Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
1	**6/26/17 Meeting Navy Action Items**						
2	Describe data available and adequacy of data to achieve objectives; data quality objectives of monitoring well network; quality and limitations	Prior to Meeting #2 (6/26/17)	This has been done in the Existing Data Report and Data Gap Analysis Report (DON, March/April 2017). In addition, additional data are being collected as part of various AOC and derivative deliverables such as the Data Gap Analysis Report, Sampling and Analysis Plan, Conceptual Site Model Development and Update Plan, Attenuation Evaluation Plan.	In Progress		CSM-Hydrogeology	
3	Anisotropy - groundwater flow paths not adequately characterized by groundwater gradient	Prior to Meeting #2 (6/26/17)	Revised gradients are being developed based on the recent well survey and will be further evaluated as part of the synoptic water level study under transient conditions. Use of multi-level Westbay sampling points for head will also assist in this effort. Longitudinal K = 4500 ft/d (Oki);Vertical K = 7.5 ft/d. Longitudinal to Vertical anisotropy of 600:1); Oki 2005, Kh transverse = 1500 ft/day; so longitudinal to transverse = 3:1. Larger anisoptries have been used by other investigators in the area. These will be considered during model calibration.	In Progress		CSM-Hydrogeology	
4	Major hydrogeologic barriers near Oily Waste Disposal Facility (tanks?) should be described or referenced. Rainfall recharge is large where there is no caprock. 10 to 25 inches per year in Red Hill vicinity (Oki 2005; Giambelluca 1983).	Prior to Meeting #2 (6/26/17)	We are not sure what barriers you are referring to. This will be addressed in the CSM. Note down- and cross-gradient of OWDF the presence of Honolulu Volcanics and confluence of N. and S. Halawa Streams. Infiltration will also be further evaluated.	In Progress		CSM-Hydrogeology	
5	Adequacy of sentinel well network	Prior to Meeting #2 (6/26/17)	Will be evaluated as part of the Sentinel Well Network Plan derivative deliverable.	In Progress		Sentry Wells	
6	Resurvey well elevations	Prior to Meeting #2 (6/26/17)	Mostly complete… additional wells being considered.	In Progress		CSM-Hydrogeology	
7	Role of valley fill unit is a data gap	Prior to Meeting #2 (6/26/17)	Additional investigations including well/Westbay installations, synoptic water level study, and potential seismic lines will further determine how valley fill is handled.	In Progress		CSM-Geology	
8	Assimilate and use information from two different pump tests and long-term monitoring of WLEs on-site and non-Navy wells; measurement of water quality parameters	Prior to Meeting #2 (6/26/17)	Synoptic water level study will be evaluated as well. This can help determine anisotropies as well.	In Progress		CSM-Hydrogeology	
9	Does groundwater potentially impacted from Red Hill USTs remain in the Moanalua Aquifer only impacting the Red Hill Shaft or is there a flow component toward the Waimalu Aquifer where major pumping centers are located? The GW flow system is very dynamic in time.	Prior to Meeting #2 (6/26/17)	GW flow contours for different seasons/years will be evaluated using resurveyed data and new information from proposed wells/Westbay pts. Use of all data, including synoptic water level measurements by USGS from 2002-2012 as well as the new synoptic study. Groundwater modeling efforts will also assist in this evaluation.	In Progress		CSM-Hydrogeology	
10	If so, is it due to unidentified subsurface structures?	Prior to Meeting #2 (6/26/17)	What structures? The CSM will further address this. Most likely these include depth of valley fill, lava tubes in pahoehoe, and thick a'a clinker zones. The most probable pathway for a majority of groundwater flow is likely in the clinker zones.	In Progress		CSM-Geology	
11	Need to characterize nature of connectivity between the Honolulu and Pearl Harbor Aquifer Sectors	Prior to Meeting #2 (6/26/17)	The boundary between these sectors is administrative, not hydrogeologic.	No issue		CSM-Hydrogeology	
12	North Halawa Valley should be further investigated	Prior to Meeting #2 (6/26/17)	Yes, new monitor wells proposed and geophysical surveys being considered.	In progress (See #6)		CSM-Hydrogeology	
13	Characterization of Valley Fill (extent, and hydrogeologic properties)	Prior to Meeting #2 (6/26/17)	Same as above.	In Progress (See #6)		CSM-Hydrogeology	

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14	*Pumping test of May 2015 shows response on Red Hill side of N (and S) Halawa valleys to pumping changes in Halawa Shaft*	Prior to Meeting #2 (6/26/17)	Maybe, but the water level responses are complicated, and appear to be affected by Red Hill Shaft pumping too. The results are actually a little more ambiguous than has been described. The synoptic water level study will better help understand this. It is critical that all parties participate in the pumping schedule proposed by the USGS.	In Progress		CSM-Hydrogeology	
15	*Conduct a series of coordinated aquifer tests to definitely measure hydraulic connection between Red Hill area and Halawa municipal water source area*	Prior to Meeting #2 (6/26/17)	This is part of the synoptic study.	In Progress		CSM-Hydrogeology	
16	Untested assumption: 1) Valley fill and underlying saprolite act as barriers to flow between RHBFSF and nearest BWS water supplies; no *direct* data	Prior to Meeting #2 (6/26/17)	Several USGS studies indicate valley fill extends below WT. Indirect evidence (pump test response across valley fill or series of coordinated aquifer tests) can help bridge this data gap. Additional studies are being conducted to further evaluate this.	In Progress (see #6)		CSM-Hydrogeology	
17	Untested Assumption: 2) Regional flow is from NE to SW near RHBFSF; too few wells to understand flow directions and rates	Prior to Meeting #2 (6/26/17)	Although various USGS studies show regional gradients toward the SW, additional monitor wells are being planned to collect hydraulic head data to address this.	In Progress		CSM-Hydrogeology	
18	Hunt (1996) chose North Halawa valley as a geohydrologic barrier but not on the basis of direct evidence of flow or geologic conditions	Prior to Meeting #2 (6/26/17)	The USGS (Izuka 2012) and other USGS reports also showed valley fill extends below the water table near Halawa Shaft. Additional investigations are planned to further evaluate this.	In Progress (See #9)		CSM-Hydrogeology	
19	No borings to delineate lithology and dimensions of valley fill material; no evidence that valley fill extends below water table;	Prior to Meeting #2 (6/26/17)	Hydrogeologic response between the units is more critical; additional borings/wells are being installed to further evaluate this.	In Progress (See #6)		CSM-Geology	
20	Width of Halawa valley fill is exaggerated - deep valley fill is only in eastern branch of South Halawa Stream and does not extend to western branch	Prior to Meeting #2 (6/26/17)	This comment is not clear. Deeper valley fill exists toward the west in Halawa Valley. To the west, near the confluence of North and South Halawa valleys, the H-3 boring logs show deeper valley fill that ex to further evaluate this tends below the water table. Additional investigations are underway to evaluate valley fill.	In Progress (See #9)		CSM-Geology	
21	Model should not include valley fill barriers till further evidence of barrier; model should attempt to calibrate without barrier and if possible, then use that model	Prior to Meeting #2 (6/26/17)	Valley fill permeabilities will initially be assigned the same permeability as basalt until geologic/hydrogeologic data can be better evaluated in this regard. Investigations are planned to further evaluate this.	In Progress		CSM-Hydrogeology	
22	Need one or more monitoring wells to be installed along northwesterly direction from RHBFSF; to estimate change of flow direction and rates from RHFSF toward Halawa shaft during pumping of Red Hill and Halawa shaft	Prior to Meeting #2 (6/26/17)	Additional monitor wells are being planned to collect hydraulic head data to address this issue.	In Progress		CSM-Hydrogeology	
23	Regional gradient to southwest is contradicted by TEC 2010 letter report	Prior to Meeting #2 (6/26/17)	We recognize that there are various interpretations of groundwater flow gradients in previous reports. New data and survey information will resolve this.	In Progress (see #9)		CSM-Hydrogeology	
24	Describe CSM elements - historic data; quality of information; format of deliverables	Prior to Meeting #2 (6/26/17)	This is being done and is part of the CSM Development and Update Plan.	In Progress		CSM-Hydrogeology	
25	Define boundaries of site, study area and modeling domain	Prior to Meeting #2 (6/26/17)	This was discussed during meetings 2 and 3 and has been addressed.	Resolved		Flow Model	
26	BCs should reflect real-time measurement of heads	Prior to Meeting #2 (6/26/17)	The objective is not to evaluate real time water level changes. Boundary conditions for the model will be evaluated from evaluation of recent water level data.	In Progress		Flow Model	
27	Modeled BCs should be far enough to not impact Halawa Shaft pumping or have flow directions toward Halawa shaft from RHBFSF	Prior to Meeting #2 (6/26/17)	We have model BCs far enough to not impact Halawa Shaft pumping.	Resolved		Flow Model	

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28	There are anomalously high water levels within the Red Hill Ridge area which respond to pumping stresses likely from the Halawa Shaft. How will model use this information?	Prior to Meeting #2 (6/26/17)	New precision surveying has been done to establish more accurate groundwater level elevations, and integration of the synoptic water level study will also help resolve this issue. The numerical model will be calibrated to match the groundwater levels.	In Progress		Flow Model	
29	Delineate perched water conditions at Red Hill in the basalt and valley fill units	Prior to Meeting #2 (6/26/17)	These conditions (where they may be found) are being integrated into the CSM at Red Hill and are being evaluated through the monitoring network at the prison beneath South Halawa Valley. As appropriate, this will be considered in the model for recharge.	In Progress		CSM-Hydrogeology	
30	Suggest using recharge values already calculated by USGS	Prior to Meeting #2 (6/26/17)	Infiltration testing is planned for Red Hill to further evaluate this near the source zone. The USGS recharge calculations refer to GW recharge rates presented as maps in Engott 2015 and Izuka 2016. Impacts of the other features noted are not included in the USGS calcs. The modeling plan is to start by inputting the USGS recharge rate map data to the model, then adjusting the rates locally to account for other features such as saprolite cap above Red Hill, cement plant, quarry, lined stream channels, etc.	In Progress		CSM-Hydrogeology	
31	Evaluate past modeling efforts	Prior to Meeting #2 (6/26/17)	Past modeling efforts are being evaluated and are summarized in the GWMEP. We are also conducting more evaluations such as mass balance components as new data become available.	In Progress		Flow Model	
32	"Dominant GW flow direction is to northwest, not toward Red Hill shaft to southeast"	Prior to Meeting #2 (6/26/17)	See Response #9.	In Progress (See #9)		CSM-Hydrogeology	
33	Rotzoll and El-Kadi (2007) model not adequately calibrated for flow directions due to survey issues.	Prior to Meeting #2 (6/26/17)	We are not depending on the 2007 model and are resolving survey issues.	In Progress		Flow Model	
34	Questions about flow directions and rates between Moanalua and Halawa valleys; use defensible approach of Oki (2005) to address this data gap; correcting for head errors showed flow direction to northwest (and not from NE to SW) in area of RHBFSF	Prior to Meeting #2 (6/26/17)	In Progress (See #9)	In Progress (See #9)		CSM-Hydrogeology	
35	Fig 3 on pg 38 of Mink, 1980 "State of the relationship between the Groundwater Resources of Southern Oahu" shows GW flow direction from Red Hill toward Halawa Shaft	Prior to Meeting #2 (6/26/17)	This map in Mink 1980 only shows regional dashed water level contours with no data points at all in our area of interest!	Resolved (See #9)		CSM-Hydrogeology	
36	Heads at OWDFMW01 are unconfined basal aquifer and not confined; confining units are about 1000 feet away and no upward gradients or "major hydrogeologic barriers"	Prior to Meeting #2 (6/26/17)	Individual massive basalt layers can also create localized confined aquifer conditions.	Resolved		CSM-Hydrogeology	
37	Limitations and Sensitivity of model; approach to improve model; professional judgements	Prior to Meeting #2 (6/26/17)	Comment not clear, but the GWMEP describes the technical approach for the modeling and includes a sensitivity study. Of course, we always describe model uncertainties and limitations in modeling reports.	Resolved		Flow Model	
38	Gather input at important decision points from stakeholders and regulators	Prior to Meeting #2 (6/26/17)	That's the point of having GWFM working group meetings and detailed review and comment of draft documents before final distribution. In addition, it is incumbent on all stakeholders to point out available information sources (including well data) and help with obtaining all pertinent data.	Resolved		Other	
39	Simulate drought scenario; simulate distribution of pumping and location of hypothetical new well in future scenario; get input from stakeholders on this	Prior to Meeting #2 (6/26/17)	The draft GWMEP states "This modeling will help ascertain potential risk to water supply as a result of a potential range of releases from the Red Hill Bulk Fuel Storage Facility under a range of reasonable pumping conditions within the model domain." We would welcome input from BWS on future well locations.	In Progress		Flow Model	

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40	Uncertainty about groundwater flow paths (and about gradients)	Prior to Meeting #2 (6/26/17)	In Progress (See #9)	In Progress (See #9)		CSM-Hydrogeology	
41	Free phase may be near gw interface (RHMW02 exceeded 1% limit of 45 µg/L)	Prior to Meeting #2 (6/26/17)	COC concentrations are a good indication of this when effective solubility levels are reached. Not sure what the conc value is in reference to? These issues are further addressed in the Attenuation Evaluation Plan.	In Progress		Nat Atten	
42	early detections of a thin free product layer were followed by a long history of no detections.	Prior to Meeting #2 (6/26/17)	We don't recall seeing any free product layer detection. In 2007-08 we recall a sheen was reported. Not sure what the point is?	?		Nat Atten	
