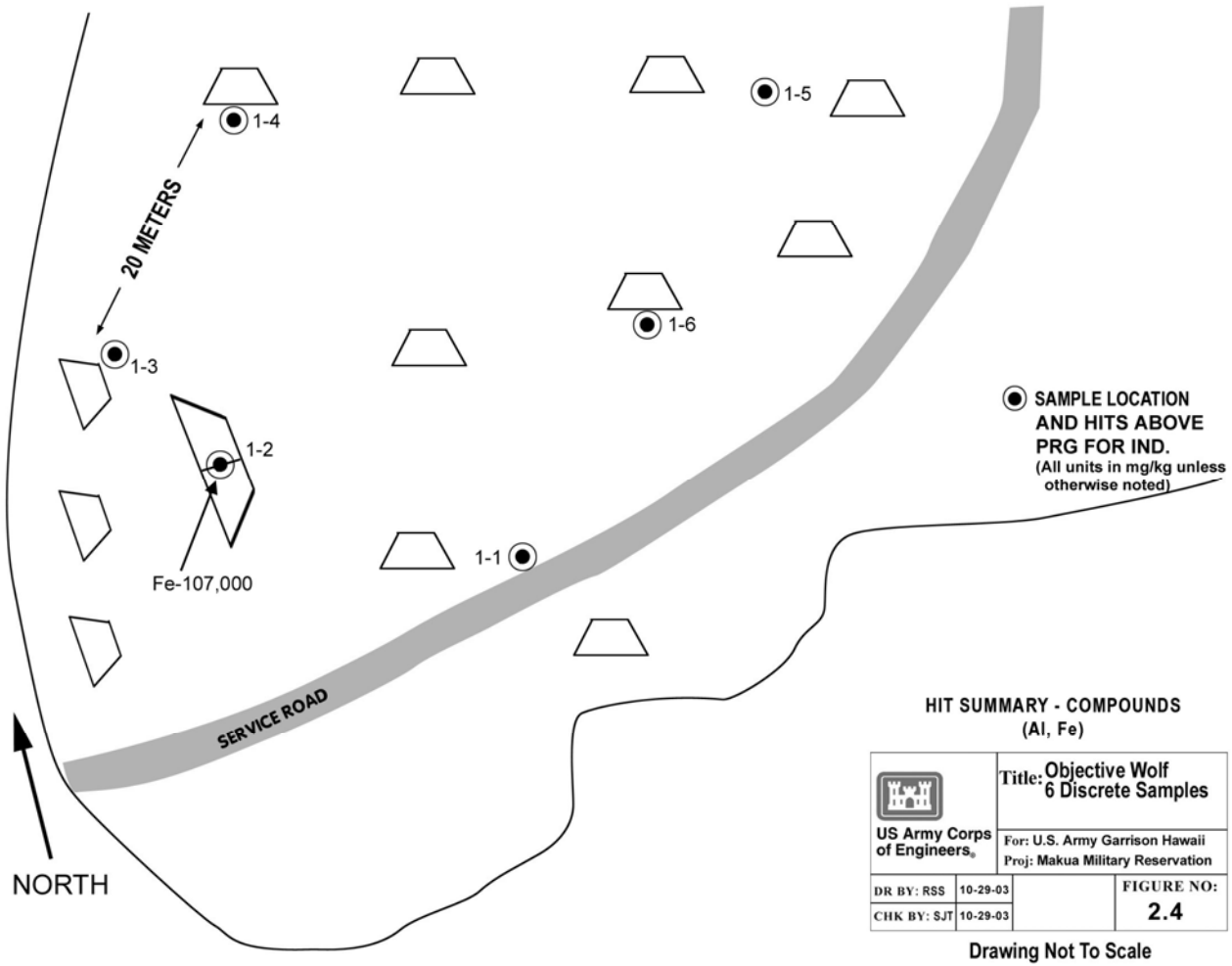


Figure 2.5 Objective Elk

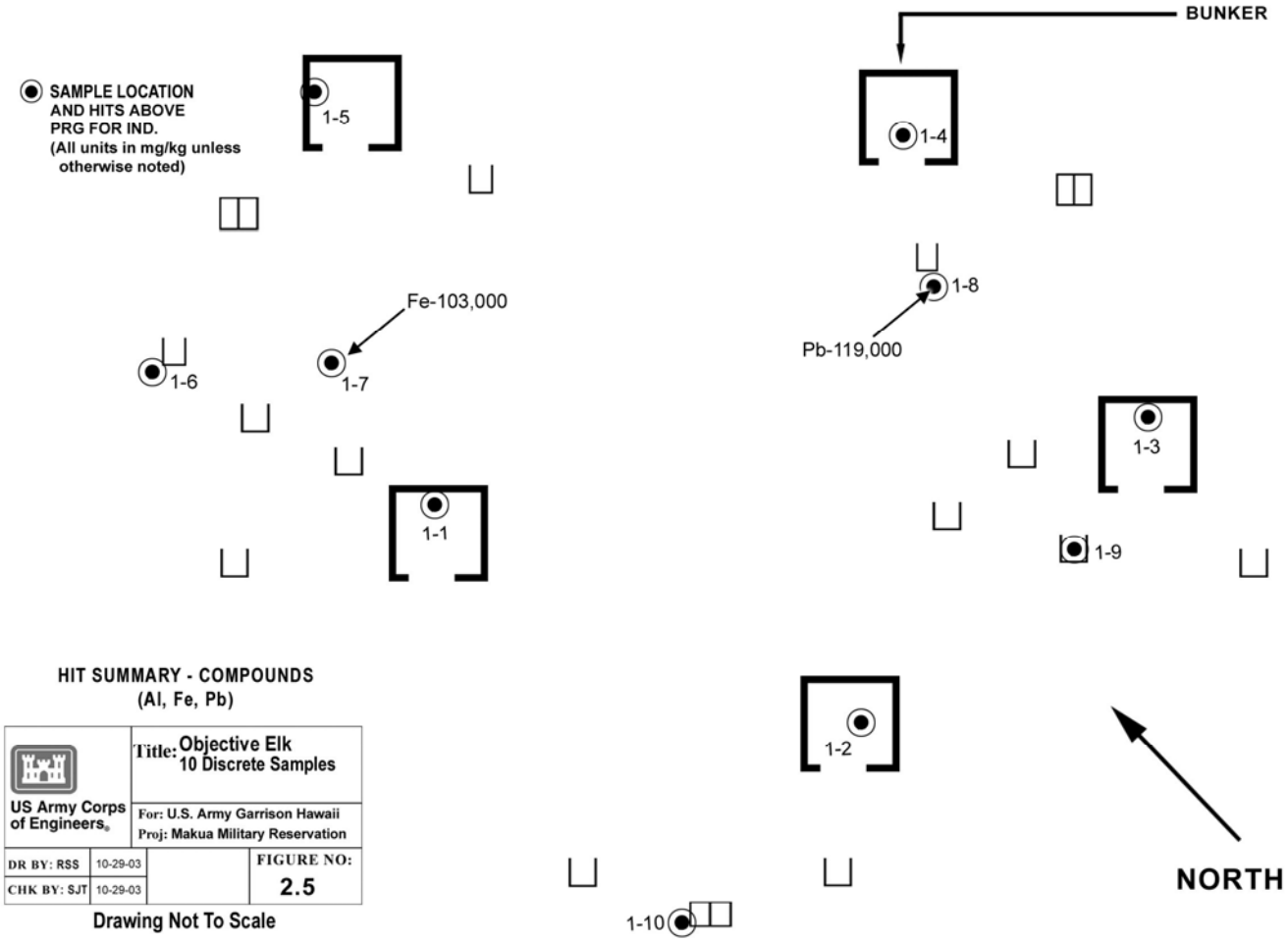
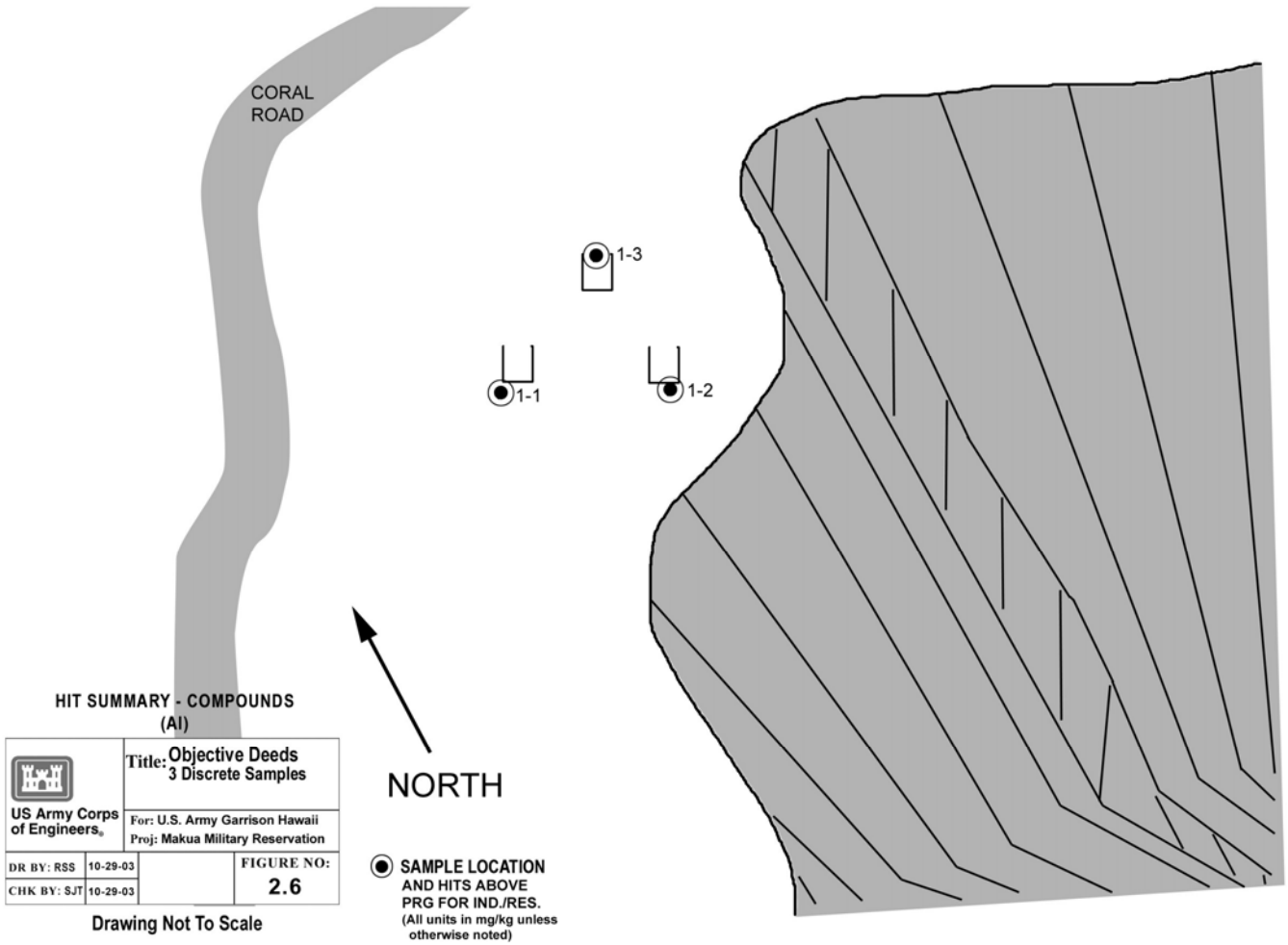


Figure 2.6 Objective Deeds



2.2.8 Objective Badger

This training area consists of five fixed positions reinforced with automobile tires (tire forts). A total of 10 discrete soil samples were collected from the five sites within or adjacent to the tire forts of Objective Badger (Figure 2.7). The five samples within the tire forts were collected along the walls or in areas near the pop-up targets located inside. Additionally, five samples were collected adjacent to the tire forts in areas that appeared to be in the "direct line of fire" during a combined-arms live-fire exercises (CALFEX).

2.2.9 Objective Buffalo

This training area consists of 11 fixed target positions (berms) and a small adjacent trench line just south of the service road. This objective is located on the rocky and rugged portion of an alluvial fan associated with Kaiahi Gulch. Five discrete soil samples were collected from the fixed target berms, and one was collected within the trench line associated with this objective (Figure 2.8). Soil samples collected at Objective Buffalo were biased toward bald areas associated with the target berms or the trench line.

2.2.10 Counter Attack Area

This training area consists of a broad, relatively flat area of 50 fixed target positions (berms). A total of 14 discrete soil samples were collected from the Counter Attack Area (CAA) (Figure 2.9). Because the CAA covers a large area, 14 discrete soil samples were collected in representative areas bare of vegetation, locations that were in the "direct line of fire" during a CALFEX, or concentrated zones of small arms projectiles (mainly caliber 223, 5.5 mm, 7.62 mm and caliber 50).

2.2.11 One Hundred and Five (105) Firing Area

This area consists of a firing position for 105 mm artillery. This topographically flat area is the position of 105 mm artillery pieces that fire uprange toward the designated objectives during a CALFEX. A total of two discrete soil samples were collected at this location (Figure 2.10).

The two samples were collected in front of the artillery pieces (in slightly bare areas) in line with the 105's muzzle and the general direction of artillery fire (Figure 2.10)

Figure 2.7 Objective Badger

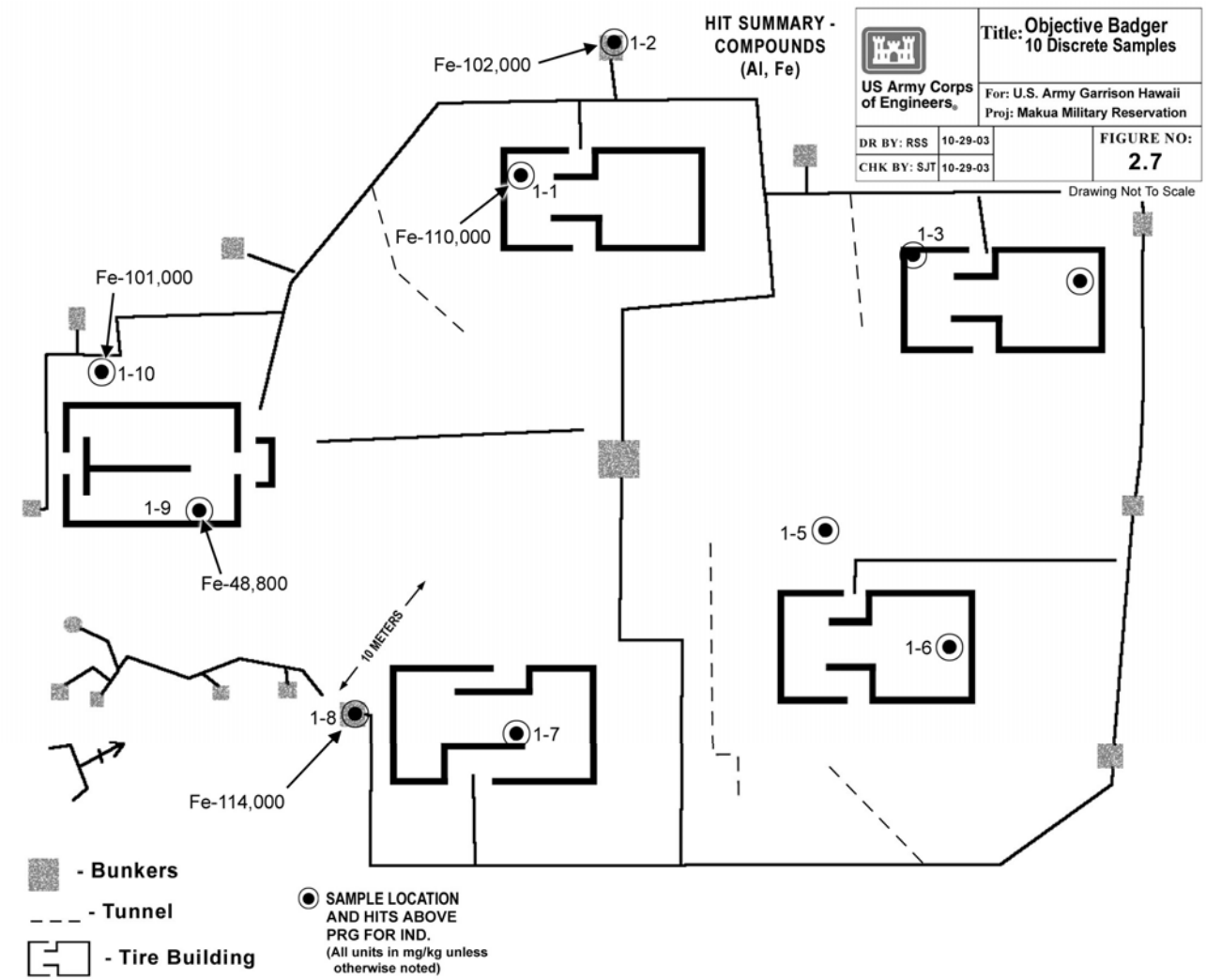


Figure 2.8 Objective Buffalo

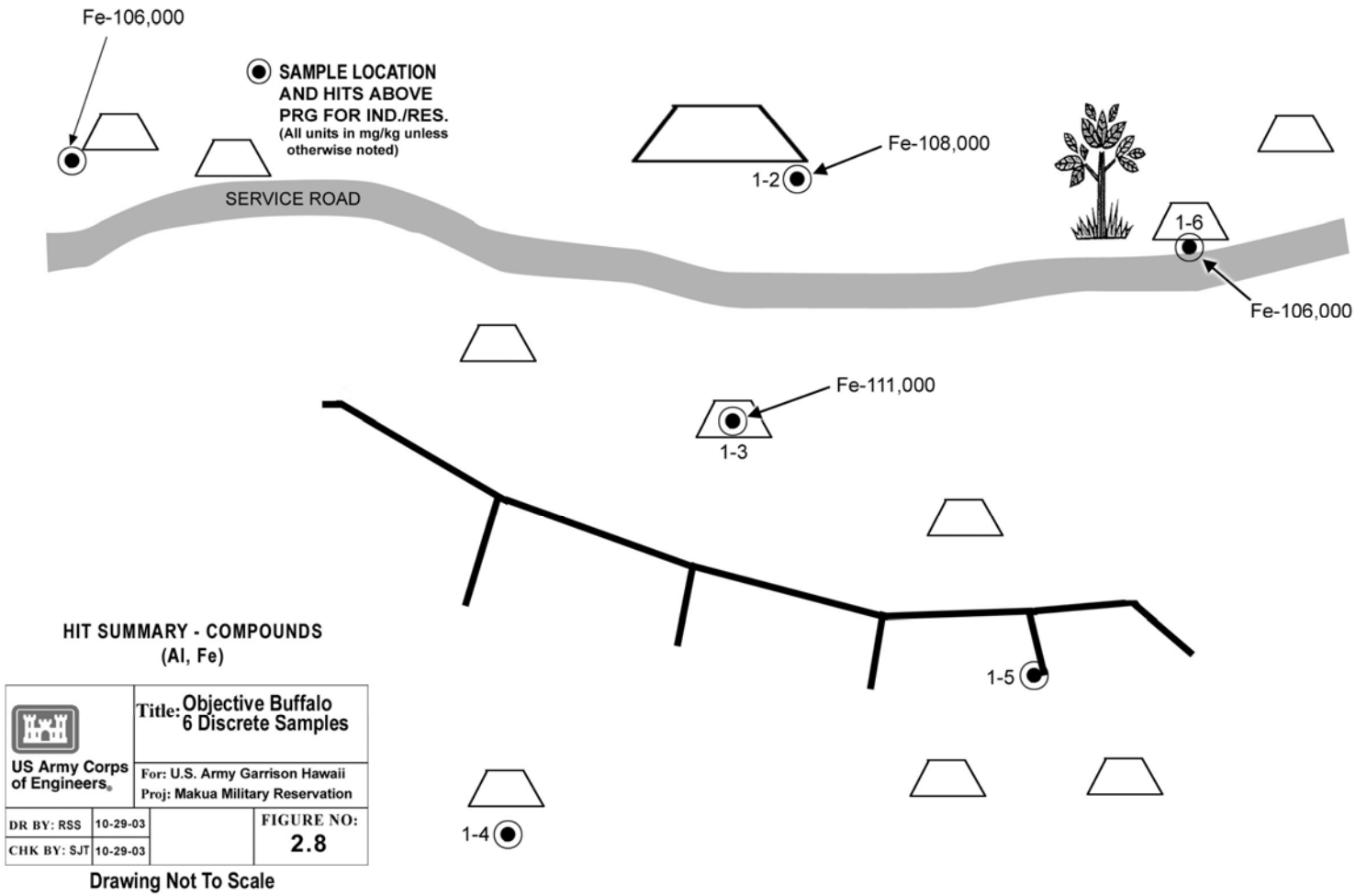


Figure 2.9 Counter Attack Area

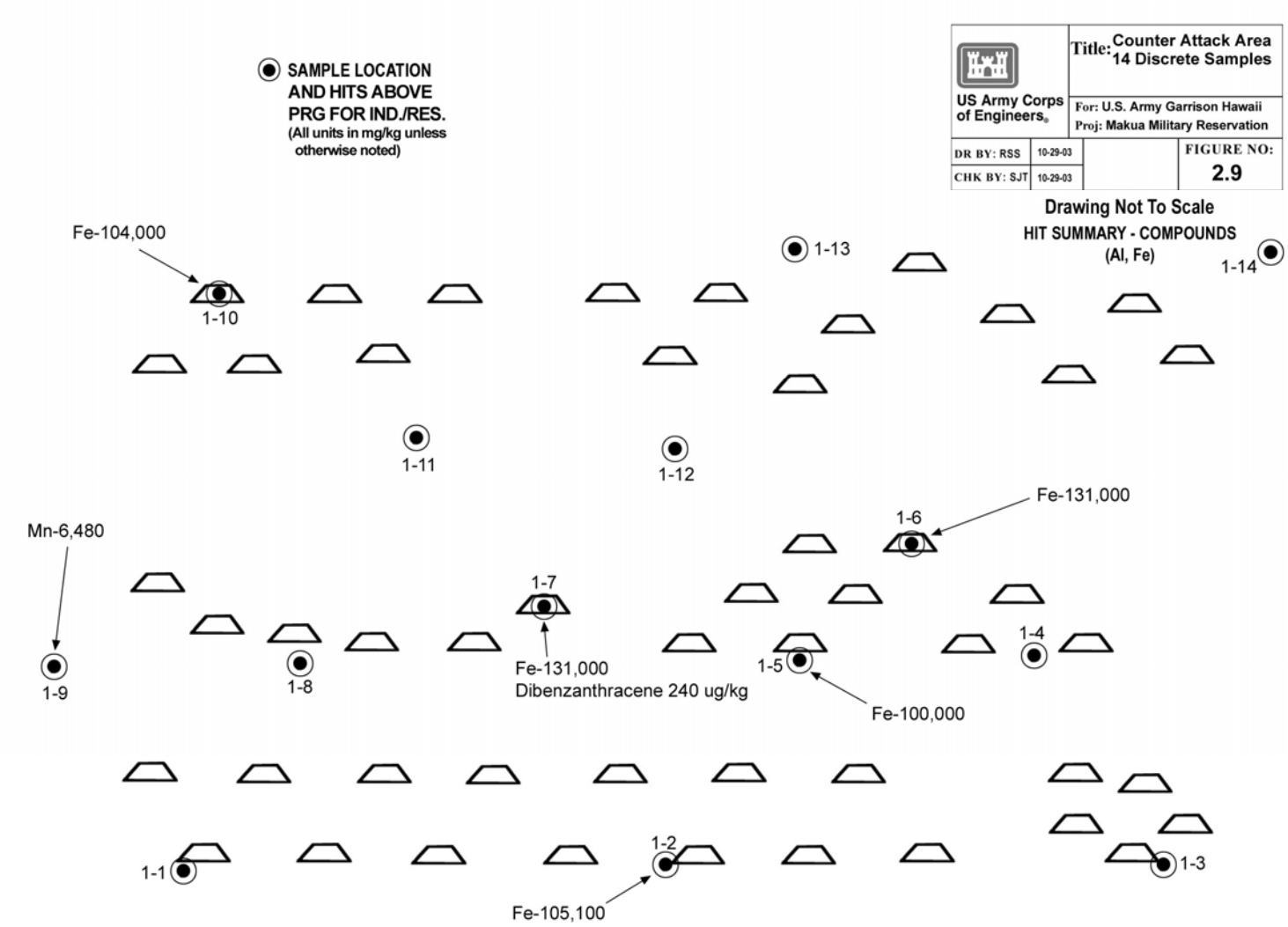


Figure 2.10 Makua Military Reservation Soil Sampling

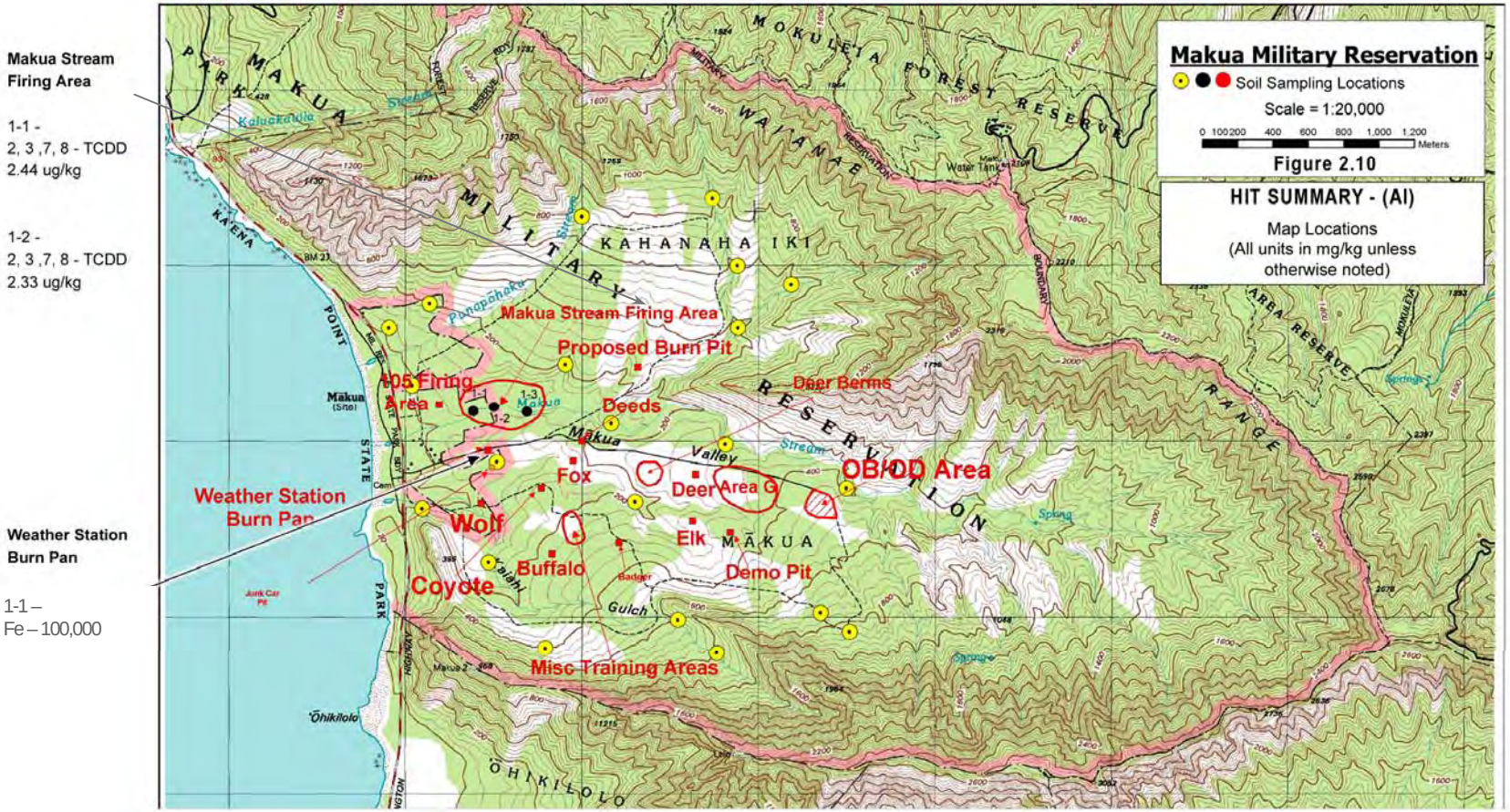


Figure 2.11 Makua Military Reservation Soil Sampling

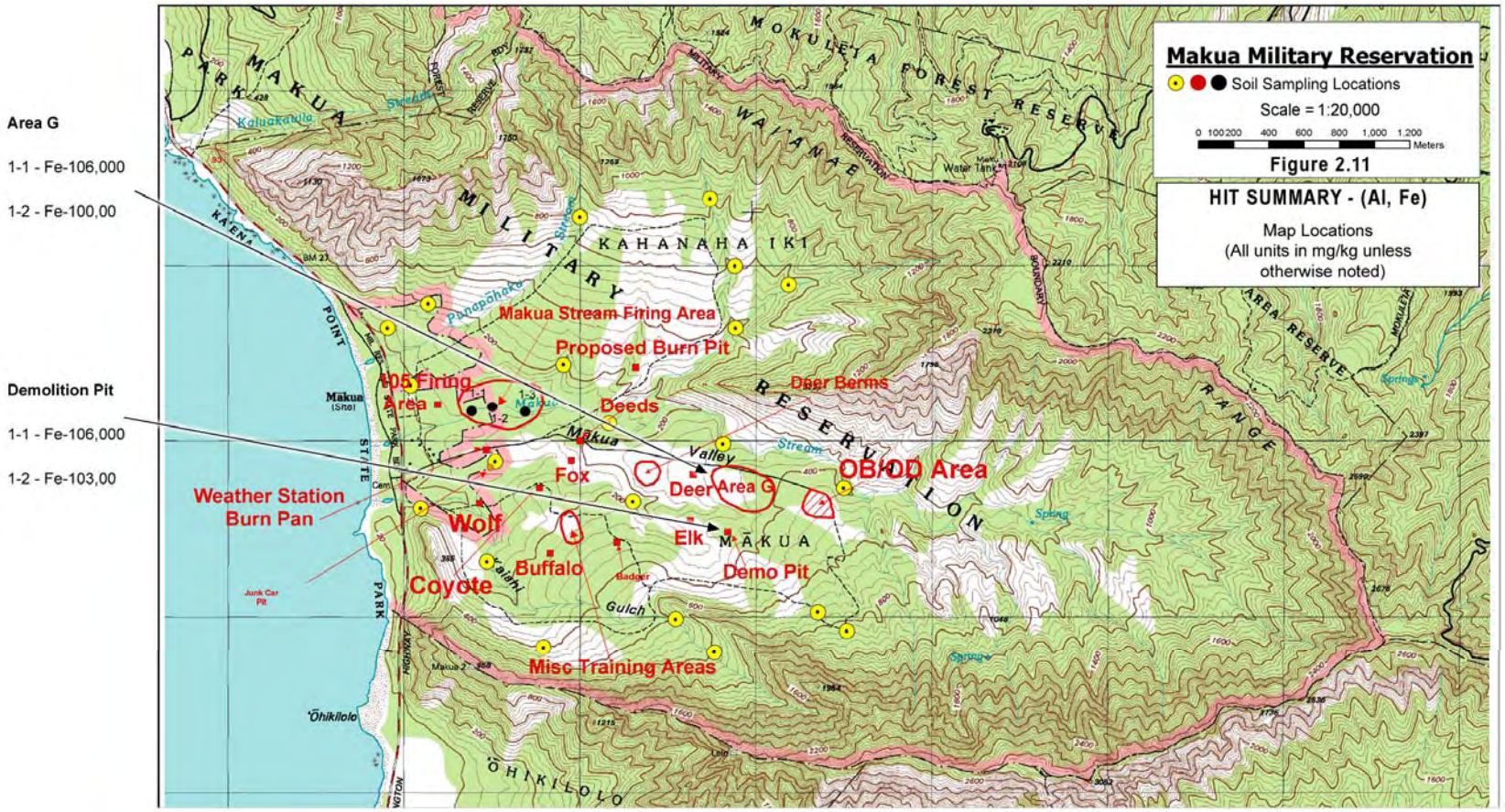


Figure 2.12 Makua Military Reservation Soil Sampling

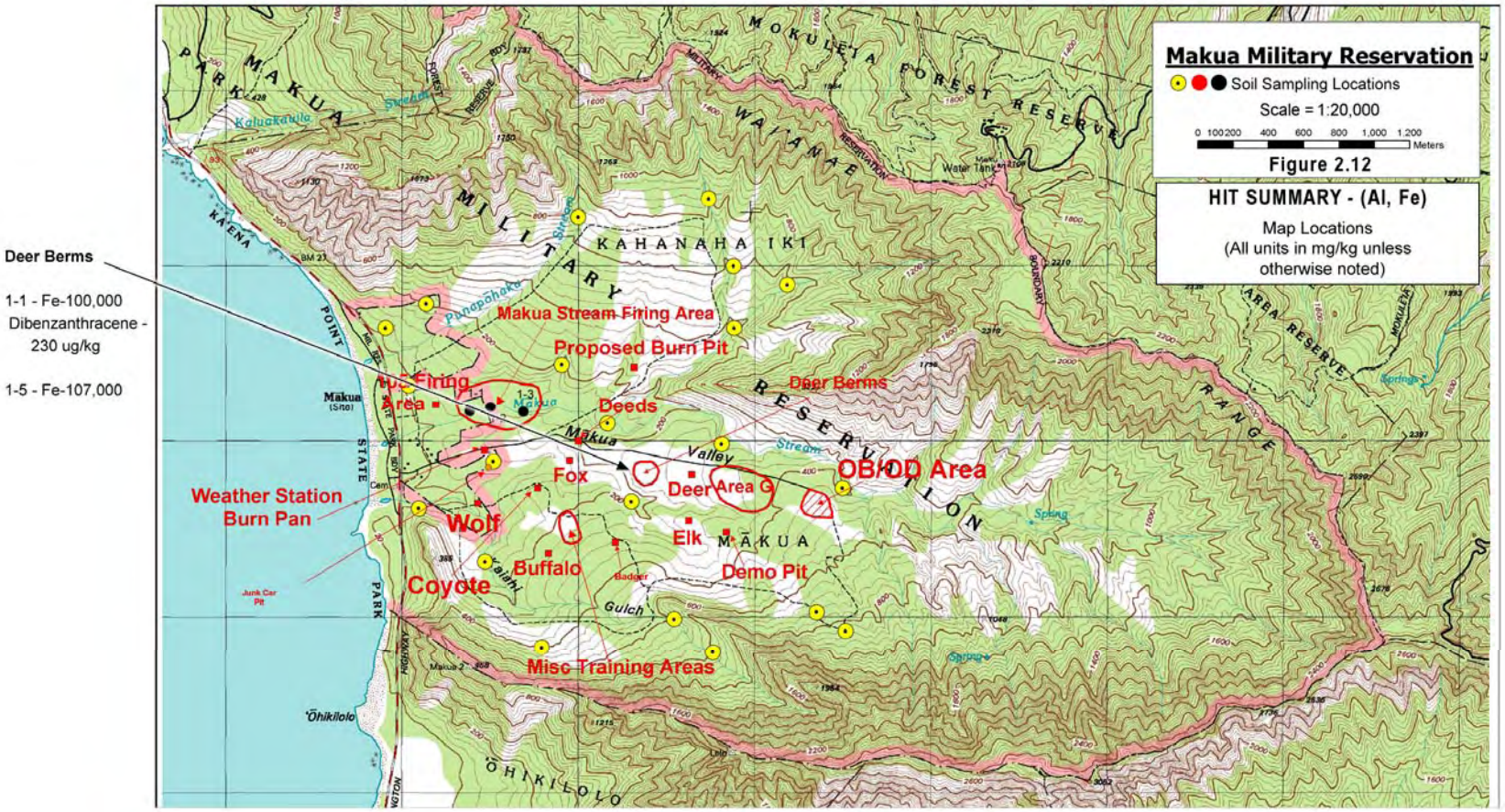
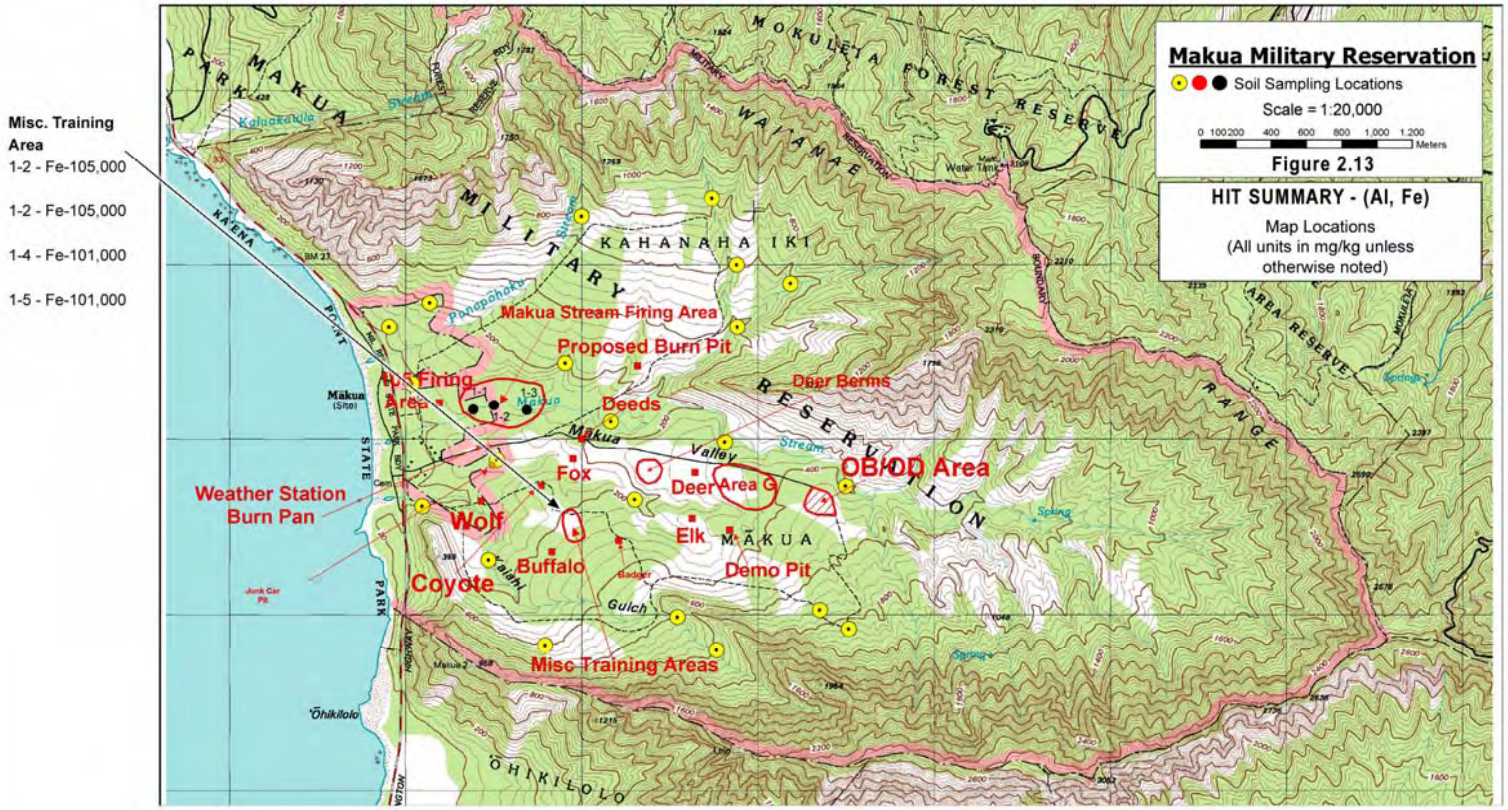


Figure 2.13 Makua Military Reservation Soil Sampling



2.2.12 Proposed Burn Pit

One discrete soil sample was collected at the Proposed Burn Pit (Figure 2.10). The proposed burn pit is located on the north firebreak road on a broad alluvial fan that trends from Kahanakahiki. The Burn Pit was never installed or used as a burn pit, but a discrete sample was collected at this location to verify the site status. The sample was collected in an area where a natural drainage would concentrate any soil contaminants located at the site.

