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An Expert Elicitation Process in Support of Groundwater Model Evaluation for Frenchman Flat, Nevada National Security Site

prepared by

Jenny Chapman and Karl Pohlmann

submitted to

Nevada Site Office
National Nuclear Security Administration
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INTRODUCTION

The U.S. Department of Energy (DOE) is implementing corrective actions at facilities where nuclear-related operations were conducted in Nevada. Among the most significant sites being addressed are the locations of underground nuclear tests on the Nevada National Security Site (NNSS). The process for implementing corrective actions for the Underground Test Area (UGTA) locations is defined in Appendix VI of a Federal Facility Agreement and Consent Order (FFACO) (1996, as amended). In broad terms, Appendix VI describes a Corrective Action Investigation (CAI) followed by a Corrective Action Decision, and implementation of a Corrective Action Plan prior to closure.

The Frenchman Flat Corrective Action Unit (CAU) is farthest along in the UGTA corrective action process. It includes ten underground tests within the Frenchman Flat topographic basin, in the southeastern portion of the NNSS. Data have been collected from drilling exploration, hydrologic testing, and field and laboratory studies. Modeling has been completed at a variety of scales and focusing on a variety of flow and transport aspects ranging from regional boundary conditions to process dynamics within a single nuclear cavity. The culmination of the investigations is a transport model for the Frenchman Flat CAU (Stoller Navarro Joint Venture, 2009) that has undergone rigorous peer review and been accepted by the State of Nevada, setting the stage for the Corrective Action Decision and progression from the investigation phase to the corrective action phase of the project.

Expectations for the corrective action phase were clarified in a 2010 revision to the FFACO. The focus is on iterative model evaluations and data collection near and downgradient of the underground nuclear tests. The intent is to continue to build confidence in the reliability of model forecasts of contaminant migration until there is sufficient confidence in the model to develop a monitoring strategy to proceed to CAU closure.

To prepare the Corrective Action Decision Document/Corrective Action Plan (CADD/CAP) for the Frenchman Flat CAU, the model evaluation process needed to be developed, as well as the related process for identifying supporting data collection activities. Deliberations were held with an ad hoc group comprised of subject matter experts knowledgeable of the conditions in Frenchman Flat and of the numerical models, including representatives of DOE and the state regulator, the Nevada Division of Environmental Protection (NDEP). A number of avenues were explored, including quantitative and statistical methods of using the numerical models of groundwater flow and transport to select the most important parameters for evaluation, providing a Bayesian framework for an iterative process of model improvement. Ultimately, the nature of the conceptual model for Frenchman Flat was deemed suitable for a more intuitive approach relying on expert judgment, particularly because extensive uncertainty and sensitivity analyses had already been performed (Stoller Navarro, 2009) and could support that approach. To this end, an expert panel was convened to select model evaluation targets and corresponding locations for new wells and data collection activities. The outcome of the panel deliberations forms the basis of the model evaluation plan and associated data collection plan. The CADD/CAP will present the data collection activities proposed for the CADD/CAP stage as part of the model evaluation plan. The details of the expert evaluation are presented here with the purpose of documenting the process and rationale in support of the CADD/CAP.

IDENTIFICATION AND ASSESSMENT OF MODEL EVALUATION TARGETS AND DATA-COLLECTION ACTIVITIES

The methodology for the CADD/CAP model evaluation is based on expert judgment of the Frenchman Flat models to identify model confidence-building targets. Quantitative modeling measures could be developed both to assess model uncertainty to aid in target selection, as well as assess uncertainty reduction after data collection, but this was not pursued because extensive sensitivity analysis and uncertainty assessments were performed for the Frenchman Flat flow and transport models and are available to support a qualitative expert judgment approach. Six steps guided the expert elicitations, as follows:

1. Identification of model evaluation targets
2. Identification of data collection programs to address the targets
3. Estimation of the reliability of each data collection activity
4. Estimation of activity costs
5. Evaluation of activities/well locations relative to CADD/CAP model evaluation objectives
6. Expert judgment selection of model evaluation wells

The advisory panel was comprised of experts in the Frenchman Flat model specifically, underground nuclear testing in general, and NNSS geology, radiochemistry, and hydrology (panel members are listed in the Appendix). The steps were carried out by the panel during meetings conducted on November 12, 2009 and February 24, 2010. Between these meetings, a survey was independently completed by each expert. The results of the expert elicitation are described below.

