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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.

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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.

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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.

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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.

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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).

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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.

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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).

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I21-51 volcanic rocks in the Hawaiian Islands, transfer of the Molokai values is not appropriate. Even if the transfer of values from Molokai were appropriate (and it's not), the draft EIS transferred the wrong value. Whereas Oki assigned values for the hydraulic conductivity of the marginal dike zone of Molokai equal to 100 ft/d (Oki, 1997, p. 37), the draft EIS used a value of only 13.2 ft/d, a significant difference. As discussed above, once the contaminant entered the volcanic rock, it would have a tendency to move within the interflow zones between lava flows which exhibit much higher values for hydraulic conductivity than average values for the composite of flows.

I21-52 The lack of knowledge for the hydraulic conductivity of both the sedimentary and volcanic rock in the MMR, or for preferential pathways in these rocks, makes it impossible for the model constructed for the draft EIS to portray either average hydraulic properties of the rocks or preferential pathways. No effort was made to evaluate the potential effect of such pathways on migration of RDX. Given this lack, it is impossible
I21-53 to calibrate a numeric ground-water model that can be shown to acceptably simulate the natural flow system.

I21-54 Knowledge of the spatial-temporal configuration of ground-water levels is mandatory for construction and calibration of a ground-water model yet this information is almost totally lacking for the MMR. Calibration of the MODFLOW model requires that the model acceptably matches known water levels and flows of the natural system being modeled by adjusting values for hydraulic conductivity within acceptable limits. Water levels for the natural system as a whole must be known and matched. In the case of the MODFLOW model constructed for the draft EIS, the model was only "calibrated" to water levels at three locations (p. 12, Appendix H), with two of the locations at the boundaries of the MMR and the third inside the MMR. These wells do not allow
I21-53 knowledge of the configuration of water levels throughout the MMR and, "calibration" of the MODFLOW model to the water levels at only these locations does not produce a truly calibrated model.

I21-55 The MODFLOW model also incorrectly used drain functions to simulate the natural process whereby ground-water discharges to the ocean. These functions arbitrarily restrict ground-water discharge to the shoreline itself and fail to represent the role that vertical hydraulic conductivity has in the discharge process. The fact that water levels are about 3 feet above sea level near the shoreline, as indicated by water levels in MW-1 through MW-4, clearly indicates that ground-water continues to discharge seaward of the
I21-56 shoreline. Failure to acceptably model this discharge, in turn, makes it impossible for the models to acceptably simulate the natural flow system over the entire MMR.

I21-53 thru I21-56 **The above discussion clearly shows that not one of the above requirements necessary for construction and calibration of a numeric model, such as MODFLOW, that acceptably simulates ground-water flow in the MMR or allows estimates for travel paths and times of a contaminant was met**. Only limited

Responses

I21-51
Hydraulic conductivity values for Molokai were used for comparison only.

I21-52
Modeling was used with a range of parameters to evaluate a range of different travel times and rates. The information obtained enabled a reasonable assessment of hydraulic conductivity, as well as an estimate of travel times and paths.

I21-53
Preferential pathways apply on a small scale, so for a model exercise such as this overall permeability can be used that included the preferential pathways. This uses a representative elementary volume (REV) of the aquifer large enough to incorporate the preferential pathways (Freeze and Cherry, 1979). Modeling was conducted with a range of parameters to evaluate a range of different travel times and rates. There was enough information to make a reasonable assessment of hydraulic conductivity and to provide an estimate of travel times and paths.

I21-54
Modeling was used with a range of parameters to evaluate a range of different travel times and rates. The information obtained enabled a reasonable assessment of spatial-temporal configuration, as well as an estimate of travel times and paths.

I21-55
The drain function in MODFLOW is commonly used to evaluate discharge along a surface water body. Appendix G-1 of the EIS has been revised to include additional runs using the SEAWAT model.

I21-56
Model discharge via the drain function was compared independently to Darcy's law (Freeze and Cherry, 1979) comparison, and the discharge was within an acceptable range.

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information was obtained that addresses, but does not satisfy the requirements of item 1. No data was collected for items 2, 4, 6, and 7. With regard to item 3, testing at wells MW- 1 through MW-5 provides an estimate for the average hydraulic conductivity (permeability) of the section of alluvium tested at these locations, but this information does not begin to satisfy the requirement stipulated in item 3. Instead of collecting the information necessary for model construction and calibration, this information was simply ASSUMED. The almost total lack of knowledge of the natural ground-water flow system within the MMR, however, makes it impossible to construct and calibrate a model that can be shown to acceptably simulate the system or the movement of contaminants within it. Although the report states that the ground-water model was acceptably calibrated to water levels in the MMR, this is not possible given the lack of information necessary for model construction and calibration and the fact that water levels in the MMR are only known at MW-5.

