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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	Docket No. 40-8838-MLA
U.S. ARMY	)	ASLBP No. 00-776-04-MLA
(Jefferson Proving Ground Site)	)	September 18, 2007

PREFILED REBUTTAL TESTIMONY OF CHARLES H. NORRIS, LPG IN SUPPORT OF CONTENTION B-1 OF INTERVENOR SAVE THE VALLEY, INC.

TEMPLATE = SECY-028

SECY-02

I. Issues Raised or in Dispute

Q.001 Have you had the opportunity to review the testimony and exhibits filed by witnesses for the Army and the staff of the Nuclear Regulatory Agency (the Staff) that address issues to which you testified in your direct testimony?

A.001 Yes, I have.

Q.002 Broadly speaking, what issues do you see the Army and the Staff raising with respect to the Save the Valley (STV) position and your direct testimony critiquing the hydrogeology components of the Field Sampling Plan (FSP), including its addenda?

A.002 As I understand the testimony of the Army and the Staff, I see them raising four broad issues regarding the STV critique of the hydrogeology components of the FSP:

1. My lack of professional qualifications to offer a technical critique, including the experiential, technical or ethical shortcomings demonstrated by my critique;
2. STV's and my misconception of the purpose of the FSP in relation to the eventual decommissioning of the Jefferson Proving Ground (JPG) Depleted Uranium (DU) site;
3. STV's and my misunderstanding of the dynamic, iterative character of the FSP in governing JPG DU site characterization activities; and
4. My misunderstanding and/or misrepresentation of particular geologic and/or hydrogeologic features of the JPG site, evaluation or sampling methods and protocols

which are associated with specific hydrogeologic components of the FSP.

II. Issue 1. Professional Qualifications

Q.003 With respect to your professional qualifications, what issues do you see the Army and the Staff raising?

A.003 Much of the criticism of my testimony follows a common, and unfortunately time-honored, pattern: I disagree in material respects with the hydrogeologic components of the FSP as proposed by the Army and approved by the Staff so, necessarily, I do not know what I am talking about, I am confused, and I misunderstand, misinterpret, misstate, and/or mislead (see, *e.g.*, Army witnesses Eaby, A14 and A15, pp. 11-13 and Skibinski, A9, pp. 6-8, or Staff witness Peckenpaugh, A.21, pp. 20-21). Rather than responding in kind, I will address the underlying disagreements regarding the regulatory framework and technical aspects of the FSP.

Some of the criticisms are less general and attack my qualifications at a specific levels. Two examples include the response by Army witness Snyder to my suggestion that ground penetrating radar (GPR) have been considered as a geophysical tool *to supplement* the FTA prior to locating the characterization wells (Norris pre-filed direct testimony A.024), and Army witness Eaby's response to my pointing out (Norris pre-filed direct testimony A.046) the inconsistency in the FSP as amended regarding the use of centralizers in the characterization wells.

Snyder dismisses my suggestion to consider GPR (Snyder testimony, A38, p. 24) because of UXO in the DU impact area FPR is too dangerous to use, and, it is unlikely to work in any case. For just the suggestion to consider GPR, Snyder concludes that:

> ...shows that Mr. Norris is quickly scanning the literature and throwing out anything that sounds good, not working from experience, or with any sincerity to resolve an actual problem.

I simply note that a technical paper presented by an SAIC Senior Geophysicist (Hoover, 2003) describes the applicability of GPR in characterizing karst features at sites. The paper reports the American Society of Testing and Materials (ASTM) guide for selecting surface geophysical methods (ASTM-6429) provides a consensus ranking of methods that gives GPR an "A" rating. The issue of UXO avoidance and worker safety, a recurring theme in the testimony of the Army and the Staff witnesses, will be addressed by another STV witness.

Eaby confirms the conflicting language on well centralizers (Eaby testimony, A33, pp. 25-27) and attributes the inconsistency to a "typographical error." However, the answer expands beyond correcting the inconsistency to a general attack my qualifications. Had I sufficient familiarity, I would have understood what the FSP as amended had intended to say and not concerned myself with what it did say.

Q.004 Are there any other criticisms or comments related to your qualifications that you feel should be addressed?

A.004 Yes, there is one addition additional observation by Eaby (Eaby testimony, A35, p30) that I feel should be addressed. Eaby comments on oil exploration geologists as a group with respect to his perception of their understanding of what "a trained rig geologist" can do and their collective tendency to suggest "... unnecessary borehole geophysical analysis ..."

