Letter I21

Review of US Army Corps of Engineers
Hydrological Investigation Report for Makua Military Reservation
February 2005

By

William Meyer[1]
October 5, 2005

INTRODUCTION

The hydrogeologic investigation completed for the Makua Draft Environmental Impact Statement (draft EIS) follows the description of work outlined in the "Hydrogeologic Investigation Work Plan, Makua Military Reservation" dated October 2002. The latter plan was completed following comments on a draft version of the plan submitted for public review in June 2002. The objective of the investigation as stated in the October 2002 workplan was to "*evaluate the potential for chemicals from Army operations to have impacted the surface water or ground-water flowing off of Makua Military Reservation*, (p.3-2)."

I21-1 This is a change from the objectives stated in the June 2002 draft plan for which the stated purpose was to "*provide information related to evaluating if Army operations have impacted groundwater, surface water, or soil throughout the Makua valley (*Hydrogeologic Investigation Work Plan, Makua Military Reservation" June 2002, p. 8)." As also stated the "*studies will evaluate whether there is the potential for any contaminates to be transported beyond the boundaries of MMR* (Makua Military Reservation) *that may contaminate the Muliwai Ponds, or any marine resources, or wildlife on or near Makua Beach"* (Hydrogeologic Investigation Work Plan, Makua Military Reservation" June 2002, p. 8).

I21-2 Despite the apparent change in objective, it is not possible to fully evaluate the potential for chemicals from Army operations to have impacted the soil, surface water or ground-water flowing off of Makua Military Reservation (MMR) without first establishing the extent that soil, surface water, and ground-water are impacted on the reservation at the present time.

I21-3 Contaminant transport from the MMR by hydrologic processes would occur by overland flow and via the ground-water system. An evaluation of these means of transport requires construction and calibration of models that simulate overland flow and the ground-water system underlying the MMR. Overland flow includes both transport of contaminated sediment and contaminants dissolved in water.

[1] Please see attached resume.

Responses

I21-1
Sampling was conducted pursuant to the Final Sampling and Analysis Plan, which was developed with input from the community.

I21-2
The hydrogeologic assessment represents a widespread evaluation of the potential for contamination as reflected in Appendix G-1. Sampling was conducted of soil, sediment, surface water, and groundwater with no pattern of contamination that would impact off-site receptors.

I21-3
The EIS was prepared in accordance with the National Environmental Policy Act and with applicable federal and Army regulations. Review of the Draft EIS by the US Environmental Protection Agency found the document to be adequate.

Comments

William Meyer
Review of Hydrological Investigation Report for Makua Military Reservation
October 5, 2005
Page 2

I21-4 Although the October workplan stated that it incorporated changes to the scope of work from that outlined in the June version of the plan based, in part, on recommendations and comments received from consultants hired by Malama Makua, **these changes failed to address the full extent of the concerns I raised in my letter to the U.S. Army dated August 6, 2002.**[2]

SITE CHARACTERIZATION

I21-5 Evaluating the potential for compounds associated with present and historic training to be transported beyond the boundaries of MMR initially requires sampling of the soil, surface water and ground-water (both the saturated and the unsaturated zones) within and beyond MMR in order to determine if contaminants associated with activities of the U.S. Army in MMR are present. As stated in my August 6, 2002 letter, for site characterization, the sampling program conducted for the Draft EIS must be obtained in a scientifically acceptable manner that satisfies requirements for investigating the spatial and temporal distribution of potential contaminants. **Neither the June or October 2002 workplan, nor the work performed for the Draft has EIS satisfied these requirements.**

I21-5

I21-6 **The MMR encompasses about 4,170 acres and sampling must be conducted in a manner that incorporates the entire area. This was not done however**.

Soil Sampling

I21-7 Instead of collecting samples on a non-biased spatial basis throughout the MMR, sample collection was purposely biased. Soil samples were only collected from18 areas of concern (as identified by the Army), and an additional 22 sites located, for the most part, outside of the roads that form the boundaries of the areas of concern. Further bias was introduced in that, as stated in the Draft EIS, "*The samples were collected as discrete samples biased toward visual observations*." The introduction of bias in the sampling program does not adhere to generally accepted scientific practice. **This failure means the results obtained from the soil sampling program conducted for the Draft EIS should not be considered as representative of the full range of potential impacts of past and present activities of the U.S. Army with regard to soil contamination**.

I21-8

I21-4 Some specific comments made in my August 6, 2002 letter for soil sampling that were not incorporated in the work preformed for the Draft EIS are as follows:

[2] For your convenience, I've enclosed a copy of that letter.

Responses

I21-4
The EIS was prepared in accordance with the National Environmental Policy Act and with applicable federal and Army regulations. Review of the Draft EIS by the US Environmental Protection Agency found the document to be adequate.

I21-5
The sampling of all environmental media (including air, sediment, soil, surface ground water) present at MMR can be used to scientifically evaluate training (both historic and present) and the likelihood of contaminates being transported off MMR. The sampling of environmental data are reported in Appendix G.

I21-6
The EIS was prepared in accordance with the National Environmental Policy Act and with applicable federal and Army regulations. Review of the Draft EIS by the US Environmental Protection Agency found the document to be adequate. Sampling of media at MMR that could potentially be contaminated was conducted.