43	Transport modeling uncertainty in porosity (0.05 used for 2007 F&T model consistent with SWAP model; inverse modeling estimated 0.031. Consider this in interpreting results	Prior to Meeting #2 (6/26/17)	This will be considered in interpreting results.	Resolved		F&T Model	
44	Perform tracer test	Prior to Meeting #2 (6/26/17)	We are in discussion with Bob Whittier and Don Thomas on this subject and are initially focused on natural tracers.	In Progress		CSM-Hydrogeology	
45	Include releases to GW from envelope surrounding the tanks	Prior to Meeting #2 (6/26/17)	We will be evaluating a range of potential release scenarios from the tanks.	In Progress		F&T Model	
46	Consequences of future potential releases; fraction NAPL immobilized in vadose zone and fraction expected to reach water table	Prior to Meeting #2 (6/26/17)	Will depend also on potential release volumes. Various LNAPL scenarios will be evaluated.	In Progress		Nat Atten	
47	Evaluate mechanisms expected to accompany different sizes of future potential fuel releases	Prior to Meeting #2 (6/26/17)	To the extent that this is related to LNAPL transport and natural attenuation, this is covered in the Attenuation Evaluation Plan.	In Progress		Nat Atten	
48	Uncertainties are too great; degree of calibration unreasonable; mixing of recent and legacy contamination; unknown footprint of source area; unknown sorption rates; unknown subsurface structure geometries (anomalous WLEs); *produce a set of probability realizations for likely transport paths and velocities*	Prior to Meeting #2 (6/26/17)	The data from new wells, precision survey, and synoptic study should reduce these uncertainties a great deal. In addition information from the attenuation study will help resolve this. The CSM will integrate older and newer data to reduce uncertainty as well. We will evaluate if a probabilistic analysis is warranted against other approaches such as bounding analyses.	In Progress		CSM-Hydrogeology	
49	Test GW samples for other fuel additives	Prior to Meeting #2 (6/26/17)	This has been addressed in the Attenuation Evaluation Plan.	In Progress		Nat Atten	
50	Examine relationships between soil vapor concentrations and groundwater heads and chemistry	Prior to Meeting #2 (6/26/17)	These data will be evaluated for this purpose. This has been addressed in the Attenuation Evaluation Plan.	In Progress		Nat Atten	
51	Is source vapor, LNAPL or dissolved contaminants in infiltrating water or a combination	Prior to Meeting #2 (6/26/17)	This is being addressed in the Attenuation Evaluation Plan.	In Progress		Nat Atten	
52	Lateral migration of LNAPL through vadose zone could affect water quality in streams	Prior to Meeting #2 (6/26/17)	Very doubtful for Red Hill; however, the CSM and Attenuation Plan should address this. However, releases from the prison may result in stream impacts.	In Progress		Nat Atten	
53	Assess degradation rates	Prior to Meeting #2 (6/26/17)	This is being addressed in the Attenuation Evaluation Plan.	In Progress		Nat Atten	

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54	Install vapor monitoring points to evaluate vapor plume over depth and time; evaluate likely LNAPL pockets	Prior to Meeting #2 (6/26/17)	Vapor sampling points exist now, and this is being addressed in the Attenuation Evaluation Plan. In addition, a Westbay is planned to be installed which will have the ability to sample soil gas in the unsaturated zone.	In Progress		Nat Atten	
55	Evidence of degradation (levels of oxygen, carbon dioxide, degradation compounds in vadose zone	Prior to Meeting #2 (6/26/17)	This is addressed in the Attenuation Evaluation Plan.	In Progress		Nat Atten	
56	How will first order rates be selected and validated	Prior to Meeting #2 (6/26/17)	This is addressed in the Attenuation Evaluation Plan.	In Progress		Nat Atten	
57	Too many undefined variables to do decay calculations with confidence; do probabilistic analysis using different velocities and directions	Prior to Meeting #2 (6/26/17)	This is addressed in the Attenuation Evaluation Plan; probabilistic analysis will not add useful information.	In Progress		Nat Atten	
58	Do simulation without decay also	Prior to Meeting #2 (6/26/17)	Particle tracking will not consider decay. Decay rates from the attenuation study will be utilized in the model.	Resolved		F&T Model	
59	List of remedial alternatives is incomplete: Include steam, heat enhanced SVE; bioaugmentation, wellhead treatment; vacuum-enhanced NAPL recovery; stabilization, interception barriers	Prior to Meeting #2 (6/26/17)	This will be addressed in the future Remediation Report deliverable.	Future Effort		Remediation	
60	Analysis of combined technologies	Prior to Meeting #2 (6/26/17)	This will be addressed in the future Remediation Report deliverable.	Future Effort		Remediation	
61	Integrate risk assessment, data collection and models to establish risk based criteria for Groundwater Protection Plan	Prior to Meeting #2 (6/26/17)	This is part of the forthcoming Risk-Based Decision Criteria Development Plan derivative deliverable.	In Progress		Risk Assessment	
62	Use iterative approach between data collection and analysis/modeling	Prior to Meeting #2 (6/26/17)	This is part of our modeling approach.	In Progress		Flow Model	

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63	**BWS 6/26/17 Meeting Comments (7/3/17):**						
64	BWS Comment #1: As recommended by the USGS, DOH, and BWS subject matter experts (SMEs), the Navy should avoid over-constraining the groundwater flow model through the use of general head boundaries along the domain boundaries as much as possible and adopt more defensible and conservative boundary conditions. These include extending the model seaward so that the ocean water column can be represented with specified head and concentration boundary conditions per Dr. Oki's recommendations, representing areal recharge and flux from the dike-intruded basalts, and using no-flow boundary conditions along the Kalihi and Waimalu domain boundaries wherever possible. The effects of all boundary condition choices should be tested through a thorough model sensitivity analysis.	7/3/17	General Head boundaries (GHBs) are most often used along lateral boundaries of a groundwater flow model to prevent over-constraining the model. No-flow boundaries do not allow for flow to occur across model lateral boundaries which may over-constrain a model if real no-flow boundaries or barriers actually do not exist at the model lateral boundary locations. The other extreme would be a specified head boundary which would act as an infinite and unconstrained source of water. This would not be justifiable within the radius of influence of large pumping centers since a specified head boundary will distort the simulation's impacts within the domain when pumping changes. GHBs on the other hand conceptually allow for distance to be placed between the actual lateral model boundary location and regions of interest such as pumping centers, such that the boundary influence is minimized. Also, specified head and no-flow boundaries are extreme cases of a GHB; if the GHB conductance is very large, it acts as a specified head boundary; and if the GHB conductance is zero, it acts as a no-flow boundary. Thus, the impact of both extremes will be evaluated in a sensitivity analyses by changing the GHB conductance value. At the groundwater modeling progress meeting, the different lateral boundaries were discussed separately. Please advise if the details provided below differ from your understanding of the meeting discussion. • Northwest and Southeast Model Boundaries: There was general consensus that it would be reasonable to use GHB conditions for the northwest and southeast model domain boundaries. GHBs would be appropriate here since that would reduce the impact of the lateral boundary on nearby pumping centers. Also, with use of the GHBs, we will evaluate the fluxes at these lateral boundaries in comparison to the conceptual understanding of the cross-boundary flows and to flows evaluated at the boundary locations by the other modeling efforts. Finally, we will evaluate the boundary impacts during sensitivity analyses. • Northeast Boundary: For the northeast boundary, we agreed with the USGS/BWS suggestion to use a specified flux boundary and locate it downstream of the dike-intruded basalt area mapped by the USGS. A no-flow boundary would not be appropriate, as there is flow occurring from the dike-intruded area into the model domain, even though it is compartmentalized. We agreed to evaluate flow in this area from a conceptual understanding as well as from other existing models to obtain reasonable values for the current modeling effort. • Southwest Boundary: For the southwest boundary, we had originally proposed to cut it off at the shoreline with a GHB condition along the lateral face to represent the remainder of the aquifers extending out to where the groundwater probably exits at the seafloor. USGS and BWS instead suggested including that entire portion as part of the active model domain and providing a constant equivalent-freshwater head boundary at the ocean-floor representative of sea-water conditions. Their reasoning was that there would be less parameters to calibrate since a lateral GHB condition as we had originally suggested would add its own degrees of freedom (one more calibration parameter which would have to coordinate with the calibrated hydraulic conductivity of the represented material). That is a good point and we will follow the suggestion for the southwest lateral boundary. Therefore, we propose now to extend the southwest lateral boundary into the ocean and use a GHB with equivalent freshwater heads along the sea floor. The lateral boundary will be a specified equivalent freshwater head boundary.			Flow Model	

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65	BWS Comment #2: The Navy did not present their approach for using the SWI2 package (Bakker et al., 2013) and there was no discussion about how the Navy is representing the bottom boundary. The Navy has also not discussed how areal recharge will be represented. We request that these two boundary conditions be included in the agenda for the third modeling group meeting so that all major boundary conditions are understood by the entire modeling group, including the SMEs.	7/3/17	We do not think it is necessary to use SWI2 for the refined MODFLOW model to meet the project objectives, nor is it needed to create a more accurate model. The points to consider in this regard are as follows: • The water supply wells within the model domain withdraw groundwater at shallower depths and pumping those wells would have only a negligible effect on the saltwater-freshwater interface. This is because of the extremely low vertical hydraulic conductivity of the basalt aquifer, very high horizontal hydraulic conductivities, and a deep saltwater interface (about 1,000 feet deep), which is more than 700 feet below the pumping well intakes. Small impact of pumping at depth was also noted in the sensitivity study conducted by the USGS (Oki 2005). Figure 34 of that report shows that the 2% salinity interface moves vertically by about 10 to 20 feet (about 2% of the saturated freshwater thickness) resulting from a change in the pumping rate of approximately 5.6 MGD. The 50% salinity isochlor (or sharp interface of the SWI2 package) would move even less. The impact of this difference on the aquifer transmissivity for freshwater is negligible – it may be noted that this same assumption of neglecting small impacts on transmissivity is made by (Gingerich and Voss 2005) (the model only extends up to mean sea level at the top) which is also the case for the Oki (2005) model. • The objective of the current groundwater flow modeling effort is to evaluate flow magnitudes and directions to conduct further studies on migration of solutes. However, the flow-field generated by MODFLOW with the SWI Package is not compatible with particle tracking routines (PATH3D) or with fate and transport models (MT3D or RT3D) that interface with MODFLOW. • Also, we have evaluated use of the SWI2 package in terms of its simulation behavior, stability, convergence, robustness and efficiency for the current modeling effort. Our testing indicated that the code takes 20 minutes to run with SWI2 Package and 2 minutes without the SWI Package for a model of a similar setting. Thus 10 simulations can be done without the SWI2 Package in the time it takes 1 simulation with the SWI2 Package. More simulations translates to a more refined calibration within the same timeframe. Also, there could be further robustness (convergence) issues with the SWI2 Package that can hinder progress. These issues could arise during scenario simulations when the model is stressed the most, thus preventing its use even if it is well calibrated. • The impact of saltwater intrusion in near-shore and offshore regions can and have been handled in other ways in a MODFLOW model without invoking density or sharp-interface approaches. One way is to assume that no flow occurs across the interface of the two fluids and set the bottom boundary to the interface location. This allows freshwater transmissivity to decline as the freshwater lens thickness becomes zero but does not allow the freshwater lens to respond to pumping further inland. Another way is to set the bottom boundary to below the saltwater zone and provide equivalent freshwater heads along the boundary, such that the saltwater zone is conceptually included in the model with boundary flows in the saltwater zone also included. This approach has the advantage of evaluating the vertical velocities in the known saltwater zones which can be used to gauge the impacts of pumping at those depths. Both of these approaches are standard and have been used in coastal settings when the saltwater concentrations or interface locations are not the objective. • Using MODFLOW to provide a flow-field for particle tracking or solute transport simulations in a coastal setting is not a novel idea. Use of the SWI2 Package with particle tracking or solute transport simulations is not standard or generally accepted			Flow Model	

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			by the scientific community – interfacing software is not yet available to adjust the MODFLOW flow-field to incorporate the corrections of the SWI2 Package. Also, we are not aware whether this has been tested, peer reviewed or published. Regarding applied recharge: At the start of calibration, we suggest using average annual recharge rates to the uppermost active layer throughout the domain. We will consider using the USGS values to start. During model calibration, we would adjust recharge rates within a reasonable range as needed to match the other available site data. We are also currently evaluating recharge rates and computations used in other models and analyses in the region.				