2.2.13 Makua Stream Firing Area

Three discrete soil samples were collected in the Makua Stream Firing Area. This area is within the "firing footprint" of the 105 mm Artillery pieces. The three discrete samples were collected uprange of the 105 firing area in the "drainage area" associated with Makua Stream. The samples were collected in overbank deposits that are in the "line of fire" for the artillery pieces during a CALFEX.

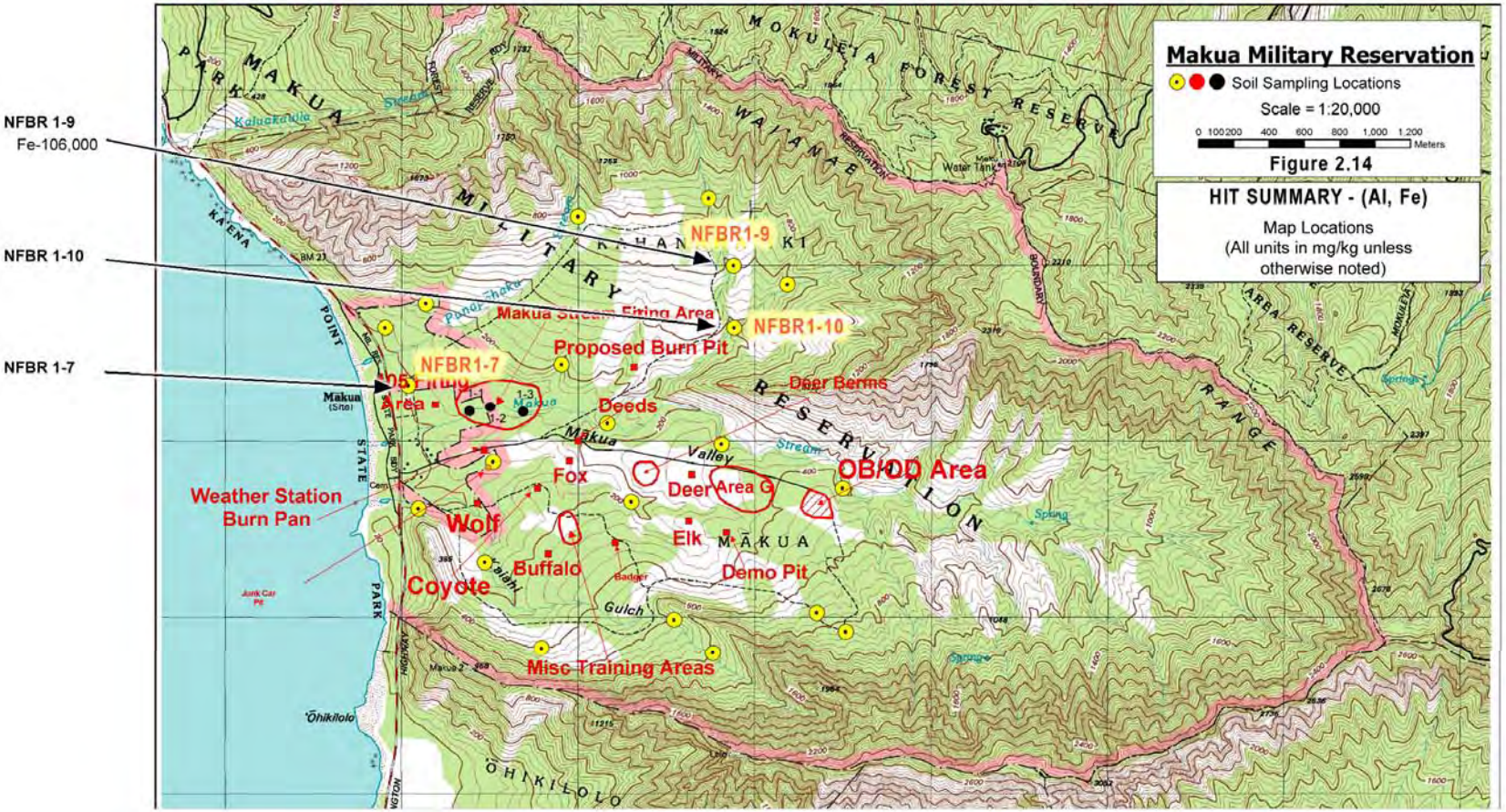
2.2.14 Weather Station Burn Pan

One discrete soil sample was collected from the burn pan at the weather station (Figure 2.10). The area sampled was a discolored area in a small depression that was barren of vegetation.

2.2.15 OB/OD Area

Five shallow soil samples were collected in the Open Burn/Open Detonation Area (Figure 2.15). Because of the presence of UXOs in this area, (and very thick vegetation) clearance was required for the traverses into and out of the sampling area as well as the sampling location itself. The five samples were collected in areas that were either small topographic depressions or slightly less vegetated and/or discolored areas.

Figure 2.14 Outlying Soil Sample Locations



2.2.16 Demolition Pit (Area)

Two discrete soil samples were collected from the Demolition pit (Figure 2.11). These samples were both collected in areas that were barren of vegetation (and slightly discolored) and chosen to be representative of the Demo Pit area.

2.2.17 Area G

Three discrete soil samples were collected from Area G (Figure 2.11). Because Area G is a large and relatively flat area, three samples were collected in areas representative of the whole objective. The sampled areas included zones of slightly less vegetation and discolored patches.

2.2.18 Miscellaneous Training Areas

Five discrete soil samples were collected from the Miscellaneous Training Areas (Figure 2.13). This relatively large area is located on a rocky hillside that is in reality a broad alluvial fan just north of Koiahi Gulch. The area is covered in short grass, making the sampling sites easy to position for representativeness. The five discrete samples were collected in minor depressions or features that had less vegetation than surrounding areas. Because the miscellaneous training areas cover such a large area, samples were collected to be as representative of the area as possible.

2.2.19 Deer Berms

Five discrete soil samples were collected from the Deer Berms (Figure 2.12). This objective includes a number of target berms that are spread over a rather large, relatively flat area. The five soil samples were collected at the fixed target berm positions. The five discrete soil samples were collected at the crown of the target berms or skewed to the side if discoloration or bare vegetation was encountered.

2.2.20 Outlying Soil Samples

An additional 22 soil samples were collected from areas mostly outside of the firebreak roads (North and South Fire Break Roads) that form the boundaries of the training areas.

Figure 2.14 shows the locations of these additional outlying shallow soil samples. The samples were collected from the fine sediments that were deposited in the intermittent streams and washes, from areas selected as being representative of a given site since metals, explosives, or other compounds would most likely collect in the materials in the bottom of the washes. One sample was also collected from the former junk car pit. The remaining 18 samples were positioned to investigate the potential for widespread distribution of contaminants throughout the Makua Valley. These are shown in Figure 2.14, and are labeled NFBR1- and SFBR1- (for North Fire Break Road and South Fire Break Road).

2.3 Boreholes and Lysimeters

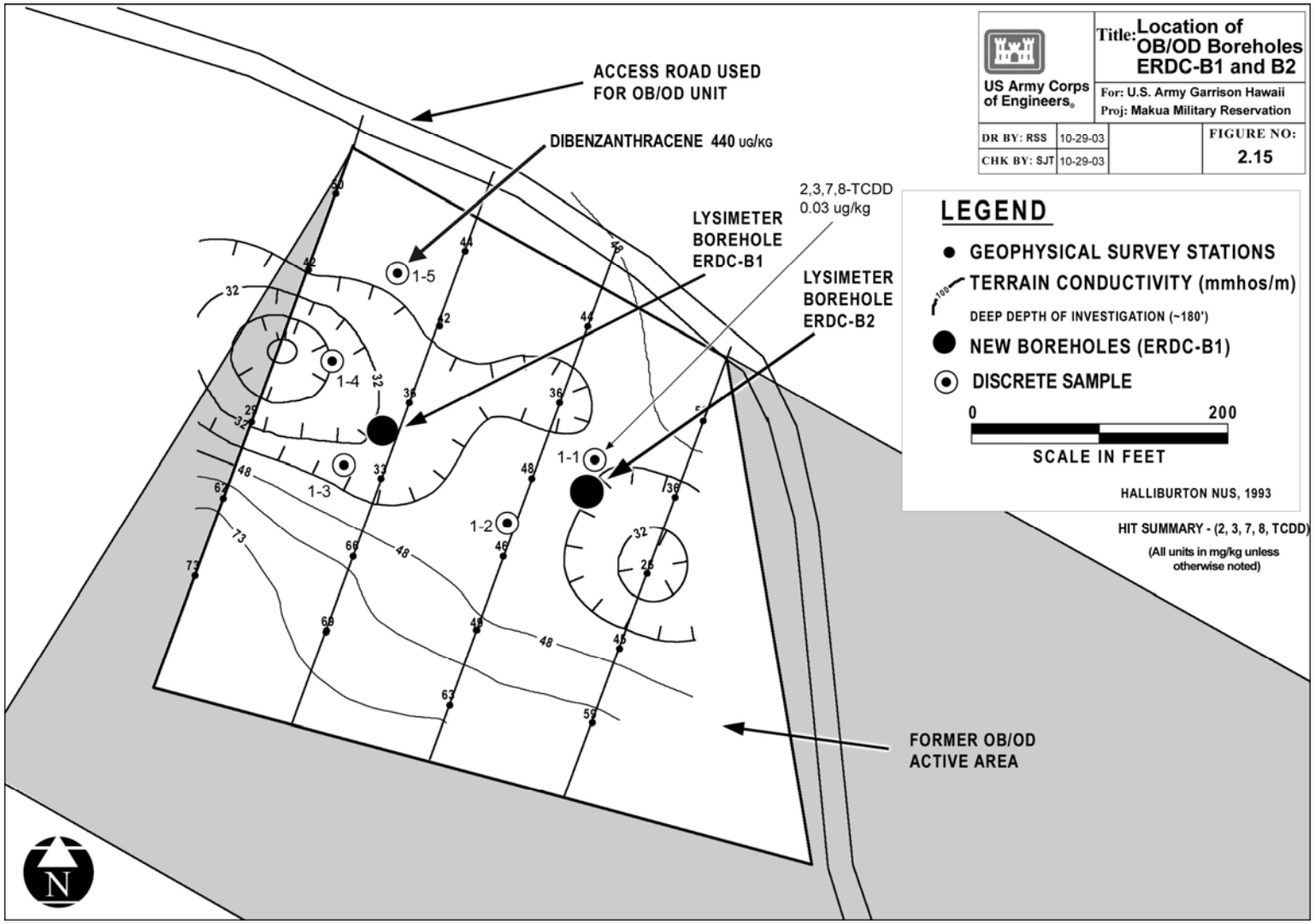
Soil samples were collected from boreholes within the OB/OD area and the former junk car pit to evaluate concentrations of contaminants from burn and disposal operations. These samples were collected to provide additional information on contaminants in the OB/OD area and former junk car pit. Figure 2.15 shows the location of these boreholes within the OB/OD area. Borehole B-1 was drilled down using a hollow stem auger drilling rig to a depth of 45 feet where a large rock was encountered. Samples were collected at intervals of 5 feet to a total depth of 45 feet within borehole B-1. All soil samples were analyzed for metal and explosives, with the sample at a depth of 10 feet analyzed for the complete suite of analytes listed in Table 2.2. The drilling rig was then switched to an air hammer rig, and the remaining 5 feet, to a depth of 50 feet, were drilled into the large boulder. The last split spoon sample at 50 feet depth was not collected, since sampling of a large boulder is not practical. Also, the deepest lysimeter should be placed in the most representative type of formation in the OB/OD area (clay/silt/sand), and not within a boulder.

Borehole B-2 was started drilling using hollow stem auger drilling methods. Again, drilling encountered a large boulder at 25 feet depth, but drilling through the boulder was achieved. At a depth of 44 feet the drilling encountered a gravel layer in which there was no recovery of samples from the split spoon sampler, and auger refusal was met. Since further

drilling in B-1 was futile, the decision was made to end the hole at 44 feet in the top of the gravel layer. Again, the lysimeter required placement in a representative formation (clay/silt/sand) in the OB/OD area. Samples were collected at intervals` of 5 feet, with all soil samples analyzed for metals and explosives, with the samples at depths of 5 and 15 feet analyzed for the complete suite of analytes listed in Table 2.2.

Drilling of the borehole in the junk car pit was difficult. The formation in the area above the junk car pit was clay with large gravel/boulders. Sample recovery using a split spoon sampler was accomplished a depths of 5 and 15 feet, with no sample recovered at depths of 10 and 20 feet due to excessive gravel in the formation. The sample at 5 feet depth was analyzed for the complete suite of analytes listed in Table 2.2, with the sample at 15 feet depth analyzed for metals and explosives. Drilling encountered auger refusal at 20 feet. The decision was made to complete the hole at a depth of 20 feet, since the formation had a high percentage of boulders that cannot be drilled by hollow stem auger methods.

Figure 2.15 Location of OB/OD Boreholes ERDC-B1 and B2



Lysimeters were installed in the boreholes in both the OB/OD area and the junk car pit. Lysimeters were installed at depths of 30 and 45 feet below grade in borehole B-1, and 30 and 42 feet below grade in borehole B-2. One lysimeter was installed in borehole B-3 (junk car pit) at a depth of 19 feet. The lysimeters will be used to collect pore water samples from beneath the OB/OD area and the former junk car pit. The porewater samples will be analyzed for as many of the complete suite of analyses as listed in Table 2.2. The amount of sample from lysimeters may be small (40 ml), so it is likely that results will be obtained only for volatile organic compounds, explosives, and metals. The amount of sample will depend on the soil types, and the ability of these soils to transmit water in the unsaturated zone.

Two rounds of groundwater samples were collected from the lysimeters in early April (April 4 and 5, 2003) and July (July 1 and 7, 2003). The amount of sample collected from the lysimeters is usually 40 to 150 ml, so there is a limit to the number of compounds that can be analyzed by the laboratory. The typical volume of 40 to 150 ml is sufficient for volatile organic analyses and explosives. This water collected from the lysimeters represents soil pore water contained within the unsaturated soil that is drawn into the lysimeter instrument. (A vacuum of 80 to 100 millibars is placed on the lysimeter to draw in the sample.)

For the first round of lysimeter sampling (April 4 and 5), water was collected from SB1A, 1B, and 2B, while SB2A and SB3A were dry. Sample volume was only sufficient enough for volatile organic analyses (40 ml) in SB1B and SB2B. This is quite common in Hawai`i, where the soils dry out and resulting infiltration is stopped, therefore providing no water for the lysimeters to sample. For the second round of groundwater sampling, the sample volume was greater, and additional analyses were run.

2.4 Streambed Soil Samples

Streambed soil sediment samples were collected to assess the impacts of metals, energetics (explosives), and other compounds that might flow with surface water from the OB/OD area as well as from the entire MMR. This surface water could recharge the groundwater

in the lower elevations, and potentially impact the groundwater chemistry. All of the streams in the Makua Valley are intermittent, so they flow only in large rainfall events. Three (3) sets of soil samples were collected from the streambeds at varying depths of 6, 12, and 18 inches below surface in Punapohaku Stream, Makua Stream, and Koiahi Gulch Stream. Soil samples were collected at depths of 6 and 12 inches in Kaluakauila Stream, because the depth of sediment in this stream was shallow (less than 12 inches). Samples were collected by hand digging with trowels. During digging, the site was checked for UXO.

The collected soil samples that were sent to an analytical laboratory to be analyzed for the compounds are listed in Table 2.2. These soil samples were collected on February 27, 2003, and were delivered to the analytical laboratory on February 28, 2003. Results of the streambed soil samples are reported in Section 3.4.

Table 2.2 Analytes and EPA Methods for Soil and Water Samples

Item	Analytes	EPA Method
Two (2) sets of OB/OD soil samples	Benzene	8021
	SVOCs	8270C/SIM
	RCRA total metals	6010B
	RCRA TCLP metals	1311/6010B
	Cyanide	9010B
	Sulfides	376.1
	Energetics (explosives)	8330
	Nitrates/nitrites	300
	Chlorinated herbicides	8151A
	Pesticides	8081A
	Dioxin/furans	8280
	PCBs	8082
	Perchlorates	314.0
	Nitroglycerine	8332
Four (4) sets of streambed soil samples	Benzene	8021
	SVOCs	8270C/SIM
	RCRA total metals	6010B
	RCRA TCLP metals	1311/6010B
	Cyanide	9010B
	Sulfides	376.1
	Energetics (explosives)	8330
	Nitrates/nitrites	300
	Chlorinated herbicides	8151A
	Pesticides	8081A
	Dioxin/furans	8280
	PCBs	8082
	Perchlorates	314.0
	Nitroglycerine	8332
Groundwater sampling - six (6) rounds from 7 monitoring wells	VOCs (including benzene)	8260B
	SVOCs	8270C/8310
	RCRA total metals	6010B
	Cyanide	9010B
	Sulfides	376.1
	Energetics (explosives)	8330
	Nitrates/nitrites	300
	Chlorinated herbicides	8151A
	Pesticides	8081A
	PCBs	8082
	Perchlorates	314.0
	Dioxin	8290 (one round)
	Nitroglycerine	8332 (one round)

Table 2.2 (Continued)
Analytes and EPA Methods for Soil and Water Samples

Item	Analytes	EPA Method
Background Sampling	Dioxin/Furans	8280
Background Sampling (on-site)	RCRA total metals RCRA TCLP metals	6010B 1311/6010B
Shallow Surface Samples From Training Area (102 site screening samples)	RCRA total metals Energetics (explosives)	6010B 8330
Shallow Surface Samples From Training Area (25 of the 102 samples)	Soil moisture content Soil salinity Grain size analysis	
Shallow Surface Samples From Training Area (21 discrete samples)	Benzene SVOCs RCRA total metals RCRA TCLP metals Cyanide Sulfides Energetics (explosives) Nitrates/nitrites Chlorinated herbicides Pesticides Dioxin/furans PCBs Perchlorates Nitroglycerine	8021 8270C/SIM 6010B 1311/6010B 9010B 376.1 8330 300 8151A 8081A 8280 8082 314.0 8332
Stream Water Samples Four (4) samples from each stream flow event	VOCs (including benzene) SVOCs RCRA total metals Cyanide Sulfides Energetics (explosives) Nitrates/nitrites Chlorinated herbicides Pesticides Dioxin/furans PCBs Perchlorates	8260B 8270C/SIM 6010B 9010B 9030B 8330 300 8151A 8081A 8290 8082 314.0
72 samples from each stream flow event	Total Suspended Solids Grain size analysis	160.1

Table 2.2 (Concluded)
Analytes and EPA Methods for Soil and Water Samples

Item	Analytes	EPA Method
Eight (8) sediment and water samples from each stream flow event	RCRA total metals energetics (explosives)	6010B 8330
Lysimeter Pore water Samples*	RCRA Totals Metals Energetics (explosives) VOCs (including benzene)	6010B 8330 8260B

One round of groundwater samples will also include bicarbonate, calcium chloride, and silica. Method detection limits are listed in Sampling And Analysis Plan (Section 7)

*The analytes sampled from the lysimeters are limited due to the small amount of sample available

2.5 Surface Water Evaluation

The sampling and analysis plan called for samples of surface water to be collected in Makua Valley streams from September 1, 2002, through September 1, 2003, for up to three flow events. This period was extended through February 2004 until samples from three stream flow events were collected from all of the four streams of interest. The streams at Makua are intermittent, in that they flow only during larger rainfall events that occur only a few times each year, if at all. Surface water sampling of intermittent stream flow was conducted on Makua Stream during a rainfall event on February 13 and 14, 2003, January 23 and 24, 2004, and February 27 through March 6, 2004. For the first event on February 13 and 14, 2003, it rained approximately 5 inches in the Waianae Range on the margins of MMR and 2 inches in the Makua Valley near the ocean. At approximately 3:00 A.M. on February 14 Makua Stream began to flow, and it flowed until February 14 at 11:00 P.M. The automated sampler began collecting samples at an interval of one 1-liter bottle every 15 minutes for 2 hours, and every 0.5 hour for another 8 hours. The sampler was then reloaded with new bottles, and set to collect one 1-liter bottle every hour for the remainder of the flow event. The maximum flows on Makua Stream occurred from approximately 5:30 A.M. until 8:30 A.M. February 14. Table 2.3 lists the samples collected for the first event. Additional rainfall summary data are presented in Appendix L.

During the flow event at Makua Stream, a total of 40 (1) liter bottles were collected. Nearly all of these bottles were analyzed for total suspended solids, with five of the bottles analyzed for the complete suite of analyses. A listing of the time of bottle collection and the analytes for the samples is included in Table 2.3. These complete suite samples were collected on February 14 at 3:09, 3:48, 4:29, 5:29, 7:45, 20:56. These intervals provided data for surface water chemistry for first flush, peak flow, and the end of the flow event. In addition, dissolved metals samples were collected and analyzed from an additional 13 samples, and total metals were collected from an additional seven bottles. A total of 20 of the bottles were collected and

analyzed for explosives across the entire range that occurred over the 1-day period. These were more samples than was outlined in the Sampling and Analysis Plan because this event may have been the only stream flow event from which we could collect samples for this EIS effort. It was also desirable to make every attempt to quantify compounds in the water across a wide range of flows.

Table 2.3 Stream Water Sampling Intervals – First Event (February 14, 2003)

(Manually Collected Samples)

Sample Number	Round	Time	Date	Analytes
Koiahi Gulch				
MMRKSSW-R1	1	7:30	2/14/03	Full Suite (see Table 2.2)
MMRKSSW-R2	2	9:10	2/14/03	Metals, Explosives
MMRKSSW-R3	3	10:58	2/14/03	Metals, Explosives
MMRKSSW-R4	4	12:20	2/14/03	Metals, Explosives
Makua Stream				
MMRMSSW-R1	1	7:45	2/14/03	Full Suite (see Table 2.2)
MMRMSSW-R2	2	9:30	2/14/03	Metals, Explosives
MMRMSSW-R3	3	11:05	2/14/03	Metals, Explosives
MMRMSSW-R4	4	12:26	2/14/03	Metals, Explosives
MMRMSSW-R5	5	14:55	2/14/03	Metals, Explosives
Punapohaku Stream				
MMRPSSW-R1	1	7:58	2/14/03	Full Suite (see Table 2.2)
MMRPSSW-R2	2	9:35	2/14/03	Metals, Explosives
MMRPSSW-R3	3	11:15	2/14/03	Metals, Explosives
MMRPSSW-R4	4	12:33	2/14/03	Metals, Explosives
MMRPSSW-R5	5	15:10	2/14/03	Metals, Explosives
MMRPSSW-R6	6	16:00	2/15/03	Metals, Explosives
Kaluakauila Stream				
MMRKASSW-R1	1	7:58	2/14/03	Full Suite (see Table 2.2)
MMRKASSW-R1	2	9:35	2/14/03	Metals, Explosives
MMRKASSW-R1	3	11:15	2/14/03	Metals, Explosives
MMRKASSW-R1	4	12:33	2/14/03	Metals, Explosives
MMRKASSW-R1	5	15:10	2/14/03	Metals, Explosives
MMRKASSW-R1	6	16:15	2/15/03	Metals, Explosives

Table 2.3 Stream Water Sampling Intervals – First Event (February 14, 2003)
(Automated Sampler, Makua Stream)

	Bottle Number		Metals and	Summary of Analytes					
Date, Time	ISCOR1	TSS	Explosives	VOCs	SVOCs	Perchlorates	Nitroglycerine	Other	Stream
2/14/03, 2:55	1	x	x					x	Makua
2/14/03, 3:09	2			x	x	x	x	x	Makua
2/14/03, 3:15	3	x	x					x	Makua
2/14/03, 3:18	4	x	x					x	Makua
2/14/03, 3:33	5	x		x				x	Makua
2/14/03, 3:48	6	x	x	x	x	x	x	x	Makua
2/14/03, 3:55	7	x		x				x	Makua
2/14/03, 3:58	8	x	x					x	Makua
2/14/03, 3:59	9	x	x					x	Makua
2/14/03, 4:29	10	x	x	x	x	x	x	x	Makua
2/14/03, 4:59	11	x	x	x					Makua
2/14/03, 5:29	12	x	x	x	x	x	x	x	Makua

	Bottle Number		Metals and	Summary of Analytes					
Date, Time	ISCOR1	TSS	Explosives	VOCs	SVOCs	Perchlorates	Nitroglycerine	Other	Stream
2/14/03, 5:59	13	x	x	x					Makua
2/14/03, 6:29	14	x	x						Makua
2/14/03, 6:59	15	x	x	x					Makua
2/14/03, 7:29	16	x	x						Makua
2/14/03, 7:59	17	x	x						Makua
2/14/03, 8:29	18	x	x	x					Makua
2/14/03, 8:59	19	x	x	x					Makua
2/14/03, 9:29	20	x	x						Makua
2/14/03, 9:59	21	x	x	x					Makua
2/14/03, 10:29	22	x	x						Makua
2/14/03, 10:59	23	x	x						Makua
2/14/03, 11:29	24	x	x						Makua
2/14/03, 11:50	25	x	x	x					Makua
2/14/03, 12:45	26	x	x	x					Makua

	Bottle Number		Metals and	Summary of Analytes					
Date, Time	ISCOR1	TSS	Explosives	VOCs	SVOCs	Perchlorates	Nitroglycerine	Other	Stream
2/14/03,12:48	27	x	x						Makua
2/14/03, 13:35	28	x	x						Makua
2/14/03, 13:38	29	x	x						Makua
2/14/03, 14:38	30	x	x						Makua
2/14/03, 14:55	31	x	x	x					Makua
2/14/03, 14:58	32	x	x	x					Makua
2/14/03, 14:59	33	x	x						Makua
2/14/03, 15:41	34	x	x						Makua
2/14/03, 16:46	35	x	x						Makua
2/14/03, 17:46	36	x	x	x					Makua
2/14/03, 18:49	37	x	x						Makua
2/14/03, 19:49	38	x	x	x					Makua
2/14/03, 20:56	39	x		x	x	x	x	x	Makua
2/14/03, 21:56	40	x	x						Makua

	Bottle Number		Metals and	Summary of Analytes					
Date, Time	ISCOR1	TSS	Explosives	VOCs	SVOCs	Perchlorates	Nitroglycerine	Other	Stream
Key									
TSS = Total Suspended Solids									
Metals and Explosives = Metals by methods 6010B (dissolved and total) and Explosives by Methods 8330									
VOCs = Volatile Organic Compounds by Method 8260B									
SVOCs = Semivolatile Organic Compounds by Methods 8270C and 8310									
Perchlorates = Perchlorated by Method 314.0									
Nitroglycerine = Nitroglycerine by Method 8332									
Other = Composite samples of bottles 1 through 10 analyzed for: Cyanide by Method 9010B, sulfides by Method 376.1									
Nitrate/nitrites by Method 300, Chlorinated Herbicides by Method 8151A, Pesticides by Method 8081A, and PCBs by Method 8082									

Table 2.4 Stream Water Sampling Intervals – Second Event (January 23, 2004)
(Manually Collect Samples)

Stream	Round	Time	Date	Analytes
Koiahi Gulch				
MMRKGSR2-1	1	10:10	1/23/04	Full Suite (see Table 2.2)
MMRKGSR2-2	2	13:05	1/23/04	Metals, Explosives
MMRKGSR2-3	3	14:50	1/23/04	Metals, Explosives
MMRKGSR2-4	4	17:34	1/23/04	Metals, Explosives
MMRKGSR2-5	5	19:05	1/23/04	Metals, Explosives
Punapohaku Stream				
MMRPSR2-1	1	12:12	1/23/04	Full Suite (see Table 2.2)
Makua Stream				
MMRMSR2-1	1	11:10	1/23/04	Full Suite (see Table 2.2)
Kaluakauila Stream				
MMRKASR2-1	1	13:55	1/23/04	Full Suite (see Table 2.2)
MMRKASR2-2	2	18:25	1/23/04	Metals, Explosives

Table 2.4 Stream Water Sampling Intervals – Second Event (January 23, 2004) (Automated Samples from Makua Stream)

Date, Time	Bottle Number MMR-SW-E4-	TSS	Metals	Explosives	Stream
1/22/04 22:41	B01	x		x	Makua
1/23/04 1:12	B02	x	x		Makua
1/23/04 1:45	B03	x		x	Makua
1/23/04 2:18	B04	x	x		Makua
1/23/04 2:48	B05	x		x	Makua
1/23/04 3:31	B06	x	x		Makua
1/23/04 3:38	B07	x			Makua
1/23/04 4:23	B08	x			Makua
1/23/04 5:24	B09	x			Makua
1/23/04 6:24	B10	x			Makua
1/23/04 7:24	B11	x	x		Makua
1/23/04 8:24	B12	x		x	Makua
1/23/04 9:24	B13	x			Makua
1/23/04 10:24	B14	x			Makua
1/23/04 11:24	B15	x			Makua
1/23/04 12:24	B16	x			Makua
1/23/04 13:24	B17	x			Makua
1/23/04 14:24	B18	x			Makua
1/23/04 15:24	B19	x			Makua
1/23/04 16:24	B20	x			Makua
1/23/04 17:17	B21	x			Makua
1/23/04 18:17	B22	x			Makua
1/23/04 19:17	B23	x			Makua

Date, Time	Bottle Number MMR-SW-E4-	TSS	Metals	Explosives	Stream
1/23/04 20:17	B24	x	x		Makua
1/23/04 21:17	B25	x		x	Makua
1/23/04 22:17	B26	x			Makua
1/23/04 23:17	B27	x			Makua
1/24/04 0:17	B28	x			Makua
1/24/04 1:17	B29	x			Makua
1/24/04 2:17	B30	x			Makua
1/24/04 3:17	B31	x			Makua
1/24/04 4:17	B32	x			Makua
1/24/04 5:17	B33	x			Makua
1/24/04 6:17	B34	x			Makua
1/24/04 7:17	B35	x			Makua
1/24/04 8:17	B36	x			Makua
1/24/04 9:17	B37	x			Makua
1/24/04 10:17	B38	x			Makua
1/24/04 11:17	B39	x			Makua
1/24/04 13:17	B40	x			Makua
1/24/04 14:17	B41	x			Makua
1/24/04 15:17	B42	x			Makua
1/24/04 16:17	B43	x			Makua
1/24/04 17:17	B44	x			Makua

Key

TSS = Total Suspended Solids

Metals by Method 6010B, Explosives by Method 8330

Table 2.5 Stream Water Sampling Intervals – Third Event (February 27, 2004)

(Manually Collected Samples)

Stream	Round	Time	Date	Analytes
Koiahi Gulch				
MMR-KGS-R3-1	1	11:00	2/27/04	Full Suite (see Table 2.2)
MMR-KGS-R3-2	2	12:40	2/27/04	Metals, Explosives
MMR-KGS-R3-3	3	16:00	2/28/04	Metals, Explosives
MMR-KGS-R3-4	4	10:00	2/29/04	Metals, Explosives
MMR-KGS-R3-5	5	16:15	3/05/04	Metals, Explosives
Makua Stream				
MMR-MS-R3-1	1	11:15	2/27/04	Full Suite (see Table 2.2)
MMR-MS-R3-2	2	12:50	2/27/04	Metals, Explosives
MMR-MS-R3-3	3	13:10	3/04/04	Metals, Explosives
Punapohaku Stream				
MMR-PS-R3-1	1	12:25	2/27/04	Full Suite (see Table 2.2)
MMR-PS-R3-2	2	13:15	2/27/04	Metals, Explosives
Kaluakauila Stream				
MMR-KAS-R3-1	1	11:55	2/27/04	Full Suite (see Table 2.2)
MMR-KAS-R3-2	2	13:05	2/27/04	Metals, Explosives

Table 2.5 Stream Water Sampling Intervals – Third Event (February 27, 2004)
(Automatically Samples from Makua Stream)

Date, Time	Bottle Number	Summary of Analytes			Stream
	MMR-MS1SCO-	TSS	Metals	Explosives	
2/27/04, 11:10	B01-1	x			Makua
2/27/04, 11:40	B02-1				Makua
2/27/04, 12:10	B03-1	x			Makua
2/27/04, 12:40	B04-1	x			Makua
2/27/04, 13:10	B05-1	x			Makua
2/27/04, 13:40	B06-1	x			Makua
2/27/04, 14:10	B07-1	x			Makua
2/27/04, 14:40	B08-1	x			Makua
2/27/04, 15:40	B09-1	x			Makua
2/27/04, 16:40	B10-1	x		x	Makua
2/27/04, 17:40	B11-1	x	x		Makua

Date, Time	Bottle Number	Summary of Analytes			Stream
	MMR-MS1SCO-	TSS	Metals	Explosives	
2/27/04, 18:40	B12-1	x			Makua
2/27/04, 19:40	B13-1	x			Makua
2/27/04, 20:40	B14-1	x			Makua
2/27/04, 21:40	B15-1	x			Makua
2/27/04, 22:40	B16-1	x			Makua
2/27/04, 23:40	B17-1	x			Makua
2/28/04, 0:40	B18-1	x			Makua
2/28/04, 1:40	B19-1	x			Makua
2/28/04, 2:40	B20-1	x			Makua
2/28/04, 3:40	B21-1	x			Makua
2/28/04, 4:40	B22-1	x			Makua
2/28/04, 5:40	B23-1	x			Makua
2/28/04, 6:40	B24-1	x			Makua
2/28/04, 11:00	B01-2	x			Makua

Date, Time	Bottle Number	Summary of Analytes			Stream
	MMR-MS1SCO-	TSS	Metals	Explosives	
2/28/04, 11:30	B02-2	x			Makua
2/28/04, 12:00	B03-2	x			Makua
2/28/04, 12:30	B04-2	x			Makua
2/28/04, 13:00	B05-2	x			Makua
2/29/04, 9:50	B06-2	x			Makua
2/29/04, 10:50	B07-2	x			Makua
2/29/04, 11:50	B01-3	x			Makua
2/29/04, 12:50	B02-3	x			Makua
2/29/04, 13:50	B03-3	x			Makua
2/29/04, 14:50	B04-3	x			Makua
2/29/04, 15:50	B05-3	x			Makua
2/29/04, 16:50	B06-3	x			Makua
2/29/04, 17:50	B07-3	x			Makua
3/4/04, 15:01	B01-4	x			Makua

Date, Time	Bottle Number	Summary of Analytes			Stream
	MMR-MS1SCO-	TSS	Metals	Explosives	
3/4/04, 16:01	B02-4	x			Makua
3/4/04, 17:01	B03-4	x			Makua
3/4/04, 18:01	B04-4	x			Makua
3/4/04, 19:01	B05-4	x			Makua
3/4/04, 20:01	B06-4	x			Makua
3/4/04, 21:01	B07-4	x			Makua
3/4/04, 22:01	B08-4	x			Makua
3/4/04, 23:01	B09-4	x			Makua
3/5/04, 0:01	B10-4	x			Makua
3/5/04, 15:38	B01-5	x			Makua
3/5/04, 16:38	B02-5	x			Makua
3/5/04, 17:38	B03-5	x			Makua
3/5/04, 18:38	B04-5	x			Makua
3/5/04, 19:38	B05-5	x			Makua

Date, Time	Bottle Number	Summary of Analytes			Stream
	MMR-MS1SCO-	TSS	Metals	Explosives	
3/5/04, 20:38	B06-5	x			Makua
3/5/04, 21:38	B07-5	x			Makua
3/5/04, 22:38	B08-5	x			Makua
3/5/04, 23:38	B09-5	x			Makua
3/6/04, 0:38	B10-5	x			Makua
3/6/04, 7:38	B11-5	x			Makua
3/6/04, 15:38	B12-5	x			Makua
Key					
TSS = Total Suspended Solids					
Metals = Metals by Methods 6010B (dissolved and total)					
Explosives = Explosives by Methods 8330					

In addition to the bottles collected by the automated samples, six rounds of grab samples were collected in Koiahi Gulch Stream, Makua Stream, Punapohaku Stream, and Kaluakahila Stream. These were collected at intervals as listed below in Table 2.3. Complete suite samples were collected from 7:30 to 7:58 for the four streams on February 14, 2003. The results of the chemical analyses for the surface water sampling are discussed in Section 3.5.

For the second event (January 23 and 24, 2004) samples were collected as listed in Table 2.4. Both manually collected samples and samples collected by the ISCO automated sampler were sent to the analytical laboratory. More samples were collected from Koiahi Gulch Stream and Makua Stream than Punapohaku Stream and Kaluakahila Stream since these two streams drain the main portions of Makua Military Reservation.

For the third event (February 27 through March 6, 2004) samples were collected as listed in Table 2.5. Both manually collected samples and samples collected by the automated sampler were sent to the analytical laboratory. This stream flow event lasted much longer than other events with the stream flowing for 8 days. A very large log flowed down the stream and damaged the automated sampler and caused a memory failure for the unit (the memory failure may have also been caused by lightening). However, the required number of samples was still removed from the damaged sampler.

Two smaller surface water flow events occurred on April 6 and 7, 2003, and January 1 and 2, 2004. These rainfall events and surface water flows were smaller than the three main events. The smaller events occurred on a Sunday or holiday, and the project staff was unaware that the flow had occurred, as we remotely checked the weather stations and estimated incorrectly that a flow would not have occurred based upon the size of the rainfall event. As a result, the samples from the ISCO automated sampler were not removed from the sampler until after the event, and past the required holding times. The water collected from the automated sampler exceeded laboratory holding times; however, the decision was made to send these samples to the laboratory for metals, explosives, and total suspended solids analyses. Appendix E lists the

sampling interval for the samples collected during the April 6 and 7, 2003, and January 1 and 2, 2004, runoff events. Additional rainfall data are contained in Appendix L.

2.6 Rehabilitation of Monitoring Well SP-7

During 1993 one monitoring well was constructed at Makua Military Reservation (Halliburton NUS, 1994). This monitoring well was installed along Makua Stream as shown in Figure 2.15. This well had not been sampled in over 9 years and without some rehabilitation, groundwater sample results could be inaccurate. The rehabilitation involved bailing the well with a small drilling rig to remove solids for approximately 2 days. The well was also lightly surged with a surge block. A total of approximately 140 gallons were bailed from well SP-7 over the 2-day period. Parameters such as conductivity, pH, oxidation/reduction potential, turbidity, dissolved oxygen, and temperature were collected. Bailing was completed only after these parameters had stabilized. This well was sampled for groundwater chemistry as outlined in Section 3.7.

2.7 Groundwater Monitoring Wells in Dry Streambeds

Surface runoff of compounds from the Makua Military Reservation constitutes a second pathway of potential importance. It is a concern that surface water flows during large rainfall events in the intermittent streams might infiltrate (recharge) the alluvial material and impact the groundwater chemistry.

Two additional shallow wells (ERDC-MW-1 and ERDC-MW-2) were installed on Makua Military Reservation as shown in Figure 2.16. These wells were installed to evaluate surface water infiltration from the Koiahi Gulch Stream and Punapohaku Stream that may be impacting the groundwater chemistry. These are the two intermittent streams north and south of Makua Stream, so these wells are north and south of the existing well SP-7. Well MW-1 was drilled to a depth of 36 feet, with a shallow water level measured at a depth of 7.5 feet from land surface. Drilling was accomplished using the hollow stem auger method. The specification called for monitoring wells to have screens above the water table so that floating compounds that

might be in groundwater would enter the well. Therefore, 30 feet of PVC screen was placed in the hole, with 6 feet of PVC blank to land surface. Elevation of the top of the wellhead is approximately 9 feet. Table 2.6 summarizes the well construction for the wells at Makua Military Reservation. Well MW-1 was developed for 2 days to allow for accurate sampling. Well MW-1 was sampled as outlined in the groundwater sampling chemistry sections of this Appendix.

Well MW-2 was drilled along Punapohaku Steam to sample groundwater along the southern portions of Makua Valley. Well MW-2 was drilled to a depth of 36 feet, with a measured water level of 8.6 feet below grade. This well was installed with 30 feet of PVC screen below land surface and 6 feet of blank casing. This shallow well will allow for floating compounds to enter the well. The well was completed and developed for 2 days to allow for proper samples to be collected. An approximate total of 1800 gallons was removed from this well during development over the 2-day period. Well MW-2 was sampled as outlined in the groundwater sampling chemistry sections of this Appendix.