I21-7
Soil samples collected at MMR were located in the areas of maximum concentrations of training activities. Background samples provided additional information to expand the spatial coverage. The sampling and analysis plan distributed to the public in 2002, as well as Appendix G-1 of the Draft EIS, discuss soil study methodology and data.

I21-8
The sampling of all enviromental media including air, soil, sediment, surface water and ground water was designed and the locations selected to maximize the data collected to ascertain the full range of impact of past and present military training at MMR. Further, soil samples collected at MMR were located in the areas of maximum concentrations of training activities.

Comments	Responses
	(Cont.) I21-8 Background samples provided additional information to expand the spatial coverage. The sampling and analysis plan distributed to the public in 2002, as well as Appendix G-1 of the Draft EIS discuss soil study methodology and data.

Comments

William Meyer
Review of Hydrological Investigation Report for Makua Military Reservation
October 5, 2005
Page 3

I21-7 a. Given the objective of the sampling program, it is necessary to collect samples on a non-biased basis throughout the MMR. The biased sampling program described in the draft work plan (and carried out in the work performed for the Draft EIS) has a strong potential to cause the Army to reach the conclusion that contaminated soil is not moving from contaminated sites during runoff events, when the opposite would actually be true.

I21-8 b. The draft plan leaves substantial room for conducting a soil sampling program that would not result in an ability to evaluate the approximate spatial distribution of potential contaminants within the entire MMR.

c. The draft plan leaves substantial room for conducting a soil sampling program that would not result in an ability to evaluate the approximate temporal distribution of potential contaminants within the entire MMR.

I21-7 d. A more definitive non-biased soil sampling program in terms of the spatial coverage for the MMR as whole needs to be specified before soil sampling actually occurs.

I21-9 e. All of the samples collected (not only 10 percent, as proposed by the draft work plan) need to be analyzed for all contaminants.

Instead of chemical analysis being conducted on all samples, only twenty percent of the collected samples were actually analyzed for contaminants. This reduction in sample analysis further biases the sampling program.

Vadose Zone (Unsaturated Zone) Monitoring

The vadose zone, which, in modern hydrology texts is referred to as the unsaturated zone, occurs between the ground-surface and the ground-water table below which openings in rocks are fully saturated with water. The pores in the unsaturated zone, by way of contrast, contain a mixture of air and water. For contaminants to enter the ground-water system underlying the MMR, they must first pass through the unsaturated zone. Most generally, this movement is the result of contaminants dissolved in water passing through the unsaturated zone to the ground-water table. Precipitation is the most common source of water for this movement.

I21-10 **The unsaturated zone sampling program conducted for the draft EIS did not permit the spatial and temporal distribution of contaminants in the unsaturated zone to be established within the MMR. Water samples were collected only at three locations, making it impossible to fully identify the potential impacts of past and present activities of the U.S. Army with regard to contamination of the unsaturated zone in the MMR.**

Responses

I21-9
The selection of analyses in the sampling analysis plan was based upon the history of past and present training activities at MMR, thereby optimizing data usability and evaluation of soil contaminants.

I21-10
In accordance with the sampling analysis plan, vadose zone samples were collected in those locations most likely to contain contamination. The lack of contamination in the groundwater wells shows there is no evidence of widespread vadose zone contamination. Appendix G-1 provides further data and discussion on these issues.

Comments

William Meyer
Review of Hydrological Investigation Report for Makua Military Reservation
October 5, 2005
Page 4

In addition to the need to establish a sampling program that follows acceptable scientific procedure, I also recommended in my May 13, 2002 letter to Mr. Calvin Mashita and in my August 6, 2002 review of the Draft Work Plan, that sampling of the unsaturated zone
I21-11 should be conducted over one or more years to fully account for seasonal and potentially longer variations in the rate and concentration of contaminant movement. **Rather than follow this recommendation, samples were only collected twice, once in April and once in June 2003. This sampling frequency makes it impossible to evaluate**
I21-12 **potentially longer variations in the rate and concentration of contaminant movement as a result of 1) variations in the movement of water through the unsaturated zone and 2) possible variations in the amount and type of contaminant available as a source of contamination.**

Sampling of water in the unsaturated zone was conducted at two locations in the OB/OD area (B-1 and B-2) and at one location in the Junk Car pit (B-3). Lysimeters were set at 30 and 42 feet at B-1 and 30 and 45 feet at B-2. The lysimeter at B-3 was set at a depth of 19 feet. Water samples were collected in April and June, 2003. As stated in the draft EIS, "*results* (of the sampling) *indicate that RDX and several other contaminates have migrated to depths of at least 50 feet (15 meters) below the surface beneath the OB/OD area* (p. 3-91)." In fact, significant concentrations of RDX were found at B-1 in both lysimeters (4.8 mg/l at 30 feet and 2.9 mg/l at 45 feet). Concentrations at B-2 were 0.027 mg/l and 0.033 mg/l at depths of 30 feet and 42 feet respectively. Significant concentrations of HMX were also found in the deepest lysimeter at B-1 (1.4 mg/l)