Identification and Prioritization of Model Uncertainties

The contaminant boundary forecast is the metric for assessing uncertainty, consistent with the emphasis on the contaminant boundary during the CADD/CAP model evaluation phase, expressed in Appendix VI of the FFACO. The model uncertainty analysis is based on the considerable effort devoted during the CAI to sensitivity analysis and evaluation of alternative conceptual models, which is translated into the model evaluation process via the expert elicitation. The panel identified and ranked ten model-evaluation targets that cover all three primary components of the Frenchman Flat CAU models (hydrostratigraphic framework model, groundwater flow model, and radionuclide transport model) (Table 1). The highest priority targets were identified as the internal continuity of the Topopah Spring Aquifer and conservative assumptions related to the source release. The assessments of relative priority of the targets were generally very consistent (note the variances in Table 2). Flow boundary conditions, the conceptual model of basin drainage to the east-southeast, and geochemical age and velocity constraints were universally considered lower priority. The remainder of the targets garnered mid-level priority.

Table 1. Model evaluation targets identified by the expert panel.

Model Evaluation Target	Priority Tier	Description of Uncertainty
Spatial extent of the welded-tuff aquifer (Topopah Spring Aquifer, or TSA) in the north	Middle	The saturated lateral extent of the welded-tuff aquifer (specifically the Topopah Spring Aquifer, TSA) at the water table along the flow path down gradient of PIN STRIPE may be underestimated in the base model. If subsurface bed dips in the structural block on the north side of the detachment fault are steeper than assumed in the base model, then the width of saturated TSA would increase along the flow path.
Internal continuity of TSA	Top	The TSA in the vicinity of PIN STRIPE is represented as a continuous, well-connected hydrostratigraphic unit in the base HFM, which is the simplest interpretation considering the alluvial cover and lack of drill hole control. However, even modest vertical displacement on north-south striking normal faults could completely disrupt the relatively thin TSA and significantly reduce the continuity of this potential flow path.
Hydraulic conductivity of TSA	Middle	The parametric distribution of K in the TSA could not be determined with confidence owing to the limited availability of pumping test-scale estimates in Frenchman Flat. Though considerably more data are available for regional HSUs and HGUs, the distributions are not specific to welded tuff aquifers in Frenchman Flat and therefore are subject to issues of transferability. In addition, it is unclear whether high simulated K values in the TSA, which have the effect of draining water from other HSUs, are real or a function of model construction.
Continuity of basalt lava-flow aquifer (BLFA)	Middle	The fractured BLFA lies within the alluvial section at or near the water table near MILK SHAKE in northern Frenchman Flat. The base HFM depicts the BLFA as three isolated bodies. However, aeromagnetic data, ground magnetic data, and boreholes coverage is insufficient to fully delineate BLFA geometry and determine whether it comprises three separate flows or erosional remnants of a single large flow.
Hydraulic conductivity of BLFA	Middle	There are no pumping test-scale estimates of K in Frenchman Flat and few relevant NNSS-wide pumping-scale estimates in lava flow aquifers.
Flow boundary conditions	Low	Groundwater flow boundary conditions, particularly inflow from the north through semi-perched alluvial and volcanic aquifers, are highly uncertain owing to the absence of field observations in this area and minimal constraints provided by the regional model.
Conceptual model of basin drainage to east, southeast	Low	As with the boundary flows, there are very limited data to determine flow directions and quantities, and thus large uncertainty.
Geochemical age and velocity constraints	Low	Using C-14 ages, a single groundwater velocity was estimated for each of five well pairs. Uncertainty arises from the few C-14 ages upon which to estimate groundwater velocity, from uncertainties related to corrections for dead carbon, and from assumptions about how the well pairs are positioned with respect to flow directions.
Source release conservative assumptions	Top	The source release for the vadose zone tests was deliberately unrealistic, projecting the full source to the water table. More accurate portrayal of a slower release and possible loss of mass to the vadose zone, would reduce the contaminant mass.
Size of exchange volume	Middle	Similar to the above, the exchange volume is assumed to intersect the water table when in fact it may not, thereby increasing contaminant access to the saturated zone.

Table 2. Prioritization of the model evaluation targets. Priority was assigned by panel members based on one having the highest priority and ten having the lowest. The average of their assessments is shown. Green corresponds to the top priority tier, yellow to the middle, and pink to the lower tier.