2.8 Deep Monitoring Wells

Two sets of nested triple sets (two locations, three wells at each location) of monitoring wells and one upgradient well were installed to provide information of groundwater chemistry deeper below land surface. A total of seven deeper monitoring wells were drilled and installed for this task. The locations of the monitoring wells are shown in Figure 2.16. These additional groundwater wells were used to evaluate the potential for contamination from the MMR to impact the groundwater discharging to the ocean. A review of data from these wells will be used to evaluate the potential impacts on groundwater of metals or explosives resulting from ordnance throughout the Makua Valley, not just the OB/OD area. These wells (ERDC-MW-3A, 3B, 3C, ERDC-MW-4A, 4B, 4C, and ERDC-MW-5) were installed downgradient of potential sources such as the OB/OD area.

Figure 2.16 Monitoring Well Locations

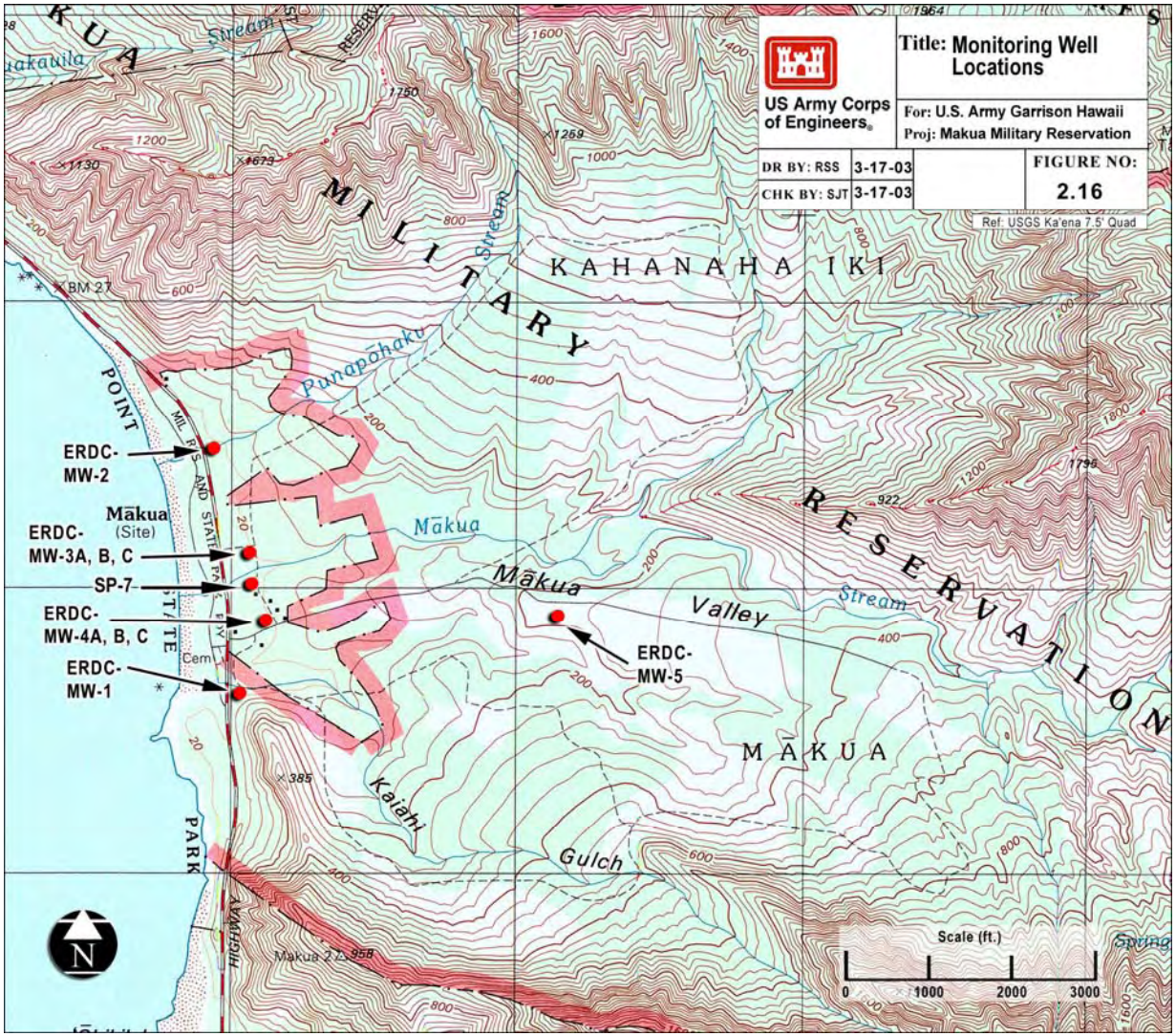
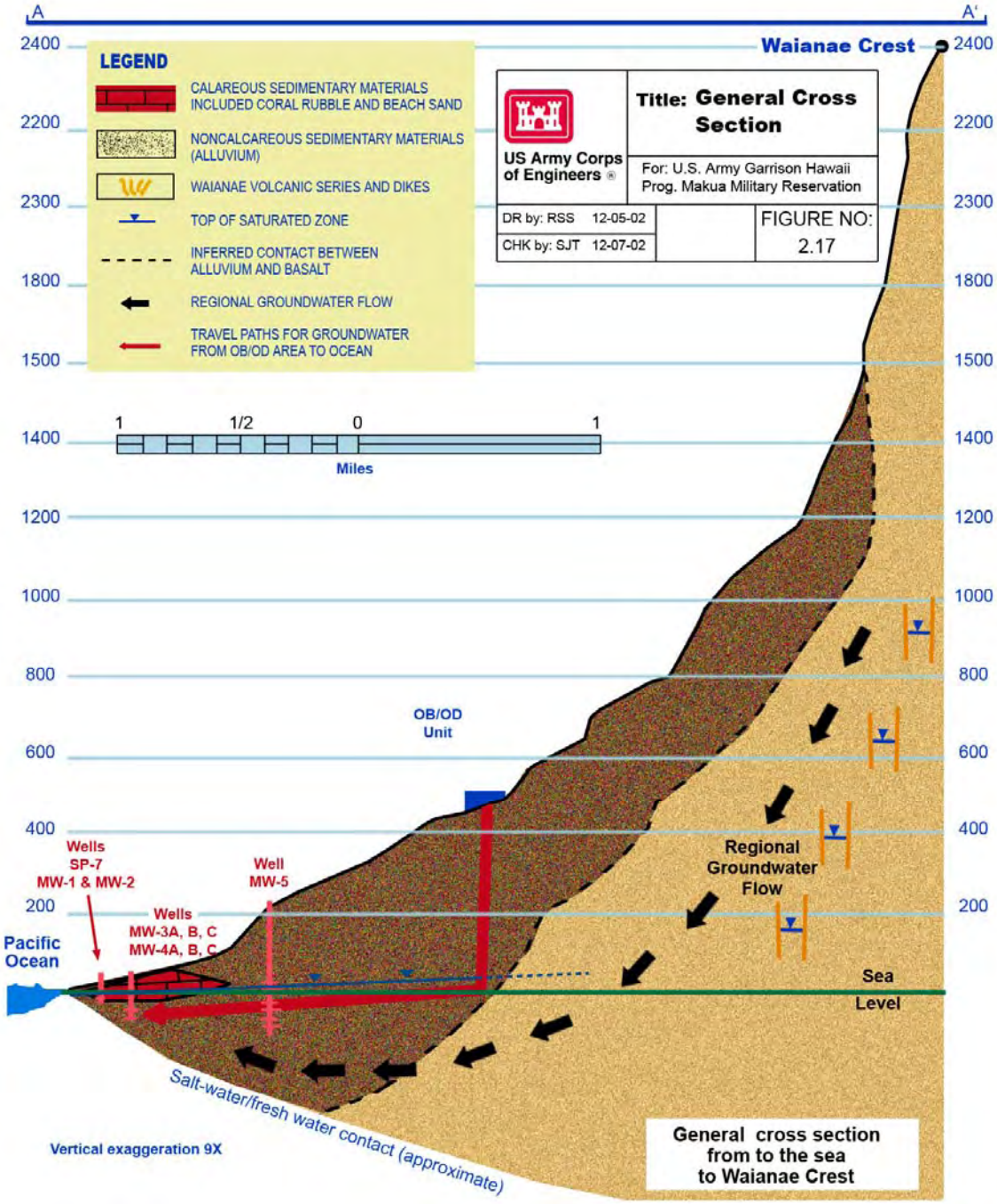


Table 2.6 Monitoring Wells at Makua Military Reservation

Well No.	Wellhead Elevation (feet MSL)	Depth from Land Surface (feet)	Elevation of Screen Interval (feet MSL)
ERDC-MW-1	10	36	+ 4 to –26
ERDC-MW-2	10.8	36	+ 5 to –25
ERDC-MW-3A	19.1	45	+4 to –26
ERDC-MW-3B	18.3	69	-26 to –51
ERDC-MW-3C	18.6	100	-51 to –81
ERDC-MW-4A	19.3	45	+ 4 to –26
ERDC-MW-4B	19.3	70	-26 to –51
ERDC-MW-4C	19.7	100	-50 to –80
ERDC-MW-5	235.4	320	20 to -85

Figure 2.17 General Cross Section



This will allow sampling of groundwater prior to it reaching receptors (the ocean). The sets of wells ERDC-MW-3A, B, C and ERDC-MW-4A, B, C were tiered to sample groundwater at different elevations. This will provide a more accurate assessment of the potential for contamination to reach the ocean by sampling different levels within the freshwater lens.

Figure 2.17 shows a cross section of the Makua Military Reservation running from the ocean (makai) to the top of the Waianae Range (mauka). There are generally two components of groundwater flow to the ocean: the regional groundwater flow in the Waianae volcanic rocks (black arrows in Figure 2.17) and potentially the groundwater flow in perched layers in the alluvium (red arrows in Figure 2.17). Groundwater percolating through the soils below the OB/OD area might travel either of these two paths shown in black or red in Figure 2.17. Figure 2.17 shows that the seven additional monitoring wells (ERDC-MW-3A, 3B, 3C, 4A, 4B, 4C, and MW-5) are designed to sample groundwater in these two paths.

Wells ERDC-MW-3A and 4A were designed to sample groundwater flowing within the alluvium, and potentially discharging at the ocean. The screened interval for ERDC-MW-3A and 4A are in the alluvial formation layers containing groundwater, sampling a somewhat deeper portion of the freshwater lens than wells SP-7, ERDC-MW-1 and ERDC-MW-2. Wells ERDC-MW-3A and 4A were installed with hollow stem auger drilling methods. They were installed to a total depth of 45 feet, with a screen length of 30 feet extending from +4 to -26 feet MSL. This screen extends above the top of the water table to allow potentially floating compounds to flow into the well.

Wells ERDC-MW-3B, 3C and 4B, 4C sample groundwater in regional groundwater flow that might flow below the existing shallow monitoring well (SP 7) or the shallower monitoring wells. The screened intervals for these wells are listed in Table 2.6. The bottom of the screened interval for ERDC-MW-3B and 4B was placed at an elevation of approximately –50 feet, with a 25feet screen extending from an elevation of about -26 to -51 feet MSL. The bottom of wells ERDC-MW-3C and 4C was placed approximately near the top of the freshwater/saltwater

interface, with a 30-feet-long screened interval at an elevation of -52 to -82 MSL. Wells ERDC-MW-3B and 4B were drilled with hollow stem auger drilling method, while the two deeper wells ERDC-MW-3C and 4C were drilled using air rotary drilling methods. The drill cuttings were also screened for gamma radiation in all of the wells.

Well ERDC-MW-5 was installed between the OB/OD area and the ocean. This well is also located between the impact area and the ocean. This well was installed at an approximate elevation of 235 feet above MSL. This well will act as an "early warning well" to measure the potential for contamination from upland areas, such as the OB/OD area or impact area, to discharge into the ocean. This well encountered a thick layer of silt and clay extending to a depth of approximately 290 feet below land surface. No water was encountered during drilling of this thick silt/clay unit from land surface to a depth of 290 feet, even though the well was allowed to sit overnight. It was evaluated that this formation would make a poor well, so drilling was continued to a total depth of 340 feet, where a higher permeability gravel layer was encountered from a depth of 290 to 340 feet. Based on a review of the drilling data with the field geologist, the project manager, and the project's technical advisor, the well was installed with 105 feet of screen from a depth of 215 to 320 feet. The screen extends from 20 feet above the water table to a depth that is 30 feet within the first formation that transmits water. Therefore, the well samples trace levels of contamination that might flow in the silt/clay layer, as well as within the gravel layer beneath. Additional explanation of the geologic information is listed in the Geologic Information Section, 3.8.3.

2.9 Background Soil Sampling Programs

The background soil-sampling program included off-site samples for dioxin and furans, as well as samples collected from Makua Valley to evaluate background metals concentrations. These samples were collected during February and September 2003 after the land access agreements were negotiated. In the case for all six background dioxin locations, samples were collected from State of Hawai`i owned or managed lands.

An additional survey of radiation levels was taken of the Island of O`ahu for comparison to the levels measured in Makua Valley. Measured radiation readings are summarized in Section 3.6. The radiation readings were taken with a GR-110 Exploranium Gamma Ray Scintillometer. On December 26, 2003, a survey trip was taken around the entire Island of O`ahu, and scintillometer readings were collected. These readings are outlined in Section 3.0 of this report.

The Background soil-sampling program included off-site samples analyzed by the laboratory for dioxin and furans, as well as samples collected from Makua Valley to evaluate background metals concentrations. Samples for dioxins and furans were collected from the boreholes in the burn area and from the streambeds. Dioxin samples were also collected during one round for all 10 groundwater wells. Locations of the off-site background soil samples are shown in Figure 2.18 and listed in Table 2.7.

It is necessary to evaluate background dioxin and furan levels in soils, since dioxin and furans are often found in soil samples, and may be unrelated to military operations at a site. Dioxin compounds are created during the burning of wood, and can be created by the brush fires that occur frequently along the Waianae Coast.

Since dioxin and furans could be created by conditions other than military operations at Makua, background samples locations were selected in other areas along the Waianae Coast. Written permission was obtained from the State of Hawai`i, as all of the locations selected were on lands owned by the State of Hawai`i. Listed below is an explanation of the samples.

Samples from the three mauka (mountain side) locations were used to evaluate background dioxin/furan levels in alluvial soil materials. Samples from stream bottoms were used to evaluate background dioxin/furan levels in streambed soil samples. The sample locations have been selected in areas that can be accessed easily. These final locations did vary somewhat from those shown in the Sampling and Analysis Plan, as the locations were moved to State of Hawai`i owned lands for access (Figures 2.19 through 2.23).

The background soil samples ERDC-BK2, 4, and 6 set were collected on February 28, 2003, and ERDC-BK1, 3, and 5 were collected on September 9, 2003. Sample results are contained in Section 3.6 of this report.

Figure 2.18 Background Sampling Locations

Table 2.7 Off-Site Background Sample Locations

Number	Depth	Media Sampled	Figure Number
ERDC-BK1A,B	6 and 12 inches	Alluvium north of Makua Valley	2.19
ERDC-BK2A,B	6 and 12 inches	Alluvium in Makaha Valley	2.20
ERDC-BK3A,B	6 and 12 inches	Alluvium in Waianae Valley	2.21
ERDC-BK4A,B	6 and 12 inches	Streambed in Keaau area	2.22
ERDC-BK5A,B	6 and 12 inches	Streambed in Makaha Valley	2.23
RDC-BK6A,B	6 and 12 inches	Streambed in Waianae Valley	2.21

2.10 Groundwater Sampling

For this project a total of six (6) rounds of groundwater samples were collected from each monitoring well, including the previously installed well (SP-7), and the nine new wells (ERDC-MW-1, 2, 3A, 3B, 3C, 4A, 4B, 4C, 5). All six rounds have been collected. The first round of groundwater samples was collected from December 15 through December 24, 2002. The second round of groundwater samples was collected from January 16 through February 13, 2003. For this second round, all the wells were sampled from January 16 2003, through January 23, 2003, except for well ERDC-MW-5, which was sampled on February 13, 2003. Sampling of this well (MW-5) was delayed due to a CALFAX occurring at Makua, as sampling cannot take place during live fire exercises. Sampling was also delayed due to pump equipment problems. The third round was collected April 1 through 7, the fourth round was collected April 21 through 28, and the fifth round was collected September 29 through October 3, 2003. The sixth round was collected in December 2003 through January 2004. This allowed for 1 full year of groundwater conditions to be sampled. The results of the groundwater sampling are listed in Section 3.7.

Figure 2.19 Detailed Background Sampling Locations ERDC-BK-1

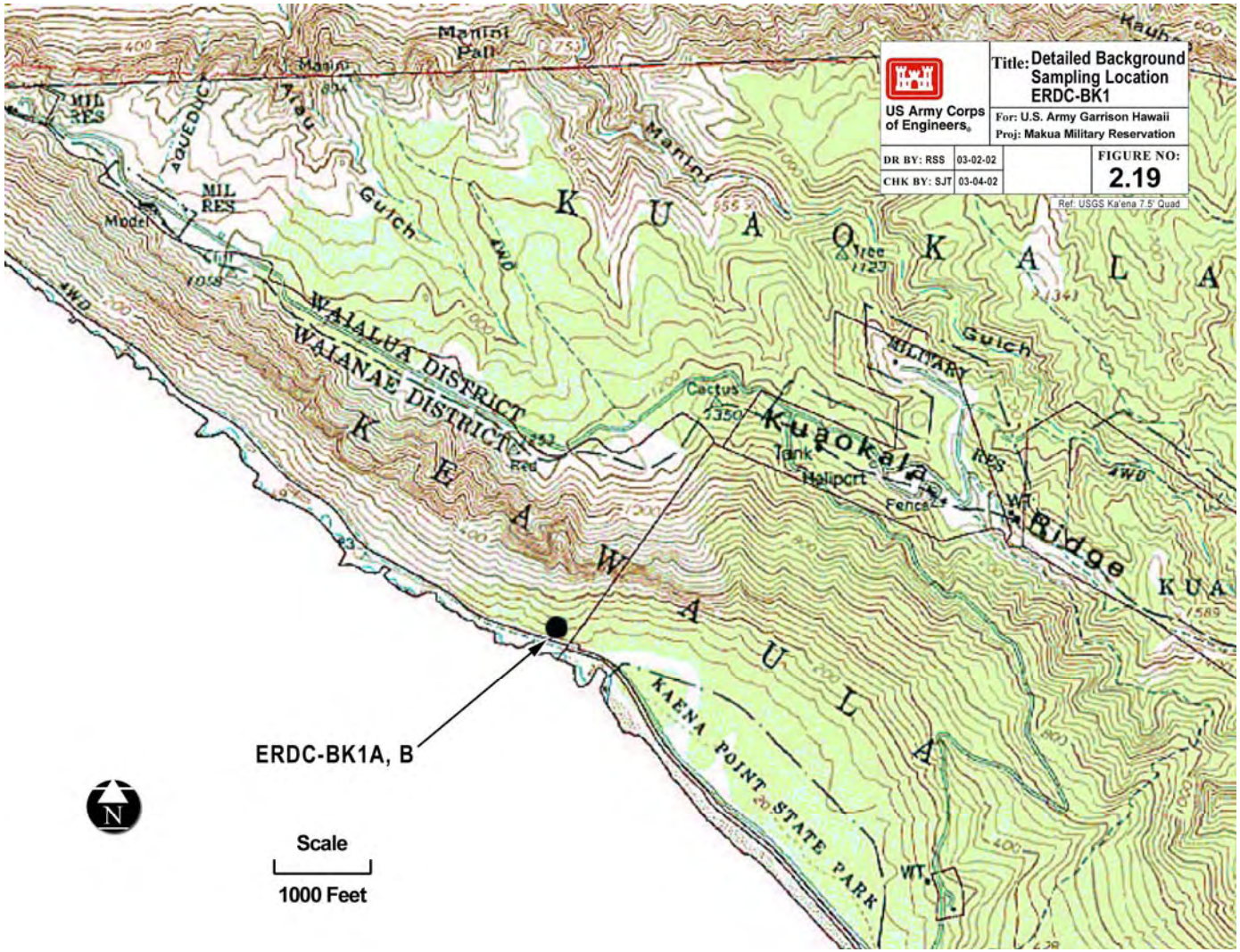


Figure 2.20 Detailed Background Sampling Locations ERDC-BK-2

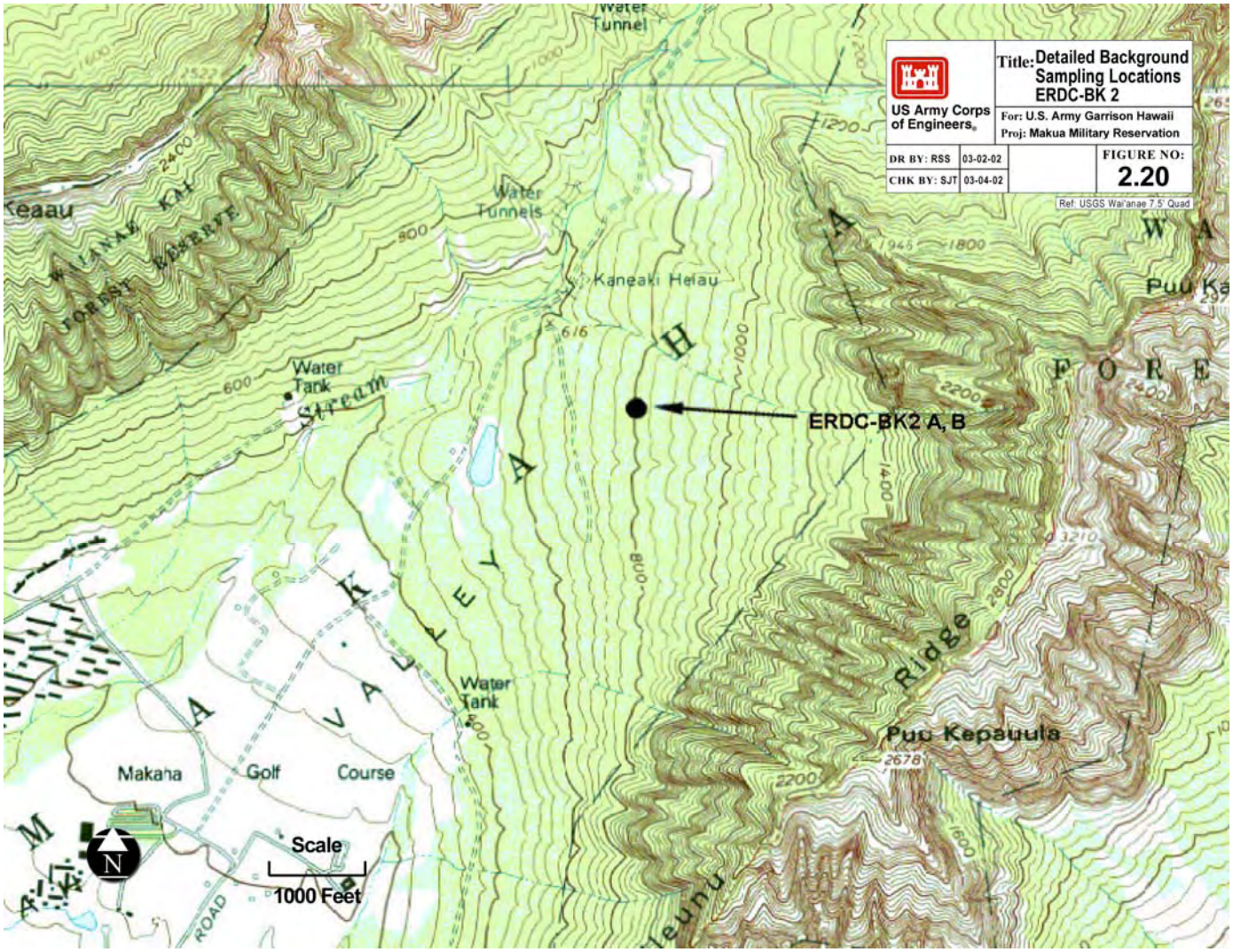


Figure 2.21 Detailed Background Sampling Locations ERDC-BK-3, 6

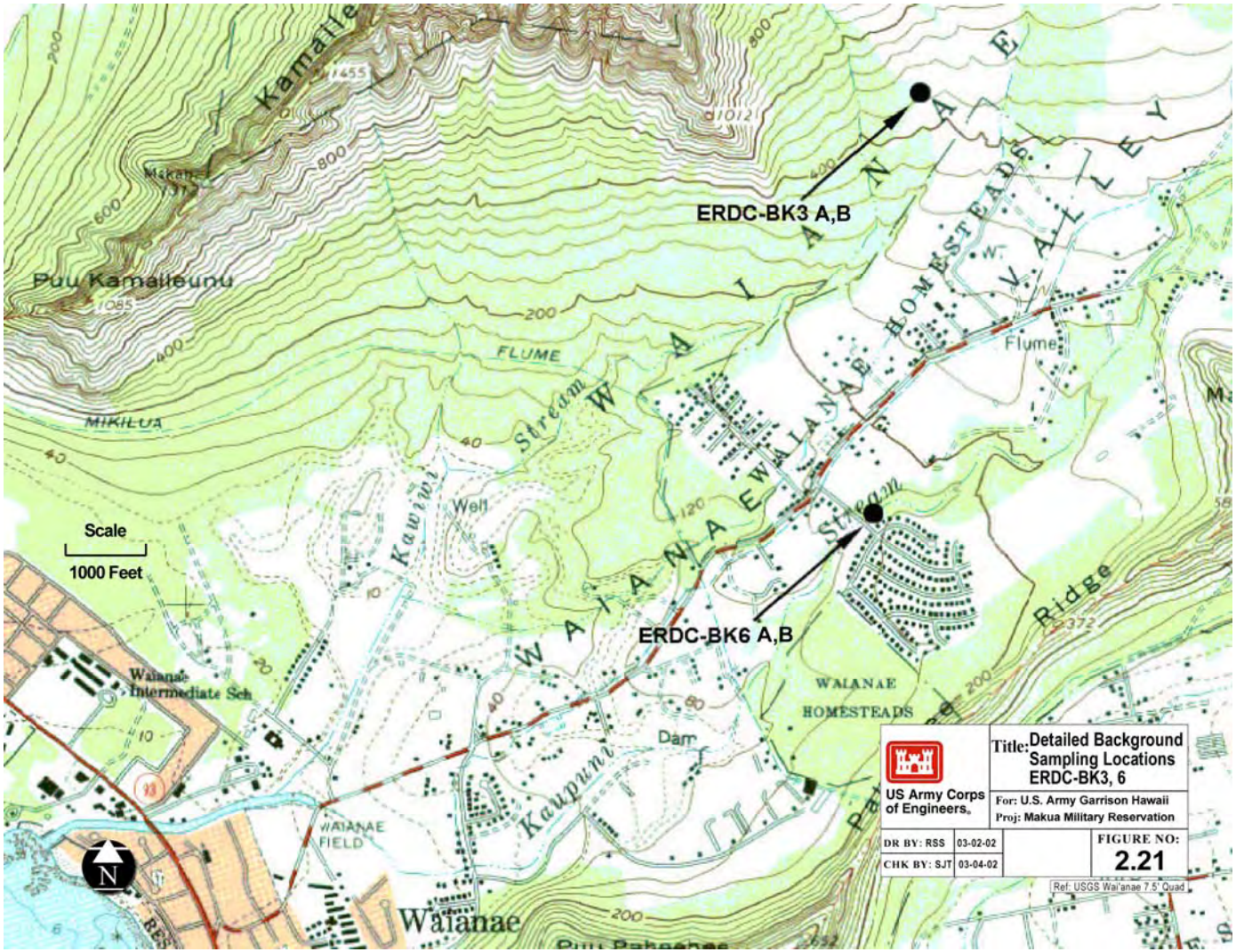


Figure 2.22 Detailed Background Sampling Locations ERDC-BK-4

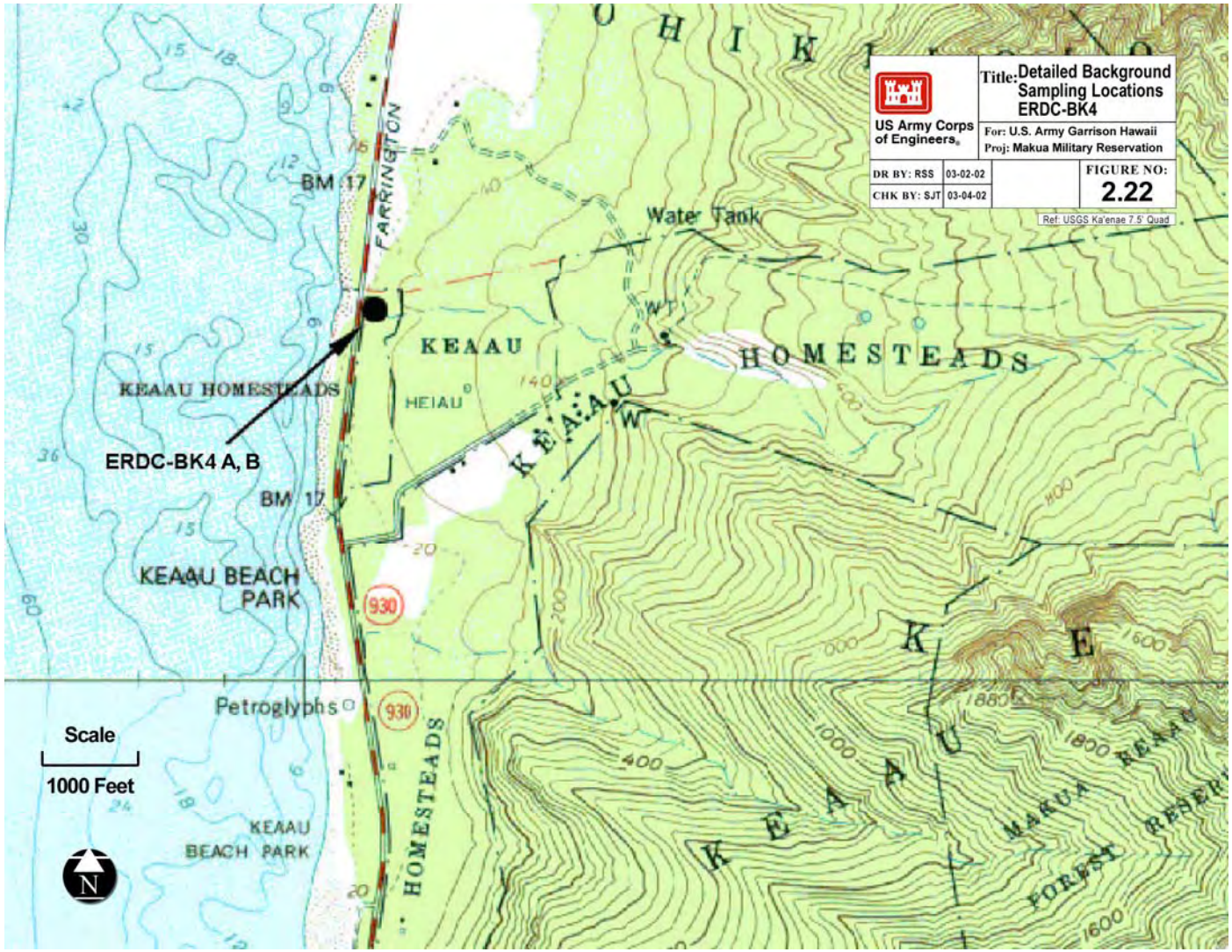
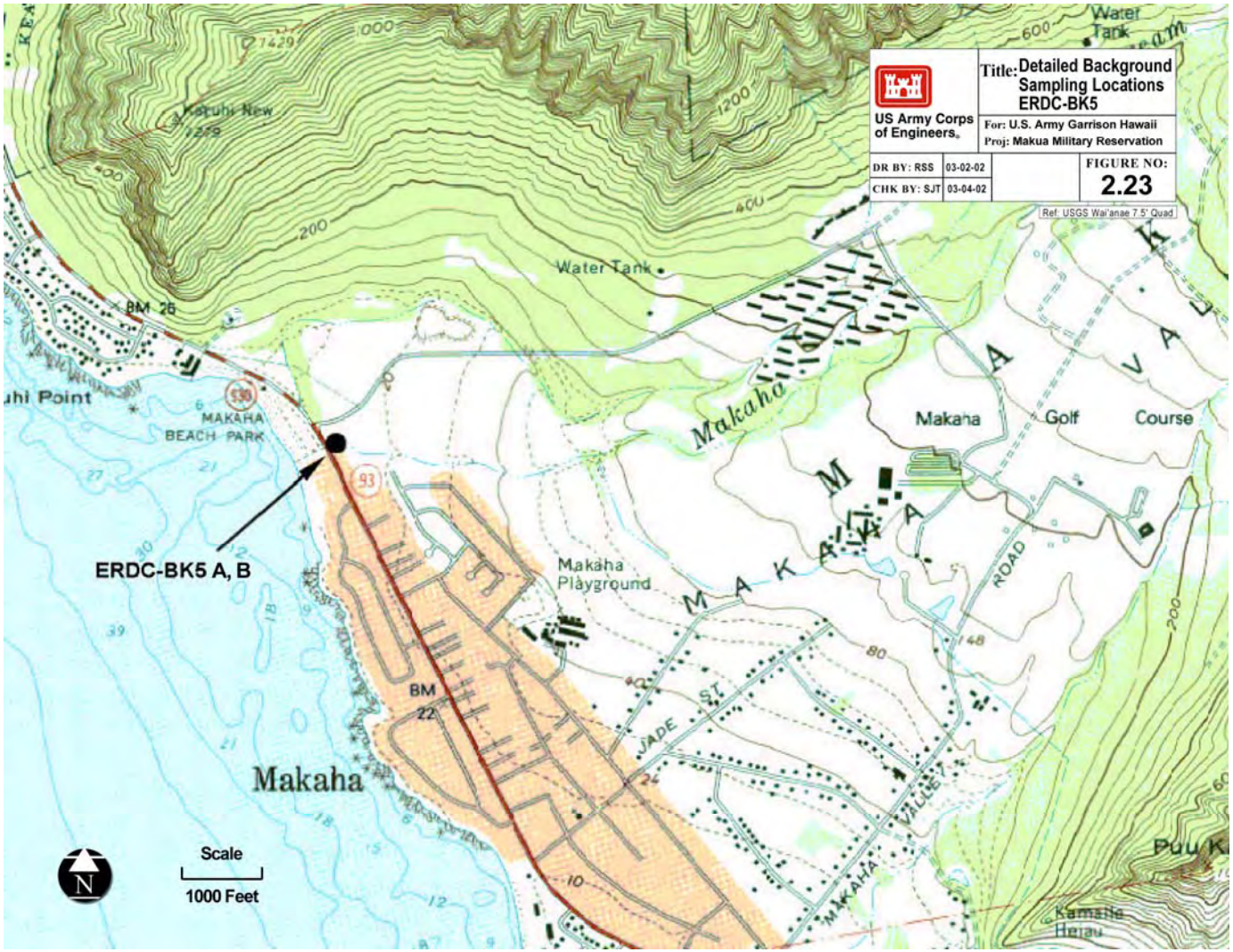


Figure 2.23 Detailed Background Sampling Locations ERDC-BK-5



2.11 Hydrogeological Characterization

Upon completion of well installations at Makua Military Reservation, measurements were collected to characterize the hydrogeologic conditions of the water bearing formations. These measurements established the configuration of the water table and its fluctuations, and provided approximations of hydraulic conductivity. Water levels were collected from the 10 monitoring wells prior to sampling the well. One complete set of water levels was collected at high tide and low tide in a period of less than 1 hour to allow for comparison between the wells. A transducer was placed in well SP-7 for several days to investigate the tidal influences on water levels. Results of the water level survey are outlined in Section 3.8 of this document.

Both falling head and rising head slug tests were conducted in each of the monitoring wells (SP-7 and ERDC-MW-1, 2, 3A, 3B, 4A, 4B, 5). These slug tests allowed for estimation of permeability in the formations in the Makua Valley. This involved the use of a solid slug that was placed in and out of the well, while the response of the well was measured with transducers and computer equipment. Results of the slug testing are outlined in Section 3.8 of this document.

2.12 Fate and Transport Modeling

Fate and transport analyses are conducted using the data collected as part of this study to estimate the potential for compounds introduced as part of military training to be transported off-site. To evaluate this, a site conceptual model is also developed that explains processes that result in groundwater flowing through Makua Valley. The two primary pathways for both MMR and the OB/OD area are considered to be: (1) contaminant release into surface soils, percolation of contaminant from the surface into the groundwater and subsequent groundwater migration off-site to the ocean or near-shore area; and (2) transport of soil particles containing contaminants that move with large rainfall events into streams discharging into the near-shore area, Muliwai ponds, or ocean. To evaluate the potential travel times for compounds discharging to the ocean, both surface water and groundwater modeling were performed. In addition, other studies

performed on-site and off-site that may provide estimates of impacts of off-site receptors are summarized.

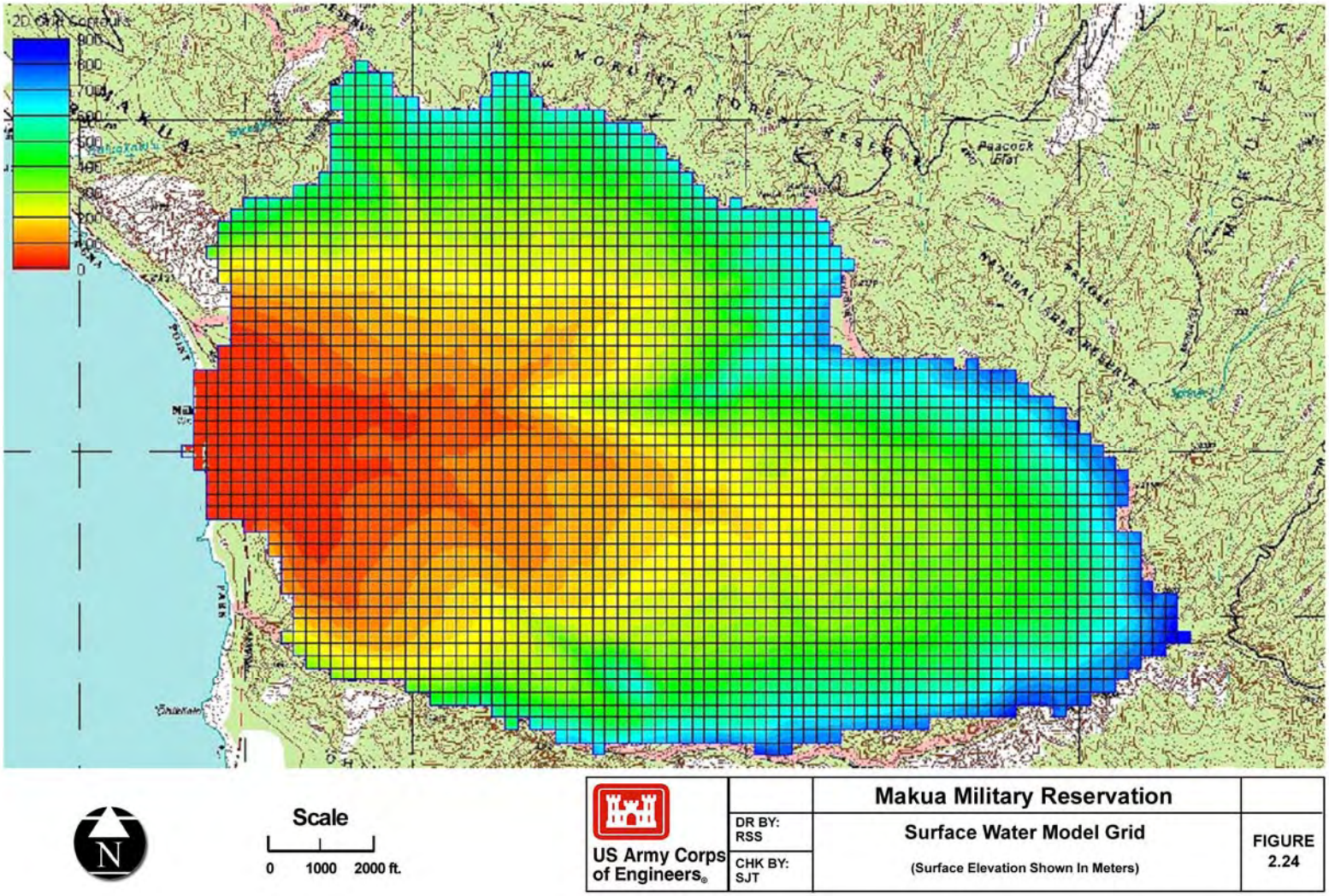
2.12.1 Surface Water Modeling

The surface water modeling portion of this study was performed and to provide estimates of groundwater recharge, and provide estimates of flow and sediment transport due to large rainfall events. The model also provides estimates of flooding inundation. The two-dimensional surface water model is designed to calculate the volume of flow at the outlet of the three streams in Makua: Punapohaku Steam, Koiahi Gulch Stream, and Makua Stream. The surface water modeling grid extends throughout Makua Valley from the top of the Waianae Mountains to the ocean as shown in Figure 2.24.