I21-13 **Because samples were obtained in only April and June, 2003, seasonal or longer term trends in the downward movement of contaminants at these location is unknown. Also the great variability of the concentration of RDX and HMX at B-1 and B-2 suggest the potential exists for even greater variability in the concentration**
I21-14 **of these compounds over the OB/OD area than that observed at the two sites. Thus, measurements obtained at B-1 and B-2 cannot be assumed to characterize contaminant levels at the OB/OD area.**

The EIS states that "*the maximum depth of migration of RDX or other compounds was not determined, but given the low permeability of the sediments beneath the OB/OD area, which impedes the downward movement of ground water, it is likely that the concentrations would decrease substantially with depth* (p.3-91)." **This statement is**
I21-15 **pure speculation and not supported by the data itself, given that extremely high concentrations of RDX and HMX were found in the deep lysimeter at B-1. Impediment of the rate of downward movement of water will not, in and of itself, reduce the concentration of a contaminant with depth given sufficient time for contaminant movement. Chemical binding of the contaminant with soil particles can, but, as stated in the report, "***RDX tends to bind to the surface of soil particles if the soil contains natural organic material. But most of the natural organic material in*

Responses

I21-11
It is common practice to collect groundwater samples over one year to evaluate the seasonal impacts from basinwide groundwater flow. The impact to the vadose zone by seasonal variation is limited; therefore, two rounds of sampling are acceptable to evaluate the vadose zone contamination that could potentially impact off-site receptors.

I21-12
Please see response to Comment I21-11.

I21-13
Sampling of downgradient wells established no downward movement of contaminants off-site. Please see Appendix G-1.

I21-14
RDX and HMX were not detected in the downgradient monitoring wells (Appendix G). The two boreholes B-1 and B-2 were placed in the regions shown from geophysical data to have the greatest potential for having been trenched and therefore the greatest potential for contamination.

I21-15
RDX and HMX are not detected in the downgradient monitoring wells. The two boreholes B-1 and B-2 were placed in the regions shown from geophysical data to have the greatest potential for having been trenched. These areas would most likely contain the highest concentrations of RDX and HMX. Also, retardation rates of RDX and HMX in the vadose zone is well documented (ERDC, 2002) to occur the further from the source area that the RDX travels in solution. In order for the RDX and HMX to be of a concern, there has to be an impacted receptor. There is no known impacted receptor.

Comments

William Meyer
Review of Hydrological Investigation Report for Makua Military Reservation
October 5, 2005
Page 5

most soils is found in the surface layer of the soil. The amount of natural organic material tends to diminish greatly with depth below the root zone of plants…At depths 30 to 50 feet (9 to 15 meters), the amount of RDX that binds with the sediment particles would be much less than in the surface soils, and a larger percentage of RDX would remain in the soil pore water (p.3-92)." **Thus, chemical binding would not be expected to significantly reduce the concentration of RDX in pore water as it moved below the deeper lysimeters. The ability of soil particles to bind with a given contaminate also has an upper limit and once this limit is reached, additional binding will not occur. In addition, as discussed below, volcanic rock underlies the OB/OD area at an altitude of about 300 ft. in the area of the OB/OD, or about 150 ft below land surface, and this rock would not be expected to contain natural organic material**. I21-16

Given that the use of the OB/OD area has fluctuated over time, thereby causing the source of contaminants to similarly fluctuate, it is entirely possible that higher concentrations of contaminants exist below the two deepest lysimeters at B-1 and B-2. This consideration further refutes the Draft EIS assumption that concentrations of contaminants measured at B-1 and B-2 decrease below the deepest lysimeters. I21-17

The Draft EIS also states that "*there is no indication that RDX has migrated to the depth of the groundwater aquifer beneath the OB/OD area; RDX was not detected in groundwater from MW-5, the nearest well to the OB/OD area.*" **This statement lacks scientific credibility and is not consistent with statements made within the draft EIS.** I21-18 In the first place, it is not possible to determine if RDX has migrated to the depth of the groundwater aquifer beneath the OB/OD because there are no wells from which to obtain samples at this location. In the second place, although MW-5 is located between the OB/OD area and the ocean, there is no reason to expect that the well automatically samples water that has moved from the area toward the ocean. Just the opposite may be true. As stated in the draft EIS, "*there are generally two components of ground-water flow to the ocean: the regional ground-water flow in the Waianae volcanic rocks (…) and potentially the ground-water flow in perched layers in the alluvium …*." (p. 59, Appendix H). This movement is shown in figure 2.17 (p. 58). Thus, if the contaminant moved into the regional flow system, it would not be detected by the well. Finally, based on a 14 ft. water level established for MW-5 (p. 159), the depth of freshwater flow at MW-5 is approximately 560 ft. below sea level, applying the Ghyben-Herzberg principle. MW-5 is screened from 20 ft above sea level to a depth of 85 ft below sea level (table 2.6, p.57). This leaves about 475 ft of freshwater flowing below the well. Given these considerations, there is no reason to expect that an absence of RDX at MW-5 indicates that RDX has not migrated to the ground-water aquifer beneath the OB/OD area. I21-19 Although MW-5 is stated to be an "*an "early warning well" to measure the potential for contamination from upland areas, such as the OB/OD area or impact area, to discharge to the ocean,*" it fails in this regard due to the large part of the freshwater column flowing below the well and owing to other possible paths of contaminant flow. I21-20

Responses

I21-16
Please see response to Comment I21-15.