I21-57 **Given the failure of the study to use models that calculate the position of the interface between freshwater and saltwater, the use of drain functions to simulate ground-water discharge to the ocean, and the failure to collect the most basic data necessary for model construction and calibration, the results presented in the Draft EIS concerning transport and fate of contaminants within the MMR represent more of an academic exercise for an ASSUMED flow system rather than a scientifically rigorous numeric model analysis of flow and contaminate transport in the MMR. Results and prediction from the fate and transport model must be considered in this light.**

Non-verifiable assumptions used in fate and transport modeling

The above discussion on ground-water modeling was largely confined to the lack of data needed to construct a numeric ground-water model that acceptably simulates water levels and flows for the natural ground-water system underlying MMR. In addition, predictions for the migration of RDX are further compromised by assumptions used in the MT3D model that are unique to this model. Although model predictions for migration of RDX are directly dependent on these assumptions, field data do not exist to verify them. Included in the assumptions are:

I21-58 a) There are no field values for specific yield or storage coefficient for any of the deposits that comprise the ground-water flow system of the MMR. Even if the hydraulic conductivity and water levels of the rock units comprising the Makua ground-water system were known, lack of knowledge concerning specific yield or storage coefficient makes it impossible to calculate defensible contaminate travel times.

I21-59 b) Although the average recharge rate equal to 7.2 inches per year used in the model is consistent with previous estimates, contaminant transport can be significantly enhanced by naturally occurring recharge rates in excess of this

Responses

I21-57
The groundwater model combined all of the geologic/ hydrogeologic information available for Makua. The model design allows for a reasonable characterization of the overall flow system within the valley and a valid estimate of potential contaminant migration rates, with and without retardation/degradation of the energetic contaminants of concern. This modeling study used a range of parameters to evaluate fate and transport estimates.

I21-58
The modeling study used specific yield/storage coefficient estimates compiled by the USGS (Hunt 1996) for aquifer systems on the island of Oahu. Because pumping from the aquifer does not occur, changes in storativity or specific yield values would make no difference in the model calculations. Rather, values for porosity were used to calculate contaminate travel times.

I21-59
Recharge rates were taken from Shade (1996), a USGS water budget study that provided a good estimate of recharge.

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value, causing the use of the average value alone to underestimate travel time of contaminants.

I21-60

c) The spatial-temporal distribution of contaminants in the ground-water system was not investigated for the vast majority of the MMR. Samples were only obtained near the shoreline and at one well (MW-5) within the interior of the reservation. Despite this lack of data, the MT3D model used in the draft EIS ASSUMED that contaminants were reaching the ground-water system only at the OB/OD area.

Conclusions reached in the draft EIS for contaminant migration are based on an assumption that a constant source of RDX (1, 3, 5-trinitro-1, 3, 5-triazine) at a concentration of 0.16 mg/l continuously enters the top of the water table over the entire OB/OD area. For no retardation or attenuation of the contaminant during transport, a plume of RDX roughly 750 meters wide at a concentration of 0.002 mg/l is predicted to reach the Makua shoreline after 50 years of travel time from the OB/OD. Assuming retardation occurs, the plume migrates much more slowly and the concentration of RDX in the water would be too small to be detectable (p. 3-93). The latter scenario is presented as the more realistic scenario (p. 15, Appendix H). The decrease in concentration for the first scenario is solely the result of dispersion during transport. Dispersion and retardation reduce the concentration observed at the boundary for the second scenario.

I21-61

Besides the considerations listed above, there are other problems associated with the fate and transport model exercise. As stated above, contaminant is assumed to enter the MMR ground-water system only at the OB/OD area. Because the spatial-temporal distribution and concentration of contaminants reaching the ground-water table was not evaluated for any location within the MMR, including the OB/OD area, the assumption that it enters only at the OB/OD area is pure conjecture. The assumption that it enters at the OB/OD area is, of course, based on the fact that RDX was found in water samples taken at this location.