As part of preparation of this surface water model, precipitation data were collected from the existing MMR weather stations, the rain gage at the stream sampling station, and eight additional rain gages placed at the top of the Waianae Range. The rain gages were in place during February 14, 2003, January 23, 2004, and February 27, 2004, surface water flow in the Makua Valley. A map showing rainfall gage locations is shown in Appendix L.

The modeling was performed using the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model (Downer and Ogden, 2002) along with the Watershed Modeling System (WMS) (Nelson, 2001) preprocessor and postprocessor. GSSHA is a physically based, distributed-parameter model that simulates physical processes occurring in the watershed that produce stream flow and sediment movement. The model is able to explicitly account for the spatial distribution of land use, soil textures, vegetation and contaminant loadings in a much more rigorous way than lumped parameter models such as Hydrological Simulation Program Fortran (HSPF) (Donigian et al., 1984). The GSSHA model, developed with U.S. Army funds, was designed in part to assess the problem of soil erosion and contaminant flow due to overland flow from Department of Defense firing ranges. It has the capability to simulate multiple runoff mechanisms and is therefore applicable to a much wider range of problems than its predecessor, CASC2D (Ogden

Figure 2.24 Surface Water Modeling Grid



and Julien, 2002, Downer et al., 2002). For this modeling effort, the model was designed to incorporate overland flow due to rainfall to stream channels, and infiltration of rainfall into the land surface.

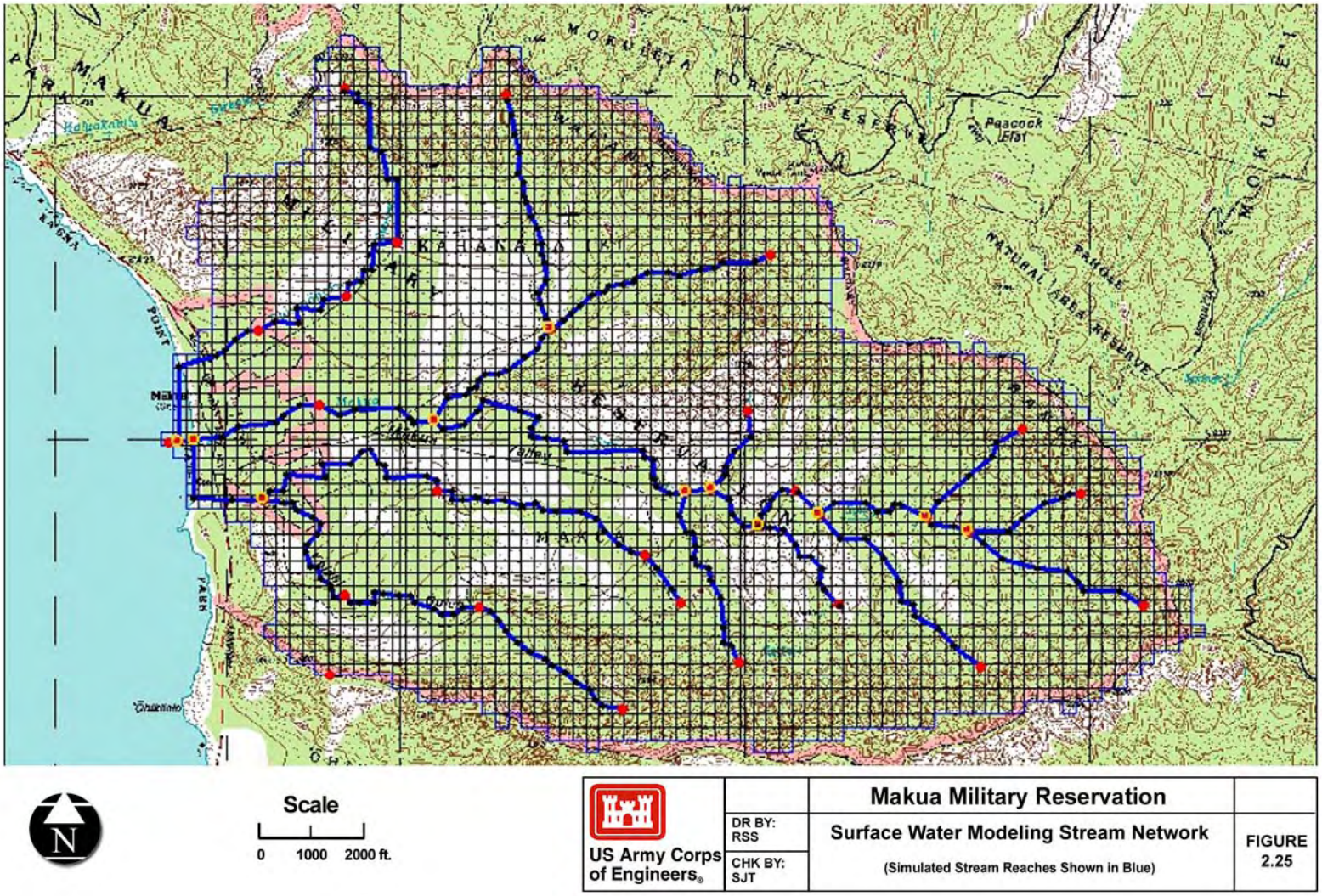
The GSSHA surface water model input data included parameters such as soil moisture content, vegetation type, soil type, and precipitation data. Soil moisture data were collected from soil samples taken throughout Makua Valley as part of this study as outlined in Section 3.4.2. Soil moisture content and grain size analyses were collected and used as input for the model. Precipitation data were collected from the three existing MMR weather stations and eight rain gages placed throughout the Makua Valley. These 11 rainfall data points provided a detailed distribution of rainfall throughout the Valley during the simulated rainfall events.

Stream flow measurements were collected as outlined in Section 3.5. Measurements or estimates of stream flow were made for Punapohaku Stream, Koiahi Gulch Stream, and Makua Stream for the February 14 2003, January 23, 2004, and February 27, 2004, flow events. Distributed parameters in the model were based on land use and soil textural classification taken from a GIS database prepared by the Range Control Division of Schofield Barracks for Makua. Stream bottom shape and slope were collected at 10 locations throughout the valley to provide input into the computer model.

The preparation of the model involved incorporating digital topography (DEM, or digital elevation model) collected on a 5-meter grid throughout Makua Valley. This is extremely detailed topography, as most other sites simulated typically have only a 10- or 30-meter digital topographic map. The stream network was then added to the model as shown in Figure 2.25. Punapohaku Stream, Koiahi Gulch Stream and Makua Stream were detailed and simulated as 1-D channels, with each stream having an outlet point for calculating the stream hydrograph.

The model grid was composed of 86 grid blocks in the east/west direction and 57 grid blocks in the north-south direction with each square having a size of 75 meters (Figure 2.24). The model was run using a time step of 30 seconds. Infiltration was calculated using the Green ..

Figure 2.25 Surface Water Modeling Stream Network



and Ampt infiltration method. Due the short simulation period, evapo-transpiration was negligible and was not simulated. An initial moisture content of 20% was used for the model runs The streambeds were simulated as trapezoidal erodible channels. Soil erosion factors include crop management of 0.005 and conservation practices of 1.0. Both of these parameters are generally used for undeveloped land this is largely vegetated by grass or trees (Downer and Ogden, 2003).

Additional model input parameters include the distributed overland flow roughness coefficient for the model area. This roughness value is analogous to a Manning's n value, and original values are estimated from standard literature sources that relate land use to overland flow roughness (Downer and Ogden, 2002). Figure 2.26 shows the overland roughness values that were used for the modeling. The different zones in Figure 2.26 represent different vegetation types, with values for roughness varying from 0.192 to 0.30.

Soil hydraulic properties that control infiltration values for different soil types throughout the Makua Valley are input parameters required for the model. Values for shallow vertical hydraulic conductivity (K_s) varied from 0.10 to 2.85 cm hr^{-1} (Figure 2.27). The values of hydraulic conductivity represent the ability of the shallow geologic material to transmit water, as part of Darcy's Law V=KI, where the variables are V, K, and I, for velocity, hydraulic conductivity, and hydraulic gradient, respectively. In Darcy's Law, for a given velocity V, the hydraulic conductivity K and the vertical gradient I are inversely related. Most of the project area has the somewhat higher hydraulic conductivity values of 2.85 cm hr^{-1}, with the streambeds and central areas having lower `values of hydraulic conductivity. During simulations, the amount of infiltration is highly dependent on K_s, as well as the slope of the land surface (higher slopes have less infiltration and more runoff), capillary head (soil suction), and the soil porosity.

The parameters used in the model were calibrated using the February 14, 2003, January 23, 2004, and February 27, 2004, flow events. The model incorporated overland flow, channel flow, and infiltration losses. The model was run for 1.7 days beginning at 0930 February 13,

2003. The model were simulated for all three events to cover the period from the beginning of rainfall until the flow of water measured at the stream outlets (measured) and the model runs (simulated) has ceased. For the February 14, 2003 flow event, the model was run for 1.7 days beginning 0930 on February 13, 2003. For the January 23, 2004 event the model was run for 1.7 days beginning at 18:00 on January 22, 2004. For the February 27, 2004 event the model simulation was run longer for 11 days, as during this stream flow event two large storms dropped rainfall on the valley. Output from the simulations utilized in this modeling exercise included stream hydrographs, infiltration to groundwater, and suspended sediment transport. Additional outputs include sand load (bed load), which was not included in this evaluation. Like all surface water models, this model's calculations for bed load are made with empirical equations. Measuring bed load in the field is not required to provide the parameters to design the model. The modeling effort focused on suspended sediment and flooding, which are more critical parameters to evaluate for impacts. For this study the bed load (or sand load) was not measured, as the Makua beach environment has abundant sand already, so more sand is not considered a significant impact. The surface water modeling effort is calibrated to the February 14, 2003, January 23, 2004, and February 27, 2004, flow events. Since there are almost no detectable levels of potential contamination in the surface water, the output of the surface water modeling has been limited to evaluating flooding and sediment transport and not the impacts of chemical constituents to off-site receptors. Since limited evaluations are made with the model, the usefulness of the surface water modeling is somewhat diminished. Additional results of the calibration and predictive runs are explained in Section 3.9.1.

Figure 2.26 Overland Flow Roughness Values (n)

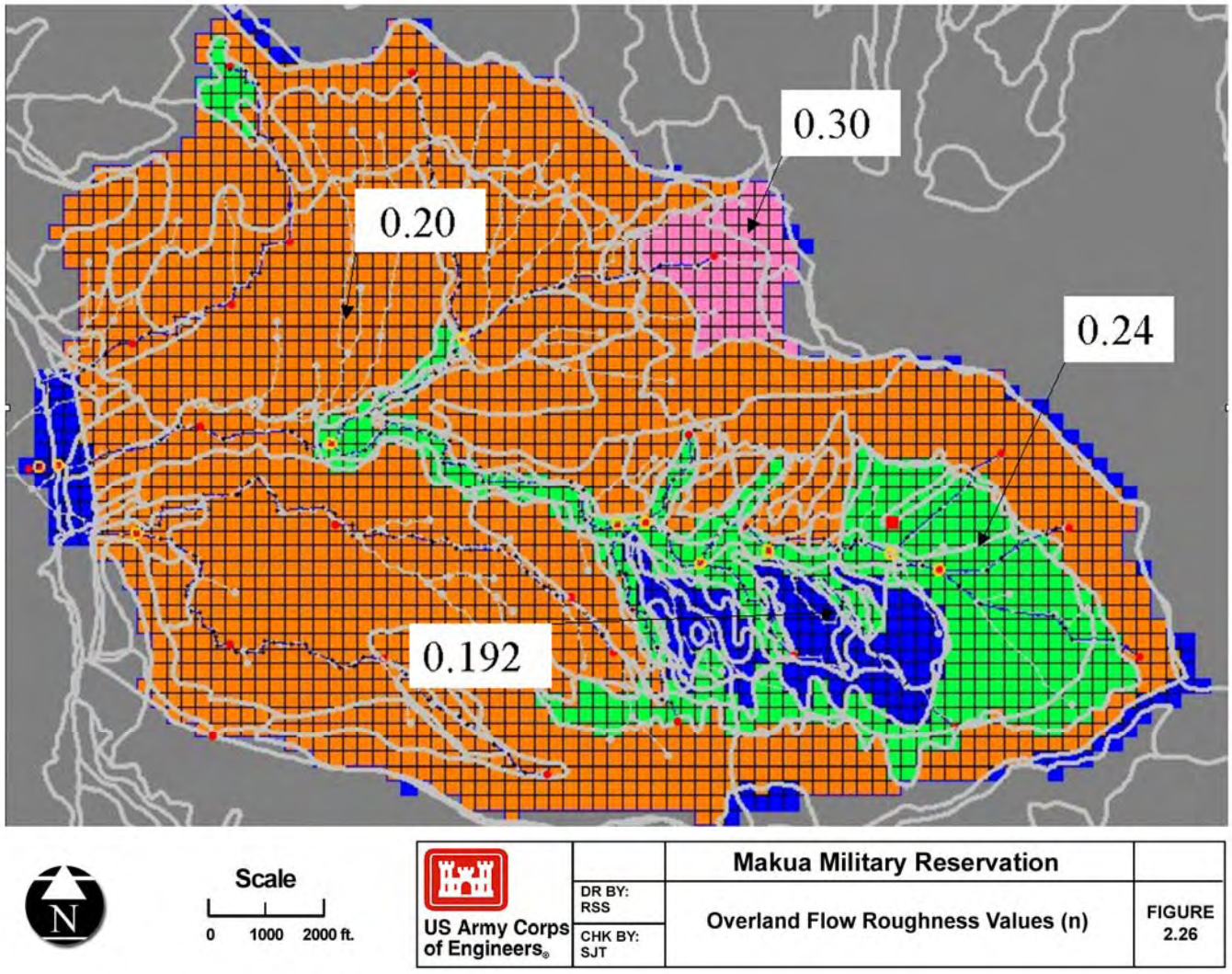
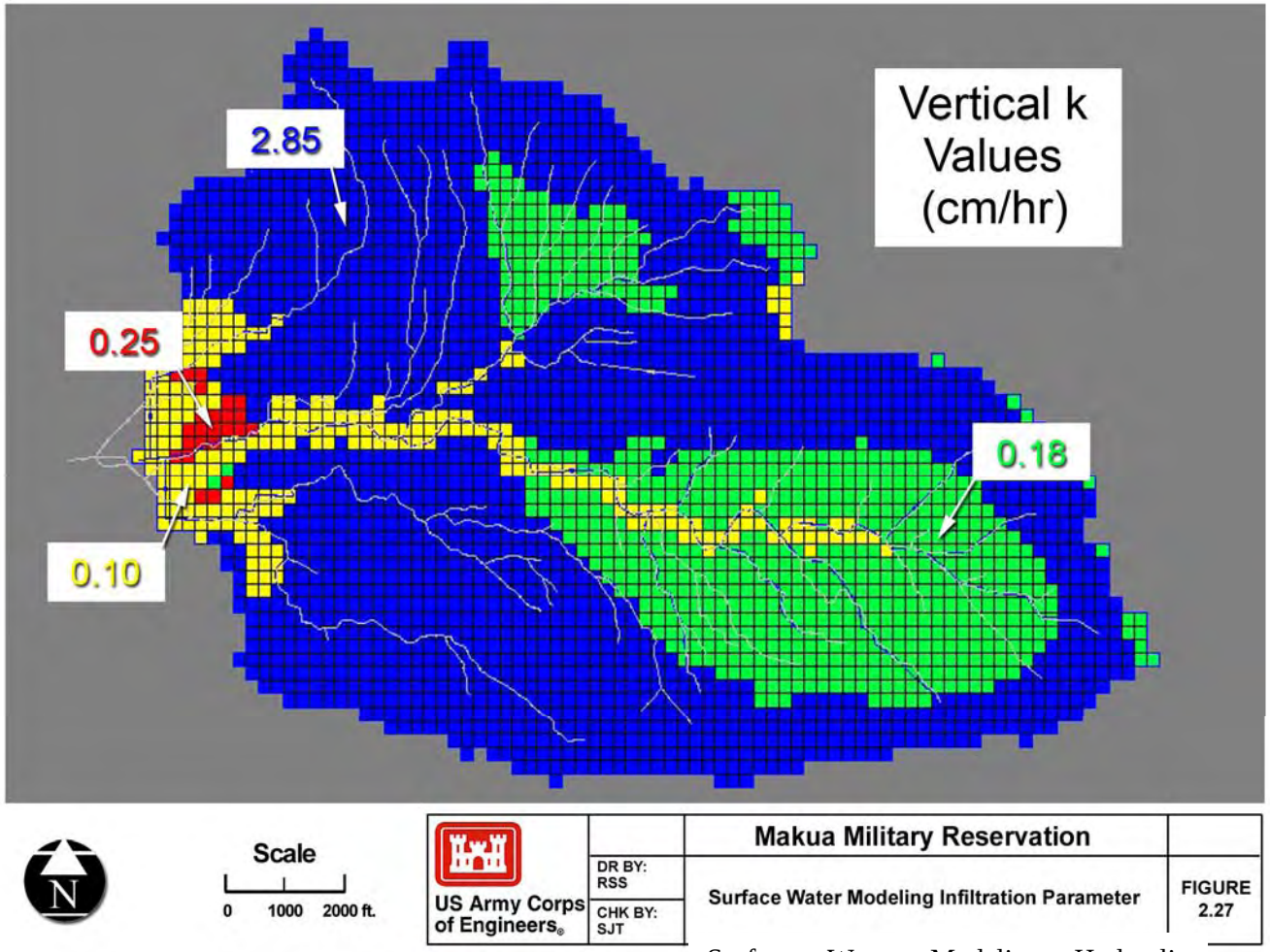


Figure 2.27 Surface Water Modeling Hydraulic Conductivity (K) Parameters



Surface Water Modeling Hydraulic Conductivity (K) Parameters

2.12.2 Groundwater Modeling

A three-dimensional flow and solute transport model was developed to provide an additional tool for evaluating the potential for off-site transport of compounds related to military operation. The model domain extends from the boundary of MMR at the top of the Waianae Range to the ocean. The models used were the U.S. Geological Survey's Modflow flow model (McDonald and Harbaugh, 1988) and the MT3D solute transport model (Zheng, 1990). The U.S. Geological Survey's MODPATH (Pollack, 1994) model was also used to estimate groundwater flow paths and travel times within the Makua Valley as outlined in Appendix H-1. Model runs were also conducted using the U.S. Geological Survey's SEAWAT model in response to reviewers comments on the Draft EIS. The SEAWAT model was designed to simulate variable-density groundwater flow and solute transport by combining a modified version of the flow model MODFLOW-2000 and the transport model MT3DMS into a single model. Additional runs using this SEAWAT model are outlined in Appendix H-2.

Complete descriptions of the site conceptual model and the use of the groundwater model are contained in Appendix H of this report. The models were created with the Department of Defense's Groundwater Modeling System (GMS) pre- and post-processing software for the MODFLOW, MT3D, MODPATH, and FEMWATER codes. The SEAWAT model was created with the Visual MODFLOW v. 4.1 pre- and post-processor. The MODFLOW model included transport within the saturated portions of the aquifer. Transport of compounds potentially in the unsaturated zone was estimated for input into the groundwater flow and solute transport models using a FEMWATER (Ogden and Julien, 2002) finite element vadose zone model, as outlined in Appendix I.

The MODFLOW, MT3D, SEAWAT, and FEMWATER model combination was used to estimate travel times for groundwater to flow from the recharge areas in the Waianae mountain range to the ocean. Travel paths of groundwater from the training areas of concern (such as the OB/OD area) to potential off-site receptors are also estimated. Input from the entire sampling

program, including the installation of monitoring wells, groundwater sampling, and slug testing, was included in the building of the groundwater models (Appendix H).

2.13 Risk Based Screening Levels for Data Comparison

For this hydrogeologic assessment of the Makua Military Reservation, results of the soil and water sampling performed by the analytical laboratory were compared to a number of lists of risked based screening levels. For this project these lists included the following:

a. Groundwater and Surface Water Risk Based Screening Levels

- Federal Maximum Contaminant Levels (MCLs), or Federal drinking water standards.
- USEPA U.S. Environmental Protection Agency (EPA) Region IX (Region IX includes Hawai`i) Preliminary Remediation Goals (PRGs) for Tap Water published October 2002.
- Hawai`i State Department of Health Hawai`i Administrative Rules Title 11 (Hawai`i Title 11-281 Tier I Action Levels for Rainfall Less than 200 cm/yr drinking water source not threatened, and 11-54-4 Basic Water Quality Criteria Applicable to All Waters**).
- USEPA U.S. EPA Region 5 Ecological Data Quality Levels (EDQLs) for Surface Water.
- Federal Ambient Water Quality Criteria (AWQC) for Freshwater** (Also called National Recommended Water Quality Criteria – 2002).

**(The "Federal Ambient Water Quality Criteria (AWQC) for Freshwater" and "11-54-4 Basic Water Quality Criteria Applicable to All Waters" are the same lists).

b. Soil and Sediment Risk Based Screening Levels

- USEPA U.S. EPA Generic Soil Screening Levels (SSLs) for Ingestion, Inhalation, and Migration to Groundwater published October 2004.
- USEPA U.S. EPA Region IX Preliminary Remediation Goals (PRGs) for Industrial Land Use Published October 2002.
- Hawai`i State Department of Health Hawai`i Administrative Rules Title 11 (Hawai`i Title 11-281 Tier I Action Levels for Rainfall Less than 200 cm/yr drinking water source not threatened).
- USEPA U.S. EPA Region 5 Ecological Data Quality Levels (EDQLs) for Soil (applicable to surface soil samples only).

- USEPA U.S. EPA Region 5 Ecological Data Quality Levels (EDQLs) for Sediment (applicable to surface soil samples only).

2.13.1 Laboratory Detection Limit Comparison

A comparison was made between the laboratory detection limits and the Region IX Preliminary Remediation Goals (PRGs), U.S. EPA Maximum Contaminant Levels (MCLs), and State of Hawai`i Conservative Risk-Based Screening Levels. Based on these values, a number of the detection limits were lowered for certain analytes for this project. These include semivolatile organics, some metals, and dioxin compounds. For semivolatile organic compound analyses in soils, U.S. EPA method 8720CSIM will be used, and for water samples, U.S. EPA method 8310 will be used. For metals analyses, method 6010Blow will be used to obtain lower detection limits for arsenic, lead, and selenium. For dioxin analyses in water, U.S. EPA method 8290 will be used to obtain lower detection limits for water samples.

2.13.2 Explanation of Risk Based Screening Levels for Data Comparison

For this hydrogeologic assessment of the Makua Military Reservation, results of the soil and water sampling performed by the analytical laboratory were compared to the industrial Preliminary Remediation Goals published by Region IX, U.S. Environmental Protection Agency (EPA). PRGs are risk-based concentrations, derived from standardized equations, combining exposure information assumptions with U.S. EPA toxicity data. PRG values are considered by U.S. EPA to be protective for humans (including sensitive groups), over a lifetime. Region IX PRGs do not address non-human health receptors such as ecological impacts. In general, under the Superfund program, no further action at a site is required for concentration levels below Region IX PRGs. These PRGs are often applied to sites for consideration in programs other than Superfund, including Environmental Impact Statements (EIS). Region IX Industrial PRGs are used for comparison of soil laboratory data, with the residential PRGs listed for informational purposes. Region IX Industrial PRG values are used to compare the laboratory analytical data to evaluate if a potential concern exists, since no soldiers or persons live at Makua, but only spend

part of their working day at the site. Chemical concentrations above the PRG levels would not automatically designate a site as "dirty," or trigger a response action. However, exceeding a PRG suggests that further evaluation of the potential risks that may be posed by potential site contaminations is appropriate. Further evaluation may include additional sampling, but also may include considering ambient (or background) levels in the environment (EPA, 2004). Region IX PRGs published in October 2002 are used, as these were the PRG values applied to the project during the field investigation and approval of the Sampling and Analysis Plan.

Results of the soil sampling performed by the analytical laboratory were also compared to U.S. EPA Generic Soil Screening Levels (SSLs) for Ingestion, Inhalation, and Migration to Groundwater. Consideration of these U.S. EPA Generic SSLs for Ingestion and Inhalation are included and used in developing the Region IX PRGs, so no separate comparison to these values are necessary (EPA, 2004).

A comparison of the Generic SSLs for the protection of groundwater has been included for 100 most common contaminants at Superfund sites. The SSLs were developed using a default dilution-attenuation factor (DAF) of 20 to account for natural processes that reduce contaminant concentrations in the subsurface such as dilution, chemical decay, and biodegradation. The geologic conditions at Makua are conducive to these processes due to the long travel paths for groundwater, and the long distances from the impact area and OB/OD to off-site receptors. Therefore, the SSLs with a DAF of 20 are used for comparison. In general, if an SSL is not exceeded for the migration to groundwater pathway, the user may eliminate this pathway from further investigation (EPA, 2004).

Soil and water samples are also compared to Hawai`i Title 11-281 Tier 1 Action Levels for Groundwater (rainfall $\leq$ 200 cm/year, drinking water source not threatened). These regulations essentially are for underground storage tanks containing products such as gasoline and diesel fuel. While there are no records of underground tanks in the Makua area, these Tier 1 values are used for comparison as a guideline if remediation of the soil would be necessary.

To evaluate the potential for ecological impacts, a comparison of soil and water samples is made to the U.S. EPA Region 5 Ecological Data Quality Levels (or Ecological Screening Levels) for soil and sediment. Ecological values similar to PRGs are not published for Region IX, so in this vacuum the Region 5 Ecological Screening Levels (ESLs) are used to provide an indication of potential impacts. The Region 5 ESLs have been used outside of Region 5 (such as the Blackbird Mine in Idaho), and the Tri-Service (Army, Navy, Air Force) Remedial Project Manager's Handbook for Ecological Risk Assessment also listed these as a source for comparison of soil values for ecological risk. The acute (short term exposure) standards are more applicable than chronic (long term exposure) standards for Makua since the streams only flow a few times each year, and the biota would be exposed to the surface water flows for only a short period of time (maybe a few days each year). They are used to provide a general indication if additional work is necessary to evaluate ecological impacts. Comparisons for soil and water (to the Region IX Industrial PRGs and MCLs) are contained in the main text o the EIS.

Comparisons to the Hawai`i State Department of Health Hawai`i Administrative Rules, Title 11-54-4 Basic Water Quality Criteria Applicable to All Waters, U.S. EPA Region 5 Ecological Data Quality Levels (EDQLs), Federal Ambient Water Quality Criteria (AWQC) for Freshwater, U.S. EPA Generic Soil Screening Levels (SSLs) for Migration to Groundwater, and Hawai`i Title 11-281 Tier I Action Levels are contained in Appendix K.

SECTION 3.0 RESULTS

Section 3.0 of this report lists an explanation of what was found during drilling, soil sampling, groundwater sampling, and modeling. Many of the data are presented in tabular form or as figures for more ease of review.

3.1 Ordnance Clearance

During the downhole drilling operations, one borehole (MW-5) was relocated due to encountering metal during drilling. The boreholes at the OB/OD area (ERDC-B1 and B2) were moved prior to drilling to avoid metal. In general, the field operations were not adversely impacted by the potential to encounter ordnance.

3.2 Summary of Makua Military Reservation Shallow Soil Tests

Results of the soil sampling reported by the analytical laboratory will be compared primarily to the industrial Preliminary Remediation Goals (PRGs) published by Region IX Environmental Protection Agency (EPA). PRGs are risk-based concentrations, derived from standardized equations, combining exposure information assumptions with U.S. EPA toxicity data. PRG values are considered by U.S. EPA to be protective for humans (including sensitive groups), over a lifetime. Region IX PRGs do not address non-human health receptors such as ecological impacts. In general, under the Superfund program, no further action at a site is required for concentration levels below Region IX PRGs. These PRGs are often applied to sites for consideration in programs other than Superfund, including Environmental Impact Statements (EIS). Region IX Industrial PRGs are used for comparison of soil laboratory data. Residential PRGs are listed for informational purposes.

Figures 2.1 through 2.13 show the locations of the sampling sites and the concentration of contaminants detected above industrial PRGs in soils detected at each location. Tables 3.1 through 3.2 list the values above Region IX PRGs in tabular form. Compounds listed in these tables represent only those detected above Region IX Industrial PRGs. Compounds that were

detected in soils at levels below industrial PRGs, and evaluated to be not naturally occurring (and possibly a result of Army operations), are listed in Appendix B.

Figure 2.1 shows and Table 3.1 lists the results for Objective Deer. No analytes above industrial PRGs were reported by the analytical laboratory in the shallow soils at Objective Deer. Appendix B contains a list of additional compounds detected that were below Region IX Industrial PRGs. Additional compounds detected at Objective Deer in sample Deer 1-1 below Region IX Industrial PRGs include low levels of dioxins (HpCDD, OCDD, 1,2,3,4,6,7,8-HpCDD), benzene, cyanide, and the pesticides Endosulfan I and II.

Figure 2.2 shows and Table 3.1 lists the results for Objective Coyote. Iron concentrations above industrial PRGs were reported by the analytical laboratory in the shallow soils at Objective Coyote. No other compounds above Region IX Industrial PRGs were detected. Appendix B contains a list of additional compounds detected that were below Region IX Industrial PRGs, but warrant discussion in this report. Additional compounds detected at Objective Coyote in sample Coyote 1-2 below Region IX Industrial PRGs include low levels of dioxin (OCDD), toluene, cyanide, and the pesticides Endosulfan I and II.

Figure 2.3 shows and Table 3.1 lists the results for Objective Fox. The analytical laboratory reported no compounds above Region IX Industrial PRGs. Appendix B contains a list of additional compounds detected that were below Region IX Industrial PRGs. Additional compounds detected at Objective Fox in sample Fox 1-3 below Region IX Industrial PRGs include low levels of dioxin (OCDD), toluene, cyanide, the herbicide dalapon, and the pesticide Endosulfan II.

Figure 2.4 shows and Table 3.1 lists the results for Objective Wolf. Iron concentrations above industrial PRGs were reported in one shallow soil sample at Objective Wolf. The analytical laboratory reported no other compounds above Region IX Industrial PRGs. Additional compounds detected at Objective Wolf in sample Wolf 1-5 below Region IX Industrial PRGs include low levels of gasoline components (benzene, MTBE) and nitroglycerin (Appendix B).

Figure 2.5 shows and Table 3.1 lists the results for Objective Elk. Iron and lead concentrations above industrial PRGs were reported by the analytical laboratory in the shallow soils at Objective Elk. Lead was reported by the laboratory in sample 1-8 in Objective Elk above Region IX Industrial PRGs. The analytical laboratory reported no other compounds above Region IX Industrial PRGs. Additional compounds detected at Objective Elk in sample Elk 1-7 below Region IX Industrial PRGs include low levels of benzene, dioxin (OCDD), and cyanide (Appendix B).

Figure 2.6 shows and Table 3.1 lists the results for Objective Deeds. The analytical laboratory reported no compounds above Region IX Industrial PRGs from Objective Deed samples. Additional compounds detected at Objective Deeds in sample Deeds 1-1 below Region IX Industrial PRGs include low levels of dioxin (OCDD, OCDF), benzene, toluene, cyanide, and nitroglycerin (Appendix B).

Figure 2.7 shows and Table 3.1 lists the results for Objective Badger. Iron concentrations above industrial PRGs were reported by the analytical laboratory in the shallow soils at Objective Badger (Figure 2.7). The analytical laboratory reported no other compounds above Region IX Industrial PRGs. Appendix B contains a list of additional compounds detected that were below Region IX Industrial PRGs. Additional compounds detected at Objective Badger in samples Badger 1-10 and 1-5 below Region IX Industrial PRGs includes low levels of dioxin (OCDD), cyanide, benzene, and some nitroglycerin.

Figure 2.8 shows and Table 3.1 lists the results for Objective Buffalo. Iron concentrations above industrial PRGs were reported by the analytical laboratory in the shallow soils at Objective Buffalo (Figure 2.8). The analytical laboratory reported no other compounds

Table 3.1 Summary of Analytical Values above Region IX Industrial PRGs

(Objective Deer, Coyote, Fox, Wolf, Elk, Deeds, Badger, Buffalo, Counter Attack Positions, Proposed Burn Pit)

	IRON mg/kg		**LEAD** mg/kg		**Dibenzanthracene** mg/kg	
	Residential PRG	Industrial PRG	Residential PRG	Industrial PRG	Residential PRG	Industrial PRG
Objective Location	23463.00	100000.00	400.00	750.00	62.00	210.00
Objective Deer						
DEER 1-01						
DEER 1-08						
DEER 1-09						
DEER 1-10						
DEER 1-12						
Objective Coyote						
COYOTE 1-06	100,000.00					
COYOTE 1-07						
COYOTE 1-08						
Objective Fox						
FOX 1-01						
FOX 1-02						
FOX 1-03						
Objective Wolf						
WOLF 1-02	107,000.00					
WOLF 1-05						

Objective Location	IRON mg/kg		LEAD mg/kg		Dibenzanthracene mg/kg	
	Residential PRG 23463.00	Industrial PRG 100000.00	Residential PRG 400.00	Industrial PRG 750.00	Residential PRG 62.00	Industrial PRG 210.00
WOLF 1-06						
Objective Elk						
ELK 1-02						
ELK 1-06						
ELK 1-07	103,000.00					
ELK 1-07	100,000.00					
ELK 1-08			119,000.00			
ELK 1-10						
Objective Deeds						
DEEDS 1-01						
Objective Badger						
BADGER 1-01	110,000.00					
BADGER 1-02	102,000.00					
BADGER 1-08	114,000.00					
BADGER 1-10	101,000.00					
Objective Buffalo						
BUFFALO 1-01	106,000.00					
BUFFALO 1-02	108,000.00					
BUFFALO 1-03	111,000.00					
BUFFALO 1-06	106,000.00					

Objective Location	IRON mg/kg		LEAD mg/kg		Dibenzanthracene mg/kg	
	Residential PRG 23463.00	Industrial PRG 100000.00	Residential PRG 400.00	Industrial PRG 750.00	Residential PRG 62.00	Industrial PRG 210.00
Counter Attack Position						
CAA 1-02	105,000.00					
CAA 1-07					240	
CAA 1-05	100,000.00					
CAA 1-06	131,000.00					
CAA 1-09	145,000.00					
CAA 1-10	104,000.00					
Proposed Burn Pit						
PBP 1-01						

Table 3.2 Summary of Analytical Values above Region IX Industrial PRGs

(Weather Station Burn Pan, OB/OD Area, Demo Pit, Area-G,

Miscellaneous Training Areas, Deer Berms, Makua Stream Firing Area)

	IRON mg/kg		**2,3,7,8-TCDD** ug/kg		**Dibenzanthracene** mg/kg	
Objective Location	Residential PRG 23463.00	Industrial PRG 100000.00	Residential PRG 0.0039	Industrial PRG 0.0160	Residential PRG 62.00	Industrial PRG 210.00
Weather Station Burn Pan						
WSBP 1-01	99,100.00					
OB/OD Area						
OB/OD 1-05					440	
OB/OD 1-01	88,300.00		0.03			
Demolition Pit Area						
DEMO-PIT 1-01	106,000.00					
DEMO-PIT 1-01	103,000.00					
Area G						
AREA-G 1-01	106,000.00					
AREA-G 1-02						
AREA-G 1-02	100,000.00					
AREA-G 1-03						

Objective Location	IRON mg/kg		2,3,7,8-TCDD ug/kg		Dibenzanthracene mg/kg	
	Residential PRG 23463.00	Industrial PRG 100000.00	Residential PRG 0.0039	Industrial PRG 0.0160	Residential PRG 62.00	Industrial PRG 210.00
Miscellaneous Training Areas						
MTA 1-01	105,000.00					
MTA 1-02	105,000.00					
MTA 1-03						
MTA 1-03						
MTA 1-04	101,000.00					
MTA 1-05	101,000.00					
Deer Berms						
DB 1-01						
DB 1-01						
DB 1-02						
DB 1-03						
DB 1-04						
DB 1-05	107,000.00					
Outlying Areas						
BG 1-04						
NFBR 1-07						

Objective Location	IRON mg/kg		2,3,7,8-TCDD ug/kg		Dibenzanthracene mg/kg	
	Residential PRG 23463.00	Industrial PRG 100000.00	Residential PRG 0.0039	Industrial PRG 0.0160	Residential PRG 62.00	Industrial PRG 210.00
NFBR 1-08 NFBR 1-09 NFBR 1-10	106,000.00					
Makua Stream Firing Area MSFA 1-01 MSFA 1-02			2.44 2.33			

above Region IX Industrial PRGs. Appendix B contains a list of additional compounds detected that were below Region IX Industrial PRGs. Additional compounds detected at Objective Buffalo in sample Buffalo 1-6 below Region IX Industrial PRGs include low levels of dioxin (OCDD), benzene, toluene, the pesticides Endosulfan I and II, diethylphthalate, and cyanide.

Figure 2.9 shows and Table 3.1 lists the results for the Counter Attack Area/Positions. Iron and dibenzanthracene concentrations above industrial PRGs were reported by the analytical laboratory in the shallow soils (Figure 2.9) of these areas. The dibenzanthracene was also in the laboratory blanks, and may not be actually in the field samples. The analytical laboratory reported no other compounds above Region IX Industrial PRGs. Appendix B contains a list of additional compounds detected that were below Region IX Industrial PRGs. Additional compounds detected at the Counter Attack Area in samples CAA 1-1 and 1-7 below Region IX Industrial PRGs include low levels of dioxin (OCDD), toluene, the pesticides Endosulfan I, the herbicide MCPP, and cyanide. Sample CAA 1-7, which was sent to the quality control laboratory (Sequoia Labs) for confirmatory sampling, reported compounds of 2,4-D (a herbicide) and the semivolatile compounds benzoanthracene, cyanide, and dibenzanthracene (Appendix B). The benzoanthracene and dibenzanthracene were in the laboratory method blank samples, and may not be actual detections for the field samples.

Figure 2-10 shows and Table 3.2 lists the analytical laboratory results for the 105 firing area, Makua Stream Firing Area, and Weather Station Burn Pan. Two samples in the Makua Stream Firing Area (MSFA 1-1 and MSFA 1-2) contained total TCDD dioxins that may be above industrial PRGs of 2.44 and 2.33 ug/kg. Total TCDD dioxin analyses are usually composed of primarily the compound 2,3,7,8-TCDD. Concentrations of total TCDD were 2.44 and 2.33 ug/kg, respectively, while the Region IX Industrial PRG for 2,3,7,8-TCDD is 0.016 ug/kg. The analytical laboratory reported no other compounds above Region IX Industrial PRGs. Appendix B contains a list of additional compounds detected that were below Region IX Industrial PRGs. Additional compounds detected in samples from the 105 firing area include mostly low levels of

dioxin (see Appendix B). Samples from the Makua Stream Firing Area contained trace levels of fuel components (benzene, toluene), and some dioxin compounds (see Appendix B for a complete list).

Figure 2.11 shows and Table 3.2 lists the analytical laboratory results for the Demolition Pit and Area G. As with many other sites, concentrations above industrial PRGs for the metal iron were reported in the shallow soils (Figure 2.11) No other compounds above Region IX Industrial PRGs were reported by the analytical laboratory. Additional compounds detected in samples from the Area G location included low levels of benzene, toluene, and cyanide (Appendix B). The demolition pit soil samples contained low levels of dioxin and the explosives HMX and RDX (below industrial PRGs). This is one of the only sites with soil samples containing explosives reported by the analytical laboratory.