I am concerned that the observations of regarding oil exploration geologists may imply or may generate inferences that my experience and qualifications are perhaps peripheral to the issues at JPG. My resume, which was submitted with my pre-filed direct testimony, summarizes my education, training and experience. I did not go into detail with respect to those qualifications in my pre-filed testimony, but in the light of the above criticism, I will provide a little detail to allow the Board to review the relevance of my qualifications.

The industry in which a geologist works is largely irrelevant to his experience. The principles of physics, geology, and chemistry are independent of the project where they are being applied. For 35 years I have applied those principles toward characterizing earth materials, fluids flowing through them, and the interactions among the fluids and the earth materials. For the first 14 years, I applied those principles in the petroleum industry. For the most recent 16 years, I have applied those principles in what is loosely known as the environmental industry. The intervening five years was spent on faculty of the University of Illinois at the Laboratory for Supercomputing in Hydrogeology, where I worked with and helped write computer programs for fluid flow and geochemical

reactions. That experience provided invaluable understanding and appreciation of the power and limitations of computer modeling. There is no part of that 35 years of industry, academic, and consulting experience that is irrelevant to the JPG site. While all of my career experience has relevance to the JPG DU site problem, the most recent 21 years may have more direct applicability. These projects focus on shallow geologic and hydrogeologic concerns, those that are part of or near our environment. The work I have done in these two decades fall into four general categories; preventing contamination, finding and remediating contamination, locating water supplies, and using computers to assist with the previous three categories. The compute modeling skills date back to my years with the supercomputer center where we wrote, developed and distributed fluid flow codes and geochemical modeling codes and taught others to use them. Several projects I am currently working on, projects in shallow fractured and karst limestone and dolomite rocks are particularly applicable and will be discussed they apply to the specific testimony.

III. Issue 2. Purpose of FSP in relation to eventual decommissioning of the JPG DU site.

Q.005 What is your opinion with respect to the purpose of the FSP in relation to the eventual decommissioning of the JPG DU site?

A.005 In my pre-filed direct testimony (Norris testimony, A.010), I offered the following

statement of my understanding of the general purpose of the FSP as amended. The FSP must

> ... meet its charge to provide characterization of the Depleted Uranium (DU) site at Jefferson Proving Grounds adequate to support the fate and transport modeling required for purposes of the ultimate decommissioning of the site in accordance with NRC regulations.

More specifically, in my pre-filed testimony answer A.011, p.5, I put the general statement in the context of hydrogeology, as follows:

> The hydrogeologic characterization activities must provide site-specific input data to the site modeling for JPG that accurately reflect the process(es), pathway(s), rate(s), and timing(s) of DU migration from the source areas to potential receptors both on- and off-site by water transport mechanisms.

My understanding and opinion of those purposes remain the same. If the time frame for the alternative schedule is to be met for the restricted-release decommissioning plan, the previously mentioned level of understanding from the FSP is needed for an accurate assessment of both the human radiological exposure and the other requirements for decommissioning.

Q.006 With respect to the purpose of the FSP in relation to eventual decommissioning of the JPG DU site, what are the principal differences of professional opinion you have with the Army's and the Staff's witnesses?

A.006 I see the following three principal differences between my opinions and the opinions expressed in the testimony of Army and Staff witnesses:

First, I understand the Army to contend that the purpose of the FSP as amended is only to characterize the site sufficiently to provide the RAI-requested inputs for RESRAD and not to characterize the site in a manner that is sufficiently complete and accurate for all purposes required for the restricted-release decommissioning plan, such as the Environmental Report required to support the Environmental Impact Statement (EIS) required to be conducted by the NRC Staff. Apparently, it is the Army's view that the Staff will determine at a later date the additional characterization beyond the FSP as amended that is necessary for the EIS or other requirements of decommissioning the JPG DU site.

Second, I understand the Army and the Staff to share the position with respect to radiological exposure that the FSP as amended is adequate because it may be possible, and is allowable, to "bound" the total effective dose equivalent (TEDE) as an acceptable exposure without full characterization, and that doing so negates the need to fully characterize the DU site.

Third, I understand Army and Staff to share the position that the RAI-requested inputs for the RESRAD model are all the information that will be needed to compute Total Effective Dose Equivalents (TEDEs) with sufficient reliability for purposes of both

restricted release decommissioning scenarios at the JPG DU site .

Q.007 Upon what testimony do you rely to form your understanding of the first difference that you listed in your answer A.006, that the Army holds the purpose of the FSP is only characterize the site sufficiently to provide the RAI-requested inputs for RESRAD and that the purpose is not characterize the site in a manner that is sufficiently complete and accurate for both purposes?