66	BWS Comment #3: To save time, the Navy should consider adopting the caprock and basalt hydrogeologic framework units found in Oki (2005) rather than developing a new framework. Valley fill should not be included in Moanalua and Halawa Valleys without defensible supporting evidence and thus the valleys should comprise Ko'olau basalt and perhaps caprock.	7/3/17	We intend to start with the framework in the currently available SUTRA model (Oki 2005) and MODFLOW (DON 2007) models and check/add geologic details from additional borehole logs and/or surface geophysics. Even though prior USGS model studies show valley fill extending below the water table, we agree to not include valley fill in the model without further defensible supporting evidence. We are planning field studies to evaluate valley fill depth and conductance to flow. We are also planning on analyzing the upcoming synoptic monitoring/aquifer test results across valley fill materials to estimate and quantify the connectivity. As an additional consideration related to the synoptic water level study, it may be appropriate to sample all wells for chloride to better understand potential water quality impacts related to various pumping conditions.			CSM-Hydrogeology	
67	BWS Comment #4: Pumping stresses from all production wells should be included in the groundwater flow model. Prior to the next meeting, the Navy should contact the Hawaii Department of Land and Natural Resources (DLNR) Commission on Water Resources (CWRM) and request a complete list of production wells in the model domain and their pumping rates over the time periods of interest.	7/3/17	We have requested, received and compiled a complete list that includes all available production wells in the model domain and their pumping rates over the time period of interest from DLNR and CWRM. Also, we believe we have collected the complete set of well information but will compare this with information provided from the requests to DLNR and CWRM as well as with the SUTRA model files (Oki 2005). Please review the list we have compiled and let us know if you have additional data that can be used in the model domain.	All well data has been requested and is being compiled into a spreadshee t as well as GIS		Flow Model	
68	BWS Comment #5: The Navy has not yet informed the modeling group about the hydrogeologic framework, the calibration targets to be used, and all pumping centers. Given their importance to defining the model domain discretization, it is premature to discuss model layering.	7/3/17	We intend to do this. We expect to provide a figure showing the 3 primary hydrogeologic units (HGU) and their geometry throughout the model domain. Future discussion will include calibration targets that will be used in evaluation of the model. We will use all pumping data within the model domain as discussed in item 4 above. We will also accordingly present our anticipated model domain discretization and layering that fits with the conceptual site model hydrogeologic unit framework. In this regard, we are intending to integrate available geologic information with additional data available from the USGS, which includes recently published structure contour maps of the top of basalt for the island of Oahu (Ko'olau) and isopach thickness map of the 'caprock' deposits for the island of Oahu (these include valley fill sediments). To produce these maps, the USGS created detailed geospatial data that can be exported as GIS format shapefiles of the maps in the Izuka et al. (2016) publication Volcanic Aquifers of Hawai'i-Hydrogeology, Water Budgets, and Conceptual Models, Scientific Investigations Report 2015-5164. Recent communications with the USGS indicate that these files will be provided shortly.			CSM-Hydrogeology	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
69	BWS Comment #6: Based on its importance to assessing the modeling approach, we request that the Navy present the calibration targets and the calibration approach at the next modeling group meeting.	7/3/17	We will assimilate and present calibration targets as discussed in item 5 above. We further expect to provide illustrations during the next meeting to show the well screen intervals plotted on cross sections of the HGUs that extend across the model domain, and overlay these sections on the proposed model layers. Finally, we are also considering calibrating the model to hydraulic heads from key wells going back to 2005 as well as data from the upcoming synoptic study.	Done		Flow Model	
70	BWS Comment #7: Based on the feedback from the SMEs to date, it appears that substantial changes to the 2007 groundwater flow model (DON, 2007) are required even before the Navy has completed its presentations about the modeling approach. These changes go beyond the AOC's stated objective of "refining the groundwater flow model". Shouldn't the AOC Parties revise the AOC Statement of Work to reflect this understanding? The most efficient and realistic approach given all the work needed to develop a defensible model is to create a new groundwater flow model and not update the 2007 groundwater flow model.	7/3/17	We are refining the 2007 groundwater flow model as stated in the AOC's objectives. There is useful information in that model pertinent to the current objectives. Also, starting the process of updating the 2007 model has been very informative and useful in planning the update. We are also now considering use of other recently published modeling codes, including MODFLOW NWT and the MODFLOW USG model in place of MODFLOW 2000 used for the 2007 flow model, and we plan to present pros and cons of these alternative models for discussion with the groundwater modeling working group. Finally, we have this model in the GMS framework and therefore it is relatively straightforward and efficient to change any of its conceptual elements or the numerical grid.			Flow Model	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
71	**Meeting #3 (8/17/17) Navy Action Items**						
72	At next working group meeting outline future group meeting schedules and modeling updates; layout plan for model development and review	9/20/2017	We intend to hold monthly meetings (as needed) with determination of the need for F2F or Webinars as appropriate	Done		Other	
73	Decide if model files will be included in preliminary model	9/20/2017	Per our formal response to BWS comments, model input and output files will not be provided until the model is finalized and security issues are addressed (as we discussed in the last meeting related to preventing sensitive information from being released to the public). Furthermore, the model input files may be provided with the following caveats: 1) BWS agrees that they will not change any of the input data without concurrence from the Navy and that all data is secured from the public domain, and 2) BWS may request the Navy to run a reasonable number of scenarios for which the Navy will provide output. Finally, the Navy will also request that any model input/output files being run by BWS and their consultants also be provided to the Navy for evaluation.	Security issues are still being addressed		Initial Model	
74	Establish plan for interim model development and review, including critical path schedule	9/20/2017	The GWMWG will meet regularly to review model development, progress and interim results as described in item #2.	Done		Initial Model	
75	Detail approach for conducting uncertainty analysis	9/20/2017	We plan on doing a bounding predictive sensitivity analysis to evaluate uncertainty	Will do		Flow Model	
76	BWS to report to Navy what data Navy requested they don't have	9/20/2017	The Navy is still awaiting response on various data availability. This is further described in the BWS well data spreadsheet.	Still trying to clarify some of the data		CSM-Hydrogeology	
77	Use MT3D to validate USG transport	9/20/2017	Will use MT3D to validate USG transport as detailed in the groundwater model evaluation plan	Will do		F&T Model	
78	Also use gradients for calibration	9/20/2017	Will use gradients with a focus on the current synoptic study for calibration	Will do		Flow Model	
79	Also use spring fluxes for calibration	9/20/2017	will use spring fluxes for calibration as detailed in the groundwater model evaluation plan	Will do		Flow Model	
80	Detail calibration method and approach	9/20/2017	Will use interactive expert calibration approach with automatic calibration using PEST as detailed in the groundwater model evaluation plan	Will do		Flow Model	
81	SWI2 will not be used as part of the flow model, but we request feedback from stakeholders on other approaches that meet project objectives	9/20/2017	Additional feedback has been received.	Ongoing		Flow Model	
82	Provide documentation and code for USG transport by end of September	9/20/2017	We have already committed to this	Done		F&T Model	
83	Detail approach to incorporate recharge into the model	9/20/2017	We will evaluate previous USGS recharge elements as a starting condition and revise local details (as appropriate) as detailed in the groundwater model evaluation plan	Ongoing		Flow Model	
84	Construct maps and cross sections for the model layers that show calibration targets	9/20/2017	This is detailed in the groundwater model evaluation plan	Ongoing		Flow Model	
85	Ensure calibration accounts for observed heads and groundwater flow directions	9/20/2017	This approach will focus on current heads observed in groundwater.	Will do		Flow Model	
86	Finalize 2nd order, class one survey data, including National Geodetic Survey review	9/20/2017	In progress files sent to National Geodetic Survey	Ongoing		CSM-Hydrogeology	
87	Compare new survey data with historical measurement point elevations and make corrections, as applicable, to historical groundwater elevations	9/20/2017	Will be conducted after the well elevation reports are finalized	Ongoing		CSM-Hydrogeology	
88	Determine bounds for discharge rates for wells to be used in the model for future estimated long-term rates	9/20/2017	Will consult with purveyors to obtain these estimates and future well locations	Ongoing		CSM-Hydrogeology	
89	Account for regional pumping effects in addition to individual well pumping effects	9/20/2017	USGS is still trying to finalize pumping schedules with BWS for current synoptic study	Ongoing		Flow Model	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
90	Reconcile well locations between what the Navy has and what the regulators have (especially CWRM and DOH)	9/20/2017	See BWS well data spreadsheet	Ongoing		CSM-Hydrogeology	
91	Send copy of map and spreadsheet of wells within the model area to all stakeholders	9/20/2017	This has been included in the GWMEP; spreadsheet was provided at the meeting	Done		CSM-Hydrogeology	
92	Complete data sharing agreement between stakeholders	9/20/2017	Discussions are underway between the Navy and BWS in this regard	Ongoing		Other	
93	Determine duration of synoptic water level study and pumping schedules it will cover	9/20/2017	This is being finalized with the Navy and USGS and needs BWS integration (see #89)	Ongoing		CSM-Hydrogeology	
94	Prioritize data request for BWS	9/20/2017	This has been done	Done		Other	
95	Recharge shapefiles from USGS	9/20/2017	Done	Done		CSM-Hydrogeology	
96	Send feedback on RTCs	9/20/2017	This will be provided at the meeting	Ongoing		Other	
97	Send out Action Item list	9/20/2017	This will be provided at the meeting and following future meetings	Ongoing		Other	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
98	**BWS 8/17/17 Mtg Comments (8/28/17):**						
99	BWS Comment #1: Thank you for the opportunity to participate in the third Red Hill groundwater modeling working group meeting held on August 17, 2017. We believe the discussion about the Navy's proposed groundwater flow and transport modeling continues to be valuable because of its technical rigor and the numerous contributions from Dr. Delwyn Oki of the United States Geological Survey (USGS), Robert Whittier of the Department of Health (DOH), and several BWS experts. We hope that the Navy and its contractors recognize the value of these contributions from Subject Matter Experts (SMEs) as they continue to develop the groundwater modeling work plan. We provide below a summary of important points from the meeting and our concerns about and recommendations for the Navy's groundwater model development.	8/28/17	Thank you for the comments and the opportunity to respond. The Navy has always understood the importance of dialogue between Subject Matter Experts (SMEs) for the modeling initiative as well as other related activities and also believes that the discussion about the proposed groundwater flow and transport modeling continues to be valuable because of its technical rigor and the numerous contributions from SMEs including Dr. Delwyn Oki of the United States Geological Survey (USGS), Robert Whittier of the Department of Health (DOH), Don Thomas (University of Hawaii), as well as other SMEs. We recognize the value of these contributions from SMEs as we continue to develop the groundwater modeling work plan and have evaluated every suggestion from the SMEs with regard to model development that achieves the objectives of the Navy. Finally, we view BWS's attempt to describe the USGS's position on various issues somewhat out of place and ask that they confine their comments to their own opinions. If the USGS or other SMEs have an opinion on various topics, they can speak for themselves as they deem appropriate. Perhaps the best forum for this to take place would be in comments related to the Issues/Action Items Summary that are being developed for this and future meetings.			Other	