The assumption that it enters the ground-water system at the OB/OD area at a constant concentration of only 0.16 mg/l is based on an unsaturated flow model that assumed:

a) recharge on top of the model equaled 7.2 inches per year,
b) dispersion coefficients for both the lateral and transverse directions,
c) a value for effective porosity equal to 0.2,
d) a value for vertical hydraulic conductivity equal to 0.1 ft/d,
e) a distribution coefficient and organic carbon content for the entire thickness of the unsaturated zone,
f) an RDX input concentration equal to 2.55 mg/l,
g) thickness of the unsaturated zone equal to 425 ft.

Responses

I21-60
The objective of the modeling was to evaluate fate and transport estimate from areas evaluated to be of potential concern. Based on a review of the data collected, the distribution of the contaminants appeared limited to the OB/OD and impact areas. Modeling was used with a range of parameters to evaluate different travel times and rates from the OB/OD and impact areas.

I21-61
The distribution of monitoring wells was designed to sample groundwater flowing from MMR that could potentially impact off-site receptors. Even assuming another contaminated site other than the OB/OD area or impact area, the monitoring well network would have evaluated impacts to off-site receptors due to groundwater flow.

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I21-62 With the exception of recharge discussed above, there are no data to support the other assumptions (b through e) used in the unsaturated flow model. Selection of other values would have resulted in significantly different travel times and concentrations of RDX reaching the ground-water table. Difficulties associated with assumption "g" have been previously discussed.

The only measurements of the concentration of RDX in water that exist in the OB/OD area are from two locations where lysimeters were installed during the EIS study. Lysimeters were installed at depths of 30 and 45 feet below land-surface at one location, and at depths of 30 feet and 42 feet at the other. Measurements were made in only April and June, 2003. Concentrations of RDX at the first location were 4.8 mg/l and 2.9 mg/l at depths of 30 feet and 45 feet respectively. These concentrations are 30 to 18 times greater than that assumed to be entering the top of the water table underlying the OB/OD area in the two model scenarios. Concentrations at the second location were 0.027 mg/l and 0.033 mg/l at depths of 30 feet and 42 feet respectively. These concentrations range from about 17 to 21 percent of the concentration assumed to be entering the top of the water table in the OB/OD area in the two model scenarios.

I21-63 The great variability between concentrations at the two locations indicates the inability to spatially characterize the OB/OD area with samples obtained from only two locations and two depths. Further, because the OB/OD area has been the scene of activity for about 50 years, samples obtained in only June and April 2003 lack the ability characterize variations in concentration over time.

I21-64 **The inability to constrain values assumed in the unsaturated zone model by actual field data points to the same conclusions for predictions from this model as those stated above for the MODFLOW and MT3D model, i.e., the unsaturated zone model represent more of an academic exercise for an ASSUMED flow system rather than a scientifically rigorous numeric model analysis of unsaturated flow and contaminate transport from the OB/OD area to the underlying ground-water table**.

SURFACE WATER MODELING

The objective stated for the surface modeling portion of the study was to *" provide estimates of groundwater recharge, and provide estimates of flow and sediment transport due to large rainfall events*" (p.71). The model "*is designed to calculate the volume of flow at the outlet of the 3 streams in Makua: Punapohaku Stream, Koiahi Gulch Stream, and Makua Stream*" (p. 71).The model is defined as "*a physically based, distributed-parameter model that simulates physical processes occurring in the watershed that produce stream flow and sediment movement*"(p.71). The model is stated to be able to "*explicitly account for the spatial distribution of land use, soil textures, vegetation and*

Responses

I21-62
The unsaturated zone modeling used estimates of parameters based on a variety of data sources from Oahu and valid assumptions commonly used in modeling exercises. There was enough information to make a reasonable assessment of hydraulic conductivity and provide estimates of fate and transport.

I21-63
The two rounds of sampling lysimeters in the vadose zone are reasonable to calculate the concentration necessary to evaluate impacts to off-site receptors. The average concentration of RDX from the lysimeters of about 5 mg/l is consistent with concentrations reported at other Army sites (Cornhusker Army Ammunition Plant (AAP) in Nebraska is about 0.2 mg/l, Milan AAP in Tennessee is 0.8 to 1.8 mg/l).

I21-64
See response to Comment I21-62.

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contaminant loading in a much more rigorous way than lumped parameter models ... ." (p. 71).