Target	Avg	Variance
Internal continuity of TSA	2	1.1
Source release conservative assumptions	3	1.8
Spatial extent of TSA in the north	4	1.2
Hydraulic conductivity of BLFA	4	5.1
Hydraulic conductivity of TSA	5	3.1
Continuity of BLFA	5	3.1
Size of exchange volume	5	8.3
Geochemical age and velocity constraints	8	3.5
Conceptual model of basin drainage to east, southeast	8	4
Flow boundary conditions	9	3.9

Identification of Field Activities

Having established the model evaluation targets, the panel as a group proposed and discussed data collection programs that could be implemented to address the model uncertainties. Eleven candidate programs were identified by consensus of the panel. Seven of these programs involved drilling a new well and four were non-drilling data collection activities. Although each program was proposed to address a specific model target, it was recognized that many of them would be capable of providing data for multiple targets. The data collection programs identified during the first elicitation meeting and their primary purposes are listed below. The seven wells considered are as follows:

- Vertical borehole downgradient of PIN STRIPE. At a distance of up to several hundred meters from the nuclear test, data from this borehole would help refine conceptualizations of the geometry of the TSA and groundwater flow in the northern area.
- Vertical borehole downgradient of PIN STRIPE. At a distance of approximately 1 km this borehole would help refine conceptualizations of the geometry of the TSA and groundwater flow in the northern area, but farther afield than the borehole listed above.
- Slant borehole at PIN STRIPE. Within two cavity radii of the working point, this borehole would help refine estimates of radionuclide source release and exchange volume size.
- Vertical borehole north of PIN STRIPE. At a distance of several hundred meters this borehole would help refine conceptualizations of the geometry of the TSA and groundwater flow in the northern area.
- Vertical borehole downgradient of MILK SHAKE. At a distance of up to several hundred meters this borehole would help to refine conceptualizations of the geometry of the BLFA and groundwater flow in the northern area.

- Slant borehole at MILK SHAKE. Within two cavity radii of the working point, this borehole would help refine estimates of radionuclide source release and exchange volume size.
- New borehole in the Central Testing Area. A new borehole in this area would help refine conceptualizations of groundwater flow model boundaries and basin drainage to the southeast as well as collect geochemistry data for estimates of groundwater velocities.

The four data collection activities considered are as follows:

- 2-D seismic surveys. Designed for collection of information to refine the model of spatial distribution of the TSA.
- Borehole dilution test. Designed for an existing well, this test would address the parametric distribution of hydraulic conductivity in the BLFA and provide data for geochemical age-dating and estimates of groundwater velocity.
- Geochemical sampling of existing wells. Intended to fill gaps in the groundwater geochemistry database to improve conceptualizations of groundwater flow model boundaries and basin drainage to the southeast, as well as estimates of groundwater velocities.
- Surface magnetometer surveys. Designed for collection of information to refine the model of spatial distribution of the BLFA near MILK SHAKE.

Reliability Estimates for the Potential Boreholes and Field Activities

The effectiveness of each potential field activity was estimated as a "reliability coefficient." The reliability coefficient is defined as a number between zero and one, where zero indicates that the collection program provides no information for reducing uncertainty and a value of one indicates the collection program completely eliminates uncertainty. The process of estimating the reliability was intended to prompt the experts to consider the practical effect of new data collection. Each panel member first made their own assessment, followed by panel discussion of the coefficients, during which members with particular knowledge of the techniques and analysis could inform others of their opinions. The individual members then had an opportunity to modify their coefficient if they wished. The individual coefficients assigned by each panel member were aggregated by calculating the arithmetic mean of the individual responses (Table 3).

The highest value of the aggregated reliability coefficients (0.74) is associated with using slant boreholes at PIN STRIPE and MILK SHAKE to test the conservative assumptions incorporated in the source release function. Relative to most other combinations of data collection and model target, there is very good agreement among the experts on the values of these reliability coefficients (both have a standard deviation of 0.13). The lowest reliability coefficient (0.23) is associated with a new borehole in the Central Testing Area for the purpose of refining the conceptualization of the groundwater flow model boundaries. As a group, data collection activities that address this target and the conceptual model of basin drainage to the southeast are assigned the lowest reliability coefficients. This opinion is held relatively consistently among the experts as evidenced by the relatively low variation in most of the associated reliability coefficients (standard deviations range from 0.15 to 0.26). The

Table 3. Matrix showing the targets addressed by the different proposed wells and activities, along with the mean reliability coefficients assigned during the first expert elicitation meeting.