A.007 Army witnesses describe the purpose of the FSP as the collection of a substantially reduced data set relative to what is necessary to achieve my statement of the objective. The Army, through its witnesses, describes a purpose that is not to understand the when, where, how, and why of depleted uranium migration by way of aqueous media, and any consequences of that migration on human and ecological receptors, all of which must be done as part of the restricted-use decommissioning process. Rather, the Army appears to perceive it sufficient that the FSP as amended provide input values for RESRAD computations of radiological doses that were specified in the Staff's November, 2004 RAI, with no effort or concern that the requirements of the entire decommissioning process be addressed.

Examples of this logic are replete in the testimony of the Army's witnesses, *e.g.*,:

Skibinski (A7, p. 4) provides a succinct statement of the Army's focus on nothing except

the radiological dose assessment:

> The characterization approach described in the FSP (SAIC 2005) and addenda (SAIC 2006a, 2006b, and 2007) was developed with the primary goal of obtaining data needed to support the radiological dose assessment in 10 Code of Federal Regulations (CFR) § 20.1403(b) and 10 CFR § 20.1403(e).

Eaby is less succinct but equally forthright that what is useful and necessary for accurate site characterization need not be part of the Army's characterization under the FSP with respect to Army's decommissioning plan objective:

> Useful and necessary geophysical and video logging of the wells for the purpose of completing an accurate site characterization cannot be done using the drilling techniques... *[Eaby, A27., p. 19]*

and,

> Contrary to Mr. Norris' assertion in his answer, it is my opinion that geophysical logging of the boreholes during drill is not necessary for the purposes of this investigation, specifically refining the CSM in support of updating RESRAD inputs and completing a decommissioning plan. *[Eaby, A35, p. 28 and 29]*

Snyder acknowledges the characterization process has an objective of ultimate decommissioning of the site, but then clarifies that, for him, that means simply RESRAD modeling:

> Throughout his testimony, Mr. Norris repeatedly refers to fate and transport modeling. As modified in his Answer 10 by the phrase "*required for purposes of ultimate decommissioning of the site in accordance with NRC regulations*," I have no problem with this reference. I would like to make it clear that, at this time, there is

> no plan for or indication that a numerical fate and transport groundwater model will be conducted for this site. The type of data required for a numerical groundwater model is somewhat different than that required for Residual RADioactivity (RESRAD) modeling. Therein may be the source of many of Mr. Norris's concerns regarding the FSP (SAIC 2005a) and its addenda (2006a, 2006b, and 2007a). *[Snyder, A25, p. 17]*

Snyder is correct in surmising that limiting the purpose of the FSP to providing only the data inputs specified in the Army's January 31, 2005 Response to the Staff RAI of October 5, 2004 to be a source of my concern. Ultimate decommissioning of the site requires more than a standard run of the RESRAD model with the specified data inputs to compute radiological doses, and the FSP as amended is not capable (nor intended to be capable in the Army's view) of the required assessments beyond the RESRAD dose computations.

Q.008 Does the Staff endorse the Army's perception of this limited purpose of the FSP, *i.e.*, as limited to providing the site-specific RESRAD inputs identified by the Army in the January 31, 2005 RAI Response as the only additional data necessary for the radiological dose assessment required for a decommissioning plan?

A.008 The Staff witnesses support the Army's position that the FSP as amended is adequate to support a decommissioning plan with respect to radiological dose assessment. However, the Staff witnesses seem silent with respect to the issue of adequacy of the FSP characterization to produce an acceptable decommissioning plan with respect to issues such as environmental impact.

Q.009 Upon what testimony do you rely to form your understanding of the second difference that you listed in your answer A.006, that the Army and the Staff share the position that less than full site characterization is adequate in order to perform a radiological exposure assessment because it may be possible to "bound" the TEDE with a more limited site characterization?

A.009 The Staff's position is most clearly expressed in the testimony of witness Ridge, in answer A20 on page 16. There the following portion of my pre-filed testimony of A.072 on page 75 is quoted:

> The characterization objective of the FSP is to provide valid, site specific data that allow a fate and transport model, whether RESRAD or some alternative program, to realistically and reliably predict the future movement and concentrations of DU at places removed from the sampling locations for the purposes of estimating dose exposures.

Ridge takes the following exception to my position:

> I disagree with Mr. Norris's statement and instead believe that the goal of the program is to provide valid, site-specific data to support a decision as to whether the site can be safely decommissioned. As such, the characterization does not necessarily need to support a realistic model of contaminant fate and transport if it can support a model that conservatively bounds the potential doses to a hypothetical offsite receptor.