Figure 2.12 shows and Table 3.2 lists the analytical laboratory results for the Deer Berms. The analytical laboratory reported concentrations above industrial PRGs for iron and the semivolatile compound dibenzanthracene in the shallow soils (Figure 2.12). No other compounds above Region IX Industrial PRGs were reported by the analytical laboratory. Appendix B contains a list of additional compounds detected that were below Region IX Industrial PRGs. Additional compounds detected in samples from the Proposed Burn Pit included low levels of dioxins (HxCDD), benzene, and MTBE. The Deer Berm samples contained low levels of dioxin, furans (HxCDF), and the explosives TNT, DNT, and tetryl. This is one of the only sites with soil samples containing explosives reported by the analytical laboratory. The sample Deer Berm 1-1F sent to the quality control analytical laboratory for confirmatory sampling reported the semivolatile compounds of benzopyrene, benzofluorathene, and dibenzanthracene. All of these compounds were in the laboratory method blank samples, and are likely not detections from the field samples however, they are reported here for completeness.

Figure 2.10 shows and Table 3.2 lists the results for the weather station burn pan area. These soil samples contained iron concentrations above industrial PRGs, like most samples in

Makua Valley. As listed in Appendix B, trace levels of dioxin, Endosulfan I and II and cyanide and some nitroglycerine were also reported by the analytical laboratory. The analytical laboratory also reported trace levels of dioxin, benzene, and MTBE below Region IX Industrial PRGs from samples collected at the proposed burn pit area. (The proposed burn pit was proposed, but never used by the Army.)

Figure 2.14 shows and Table 3.2 lists the analytical laboratory results for the Open Burning/Open Detonation Area that are above Region IX Industrial PRGs. As with many other sites, iron concentrations above industrial PRGs were reported by the analytical laboratory in the shallow soils (Figure 2.14). At the OB/OD area, the chemical dioxin (2,3,7,8-TCDD) with a concentration of 0.03 ug/l and dibenzanthracene were detected in concentrations above Region IX Industrial PRGs. The dibenzanthracene is also present in the laboratory blanks, and could be laboratory contamination (not necessarily this compound detected in the field). Appendix B contains a list of additional compounds detected that were below Region IX Industrial PRGs. All five of the samples in the OB/OD area were analyzed for the complete suite of compounds listed in Table 2.2. Additional compounds detected in samples from the OB/OD soils include low levels of perchlorate, benzene, toluene, pesticides, herbicides, PCBs, and explosives (Appendix B). Additional compounds detected in the samples from the OB/OD area reported by the quality control laboratory included 2,4-DNT, anthracene, benzoanthracene, dibenzanthracene, and PCB-1260. The benzoanthracene and dibenzanthracene are likely laboratory contaminants, and were not in the field samples.

An additional ten background soil samples (for metals) and 22 outlying soil samples (for metals and explosives) were collected. These are shown in Figure 2.14. Table 3.2 lists the compounds from these soil samples above Region IX Industrial PRGs. Iron concentrations above Industrial PRGs were reported by the analytical laboratory in sample NFBR-1-09. No explosive compounds were detected in any of these outlying samples. (All the outlying soil samples were analyzed for metals and explosives.)

To evaluate the potential for leaching of metals from soils in the Makua Valley, the TCLP (Toxic Characteristic Leaching Procedure) tests were conducted on 35 soil samples from throughout the Makua Valley. Results of these soil samples are listed in Appendix C. The TCLP tests are generally designed to show the potential for soils to leach metals in a typical landfill setting; however, they can also be used to evaluate the potential for soils to leach compounds potentially into the groundwater.

The results of the TCLP metals tests taken from shallow soil samples on the Makua Military Reservation showed that the leaching of potentially hazardous metals from Makua soils is generally low. The concentrations of mercury, barium, and strontium are all less than 10 ppm. TCLP samples for the metal mercury may be above action levels from the 105 firing area, Area G, Makua Stream Firing Area, OB/OD area, Wolf, and the weather station burn pan contained mercury (concentration varying from 1.5 to 5.3 mg/l), with most of these values being semi-quantified results (Appendix D). Semi-quantified results are reported by the laboratory, but the concentration levels are not considered accurate. If accurate, these concentrations are above the toxic characteristic regulatory level of 0.2 mg/l. Mercury has not impacted the water chemistry because mercury levels in groundwater and surface water samples are not elevated. Mercury is contained naturally within the soil and rocks in the Makua Valley.

Calcium, magnesium, sodium, and potassium show some small potential for leaching from the soil, with sodium showing the greatest potential for leaching with TCLP values over 1000 mg/l. Since these compounds were not found in groundwater above Region IX PRGs or MCLs, these compounds have apparently not leached to the groundwater.

In summary, the laboratory results reported for soil samples from most of the sites at the Makua Military Reservation contained concentrations of iron above Region IX PRGs. This metal is a naturally occurring by-product of weathered basalts as can be seen from Table 3.3 (from Presley et al., 1997). Table 3.3 lists the concentration of these metals in the basaltic rocks of the Waianae Mountains. Since the soils sampled under this project are derived from these rocks, the

laboratory results naturally show elevated levels of these metals. While being above Region IX industrial PRG levels, the observed concentrations of metals are not considered hazardous and are naturally occurring, and are not a result of Army operations.

Other compounds with concentrations above Region IX Industrial PRGs include lead (Elk sample 1-08). The lead sample was taken from a berm, and had likely received projectile fire. Only one site contained antimony, out of 123 metals analyze conducted at Makua. Dieldrin (a pesticide) and 2,3,7,8-TCDD (dioxin) were reported by the laboratory above Region IX Industrial PRGs. The compound dieldrin is a pineapple pesticide, and likely was brought in with tradewinds over the Waianae Mountains from the pineapple fields between Wahiawa and Waialua/Haleiwa on the North Shore portions of O`ahu. The compound 2,3,7,8-TCDD was contained in one sample at a low level of 0.03 ug/kg. Dibenzanthracene was detected in the three samples from the quality control analytical laboratory but may be laboratory contamination, as this compound was also in the laboratory control blanks.

The laboratory results of a majority of the soil samples collected at Makua do not contain concentrations of the compounds from military operations above Region IX Industrial PRGs. There are low levels of some additional compounds below Region IX PRG levels, including dioxins, pesticides, herbicides, explosives, volatile organic compounds, and semivolatile organic compounds. Many of these compounds are likely the result of grass/brush burning operations. Low levels of dioxins (HpCDD, OCDD, OCDF, HpCDD, HxCDD) and furans (HxCDF) are common in areas, such as Makua Military Reservation, that have been burned. As a result of burning, it is also common to find low levels of hydrogen cyanide, volatile organic compounds, and semivolatile organic compounds (PAHs). The low levels of cyanide, diethylphthalate, and di-n-butylphthalate could be the result of burning operations (Engelbeen, 2002).

Low levels of benzene, toluene, xylene, and MTBE were detected in a number of samples. A great majority of these detections by the laboratory were semi-quantified results, labeled with a J flag (Appendix B). These semi-quantified results generally result from

concentrations that are very near the ability of the instrument detection. All the gasoline component levels detected are below Region IX Industrial PRGs. These gasoline by-products could be the result of fueling or mowing/weed cutting operations at Makua Military Reservation.

Low levels of pesticides were reported in some samples (dieldrin, Endosulfan I and II). These pesticides may have been transported by trade winds across the Waianae Mountains, or may have been introduced by wood treated for termite control in the training area. For example, wooden pallets, often treated with pesticides for termite control, may have been brought into the training areas. Several samples contained low levels of herbicides (dalapon, 2,4-D, MCPP), which could have been introduced by weed controlling operations. There have been herbicides sprayed at Makua to control weeds along the road.

A few samples contained explosive compounds (nitroglycerin, HMX, RDX, TNT and DNT). Some low levels of these compounds would be expected at a military training site. Out of nearly 123 shallow samples analyzed for explosives, only six samples had concentrations of explosives above detection limits of the analytical laboratory.

Table 3.3 Mean Major and Trace Element Values for the Two Major Volcanic Units Found in the Vicinity of Makua Valley, After Presley, 1997

Element	Palehua Member	Kolekole Volcanics
	Mean Concentration (ppm)	Mean Concentration (ppm)
Aluminum (as Al2O3)	156,000	137,000
Iron (as FeO)	100,100	98,000
Manganese (as MnO)	2,000	2,000
Chromium	7.1	391.0
Nickel	7.6	382.1
Copper	13.6	94.2
Zinc	143.4	159.9
Barium	510.9	444.6
Lead	3.2	1.4

3.3 Borehole Lysimeters

Tables 3.4 and 3.5 list the analytical laboratory results for the borehole soil samples collected from the three lysimeter boreholes drilled at Makua Military Reservation. Eight soil samples were collected from each of the two lysimeter borings in the OB/OD area (ERDC-B1 and ERDC-B2) at 5-foot intervals. Two soil samples were collected from the boring in the junk car pit (ERDC-B3).

Table 3.4 lists the analytical laboratory borehole soil sample results above Region IX PRG levels. One of the samples contains concentrations of chromium and iron above industrial PRG values. Iron is a naturally occurring by-product of weathered basalt as can be seen from Table 3.3 derived from Presley et al. 1997 (also see discussion in Section 3.2).

Table 3.5 lists analytical laboratory borehole soil sample results for compounds detected by the laboratory at concentrations below Region IX PRGs. These are chemicals that were detected and reported by the laboratory, but that are not considered to be present in concentrations that represent a risk to human health. Values for metals, nitrates, and other compounds

considered to be naturally occurring are excluded from Table 3.5 for simplicity. Samples were analyzed for explosives from all the borehole samples, with the only explosive detected being perchlorate in borehole B-1 at a depth of 10 feet and in borehole B-2 at a depth of 15 feet (Table 3.5). Borehole B-1 samples from a depth of 10 feet contained dioxin, acetone, and acenaphthylene at low levels. Borehole B-2 samples at 5-foot depth contained dioxin, acetone, acenaphthylene, trichlorofluoromethane, and the pesticides alpha-BHC and gamma-chlordane. Borehole B-2 samples at 15-foot depth contained acenaphthylene and dioxin (OCDD). Most of these compounds are at low levels, and many of them may be from off-site sources. For example, the pesticides (alpha-BHC, gamma-chlordane) may have been transported from off-site agricultural fields, or introduced by wood treated for termites.

Table 3.4 Analytical Laboratory Borehole Soil Sample Results Above Region IX PRGs

Analyte	Compound Type	Level (mg/kg)	> PRG Industrial	PRG_IND (mg/kg)
CHROMIUM	Metal	490	YES	450
IRON	Metal	106000	YES	100000

Table 3.5 Analytical Laboratory Borehole Soil Samples Results—Detected Compounds Below PRGs

Label	Borehole #	Depth Below Grade (feet)	Analyte	Compound Type	Level (ug/kg)	Semi-Quantified	PRG_RES (ug/kg)	PRG_IND (ug/kg)
BHSS1-2	B-1	10	OCDD	Dioxin/Furan	0.06			
BHSS1-2	B-1	10	ACETONE	VOC	30	J	1600000	6200000
BHSS1-2	B-1	10	ACENAPHTHYLENE	SemiVOA	71	J		
BHSS1-2	B-1	10	PERCHLORATE	Explosive	1670			
BHSS2-1	B-2	5	OCDD	Dioxin/Furan	0.031			
BHSS2-1	B-2	5	ALPHA-BHC	Pesticide	0.91	J	90	359
BHSS2-1	B-2	5	GAMMA-CHLORDANE	Pesticide	0.55	J		
BHSS2-1	B-2	5	ACETONE	VOC	71		1600000	6200000
BHSS2-1	B-2	5	TRICHLOROFLUOROMETHANE	VOC	17		385818	2000000
BHSS2-1	B-2	5	ACENAPHTHYLENE	SemiVOA	55	J		
BHSS2-3	B-2	15	OCDD	Dioxin/Furan	0.03			
BHSS2-3	B-2	15	ACENAPHTHYLENE	SemiVOA	80	J		
BHSS2-3	B-2	15	PERCHLORATE	Explosive	120	J		
BHSS3-1	B-3	5	OCDD	Dioxin/Furan	0.085			
BHSS3-1	B-3	15	BIS(2-ETHYLHEXYL)PHTHALATE	SemiVOA	220	J	34741	1231121

To evaluate the potential for leaching of metals from soils in the Makua Valley, the TCLP tests were conducted on four subsurface soil samples from the drilled boreholes. Results of these soil samples are listed in Appendix C. The TCLP tests are generally designed to show the potential for soils to leach metals in a typical landfill setting; however, they can also be used to evaluate the potential for soils to leach compounds potentially into the groundwater.

The results of the TCLP metals tests taken from shallow soil samples on the Makua Military Reservation showed that the leaching potential of hazardous metals from Makua soils is generally low. The metals mercury, barium, and strontium are all less than 10 ppm. All of the values for TCLP from the borehole data are below the regulatory level for toxicity (Appendix C).

The compounds calcium, magnesium, sodium, and potassium do show some small potential for leaching from the soil, with sodium showing the greatest potential for leaching with values over 1000 mg/l. However, the potential for leaching of these compounds to the groundwater is very low, since these compounds were not found in groundwater above Region IX PRGs or MCLs.

3.3.1 Lysimeter Porewater Results

Results from the soil pore water collected from the lysimeters and reported by the analytical laboratory detected some compounds above Region IX PRGs. Lysimeter porewater samples were analyzed for explosives, metals, and volatile organic compounds. For samples collected from the first rounds of lysimeter samples, many of the lysimeters were dry, and of those that provided a sample, only two lysimeters (SB1A, SB3A) provided enough sample for explosive analyses. For the second sample round SB3A was dry, while most other lysimeters (SB1A, 1B, 2A, 2B) provided enough sample for explosives (EPA 8330 and 8332 Nitroglycerine) and volatile organic analyses.

Table 3.6 lists the lysimeter sample results above Region IX PRGs. Samples from four of the lysimeters installed in the OB/OD area (SB1A, 1B, 2A, 2B) had concentrations of RDX reported by the analytical laboratory varying from 33 ug/l to 21,000 ug/l. The average detected

RDX concentration is 5712 ug/l, and an average concentration removing the high and low values (as anomalous) is 2511 ug/l. The explosive HMX and volatile organic compounds chloroform and carbon tetrachloride were also reported by the laboratory (Table 3.6) at concentrations above Region IX PRGs.

Table 3.7 lists compounds reported by the analytical laboratory below Region IX PRGs, but above laboratory detection limits. For lysimeters below the OB/OD area these compounds include low levels of the explosives 2-AM-4,6-DNT, 4-AM-2,6-DNT, and 2,4-DNT and the volatile organic compounds tetryl, toluene, carbon disulfide, xylene, ethlybenzene, and styrene. The sample collected from the lysimeter adjacent to the junk car pit (SB3A) analyzed by the laboratory contained carbon disulfide, tetryl, and toluene below Region IX PRGs and MCLs.

Explosive compounds and volatile organic compounds have been detected in porewater samples from below the OB/OD area and the junk car pit, but the lack of these compounds in sampled groundwater supports the assessment that receptors are not being impacted by chemicals in groundwater flow. Estimated fate and transport of these compounds is discussed further in the Fate and Transport Section of this report (Section 4.7).

3.4 Streambed Soil Samples

Table 3.8 and Table 3.9 list the analytical laboratory results for the streambed soil samples. Four sets of soil samples were collected from the streambeds at varying depths of 6, 12, and 18 inches below surface. The location of the streambed soil samples is shown in Figure 3.1.

Figure 3.1 Streambed Soil Sample Locations

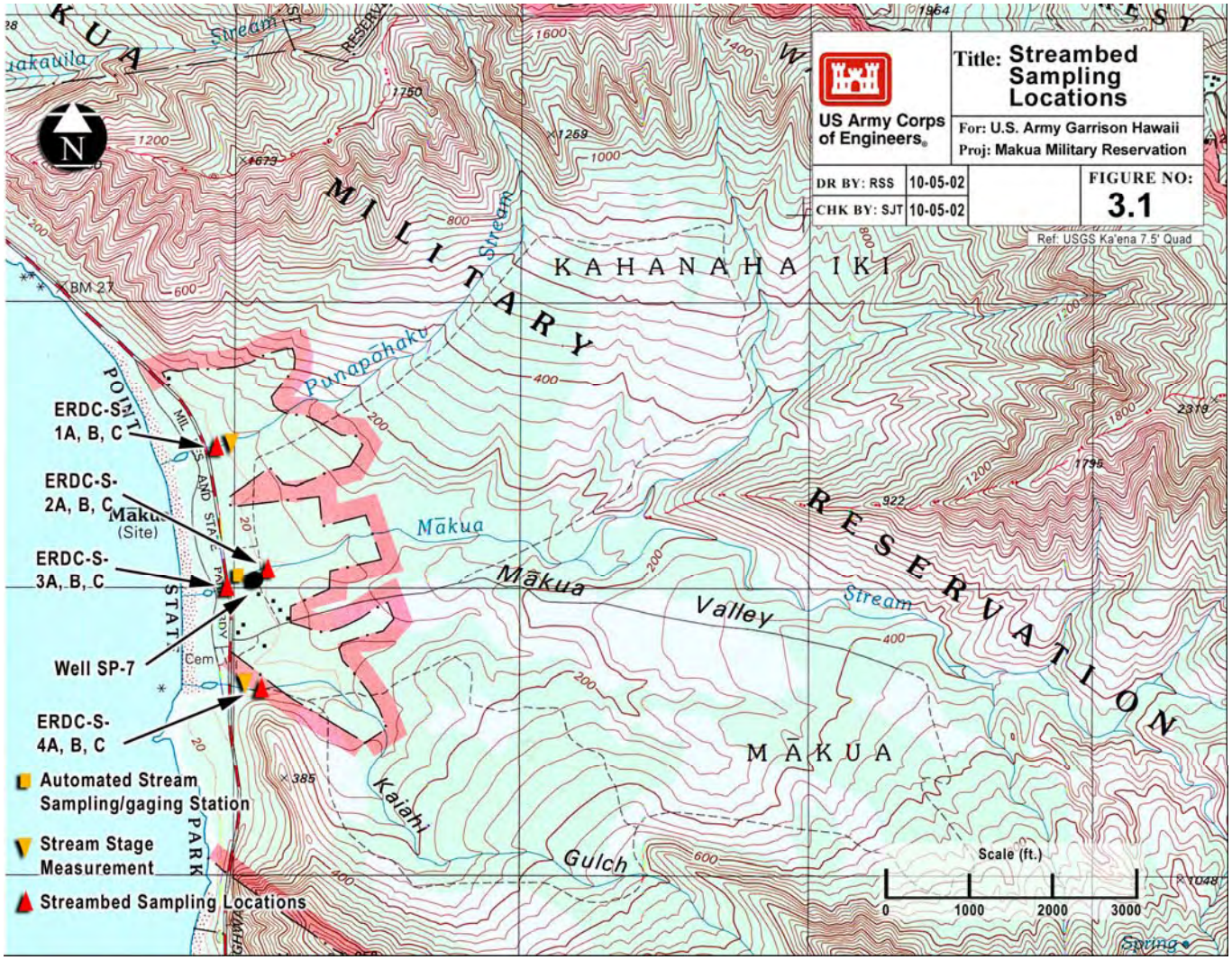


Table 3.8 lists that no compounds were reported by the analytical laboratory above Region IX PRGs. Table 3.9 lists reported analytical laboratory results for compounds that are above laboratory detection limits, but that are not naturally occurring compounds. These compounds listed in Table 3.9 have levels that are below industrial PRGs. Many of these compounds reported by the laboratory are J flag semi-quantified results, meaning that the levels are so low that the laboratory cannot positively identify the concentrations (or level), thereby obtaining a semi-quantified result.

Table 3.9 lists that Kaluakauila Stream sediments contained low levels of acetone and the pesticide alpha-BHC. Punapohaku Stream soil samples contained the volatile organic compounds acetone, 2-butanone, and iodomethane. None of these compounds was detected in the laboratory method blanks, so these are believed to be in the samples. Makua Stream soil samples also contained acetone, as well as bis-(2-ethylhexyl)phthalate and 2-butanone. Koiahi Gulch stream (Table 3.9) contained these same compounds, as well as the pesticides aldrin, alpha-BHC, and gamma-BHC. All of these compounds are found at levels that are far below industrial PRGs, and therefore are not considered hazardous.

Table 3.6 : Analytical Laboratory Lysimeter Water Sample Results Above Region IX PRGs

Date			**4-Apr-03**	**4-Apr-03**	**4-Apr-03**	**4-Apr-03**	**7-Jul-03**	**7-Jul-03**	**7-Jul-03**	**7-Jul-03**
Lysimeter			**SB1A**	**SB1B**	**SB2A**	**SB2B**	**SB1A**	**SB1B**	**SB2A**	**SB2B**
			30 ft bgs	**42 ft bgs**	**30 ft bgs**	**41.5 ft bgs**	**30 ft bgs**	**42 ft bgs**	**30 ft bgs**	**41.5 ft bgs**
Compound	PRG	MCL	**Concentrations in ug/l**							
Carbon Tetrachloride	0.17	5.0	0.47 (J)	ND	*	2.10	2.20	1.50	<0.20	1.10
Chloroform	0.16	NA	ND	ND	*	ND	ND	0.43 (J)	ND	ND
HMX	1,825	NA	ND	**	*	**	<PRG	2,700	<PRG	<PRG
RDX	0.61	NA	4,800	**	*	**	2,700	21,000 and 2,900 (E)	27	33 (E)

Key:

J = Qualifier indicative of semi-quantified results, E = Rerun of sample, ND = Not detected by laboratory method, * = lysimeter dry

** = insufficient sample available for this analysis, bgs = below ground surface, PRG = EPA Region 9 Preliminary Remediation Goal

<PRG = Value below PRG (see table 3.7 for values below PRG), NA=Not available

Table 3.7 Analytical Laboratory Lysimeter Water Sample Results Below Region IX PRGs

(All Values in ug/l)

Sample Label	Location/Round	Sample Date	2,4-DNT	2-AM-4,6-DNT	4-AM-2,6-DNT	CARBON DISULFIDE	CHLOROFORM	CHLOROMETHANE	ETHYLBENZENE	HMX	M/P-XYLENES	O-XYLENE	STYRENE	TETRYL	TOLUENE
PRG			73.00			1,000.00	6.20	1.50	1,300.00	1825		1,400.00	1,600.00	360.00	720.00
MCL									700.00				100.00		1,000.00
MMRSB1A	SB1A	4/2/2003		0.24J	1.3				0.47J	480J	2.4	0.8J		0.89J	0.66J
MMRSB1A-R2	SB1A	7/7/2003					0.2J								
MMRSB1A-R2	SB1A-R2	7/1/2003								520E					
MMR-SB1A-R2	SB1A-R2	7/8/2003				0.87J			0.32J		1.1J	0.71J			
MMRSB1A-R2DL	SB1A-R2	7/1/2003								540					
MMRSB1B	SB1B	4/3/2003				41E			0.99J		4.8	1.9	0.44J		1.2
MMRSB1B-R2	SB1B-R2	7/7/2003								1400E					
MMRSB1BDL	SB1B	4/3/2003				35					4J	1.6J			1.1J
MMRSB1B-R2	SB1B-R2	7/1/2003								1400E					
MMR-SB1B-R2	SB1B-R2	7/8/2003				2.7			0.21J		0.67J	0.37J			0.47J
MMRSB2A-R2	SB2A-R2	7/1/2003	4.1	0.57J	0.82J					6.7					
MMRSB2B	SB2B	4/3/2003				8.5	0.59J		0.22J		0.71J	0.31J	0.24J		1.1
MMRSB2B-R2	SB2B-R2	7/7/2003					0.46J								
MMRSB2B-R2	SB2B-R2	7/1/2003	2.1P							2.9					
MMR-SB2B-R2	SB2B-R2	7/8/2003				41		0.86J	0.28J		1.4J	0.6J			0.26J
MMRSB2B-R2DL	SB2B-R2	7/1/2003	2J							3.8					
MMRSB3A	SB3A	4/2/2003				0.72J								0.55J	0.41J

Key: J= Semiquantified Result, E = Rerun of sample, PRG = Drinking Water Preliminary Remediation Goal, MCL = Drinking Water Maximum Contaminant Limit

Values listed are those above laboratory detection limits

Table 3.8 Analytical Laboratory Streambed Soil Sample Results Above Region IX PRGs

Table 3.8 Analytical Laboratory Streambed Soil Sample Results Above Region IX Industrial PRGs									
Label	Stream	Analyte	Compound Type	Level (mg/kg)	Semi-quantified	> PRG Res	> PRG Ind	PRG Res	PRG Ind
								(mg/kg)	(mg/kg)
No Compounds Above PRGs in Streambed Soil Samples									

Table 3.9 Analytical Lab Streambed Soil Samples Results—Detected Compounds Below PRGs

Table 3.9 Analytical Laboratory Streambed Soil Sample Results - Detected Compounds Below Region IX Industrial PRGs							
Label	**Stream**	**Analyte**		**Level (ug/kg)**	**Semi-quantified**	**PRG Res (ug/kg)**	**PRG Ind (ug/kg)**
KASBS-0.5	Kaluakauila Stream	ACETONE	VOC	71		1569639	6035957
KASBS-1.0	Kaluakauila Stream	ALPHA-BHC	Pesticide	0.36	J	90	359
KASBS-1.0	Kaluakauila Stream	ACETONE	VOC	60		1569639	6035957
KSBS-0.5	Koiahi Gulch	BENZO(B)FLUORANTHENE	SemiVOA	21	J	621	2109
KSBS-0.5	Koiahi Gulch	BENZO(G,H,I)PERYLENE	SemiVOA	14	J		
KSBS-0.5	Koiahi Gulch	ACETONE	VOC	130		1569639	6035957
KSBS-0.5	Koiahi Gulch	BENZENE	Gasoline	2.5	J	601	1315
KSBS-0.5	Koiahi Gulch	BIS(2-ETHYLHEXYL)PHTHALATE	SemiVOA	200	J	34741	123121
KSBS-1.0	Koiahi Gulch	ALDRIN	Pesticide	2.9		27	101
KSBS-1.0	Koiahi Gulch	ALPHA-BHC	Pesticide	1.8	J	90	359
KSBS-1.0	Koiahi Gulch	GAMMA-BHC (LINDANE)	Pesticide	0.51	J	437	1741
KSBS-1.0	Koiahi Gulch	2-BUTANONE	VOC	11	J		
KSBS-1.0	Koiahi Gulch	ACETONE	VOC	95		1569639	6035957

Table 3.9 Analytical Laboratory Streambed Soil Sample Results - Detected Compounds Below Region IX Industrial PRGs							
Label	**Stream**	**Analyte**		**Level (ug/kg)**	**Semi-quantified**	**PRG Res (ug/kg)**	**PRG Ind (ug/kg)**
KSBS-1.5	Koiahi Gulch	ALPHA-BHC	Pesticide	2.2	J	90	359
KSBS-1.5	Koiahi Gulch	GAMMA-BHC (LINDANE)	Pesticide	0.59	J	437	1741
KSBS-1.5	Koiahi Gulch	ACETONE	VOC	78		1569639	6035957
KSBS-1.5	Koiahi Gulch	BIS(2-ETHYLHEXYL)PHTHALATE	SemiVOA	340	J	34741	123121
MSBS-0.5	Makua Stream	2-BUTANONE	VOC	12	J		
MSBS-0.5	Makua Stream	ACETONE	VOC	150		1569639	6035957
MSBS-1.0	Makua Stream	ACETONE	VOC	21		1569639	6035957
MSBS-1.0	Makua Stream	BIS(2-ETHYLHEXYL)PHTHALATE	SemiVOA	230	J	34741	123121
MSBS-1.5	Makua Stream	ACETONE	VOC	21		1569639	6035957
MSBS-1.5	Makua Stream	1,3-DNB	Explosive	190	J	6110	61561
MSBS-1.5	Makua Stream	2-BUTANONE	SemiVOA	3.1		7325	27102
MSBS-1.5	Makua Stream	ACETONE	VOA	29	J	1569	6036
MSBS-1.5	Makua Stream	BIS(2-ETHYLHEXYL)PHTHALATE	SemiVOA	81		35	123
MSBS-1.5	Makua Stream	METHYLENE CHLORIDE	VOA	0.89	J	9	20.5

Table 3.9 Analytical Laboratory Streambed Soil Sample Results - Detected Compounds Below Region IX Industrial PRGs							
Label	**Stream**	**Analyte**		**Level (ug/kg)**	**Semi-quantified**	**PRG Res (ug/kg)**	**PRG Ind (ug/kg)**
PSBS-0.5	Punapohaku Stream	ACETONE	VOC	130		1569639	6035957
PSBS-1.0	Punapohaku Stream	ACETONE	VOC	60		1569639	6035957
PSBS-1.5	Punapohaku Stream	2-BUTANONE	VOC	10	J		
PSBS-1.5	Punapohaku Stream	ACETONE	VOC	65		1569639	6035957
PSBS-1.5	Punapohaku Stream	IODOMETHANE	VOC	9.2			

3.5 Surface Water Sampling

The three water flow events (February 14, 2002, January 23, 2004, and February 27, 2004) provided valuable data on the chemistry of surface water flowing from the Makua Military Reservation. Figure 3.2 shows the distribution of measured surface water flows on Makua Stream during these three stream flow events. Each point of the graph indicates a measurement taken by the ISCO brand flowmeter, with measurements taken every 2 minutes. For the February 14 flow (Figure 3.2), the low volume is quite variable, but the peak flow occurred from approximately 5:30 until 8:30 A.M.. The maximum velocity recorded was the first reading taken at 0.29 meters per second. For the January 23, 2004, flow event, peak flow occurred at approximately 2:30 A.M. and again at 8:15 A.M., with velocities of 2.0 meters per second. For the February 27, 2004, event, peak flow is not known, since the ISCO automated flow meter was damaged and the database was erased (see explanation in Section 2.5).

Figure 3.2 also shows two graphs of total suspended sediment data versus time for the different flows sampled on Makua Stream. Figure 3.2 contains two graphs of total suspended sediment measurements (mg/l) versus time. These graphs show that suspended solids are higher in the early part of the stream flow, with sediment transport falling below 10 mg/l toward the end of the stream flow event.

Stream water samples were collected from the entire flow range, with samples collected for first flush, peak flow, and ending flow. Tables 3.10 and 3.11 list a summary of surface water sampling data reported by the analytical laboratory for the stream sampling from the three events. Table 3.10 lists the compounds that were detected in water above Region IX PRGs and MCLs from the three events.

For the first event, Koiahi Gulch Stream has concentrations of the pesticides aldrin, aldrin-BHC, heptachlor, and heptachlor epoxide above Region IX PRGs for the first sampling event (Table 3.10). A sample from Punapohaku Stream has concentrations of aldrin and beta-BHC above Region IX PRGs (Table 3.10). A sample from Makua Stream has concentrations of

benzene slightly above Region IX PRGs and the metals thallium and iron above Region IX PRGs. A sample from Kaluakauila Stream has a thallium concentration above Region IX PRGs. Dissolved metals are metals measured by the laboratory that represents metal concentrations dissolved in the water without the metal particulates. Total metals are those metals dissolved in the water, as well as metals in particulate form flowing within the water. Two stream water samples for total thallium were above Region IX PRGs for the first event. Total metals analyses are not considered as representative of actual conditions as are dissolved metals.

For the second event, Table 3.10 lists the compound RDX in one sample above Region IX PRGs. From a total of 81 explosive samples collected from all the stream flow events, only one sample from the first flow at Makua Stream had concentrations of RDX above PRGs of 1.7 ug/l/. Table 3.10 lists the metals chromium, aluminum, iron, manganese, and vanadium above tap water PRGs in samples from Makua Stream in the early part of the stream flow from the second event. These analyses are total metals, that is, metals both dissolved and particulate, in the water and represent biased high values.

For the third event, Table 3.10 lists compounds detected above PRGs. A number of metals were reported in stream water samples above PRGs, including iron, chromium, aluminum, and vanadium. A few samples contained the pesticide heptachlor above PRGs.

Table 3.11 and 3.12 list the compounds that were detected by the laboratory but were below Region IX PRGs and MCLs for the three stream flow events. This table includes a somewhat more extensive list of compounds detected by the laboratory methods; however, these compounds' levels are all below the regulatory limits established by the Region IX PRG and MCL standards. Table 3.11 and 3.12 list only compounds that are not naturally occurring; that is, concentrations of some metals, chlorides, and sulfates are not reported for simplicity. For the first event, samples from the