Model Evaluation Target	**Data Collection Program**										
	Vertical borehole downgradient from PIN STRIPE (100s m)	**Vertical borehole downgradient from PIN STRIPE (1 km)**	**Slant borehole at PIN STRIPE (2 Rc)**	**Borehole north of PIN STRIPE (100s m)**	**Vertical borehole downgradient from MILK SHAKE (100s m)**	**Slant borehole at MILK SHAKE**	**New well in Central Testing Area**	**2-D seismic survey**	**Borehole dilution test (existing well)**	**Geochemical sampling of existing wells**	**Surface magneto-meter survey**
Spatial extent of TSA in the north	0.40	0.41		0.54				0.64			0.51
Internal continuity of TSA	0.40	0.42		0.39				0.70			0.50
Continuity of BLFA					0.50						0.73
Hydraulic conductivity of TSA	0.66	0.64	0.46	0.59							
Boundary conditions	0.29	0.28		0.36			0.23		0.36	0.50	
Hydraulic conductivity of BLFA					0.67	0.50					
Conceptual model of basin drainage to east, southeast	0.31	0.42			0.38	0.34	0.36			0.49	
Geochemical age and velocity constraints	0.38	0.49		0.49	0.35		0.42		0.43	0.56	
Source release conservative assumptions	0.56		0.74	0.37	0.60	0.74					
Size of exchange volume			0.69			0.67					
Average reliability	**0.43**	**0.44**	**0.63**	**0.46**	**0.50**	**0.56**	**0.34**	**0.67**	**0.40**	**0.52**	**0.58**

greatest disagreement between individual experts is seen for the reliability of vertical boreholes near PIN STRIPE to characterize the internal continuity of the TSA and to test the conservative assumptions regarding source release (standard deviations range from 0.27 to 0.30).

Activity Costs

Cost is another aspect that each expert considered, particularly in relation to the activity's reliability and the relative importance of the target it addresses. Detailed cost estimates were not constructed given the preliminary stage of planning. Rather, rough, order-of-magnitude estimates provided the panelists with guidance for their determinations of the most favorable field activities from a cost-benefit perspective (Table 4). For the well activities, these estimates reflect the field costs of the activity (drilling and aquifer testing), not subsequent modeling and analysis. The non-drilling activities inherently require additional analysis to be useful, and such interpretation is included in the estimate.

Table 4. Estimates of activity costs.

Activity	Rough, Order-of-Magnitude Cost Estimate
Vertical borehole several hundred meters downgradient from PIN STRIPE	$3,000,000
Vertical borehole one km downgradient from PIN STRIPE	$3,000,000
Slant borehole within 2 cavity radii of PIN STRIPE	$6,000,000
Vertical borehole several hundred meters north of PIN STRIPE	$3,000,000
Vertical borehole several hundred meters downgradient from MILK SHAKE	$3,000,000
Slant borehole within 2 cavity radii of MILK SHAKE	$6,000,000
Borehole in the Central Testing Area	$3,000,000
2-D seismic surveys	$500,000
Borehole dilution test in basalt lava-flow aquifer	$1,500,000
Geochemical sampling of existing wells	$100,000
Surface magnetometer surveys	$50,000

Assessment of Potential Model Evaluation Activities Relative to Other Objectives

With the recent revision to the FFACO, the objective for the corrective action phase is clarified to focus on model evaluation and building confidence in the reliability of model forecasts. Once that confidence is sufficient, monitoring and institutional controls will be developed for presentation in a Closure Report. Given the expectation for groundwater monitoring at the CAU and the costs associated with drilling wells in the Frenchman Flat environment, the potential usefulness of wells for a future groundwater monitoring network is a reasonable factor to consider when selecting well locations. This is consistent with the concept of dual-purpose wells encouraged by NDEP for the corrective action at the Central Nevada Test Area (Liebendorfer, 2001). In the case of Frenchman Flat, model evaluation is the purpose of the new wells, but it is of interest to assess the potential for future monitoring use.

A previous *ad hoc* committee recommended the following types of monitoring for Frenchman Flat:

- Background monitoring
- Exposure monitoring (point-of-use)
- Compliance monitoring
- Sentinel wells (early warning of contaminant migration)

The experts were asked to rank each proposed model evaluation well or activity by selecting between the following: does not address objective (0), meets objective poorly (1), meets objective (2), or meets objective very well (3). In general, the experts did not find that the model evaluation wells and activities were very effective at meeting the monitoring objectives (Table 5). There is general expert agreement on the poor match between the background and exposure monitoring objectives and the proposed wells. There is more spread in the responses in regard to the compliance monitoring and sentinel well objectives. This variation in response, such as one expert saying an activity did not address the objective at all while another said it met the objective very well, suggests there may have been different interpretations of these two objectives.

For the compliance monitoring objective, the two vertical boreholes at PIN STRIPE, the vertical borehole at MILK SHAKE at a distance of several 100 m, and the borehole in the Central Testing Area, all achieved average rankings indicating they would satisfy the objective. The vertical borehole 1 km downgradient from PIN STRIPE also achieved average rating for meeting the sentinel well objective. The wells several 100 m downgradient of MILK SHAKE and in the Central Testing Area also had over half the respondents say they would satisfy the sentinel objective, though their average score was below two. Otherwise, the other well and objective combinations had below average ratings, indicating that the averaged expert opinion is that the wells and activities would not meet the monitoring objectives.