I21-17
Please see response to Comment 21-15.

I21-18
Analysis of the data supports the assessment that there was no impact to off-site receptors from the RDX and HMX in groundwater flow from the OB/OD area (see Appendix G-1).

I21-19
MW-5 is directly in the flow path of groundwater flowing from beneath the OB/OD area and the ocean. Given the low detection limit of the explosive method (EPA 8330), and flow within a porous media environment, dispersion of the compound dissolved in water flowing downgradient would show at least trace levels in well MW-5 if RDX was flowing downgradient. Trace levels of RDX were not found in MW-5.

I21-20
All monitoring wells at MMR were designed to provide "sampling support" to each other, i.e. wells located downgradient of MW-5 were also sampled to determine if contaminates moved passed MW -5 and would then be picked up by multiple sampling events for other monitoring wells. Given the low detection limit of the explosive method (EPA 8330), and flow within a porous media environment, dispersion of the compound dissolved in water flowing downgradient would show at least trace levels in well MW-5 if RDX was flowing downgradient. It is necessary for the RDX to first travel though the shallow part before it travels to the deeper parts of the water column. Trace levels of RDX were not found in MW-5.

Comments

William Meyer
Review of Hydrological Investigation Report for Makua Military Reservation
October 5, 2005
Page 6

Ground Water Sampling

Ground water samples for chemical analysis were obtained from 5 locations (MW-1 through MW-5). MW-1 through MW-4 are located along the western boundary of the MMR while MW-5 is located 7,500 feet inland between the OB/OD area and the shoreline. Three nested piezometers were installed at selected depths at MW-3 and MW-4. All of the wells were completed in sedimentary rock or alluvium. The nested piezometers at MW-3 and MW-4 allowed sampling of ground-water at different depths at each location. Wells MW-3C and MW-4C are the deepest wells of the four locations along the western boundary of the MMR and allow sampling of ground-water to depths of 81 and 80 ft. below sea level respectively (table 2.6, p. 57). Given an average water level along the western boundary of about 3.0 ft. (p.159), the depth of freshwater flow is approximately 120 ft. below sea level (assuming the Ghyben-Herzberg principle applies), so that wells MW-3C and MW-4C are able to sample only the upper 65-66 percent (80 ft. / 123 ft.) of the freshwater column at their location. MW-1 and MW-2 are both screened to a depth of about 25-26 ft. below sea level and can only sample the upper 20 percent of the freshwater at their location (table 2.6, p. 57). As stated above, MW-5 only penetrates some 85 ft. into a freshwater column that extends from about 14 ft above sea level to a depth of about 560 ft. below sea level. Thus the well can only sample the upper 17 percent of the freshwater flow system ((14 + 85) ft. / 574 ft.).

I21-21 The large screened interval of all of the wells can also lead to potential problems regarding identification of the actual depth and concentration of any contaminant found unless the contaminant is equally dispersed throughout the vertical column, which would
I21-22 not be expected. This potential problem can be overcome only with more observation wells at each site, each with a smaller screened interval than that used. This distribution of wells is not significantly different from that proposed in the June 2002 draft plan that called for water samples to be obtained at locations MW-1 through MW-4 and SP-7 (located near MW-5) for which I stated in my August 6, 2002 review of the plan:

I21-23 *"By restricting data collection to the immediate vicinity of the western boundary, the draft work plan fails to characterize the MMR proper in terms of the existence or absence of contaminated ground water in either the unsaturated zone or the saturated zone. This is a major failure of the plan. It is not possible to assess*
I21-24 *whether activities of the U.S. Army have impacted ground water within the MMR without sampling ground water within the area itself. It is also not possible to establish the fate and transport of contaminants contained within the ground*
I21-25 *water system of the MMR without knowing where they exist and in what quantity and concentration.*

Although positive results obtained from sampling ground water at the western boundary will indicate that the activities of the U.S. Army have impacted ground

Responses

I21-21
Well screen length for each monitoring well was selected to detect potential contaminants within the porous zone; this area is the most likely pathway for contaminate movement thru the aquifer system. Given the low detection limit of the laboratory methods used, even with some dilution caused by a larger screen, parts per trillion levels can still be detected for contaminants. Contaminants were not found in identified wells.

I21-22
Please see response to Comment I21-21.

I21-23
The monitoring wells in MMR were located and completed to maximize the data collected to assess if Army activities (including present past and future training activities) impacted off-site receptors.

I21-24
Please see response to Comment 21-23.

I21-25
Sampling and testing were conducted at MMR to evaluate the potential impacts to off-site receptors. The representative sampling scheme was performed and data analysis showed no potential for contamination to impact off-site receptors.

Comments

William Meyer
Review of Hydrological Investigation Report for Makua Military Reservation
October 5, 2005
Page 7

I21-26 *water within the MMR, these results will fail to indicate where contamination has occurred and the current status of contaminants within the MMR. Negative results obtained from sampling ground water at the western boundary for contaminants will not, in and of themselves, establish whether contaminated water exist within the MMR or has occurred and traveled beyond the MMR. Negative results demonstrate only that contaminated water is not presently at the western boundary."*

The addition of sampling at MW-5 does not change the above conclusions.