100	BWS Comment #2 Navy Preliminary Flow and Transport Model: The Navy stated that they will create a preliminary flow and transport model (preliminary model) for the Red Hill groundwater flow system that will be documented in an early 2018 technical memorandum. This "interim" memorandum is intended to provide input information for the tank upgrade alternative (TUA) study. According to AECOM, the December 2017 deadline for the preliminary model work will require the preliminary model to be developed using data available now and in the immediate term. It appears that development of the preliminary model will likely not include very important new data to be collected from the proposed installation of new Navy monitoring wells in Halawa Valley or some or all the valuable data from the ongoing USGS synoptic water level study. Furthermore, the Navy has yet to provide any information about how the sources of contaminants will be represented (source term selection) or the specifics of the transport model development. The Navy verbally agreed in the meeting to include SME review of the preliminary model and its files. The BWS reiterates its request that the Navy provide a detailed description and schedule for the development, calibration, and application of the Red Hill groundwater flow and transport model and how results from the preliminary model will be used in the TUA task. There are insufficient data currently available about groundwater flow paths and aquifer properties in Halawa Valley between Red Hill and our Halawa Shaft to build a credible flow and transport model. A considerable amount of additional field data are necessary to develop a conceptual site model (CSM) for current critical areas of concern and past/future Red Hill contamination; to construct a defensible approach to simulate groundwater transport, and to quantify uncertainty in the transport predictions. The BWS has repeatedly pressed for such data to be collected and welcome the Navy's proposed new monitoring wells in Halawa Valley. However, our oft-stated concern about the defensibility of any model built without these necessary data remains unchanged. We ask that the regulatory agencies ensure timely technical review of the preliminary model and its files by SMEs before the preliminary model results are used or reported.	8/28/17	There are decisions that need to be made in a timely fashion in order to meet the timetable in the AOC for the Tank Upgrade Alternatives (TUA) decision. Results from the Interim modeling will be used to help inform decisions related to the TUA. If additional data are not available by the time the preliminary model is being developed, then they cannot be incorporated into the model, and decisions need to be made with the information that is available. This is why the Navy is proceeding as fast as possible in collecting new data in order to address this concern. The Navy will be simulating a range of conditions for valley fill (as described in the Groundwater Model Evaluation Plan). This was previously done as a sensitivity analysis by Oki (2005). As more data becomes available relative to valley fill, it will be integrated into the model. The Groundwater Model Evaluation Plan that was recently submitted by the Navy also generally describes how fate and transport will be dealt with in the modeling process. Much of this was verbally discussed during the last stakeholder meeting and will continue to be discussed at future meetings. The Navy will continue to consider stakeholder input on these efforts as we go forward.			Initial Model	
101	BWS Comment #3 Development of the Numerical Groundwater Flow Model: Much of the meeting's discussion focused on how the interactions between fresh groundwater and denser seawater should be represented in the Navy's model. These discussions made it plainly evident that the USGS, DOH, and BWS modeling experts disagree with the approach proposed by Dr. Sorab Panday, the Navy's modeling consultant (GSI Environmental, subcontractor to AECOM). Dr. Oki of the USGS and BWS experts expressed serious doubts that Dr. Panday's approach would provide a sufficiently accurate representation of the simple flow physics of fluids with varying densities. Dr. Oki suggested that Dr. Panday perform several simple model simulations that would show the bias and errors of his approach, but Dr. Panday would not agree to do so. The BWS supports Dr. Oki's suggestions and believes that a potentially important aspect of the Navy's	8/28/17	The comment states that "there are serious doubts that Dr. Panday's approach would provide a sufficiently accurate representation of the simple flow physics of fluids with varying densities" and that "important aspect of the Navy's model is an ability to simulate the evolution and changes of the thickness in the fresh water zone over time". However, as indicated in our response to comments on the June 26, 2017 meeting and in the presentation used for the August 17, 2017 meeting, our objective is not about flow of fluids with varying densities which lie hundreds of feet below the water table surface. Also, as detailed in our response to comments, the Oki (2005) model showed that the impact of pumping on the interface was small and	In Progress		Flow Model	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
	model is an ability to simulate the evolution and changes of the thickness in the fresh water zone over time. We request that the regulatory agencies ask the Navy to demonstrate that their approach of not simulating density dependent flow will not bias estimates of groundwater levels and flow rates over time within the model domain. Such a demonstration should begin with Dr. Oki's suggested test simulations. It appears that the Navy is planning to calibrate the groundwater flow model to observe groundwater levels and spring flows for the period from 2014 to the near present. Both the USGS and BWS are concerned that this length of time for demonstrating agreement between observations and model predictions is too short, even if the Navy includes a several year start-up period. Available groundwater level observations in the area of interest during this short period are very sparse and limited to only a few locations, which means the calibration will contain high uncertainty about the large model areas without any groundwater level observations. This high uncertainty can be reduced by calibrating over a longer time period, such as the calibration period used in Oki (2005). Both the USGS and BWS suggested that the Navy calibrate over the same time period used in Oki (2005) so that the Navy can: 1) reduce uncertainty about groundwater level predictions in large portions of the model; and, 2) generate a more defensible estimate of groundwater levels across the entire model area for present conditions. The BWS requests that the regulatory agencies direct the Navy to extend the calibration period to match that used by Oki (2005) in order to reduce uncertainties in model predictions. Dr. Sorab Panday and BWS experts agreed it is very important that the Navy include the effects of uncertainty on predictions from the groundwater flow and transport models using best modeling practices. Specifically, it was agreed that the Navy formally investigate the impacts of uncertainty in model components (boundary conditions, aquifer properties, initial conditions, etc.) on model predictions using constrained uncertainty analysis. BWS strongly recommends that the regulatory agencies direct the Navy to include such analyses as a required part of the CSM and the calibration and application of the flow and transport model. Mr. Mark Manfredi agreed that the Navy will provide the input and output files for the Navy preliminary and final groundwater flow and transport models to the BWS and other SMEs for technical review. The BWS appreciates the Navy's agreement and requests that the Navy's contractors include suitable times for SME review in their schedules for model development. AECOM agreed to provide a detailed schedule for the groundwater model development (both preliminary and final) in the next groundwater modeling working group meeting to be conducted the week of September 18, 2017. The Navy stated that it will include measured flow rates at Kalauao Springs and spatially varying recharge as part of its model development. Using spatially-varying recharge rates such as those from Engott et al. (2015) will likely improve the model's ability to predict groundwater levels. Comparing simulated and observed spring flow rates will also help improve the calibration of the groundwater flow model.		such small changes in salinity have a negligible impact on the simulated transmissivity of the freshwater aquifer. This is another example of how the Navy takes the comments of the SMEs very seriously. However, upon further analysis, several issues with running the SWI2 module of MODFLOW for this project were uncovered as we disclosed in the August 2017 meeting. We further evaluated and suggested two alternatives (including pros and cons) that have been commonly used to evaluate groundwater flow and solute transport in coastal systems when saltwater evaluations are not the objective of the analyses. Please see the response to comments on the June 26, 2017 meeting. The two approaches presented include the preferred approach which was to provide equivalent freshwater heads along the coastal boundary to conceptualize the deeper saltwater intrusion that occurs from the sea floor. This methodology is not novel and Dr. Panday has used this approach in modeling coastal aquifer systems during his career. Publications by Dr. Motz from the University of Florida also provide a validation of this approach for approximating the hydraulic heads in freshwater portions of a coastal aquifer (Motz, 2004; Motz and Sedighi, 2006). Dr. Panday was reluctant to perform experiments for fear that one could lead to another and then another which would then divert focus from the project. While we did seriously consider the expected results of running these simulations, this is now immaterial since we have decided to use another approach, as discussed below. In considering discussions from SMEs detailed in the August 2017 meeting, the Navy has had further internal discussions. It was clear in the meeting that the issue was not about the movement of the saltwater/freshwater interface beneath the pumping wells and was really about the reduction in freshwater transmissivity near the coast due to the presence of the interface. After all, the interface is over 800 feet below the pumping zone and there is a large horizontal anisotropy. Therefore, we will use the other approach discussed during the August 2017 meeting for simulating freshwater flow in coastal aquifer systems. This method provides a no-flow boundary across the saltwater interface. This approach also captures the freshwater transmissivity zone using a constant density model like MODFLOW. The method is also widely applied for simulating coastal aquifers when saltwater intrusion itself is not the objective. It has been successfully used in Hawaii for example, by Glenn et al, 2013; Ghazal et al, 2017, Whittier et al, 2010, Whittier et al, 2015. This approach is also used for modeling coastal aquifer systems elsewhere. For example, prominent researchers at the USGS have used MODFLOW-2005 in a similar setting to conditions of the Red Hill model, whereby their objective was to delineate capture zones in a coastal aquifer system (Brakefield et al, 2013). A search of USGS Florida Water Science Center Publications itself shows several constant density models being used in coastal aquifer systems when saltwater intrusion is not the objective as in the Red Hill Model case. As another example, the publication by Paschke (2007) contains several examples of MODFLOW models developed in coastal or saline settings to evaluate transport of contaminants including two in the Tampa area, and one in the Salt Lake Valley area. Conversely, we have not come across any publication that includes density dependent saltwater intrusion processes for investigations that do not directly focus on saltwater interactions (i.e., solute transport analyses). We are therefore following a defensible approach for groundwater flow, particle tracking and transport simulations, which has been previously used, tested, published, and is widely accepted by the scientific community. At the August 2017 meeting, we presented a model calibration strategy that uses annual average steady-state flow conditions similar to current conditions. The				

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
			resulting steady-state flow model will be used to evaluate long-term strategies. We also presented a model calibration strategy for shorter-term seasonal transient conditions, if such data are available. The Navy would use such a model for scenario evaluations related to transient (shorter-term) conditions and changes. We suggested an initialization approach for the transient simulations with a 1-year initialization period. The only objection we heard to this strategy at the meeting was to use a longer initialization period, to which we agree, if that is needed. For the simulation of long-term steady-state conditions, we will use all available pertinent data including historical data to calibrate the model so that no pertinent data will be ignored. We will review, evaluate, and where appropriate, utilize long-term water level trends and extrapolate older data within the model domain onto the current time-frame incorporating all available information. A higher weight will be assigned to the recent synoptic water level data during model calibration and a lower weight will be applied to the extrapolated older data. While there was discussion on the topic of model uncertainty at the August 2017 meeting, Dr. Panday did not agree that "it is very important that the Navy include the effects of uncertainty on predictions from the groundwater flow and transport models using best modeling practices. Specifically, it was agreed that the Navy formally investigate the impacts of uncertainty in model components (boundary conditions, aquifer properties, initial conditions, etc.) on model predictions using constrained uncertainty analysis". Rather, Dr. Panday only agreed that use of constrained uncertainty analysis will be evaluated and specifically noted that he does not commit to anything without discussions with and consent of the Navy. This issue is being further discussed with the Navy and a decision will be forthcoming. The model codes are publicly available. In addition, the model GUI (GMS) is proprietary and is available for sale. The GIS database will be continued to be updated and SMEs (including BWS) will be provided with those updated databases as they become available, once the associated security issues are addressed (as discussed in our last meeting). Furthermore, BWS must agree to not change any of the data in the GIS database without the Navy's approval and that all sensitive data will be secured from the public domain. Model input and output files will not be provided until the model is finalized and security issues are addressed (as we discussed in the last meeting related to preventing sensitive information from being released to the public). Furthermore, the model input files may be provided with the following caveats: 1) BWS agrees that they will not change any of the input data without concurrence from the Navy and that all data is secured from the public domain, and 2) although not agreed to in the meeting, the Navy may agree to running a reasonable number of scenarios at BWS's request after the model is calibrated for which the Navy will provide output. Finally, the Navy will also request that any model input/output files being run by BWS and their consultants also be provided to the Navy for evaluation. The Navy is under an extremely tight deadline for finalizing model development and currently intends to submit the model results in mid-January 2018. In order to minimize possible issues with model development, the Navy is fully committed to meeting with SMEs on a regular basis to discuss various modeling issues in an effort to keep an open communication throughout the process. The Navy will provide a general schedule for development of both the preliminary and final groundwater models at the next Groundwater Modeling Working Group Meeting scheduled for September 22, 2017. Available flow rates for springs (including Kalauao Springs) and spatially varying				

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
			recharge rates within the modeling domain will be used as appropriate in the development and calibration of the model.				