Existing wells in the general Frenchman Flat vicinity were also evaluated against the monitoring objectives (Table 6). With the exception of providing information regarding background conditions, the existing wells did not rank high for meeting the monitoring objectives. This is not surprising, given that they were located and constructed for other purposes. Fifteen of the 27 wells were found to meet the background monitoring objective by most of the experts. None of the wells were collectively identified as meeting the exposure monitoring and sentinel well objectives. Two wells were indicated as meeting the compliance monitoring objective: ER 5-3 and UE5n.

Table 5. Average assessment of effectiveness of new wells/activities at meeting monitoring objectives. The column "#" indicates the number of experts rating the well as meeting the objective.

Borehole/Data Collection Activity	Background			Exposure			Compliance			Sentinel		
	Avg	Var	#	Avg	Var	#	Avg	Var	#	Avg	Var	#
Vertical borehole several 100 m downgradient from PIN STRIPE	0.71	0.57	1	1.29	1.90	3	2.43	0.62	6	1.57	1.29	3
Vertical borehole 1 km downgradient from PIN STRIPE	1.43	1.95	4	0.86	0.81	2	2.14	0.81	5	2.00	1.33	5
Slant borehole within 2 cavity radii of PIN STRIPE	0.14	0.14	0	1.43	2.29	3	1.86	1.14	3	1.14	1.14	2
Vertical borehole several 100 m north of PIN STRIPE	1.71	0.90	5	0.57	0.62	1	0.86	0.14	0	0.29	0.24	0
Vertical borehole several 100 m downgradient of MILK SHAKE	0.86	0.81	2	1.29	1.90	3	2.29	0.57	6	1.71	1.24	4
Slant borehole within 2 cavity radii of MILK SHAKE	0.14	0.14	0	1.43	2.29	3	1.71	1.57	3	0.86	1.14	1
Borehole in the Central Testing Area	0.86	0.48	1	1.29	1.24	3	2.14	0.48	6	1.57	0.95	4
2-D seismic surveys	0.00	0.00	0	0.14	0.14	0	0.00	0.00	0	0.00	0.00	0
Borehole dilution test in basalt lava-flow aquifer	0.14	0.14	0	0.43	0.62	1	1.43	1.29	4	0.14	0.14	0
Geochemical sampling of existing wells	1.57	1.62	4	0.57	0.62	1	0.71	0.57	1	0.86	1.48	2
Surface magnetometer surveys	0.00	0.00	0	0.29	0.57	1	0.57	0.95	2	0.00	0.00	0

Table 6. Average assessment of the effectiveness of existing wells at meeting monitoring objectives. The column "#" indicates the number of experts rating the well as meeting the objective.

	Background			Exposure			Compliance			Sentinel		
	Avg	Var	#	Avg	Var	#	Avg	Var	#	Avg	Var	#
ER 6-1	1.57	0.95	4	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
ER 6-1#2	1.57	0.95	4	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
TW B	1.29	1.24	3	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
WW C	1.71	0.90	5	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
WW C-1	1.71	0.90	5	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
WW 4	1.86	0.48	5	0.14	0.14	0	0.00	0.00	0	0.00	0.00	0
WW 4A	1.86	0.48	5	0.14	0.14	0	0.00	0.00	0	0.00	0.00	0
UE 11A	1.86	1.14	5	0.29	0.24	0	0.71	0.57	1	0.29	0.24	0
PW 3	2.29	0.57	6	0.14	0.14	0	0.43	0.29	0	0.43	1.29	1
PW 2	2.14	0.48	6	0.29	0.24	0	0.71	0.57	1	0.43	0.62	1
PW 1	2.14	0.48	6	0.14	0.14	0	0.43	0.29	0	0.43	0.62	1
ER 5-3	1.43	2.29	3	0.43	0.62	1	1.43	1.29	4	1.14	1.14	2
ER 5-3#2	1.43	2.29	3	0.43	0.62	1	1.29	1.24	3	1.29	1.24	3
UE 5c	2.29	0.57	6	0.71	0.90	2	0.43	0.29	0	0.14	0.14	0
ER 5-4	1.43	2.29	3	0.29	0.24	0	1.00	1.00	1	0.71	1.24	1
ER 5-4#2	1.43	2.29	3	0.29	0.24	0	1.00	1.00	1	0.86	1.14	1
RNM 1	0.14	0.14	0	0.57	1.29	1	0.86	1.48	2	0.29	0.24	0
RNM 2	0.14	0.14	0	0.43	0.62	1	0.71	0.90	2	0.29	0.24	0
RNM 2s	0.14	0.14	0	0.71	1.57	2	1.00	0.67	2	0.43	0.29	0
UE5n	0.43	1.29	1	1.14	2.14	3	2.00	1.33	5	0.57	0.95	2
HTH-3	2.00	1.33	5	0.57	0.62	1	0.43	0.29	0	0.86	0.81	2
WW 5B	2.14	0.81	5	1.29	1.90	3	1.00	2.00	2	1.00	2.00	2
WW 5C	2.14	0.81	5	1.14	1.48	3	0.57	0.62	1	0.86	1.48	2
WW 5A	2.14	0.81	5	0.86	1.14	1	0.43	0.29	0	0.57	0.62	1
HTH-F	1.29	1.24	3	0.00	0.00	0	0.14	0.14	0	0.00	0.00	0
SM 23	1.14	1.48	3	0.29	0.24	0	0.29	0.24	0	0.14	0.14	0
Army #1	1.14	1.48	3	0.43	0.29	0	0.29	0.24	0	0.14	0.14	0