It is apparent from the above discussion, that none of the wells allow the entire thickness of the ground-water flow system to be sampled at any point in the flow system. In fact, most of the wells sample 20 percent or less than the freshwater column at their locations.

The draft EIS concludes that "*overall the ground-water sampling data show that sporadic detections of trace levels of several ground-water contaminants have been observed, but the results suggest that the ground-water does not contain concentrations that present significant risk to human health*". Given the extremely limited amount of data collected and the equally limited sampling within MMR that was conducted for the draft EIS (one
I21-27 well (MW-5) within MMR proper that only sampled about 17 percent of the flow system at its location), the above conclusion reached by the draft EIS is not justified. It is simply
I21-26 not possible to assess whether activities of the U.S. Army have impacted ground water quality within the MMR without sampling ground water within the area itself utilizing a much more scientifically based data collection program than that used for the draft EIS.

I21-27 **In order to establish a sampling program that will evaluate the potential for chemicals from Army operations to have impacted ground-water flowing off MMR, it is necessary to first, understand that system, and second, to establish a scientifically acceptable sampling program in concert with this understanding. The draft EIS does not fulfill either requirement.**

I21-28 **The draft EIS presents a confused and incorrect picture of the ground-water system underlying the MMR. This confusion leads to inaccurate assumptions and interpretations of both the natural flow system and the results obtained from sampling of water quality and, ultimately, model construction for both the vadose and saturated zones, and interpretation of model results.**

Figure 2.17 (p. 58, draft EIS) presents a generalized cross section for the ground-water flow system underlying the MMR. As shown, ground-water occurs as dike confined water in the volcanic rocks and as perched water in the alluvium overlying the volcanic rock. Water in the volcanic rocks is defined as the regional ground-water flow system. The perched water is presented as "possibly present" and is shown to be more than 200 feet above the regional flow system over most of the MMR. As also shown, the perched

Responses

I21-26
In addition to the monitoring wells along the western boundary (through which all discharging groundwater must pass), monitoring well MW-5 in the center of the valley, shows no pattern of contamination. The process used was a scientifically based sampling program that investigated flow paths most likely to impact off-site receptors. If there were a contamination problem at Makua, groundwater samples would have shown contamination. Groundwater contamination at MMR, however, was not found.

I21-27
Soil, sediment, surface water and groundwater media were sampled at locations where introduction of contaminates into the environment was most likely. The data collected for MMR provided an acceptable data set of information to establish the potential environmental impacts of training activities. See Appendix G-1.

I21-28
Figure 2.17 in Appendix G-1 has been revised to incorporate additional information.

Comments

William Meyer
Review of Hydrological Investigation Report for Makua Military Reservation
October 5, 2005
Page 8

water body is continuous to the ocean and the perching member is the top of the volcanic rock. The draft EIS, however, describes the alluvium as "generally poorly permeable, with ground-water flow likely being concentrated in discontinuous lenses of stream gravel deposits" (p.4, Appendix H). Ground-water in the general area of the OB/OD area is shown to move vertically downward from the perched water body into the regional ground-water flow system in the volcanic rock. Water from the regional flow system is shown to be moving upward into the perched water body near the western boundary of the MMR.

Finally, the flow system depicted in figure 2.17 shows the top of the volcanic rock at an altitude of about 300 ft. in the area of the OB/OD, or about 150 ft below land surface. It also depicts the water table for the regional flow system at an altitude of about 100 ft. In the vadose zone model discussed below, however, the alluvium is considered to continue to a depth of at least 425 ft below ground-surface at the OB/OD and the water table was considered to lie within the alluvium at an altitude of about 25 ft. Neither the presence of volcanic rock, nor the potential presence of the regional water table at a much higher altitude than 25 ft. was simulated. The disconnect between the geometry of the
I21-29 unsaturated flow system in the area of the OB/OD depicted in figure 2.17 and that modeled is not acceptable, and the vadose zone model results are not credible as a result. Although figure 2.17 is presented as a general cross section from the Waianae Crest to the Pacific Ocean through the OB/OD area, a cross section based on actual topography for the MMR through the OB/OD area makes it difficult to assume that the volcanic rocks or the regional flow system are at much lower altitudes than shown on the cross section. In fact, the water table of the regional flow system may be higher. Modeling volcanic rock and/or the water table at a higher altitude than that assumed in the vadose
I21-30 zone model would result in the model predicting higher concentrations of RDX reaching the water table.

Given the general movement of ground-water depicted in figure 2.17 and the goal of determining the potential for chemicals from Army operations to have impacted ground-water flowing off MMR, it is necessary to establish a sampling program in both the perched ground-water body in the alluvium, assuming it exists, and the regional flow
I21-31 system contained within the volcanic rock. This was not done however. Only one well was constructed in the alluvium within the MMR (MW-5), and no wells were constructed into the volcanic rocks underlying the MMR.