102	BWS Comment #4 Development of the Groundwater Transport Model: Dr. Sorab Panday proposed to use the MODFLOW-USG (unstructured grid) flow code to simulate groundwater flow and a currently unverified USG transport code to simulate migration of groundwater contaminants. The MODFLOW-USG flow code has been tested for numerous cases over the last several years and its documentation and source code have been available from the USGS for review over that same period, all of which make it a suitable choice for flow simulation. The BWS has serious concerns about the suitability of the USG transport code for the Red Hill project. According to Dr. Panday, the USG transport code has been applied to only two projects, for which there are no final reports available for review, and the source code and documentation will only be made available in September 2017. This means that the Navy's recommended modeling tool to predict migration of contaminants (transport) will have undergone very limited review and testing prior to being used for the Red Hill modeling, raising the possibility of significant errors in model predictions. Moreover, GSI has not demonstrated that the model input and output files can be easily and accurately modified and visualized using conventional MODFLOW interfaces such as Groundwater Vistas or Groundwater Modeling Systems (GMS). The BWS recommends that the regulatory agencies and the Navy avoid using MODFLOW-USG transport and instead adopt a very well tested and understood transport code paired with a suitable groundwater flow code. The combination of codes should also correctly simulate the variable density interactions between freshwater and seawater.	8/28/17	The Navy conducted a careful analysis for the use of different models and presented a table describing the pros and cons for various potential models as they relate to the Navy's modeling objective. The Navy has selected MODFLOW-USG for the reasons we discussed during the August 2017 meeting since this code best allows the Navy to meet its modeling objectives. The transport module within MODFLOW-USG using unstructured grids has been available within the Groundwater Vistas Interface for several years now and may have been used more by others unbeknown to us. Testing of the transport modules of USG-Beta is admittedly limited and therefore the Navy will test the modules against results from MODFLOW-NWT / MT3D for the same hydrogeologic setup as with MODFLOW-USG. As discussed at our August 2017 meeting, all 3 codes which were discussed are available within the GMS framework and therefore conversion from one set of codes to another is straightforward. The advantages of proceeding with MODFLOW-USG were discussed at the August 2017 meeting and include robust and efficient simulations for developing and calibrating the Red Hill model.	Resolved. MODFLOW USG will be used as the primary model		Flow Model	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
103	**Meeting #4 (9/22/2017) Navy Action Items**						
104	General Model Concerns						
105	Respond to BWS' primary model concerns: • Lack of data • Concern with relatively flat, but still dynamic, GW gradients • Uncertainty analysis • Geometry and properties of valley fill • Freshwater head boundary	10/19/2017	• There is sufficient data within the Red Hill Area to help calibrate a groundwater model for evaluating groundwater migration of contaminants from Red Hill. Also, we are collecting additional data to establish the communication between Red Hill and the BWS wells. • We are evaluating gradients between nearby wells which will be a included in the calibration effort. • We will conduct a predictive sensitivity analysis to establish bounds on results considering reasonable ranges of parameter values. BWS consultants agreed that is an acceptable approach. • We are collecting data to try to establish geometry and properties of valley fill. Also, we are evaluating the results of synoptic studies (conducted in 2006, 2015) to further consider potential connectivity between Red Hill and the Halawa Shaft. • The model will only simulate the freshwater portions of the aquifer and the bottom boundary will be located at the freshwater/saltwater interface. As noted earlier, we will not be simulating the freshwater head approach that was first provided as an alternative to including saltwater in the simulations (this is an update to #101).	Done		Flow Model	
106	Determine appropriate ranges/bounds for key groundwater parameters (i.e., recharge, K, porosity, etc.)	10/19/2017	We are establishing ranges/bounds for key groundwater parameters.	Ongoing		CSM-Hydrogeology	
107	Show the sensitivity analyses previously done, and their results, for determining appropriate bounds for key parameters.	10/19/2017	A literature review of previous analyses will be provided in the groundwater modeling report and will include key findings including sensitivity analyses.	Ongoing		Flow Model	
108	Look at range of valley fill/recharge sensitivities	10/19/2017	We will consider valley fill and recharge in sensitivity analyses	Will do		CSM-Hydrogeology	
109	Interim Model Calibration						
110	Determine direction of groundwater flow within the model area and evaluate the effect of pumping scenarios on flow direction	10/19/2017	We are evaluating gradients between nearby wells which will be a included in the calibration effort. We will evaluate various pumping scenarios for their impact on flow and direction	Ongoing		Flow Model	
111	Use 2015 USGS synoptic water level study data to calibrate the interim model against steady state and transient conditions	10/19/2017	Yes	Will do		Initial Model	
112	Focus uncertainty analysis on Hālawa Shaft under a range of pumping and K (valley fill) values	10/19/2017	We will conduct uncertainty analyses for a range of concerns including reasonable pumping rates at Halawa Shaft and established bounds of valley fill K-values	Will do		Flow Model	
113	Evaluate K values in GW Model Evaluation Plan and determine if they are appropriate for use in the model (values were from Maui)	10/19/2017	We are establishing ranges/bounds for key groundwater parameters including K-values. (see #106)	Ongoing		CSM-Hydrogeology	
114	Evaluate using dual porosity for transport	10/19/2017	We will consider use of dual porosity transport for evaluating migration of solutes.	Ongoing		F&T Model	
115	Evaluate the pumping ranges to be incorporated into the interim steady-state scenario, and determine how to calibrate them. Include past pumping data in this effort.	10/19/2017	The steady-state interim model will use average conditions for the steady-state scenarios. We are considering various past conditions including 2006, 2015 and 2016 conditions since good synoptic data is available during those time periods. Pumping data assembled for evaluation	Ongoing		Initial Model	
116	Use past and current synoptic data to establish a head field	10/19/2017	Yes. See response above.	Will Do		Flow Model	
117	Evaluate heads going down with depth from fresh water into salt water in SUTRA model	10/19/2017	We are evaluating heads at different depths in the SUTRA model to establish vertical gradients.	Will Do		Flow Model	
118	Set time period for calibration	10/19/2017	See comment number 115 above.			Flow Model	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
119	Use USGS recharge map from Engott report as starting point for model recharge	10/19/2017	Yes.	Will do		CSM-Hydrogeology	
120	Model Boundaries						
121	Conduct sensitivity analyses to evaluate model boundaries	10/19/2017	We will perform sensitivity analyses on model boundaries to establish their impact on calibration as well as on the predictions.	Will do		Flow Model	
122	Determine how to address uncertainty in layer properties and bottom boundary	10/19/2017	Sensitivity analyses will be conducted on the predictions of interest to evaluate the impact of uncertainty in bottom boundary and layer properties. Will report out at next meeting	Will Do		Flow Model	
123	Evaluate impact of model boundary conditions on flow generation within the model area	10/19/2017	Please see response to comment 121 above.	Will do		Flow Model	
124	Deliverables and Upcoming GWMWG Meetings						
125	Send out Navy responses to Action Item list from last GWMWG meeting to all meeting attendees (by 9/29/2017)	10/19/2017	This will be an ongoing effort associated with each GWMWG Meeting. Issues/Actions and comments will be sent out prior to each meeting.	Ongoing		Other	
126	Send Navy Action Item list for this GWMWG meeting to all meeting attendees (by 9/29/2017)	10/19/2017	See 122	Ongoing		Other	
127	Provide updated priority list to BWS of wells and data, with a map domain	10/19/2017	Yes. AECOM/Navy is preparing an updated list of questions to help resolve various discrepancies in the data	Ongoing		CSM-Hydrogeology	
128	Provide an update on the interim model at the next GWMWG meeting	10/19/2017	Yes	Will Do		Initial Model	
129	Present the updated CSM in October 2017	10/19/2017	This meeting has been rescheduled for the week of November 13th	Wil Do		CSM-Hydrogeology	
130	Submit Interim Modeling Report in early February 2018; be sure to include discussion of Delwyn's models, as well as Oki and Gingerich and Whittier	10/19/2017	Yes	Will Do		Initial Model	
131	Coordinate with BWS and EPA Data Sharing Group to finalize a data sharing agreement, and iron out details on the GIS database	10/19/2017	The Navy is coordinating this effort	Ongoing		Other	
132	Other						
133	Request new BWS well log from CWRM	10/19/2017	In progress	Ongoing		CSM-Hydrogeology	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
134	**BWS 9/22/2017 Meeting Comments (10/18/17)**						
135	There is a lack of important hydrogeologic data near the RHBFSF. The most important data gaps are a) characterization of the spatial variability in the basalt hydraulic properties; b) identification of possible preferential flow paths through clinkers, lava tubes, or fractures; c) recharge rates; and d) hydraulic head gradients near the RHBFSF. We remain concerned that the Navy modeling team will overlook the importance of the uncertainties caused by these data gaps to their risk assessment or make unjustified simplifications about Red Hill hydrogeology to streamline and shorten the data analysis and modeling tasks. A key part of the Conceptual Site Model (CSM) that remains missing is a description of how the hydrogeology will be parameterized and the upper and lower boundaries for these parameters. According to the groundwater model evaluation plan (DON, 2017), the Navy is following American Society for Testing and Materials (ASTM) 5981-96 (Calibrating a Groundwater-Flow Application), which states the parameterization and setting of boundaries should be completed before any model simulations are performed; however, the Navy's proposed approach appears to contradict the ASTM guidelines as they have yet to present the recommended ranges of parameter values and boundary settings.	10/18/2017	This comment has been made several times already by BWS to which the Navy has responded. Hydrogeologic data will be described in the CSM. Additional significant hydrogeologic information is becoming available in the Red Hill area relative to clinker zones (including the Red Hill shaft log from Stearns), valley fill/weathered basalt, gradients. recharge rates, etc. This data will continue to be incorporated into the CSM. As additional data become available the CSM will be further updated. Due to the significant thickness of valley fill/weathered basalt which acts as a potential barrier to flow, some of pathways take on a lower significance relative to Halawa Shaft. The boundary conditions will be finalized before simulations are performed. We have presented the conceptual model including boundary types (WEL, GHB, etc) proposed for the model at previous meetings. We are in the process of assimilating the data to implement boundary conditions values. Parameter values will be completed when the model calibration is completed. Calibration targets will be established before any model simulations are performed. In addition, we are glad the BWS views the ASTM standards and guidelines appropriate for modeling applications; however, to set the record straight, D5981-96 does not state that setting of boundaries or calibration targets must be completed before any model simulations are performed.	Ongoing		CSM-Hydrogeology	
136	Groundwater head gradients are dynamic and very flat. Partly because of the basalt's very high transmissivity, small differences in water levels can significantly change the direction and velocity of groundwater flow. Besides being relatively flat, hydraulic gradients near Red Hill are very dynamic (changing with time) because of the temporal variability in the large pumping rates at Red Hill Shaft and Halawa Shaft and because of the large temporal and spatial variations in recharge rates near and upgradient of Red Hill. To date, the Navy has yet to describe the water levels and hydraulic gradients that characterize the groundwater flow direction and velocity in this area. This characterization should include a discussion of the potential importance of measurement error in the water levels: transience in the water levels caused by natural processes such as barometric changes, recharge, and pumping; and, how assumptions about basalt hydraulic properties affect inferred groundwater flow directions. A key part of the CSM that remains missing is the error bars associated with the water levels that will be used for calibration targets. According to ASTM 5981-96 (Calibrating a Groundwater-Flow Application), which the groundwater model evaluation plan (DON, 2017) states that the Navy is following, calibration targets should be established before any model simulations are performed.	10/18/2017	We are following ASTM standards, please see Response #105. As such we are assimilating water level and spring flow data for use as calibration targets.	Ongoing		CSM-Hydrogeology	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
137	An uncertainty analysis is needed. The RHBFSF stores an enormous amount of fuel above Oahu's sole-source aquifer and near to one of the BWS's most important drinking water supply points. As such, the continuing deterioration of the steel and concrete in the Red Hill tanks poses a risk to the drinking water supply for much of Oahu. Understanding this risk should be a necessary first step before the AOC Parties choose a tank upgrade alternative (TUA). Therefore, the interim model should estimate the risk by capturing likely outcomes of contaminant migration from Red Hill given the data gaps and uncertainties. The same is true of the final model. During the 3rd GWMWG meeting, BWS asked if the Navy modeling team will conduct an uncertainty analysis to quantify risk given the lack of data to characterize the site hydrogeology, the very flat hydraulic gradients, and the potentially important transience of the system. BWS was pleased to hear that Dr. Sorab Panday state that such an analysis would be valuable and would be conducted. Dr. Panday and the BWS discussed that the null-space Monte Carlo method is a proven approach for quantifying uncertainty, is documented in several USGS reports, and is often implemented using the PEST software (Watermark Numerical Computing, 2016). BWS believes that the sensitivity analysis briefly discussed by the Navy's modeling team will not provide an estimate of risk to groundwater that is as defensible as the risk estimate from an uncertainty analysis. During the September 22nd meeting, BWS stated that the uncertainty analysis that includes the null-space Monte Carlo method is one of the most defensible ways to quantify the range of possible groundwater flow paths from Red Hill tanks to potential receptors given the uncertainty in important hydrogeologic variables and processes caused by the lack of data and information. Such an uncertainty analysis would describe the range of possible flow paths using "spaghetti" plots of particle tracks from Red Hill generated from the various reasonably calibrated flow models. These plots could then be used to estimate the risk to Oahu drinking water. The Navy's modeling team did not explain how their sensitivity analyses would be done, but the BWS believes that sensitivity analyses will describe variations in a single "spaghetti strand" and, unlike the uncertainty analysis, will not estimate the risk by evaluating all the strands.	