Thus, the Staff's position, as expressed by Ridge, appears to agree with the Army's to the extent that JPG site characterization need not support a realistic and reliable prediction of

depleted uranium movement and concentrations, so long as the potential dose to a hypothetical offsite receptor is conservatively bounded at a level below the limit set by NRC regulations. However, the Staff does not appear to limit the data to be collected by the FSP to that specified in the Army's January 31, 2005 RAI Response. Instead, the Staff agrees with STV that the "goal of the program is to provide valid, site specific data to support a decision as to whether the site can be safely decommissioned." Moreover, to achieve this goal, the Staff does not rule out the need for a realistic model *if conservative bounding is not possible at the JPG DU site.*

Other Staff witness support the concept of limiting characterization to the point of supporting bounded exposure computations, as well. These include McLaughlin (A10, page 5), and Peckenpaugh (A14, p. 15; A17, p. 17; and A21, p. 20).

Q.010 What does *bounding* mean in the context of radiological dose computations.

A.010 A bounded radiological dose is used in lieu of a predicted dose. It provides a "no more than" projection of what a dose might be at some point along a migration path. Ridge provides a description of the concept of *bounding* through one example of how it may be implemented (Ridge, A20, on pages15 and 16):

> At A.019, Mr. Norris states that meaningful fate and transport modeling requires measurement of chemical parameters that control uranium mobility at places and times sufficient to establish spatial and temporal variability along each critical groundwater path. In general, I agree that it

> is important to understand the variability of chemical conditions in the area in which DU may be transported. ... However, the necessary amount of characterization of variability depends on the assumptions made in the performance assessment model used to support a decommissioning decision. For example, Basis "J" correctly indicates that uranium transport is sensitive to redox conditions (often quantified as Eh). Oxidized uranium (U(VI)) is more mobile than reduced uranium (U(IV)). If the Army takes credit for reduction of uranium to limit modeled uranium transport, relatively detailed characterization of redox conditions would be needed to support the Army's assumptions about where and for how long uranium would be present as U(IV). However, if the Army assumed that all of the uranium is present in the more mobile U(VI) form, less characterization of redox conditions would be needed because the assumption would maximize predicted offsite concentrations of uranium (i.e., the assumption would be conservative).

Q.011 How does the bounding concept impact site characterization needs, if it is used?

Q.011 The use of bounding for one element can cascade through the assessment process, sequentially eliminating or reducing other aspects of characterization. In the above example by Ridge, the need for the characterization of redox conditions and variations, one factor for uranium mobility, can be eliminated by bounding the assessment to a redox condition representative of relatively high mobility. Hypothetically, the result of that bounded analysis of uranium migration through soil might show concentrations migrating from soil into groundwater too low to be of concern. Were that the case, there would seemingly be no need to characterize the parameters that control groundwater flow rates or volumes, since if the bounded exposure going into groundwater is not of concern, groundwater cannot be of concern.

This hypothetical propagation of reduced characterization is anticipated in the real world

by the FSP as amended with the deferral of collecting some hydrogeologic characterization data. Peckenpaugh, (A14, p. 13) anticipates this exact scenario when observing, "Obtaining hydraulic conductivity values may not be necessary for developing bounding conservative values for DU transport at the site."

Army witnesses do not appear to discuss explicitly the term *bounding* as a concept or practice in their testimony. However, from the design of the FSP, bounding is clearly anticipated conceptually and practically. Information that is specified by NUREG-1757, Vol.1, Groundwater (Sec. 16.3.7), Rev. 2 for site characterization in a decommissioning plan includes, among many other items, the following: groundwater flow directions and velocities; [d]escriptions of all aquifer tests should also be provided; and [p]hysical parameters such as storage coefficients, transmissivities, hydraulic conductivities, porosities, and intrinsic permeabilities. These are elements that can only be determined by physical measurements or computed from physical measurements that are taken. Yet, the FSP as amended does not currently require any of these measurements or computations. If mentioned in the FSP as amended at all, these measurements are deferred until some specified later date at which the measurements "could" or "may" be made, if it turns out it is necessary to take them.

These are not optional parameters for groundwater assessment of a decommissioning plan at a site with restricted release. They can only be optional or extraneous or unnecessary if the groundwater system is removed from consideration as a pathway for

exposure, because if there is a groundwater pathway, these parameters must be determined to characterize it. Since there is no question that a groundwater system exists under the site, and there is agreement that it is a complex groundwater setting, deferring the collection of otherwise required data until it is necessary reflects the expectation that some combination of bounding calculations will be used to remove it from consideration. This seems to be a reversal of the position taken by SAIC in the Technical Memorandum submitted with the FSP (SAIC, 2004), wherein the previous bounding condition of zero for groundwater (ground water was not part of the exposure model) was eliminated as the first of three issues of major concern.