The flow system depicted in figure 2.17 is in direct contrast to that presented for the ground-water system by Zones (1961) (figure 377.2, p. D-242) wherein the water table, below which the sedimentary and volcanic rocks are saturated occurs within the sedimentary rock at the middle-lower portion of the valley and in the volcanic rock at the middle -upper parts of the valley. There is only one ground-water body as a result. Zone's description is more consistent with the general description of the occurrence of ground-water in the Hawaiian Islands (Gingerich and Oki, Ground-water in Hawaii). For Zone's

Responses

I21-29
The vadose zone modeling is a column model unrelated to Figure 2.17 in Appendix G-1. The vadose zone model is not intended to evaluate the geometry of the unsaturated flow system in the area of the OB/OD; rather, it provides estimates of retardation and degradation of RDX in the subsurface for certain model simulations. Figure 2.17 has been revised to incorporate additional information.

I21-30
The modeling was constructed in accordance with the available geologic data. The modeling incorporated a range of runs, including a practical worst case scenario with no retardation or decay, that would predict higher concentrations of RDX. Please see Appendix G-1 for a list of all runs conducted.

I21-31
No perched water bodies were encountered during the drilling of monitoring wells.

Comments

William Meyer
Review of Hydrological Investigation Report for Makua Military Reservation
October 5, 2005
Page 9

description, water moves both horizontally and downward in the sedimentary rock into the volcanic rock in the middle part of the MMR and horizontally and upward from the volcanic rock into the sedimentary rock in the lower part of the MMR near the ocean. Thus, a contaminant with a density equal to or greater than that of freshwater, such as RDX and HMX, reaching the top of the water table in the middle part of the MMR would be expected to move vertically downward from the sedimentary rock into the regional ground-water system in the underlying volcanic rock.

Once the contaminant entered the basaltic lava flows that comprise the volcanic rock, it would have a strong tendency to enter and move within the interflow zones between lava flows. The hydraulic conductivity of these zones will generally be significantly greater than the average value of a given flow or series of flows and, as a result, the horizontal movement of water in the volcanic rock is largely confined to these zones causing them to represent preferential flow paths. Travel time for a contaminant to reach the shoreline
I21-32 would be expected to be much greater than that predicted by a model using average values for hydraulic conductivity such as is the case for the MODFLOW model used in the draft EIS.

In the lower part of the MMR, the contaminant would be expected to move upward from the volcanic rock into the overlying sedimentary rock and ultimately into the ocean. This movement would be largely controlled by the vertical hydraulic conductivity of the volcanic rock. Despite the difference in the ground-water systems depicted by Zones and by figure 2.17 for MMR, the direction of ground-water movement within MMR is
I21-31 essentially consistent for both systems. This, in turn, still indicates the need to sample water in both the alluvium and the volcanic rocks.

GROUND-WATER AND CONTAMINANT TRANSPORT MODELING

On page 1 of Appendix H, the statement is made that a numeric ground-water model was created that encompassed the roughly 4,170 acres of Makua Valley extending from the ridges that surround the valley (including Kahanahaiki) to the Waianae coast. The U.S. Geological Survey (USGS) models MODFLOW and MT3D were used to simulate ground-water flow and transport (of contaminants) respectively. It is also stated that "*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 ground-water flow and the migration of the energetics compound RDX ... which has been found in the sub-surface soil and lysimeter samples collected from beneath two separate potentially impacted areas (i.e., the OB/OD Area and the Impact Area).* **I do not agree, however, that the MODFLOW MODEL**
I21-33 **was calibrated and as a result, it cannot be used to acceptably simulate ground-water flow within the MMR. Given this, the MT3D MODEL cannot be used to acceptably simulate the movement of contaminant transport within the MMR.**

Responses

I21-32
Longer travel times would only reduce the impacts to off-site receptors.

I21-33
This groundwater model was calibrated to be consistent with other modeling studies, including those done by the USGS. Models are useful to assess different scenarios. The groundwater modeling is used to evaluate potential impacts to get an overall idea of travel times. The results of the sampling showed no off-site groundwater contamination, and therefore the modeling results was not used in the impact analysis.

Comments

William Meyer
Review of Hydrological Investigation Report for Makua Military Reservation
October 5, 2005
Page 10

I21-33 **Conclusions based on model predictions are not scientifically supportable as a result.**

I21-34 The use of MODFLOW, and therefore MT3D, are inappropriate for modeling the ground-water flow system of the Makua Valley. The natural fresh ground-water system that underlies it transitions to saltwater, and MODFLOW does not simulate this transition. This, in turn, means that the vertical extent of the freshwater flow system underlying Makua Valley cannot be determined from the MODFLOW model. The I21-35 inability to define the entire flow system means that all of the potential contaminant flow paths cannot be identified. The inability to define the entire flow path also causes the model to simulate incorrect values for the average hydraulic properties of the natural ground-water system. In order to account for the transition from freshwater to saltwater, the work plan called for use of the U. S. Geological Survey's SEAWAT model that simulates variable density flow, meaning that the transition to saltwater would be modeled. This, in turn, allows the full extent of the freshwater flow system and flow paths to be identified. As stated in the workplan, the model, according to the work plan would be a "*three-dimensional flow and solute transport model incorporating variable density*…. (p. 3-48)". I21-36 Failure to use a variable density flow model cannot be justified given the goal of the modeling effort.