10/18/2017	Likely outcomes of contaminant migration from Red Hill will be simulated given the data gaps (which are being addressed) and uncertainties. Regarding sensitivity analyses, our approach discussed is defensible and there is no justification for "evaluating all the strands" as noted in our discussion at the last meeting. The goals of the Navy's modeling efforts are to help understand flow gradients, contaminant fate and transport as it relates to the potential impacts to water supply wells from releases at Red Hill under a range of reasonably conservative pumping scenarios. The Navy's intent is to do this in a technically defensible manner given the time frame we have. Applying the null-space Monte Carlo method is not necessary to evaluate groundwater flow paths from Red Hill tanks to potential receptors. A Monte Carlo analysis will not add any information about the principal hydrogeologic factors that control groundwater flow directions. Groundwater flow directions are primarily controlled by hydraulic gradients, which are defined by the spatial distribution of hydraulic heads (groundwater levels). Subsurface barriers such as valley fill deposits and saprolite can also affect groundwater flow. At this site the other hydrogeologic factors are much less important in defining groundwater flow paths. To address these primary uncertainties, hydraulic gradients and subsurface barriers, the Navy is currently installing additional wells, collecting geologic information on subsurface barriers and monitoring hydraulic gradients. Groundwater monitoring is also being conducted by the US Geological Survey, during periods of controlled pumping at Halawa Shaft, Red Hill Shaft and the Moanalua area wells. As true for any groundwater flow evaluation, some uncertainty will remain even after new data define these two primary hydrogeologic factors. However, this uncertainty can be adequately addressed by the sensitivity analysis described during the last working group meeting. This sensitivity analysis will be consistent with the ASTM D5447: Standard Guide for Application of a Ground-Water Flow Model to a Site-Specific Problem. This ASTM guide states: "Sensitivity analysis is a quantitative method of determining the effect of parameter variation on model results. The purpose of a sensitivity analysis is to quantify the uncertainty in the calibrated model caused by uncertainty in the estimates of aquifer parameters, stresses, and boundary conditions". Performing a more computationally intensive uncertainty analysis, such as the Monte Carlo method, will not provide any additional information to better characterize or more precisely define the most important hydrogeologic factors. Rather, the Monte Carlo method would require more assumptions about the uncertainty in each hydrogeologic parameter and a significantly longer time to run, thus reducing the number of simulations. Therefore applying the Monte Carlo method is inappropriate and not useful to meet the objective for this modeling project. Finally, the Navy will be evaluating use of sentry wells as determined by the analyses, to guard against the impact of uncertainty.	Ongoing		Flow Model	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
138	Base case scenario for interim model should not have valley fill. During the 3rd GWMWG meeting, BWS stated that, given the lack of data to characterize the three-dimensional geometry and hydraulic properties of valley fill, the base case or default assumption for the interim model should be there is no valley fill below the water table between Red Hill and Halawa Shaft. BWS suggests that an updated CSM define the valley fill characteristics (geometry below water table, hydraulic properties) as model calibration parameters and to provide upper and lower bounds for those parameters.	10/18/2017	As previously stated, in at least 12 of our past responses to this and related repetitive BWS comments (see #7, #10, #12, #13, #16, #18 #19, #20, #21, #66, #111, and #112), the Navy will evaluate a range of conditions related to valley fill/weathered basalt (saprolite) relative to hydraulic conductivities and valley fill/weathered basalt geometry acting as a potential barrier. Higher weighting will be applied to those characteristics that 1) correlate to defensible geologic interpretation of prior studies, well logs, borehole geophysics, etc., 2) evaluation of water level data including pumping events to help ascertain the presence of boundary conditions, 3) seismic interpretations, and 4) Westbay permeability testing. Our intent is to use the most technically defensible approach for evaluation of valley fill/weathered basalt potentially acting as a barrier to flow and chemical transport that allows for proper model calibration. Further, we will conduct sensitivity analyses specifically on this issue to evaluate the impact of uncertainties to the calibration and to the prediction.	Ongoing		CSM-Hydrogeology	
139	Use of freshwater heads instead of density-dependent flow - During the 2nd and 3rd GWMWG meetings, BWS and Dr. Delwyn Oki from the USGS expressed concerns that the "freshwater head" approach proposed by the Navy's modeling team is an inappropriate simplification of the conditions near the ocean boundary and would introduce errors in groundwater flow paths. In response to this concern, the Navy's modeling team proposed to use a no-flow boundary to mimic the effects of the density-dependent flow. During this explanation of how the no-flow boundary would be implemented, Dr. Oki and BWS noted several major problems with the approach proposed by the Navy. Dr. Panday acknowledged these concerns but could not address them at the meeting and committed to revisiting the issue. To help address our concern with the Navy modeling team proposed "no-flow" approximations to represent the effects of density-dependent flow, BWS requested that comparisons be made between a model using the Navy's approach and a model that properly solves for density-dependent flow and uses the parameters from the Navy's calibrated model. During the 4th GWMWG meeting, BWS made it clear that the approach proposed by the Navy to use a no-flow boundary to represent the transition between fresh water and underlying seawater is contrary to the ASTM standard 5609-94 (Defining Boundary Conditions in Groundwater Flow Modeling), which, in the groundwater model evaluation plan (DON, 2017), the Navy states that they are following.	10/18/2017	The apparent concern from USGS SME was that water levels near the coast may not be as high as we had indicated. Dr. Panday did not commit to revisiting this issue. He mentioned that the Navy team is still collecting data and that we will evaluate the data when it is all assimilated to finally set the bottom boundary depth nearer to the coastline. BWS now suggests we use a density-dependent flow model. Previously, they suggested we use a sharp-interface model using the SWI2 package. We have shown the restrictions with the SWI2 package including its inability to use the flow-field generated to perform transport or particle tracking simulations. BWS experts mentioned they had a call in to the author of the SWI2 package to ascertain if that was true and look forward to hearing their response at the next meeting. However, BWS experts could have noted that from simply reading the SWI2 document leading one to question if they are really familiar with SWI2 and its restrictions. In any case, a density-dependent model is already available. It is the SUTRA model of Dr. Oki. We are evaluating results from this model as well. Modeling efforts being conducted by the Navy team is appropriate and defensible as discussed previously. It is not contrary to ASTM standards as claimed by BWS. In fact, ASTM 5609-94, which BWS experts reference, explicitly states "If diffusion is neglected and the salty groundwater seaward of the interface is assumed to be static, the freshwater-saltwater transition zone can be treated as a sharp interface and can be taken as the bounding stream surface (no-flow) boundary of the fresh ground-water flow system". This is exactly what we are doing and it is appropriate for our objectives.	Ongoing		Flow Model	
140	Hydraulic Properties of Basalt - The Navy's groundwater model evaluation plan states that "In the Facility vicinity, the arithmetic mean, geometric mean, and median values of hydraulic conductivity for dikefree volcanic rocks were respectively 1700, 900, and 1200 feet/day (DON 2007)." However, these values are from a hydrogeologic study of Maui (DON, 2007; Rotzoll and El Kadi, 2007), not of the Red Hill vicinity. Factual errors like these in part drive our concerns about the Navy modeling team's grasp of the hydrogeology of Oahu's Moanalua and Halawa Valleys. BWS is concerned that the Navy modeling teaming will use a simplistic model to represent the basalt properties instead of focusing on the significant heterogeneities in basalt that act as preferential pathways. These include clinker zones, lava tubes, and fractures. A simplistic representation of basalt is typically appropriate for regional models addressing water supply issues, but it is not appropriate for risk assessments that focus on contaminant transport at the scale of hundreds to thousands of feet in which the preferential pathways are critical.	10/18/2017	As previously described in various responses to BWS on this topic (including responses #68, #105, #106, and #113), the Navy is evaluating both literature values (especially from prior modeling exercises in this area) and site-specific properties of basalt hydraulic properties. Site-specific data will include evaluation of a range of conditions from clinker zones to weathered basalt (saprolite). This site-specific data, where available, will be used to support the modeling effort. In particular, where we have data that represents significant impacts to flow (such as the clinker zones at Red Hill where the source area is), we will integrate that data into the model. Otherwise, we will use effective parameter values representative of the basalt (as other modelers have done) elsewhere in the model domain.	Ongoing		CSM-Hydrogeology	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
141	Hydraulic Head Data - The Navy modeling team proposed to use a steady-state model calibration to average conditions in a period during 2015 for the interim model. The Navy modeling team stated this decision without presenting hydrographs from monitoring wells with water level data or discussing the transience in the calculated magnitude and direction of the hydraulic gradients. If the Navy groundwater modeling team uses a quasi-steady-state condition that has not been properly vetted, then the interim model could have biases and unknown errors in the model properties that will affect our understanding of the risk to groundwater but not be discovered until the Navy calibrates a model using transient water level conditions. The BWS is concerned that the decision for a steady-state calibration model seems to have been made out of expediency and not because it is an appropriate modeling approach for evaluating risk from groundwater contaminant transport. The Navy groundwater modeling team has not demonstrated from a risk assessment perspective why a steady-state calibration model should be used instead of a transient calibration model. Moreover, the task of developing calibration targets for a single steady-state calibration will introduce even more uncertainty into the model results than using transient calibration data. For instance, error bars for monitoring well water level and springs flow calibration targets for a steady-state model will be much larger than the error bars associated with the point measurements for the same monitoring well water levels and spring flows for a transient model.	10/18/2017	Hydrographs have been compiled from wells within the modeling domain (including 2016 synoptic data). In addition, new gradient maps are being developed that better represent our current understanding of the area hydrogeology. We are calibrating to the transient synoptic water level study as suggested by Dr. Oki. Finally, the Navy is developing it's risk assessment in a manner that is consistent with EPA and ASTM approaches. The Navy has addressed repetitive BWS comments relative to model calibration in various prior responses including #69, #78, #79, #80, #85, #101, #110, #111, #115, and #118.	Ongoing		Flow Model	
142	Recharge - The Navy groundwater modeling team stated that the recharge rates recently estimated by the USGS may be too high along Red Hill. The groundwater model evaluation plan states: "it appears that the low permeability of the thick saprolitic soil overlying the Red Hill ridge was not accounted for by the USGS study" (DON, 2017). The BWS is concerned that the Navy may be overlooking valuable information about ongoing recharge within Red Hill ridge and its saprolitic soil cover. There is ample evidence of recharge within the ridge, including historical and presentday seepage into the upper and lower Red Hill tunnels, even with the grouting of the tunnel ceiling and walls, and the extensive water collection system that sends water to the oil-water treatment system. The rate of recharge can be quite large based on the image of a worker standing knee deep in water while excavating a Red Hill tunnel in its recent historical video (see minute 1 :40 in . https://www.youtube.com/watch?v=0Bx81 rD206A&feature=youtu.be). The Navy should quantify the subsurface water flux, e.g., the water flux onto the tunnel ceilings, rather than focusing on the saprolitic soil because it is easy to see there is a significant amount of inflow into the Red Hill Ridge's interior based on what has been observed historically and what is currently observed in each RHBFSF tunnel. As part of the CSM, the Navy modeling team should provide a water budget for the Red Hill groundwater system, explain any concerns with the USGS recharge rates, and describe how they plan to parameterize recharge for the interim and final groundwater models.	10/18/2017	BWS has commented on this on at least 3 prior occasions (see #30, #83, and #119). Consistent with our previous responses, the Navy will utilize the USGS recharge map (Engott 2015) as a starting point. Soil studies and observations by the Navy contractor related to installation of monitoring wells (RHMW9, 10) indicate that surficial soils on top of Red Hill are saprolitic with relatively low permeabilities. Infiltrometer testing will be conducted to help verify this. Recharge will be adjusted from the USGS values to better reflect local conditions such as surface cover and soil permeabilities. BWS falsely states that "there is ample evidence of recharge within the ridge, including historical and present-day seepage into the upper and lower Red Hill tunnels, even with the grouting of the tunnel ceiling and walls, and the extensive water collection system that sends water to the oil-water treatment system". There is a water collection system within the access tunnels that was designed to capture and pump out water seeping into the tunnels. This type of system is common for subsurface structures such as Red Hill in order to prevent potential flooding and significant water intrusion into subsurface structures. Water seepage into the access tunnels has been very minimal and associated sump pumps used to remove seepage water into the tunnel operate very seldom. As a matter of fact, the little water that does seep into the access tunnel collection system, generally evaporates before it reaches the sump pumps. In addition, access tunnel construction records indicate very little water infiltration during construction. This is an excellent indication that seepage from the surface is minimal. Finally, the reference to the YouTube video as indicating that "the rate of recharge can be quite large" is very misleading since the tunnel shown in the video is the Navy's Red Hill Water Shaft (not the Red Hill tank access tunnels). An objective observation of the tunnel shown in the video demonstrates no resemblance to the access tunnels that extend through the tank farm. Red Hill shaft is a <u>water supply tunnel</u> completed along a deeper clinker zone at and below the water table. Of course, one would expect water infiltration in such a tunnel since that is what it is designed for. Water flowing into the Red Hill shaft tunnel has NO bearing on seepage within the Red Hill tunnels as BWS seems to imply.	Ongoing		CSM-Hydrogeology	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