Input parameters for the model include soil moisture content, vegetation type, soil type, and precipitation. Other input parameters included grain size, stream bottom shape and slope, land surface slope, an equation to calculate infiltration (p.73, section 2.12.1). Additional input parameters included soil erosion factors, overland flow roughness coefficients, soil hydraulic properties that control infiltration rates for different soil types, and values for shallow vertical hydraulic conductivity (p.76, section 2.12.1).
These parameters were, according to the draft EIS, calibrated to the February 14, 2003 flow event (p.76, section 2.12.1). Calibration was accomplished 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 included streamflow and total suspended solids (TSS) measurements taken on Punapohaku Stream, Koiahi Gulch Stream, and Kaluakauila Stream*" (p.168). "*The surface water modeling effort was calibrated to the February 14, [2003] flow event*" (p. 76).

Output from the model includes stream hydrographs, infiltration to ground-water, and suspended sediment transport (p. 76). Information provided by the model is stated to include "*an estimate of total suspended solids from the February 14, 2003 storm, and sediment load and stream flow for a much larger estimated rainfall event. The model also provided estimates of the volume of infiltration to ground-water that occurred during the February 14 flow event*" (p.167).

Conclusions reached from the suspended sediment data collected from the February 14, 2003 flow event was "*that almost undetectable levels of potential contamination are leaving the Makua Military Reservation*" (p. 184). The draft EIS also concluded that "*the total suspended sediment discharge in the streams is small*" (p.186).

I21-65 **Although the draft EIS concludes that the model was calibrated to flows of water and sediment measured for the February 13-14 2003 flow event and states the surface water modeling effort was calibrated to the February 14, 2003 flow event, I do not agree that calibration was accomplished. The fact that the model is able to "*explicitly account for the spatial distribution of land use, soil textures, vegetation and contaminant loading in a much more rigorous way than lumped parameter models*" (p. 71) is equally a strength and a weakness. In order for the model to acceptably**
I21-66 **reproduce observed flows of water and sediment, each of the spatially distributed parameters must be known or at least constrained by field data. The flow and**
I21-67 **sediment discharge data to which the model is calibrated must also be scientifically defensible. Neither requirement is met in calibration of the model.**

Responses

I21-65
The match of simulated and measured data was within common practices, and attained the goals of the modeling effort: to provide an estimate of 100-year flood inundation and sediment load.

I21-66
The surface water modeling uses parameters obtained from both field data and information from the literature as discussed in Appendix G-1. It is standard practice in the surface water modeling field to use both field collected and literature obtained parameters to design the model.

I21-67
See response to Comment I21-65.

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As stated above, input parameters for the model include:

1) soil moisture content,
2) vegetation type,
3) soil type, including grain size by percentage
4) precipitation,
5) stream bottom shape and slope,
6) land surface slope,
7) an equation to calculate infiltration,
8) soil erosion factors,
9) overland flow roughness coefficients,
10) soil hydraulic properties that control infiltration rates for different soil types, and,
11) values for shallow vertical hydraulic conductivity.

I21-68 I21-69 Work preformed for the draft EIS did not acceptably account for all of these parameters. In some cases, particularly for most of the parameters requiring field work, no field data was collected at all.

I21-70 Although the model requires soil moisture conditions immediately prior to a given flow event, the model used soil moisture values obtained from 25 soil measurements for which the date of sampling is not specified (p.8, 1st paragraph). It is not clear from the draft EIS then, if the samples are representative of soil moisture conditions immediately prior to the February 2003, January 2004, and February 2004 flow events.

I21-71 The role that vegetation type plays in the model process is undefined as is assignment of model values for this parameter.

I21-72 The distribution of grain size or percentage of silt and sand at a given location used in the model was the average percentage of these sizes determined from the soil sampling program (p.170), but this program was limited in scope, and by averaging percentage of grain size, the distributed parameter capability of the model is negated.

I21-73 The equation to calculate infiltration and soil erosion factors would both have unverifiable parameters within it that are not discussed.

I21-74 Overland flow roughness coefficients are subjective and not verifiable with field data.

I21-75 Soil hydraulic properties that control infiltration rates are undefined in the draft EIS and field work to establish these properties were not defined.

I21-76 Values for shallow hydraulic conductivity were not obtained during the field work conducted during the preparation of the draft EIS.

Responses

I21-68
See response to Comment I21-66.

I21-69
See response to Comment I21-66.

I21-70
Soil moisture data were collected primarily in September and October, 2002. Additional text has been added to Appendix G-1.