SELECTION OF CADD/CAP MODEL EVALUATION WELLS

The individual expert panel members each rated the potential model evaluation wells based on the following:

- Impact analysis of each activity/well
  - Number of model evaluation targets the activity will address
  - Importance of the evaluation targets affected
  - Potential effectiveness of the activity for reducing uncertainty in targets
- Cost
- Effectiveness at addressing monitoring objectives

In addition, the experts were asked to evaluate and recommend existing wells that would be effective for monitoring.

There was unanimous agreement among the panel members that the top two priorities for model-evaluation wells are the vertical borehole several hundred meters downgradient from PIN STRIPE and the vertical borehole several hundred meters downgradient from MILK SHAKE (Figure 1; Table 7). There was also near-unanimous agreement that the 2-D seismic surveys, a slant borehole at MILK SHAKE, the borehole dilution test, and a vertical borehole north of PIN STRIPE were lowest in priority of the proposed activities.

Aside from these clear outcomes of the survey, there was ambiguity regarding the intent of the experts for the final well selection. For example, the survey was not constructed in a manner that allowed distinguishing whether or not the responder believed that boreholes 100s of meters and a kilometer from PIN STRIPE were both needed, or if one was constructed, then the other would have lesser priority than another activity. To resolve such issues, a final elicitation meeting was held to consider the survey results and develop data collection recommendations.

At the final meeting, conducted on February 24, 2010, the experts resolved to consider the potential activities that require drilling a well separate from those that do not require drilling. These separate priority lists are shown in Table 8.

The panel was divided on the issue of whether or not two wells were needed downgradient of PIN STRIPE at the specified distances. Discussion centered on the multiple objectives of the wells, whether the primary driver was identifying evidence of radionuclide transport or evaluating the TSA pathway (continuity and spatial extent). These two objectives were the highest priority targets, with the reliability coefficients indicating that the well at a distance of 100s of meters would be most effective at addressing the transport issue (source release conservative assumptions), and the well at one km being most effective at addressing the spatial extent and continuity of the TSA.

The problem was tackled from a different direction by acknowledging that the two wells several hundred meters from PIN STRIPE and MILK SHAKE will be recommended in the CADD/CAP, and posing the question of which of the three mid-priority wells would each expert select as their next choice. The resulting discussion rapidly concentrated on decisions contingent on the speculated findings in the PIN STRIPE 100m well. For example, a universal opinion was that if radionuclides were detected above drinking water standards in the well located several hundred meters from PIN STRIPE, the next priority was a well farther downgradient (at one kilometer, or perhaps some intermediate distance). Conversely, if no radionuclides were detected at the first well, the experts' assessment of the value of the 1-km well dropped significantly and more priority was assigned to a well in the Central Testing Area.

The experts eventually concluded that the best use of CADD/CAP resources would be realized by implementing the iterative approach presented in the revised UGTA process flow diagram. The two vertical boreholes several hundred meters downgradient of PIN STRIPE and MILK SHAKE could be installed for model evaluation and the model forecasts evaluated against the data gained from them. Dependent on the outcome of that evaluation, the righthand iterative loop for model refinement could be exercised to drill additional model evaluation wells.

In regard to the now separate question of the non-drilling activities, the group supported conduct of the geochemical sampling and magnetometer surveys, consistent with the survey results.

Though none of the existing wells are recommended by the experts in regard to model evaluation and uncertainty reduction, some were recommended as providing value for monitoring objectives (Figure 1). Wells UE5n and ER 5-3 are recommended as providing data for compliance monitoring. PW-2, ER 5-3#2, ER 5-4, WW 5B, WW 5C, ER 5-4#2, WW 5A, UE11A, and HTH-3 are suggested for consideration in providing background data. Other wells considered but not highly rated are given in Table 9.