Q.012 Upon what testimony do you rely to form your understanding of the third difference that you listed in your answer A.006, namely that the Army and the Staff share the position that a standard RESRAD model run using the site-specific data inputs specified in the Army's January 31, 2005 RAI Response is the appropriate modeling tool to perform exposure calculations for the JPG DU site?

A.012 The testimony of virtually all of the Army's and Staff's witnesses describe the objective of the FSP or the eventual use of the information obtained from the FSP as input to RESRAD. Many of both the Army's and the Staff's witnesses express a distinction between RESRAD and alternative fate and transport models, with the latter being dismissed as inconsistent with the objectives and purpose of the FSP and the former being identified as the sole basis for the radiological assessment supported by the FSP

characterization effort.

Q.013 What are the implications of the use of a standard RESRAD run as the sole basis for the human radiological exposure assessment at the JPG DU site?

A.013 As Army's witness Eaby discusses in his testimony (Eaby, A9, p. 7), citing NUREG 1757, Volume 2, the JPG DU site is, by regulation, a technically complex site, if only by virtue of it's karst setting. As such, it requires special characterization efforts. Among those extra efforts, NUREG 1757, Volume 2 states, "Technically complex sites may require more advanced ... assessment performance modeling and analysis approaches ..." RESRAD is the standard assessment performance model for human radiological exposure and from this guidance alone it is questionable that it is the appropriate assessment tool.

Army's May 25, 2005 cover letter to Staff witness McLaughlin transmitting the FSP included a technical memorandum entitled "Identification of Key Site-Specific Data to enhance the accuracy and reliability of RESRAD Modeling of the Depleted Uranium Impact Area, Jefferson Proving Ground, Indiana " that was prepared by SAIC and is dated September 8, 2004. The assessments performed by SAIC for that memorandum used RESRAD Version 6.22 and did include groundwater in the assessment. In addition to a sensitivity analysis, SAIC's report "identified three major areas of concern regarding the dose assessment process" that were part of the Army's 2002 decommissioning plan. One of those major areas of concern, the first area of concern listed by SAIC, was that

groundwater contamination should be part of the RESRAD analyses.

Long before the September of 2004 Memorandum from SAIC, SAIC, the Army and the Staff were well aware of karst geology underlying the JPG DU area. On May 20, 2004, Staff witness McLaughlin issued an RAI to Army (NRC, 2004) regarding Army's 2003 proposed changes to the Environmental Radiation Monitoring Program (U.S. Army, 2003). The plan was written by SAIC. In the Basis for Question 2 of the RAI, McLaughlin quotes heavily from the Army's plan, as follows:

> In the ERM, the Army states: "To assess the groundwater conditions in and surrounding the DU Impact Area, a number of groundwater monitoring wells were installed and sampled over a substantial period at locations experts believed adequate for acquiring such information." "No one can ensure that groundwater monitoring systems in karst environments will not involve a contaminant 'end-running' a network." "It is well known that a complete deterministic description of the preferential pathways is not possible in karst/fractured environments." "The site is located in karst topography; therefore, the complex physics of flow and transport in fractured media apply. In these systems, the flow patterns may or may not match the directions typically inferred from the slopes indicated on groundwater table maps. Therefore, locating monitoring wells directly downgradient of a source area is complicated. In addition, migration of uranium in the subsurface is a complex biogeochemical reactive process."

It was known at least by 2003 to Army, its contractor SAIC, and the Staff that karst was part of the site hydrogeology. In 2004, SAIC was proposing to add groundwater contamination to the site RESRAD model. But, RESRAD is incapable of realistically modeling karst hydrogeology. According to the RESRAD users manual, page 2-11, "The groundwater pathway models implemented in the RESRAD code apply only to situations

for which the hydrological strata can reasonably be approximated by a sequence of uniform, horizontal strata." If groundwater under and around the JPG DU site are part of the human radiological exposure assessment, RESRAD cannot be used as the assessment performance model. For the Army to propose an FSP in 2005 that focuses only on collecting data specifically for RESRAD modeling and for the Staff to approve that FSP, Army and the Staff must have had the joint expectation, before the FSP was implemented or any data was collected, that groundwater would not be part of the exposure assessment.