143	Density-dependent flow - The Navy groundwater modeling team proposed to ignore density-dependent flow to reduce model run time. During the 3rd GWMWG meeting, the Navy groundwater modeling team could not answer USGS and BWS concerns about the Navy's proposed approach to use fresh-water head boundary conditions. During the 4th GWMWG meeting, the Navy groundwater modeling team could not answer concerns raised by the USGS and BWS about a proposed approach to use no-flow boundary conditions to represent the freshwater-seawater interface. In the 4th GWMWG meeting, it became readily evident that the Navy groundwater modeling team was unware of the measured groundwater levels near the caprock and that they would have to rethink how they will define and parameterize these boundary conditions.	10/18/2017	As previously stated (multiple times), density dependent flow is not the objective of this model as has been clearly stated time and again. Our freshwater proposed approach is also a valid approach and has been documented in the literature. We evaluated some of the concerns and the site information and chose an alternative approach that we presented in the 4th GWMWG meeting. There were no issues as to the approach but we were still in the process of evaluating the water level data. There was nothing to rethink but we will assess the bottom boundary location upon completion of evaluating this water level data. Also see our response #139.	Ongoing		Flow Model	
144	Transport - The Navy groundwater modeling team has not yet presented a conceptual plan to model transport. Key parameters such as source terms, biodegradation rates, porosity, and dispersivity values have yet to be presented. Equally important is the conceptualization of the migration distance, directions, and rates that fuel released from the RHBFSF can travel within the vadose zone located between the release points and the groundwater surface (water table).	10/18/2017	Contrary to the BWS assertion that the Navy has not presented a conceptual plan to model transport, the Navy has described this at the meetings and in our responses, including #45, #58, #100, #77, #86, and #114. To be clear, minimal attenuation information is likely to be available for the interim model and it will likely be based on conservative assumptions. As attenuation data becomes available, appropriate rates will be used in the USG transport model that will be developed next year. In addition, as we have said several times, MT3D will be used to help verify the USG transport model. Various approaches to LNAPL migration evaluation are being considered as discussed at the last F2F meeting including analytical and numerical simulations.	Ongoing		F&T Model	
145	How Can Proposed Interim Modeling Approach Properly Assess Risk to Aquifer? - During the third GWMWG meeting, the Navy groundwater modeling team stated that they will create an interim flow and transport model for the Red Hill groundwater flow system that is intended to provide input information for the tank upgrade alternative (TUA) study. Given that proposed TUAs span a wide range of risks of fuel release, the interim modeling should directly and defensibly evaluate the risk that groundwater contamination from Red Hill can migrate to Halawa Shaft and other water supplies. Otherwise, how will the Regulatory Agencies be able to make a defensible TUA choice? From the BWS's perspective, if the risk of Red Hill contaminant migration to Halawa Shaft (or other water supplies) is significant, then a TUA with a low risk of release should be chosen. We hope that the Regulatory Agencies share this same perspective. The Navy's proposed steady-state approach replaces numerous individual groundwater level measurements with a single average for each well location. Similar averaging must be applied to the time-varying pumping rates and spring discharges. This means the averaged calibration targets for water levels and spring flow will each represent a composite value that will have much larger error bars than would the individual values used to create each averaged target. Instead of estimating aquifer properties by calibrating the groundwater model to many different hydrologic conditions represented by the changes in pumping and recharge over time, the Navy's approach is to create a single and hypothetical condition based on averages and then presume that the hypothetical condition represents steady-state conditions that are important for understanding risks from contaminant migration. The BWS has concerns with the steady-state approach for several reasons. First, the assumption that average conditions represent steady-state conditions is not necessarily true. Steady-state conditions require that the total inflows into (recharge, lateral flows) the groundwater model domain perfectly balance the outflows (pumping, springs, lateral flow) from the groundwater domain so that the water levels and flows do not change over time. This means there is no change in the amount of water stored in the aquifer. The period over which the water levels are being averaged is, by definition, not steady-state if the inflows and outflows are changing or if the amount of water stored in the aquifer is changing. If the Navy wishes to force the steady-state assumption, then BWS recommends that the Navy evaluate the aquifer properties and their estimates of recharge and boundary condition choices from their "steadystate" interim model calibration by using them to simulate other hydrologic data sets from other years. Another BWS concern with a steady-state calibration is that it will not provide any information about the storage properties of the basalt aquifer. Storage properties are necessary for understanding how quickly changes in pumping rates (such as those expected when a fuel release occurs and those for remediation design) affect groundwater flow directions and rates. The BWS supports the transient calibration approach described by Dr. Oki during the third GWMWG meeting. Dr. Oki and the BWS pointed out that a transient calibration will provide a way to	10/18/2017	We are not trying to simulate every fluctuation that happened in history. There is always averaging included in any model or simulation. We are trying to develop a model to use it to evaluate flows and transport under Red Hill. Just because you capture some transient changes does not prove anything since you add that many more unknowns that can also be tuned to capture those changes. We will be using the transient responses to the synoptic studies to evaluate the transient response and further characterize the system as suggested by the Dr. Oki at the last GWMWG meeting. The current synoptic study has several different hydrologic conditions with different pumping rates. From a risk standpoint, the Navy is following accepted protocols for evaluating risk as outlined in ASTM RBCA standards (for which Mr. Stanley was a principal author and trainer) and EPA protocols. The Navy is also planning on use of sentry wells to help ensure that unacceptable risks are prevented/minimized.	Ongoing		Initial Model	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
	estimate, or at least bound, the storage properties. A transient calibration run over a sufficiently long-time period will also test the choices of recharge rates and other boundary conditions. Thus, the steady-state calibration approach proposed by the Navy groundwater modeling team will not be able to investigate potentially important dynamics that could be critical to characterizing the groundwater flow system. Yet another BWS concern is that the Navy's approach for model calibration is contrary to ASTM 5981-96 (Calibrating a Groundwater-Flow Application), which the groundwater model evaluation plan (DON, 2017) states the Navy is following. In order to help address the problem of nonuniqueness, ASTM 5981-96 recommends calibrating to data collected from multiple distinct hydrological conditions. At Red Hill, the primary site conditions that will create distinct hydrological conditions are different pumping rates and recharge rates, which exist in the transient data, but are lost when averaged and used in a steady-state simulation. Given the large uncertainties about how hydraulic conductivity, storage properties, and recharge vary across the RHBFSF and its vicinity, the BWS fully supports the recommendation for a constrained uncertainty analysis made by Dr. Panday during the third GWMWG meeting. The BWS believes that the Navy modeling team should revise their modeling approach to instead yield defensible estimates of the risk from RHBFSF fuel releases of various magnitudes to our water supplies that will be useful and appropriate for the TUA selection process.						
146	Interim Model Will Incorporate Little to No Data from New Monitoring Wells - There are insufficient data currently available about groundwater flow paths and aquifer properties in Halawa Valley between the RHBFSF and the BWS Halawa Shaft to build a credible groundwater flow and transport model. A considerable amount of additional field data about geology, groundwater levels, groundwater chemistry, and hydraulic properties are needed to: • Develop a CSM for current and future Red Hill contamination; • Construct a numerical model that defensibly simulates groundwater flow and transport, and, • Quantify uncertainty in the contaminant migration predictions. The BWS has repeatedly recommended such data be collected and welcomes the Navy's proposed new monitoring wells in Halawa Valley. However, given the impending deadline for the interim model and the fact that drilling of the first off-Site well has only just begun, it appears that little to no new data from Halawa Valley will be used in constructing and calibrating the Navy's interim groundwater model. The new monitoring wells and associated aquifer testing will provide some of the data needed to better understand groundwater flow and solute migration in this critical area. If few to no new data will be ready in time for the interim groundwater model, then the Navy should use a constrained uncertainty analysis to evaluate the effects of all the likely properties and stresses in this area on the risk of contaminants migrating from the RHBFSF to Halawa Shaft and other water supply points.	10/18/2017	We have discussed this also before. You make decisions with the information you have and whatever information that is available for use by the model in a timely manner will be used. We currently have sufficient information to develop a credible interim model and as additional information is obtained, it will also be utilized in the model.	Ongoing		Initial Model	
147	MODFLOW-USG Transport Code is Unverified and Proprietary - Dr. Panday proposed to use his currently USG transport code to simulate migration of groundwater contaminants for the Navy's interim and final groundwater models. The BWS has concerns about using an unverified and proprietary modeling code for the high-risk, high profile RHBFSF project. According to Dr. Panday, the USG transport code has been applied to only two projects, for which there are no final reports available for review, and the source code and documentation were to be made available in September 2017. As of this writing, neither the Navy nor Dr. Panday have made the source code and documentation available. BWS is not comfortable with the Navy planned use of Dr. Panday's USG transport code. As part of the next GWMWG meeting, we ask that the Navy provide the USGS, BWS, and other interested parties the source code for the transport code, a hard copy of the code documentation, communication from the authors of GMS to confirm whether or not the transport code is fully functional in GMS, communication from the USGS regarding their involvement with the development or verification of the transport code, communication for the USGS regarding their plans for developing a transport code for MODFLOW-USG, electronic copies of reports that have used Dr. Panday's transport code, and a list of references that have provide a thirdparty verification of the accuracy of the USG transport code.	10/18/2017	As we have previously described in our responses to comments including #9, #16, #18, #19, #20, #21, #22, #37, and #48, we have addressed this issue. Continuing to focus on issues that the Navy has responded to seem to be counterproductive. We will not be simulating transport in the interim model as discussed in the last GWMWG. The transport code is already available from the GSI website. USGS is not in the business of providing such communications as requested by BWS. Finally, we provided a plan to verify the USG-Transport code against MT3D for the Red Hill model. If the results of the test are inconsistent, we will use MT3D for further simulations. This was also discussed earlier.	Ongoing		F&T Model	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
148	**Meeting #5 (11/17/17) Navy Action Items**						
149	BWS main concerns: a. How available data will be integrated into the model b. How model uncertainty will be addressed c. How spatial variability of hydraulic conductivity of basalts and saprolite will be considered d. Present groundwater hydraulic gradient maps e. Calibration targets, error bounds, etc.	11/17/2017	a. This has been presented in the GWMEP and will be presented at the 12/20/2017 GWFMWG meeting. b. This has been answered in response to numerous previous comments c. This will be presented in the 12/20/2017 GWFMWG meeting d. A range of hydraulic gradient maps will be presented at the 12/20/2017 GWMWG meeting e. This will be presented in the12/202017 GWFMWG meeting			Flow Model	
150	Integrate data with bounds into CSM report	11/17/2017	The Navy is doing this.			CSM-Hydrogeology	
151	Explain how the model will be calibrated.	11/17/2017	This has been discussed at various GWFMWG meetings, in the GWMEP, and will be provided in the modeling report.			Flow Model	
152	How will the model be built and used.	11/17/2017	This has been discussed at various GWFMWG meetings, in the GWMEP, and will be provided in the modeling report.			Flow Model	
153	Evaluate whether to vary the K value or just have one value per geologic material	11/17/2017	This will be presented at the 12/20/17 GWFMWG meeting.			Flow Model	
154	Determine bounds to use for sensitivity analyses (e.g., saprolite can vary by several orders of magnitude). Variability applies to recharge, K, etc.	11/17/2017	This will be presented at the 12/20/17 GWFMWG meeting.			Flow Model	
155	Conduct sensitivity analysis for interim model as a means of uncertainty analysis	11/17/2017	Please see responses to comments			Flow Model	
156	Compile and review USGS barometric records (especially for 2015) for hydrographs of RHMW-07 and other wells	11/17/2017	On-going (Doug)			Flow Model	
157	USGS will provide all groundwater elevation data for the 2017 synoptic study; BWS and Navy will review and approve flow data for distribution to AOC parties and SMEs	11/17/2017	The Navy concurs			CSM-Hydrogeology	
158	Identify springs whose discharges are measured using stream gages and add their discharge to the water balance	11/17/2017	Based on discussion related to spring discharges into streams, the database has now been upgraded to include these discharges.			CSM-Hydrogeology	
159	Use 2015 synoptic study for model calibration	11/17/2017	As the Navy has stated on numerous occasions, the 2015 synoptic study will be used during model calibration.			Flow Model	
160	Prepare the following deliverables: a. Prepare CSM technical memorandum b. Prepare interim modeling report	11/17/2017	a. on-going b. on-going. Report is due 2/10/2018			CSM-Hydrogeology	
161	Determine when to have another GWFMWG meeting (before the TUA decision is due) - done 12/20/2017 and 1/11/2018,	11/17/2017	The next GWFMWG meetings are scheduled for 12/20/2017 and 1/11/2018			Other	
162	Address sensitivity to spring flow	11/17/2017	Spring flow will be discussed at the GWMWG meeting.			Flow Model	
163	Address sensitivity to model bottom elevation	11/17/2017	This was addressed in the 11/17/2017 GWFMWG meeting.			Flow Model	
164	Distribute 11/16/17 meeting presentation	11/17/2017	Done.			Other	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
165	**Meeting #6 (12/20/17) Navy Action Items**						
166	**Data acquisition:** • Evaluate existing BWS data for Hālawa shaft and, if necessary, work with BWS and/or USGS to obtain groundwater elevation data for Hālawa Shaft (aside from the 2015 data already compiled), particularly from 1996 to the present. This data will then be used in trend analysis.		Navy will be sending request to BWS for all Halawa Shaft data a. Navy has flow data for 2014 – Aug 2017 b. Navy has elevation data only for part of 2015			CSM-Hydrogeology	
167	**Data evaluation / re-evaluation:**					Choose an item.	