Figure 3.2 Distribution of Makua Stream Flow

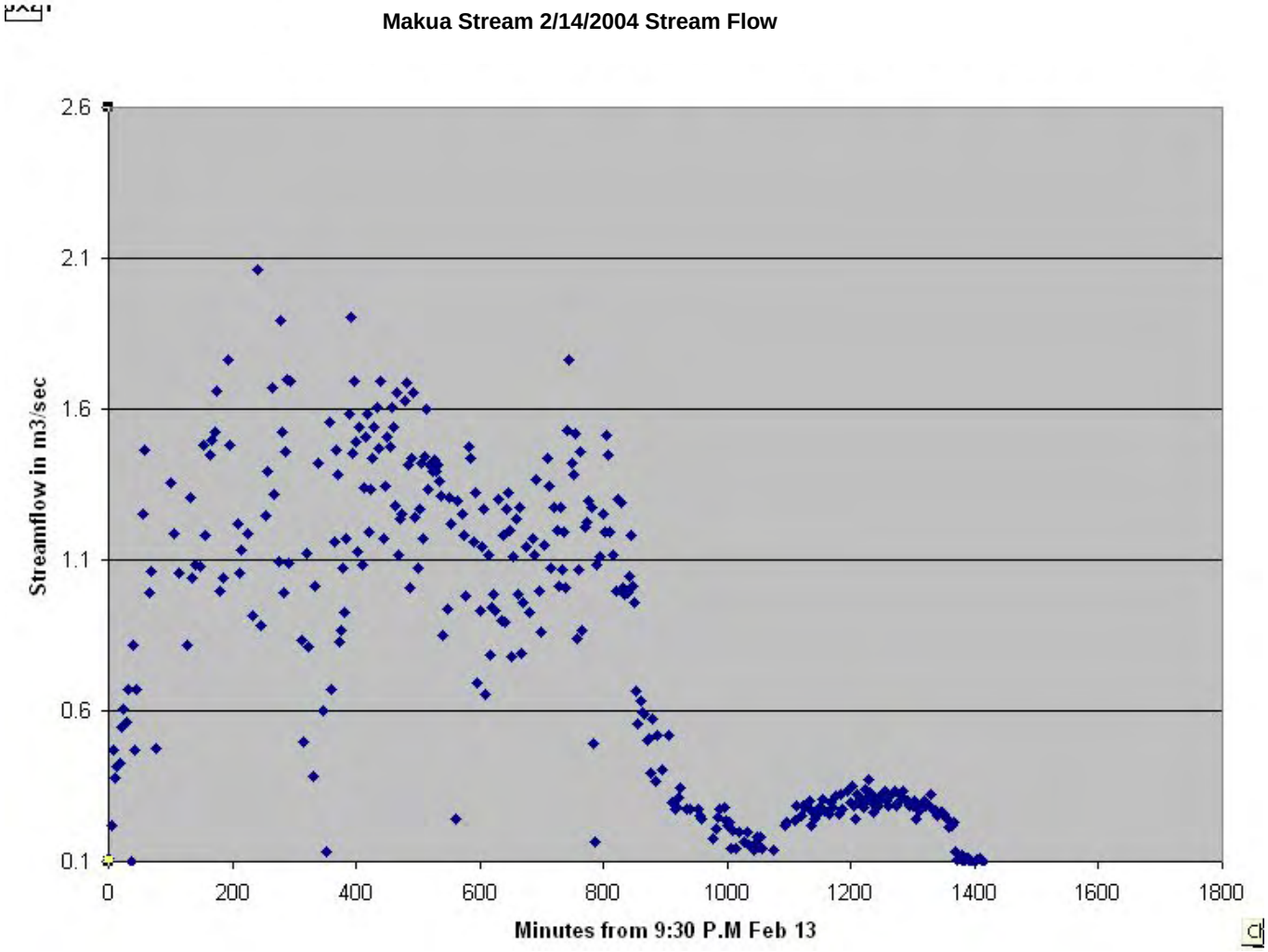


Figure 3.2 Distribution of Makua Stream Flow

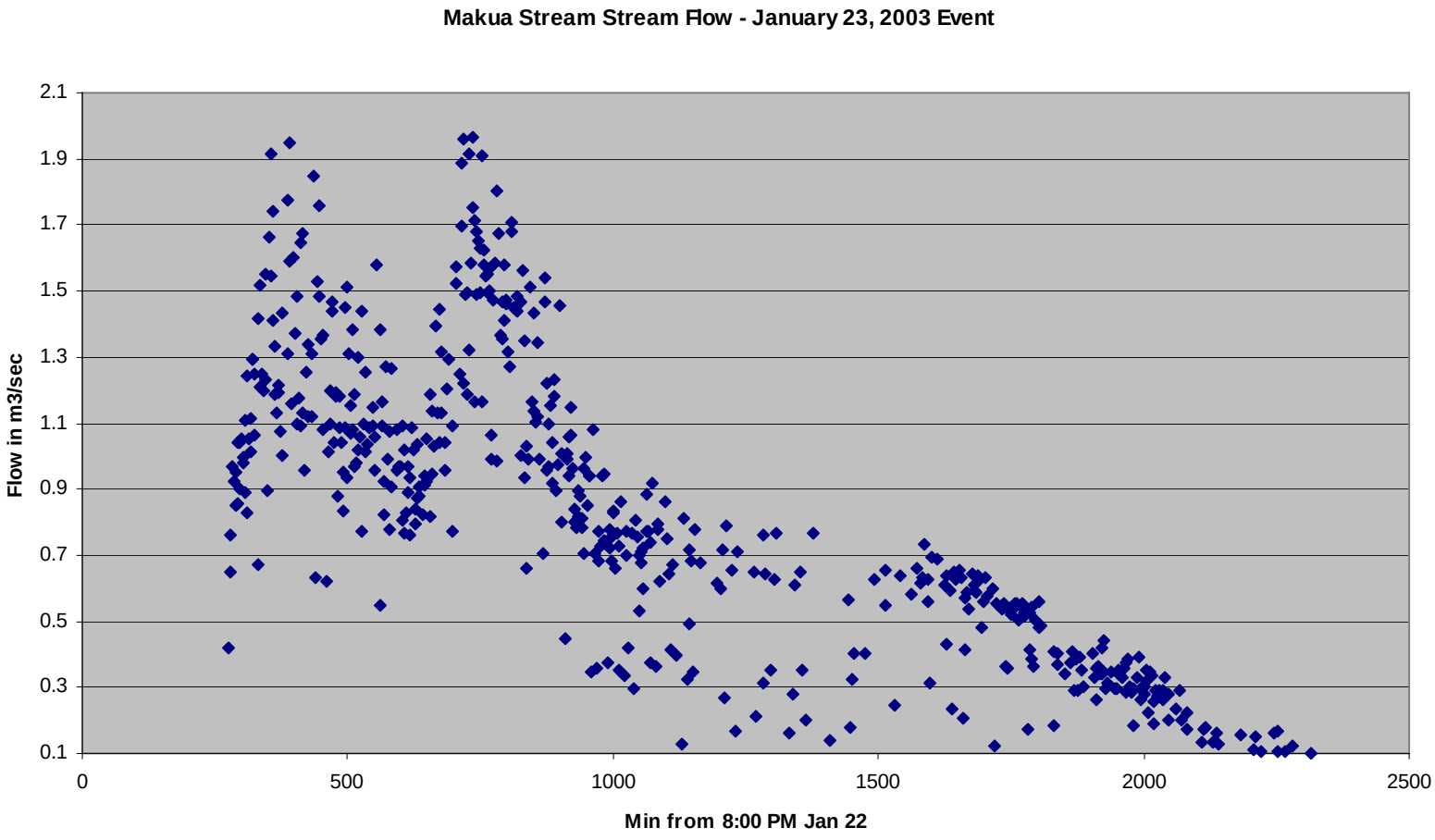


Figure 3.2 Distribution of Makua Stream Flow

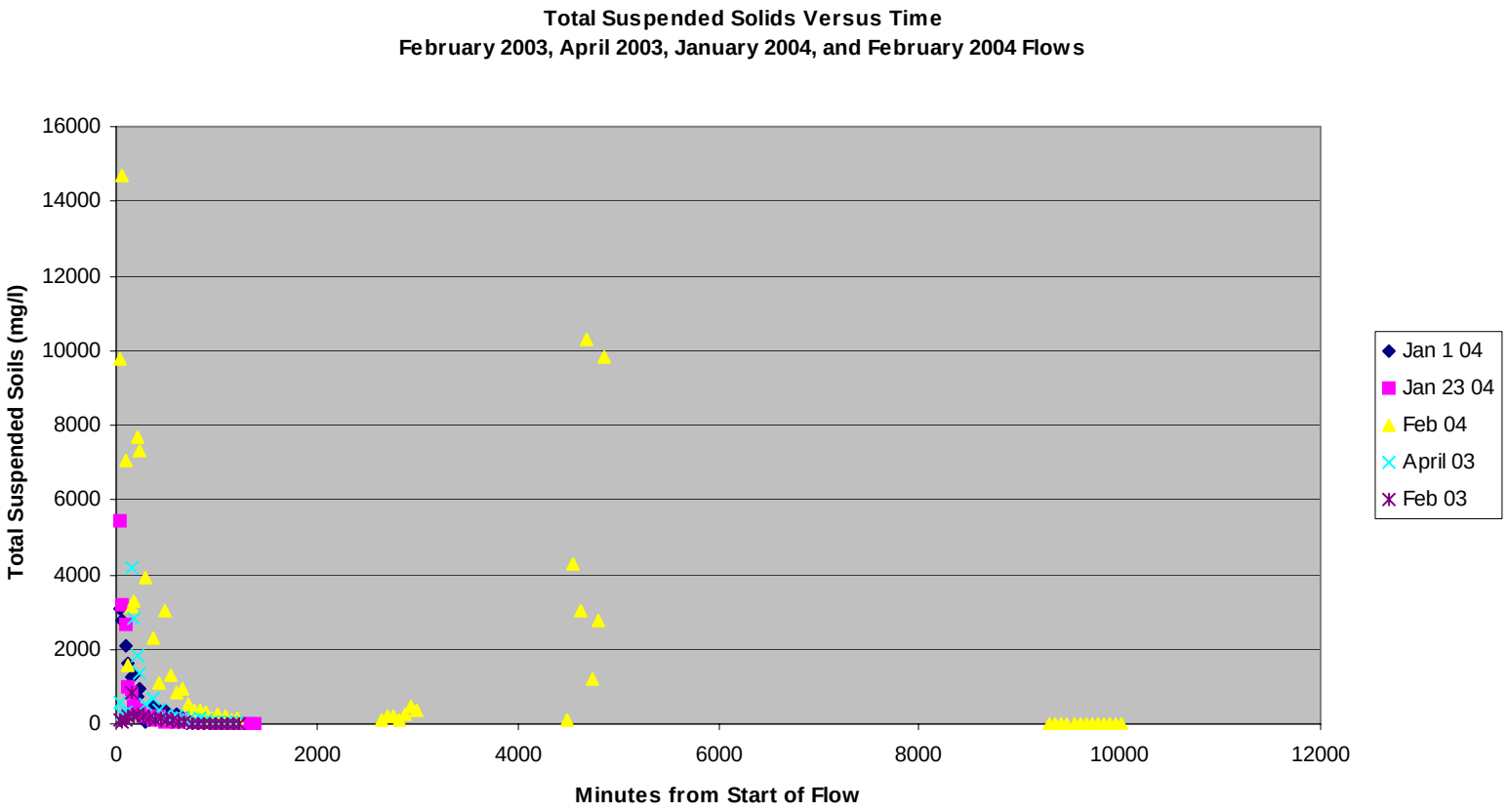
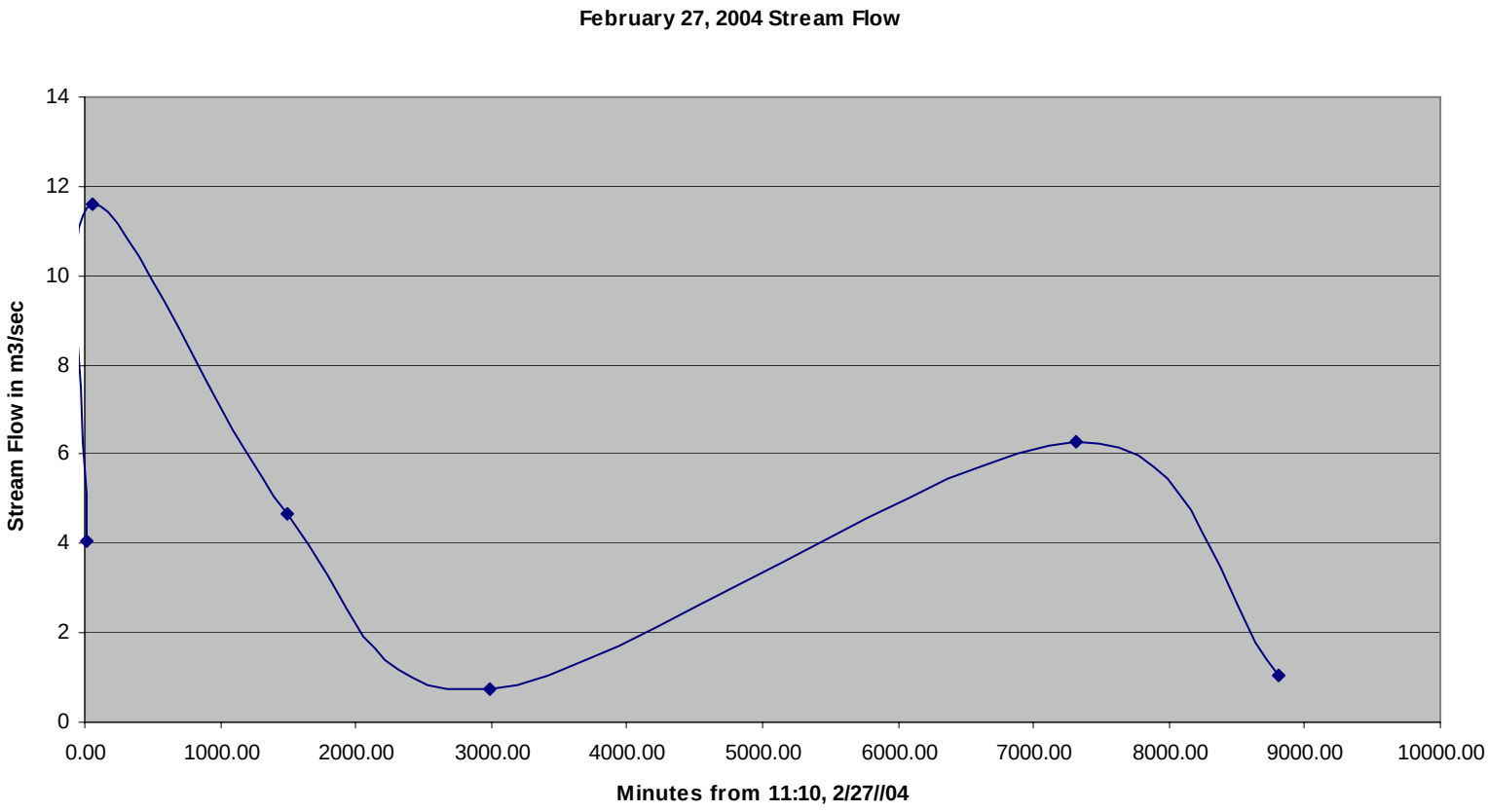


Figure 3.2 Distribution of Makua Stream Flow



northernmost Kaluakauila Stream contained trace levels of gasoline by-products (benzene, xylene, toluene) and trace levels of dioxin/furans. The first event, samples from Koiahi Gulch Stream contained trace levels of pesticides (see Table 3.10), dioxin/furans, and perchlorate at approximately 2 ug/l. The first event samples from Makua Stream contained the volatile organic compound 2-bentanone, styrene, 1,2,4-trimethylbenzene, gasoline components (benzene, xylene, toluene, ethylbenzene), trace levels of dioxin/furan, and two samples with explosives. The first event, samples from Punapohaku Stream contained levels of pesticides, gasoline components, and trace levels of dioxin/furans.

For the second round a few compounds are listed in Table 3.11, including cyanide and RDX. For the second flow event fewer small detections of pesticides and gasoline by-products were reported by the analytical laboratory. This may have been a shorter time between stream flow, so fewer trace level compounds were contained in stream flow and reported by the analytical laboratory. For the third round of surface water sampling, trace levels of acetone, lindane, arsenic, and RDX were reported by the analytical laboratory in surface water samples.

On Makua Stream, out of a total of 81 samples collected over the complete period of the stream flow from three events that were analyzed for explosives, only two of the samples had detectable levels of explosives (Table 3.10 and 3.11).

The data collected from stream flow events show that almost undetectable levels of potential contamination are leaving the Makua Military Reservation. A review of laboratory results for the first stream flow event from a total of 57 metals samples collected from all four streams indicated that only two samples for total thallium (dissolved and particulate) and one sample for iron were above Region IX PRGs. Thallium is likely a naturally occurring compound as suggested by the Navy at Pearl Harbor (Navy, 2002). For the first stream flow event, from a total of 57 samples collected from all four streams analyzed by the laboratory for explosives, only one contained perchlorate, and two contained 2,4-DNT. For the first stream flow event, none of the samples analyzed by the laboratory detected TNT, RDX, or nitroglycerine. Some samples

have trace levels of dioxin/furan, which are likely represent background concentrations (see Section 3.6). Some samples contain trace levels of gasoline components, which are likely a result of vehicles and lawnmowers operating at MMR.

Results reported by the analytical laboratory above Region IX PRGs and MCLs for the second and third events include RDX above PRGs of 1.7 ug/l and a few selected samples with chromium, aluminum, iron, manganese, and vanadium above tap water. For the third event Table 3.10 lists compounds detected above PRGs. A number of metals were reported in stream water samples above PRGs, including iron, chromium, aluminum, and vanadium. A few samples contained the pesticide heptachlor above PRGs.

Results of two smaller (April 2003 and January 1, 2004) surface water sampling events are not considered as reliable as the three major events (February 2003, January 22, 2004, and February 27, 2004), since the samples were stored past holding times. However, the results of this sampling are listed in Appendix E to provide additional information. No explosive compounds were detected in the water samples, but dissolved aluminum, iron, manganese, and vanadium were detected above Region IX PRGs. A few samples contained chromium concentrations above MCL values. These metal concentrations are likely the result of surface water transportation of metals that are normally contained within the soils in the Makua Valley.

Table 3.10 Results of Surface Water Sampling – Compounds Reported by the Analytical Laboratory Above Region IX PRGs.

First Event—February 14, 2003

Stream	Sample Number	Time	Compound	Compound Type	Level (ug/l)	PRG (ug/l)	MCL (ug/l)
Koiahi Gulch	KSSW-R1	7:30	Aldrin	Pesticide	0.030	0.004	N/A
Koiahi Gulch	KSSW-R1	7:30	Aldrin-BHC	Pesticide	0.032	0.011	N/A
Koiahi Gulch	KSSW-R1	7:30	Heptachlor	Pesticide	0.045	0.015	0.40
Koiahi Gulch	KSSW-R1	7:30	Heptachlor Epoxide	Pesticide	0.020	0.007	0.20
Makua Stream	ISCOR1-2	3:09	Benzene	Gasoline	0.36	0.35	5.0
Makua Stream	MSSW-R1	7:45	Benzene	Gasoline	0.44	0.35	5.0

Stream	Sample Number	Time	Compound	Compound Type	Level (ug/l)	PRG (ug/l)	MCL (ug/l)
Makua Stream	ISCOR1-1	2:55	Thallium	Metal	6.86	2.4	2.0
Makua Stream	ISCOR1-9	3:59	Iron	Metal	12,300	11,000	N/A
Punapohaku Stream	PSSW-R1	7:58	Aldrin	Pesticide	0.023	0.004	N/A
Punapohaku Stream	PSSW-R1	7:58	Beta-BHC	Pesticide	0.094	0.0370	N/A
Kaluakauila Stream	KASSW-R1	7:58	Thallium	Metal	6.02	2.4	2.0

Table 3.10 (Continued)

Results of Surface Water Sampling - Compounds Reported by the Analytical Laboratory Above Region IX PRGs or MCLs

Second Event—January 23, 2004

Stream	Sample Number	Time	Compound	Compound Type	Level	Level_ Units	> PRG	> MCL	PRG	PRG_ UNIT	MCL	MCL_ UNIT
Makua	MMRMSR2-1	11:10	IRON	Metal	17.1	mg/l	YES		10.950	mg/l		
Makua	MMR-SW-E4-B01	1/22/2004 22:41	RDX	Explosive	1.7	ug/l	YES		0.611	ug/l		
Makua	MMR-SW-E4-B02	1:12	CHROMIUM	Metal	0.463	mg/l		YES	0.110	mg/l	0.1	mg/l
Makua	MMR-SW-E4-B02	1:12	ALUMINUM	Metal	75	mg/l	YES		36.499	mg/l		
Makua	MMR-SW-E4-B02	1:12	IRON	Metal	167	mg/l	YES		10.950	mg/l		
Makua	MMR-SW-E4-B02	1:12	MANGANESE	Metal	2.73	mg/l	YES		0.876	mg/l		
Makua	MMR-SW-E4-B02	1:12	VANADIUM	Metal	0.418	mg/l	YES		0.255	mg/l		
Makua	MMR-SW-E4-B04	2:18	CHROMIUM	Metal	0.227	mg/l		YES	0.110	mg/l	0.1	mg/l
Makua	MMR-SW-E4-B04	2:18	IRON	Metal	76	mg/l	YES		10.950	mg/l		
Makua	MMR-SW-E4-B04	2:18	MANGANESE	Metal	1.37	mg/l	YES		0.876	mg/l		
Makua	MMR-SW-E4-B06	3:31	CHROMIUM	Metal	0.119	mg/l		YES	0.110	mg/l	0.1	mg/l
Makua	MMR-SW-E4-B06	3:31	IRON	Metal	40.7	mg/l	YES		10.950	mg/l		
Makua	MMR-SW-E4-B11	7:24	IRON	Metal	17.6	mg/l	YES		10.950	mg/l		

Table 3.10 (Continued)

Results of Surface Water Sampling - Compounds Reported by the Analytical Laboratory Above Region IX PRGs or MCLs

Third Event—February 27 through March 6, 2004

Stream	Sample Number	Time	Compound	Compound Type	Level	Qualifier	Level_ UNITS	> PRG	> MCL	PRG	PRG_ UNIT	MCL	MCL_ UNIT
Kaluakauila	MMR-KAS-R3-2	13:05	IRON	Metal	15.2		mg/l	YES		10.950	mg/l		mg/l
Koiahi	MMR-KGS-R3-1	11:55	GAMMA-BHC	Pesticide	0.052	J	ug/l	YES		0.052	ug/l	0.20	ug/l
Koiahi	MMR-KGS-R3-1	11:55	HEPTACHLOR	Pesticide	0.015	J	ug/l	YES		0.015	ug/l	0.40	ug/l
Koiahi	MMR-KGS-R3-1	11:55	IRON	Metal	36.4		mg/l	YES		10.950	mg/l		mg/l
Koiahi	MMR-KGS-R3-2	13:05	CHROMIUM	Metal	0.147		mg/l		YES	0.110	mg/l	0.10	mg/l
Koiahi	MMR-KGS-R3-2	13:05	IRON	Metal	52.1		mg/l	YES		10.950	mg/l		mg/l
Makua	MMR-MSISCO-B11-1	17:40	CHROMIUM	Metal	0.516		mg/l		YES	0.110	mg/l	0.10	mg/l
Makua	MMR-MSISCO-B11-1	17:40	ALUMINUM	Metal	111		mg/l	YES		36.499	mg/l		mg/l
Makua	MMR-MSISCO-B11-1	17:40	IRON	Metal	184		mg/l	YES		10.950	mg/l		mg/l
Makua	MMR-MSISCO-B11-1	17:40	MANGANESE	Metal	2.51		mg/l	YES		0.876	mg/l		mg/l
Makua	MMR-MSISCO-B11-1	17:40	VANADIUM	Metal	0.457		mg/l	YES		0.255	mg/l		mg/l
Makua	MMR-MS-R3-1	11:15	THALLIUM	Metal	0.00903	J	mg/l	YES	YES	0.002	mg/l	0.00	mg/l
Makua	MMR-MS-R3-1	11:15	BERYLLIUM	Metal	0.00874	J	mg/l		YES	0.073	mg/l	0.00	mg/l

Stream	Sample Number	Time	Compound	Compound Type	Level	Qualifier	Level_ UNITS	> PRG	> MCL	PRG	PRG_ UNIT	MCL	MCL_ UNIT
Makua	MMR-MS-R3-1	11:15	CHROMIUM	Metal	0.927		mg/l		YES	0.110	mg/l	0.10	mg/l
Makua	MMR-MS-R3-1	11:15	ALUMINUM	Metal	169		mg/l	YES		36.499	mg/l		mg/l
Makua	MMR-MS-R3-1	11:15	HEPTACHLOR	Pesticide	0.047	J	ug/l	YES		0.015	ug/l	0.40	ug/l
Makua	MMR-MS-R3-1	11:15	IRON	Metal	315		mg/l	YES		10.950	mg/l		mg/l
Makua	MMR-MS-R3-1	11:15	MANGANESE	Metal	10.3		mg/l	YES		0.876	mg/l		mg/l
Makua	MMR-MS-R3-1	11:15	VANADIUM	Metal	0.838		mg/l	YES		0.255	mg/l		mg/l
Makua	MMR-MS-R3-2	12:50	BERYLLIUM	Metal	0.00418	J	mg/l		YES	0.073	mg/l	0.00	mg/l
Makua	MMR-MS-R3-2	12:50	CHROMIUM	Metal	0.627		mg/l		YES	0.110	mg/l	0.10	mg/l
Makua	MMR-MS-R3-2	12:50	ALUMINUM	Metal	114		mg/l	YES		36.499	mg/l		mg/l
Makua	MMR-MS-R3-2	12:50	IRON	Metal	209		mg/l	YES		10.950	mg/l		mg/l
Makua	MMR-MS-R3-2	12:50	MANGANESE	Metal	3.63		mg/l	YES		0.876	mg/l		mg/l
Makua	MMR-MS-R3-2	12:50	VANADIUM	Metal	0.505		mg/l	YES		0.255	mg/l		mg/l
Punapohaku	MMR-PS-R3-1	12:25	HEPTACHLOR	Pesticide	0.016	J	ug/l	YES		0.015	ug/l	0.40	ug/l

Table 3.11 Results of Surface Water Sampling – Compounds Detected and Reported by the Analytical Laboratory Below Region IX PRGs.

First Event—February 14, 2003

Stream	Label	Compound	Compound Type	Value (ug/l)	PRG (ug/l)	MCL (ug/l)
Kaluakauila Stream	KASSW-R1	BENZENE	Gasoline	0.25000	0.35	5
Kaluakauila Stream	KASSW-R1	M/P-XYLENES	Gasoline	0.65000		
Kaluakauila Stream	KASSW-R1	O-XYLENE	Gasoline	0.24000	1400	
Kaluakauila Stream	KASSW-R1	TOLUENE	Gasoline	1.10000	720	1000
Kaluakauila Stream	PSSW-R1	1,2,3,4,6,7,8-HpCDD	Dioxin/Furans	0.000004924		
Kaluakauila Stream	KASSW-R1	1,2,3,4,6,7,8-HpCDF	Dioxin/Furans	0.00001122		
Kaluakauila Stream	KASSW-R1	OCDD	Dioxin/Furans	0.00002215		
Kaluakauila Stream	KASSW-R1	OCDF	Dioxin/Furans	0.00001364		
Kaluakauila Stream	KASSW-R1	Total HpCDD	Dioxin/Furans	0.000004924		
Kaluakauila Stream	KASSW-R1	Total HpCDF	Dioxin/Furans	0.00001122		
Koiahi Gulch	KSSW-R1	DELTA-BHC	Pesticide	0.02500		
Koiahi Gulch	KSSW-R1	ENDRIN	Pesticide	0.03100	11	2

Stream	Label	Compound	Compound Type	Value (ug/l)	PRG (ug/l)	MCL (ug/l)
Koiahi Gulch	KSSW-R1	GAMMA-BHC (LINDANE)	Pesticide	0.04700	0.052	0.2
Koiahi Gulch	KSSW-R1	BENZENE	Gasoline	0.31000	0.35	5
Koiahi Gulch	KSSW-R1	M/P-XYLENES	Gasoline	0.83000		
Koiahi Gulch	KSSW-R1	O-XYLENE	Gasoline	0.31000	1400	
Koiahi Gulch	KSSW-R1	TOLUENE	Gasoline	1.40000	720	1000
Koiahi Gulch	KASSW-R1	1,2,3,4,6,7,8-HpCDD	Dioxin/Furans	0.00009479		
Koiahi Gulch	KSSW-R1	1,2,3,4,6,7,8-HpCDF	Dioxin/Furans	0.00005247		
Koiahi Gulch	KSSW-R1	1,2,3,6,7,8-HxCDF	Dioxin/Furans	0.000008868		
Koiahi Gulch	KSSW-R1	OCDD	Dioxin/Furans	0.0008342		
Koiahi Gulch	KSSW-R1	OCDF	Dioxin/Furans	0.0001707		
Koiahi Gulch	KSSW-R1	Total HpCDD	Dioxin/Furans	0.0001634		
Koiahi Gulch	KSSW-R1	Total HpCDF	Dioxin/Furans	0.00005247		
Koiahi Gulch	KSSW-R1	Total HxCDF	Dioxin/Furans	0.00003598		
Koiahi Gulch	KSSW-R1	PERCHLORATE	Explosive	2.07000		
Koiahi Gulch	KSSW-R1	PERCHLORATE	Explosive	2.60000		
Makua Stream	ISCOR1-02	2-BUTANONE	VOC	35.00000		

Stream	Label	Compound	Compound Type	Value (ug/l)	PRG (ug/l)	MCL (ug/l)
Makua Stream	ISCOR1-05	2-BUTANONE	VOC	27.00000		
Makua Stream	ISCOR1-05	BENZENE	Gasoline	0.27000	0.35	5
Makua Stream	ISCOR1-07	2-BUTANONE	VOC	21.00000		
Makua Stream	ISCOR1-07	BENZENE	Gasoline	0.20000	0.35	5
Makua Stream	ISCOR1-10	2-BUTANONE	VOC	18.00000		
Makua Stream	ISCOR1-10	BENZENE	Gasoline	0.25000	0.35	5
Makua Stream	ISCOR1-12	2-BUTANONE	VOC	12.00000		
Makua Stream	ISCOR1-12	BENZENE	Gasoline	0.25000	0.35	5
Makua Stream	ISCOR1-12	STYRENE	VOC	0.20000	1600	100
Makua Stream	ISCOR1-39	M/P-XYLENES	Gasoline	0.33000		
Makua Stream	ISCOR1-39	TOLUENE	Gasoline	0.29000	720	1000
Makua Stream	MSSW-R1	1,2,4-TRIMETHYLBENZENE	VOC	0.34000	12	
Makua Stream	MSSW-R1	ETHYLBENZENE	Gasoline	0.29000	1300	700
Makua Stream	MSSW-R1	M/P-XYLENES	Gasoline	1.70000		
Makua Stream	MSSW-R1	O-XYLENE	Gasoline	0.56000	1400	
Makua Stream	MSSW-R1	TOLUENE	Gasoline	2.70000	720	1000

Stream	Label	Compound	Compound Type	Value (ug/l)	PRG (ug/l)	MCL (ug/l)
Makua Stream	KSSW-R1	1,2,3,4,6,7,8-HpCDD	Dioxin/Furans	0.000005164		
Makua Stream	MSSW-R1	OCDD	Dioxin/Furans	0.00002816		
Makua Stream	PSSW-R1	2,4-DNT	Explosive	0.31000	73	
Makua Stream	ISCOR1-03	2,4-DNT	Explosive	0.23000	73	
Punapohaku Stream	PSSW-R1	DELTA-BHC	Pesticide	0.01800		
Punapohaku Stream	PSSW-R1	HEPTACHLOR	Pesticide	0.01100	0.015	0.4
Punapohaku Stream	MSSW-R1	BENZENE	Gasoline	0.26000	0.35	5
Punapohaku Stream	PSSW-R1	M/P-XYLENES	Gasoline	0.72000		
Punapohaku Stream	PSSW-R1	O-XYLENE	Gasoline	0.27000	1400	
Punapohaku Stream	PSSW-R1	TOLUENE	Gasoline	1.20000	720	1000
Punapohaku Stream	MSSW-R1	1,2,3,4,6,7,8-HpCDD	Dioxin/Furans	0.000005298		
Punapohaku Stream	PSSW-R1	OCDD	Dioxin/Furans	0.000026		

Table 3.12 Results of Surface Water Sampling – Compounds Detected and Reported by the Analytical Laboratory Below Region IX PRGs.

Second Event—February 14, 2003

Third Event—February 27 - March 6, 2004

Second Event - January 23, 2004										
Stream	**Label**	**Compound**	**Compound Type**	**Value**	**Qualifier**	**Units**	**PRG**	**PRG Unit**	**MCL**	**MCL Unit**
Koiahi Gulch	MMRKGSR2-1	CYANIDE	Chemical	0.015		mg/l	0.730	mg/l		mg/l
Makua	MMR-SW-E4-B03	RDX	Explosive	0.37	J	ug/l	0.611	ug/l		ug/l
Koiahi Gulch	MMRKGSR2-3	CHROMIUM	Metal	11		ug/l	110	ug/l	1000	ug/l
Koiahi Gulch	MMRKGSR2-3	LEAD	Metal	1.2		ug/l			15	ug/l
Third Event - February 27 - March 6, 2004										
Kaluakauila	MMR-KAS-R3-1	ACETONE	Solvent	5.5	J	ug/l	608.333	ug/l		ug/l
Kaluakauila	MMR-KAS-R3-1	GAMMA-BHC (LINDANE)	Pesticide	0.016	J	ug/l	0.0517	ug/l	0.2	ug/l
Makua	MMR-MS-R3-1	ACETONE		8.3	J	ug/l	608.3333	ug/l		ug/l

Third Event - February 27 - March 6, 2004										
Stream	**Label**	**Compound**	**Compound Type**	**Value**	**Qualifier**	**Units**	**PRG**	**PRG Unit**	**MCL**	**MCL Unit**
Makua	MMR-MS-R3-1	ARSENIC		0.00656	J	mg/l		mg/l	0.01	mg/l
Makua	MMR-MS-R3-1	RDX		0.61	J	ug/l	0.611	ug/l		ug/l
Makua	MMR-MS-R3-2	ARSENIC		0.00521	J	mg/l		mg/l	0.01	mg/l

3.6 Background Sampling

A background radiation survey was conducted to provide a database for comparing radiation values found in the Makua Valley samples with values at other locations on O`ahu. The survey was conducted on December 26, 2003, using a GR-110 Exploranium Gamma Ray Scintillometer. The comparative units are in counts per second. This instrument reads levels of gamma radiation. Radioactive contamination from an alpha or a beta source will occur in conjunction with a gamma source, so that measuring for gamma is a very good tool for screening for radioactive contamination. Gamma radiation is the only type of radiation of concern in the Makua Valley. The instrument was placed on the ground surface at the selected sites, and the measurements were taken after the readings had stabilized. The locations and results are listed in Table 3.14. In general the lowest values were obtained on sand beaches. The highest values were in the weathered clays on the Dole pineapple plantation, and volcanic rock areas had intermediate values. The lowest value of 8.6 counts per second (cps) was obtained on the beach at the North Shore. The highest value of 105.1 cps was recorded at the Dole pineapple plantation. These values are within the range of values measured from soil samples in Makua Valley.

Table 3.13 lists the range of measured radiation readings from the scintillometer during the fieldwork at Makua Military Reservation. Radiation counts for the soil samples collected from the monitoring well boreholes during drilling varied from 15 to 47.3 counts per second. Radiation counts for the soil samples collected from the lysimeter boreholes (B-1, B-2, and B-3) varied from 18.3 to 29 counts per second. The range of radiation readings from shallow soil samples in Makua Valley was 21 to 40 counts per second (cps), with most samples registering 20 to 30 counts per second. A review of these data shows that all radiation measurements are within the range of values normally found on O`ahu; therefore, there is no indication of radiation contamination from operations at Makua Military Reservation. These radiation levels are within the safe range of expected values.

Table 3.13 Background Scintillometer Readings

Location	GPS Data	Reading (CPS)
Diamond Head State Monument	N21 degrees 16.050 min W157 degrees 47.991 min	39.4
Hanauma Bay	N21 degrees 16.409 min W157 degrees 41.608 min	27.2
Scenic Overlook	N21 degrees 18.541 min W157 degrees 39.441 min	20.4
Sea Life Park	N21 degrees 18.777 min W157 degrees 39.712 min	30.7
Waimanalo State Park	N21 degrees 19.896 min W157 degrees 41.666 min	17.3
Kailua Beach	N21 degrees 23.874 min W157 degrees 43.671 min	11.9
Kualoa Park	N21 degrees 30.745 min W157 degrees 50.266 min	15.1
Polynesian Cultural Center	N21 degrees 38.370 min W157 degrees 55.185 min	21.3
Turtle Bay Resort	N21 degrees 40.480 min W158 degrees 02.378 min	14.1
Dole Pineapple Plantation	N21 degrees 30.292 min W158 degrees 03.008 min	105.1
Dole Visitors Center	N21 degrees 31.553 min W158 degrees 02.301 min	81.4
Dole Pineapple Plantation	N21 degrees 32.179 min W158 degrees 02.525 min	43.5
Dole Pineapple Plantation	N21 degrees 33.639 min W158 degrees 03.621 min	88.4
North Shore	N21 degrees 34.639 min W158 degrees 07.383 min	38.1

Table 3.13 (Concluded)

Background Scintillometer Readings

Location	GPS Data	Reading (CPS)
Kaena Point	N21 degrees 34.797 min W156 degrees 14.247 min	24.1
North Shore	N21 degrees 39.496 min W158 degrees 03.454 min	8.6
Scenic View Below Pali	N21 degrees 21.913 min W157 degrees 46.783 min	27.2
Ewa Train Station	N21 degrees 19.891 min W158 degrees 02.745 min	33.4
Aloha Tower	N21 degrees 18.434 min W157 degrees 51.862 min	66.7
CPS = Counts Per Second		

Table 3.14 Summary of Radiation Readings from Makua Military Reservation Soil

Location	Values (CPS)
Well MW-1	0
Well MW-2	18 to 20
Well MW-3A	17 to 35
Well MW-3B	15 to 35
Well MW-3C	15
Well MW-4A	18 to 20
Well MW-4B	18 to 20
Well MW-4C	15 to 45
Well MW-5	31 to 47.3
Borehole B-1	18.3 to 22.8
Borehole B-2	18.5 to 22.0
Borehole B-3	28 to 29
Shallow Soil Samples (throughout valley)	21 to 40

Results of off-site dioxin and furan background sampling are listed in Table 3.15. Samples were collected from depth of 6 inches (labeled the "A" sample) and from 12 inches (labeled the "B" sample). Samples of the alluvium (ERDC-BK-1A and B), which is located north of Makua (Figure 2.19), had the dioxin compound OCDD, while dioxin and furan compounds were not reported by the analytical laboratory above detection limits from the alluvium samples in Makaha and Waianae Valleys (Figure 2.20 and 2.21). All stream samples located in Keaau Valley, Waianae Valley, and Makaha Valley had dioxin and furan concentrations. Samples from both streambeds in Makaha Valley (Figure 2.20) and Waianae Valley (Figure 2.21) had TCDD values above Region IX PRGs. The presence of these off-site dioxin and furan compounds

indicates that these compounds are present at background concentrations all along the Waianae Coast.

3.7 Summary of Analytical Results for Groundwater Samples for Makua Military Reservation

One round of groundwater samples for all ten monitoring wells was analyzed for naturally occurring chemical constituents, including magnesium, calcium, silica, bicarbonate, calcium, and chloride. Comparison of these chemical constituents between wells in the Makua Valley and other wells along the Waianae Coast can provide information on the travel paths of groundwater recharging in the mountain ranges, and discharging along the beach. Figure 3.3 shows a plot of the magnesium versus calcium concentrations for the ten monitoring wells at Makua, with the background showing ranges of these constituents from other wells with open intervals within the Ewa Caprock, Waianae Basalts, and Koolau Basalts. Figure 3.4 shows a comparison of silica concentration versus the calcium/magnesium concentration for the ten wells, with the background showing ranges of these constituents from other wells within the Ewa Caprock, Waianae Basalts, and Koolau Basalts. Data from off-site wells for these figures were taken from Woodward Clyde (1998) and HLA (1996). The water quality measured in well MW-3A suggests that it is predominantly recharged by water that infiltrates locally within the calcium carbonate-dominated, near-shore sand deposits. The geochemical signature of most of the remaining wells is consistent with the water in these wells originating predominantly from the basaltic and basaltic-derived alluvial inland deposits. The silica level measured in MW-5 is higher than in other wells. The redox conditions within the upper alluvium at this site may lead to more leaching of silica down to the aquifer. The soil samples from MW-5 indicated a highly weathered, weakly consolidated layer that extended over 200 feet above the water table. The thickness and occurrence of this layer is unusual for this area of O`ahu and is most likely the source of the silica in the groundwater at the site.

Figure 3.3 Graph of Magnesium Versus Calcium Concentrations of Groundwater in Makua Valley and Other Areas of O`ahu

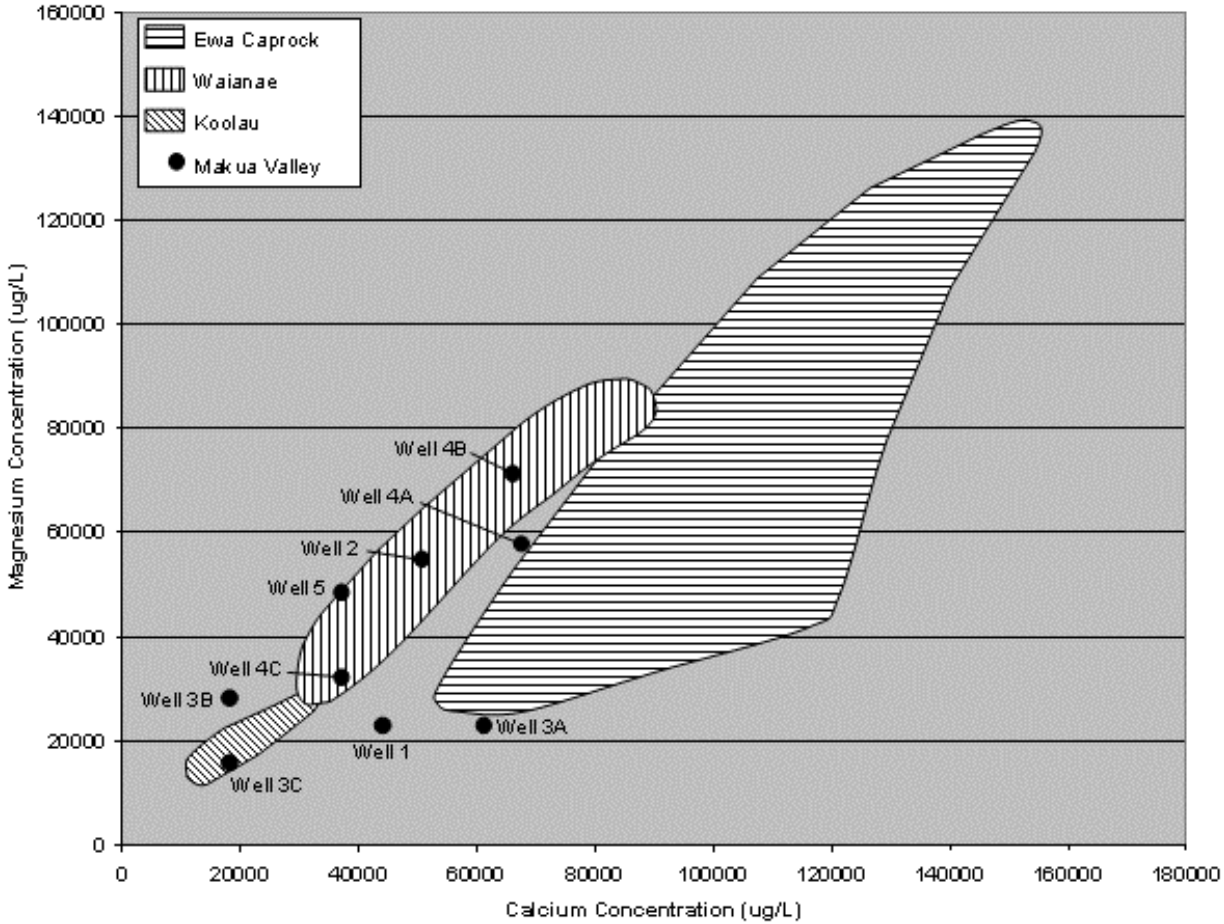
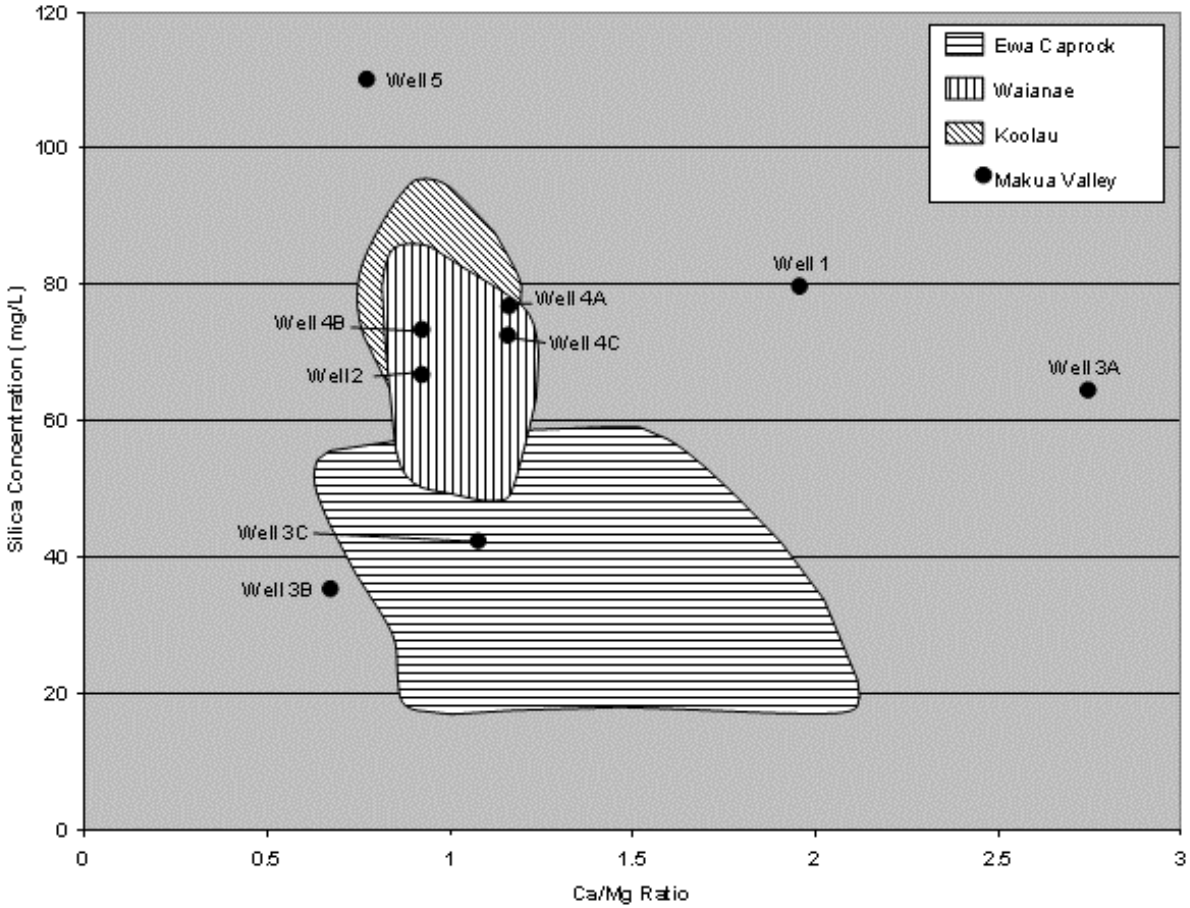


Figure 3.4 Graph of Silica Versus Calcium/Magnesium Ratios Versus Silica Concentrations of Groundwater in Makua and Other Areas of O`ahu



Based on results analyzed and reported by the analytical laboratory, no significant contamination above targeted MCLs and PRGs was detected in the six rounds of groundwater sampling at the Makua Military Reservation. Only sixteen samples had concentrations of a compound above the targeted MCL and PRG values and most of these had J flags, indicating that the concentrations were low enough to be near the detection limit for the analytical methods being used (Table 3.16). A "J" value means that the laboratory reports the compound as being present in the sample, but that the concentration is below reliable limits on reporting the quantity. All these samples with detections above MCLs or PRGs were from the first three rounds of groundwater sampling, with the latter three rounds having no detections above MCLs or PRGs. The wells and concentration values above PRGs or MCLs are shown in Table 3.16.