IV. Issue 3. the dynamic, iterative character of the FSP

Q.014 How would you describe the basic character of the FSP?

A.014 I would describe it as a field sampling and data evaluation program with a dynamic, iterative character that, had it been constructed and implemented properly, would have been capable of providing the necessary site characterization to address all decommissioning needs and scenarios with a reasonable budget and within the five-year period of the alternative schedule.

Q.015 With respect to the basic (dynamic, iterative) character of the FSP in governing

JPG DU site characterization activities, how would you describe the differences of professional opinion between you and the Army and Staff witnesses?

A.015 I see the following two principal differences between my opinions and the opinions expressed in the testimony of Army and Staff witnesses:

First, through their witnesses, the Army and the Staff appear to be saying that there is insufficient data at this time to rule out "bounded" TEDE computations. As a result, STV cannot object that the FSP is deficient at this time for being unable to map and measure DU contamination sufficient to support "point or range" TEDE computations for on- and off- site scenarios. Were it eventually proven that "bounded" TEDE computations cannot be supported, the FSP could then be amended as required to support "point or range" TEDE. Hence, if bounded TEDE computations prove appropriate, STV is wrong; the FSP is fine. If point or range TEDE computations are necessary, STV is premature; the FSP can be modified to add any additional characterization that is needed.

Second, the Army and the Staff both make clear that the FSP as designed depends on only a partial or limited characterization of the JPG site. In particular, they seem to be basing the case for a partial or limited characterization on the following premises, in addition to the premise that bounded, rather than point or range, TEDE computation is appropriate for all decommissioning purposes:

a. The TEDE contribution from the hydrogeologic pathways for each medium may "conservatively" be assumed to be "bounded" as zero outside the DU impact area if no DU is detected along the road system which encloses the impact area; and

b. The TEDE contribution from the abiotic pathways for each medium may "conservatively" be "bounded" below the allowed regulatory limit within the DU impact area based on the sampling activities conducted along the road system which encloses the impact area.

Q.016 How does the Army and Staff position on the first major issue differ from your perception of a proper FSP?

A.016 The FSP as it exists functions to nominally meet a checklist of data collection objectives without acquiring the information that can test and refine the CSM, characterize the hydrogeology of the site, and build the data set necessary to model all assessments necessary for decommissioning. Problems related to design, placement, and sequencing of individual medium sampling programs will be addressed in a subsequent portion of my rebuttal. Here I will address a slightly different issue with respect to the iterative nature of the FSP.

As the FSP is being defined presently, there is an insistence upon deferring data

acquisition on the premise that it may not be necessary. This problem is particularly severe with respect to groundwater. The characterization of hydraulic properties is being deferred. Head data to be collected from new wells will be minimal, if not singular, and sampling protocols for ground water analyses have yet to be finalized. There are 10 well nests out there that could be providing a stream of information that would allow the Army, the Staff, and the public to begin to understand how the site works hydrologically and provide evidence of where additional data may be needed. But, except for the locations of the wells, the core descriptions, the well completion details and maybe a water level or two, apparently no data is being prepared. It appears that any interest in understanding the site is outweighed by some fear of what the data may say.

Certainly the concept that, unless it can be proven that bounded TEDE computations are invalid, they will be used, puts the cart before the horse, since the concept is predicated upon the failure to collect the data that justifies it. This puts the burden of proof on the public or the NRC to somehow document, without necessary data to do so, that assumptions backing the bounding are in fact conservative. The Army should be bringing together and integrating the data that establishes the validity of bounded TEDE computations, not challenging the public or the NRC to prove that they shouldn't. There is every reason to expect bounded TEDEs to prove invalid. This site is a restricted-release site with no clean up, littered with DU over a large area. The failure case is a farmer planting his garden over weathered projectiles and drinking water from a sand lens in the glacial tills under the weather projectiles. Projectiles have literally plowed the

soils, destroying the fabric that could help retard DU migration. Ordnance is found in caves in JPG, dropping through sink holes, as will DU. Biota studies of invertebrate fauna in caves show impairments associated with disproportionately in DU impact area caves. Individually any of these call for proof bounded TEDE are valid.

Q.017 How does the Army and Staff position on the second major issue differ from your perception of a proper FSP?