Although, the report states that the MODFLOW model was calibrated, a necessary condition for use of the model for predictive purposes, the model's inability to simulate the natural flow system as discussed immediately above, and the data available for calibration does not allow this. The use of a numeric ground-water model, such as I21-37 MODFLOW, for predictive purposes requires that the model acceptably reproduces flows and water levels in the natural system it's simulating. In order to accomplish this, the model needs to acceptably simulate: 1) the external and internal geometry of the natural system (geologic framework), 2) the boundary conditions at the external boundaries of the system in terms of water levels and flows, 3) the spatial distribution of the hydraulic properties of the geologic framework that control the movement and storage of water (transmissivity and/or hydraulic conductivity, and storage coefficient or specific yield). (O.L. Franke and T.E. Reilly, U.S. Geological Survey Water-Supply Paper 2315, p.1).

I21-38 The use of a model for predicting the fate and transport of a contaminant requires additional information, including the permeability and porosity of preferential pathways, and the potential for chemical retardation, and mechanical dispersion.

Despite the statement in the draft EIS that the alluvium is "generally poorly permeable, with groundwater flow likely being concentrated in discontinuous lenses of stream gravel deposits, the MODFLOW model constructed for the draft EIS simulates a continuous water body throughout the alluvium and also simulates a relatively high value for the hydraulic conductivity of the lower 50 ft of the alluvium (approx. 83 feet/day (ft/d)) in order for model predicted water level at MW-5 to be acceptably near the actual water

Responses

I21-34
Use of MODFLOW and MT3D are appropriate given the uses of the model: to roughly evaluate travel times and pathways. Appendix G-1 of the EIS has been revised to include additional runs using the SEAWAT model.

I21-35
The monitoring wells in MMR were located and completed in areas to maximize the data collected to assess the entire flow system. Further, the wells were located to determine if Army activities impacted the environment or if contaminates were moving along preferred pathways.

I21-36
Use of MODFLOW and MT3D are appropriate given the uses of the model: to roughly evaluate the range of travel times and pathways. The greatest simulated differences in the groundwater flow field obtained using a density-dependent model will occur in the immediate vicinity of the shoreline, which will not materially affect the estimated travel time for a contaminant that is assumed to originate from a source located over an mile inland of the shore. Appendix G-1 of the EIS has been revised to include additional runs using the SEAWAT model.

I21-37
Travel times match with those calculated independently with Darcy's law (Freeze and Cherry, 1979). Therefore, the model acceptably reproduces flows and water levels in the natural system.

I21-38
Model design included data on permeability collected from the wells (Table 3.19 of Appendix G-1) and porosity estimated from the moisture content data (Appendix F in Appendix G-1).

Comments	Responses
	(Cont.) I21-38 The model uses a representative elementary volume (REV) of the aquifer large enough to incorporate the preferential pathways (Freeze and Cherry, 1979).

Comments

William Meyer
Review of Hydrological Investigation Report for Makua Military Reservation
October 5, 2005
Page 11

level measured at the well. As indicated by model construction and by model predicted water levels (figure 9, Appendix H), the model simulated a continuous water body extending from the alluvium into the underlying basalt. Thus, not only is ground-water continuously present in the alluvium and highly permeable in its lower part, it is not perched. Finally, as shown in figure 9, Appendix H, water levels higher than about 20 ft in the volcanic rock were not predicted by the model. Because, as shown in figure 2.17 (p. 58), water levels in the regional flow system reach altitudes of more than 1000 ft., the
I21-39 model fails to replicate the vast majority of the water flow system contained within the MMR.

The MODFLOW model was supposedly calibrated to average values for the hydraulic conductivity of the rocks comprising the MMR ground-water system, but, even if this were true (and, as discussed below, it's not), average hydraulic properties are not
I21-40 appropriate for predicting travel times, particularly in the type of geologic setting that underlies MMR. The use of average properties neglects the potential existence of
I21-41 preferential flow paths in the sedimentary rock underlying the MMR created by zones of hydraulic conductivity greater average. It also neglects preferential pathways in the
I21-42 interflow zones between lava flows comprising the volcanic rock underlying the MMR. The hydraulic conductivity of these zones is generally much greater than average.

Given the above requirements for construction and calibration of a ground water model that simulates the natural ground-water system within the MMR and the fate and transport of contaminants within it, it is necessary to obtain field information on:

1) The spatial distribution, concentration, and rate of movement of the contaminant in the unsaturated zone above the ground water table over the entire MMR,
2) the extent and thickness of the geologic units comprising the flow system,
3) The spatial distribution of the hydraulic properties (permeability and porosity) of the geologic units (calcareous, alluvial, and basalt) comprising both the unsaturated and saturated parts of the ground water system; including the permeability and porosity of preferential pathways. As stated above, average properties are not appropriate for travel times, particularly in the type of geologic setting that underlies the MMR,
4) the spatial-temporal distribution of ground water levels in each of the three geologic units (calcareous, alluvial, and basalt) underlying the area,
5) the spatial-temporal distribution of ground water recharge to and discharge from the units (including high level springs and streams),
6) the hydraulic connection of the system with the discharge areas (mainly the ocean in this case, but also high level streams and springs), and
7) The spatial-temporal distribution of the contaminant(s) within the ground water system over the entire MMR.