Table 7. Wells and activities considered for model evaluation and their summary ranking.

Proposed CADD/CAP Model Evaluation Activities		# in Favor of Inclusion
Vertical borehole several 100 m downgradient from PIN STRIPE	↑	7
Vertical borehole several 100 m downgradient of MILK SHAKE	↑	7
Vertical borehole 1 km downgradient from PIN STRIPE	↗	5
Geochemical sampling of existing wells	↗	5
Surface magnetometer surveys	→	4
Borehole in the Central Testing Area	→	4
Slant borehole within 2 cavity radii of PIN STRIPE	→	3
2-D seismic surveys	↓	1
Slant borehole within 2 cavity radii of MILK SHAKE	↓	1
Borehole dilution test in basalt lava-flow aquifer	↓	1
Vertical borehole several 100 m north of PIN STRIPE	↓	0

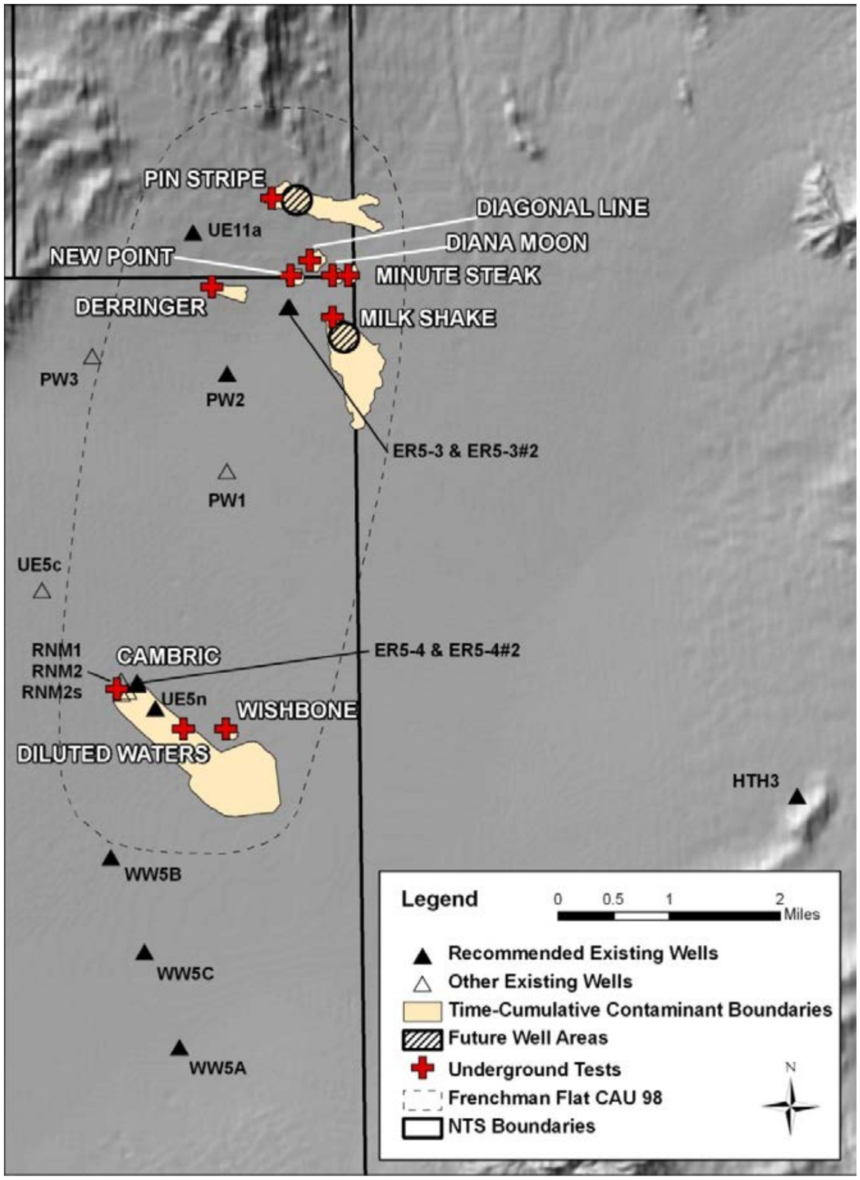

Figure 1. The Frenchman Flat CAU, showing locations of underground nuclear tests, approximate model-based time-cumulative contaminant boundaries, the general locations for the two recommended new model-evaluation wells, and existing wells recommended for consideration in a future monitoring network.

Table 8. Priority list for model evaluation activities, separated by drilling and non-drilling activities.