168	• Continue review of boring logs, geology, seismic study results, and previous studies to further evaluate the extent of saprolite/valley fill between Red Hill Shaft and Hālawa Shaft		The Navy is doing this.	On-going		CSM-Hydrogeology	
169	• Continue the review of saprolite hydraulic conductivity values (e.g. Hunt 1996), including newly acquired data for consideration in selection of ranges for the model domain		The Navy is doing this.	On-going		CSM-Hydrogeology	
170	• Recheck groundwater elevation corrections from high accuracy survey to ensure they were incorporated into the water level trend evaluations and other evaluations related to groundwater elevations		Completed.	Completed		CSM-Hydrogeology	
171	• Adjust spring discharge rates as a function of local groundwater head value (at Navy Aiea well)		The Navy is reviewing spring and nearby head correlations.	On-going		Flow Model	
172	• Further evaluate the range of low hydraulic conductivity values for caprock (may need to lower current values)		The Navy has revised the range of hydraulic conductivity values allowed during calibration for the interim model. Additional adjustments will be considered as new data becomes available, especially for the final model.			CSM-Hydrogeology	
173	• Re-evaluate the weights assigned to each calibration well and consider separating pumping wells from monitoring wells		Weighting for calibration wells has been re-evaluated. The Navy is evaluating calibration with equal weights on a model-wide basis as well as for wells in the focus area of interest.			Flow Model	
174	• Re-evaluate the scale factor for precipitation. Use gauges within the model area that are more closely related to what the expected precipitation at Red Hill and not from further downstream stations		The Navy has selected data from gauges closer to the Red Hill facility and allowed different scale factors during calibration of the interim and final models.			Flow Model	
175	• Evaluate control point values along the boundaries in groundwater contouring evaluations and consider removing the control point near H3		While some control points are used along the boundaries, the Navy has removed the control point near H3 for purposes of contouring heads.			CSM-Hydrogeology	
176	• Consider adjusting leakance (or another technique) at various points along Red Hill Shaft to reflect higher K near the end of the shaft		The Navy is further evaluating this, especially for the final flow model.			Flow Model	
177	**Modeling effort:**					Choose an item.	
178	• Consider error from vertical flow component within wells (especially Halawa Deep Monitoring Well [2253-03]) as a part of the "model errors" evaluation		Since Halawa Deep is a deep open borehole, the apparent water table elevation is a function of the flow units that the well is open to. In addition, there is known vertical flow within this well. The Navy will consider this in evaluation of potential calibration errors.			Flow Model	
179	• Re-evaluate vertical heads along NW and SE GHB boundaries. Evaluate impact of assigning heads in Layer 5 only at the general head boundary to see if they quickly equilibrate		This will be considered in the final flow model.			Flow Model	
180	• Test the sensitivity of the groundwater flow model (and particle tracking) to the geometry and anisotropy of valley fill/saprolite		This will be done for the final model			Flow Model	
181	• Allow longitudinal-to-horizontal anisotropy ratio of 0.33 to vary during model calibration		This will be part of a sensitivity analysis			Flow Model	
182	• Evaluate if feasible to smooth contouring of water levels		The Navy has done this and the Navy has evaluated smoothing of contours.	Completed.		CSM-Hydrogeology	
183	• Complete three-point groundwater gradient evaluations, compare to groundwater elevation data		The Navy has completed these for 2006, 2015, and 2017. The Navy has also done this for the November 2016 synoptic water level study.	Completed		CSM-Hydrogeology	
184	• Give precedence to water level differences over absolute water levels during calibration specially between Red Hill and Halawa Shaft		This is being further evaluated. Water level differences will also be evaluated during the model calibration, especially between the Red Hill area and Halawa Shaft.			Flow Model	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

No.	Comments/Concerns	Initial Comment Date	Remarks/Responses	Resolution	Resolution Date	Category	Response to Navy
185	**Deliverables:**					Choose an item.	
186	• Submit high precision survey report to AOC parties and SMEs		Navy has submitted report.			CSM-Hydrogeology	
187	• Update USGS on results of geophysical survey once results are finalized		The Navy will do this. The field work was completed in December 2017, and is being processed now.			CSM-Hydrogeology	
188	• Provide EPA email update regarding the discussions they missed		Navy has sent an email that contained action item list from December 20, 2017 Groundwater Flow Model Working Group Meeting.			Other	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

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189	**Meeting #7 (1/11/17) Navy Action Items**						
190	**Analyses and Evaluations**					Choose an item.	
191	• Evaluate skin effects on RHMW11 cores		Ongoing.			Choose an item.	
192	• Evaluate using NMR to evaluate saturation of saprolite zone prior to well installation		Under consideration.			Choose an item.	
193	• Consider installing transducers to measure infiltration at the quarry		Waiting to see quarry permit information. This item may be part of future discussions with the quarry operator.			Choose an item.	
194	• Evaluate barometric efficiencies of wells		Ongoing			Choose an item.	
195	• Evaluate drain elevations to ensure they properly reflect discharge from basalt (e.g., changing elevation from -10 ft msl to +10 ft msl)		Completed			Choose an item.	
196	• Evaluate impact of clinker zone at the Red Hill Shaft area		Completed and presented at Feb 2018 GWFMWG meeting			Choose an item.	
197	• Conduct sensitivity analysis to storage parameters		Ongoing			Choose an item.	
198	• Calibration-constrained sensitivity analyses will be conducted where possible		Ongoing			Choose an item.	
199	• Compare USGS particle tracking code to the code used by the Navy		MODPATH3DU from S. S. Papadopulos and Associates, Inc. is being used.			Choose an item.	
200	• Re-evaluate cross-sections and depictions of continuity of clinker zones and a'a flows; include evaluation of strike and dip with cross-sections		Cross-section B-B' is being revised.			Choose an item.	
201	• Evaluate historical precipitation events during synoptic studies		We examined modeled vs. observed heads during calibration, and we are confident that precipitation does not have a significant direct impact on water levels			Choose an item.	
202	**Data**					Choose an item.	
203	• Work with BWS to obtain groundwater chemistry data for their wells, particularly Hālawa Shaft		- 6/6/2017, The Navy sent data request letters sent to Mayor Caldwell, Stephen Anthony (USGS), and Suzanne Case (DLNR) this included a request for water chemistry data. - 6/27/2017, BWS responded to the data request letter sent to Mayor Caldwell by saying they see a benefit to helping the Navy, but indicated they haven't been given the data they've asked for. - On 7/31/2017 the Navy and BWS requested that AECOM select our top three data priorities. - On 8/3/2017 the Navy sent BWS a message with our top three data requests attached; this prioritized request did not include groundwater chemistry, as geologic, well construction, and pumping data were deemed more important. - The Navy still needs the lower-priority data (especially water quality) previously requested.			Choose an item.	
204	• Review metadata of USGS recharge file		Ongoing			Choose an item.	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

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205	• Include supporting groundwater elevation and pumping data used to calculated average elevations and rates		The 2006 data used to calculate averages are from the TEC report. This is not publically releasable. The 2015 head data were obtained from the USGS website. Pumping data are not publically releasable.			Choose an item.	
206	• Update Moanalua DH43, Ka'amilo Deep, and TAMC-MW2 groundwater elevation data to ensure all relevant data is included (2015 synoptic study)		These data have been included in the 2015 synoptic study modeling.			Choose an item.	
207	**Field Work**					Choose an item.	
208	• Install new pressure transducer in RHMW11 (working with Delwyn Oki)		A transducer has been installed in Zone 8 with the pumping port open. The Navy is coordinating with USGS to place transducers in the shallow wells at Halawa Correctional Facility.			Choose an item.	
209	• AECOM to coordinate with Regulators and SMEs to allow viewing of RHMW11 cores		The Navy will coordinate with Regulators and SMEs to allow core inspections prior to, during, or following the March 2018 meetings (contingent on schedule availabilities).			Choose an item.	
210	• Measure strikes and dips in active Hawaiian Cement quarry (working on getting permission)		Working with Hawaiian Cement on getting permission to gain access to their quarry.			Choose an item.	
211	• Sample Westbay well for temperature, and major ion concentrations		Temperature data from RHMW11 will be discussed at the February GWFMWG meeting. RHMW11 will be sampled in March 2018 (following the synoptic study). The will include major cations and anions.			Choose an item.	
212	• Coordinate with the University of Hawaii to collect sample from RHMW11 for isotopic analysis		The Navy and University of Hawaii will coordinate sampling of RHMW11 similar to previous sampling events conducted at the Facility.			Choose an item.	
213	**Deliverables and Scheduling**					Choose an item.	
214	• Clarify how recharge will be considered in the model and conceptual site model with particular attention given to incorporating quarry recharge, rainfall, and streambed infiltration		Ongoing.			Choose an item.	
215	• Consider using synoptic studies to evaluate anisotropy		The Navy is evaluating the impact of anisotropy on capture zone predictions.			Choose an item.	
216	• Color code particle tracking figures to show which layers the particles are in		Completed.			Choose an item.	
217	• Navy to provide PDF of slides with higher figure resolution (for figures approved for public release)		The Navy will send these to the stakeholders and are ongoing.			Choose an item.	
218	• Provide action item list to meeting attendees		Updated versions are provided prior to each GWFMWG meeting.			Choose an item.	
219	**Next GWFMWG meetings:**					Choose an item.	
220	• Monday February 12th (half-day; webinar)					Choose an item.	
221	• Friday March 16th (full-day; in-person)					Choose an item.	

Meetings: 2017: June 26, August 17, September 22, November 17, December 20; 2018: January 11
Red Hill Bulk Fuel Storage Facility
Joint Base Pearl Harbor-Hickam, O'ahu, HI

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