I21-71
Vegetation type is related to roughness, which is a parameter in the overland flow calculation. This parameter was discussed in Appendix G-1.

I21-72
The surface water modeling in Appendix G incorporated the distributed parameter capability by using different soil types at MMR as listed in USDA 1972. The average percentage of grain size was calculated using a total of 41 soil samples from across MMR.

I21-73
See response to comment I21-62.

I21-74
Documented values for roughness coefficients obtained from scientific literature and acceptable scientific assumptions on parameters were relied on to design the model, and the model is in line with standard practices.

I21-75
See response to Comment I21-66.

I21-76
Shallow hydraulic conductivity tests collected in Hawaiian shallow soils tends to underestimate permeability rates.

Comments	Responses
	(Cont.) I21-76 Most of the infiltration occurs in secondary permeability that is not measured from laboratory or double ring infiltrometer tests (HLA, 1996). Therefore, these tests were not conducted, and infiltration parameters were instead taken from field surveys, and values from a variety of sites and modeling studies conducted in the literature.

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I21-77 As stated in the draft EIS, "*during simulations, the amount of infiltration is highly dependent on K_s* (shallow hydraulic conductivity*), as well as the slope of the land surface (higher slopes have less infiltration and more runoff), capillary head (soil suction, and soil porosity* (p. 76)*."* Runoff rates are directly dependent on infiltration rates so that the importance of the above parameters in the overall modeling effort should be apparent. Of these, values for Ks, capillary head, and soil porosity were not available for the MMR and as a result, assumed values were used in the modeling process.

I21-78 The model was first "calibrated" to water flow during the February 14, 2003 flow event after which it was "calibrated" to sediment flow for the same event. For "calibration" to water flow, infiltration rates, overland flow roughness, and streambed roughness were adjusted (p. 171). Once the flow part of the model was completed, the sediment discharge portion of the model was "calibrated" by adjusting soil erosion ability values (p. 171). None of the above values were constrained by field data available from the MMR. Soil erosion properties of sand and silt percentages were held constant "*since these values were measurable data taken from as the average of sieve analysis*" (p. 171) (for soil samples taken in Makua Valley). As stated above, however, the soil sampling program was biased and therefore not necessarily representative of the MMR as a whole, and by averaging the percentage of grain size distribution, the distributed parameter capability of the model is negated.

Initial infiltration rates used in the model were obtained from a manual, but adjusted as necessary. Overland flow roughness values were also derived from the same manual. Streambed roughness was investigated in the field, but these values are highly subjective and were also adjusted as needed in the "calibration" process. The model was found to be sensitive to soil erosion values, and once again these values were adjusted as needed to obtain "calibration" to observed data.

I21-79 I21-80 **Not only is the model unconstrained with regard to the parameters used to "calibrate" it, the flow and sediment discharge data to which the model is calibrated have not been shown to be scientifically defensible**. The draft workplan did not provide a mechanism for converting stream stage to stream discharge and, failing this, it is not possible to establish instantaneous or total discharge during a given runoff event, which is one of the main purposes for gaging the stream. Flow is not measured directly, and therefore there needs to be data collected that relate whatever parameter is being measured to flow. Normally, a relationship between streamflow and stream stage (the height of the stream surface above a specified datum) is developed and stage is the parameter measured. The relationship between flow, stage, and velocity of flow is highly dependent on the cross sectional area that flow occurs within, and this area changes for different values of flow. None of this data is discussed in the draft EIS and its doubtful, given the work involved to establish the relation between stage and flow, that this work was accomplished.

I21-81

Responses

I21-77
The calibration effort took into effect the balance between the runoff and infiltration rates.

I21-78
See response to Comment I21-72.

I21-79
See response to Comment I21-66.

I21-80
As stated in the sampling analysis plan, the purpose of the flow measurements is to help select samples for analysis by the laboratory over a range of flows. Accordingly, the EIS study required a temporary gaging station, not a permanent USGS gaging station as alluded to in this comment.

I21-81
See response to comment I21-80.

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Lack of accurate flow data also makes it impossible to relate flow to sediment discharge, since the latter, for a given flow event, is actually a quantity of suspended sediment, in mass units, transported during the event. Given a lack of accurate flow data, it is not possible to convert sediment concentration values obtained from sediment samples to these units. The collection of sediment samples must also follow a prescribed protocol and this does not appear to have been accomplished. Finally, considerable amounts of sediment are moved from valleys as bed load. There was no effort to obtain or estimate this movement.