Proposed Wells		# in favor
Vertical borehole several 100 m downgradient from PIN STRIPE	⇧	7
Vertical borehole several 100 m downgradient of MILK SHAKE	⇧	7
Vertical borehole 1 km downgradient from PIN STRIPE	⇗	5
Borehole in the Central Testing Area	⇨	4
Slant borehole within 2 cavity radii of PIN STRIPE	⇨	3
Slant borehole within 2 cavity radii of MILK SHAKE	⇩	1
Vertical borehole several 100 m north of PIN STRIPE	⇩	0

Proposed Activities		# in favor
Geochemical sampling of existing wells	⇧	5
Surface magnetometer surveys	⇗	4
2-D seismic surveys	⇩	1
Borehole dilution test in BLFA	⇩	1

Table 9. Recommended existing wells for a future Frenchman Flat monitoring network. Wells above the horizontal line (HTH-3 and above) are recommended for monitoring network consideration.

Existing Wells		# in Favor of Inclusion
UE5n	↑	7
PW 2	↑	6
ER 5-3	↑	6
ER 5-3#2	↗	5
ER 5-4	↗	5
WW 5B	↗	5
WW 5C	↗	5
ER 5-4#2	→	4
WW 5A	→	4
UE 11A	→	4
HTH-3	→	4
PW 3	→	3
RNM 2s	→	3
PW 1	→	3
WW C	↘	2
WW C-1	↘	2
WW 4	↘	2
WW 4A	↘	2
UE 5c	↘	2
RNM 1	↘	2
Army #1	↘	2
RNM 2	↓	1
ER 6-1	↓	0
ER 6-1#2	↓	0
TW B	↓	0
HTH-F	↓	0
SM 23	↓	0

CONCLUSIONS

The evaluation of underground nuclear tests in Frenchman Flat is advancing in the FFACO process from the investigation stage of data collection, analysis and modeling, into a period of model evaluation. An expert elicitation process was developed and implemented to select targets for data collection during model evaluation, prioritize those targets, and identify effective data collection plans to reduce the uncertainty associated with each. The elicitation panel was comprised of experts in the Frenchman Flat model specifically, underground nuclear testing in general, and NTS geology, radiochemistry, and hydrology.

Ten model-evaluation targets were identified, relating to all three primary components of the Frenchman Flat CAU models (hydrostratigraphic framework model, groundwater flow model, and radionuclide transport model). The highest priority targets are the internal continuity of the Topopah Spring Aquifer and conservative assumptions related to the source release. Intermediate priority was assessed for the hydraulic conductivity of the TSA and Basalt Lava Flow Aquifer, the spatial extent of the TSA, continuity of the BLFA, and size of the exchange volume around the tests. Flow boundary conditions, the conceptual model of basin drainage to the east-southeast, and geochemical age and velocity constraints have the lowest priority.

Eleven data collection activities were identified that could reduce uncertainty in the model evaluation targets. Seven new wells were included in the group, along with four non-drilling data collection efforts. The panel estimated the effectiveness of each data collection concept at reducing uncertainty in the model evaluation targets. Those reliability estimates were considered alongside the number of evaluation targets the activity would address, the priority of those targets, the cost of the activity, and future use of the new wells for monitoring.

The final recommendation by the panel is to drill two wells, perform a magnetometer survey, and conduct geochemical sampling. A vertical borehole (slant wells were also considered) several hundred meters downgradient from PIN STRIPE and a vertical borehole several hundred meters downgradient from MILK SHAKE are the recommended well locations. The primary objective of the PIN STRIPE borehole is to refine conceptualizations of the geometry of the TSA and groundwater flow in the northern area. The primary objective of the MILK SHAKE borehole is to refine conceptualizations of the geometry of the BLFA and groundwater flow in the northern area. Both wells will also provide data on hydraulic properties and are expected to reduce uncertainty in the transport processes, particularly source release assumptions. The panel anticipates that the recommended wells will prove useful for compliance monitoring.

Existing wells were considered by the panel but not found useful in regard to model evaluation and uncertainty reduction, though monitoring uses were identified. Wells UE5n and ER 5-3 are recommended as providing data for compliance monitoring. PW-2, ER 5-3#2, ER 5-4, WW 5B, WW 5C, ER 5-4#2, WW 5A, UE11A, and HTH-3 are suggested for consideration in providing background data.

REFERENCES

Federal Facility Agreement and Consent Order. 1996 (as amended March 2010). Agreed to by the State of Nevada; U.S. Department of Energy, Environmental Management; U.S. Department of Defense; and U.S. Department of Energy, Legacy Management. Appendix VI, which contains the Underground Test Area Strategy, was last amended March 2010, Revision No. 3.

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APPENDIX: LISTING OF EXPERT ELICITATION MEMBERS AND FACILITATORS

Elicitation Panel Members

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