Table 3.15 Background Dioxin Sample Results—Soil Samples

Table 3.15 Background Dioxin Soil Sample Results (All concentrations in ug/l)						
Sample Label	Date Sampled	Analyte	Value	Residential PRG	Industrial PRG	Method Detection Limit
ERDC-BK 1A	8/25/03	OCDD	0.131			0.02
ERDC-BK 1B	8/25/03	OCDD	0.104			0.018
ERDC-BK 4A	05/28/03	1,2,3,4,6,7,8-HpCDD	0.045			0.007
ERDC-BK 4A	05/28/03	1,2,3,4,6,7,8-HpCDF	0.013			0.005
ERDC-BK 4A	05/28/03	1,2,3,4,7,8-HxCDF	0.005			0.003
ERDC-BK 4A	05/28/03	OCDD	0.593			0.013
ERDC-BK 4A	05/28/03	OCDF	0.032			0.009
ERDC-BK 4A	05/28/03	Total HpCDD	0.045			0.007
ERDC-BK 4A	05/28/03	Total HpCDF	0.151			0.005
ERDC-BK 4A	05/28/03	Total HxCDF	0.005			0.003
ERDC-BK 4B	05/28/03	1,2,3,4,6,7,8-HpCDD	0.027			0.010
ERDC-BK 4B	05/28/03	OCDD	0.312			0.016
ERDC-BK 4B	05/28/03	Total HpCDD	0.027			0.010
ERDC-BK 4B	05/28/03	Total HpCDF	0.033			0.005
ERDC-BK 5A	8/25/03	OCDD	0.212			0.019
ERDC-BK 5B	8/25/03	1,2,3,4,6,7,8-HpCDF	0.168			0.008
ERDC-BK 5B	8/25/03	OCDD	0.100			0.022
ERDC-BK 5B	8/25/03	Total HpCDD	3.891			0.011
ERDC-BK 5B	8/25/03	Total HpCDF	3.995			0.007
ERDC-BK 5B	8/25/03	Total HxCDD	4.095			0.008
ERDC-BK 5B	8/25/03	Total HxCDF	3.830			0.004
ERDC-BK 5B	8/25/03	Total PeCDD	3.674			0.009

Table 3.15 Background Dioxin Soil Sample Results (All concentrations in ug/l)						
Sample Label	Date Sampled	Analyte	Value	Residential PRG	Industrial PRG	Method Detection Limit
ERDC-BK 5B	8/25/03	Total PeCDF	4.481			0.006
ERDC-BK 5B	8/25/03	Total TCDD	1.725	3.9E -03	1.60E-02	0.005
ERDC-BK 5B	8/25/03	Total TCDF	1.865			0.003
ERDC-BK 6A	05/28/03	1,2,3,4,6,7,8-HpCDD	0.132			0.017
ERDC-BK 6A	05/28/03	1,2,3,4,6,7,8-HpCDF	0.077			0.009
ERDC-BK 6A	05/28/03	OCDD	1.865			0.042
ERDC-BK 6A	05/28/03	OCDF	0.167			0.029
ERDC-BK 6A	05/28/03	Total HpCDD	0.132			0.017
ERDC-BK 6A	05/28/03	Total HpCDF	0.485			0.009
ERDC-BK 6B	05/28/03	1,2,3,4,6,7,8-HpCDD	0.052			0.009
ERDC-BK 6B	05/28/03	1,2,3,4,6,7,8-HpCDF	0.022			0.006
ERDC-BK 6B	05/28/03	OCDD	0.659			0.021
ERDC-BK 6B	05/28/03	OCDF	0.052			0.014
ERDC-BK 6B	05/28/03	Total HpCDD	4.178			0.007
ERDC-BK 6B	05/28/03	Total HpCDF	4.331			0.006
ERDC-BK 6B	05/28/03	Total HxCDD	4.584			0.006
ERDC-BK 6B	05/28/03	Total HxCDF	3.766			0.003
ERDC-BK 6B	05/28/03	Total PeCDD	5.362			0.008
ERDC-BK 6B	05/28/03	Total PeCDF	5.294			0.006
ERDC-BK 6B	05/28/03	Total TCDD	2.257	3.9E -03	1.60E-02	0.005
ERDC-BK 6B	05/28/03	Total TCDF	1.940			0.003

* TOTAL TCDD is primarily composed of 2,3,7,8 TCDD

Table 3.16 Groundwater Chemistry Results Above Region IX PRGs and MCLs

WELL NUMBER	COMPOUND	QUALIFIER	CONCENTRATION	PRG	MCL
Round 1					
MMRMW3B	Benzene	J	0.92 ug/l	0.35 ug/l	5.0 ug/l
MMRMW3C	Arsenic	J	0.0047 mg/l	0.000045 mg/l	0.01 mg/l
MMRMW4A-R1	Arsenic	J	0.0053 mg/l	0.000045 mg/l	0.01 mg/l
MMRMW4A-R1	RDX	J	0.62 ug/l	0.61 ug/l	(no value)
MMRMW4B	Arsenic	J	0.00422 mg/l	0.000045 mg/l	0.01 mg/l
MW-5-R1	Thallium	J	0.0123 mg/l	0.00241 mg/l	0.002 mg/l
MW-5-R1	Arsenic	J	0.0096 mg/l	0.000045 mg/l	0.01 mg/l
Round 2					
MMRMW3B-R2	Benzene	J	0.8 ug/l	0.35 ug/l	5.0 ug/l
MMRMW3C-R2	Heptachlor epoxide	J	0.039 ug/l	0.007 ug/l	0.2 ug/l
MMRMW5RIN-2*	Benzene	J	0.63 ug/l	0.35 ug/l	5.0 ug/l
*(Rinsate sample for well MW-5)					

Table 3.16 (Concluded)

Groundwater Chemistry Results Above Region IX PRGs and MCLs

WELL NUMBER	COMPOUND	QUALIFIER	CONCENTRATION	PRG	MCL
Round 3					
MMRMW4A-R3	Thallium	J	0.00899 mg/l	0.00241 mg/l	0.002 mg/l
MMRMW4B-R3	Thallium	J	0.00627 mg/l	0.00241 mg/l	0.002 mg/l
MMRMW4C-R3	Iron		17.4 mg/l	11.0 mg/l	
MMRMW3B-R3	Alpha-BHC	J	0.039 mg/l	0.011 mg/l	
MMRMW3B-R3	Beta-BHC	J	0.049 mg/l	0.037 mg/l	
MMRMW3B-R3	Benzene	J	0.37 ug/l**	0.00241 mg/l	0.002 mg/l
MMRMW4C-R3	Bis(2-ethylhexyl)phthalate	J	14.0 mg/l	4.8 mg/l	
Round 4, 5, and 6					
MMRMW3A-R5	Thallium	J	0.00883 mg/l	0.002 mg/l	

**Duplicate from the 2A/2C laboratory reported 0.41 ug/l

J= J Flag indicative of semi-quantified results

All of these results (except for some thallium and iron samples) were flagged as J values, which means that the concentrations are near the detection limit for the method being used. The concentrations for arsenic, thallium, and RDX that were reported by the analytical laboratory in the first round of groundwater samples above Region IX PRGs were not detected above Region IX PRGs in the second round of groundwater samples (except for thallium in well 3A from the fifth round)(see also Table 3.16). Compounds above Region IX PRGs in the second round include benzene in well MW-3B and heptachlor epoxide in MW-3C. Compounds above Region IX PRGs in the third round of groundwater samples include thallium for wells MW-4A and 4B; iron and bis-(2-ethylhexyl)-phthalate in well MW-4C; and benzene, alpha-BHC, and beta-BHC in well MW-3B. No compounds above MCLs or PRGs were reported by the analytical laboratory for the fourth, fifth, or sixth rounds of groundwater samples. Tables 3.17A and 3.17B list some of the additional analytes in the groundwater from monitoring wells at Makua Military Reservation detected or reported by the analytical laboratory above laboratory detection limits, but below PRGs or MCLs. A complete list of compounds reported by the laboratory above laboratory detection limits is provided as Appendix D.

Table 3.17A lists that chloride concentrations varied from 37 to 231 mg/l, which are concentrations somewhat higher than in other parts of O`ahu. Slightly higher chloride concentrations can result from water flowing through the Waianae Basalts, which can add chloride to the groundwater. Nitrate (nitrate and total nitrogen) concentrations (Table 3.17A) are 3.5 mg/l or less, which are background levels for most groundwater. Low levels of some fuel components (1,2,4,trimethylbenzene, ethylbenzene, M/P-xylenes, O-xylene, and toluene) were reported by the laboratory as semiquantified results (J flags). All of the fuel components are at barely detectable levels, and were also present in some of the trip blanks, indicating that the samples may have been exposed to fuel components in their trip to the laboratory. Table 3.17B lists that rounds 2 and 3 of well MW-3C contained a trace level of the pesticide Endosulfan I. Only two wells had detectable levels of explosives reported by the analytical laboratory. The

explosives in well MW-4A include trace levels of RDX and 2,4,6-TNT, and the explosives in well MW-4B included trace levels of perchlorate. A number of wells have low levels of dioxin and furan compounds, including 1,2,3,4,6,7,8-HpCDD, 1,2,3,4,6,7,8-HpCDF.1,2,3,6,7,8-HxCDD, 1,2,3,6,7,8-HxCDF, OCDD, and OCDF (Table 3.17B).

Except for the detection of thallium in the first round of sampling for well MW-5, and the third round of sampling from wells MW-4A and 4B (thallium was not detected above MCLs in the subsequent rounds), the groundwater in Makua Valley would meet drinking water standards as established by the U.S. EPA. The thallium concentrations are likely naturally occurring, just as suggested by the Navy at Pearl Harbor (Navy, 2002). While there are compounds found in the wells, there is no pattern of contamination that would be indicated by compounds reported by the laboratory in each sampling event. The chloride concentrations are somewhat elevated (taste levels for chloride are 250 mg/l), so that the water in Makua Valley would not taste as good as water from other parts of O`ahu. However, it would be considered of drinking water quality.

Table 3.17A Selected Groundwater Chemistry Data for the Makua Military Reservation Monitoring Wells

(Naturally Occurring Compounds)

Sample Name	Location	Chloride (mg/l)	Nitrate-N	Nitrite	Qualifier
MMRMW1-R1	MW-1	188.000			
MMRMW1-R1	MW-1		1.33000		
MMRMW1-R2	MW-1	200.000			
MMRMW1-R2	MW-1		1.25000		
MMRMW1-R3	MW-1	193.000			
MMRMW1-R3	MW-1		1.4000		
MMRMW1-R4	MW-1	197.000			
MMRMW1-R4	MW-1		1.3800		
MMR-MW1-R5	MW-1	208.000			
MMR-MW1-R5	MW-1		1.28000		
MMRMW1-R6	MW-1	176.000			
MMRMW1-R6	MW-1		1.46000		
MMRMW2-R1	MW-2	171.000			
MMRMW2-R1	MW-2		0.202000		
MMRMW2-R2	MW-2	202.000			
MMRMW2-R2	MW-2		0.26000		
MMRMW2-R3	MW-2	231.000			
MMRMW2-R3	MW-2		1.68000		
MMRMW2-R4	MW-2	191.000			

Sample Name	Location	Chloride (mg/l)	Nitrate-N	Nitrite	Qualifier
MMRMW2-R4	MW-2		0.26000		
MMR-MW2-R5	MW-2	185.000			
MMR-MW2-R5	MW-2		0.2000		
MMRMW2-R6	MW-2	191.000			
MMRMW2-R6	MW-2		2.35000		
MMRMW3A-R1	MW-3A	42.2000			
MMRMW3A-R1	MW-3A		0.767000		
MMRMW3A-R2	MW-3A	48.6000			
MMRMW3A-R2	MW-3A		0.723000		
MMRMW3A-R2	MW-3A			0.162000	
MMRMW3A-R3	MW-3A	54.8000			
MMRMW3A-R3	MW-3A		0.783000		
MMRMW3A-R4	MW-3A	53.8000			
MMRMW3A-R4	MW-3A		0.67300000		
MMR-MW3A-R5	MW-3A	2.29000			J
MMR-MW3A-R5	MW-3A		0.446000		
MMRMW3A-R6	MW-3A	50.2000			
MMRMW3A-R6	MW-3A		0.731000		
MMRDUP-R3	MW-3B	40.1000			
MMRMW-3B	MW-3B	37.000			
MMRMW3B-R2	MW-3B	164.000			
MMRMW3B-R2	MW-3B		2.09000		

Sample Name	Location	Chloride (mg/l)	Nitrate-N	Nitrite	Qualifier
MMRMW3B-R3	MW-3B	38.8000			
MMRMW3B-R4	MW-3B	37.8000			
MMR-MW3B-R5	MW-3B	39.3000			
MMRMW3B-R6	MW-3B	32.4000			
MMRMW-3C	MW-3C	55.2000			
MMRMW-3C	MW-3C		0.497000		
MMRMW3C-R2	MW-3C	65.000			
MMRMW3C-R2	MW-3C		0.446000		
MMRMW3C-R3	MW-3C	57.7000			
MMRMW3C-R3	MW-3C		0.399000		
MMRMW3C-R4	MW-3C	56.6000			
MMRMW3C-R4	MW-3C		0.363000		
MMR-MW3C-R5	MW-3C	59.1000			
MMR-MW3C-R5	MW-3C		0.45000		
MMRMW3C-R6	MW-3C	52.9000			
MMRMW3C-R6	MW-3C		0.515000		
MMRMW4A-R1	MW-4A	172.000			
MMRMW4A-R1	MW-4A		2.11000		
MMRMW4A-R2	MW-4A	172.000			
MMRMW4A-R2	MW-4A		2.25000		
MMRMW4A-R3	MW-4A	188.000			
MMRMW4A-R3	MW-4A		2.29000		

Sample Name	Location	Chloride (mg/l)	Nitrate-N	Nitrite	Qualifier
MMRMW4A-R3DUP	MW-4A	186.000			
MMRMW4A-R3DUP	MW-4A		2.3000		
MMRMW4A-R4	MW-4A	133.000			
MMRMW4A-R4	MW-4A		2.28000		
MMR-MW4A-R5	MW-4A	204.000			
MMR-MW4A-R5	MW-4A		2.44000		
MMRMW4A-R6	MW-4A	198.000			
MMRMW4A-R6	MW-4A		2.37000		
MMRMW-4B	MW-4B	161.000			
MMRMW-4B	MW-4B		2.19000		
MMRMW-4BDUP	MW-4B	160.000			
MMRMW-4BDUP	MW-4B		2.19000		
MMRMW4B-R2	MW-4B	36.7000			
MMRMW4B-R3	MW-4B	153.000			
MMRMW4B-R3	MW-4B		2.4000		
MMRMW4B-R4	MW-4B	168.000			
MMRMW4B-R4	MW-4B		2.19000		
MMRMW4B-R4DUP	MW-4B	167.000			
MMRMW4B-R4DUP	MW-4B		2.18000		
MMR-MW4B-R5	MW-4B	149.000			
MMR-MW4B-R5	MW-4B		2.39000		
MMRMW4B-R6	MW-4B	157.000			

Sample Name	Location	Chloride (mg/l)	Nitrate-N	Nitrite	Qualifier
MMRMW4B-R6	MW-4B		2.28000		
MMRMW-4C	MW-4C	173.000			
MMRMW-4C	MW-4C		2.09000		
MMRMW4C-R2	MW-4C	182.000			
MMRMW4C-R2	MW-4C		2.22000		
MMRMW4C-R2DUP	MW-4C	184.000			
MMRMW4C-R2DUP	MW-4C		2.22000		
MMRMW4C-R3	MW-4C	180.000			
MMRMW4C-R3	MW-4C		2.14000		
MMRMW4C-R4	MW-4C	181.000			
MMRMW4C-R4	MW-4C		2.22000		
MMR-MW4C-R5	MW-4C	186.000			
MMR-MW4C-R5	MW-4C		2.29000		
MMRMW4C-R6	MW-4C	165.000			
MMRMW4C-R6	MW-4C		2.24000		
MMR-DUP-R5	MW-5	48.9000			
MMR-DUP-R5	MW-5		2.24000		
MMRMW5-R2	MW-5	157.000			
MMRMW5-R2	MW-5		1.22000		
MMRMW5-R3	MW-5	152.000			
MMRMW5-R3	MW-5		1.14000		
MMRMW5-R4	MW-5	153.000			

Sample Name	Location	Chloride (mg/l)	Nitrate-N	Nitrite	Qualifier
MMRMW5-R4	MW-5		1.19000		
MMR-MW5-R5	MW-5	160.000			
MMR-MW5-R5	MW-5		1.18000		
MMRMW5-R6	MW-5	148.000			
MMRMW5-R6	MW-5		1.23000		
MW-5-R1	MW-5	157.000			
MW-5-R1	MW-5		0.891000		
MMRMWSP7-R2	SP 7	53.7000			
MMRMWSP7-R2	SP 7		1.96000		
MMRSP-7	SP 7	49.9000			
MMRSP-7	SP 7		1.88000		
MMRSP-7DUP	SP 7	49.8000			
MMRSP-7DUP	SP 7		1.87000		
MMRSP7-R3	SP 7	61.5000			
MMRSP7-R3	SP 7		2.16000		
MMRSP7-R4	SP 7	50.3000			
MMRSP7-R4	SP 7		3.52000		
MMR-SP7-R5	SP 7	51.9000			
MMR-SP7-R5	SP 7		2.4600		
MMR-SP7-R5DUP	SP 7	51.4000			
MMR-SP7-R5DUP	SP 7		2.44000		
MMRSP7-R6	SP 7	44.6000			

Sample Name	Location	Chloride (mg/l)	Nitrate-N	Nitrite	Qualifier
MMRSP7-R6	SP 7		1.97000		
MMRSP7-R6	SP 7			0.097000	J
Nitrate PRG is 1 mg/l.					

Table 3.17B Selected Groundwater Chemistry Data for the Makua Military Reservation Monitoring Wells Below PRGs and MCLs

(Select Compounds Other Than Chloride and Nitrate (Table 3.17A) including Dioxin and Furans)

Table 3.17B Selected Groundwater Chemistry Data for the Makua Military Reservation Monitoring Wells Below PRGs and MCLs

(Select Compounds Other Than Chloride and Nitrate (Table 3.17A) including Dioxin and Furans)

Compound		1,2,3,4,6,7,8-HpCDD	1,2,3,4,6,7,8-HpCDF	1,2,3,6,7,8-HxCDD	1,2,3,6,7,8-HxCDF	1,2,3,7,8,9-HxCDD	1,2,4-TRIMETHYL BENZENE	2,4,6-TNT	BENZENE	BETA-BHC	CHLOROFORM	DELTA-BHC	ENDOSULFAN I
Unit		pg/l	pg/l	pg/l	pg/l	pg/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l
PRG							12.33	2.24	0.34	0.04	6.17		
MCL									5.00				
Sample Label	**Location/Round**												
MMRMW1-R1	MW-1	3.952	3.867X				0.48J						
MMRMW1-R2	MW-1												
MMRMW1-R4	MW-1												
MWRMW2-R1	MW-2	5.296	2.298X										
MMRMW2-R1	MW-2						0.38J						
MMRMW2-R2	MW-2												
MMRMW2-R4	MW-2												
MWRMW3A-R1	MW-3A	1.609											
MMRMW3A-R1	MW-3A						0.4J						
MMRMW3A-R2	MW-3A												
MMR-MW3A-R5	MW-3A										0.32J		
MMRMW-3B	MW-3B		1.433X				0.48J						
MMRMW3B-R2	MW-3B												
MMRMW3B-R3	MW-3B											0.024J	
MMRMW3B-R4-RIN	MW-3B								0.21J				
MMRDUP-R3	MW-3B									0.027J		0.014J	
MMRMW-3C	MW-3C						0.52J						

Table 3.17B Selected Groundwater Chemistry Data for the Makua Military Reservation Monitoring Wells Below PRGs and MCLs

(Select Compounds Other Than Chloride and Nitrate (Table 3.17A) including Dioxin and Furans)

Compound		1,2,3,4,6,7,8-HpCDD	1,2,3,4,6,7,8-HpCDF	1,2,3,6,7,8-HxCDD	1,2,3,6,7,8-HxCDF	1,2,3,7,8,9-HxCDD	1,2,4-TRIMETHYL BENZENE	2,4,6-TNT	BENZENE	BETA-BHC	CHLOROFORM	DELTA-BHC	ENDOSULFAN I
Unit		pg/l	pg/l	pg/l	pg/l	pg/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l
PRG							12.33	2.24	0.34	0.04	6.17		
MCL									5.00				
Sample Label	**Location/Round**												
MMRMW3C-R2	MW-3C												0.45
MMRMW3C-R3	MW-3C												0.26
MMRMW3C-R4	MW-3C												
MMR-MW3C-R5	MW-3C										0.3J		
MMRMW4AR1	MW-4A	2.783											
MMRMW4A-R1	MW-4A						0.45J	0.61JN					
MMRMW4A-R2	MW-4A							0.26JN					
MMRMW4A-R6	MW-4A												
MMRMW-4B	MW-4B	3.949	6.079X										
MMRMW4B-R2	MW-4B												
MMRMW4B-R4	MW-4B												
MMRMW4B-R4DUP	MW-4B												
MMR-MW4B-R5	MW-4B												
MMRMW-4C	MW-4C		2.062X				0.4J						
MMRMW4C-R2	MW-4C												
MMRMW4C-R4	MW-4C												
MW-5-R1	MW-5												
MMRMW5-R2	MW-5	58.6	14.63	3.09	2.746I	2.472							
MMR-DUP-R5	MW-5										0.21J		
MMRMW5RIN-R2	Rinsate												
MMRMWSP7-R2	SP 7												

Table 3.17B Selected Groundwater Chemistry Data for the Makua Military Reservation Monitoring Wells Below PRGs and MCLs

(Select Compounds Other Than Chloride and Nitrate (Table 3.17A) including Dioxin and Furans)

Compound		1,2,3,4,6,7,8-HpCDD	1,2,3,4,6,7,8-HpCDF	1,2,3,6,7,8-HxCDD	1,2,3,6,7,8-HxCDF	1,2,3,7,8,9-HxCDD	1,2,4-TRIMETHYL BENZENE	2,4,6-TNT	BENZENE	BETA-BHC	CHLOROFORM	DELTA-BHC	ENDOSULFAN I
Unit		pg/l	pg/l	pg/l	pg/l	pg/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l
PRG							12.33	2.24	0.34	0.04	6.17		
MCL									5.00				
Sample Label	**Location/Round**												
MMRSP-7	SP 7												
MMR-SP7-R5	SP 7										0.28J		
MMRSP7-R6	SP 7										0.25J		

Key: X,J= Semiquantified Result, B,E = Rerun of sample, PRG = Drinking Water Preliminary Remediation Goal, MCL = Drinking Water Maximum Contaminant Limit

N = Definition of compound is suspect -presumptive evidence

Values listed in table are above laboratory detection limits

Table 3.17B Selected Groundwater Chemistry Data for the Makua Military Reservation Monitoring Wells Below PRGs and MCLs (Continued)

(Select Compounds Other Than Chloride and Nitrate (Table 3.17A) including Dioxin and Furans)

Compound		ENDRIN KETONE	ETHYLBENZENE	LEAD	M/P-XYLENES	OCDD	OCDF	O-XYLENE	PERCHLORATE	RDX	TOLUENE	Total HpCDD	Total HpCDF	Total HxCDD	Total HxCDF
Unit		UG/L	UG/L	MG/L	UG/L	PG/L	PG/L	UG/L	UG/L	UG/L	UG/L	PG/L	PG/L	PG/L	PG/L
PRG			2.91							0.61	723.42				
MCL			700.00	0.02							1,000.00				
Sample Label*	**Well Location**														
MMRMW1-R1	MW-1		0.25J		1J	25.14B	4.667	0.38J			0.76J	3.952			
MMRMW1-R2	MW-1				0.47J						0.82J				
MMRMW1-R4	MW-1										1.4				
MWRMW2-R1	MW-2					18.03B	5.644					8.361	4.219		
MMRMW2-R1	MW-2				0.42J						0.25J				
MMRMW2-R2	MW-2				0.41J						0.74J				
MMRMW2-R4	MW-2										0.85J				
MWRMW3A-R1	MW-3A					11.24B	1.549					1.609			
MMRMW3A-R1	MW-3A				0.45J						0.29J				
MMRMW3A-R2	MW-3A										0.44J				
MMR-MW3A-R5	MW-3A														
MMRMW-3B	MW-3B				0.7J	7.131B		0.28J			0.64J				
MMRMW3B-R2	MW-3B				0.4J						0.74J				
MMRMW3B-R3	MW-3B														
MMRMW3B-R4-RIN	MW-3B										1				
MMRDUP-R3	MW-3B														
MMRMW-3C	MW-3C				0.7J			0.27J			0.53J				
MMRMW3C-R2	MW-3C										0.31J				
MMRMW3C-R3	MW-3C														
MMRMW3C-R4	MW-3C										1.2				
MMR-MW3C-R5	MW-3C														
MMRMW4AR1	MW-4A					20.28B						2.783			

Table 3.17B Selected Groundwater Chemistry Data for the Makua Military Reservation Monitoring Wells Below PRGs and MCLs (Continued)

(Select Compounds Other Than Chloride and Nitrate (Table 3.17A) including Dioxin and Furans)

Compound		ENDRIN KETONE	ETHYLBENZENE	LEAD	M/P-XYLENES	OCDD	OCDF	O-XYLENE	PERCHLORATE	RDX	TOLUENE	Total HpCDD	Total HpCDF	Total HxCDD	Total HxCDF
Unit		UG/L	UG/L	MG/L	UG/L	PG/L	PG/L	UG/L	UG/L	UG/L	UG/L	PG/L	PG/L	PG/L	PG/L
PRG			2.91							0.61	723.42				
MCL			700.00	0.02							1,000.00				
Sample Label*	**Well Location**														
MMRMW4A-R1	MW-4A				0.58J			0.21J			0.36J				
MMRMW4A-R2	MW-4A				0.31J					0.48J	0.59J				
MMRMW4A-R6	MW-4A									0.23J					
MMRMW-4B	MW-4B					19.86B	4.707X					3.949	2.195		
MMRMW4B-R2	MW-4B				0.45J						0.82J				
MMRMW4B-R4	MW-4B								1.45J		0.41J				
MMRMW4B-R4DUP	MW-4B								1.78J						
MMR-MW4B-R5	MW-4B	0.099J													
MMRMW-4C	MW-4C				0.47J	9.351B					0.31J				
MMRMW4C-R2	MW-4C				0.36J						0.61J				
MMRMW4C-R4	MW-4C										1.7				
MW-5-R1	MW-5			0.0086J											
MMRMW5-R2	MW-5				0.41J	333.1B	76.19				0.78J	94.66	49.38	10.89	8.43
MMR-DUP-R5	MW-5			0.00294J											
MMRMW5RIN-R2	Rinsate		0.23J		1.1J			0.41J			2.7				
MMRMWSP7-R2	SP 7										0.58J				
MMRSP-7	SP 7					15.38B	3.661								
MMR-SP7-R5	SP 7														
MMRSP7-R6	SP 7														

Key: X,J= Semiquantified Result, B,E = Rerun of sample, PRG = Drinking Water Preliminary Remediation Goal, MCL = Drinking Water Maximum Contaminant Limit

N = Definition of compound is suspect -presumptive evidence

Values listed in table are above laboratory detection limits

3.8 Hydrologic/Hydrogeologic Characterization

The hydrogeologic characterization portions of this study include the rainfall (meteorological) data and the surface water measurements collected. The hydrogeologic characterization portions of this study include the water level information and the permeability (slug) testing information.

3.8.1 Rainfall Data

Data from the three on-site weather stations, as well as the eight additional rainfall gages were collected as part of this study. The data are summarized in the surface water modeling results (Section 3.9.1).

3.8.2 Soils Data

The results of soil moisture content and grain size analyses are listed in Appendix F. The average moisture content of soil samples collected at Makua was 8.2, which means that an average of 8.2% of the soils volume was water. This soil-moisture data was collected during September to October, 2002. This is generally a low value, and is indicative of the drier conditions at Makua. The average particle distribution of samples collected (Appendix F) was 64% fine material (that is, particles less than sand size), 33% sand size particles, and 3% gravel size particles.

3.8.3 Geologic Information

Borehole information from the drilling operations was logged for each of the monitoring wells at Makua Military Reservation. Borehole logs are listed in Appendix A.

Well MW-1 encountered sand nearly the entire depth of the well. Drilling of well MW-2 encountered sand for the first foot of drilling, and then encountered clay to a depth of 35 feet.

Well MW-3A drilled in silt to 18 feet, and then graded into sand to a depth of 35 feet. Well MW-3B also drilled in silt to 18 feet, sand to 60 feet, and then clay with basaltic rock fragments to a depth of 70 feet. Well MW-3C encountered silt to a depth of 25 feet, a layer of basaltic boulders to 45 feet, clay from 45 to 60 feet, basaltic boulders from 60 to 85 feet, and silty

clay from 85 to 106 feet. These three wells (MW-3A, B, C) were installed about 10 feet apart, and indicate that the geology in the area of these wells is layers of interbedded silt, boulders with clay, and sand.

Well MW-4A encountered sand the entire depth of the hole to 35 feet. Wells MW-4B and 4C encountered sand to a depth of 60 feet, and a basalt boulder layer with sand from 60 to 70 feet. In well MW-4C the basaltic boulder layer extended from 60 to 85 feet, with a clay and gravel layer extending from 85 to 100 feet. A higher amount of sand was encountered during the drilling of wells MW-4A, B, and C, with some layers of basaltic boulders and clay.

Well MW-5 was by far the deepest well, with a total depth of 340 feet during drilling. The well encountered a silt/clay layer to a depth of 290 feet, and then gravel beneath that. The gravel layer provides a higher permeability zone, and could transmit water from the Waianae Range to the ocean.

Radiation readings in the Makua samples were 10 to 60 counts per second. These values are within those measured on other parts of O`ahu (Section 3.6). Therefore, there is no indication that radiation above background levels is found in the Makua Valley.

3.8.4 Water Level Measurements (in Wells)

A number of groundwater measurements were collected as part of this study. Table 3.18 lists the water levels collected from the Makua Military Reservation monitoring wells, and Figure 3.5 shows a map of the water levels. The water levels are generally 3 feet above sea level in all of the boundary wells (MW-1, 2, 3A, 3B, 3C, 4A, 4B, 4C, SP-7). The water level in the upgradient well (MW-5) is approximately 14 feet above sea level, and appears to be in a confined aquifer portion of the Valley. The groundwater is likely measured in a freshwater lens that is floating on sea water beneath well MW-5. Given this assumption, the approximate groundwater gradient in the Makua Valley is 0.003. Figure 3.6 shows a hydrograph of water level fluctuations in well SP-7 from January 17, 2003, 4:45 P.M. for 2 days (2880 min). Figure 3.6 shows that approximate tidal fluctuation is less than 0.10 foot. Such a small fluctuation would be expected

in a well in a shallow unconfined aquifer nearly 1000 feet inland of the ocean. Tidal fluctuations are typically found more prominently within a few 100 feet of the shoreline (Jiao and Tang, 1999).

Table 3.18 Water Levels Measured in Monitoring Wells at Makua Military Reservation

	Monitoring Well Number																													
	MW-1			MW-2			MW-3A			MW-3B			MW-3C			MW-4A			MW-4B			MW-4C			MW-5			SP-7		
Date	TOC	Gr. Level	Water Elevation	TOC	Gr. Level	Water Elevation	TOC	Gr. Level	Water Elevation	TOC	Gr. Level	Water Elevation	TOC	Gr. Level	Water Elevation	TOC	Gr. Level	Water Elevation	TOC	Gr. Level	Water Elevation	TOC	Gr. Level	Water Elevation	TOC	Gr. Level	Water Elevation	TOC	Gr. Level	Water Elevation
Well Elevation (est.)	12.9	9.95		13.59	10.81		22.02	19.11		21.25	18.34		21.8	18.6		22.23	19.25		22.16	19.27		22.67	19.71		234.95	235.35		19.13	13.01	
10/11/2002		6.8	6.1		8.6	4.99																								
10/15/2002								16.2	5.82																					
10/26/2002								14.6	7.42																					
11/20/2002											15.45	5.8								15.9	6.26									
12/5/2002														15.4	6.4								11.7	10.97						
12/9/2002																										223	11.95			
12/10/2002																														
12/12/2002	9.41		3.49																											
12/23/2002																														
1/16/2003	9.38		3.52	10.2		3.39																								
1/17/2003							18.77		3.25							18.72		3.51												
1/21/2003										17.7		3.55							18.61		3.55									
1/22/2003																												15.7		3.43
1/23/2003													18.29		3.51							19.1		3.57						

		Monitoring Well Number																													
		MW-1			MW-2			MW-3A			MW-3B			MW-3C			MW-4A			MW-4B			MW-4C			MW-5			SP-7		
	Date	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water
				Elevation			Elevation			Elevation			Elevation			Elevation			Elevation			Elevation			Elevation			Elevation			Elevation
	1/24/2003	8.94		3.96	10.04		3.55	18.62		3.4	17.79		3.46	18.25		3.55	18.64		3.59	18.56		3.6	19.07		3.6	220.71	220.71	14.24	15.72		3.41
	2/13/2003																									220.66	220.66	14.29			
Low Tide	4/3/2003	8.71		4.19	10.29		3.3	18.25		3.77	17.77		3.48	18.09		3.71	18.21		4.02	18.14		4.02	18.62		4.05				15.35		3.78
High Tide	4/3/2003	8.7		4.2	10.18		3.41	18.26		3.76	17.47		3.78	17.98		3.82	18.21		4.02	18.14		4.02	18.62		4.05				15.35		3.78
	4/1/2003	8.55		4.35	10.16		3.43	18.21		3.81																					
	4/2/2002																18.16		4.07	18.11		4.05									
	4/3/2003										17.77		3.48																15.35		3.78
	4/7/2003																									220.51		14.44			
	6/23/2003	9.24		3.66																											
	6/24/2003				10.85		2.74	18.8		3.22																			15.88		
	6/25/2003										18.06		3.19																		
	6/26/2003													18.69		3.11				18.51		3.65									
	6/27/2003																18.78		3.45				19.19		3.48						
	7/1/2003																									221.45					
Low	9/9/2003	9.41		3.49	10.69		2.9	19.06		2.96	18.23		3.02	18.74		3.06	19.02		3.21	18.98		3.18	19.48		3.19	220.11		14.84	16.17		2.96

		Monitoring Well Number																													
		MW-1			MW-2			MW-3A			MW-3B			MW-3C			MW-4A			MW-4B			MW-4C			MW-5			SP-7		
	Date	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water	TOC	Gr. Level	Water
				Elevation			Elevation			Elevation			Elevation			Elevation			Elevation			Elevation			Elevation			Elevation			Elevation
Tide																															
High Tide	9/9/2003	9.38		3.52	10.49		3.1	19.05		2.97	18.18		3.07	18.61		3.19	19		3.23	18.96		3.2	19.45		3.22	220.03		14.92	16.12		3.01
	9/29/2003	9.18		3.72																											
	9/30/2003				10.33		3.26	18.86		3.16																					
	10/1/2003										17.93		3.32	18.38		3.42													15.93		3.2
	10/2/2003																18.84		3.39	18.75		3.41	19.28		3.39						
	10/3/2003																									220.25		14.7			
	12/29/2003	9.2		3.7																									16.16		2.97
	12/31/2003																18.96		3.27	18.9		3.26	19.38		3.29						
	1/2/2004													18.35		3.45															
	1/4/2004				8.43		5.16																			220.51		14.44			
	1/7/2004							17.51		4.51	16.81		4.44																		

Key:

TOC = Top of Casing Measurement

Gr. Level = Measurement taken at Ground Level

Water Elevation = Water Level in feet above mean sea level (Surveyed elevation of TOC - Water level from TOC)

Figure 3.5 Water Table Map

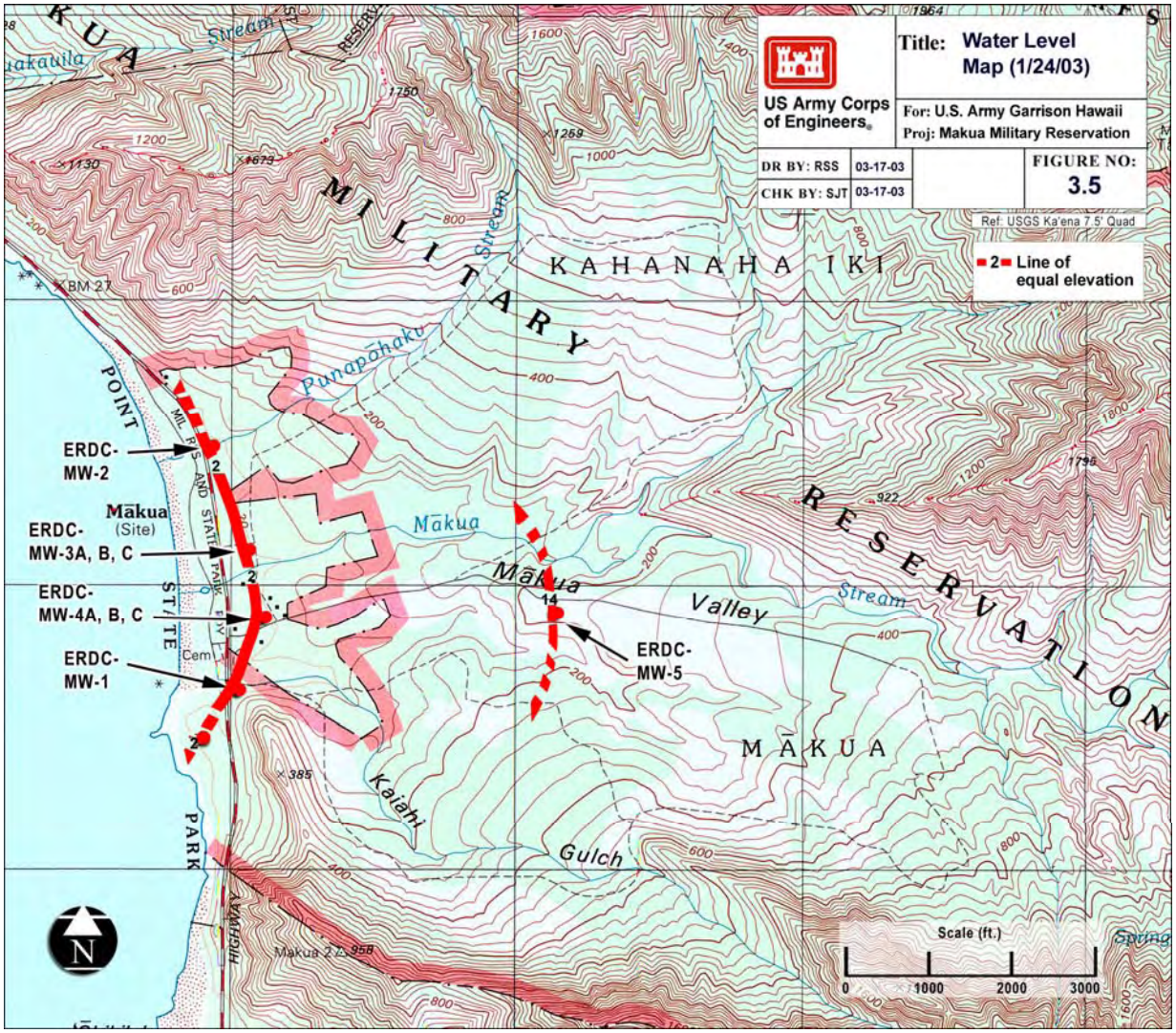
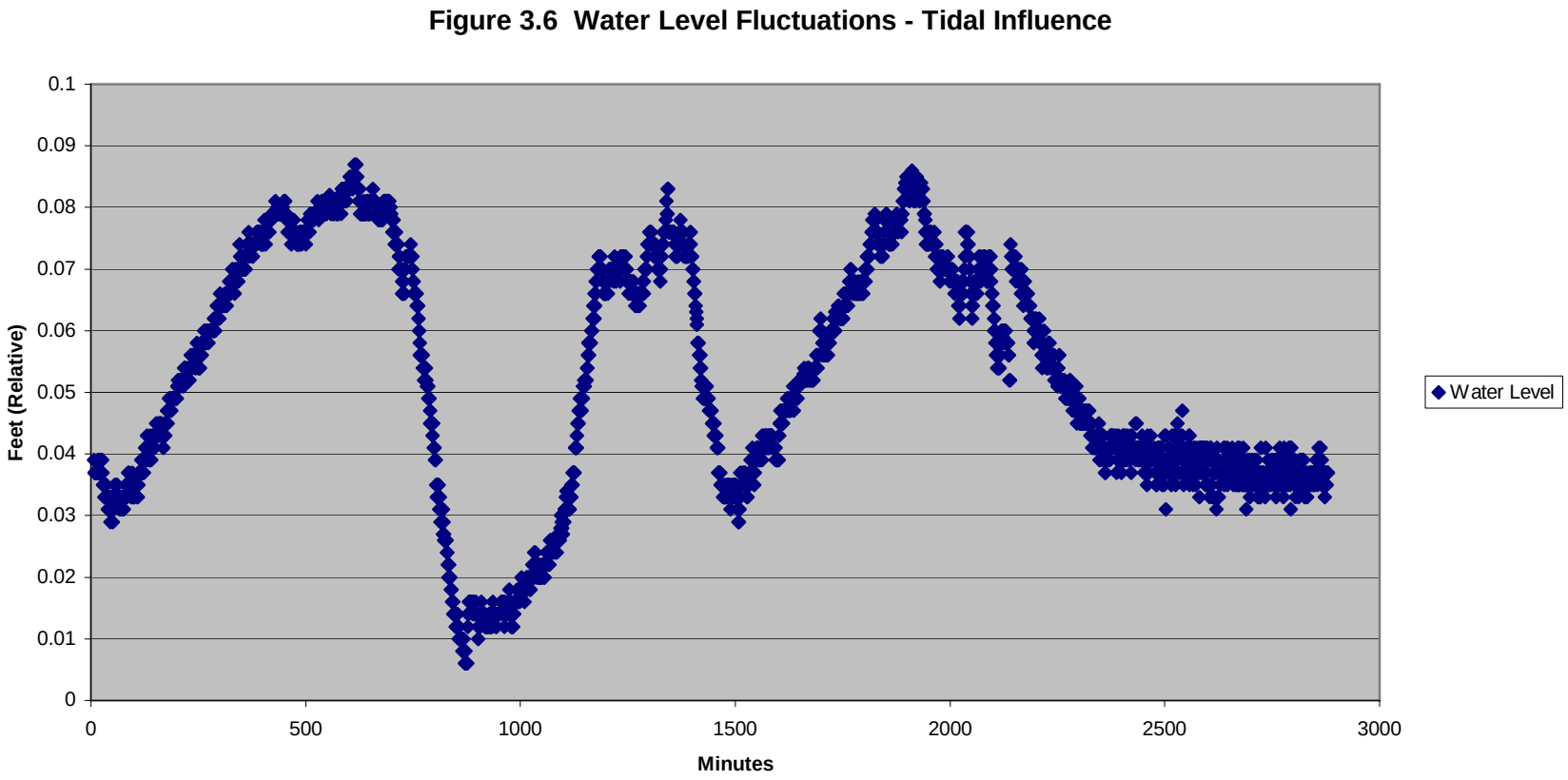


Figure 3.6 Water Level Fluctuations



3.8.5 Permeability (Slug Testing)

Hydraulic conductivity (K) tests were conducted on wells MW-1, MW-2, MW-3A, MW-3B, MW-3C, MW-4A, MW-4B, MW-4C, MW-5, and SP-7. The hydraulic conductivity test data were analyzed using AQTESOLV for Windows. The unconfined Bouwer-Rice and unconfined Hvorslev methods seemed to give the best fit for most the Makua well data. The confined Cooper-Bredehoeft-Papadopulos method was used on MW-5. The hydraulic conductivity values ranged from 0.37 ft/day to 75.11 ft/day. The average K is 12.60 ft/day. All the values obtained fit in the range of what would be expected for a fine to coarse sand as shown by Freeze and Cherry (1979) in their graph entitled "Typical K Values for Consolidated and Unconsolidated Aquifers." The hydraulic conductivity values determined for each well are in Table 3.19.