A.017 As with my previous answer, much of the difference is related to design, placement, and sequencing of individual medium sampling programs will be addressed in a subsequent portion of my rebuttal. But an overarching problem is that the premises upon which the "conservative" bounding conditions are being set are not based upon observation or data, but are rather based upon assumptions that have not been validated. It is assumed, not demonstrated, that wells completed along the east side of the DU perimeter are intercepting water flowing onto the DU area. It is assumed, not demonstrated, that wells completed along the west side of the DU perimeter are intercepting water flowing from the DU area. It is assumed, not demonstrated, that there is no deeper karst network below the shallow karst network that would introduce even greater complexity to the hydrogeology under the site. It is assumed, not demonstrated, that if DU will migrate in the groundwater from the DU site in the next 1000 years, it is doing so now and is passing by the wells along the west perimeter. It is assumed, not demonstrated, that interpretations from base flow separation of stream gauging records will not be impaired

by losing reaches of streams that recharge water to deeper conduits. It is assumed, but not demonstrated, that sediments washing from the DU site cannot leave without being monitored at the culverts along the west perimeter. It is somewhat ironic that SAIC's understanding of the complexity of the site appears better when they wrote the proposed changes in the ERM program in 2003 than is demonstrated in the FSP and their testimony now (See, above, the SAIC quotations cited by McLaughlin in A.012.)

Each of these assumptions may be a reasonable starting point for a conceptual site model that is the best of all worlds. But they must be challenged and tested if there to be any confidence in them. And that is what this FSP does not do.

V. Issue 4. Particular Methods or Protocols Associated with Hydrogeology Issues of the FSP

Q.018 What do you see as the principal differences of professional opinion between you and the Army's and the Staff's witnesses regarding particular methods or protocols associated with specific hydrogeology components of the FSP?

A.018 The most efficient answer is probably an enumeration and discussion of what I believe the FSP needs to do or change to allow the production of an acceptable decommissioning plan at both the level of human dose exposure and at the level of human and

environmental health, both of which I understand to be the responsibility of the NRC for this site. It is inefficient, time consuming, expensive, and potentially duplicative to perform a characterization FSP that only gets you part way there.

A number of issues have faded, I think, as I understand the testimony. I see five primary issues with substantive differences that remain and that impact site characterization and data evaluation. I do believe these differences are more clearly defined as a result of the testimony. I see three new issues that have appeared as a result of Army and Staff testimony. The issues that have faded will be addressed in testimony of the remaining and added issues. The five clarified issues are the following:

1. The FSP site characterization program should be modified with the expectation of an expanded network of characterization wells, to investigate the potential for and evidence of deeper karst elements that may channel water in directions other than toward the local, on-site streams or at discharges outside the current monitoring web; *i.e.*, currently unmonitored groundwater discharges.

2. Prior to the installation of additional characterization wells, Big Creek, Middle Fork Creek and the unnamed tributary of Big Creek that enters the DU Impact area north of D Road should be surveyed with one or more seepage runs to identify those stream reaches with readily apparent flow increases or decreases, thereby identifying where active conduits intersect and interact with the surface

drainage system.

3. Also prior to installation of any additional monitoring wells, remote-sensing and on-the-ground geophysical programs should be instituted that are designed to delineate in three dimensions major, open karst pathways that would dominate the groundwater flow system into and from the DU Impact area. These programs should be designed in a manner capable of identifying multiple monitoring sites within critical pathways.

4. The sample collection locations, timings, and methods should be re-evaluated and re-redesigned as necessary to aggressively find migrating DU, in each medium at times, at locations and under conditions that are most likeliest to find it and that document variations in the migration rates.

5. The sample analysis protocols and methods to detect and measure DU in the samples should be improved, if only during the characterization period. Characterization monitoring serves different purposes and has different requirements than compliance monitoring, and the characterization program should reflect that.

The following are three additional issues that seem to have arisen as a result of testimony on behalf of the Army or the Staff, or have been introduced outside the scope of STV's

original pre-filed testimony:

6. A sea change is needed for the focus of the site characterization, from a position of "let's wait and see whether we must have this information to get the RESRAD number" to a position of "if we're going to leave this much uranium and this much ordnance on this site forever, we want to be very, very certain we haven't overlooked *anything* that may threaten our neighbors or their environment."

7. The choice of the Kd approach for modeling the mobility of uranium is not appropriate and is dated with respect to current computational abilities.

8. The FSP data sets should be expanded to include appropriate inputs for a full capability fate and transport model where those differ from what is needed for RESRAD.

Q.019 Would you expand briefly on item 1, that there needs to be evaluation of an as yet uncharacterized portion of the site karst system?