I21-82

I21-83

As stated in my August 6, 2002 review of the June workplan, the inability to determine stream discharge, total suspended sediment discharge, and bed load for runoff events for Makua Stream given the draft plan's outline for collecting this information is a major failure of the plan.

I21-84

The inability to constrain values assumed in the surface water –sediment transport model by actual field data and the apparent lack of scientific credibility associated with the flow and sediment data it was calibrated to, leads to the same conclusions for predictions from this model as those stated above for the MODFLOW, MT3D and Vadose models, i.e., the surface water-sediment transport model represents more of an academic exercise for an ASSUMED flow-sediment discharge system rather than a scientifically rigorous numeric model analysis of water flow and sediment transport from the OB/OD area. Given this, the model is not capable of fulfilling the objectives for which it was made, i.e., predicting water and sediment flow for assumed precipitation events occurring at MMR.

I21-86

The model is further weakened as a predictive tool by the fact that sediment yield was "calibrated" in the model to the February 14, 2003 flow event during which "measured peak flow" equaled about 2.2 meters per second or about 79 cubic feet per second, (cfs) (fig. 3.8 p. 174). This was a minor flow event during which very little if any sediment transport would be expected. As stated in my review August 6, 2002 review of the June 2002 workplan:

> USGS studies in Hawaii have shown that sediment transport increases with increasing stream discharge. Maximum stream discharge in Hawaii -- which occurs during significant storm events -- is much greater than the average stream discharge associated with average conditions of precipitation. For instance, the USGS has measured Makaha Stream's discharge from July 1959 to the present time. According to USGS Water-Data Report HI-99-1 (2000), the average discharge of this stream during the water years from 1960-1999 (a water year runs from October of one year through September of the following year) was 1.82 cubic feet per second. The maximum discharge during this time period -- which

Responses

I21-83
Standard bottle filling techniques were used, as described in the sampling analysis plan.

I21-84
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. Text has been added to Appendix G-1 to address bed load.

I21-85
The model simulates suspended sediment discharge and stream discharge for the 100 year storm event, which was the objective of the modeling effort. Appendix G-1 has been revised to provide a discussion of bed load.

I21-86
Please see responses to Comments I21-57 and I21-66.

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occurred on November 14, 1996 -- was 2,680 cubic feet per second, over 1,470 times the average discharge.

The largest estimated peak flow for Makua Stream was measured by the USGS in 1976. This flow is also estimated to be the 50 year flood event (p.3-76). The agency further estimated the 100 year flood to be about 5,500 cfs (p. 3-76). When compared to these values, the minor nature of the February 14, 2003 flow event is apparent. It should also be apparent that little if any sediment discharge would be expected from the February 14 event. Given this consideration, even if the model were actually calibrated to the sediment yield derived from the February 14, 2003 event (and it isn't), the model is not capable of predicting sediment yield for significant flow events. I21-86

It is also not possible for the model to provide estimates for ground-water recharge based on its calculated value for infiltration from a given flow event (p. 167). The model assumes no loss of water from evapotranspiration, which, in Hawaii, constitutes a significant part of the water budget. For instance, the USGS indicates that loss of water by evapotranspiration from the Waianae area equals 63 million gallons per day from an average rainfall of 103 million gallons per day, or an average loss of about 61 percent (table 13, p. A42, USGS PP 1412-A). Thus, once again, even if the model were calibrated it is not capable of predicting a value for infiltration to the ground-water as stated. I21-87

References

Franke, O.L. and Reilly, T.E., 1987, The effects of boundary conditions on the steady-state response of three hypothetical ground-water systems-results and implications of numeric experiments, U.S. Geological Survey Water-Supply Paper 2315.

Gingerich, S.B. and Oki, D.S., 2000, Ground water in Hawaii, U.S. Geological Survey Fact Sheet.

Oki, D.S., 1997, Geohydrology and numerical simulation of the ground-water flow system of Molokai, Hawaii: U.S. Geological Survey Water Resources Investigation Report 97-4176.

Zones, C.P., 1961, Discharge of ground water by Phreatophytes in the Waianae District, Oahu, Hawaii: U.S. Geological Survey Professional Paper 424-D.

Responses

I21-86
The model was calibrated to the 14 February 2003 event (please see Appendix G-1). The modeling was conducted in accordance with the objectives outlined in the sampling and analysis plan.

I21-87
Please see response to Comment I21-66.

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