Table 3.19 Hydraulic Conductivity Values from Monitoring Wells

WELL NUMBER	HYDRAULIC CONDUCTIVITY
MW-1	5.45 ft/day
MW-2	2.28 ft/day
MW-3A	75.11 ft/day
MW-3B	51 ft/day
MW-3C	6.255 ft/day
MW-4A	0.37 ft/day
MW-4B	6.7 ft/day
MW-4C	1.67 ft/day
MW-5	22.65 ft/day
SP-7	5.09 ft/day
	Average K =12.60 ft/day

3.9 Surface Water and Groundwater Modeling Results

Sections 3.9.1 and 3.9.2 contain the surface water modeling and groundwater modeling results.

3.9.1 Surface Water Modeling Results

The surface water modeling provided helpful calculations used to evaluate the hydrology of the Makua Valley. Information provided by the surface water modeling includes an estimate of total suspended solids load from the February 14, 2003, January 23, 2004, and February 27, 2004, storms and sediment load and stream flow for a much larger estimated rainfall event (100-year storm). The model also provided estimates of the volume of infiltration to groundwater that occurred during the February 14, 2003, January 23, 2004, and February 27, 2004, flow events. These infiltration values can be compared to those recharge estimates as part of the groundwater modeling outlined in Section 3.9.2 and Appendix G. The model also provided information on the potential areas of flooding for a 24-hour, 100-year storm and the volume of suspended sediment that might be discharged from the valley.

The amount of water infiltrated during the February 14, 2003, January 23, 2004, and February 27, 2004, flow events are shown in Figure 3.7A, 3.7B, and 3.7C respectively. Values of infiltration are expressed as the total infiltration amount (in cm). For the February 14 event, infiltration varied from 1 to 67 cm, with a mean of 8 cm of water (Figure 3.7A). For the January 23 event, infiltration varied from 1 to 14 cm of water, with a mean of 4 cm (Figure 3.7B). For the February 27 event, infiltration varied from 7 to 88 cm of water, with a mean of 23 cm (Figure 3.7C). Consistent with our understanding of the hydrology at the site, the steepest areas generate less recharge than the flatter areas. As expected, areas that received more rainfall generated more recharge. Other storm events may provide more rainfall in other areas, so that the recharge simulated by the model is influenced by the distribution of this particular rainfall event. The largest event (February, 2004) generated the most infiltration, since it occurred over a 1 week period with two large storms passing through the Makua Valley.

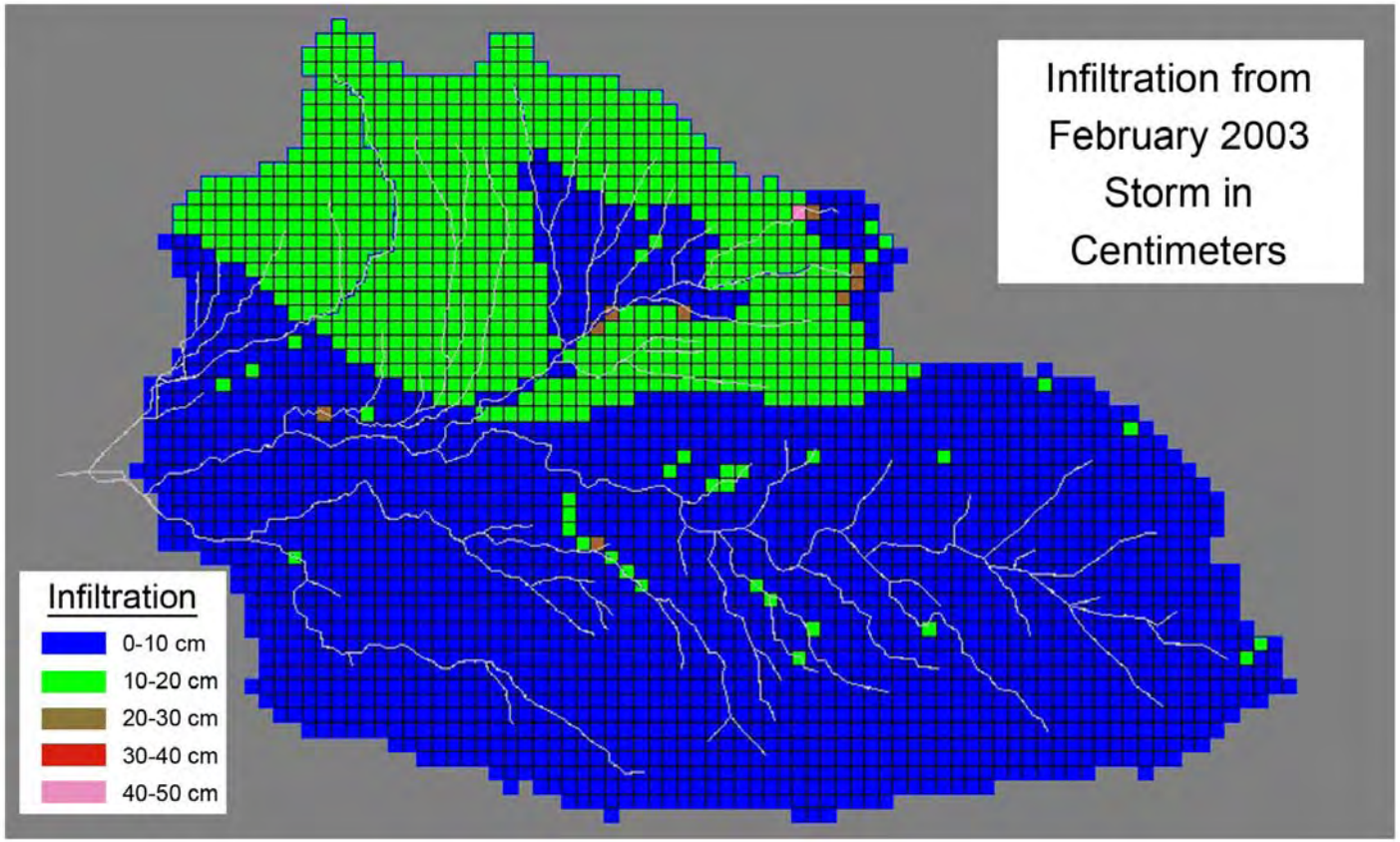
For the February 14 event, the model calculated the total volume of rainfall in the Makua Valley as 1,364,244 m^3, with a total volume of 1,237,824 m^3 infiltrating. This represents 91% of the rainfall infiltrating to the ground, or left on the surface as ponded water, with 122,067 m^3, or about 9%, discharging into the streams and then into the ocean. For the January 23 event the model calculated total volume of rainfall in the Makua Valley was 639,244 m^3, with a total volume of 596,600 m^3infiltrating. This represents 93% of the rainfall infiltrating to the ground, or left on the surface as ponded water, with 42,385 m^3, or about 7%, discharging into the streams and then into the ocean. For the February 27 event, the model calculated total volume of rainfall in the Makua Valley was 4,393,952 m^3, with a total volume of 3,747,119 m^3 infiltrating. This represents 85% of the rainfall infiltrating to the ground, or left on the surface as ponded water, with 625,889 m^3, or about 15%, discharging into the streams and then into the ocean. A review of these numbers indicates that a great percentage of large rainfall events infiltrates or remains as ponded water on surface.

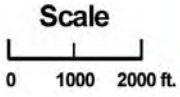
The model calculated a total suspended sediment discharge for the three different flow events. Model simulated total suspended sediment (silt and clay fractions) was 1,540 m3 for the February 2003 flow event, 28.7 m3 for the January 2004 flow event, and 2,090 m3 for the February 2004 flow event, which were simulated by calibrating the model to the total suspended solids (TSS) values measured during the flow events.

The model is calibrated to the three flow events by comparing simulated flows of water and sediment with measured flows, and then adjusting parameters until an acceptable match is achieved. Overland flow, roughness, hydraulic soil properties, and soil erosion ability parameters were adjusted. Measured values in Makua Valley include the stream flow and TSS measurements taken on Punapohaku Stream, Koiahi Gulch Stream, and Kaluakauila Stream. The stream hydrographs are comparisons of flow volume versus time. Figure 3.8A, B, and C show simulated versus measured stream hydrographs of the Makua Stream and Koiahi Gulch Stream for the February 14, 2003, January 23, 2004, and February 27, 2004 flow events,

respectively. Figure 3.9A, B, and C show the simulated versus measured stream hydrographs of the Punapohaku Stream, and total suspended sediment discharging from Makua Valley for the February 14, January 23, and February 27 flow events, respectively. The model provides acceptable agreement between the simulated and measured stream flows, with the exception of the TSS for the February, 2003 flow. Calibration was acceptable for 2 of the 3 TSS simulations (January 2004 and February 2004), but overestimated TSS for the February 2003 flow. Once the model was created, the predictive runs were made to provide estimates of stream flow and suspended sediment transport for a larger 100 year rainfall event.

Figure 3.7A Surface Water Modeling Simulated Infiltration (February 14, 2003)





US Army Corps of Engineers®		Makua Military Reservation	
	DR BY: RSS	Simulated Infiltration From February 2003 Storm	FIGURE 3.7a
	CHK BY: SJT		

Figure 3.7B Surface Water Modeling Simulated Infiltration (January 23, 2004)

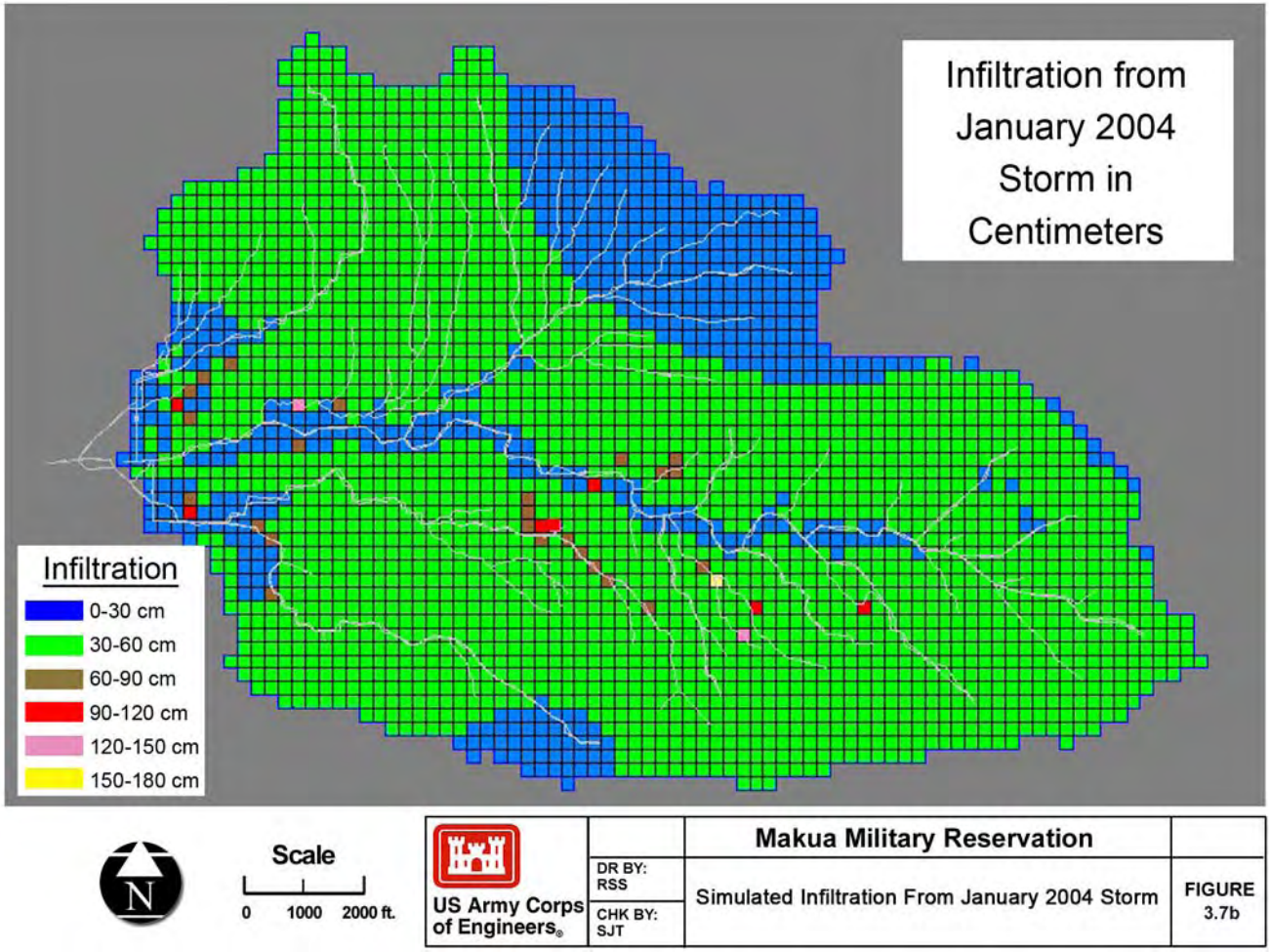
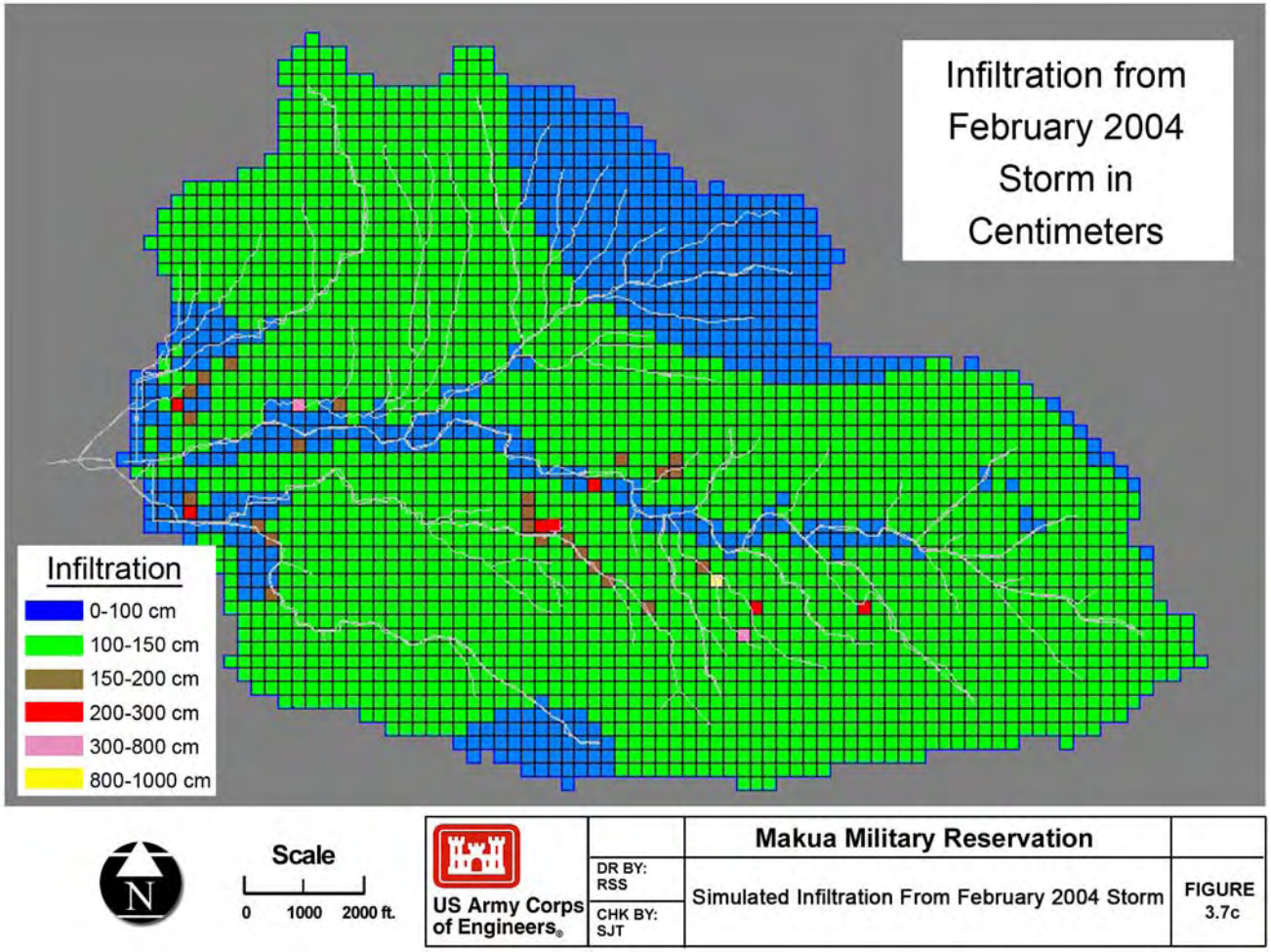


Figure 3.7C Surface Water Modeling Simulated Infiltration (February 27, 2004)



A sensitivity analysis of the surface water modeling effort was performed to identify the set of hydraulic parameters (streambed roughness, surface roughness, and infiltration) that best represent the system, and to identify those parameters that most affect the surface water system. The sensitivity analysis showed the following:

1) Infiltration rates of rainfall into the ground have a significant impact on the surface water overland flow component. The model calculated approximately 85 to 93% infiltration of rainfall, meaning that infiltration parameters are important. Initial infiltration rates for the shallow soil types of sand, clay, and silt were taken from the GSSHA manual (Downer and Ogden, 2002).

2) Overland flow roughness was not very sensitive for the surface water flow modeling, but did have some slight impact on slowing the discharge of overland flow to the streams. Higher roughness coefficients were not varied measurably from values in the GSSHA manual (Downer and Ogden, 2002), since they had little impact on the modeling results.

3) Roughness of the streambed samples was somewhat sensitive, and this parameter was increased to a value of 0.30 to slow stream flow rates. Given the large amount of vegetation in the streambeds from field observations, the streams are very rough and would require high Manning n values.

4) The volume of sediment discharged from the surface is dependent on the soil erosion properties and soil erosion factors. The volume of sediment is sensitive to the soil erosion properties, especially soil erosion ability. Sand percentage and silt percentage values are also model inputs. Silt and sand percentages were taken as the average values from the grain size analysis data for soil samples taken in Makua Valley (Appendix F). Soil erosion ability values used in the calibration were generally very low to provide for calibration with the total suspended soils data. The model was generally quite sensitive to this soil

erosion ability factor, as this parameter is entered into an empirical equation with this factor directly proportional to the amount of sediment discharged.

For the calibration process, a set of three parameters was adjusted for the calibration: infiltration, overland flow roughness, and streambed roughness. Parameters for infiltration were adjusted first, followed by overland flow roughness and streambed roughness. For the infiltration parameters, a value of 2.85 cm/hr for saturated hydraulic conductivity was used over a large portion of Makua Valley that is composed of either basaltic bedrock outcrop or sandy alluvium. Much lower values representative of finer grained materials (clay or silt), with values of 0.1 to 0.25 cm/hr, were used in areas that have more clay. Silt rich alluvium in stream bottoms (Figure 2.27) taken from the Soil Survey data (USDA, 1972).

Once the flow portion of the model was calibrated, the sediment discharge portion of the model was created and calibrated. Values for soil erosion factors of 0.005 for crop management and 1.0 for conservation practices were used, since these values are representative of undeveloped land vegetated with grass or trees (Downer and Ogden, 2002). Soil erosion properties of sand and silt percentages of 33% and 64% were held constant since these were measurable data taken as the average of sieve analyses (Appendix F). Soil erosion ability values were lowered until the TSS values calculated by the model were representative of those measured in the field by the TSS data.

The calibrated model could then be used to make predictions ofstream flow and suspended sediment transport for larger rainfall events. For the predictive run, the model was run with a 24-hour duration, 100-year storm taken from Wu (1967). For this run, 16 inches of rainfall is applied over the entire valley in a 24-hour period, and then the model is used to predict size of the flow event and the volume of suspended sediment. Figure 3.10 shows the Makua Stream hydrograph and discharge of sediment into the ocean for this large event. Both the flow and suspended sediment values would be much larger from a huge rainfall event, such as this, than for the measured February 2003, January 2004, or February 2004 storms. For this 24-hour storm

event, 77% of rainfall was absorbed by the ground and 13% was runoff. The total volume of suspended sediment was 18,242 m^3. Figure 3.11 shows the maximum extent of flooding across the Makua Valley, with the approximate depth of water in meters shown. A portion of the bottom of the Makua Valley would be flooded in such a large event.

3.9.2 Groundwater Modeling Results

A complete explanation of the development of the site conceptual model, and development of the groundwater modeling effort, is contained in Appendix H. A summary of the vadose zone modeling used to evaluate input into the groundwater model is contained in Appendix I.

A numerical model was constructed to simulate the groundwater flow and potential transport of explosives constituents within the groundwater system that underlies Makua Valley. The region that was modeled consisted of the roughly 4,170-acre hydrologic basin that includes the two major valleys (Makua and Kahanaha Iki) that drain into Makua Stream and Koiahi Gulch. The numerical model created extended from the ridges that surround these valleys to the Waianae coast of the island of O`ahu.

The U.S. Geological Survey models MODFLOW (McDonald and Harbaugh, 1986) and MT3D (Zheng, 1990) were used to simulate groundwater flow and transport, respectively. After calibrating the model by adjusting the hydraulic parameters of the various basalt and sedimentary units within the model domain to match measured water levels within the valley, the model was used to simulate groundwater flow and the migration of the energetics compound RDX (1,3,5-trinitro-1,3,5-triazine), which has been found in sub-surface soil and lysimeter samples collected from beneath two separate potentially impacted areas (i.e., the OB/OD Area and the Impact Area).

Model runs were also conducted using the US Geological Survey's SEAWAT model in response to reviewers comments on the Draft EIS. The SEAWAT model runs were designed to simulate the impact of the saltwater interface on the groundwater flow patterns in Makua Valley.

The numerical simulation results indicate that there is a possibility for the development of a plume of energetics constituents (i.e. RDX) as a result of infiltration into the groundwater system that underlies the valley. In the worst-case scenario, where no retardation or attenuation is assumed to occur to the RDX during transport through either the vadose zone or the groundwater system, a roughly 750-meter-wide plume containing 0.002 mg/L RDX is simulated to reach the Makua shoreline after 50 years of travel through the groundwater system beneath the OB/OD unit area (Appendix H). However, when the natural effects of attenuation and retardation within just the vadose zone are considered during contaminant transport, there is a considerable reduction in the size and concentration of the simulated plume, which results in the plume not reaching beyond a few thousand meters of the major impacted areas within the valley. It should also be noted that there is no evidence that groundwater in the inland portions of Makua is currently impacted by energetic constituents, or that groundwater reaching the shore has ever contained measurable levels of RDX or other energetic constituents. The simulations indicate that prior to migrating off the military reservation (Appendix H), a plume of RDX emanating from the OB/OD unit area should be detected in the down-gradient monitoring well MW-5, as well as the near-coast nested arrays of wells that were installed during this investigation.

Appendix H-2 shows the results of a cross section model using the SEAWAT code, which incorporates results of density-dependent simulations. Results of these model runs show that for a variety of model input parameters (different hydraulic conductivity value, different recharge) groundwater travel times from the OB/OD area to discharge points along the coast vary from 45 to more than 100 years. This does not include the time that would be required for potential contaminants to travel through the thick unsaturated zone from the OB/OD area to groundwater at depths of as much as 400 feet.

Additional model runs, as shown in Appendix H-2 (Figures 8 and 9), show a simulated RDX plume from the OB/OD area. The simulation indicates that under worst case assumptions RDX dissolved in groundwater might reach the shoreline after roughly 50 years of travel. The

graphics also show that should this case occur, well installed within the valley would detect RDX before it would discharge off-site. Given such long travel times, and the potential for any potential contaminants to degrade over time, as well as the lack of RDX in monitoring wells, it is extremely unlikely that potential contaminants are reaching potential off-site receptors.

Figure 3.8A Surface Water Modeling Simulated Versus Actual Hydrographs (February 14, 2003)

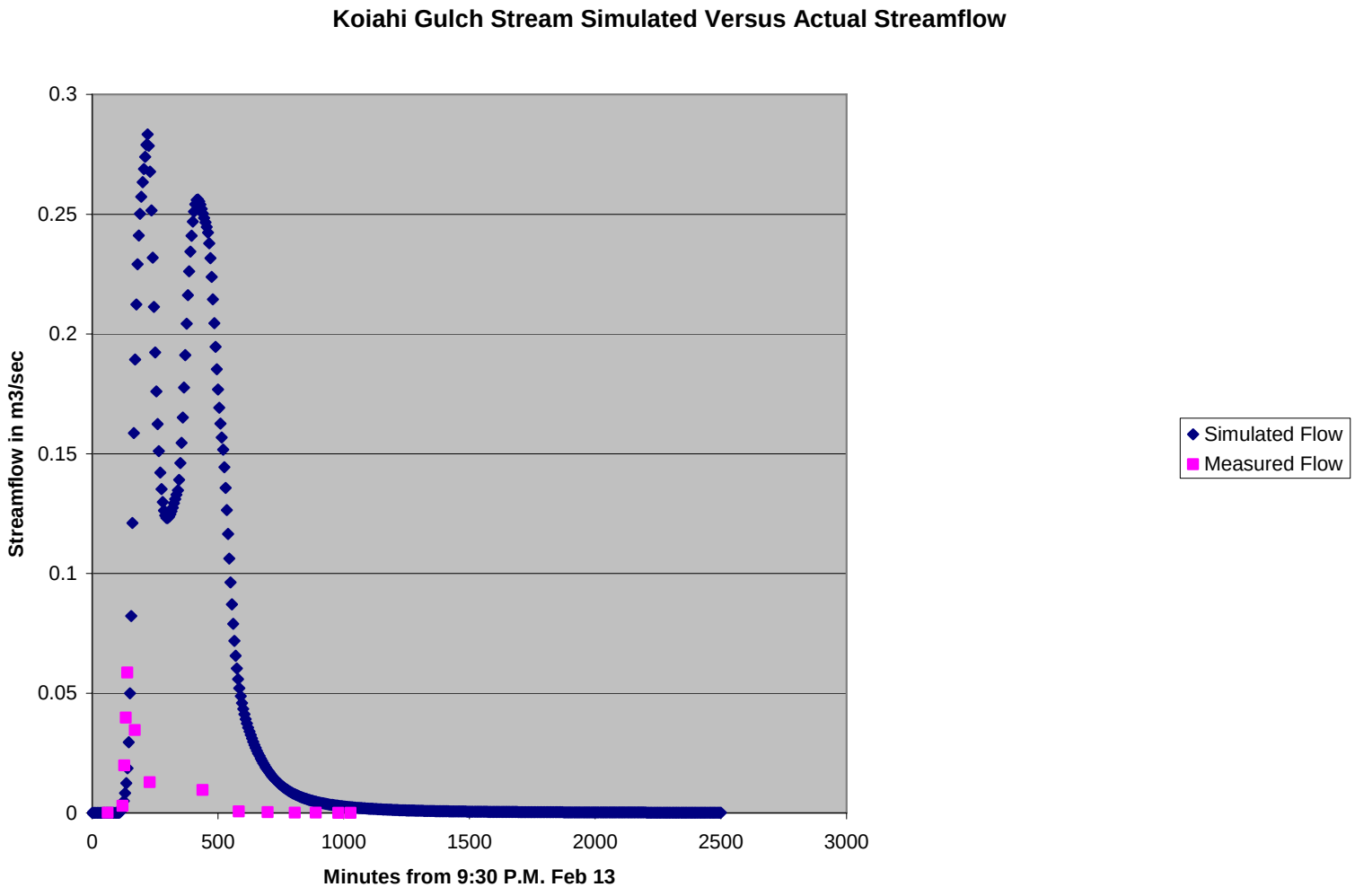


Figure 3.8A Surface Water Modeling Simulated Versus Actual Hydrographs (February 14, 2003) (Concluded)

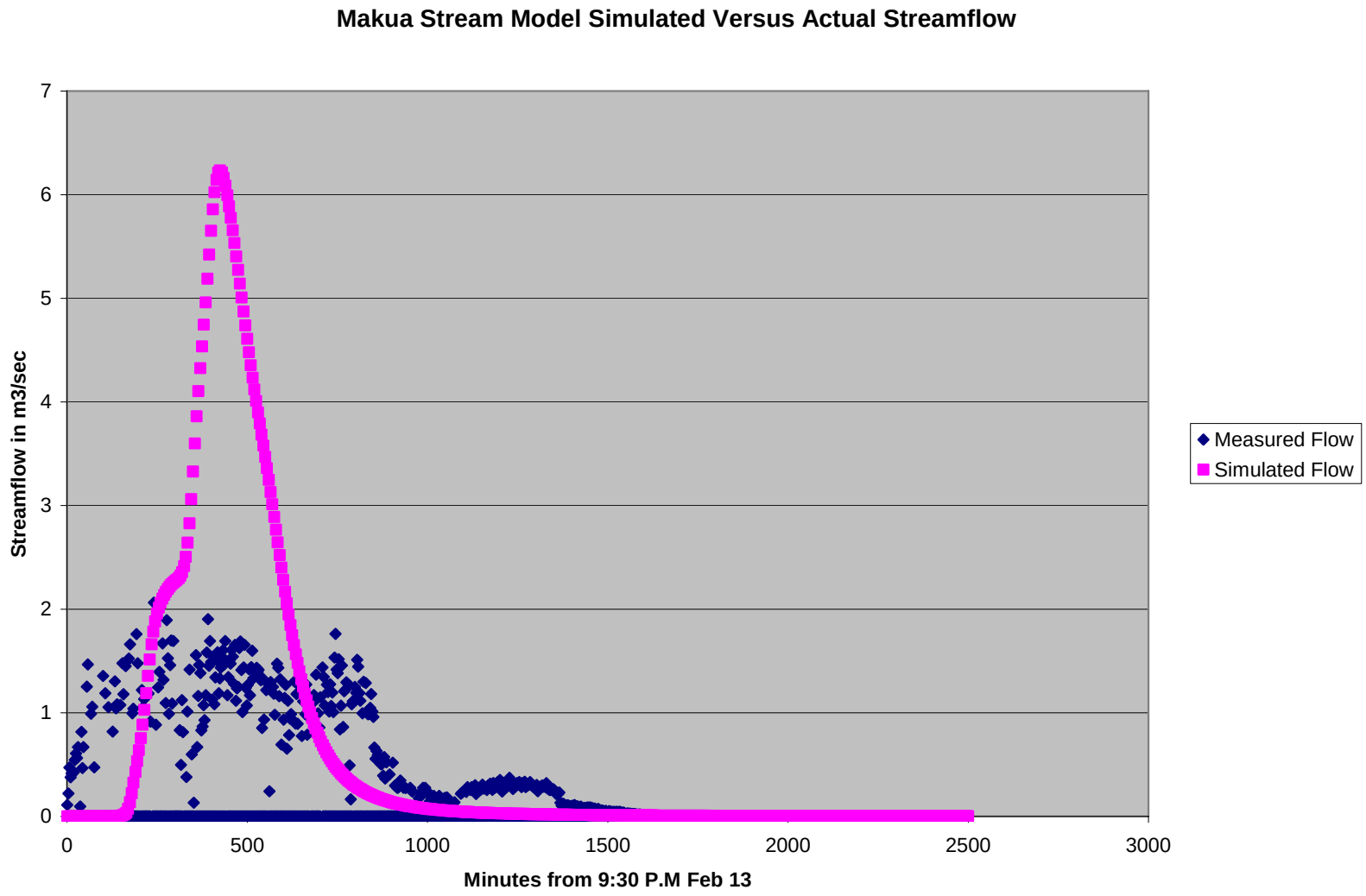
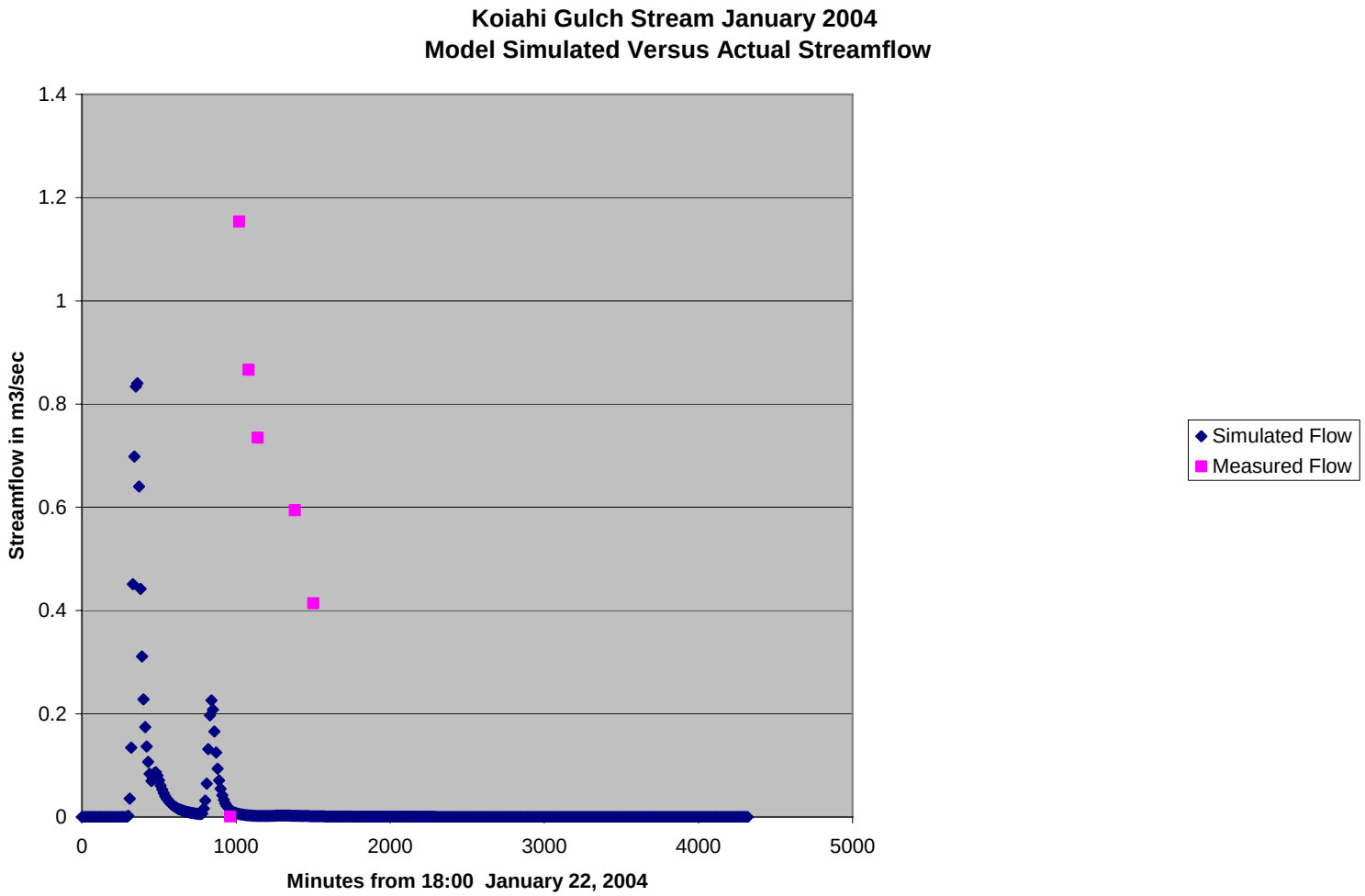



Figure 3.8B Surface Water Modeling Simulated Versus Actual Hydrographs (January 23, 2004)