Information on the spatial distribution, concentration, and rate of movement of the
I21-43 contaminants in the unsaturated zone above the ground water table underlying Makua Valley ground-water system was not collected during the Hydrologic Investigation. As

Responses

I21-39
The groundwater model incorporates an overall permeability to assess the dike impounded bodies, which method was used by the USGS to model groundwater flow in Oki (1997).

I21-40
The majority of groundwater flow is occurring in a porous media environment (alluvium). Modeling used at MMR is the same method used by the USGS to model groundwater flow in Oki (1997), as well as other modeling studies.

I21-41
The method used incorporates preferential pathways. Preferential pathways occur for only a short distance. For example, a gravel layer may occur that is then mixed with clay and silt. The hydraulic conductivity values used incorporate all of these different geologic media. Please see response to Comment I21-41.

I21-42
The groundwater model is primarily simulating groundwater flow in sedimentary formations. These are the formations between the OB/OD area and the ocean. Volcanic rock is evaluated by using an overall higher permeability.

I21-43
The monitoring wells at MMR were located and sampled by methods that provided data on the spatial and temporal distribution of contaminates through the entire aquifer system. This data coupled with modeling information was also used to determine rate of movement of potential contaminates through the environment.

Comments

William Meyer
Review of Hydrological Investigation Report for Makua Military Reservation
October 5, 2005
Page 12

discussed above, lysimeters were used at only three locations, two at the OB/OD Area and one at the Junk Car Area. Data collected from these three sites does little to define the spatial-temporal distribution of contaminants in the unsaturated zone over some 4,170 acres. Because of the limited depth at which the lysimeters were set compared to the total depth of the unsaturated zone at each of their locations, the study also failed to establish contaminant concentrations for the full thickness of the unsaturated zone at the sites where lysimeters were used. I21-44

The actual rate of movement of contaminant in the unsaturated zone was not investigated either. An average rate of movement corresponding to an average recharge rate equal to 7.2 inches per year was assumed. Although this rate is consistent with previous estimates, contaminant transport can be significantly enhanced by recharge rates in excess of this value (p. 12 Appendix H). I21-45

The disconnect between the geometry of the unsaturated flow system in the area of the OB/OD depicted in figure 2.17 and that modeled in the vadose zone is not acceptable, and, as stated previously, the vadose zone model results are not credible as a result. Thus, the value for the concentration of RDX assumed to be entering the water table at the OB/OD area for prediction of contaminant travel times and concentrations cannot be justified. I21-45 I21-46

Test drilling within the MMR to define the extent and thickness of the geologic units comprising the flow system (including the unsaturated zone) was not conducted. The construction of four monitoring wells near the shoreline (ERDC-MW-1, ERDC-MW-2, ERDC-MW3A, 3B, and 3C, and ERDC – MW 4A, 4B, and 4C) and ERDC MW– 5 allowed limited information for thickness and lithologic nature of the sedimentary deposits for their individual depths, but once again, this information does little to define the extent and thickness of geologic units throughout the entire MMR. I21-47 I21-48

Values for hydraulic conductivity of the sedimentary deposits to which each of the above wells were open was obtained by slug test (p.5, Appendix H), but otherwise field values for hydraulic conductivity of the sedimentary deposits throughout the Makua Valley do not exist. The values obtained from the tests represent only rough values for the average hydraulic conductivity of the deposits to which the wells were open rather than individual values for each layer encountered in a given well. As such, preferential flow paths are ignored, even in this limited testing. The large range in average values for hydraulic conductivity obtained from these tests (0.4 feet/day to 23 ft/day) clearly indicates a lack of uniformity in the sedimentary deposits underlying the MMR and the inappropriateness of using average values for model construction. I21-49 I21-50

There are no field values for hydraulic conductivity of the volcanic rocks in the MMR, causing the draft EIS to use values obtained for Molokai (p. 9, Appendix H) by Oki, 1997. Due to the large potential range in hydraulic conductivity values reported for

Responses

I21-44
Please see response to Comment I21-14.

I21-45
Please see response to Comments I21-28 and I21-29.

I21-46
The concentration of RDX used was an average value and represented a sound estimate of concentrations in the OB/OD area. Model runs used a range of RDX concentration, with some at the upper limit of expected values. A group of runs was conducted to obtain a range of fate and transport estimates. The results of the sampling showed no off-site groundwater contamination, and therefore the modeling results was not used in the impact analysis.

I21-47
A total of nine wells and three borehole were drilled at MMR. These test holes and their lithologic descriptions were detailed in Appendix G-1 of the Draft EIS.

I21-48
The wells were optimally located to provide lithologic information and thickness of the various geologic units present at MMR. The monitoring wells in MMR were located and completed in areas to maximize the data collected to assess impacts to off-site receptors.

I21-49
The monitoring wells at MMR were screened (see Appendix A of Appendix G-1) to provide information about the preferential flow paths of the aquifers present at MMR. This Appendix A details the lithologic description of the geologic units present in the monitoring wells.

Comments	Responses
	(Cont.) I21-50 Two order of magnitude variation in measured permeability data are common. The average of these value (Table 3.19 of Appendix G-1) is 12.6 ft/day. In order to incorporate the preferential flow paths, higher values (greater than 23 ft/day) are used. This method of using the upper end of parameters values in modeling to incorporate preferential flow paths is commonly used (see Oki, 1997).