A.019 Yes. In my pre-filed direct testimony I discussed my concern that the FSP was not investigating the possibility that drainage through karst systems at depths below the level of a stream on the site could lead to water transfer out of the stream's surface drainage basin, direct groundwater flow in a direction other than the direction of surface water

flow or shallow groundwater flow, take water from a stream, bypass or flow under stream or groundwater monitoring points, and discharge at unknown locations not subject to monitoring. These complexities are known and acknowledged in Army documents at JPG (*e.g.*, U.S. Army 2003) and the importance similarly recognized by Staff witness McLaughlin (NRC, 2004), as excerpted above in A.012.

I testified that such complexities could be the result of a contemporary karst system or the intersection of a contemporary system with one that formed potentially many millions of years ago, under completely different hydrologic conditions. There is nothing imaginative, unique or nightmarish about old karst systems (the term is paleo-karst), or portions of them, interacting with contemporaneous karst activity millions of years after they first formed. It is a common, world-wide phenomenon. Across the central United States, active surface caves in Mississippian-aged limestones (*e.g.*, the Madison Formation in the Rockies or the St. Geneve Formation in Indiana and elsewhere in the Midwest) often contain Mississippian- or Pennsylvanian-aged sediment, establishing that parts of the active surface karst system are hundreds of millions of years old. The concept is so common that it is taught to geology students in undergraduate field camps.

I am currently working on waste disposal and remediation sites in Silurian- and Ordovician-aged limestones and dolomites covered with a veneer of glacial sediments, on the eastern flank of the Illinois Basin. This is a geologic and stratigraphic setting directly parallel to that of JPG. Shallow, contemporary karst development is occurring in these

fractured carbonates, as is occurring at JPG. At these sites parts of the active conduit system are also clearly paleo-karst, as evidenced by in-cave sediments that are hundreds of millions of years old (*e.g.*, Plotnick, 2007). Two sites I have recently evaluated have Pennsylvanian-aged sediments filling paleo-karst sinkholes in fractured Silurian dolomites that occur immediately below the glacial sediments. Based upon my experience, education and training, it is far likelier that the old carbonates under the JPG contain a paleo-karst component than that they don't.

Two of the Silurian carbonate sites I am currently working on show divergent flow directions between the near surface flow and deeper, conduit flow, a phenomenon discussed in U.S. Army 2003 and cited in NRC 2004. At these sites, shallow groundwater and deeper groundwater flow to different discharge points at different elevations. The shallow groundwater discharges to local surface drainage and the deeper groundwater discharges further away at a discharge with lower elevation. Recharge at both of these sites is local precipitation and neither shallow nor deeper flow at either site is influenced by a regional flow system.

Characterizing a hybrid of contemporaneous and paleo-karst elements can be more difficult than working with a solely contemporaneous system. But, an entire system must be characterized as thoroughly as the contemporary portion of that system to determine whether and when site contaminants leave the site and where they are going. The FSP does not provide for that characterization, in part because the need is not recognized.

Army witnesses who testified on the issue of a deeper, older conduit network that is part of the conduit network to be addressed by the FSP universally rejected the entire concept as being hypothetical, speculative, or without any evidence. However, evidence at multiple levels document groundwater flow patterns and conditions indicative of an active karst network below the levels of the surface drainage on this site.

It is generally recognized that Big Creek and Middle Creek are losing streams along some reaches at some times of the year. This has, for at least the last five years, been routinely acknowledged in site documents, including reports prepared for Army by SAIC. For example, the previous decommissioning plan (U.S. Army, 2002a), on page 3-16, describes the conditions under the DU impact area as follows:

> The aquifer is unconfined to semi-confined and is recharged by infiltration of precipitation to the bedrock aquifer concentrated along fractures within the glacial till and in areas where the creek channels are losing water to the groundwater system.

Conditions consistent with that interpretation are documented in on-site groundwater by monitoring well MW-09, within the DU impact area near Big Creek. Water levels recorded in MW-09 as part of the ERM program routinely show elevations that are approximately 10 feet below the water elevation in adjacent Big Creek. The lower water levels in MW-09 indicate that flow in this vicinity is from Big Creek into the groundwater and not from groundwater into Big Creek. With the current state of site characterization, it is not possible to determine where that groundwater discharges, only

that it isn't to Big Creek in the vicinity of the well. It may discharge back into Big Creek at some point downstream, and beyond the DU impact area site boundary, where Big Creek is at an elevation below the water elevation in MW-09. It may flow away from Big Creek to an entirely different stream. Since the route of migration has not been mapped there is no way to know. But in either case, surface water that had been in Big Creek is now groundwater and invisible to surface water monitoring for quality, staging, or flow.

Local data indicate some options for where the water may flow. MW-09 is completed in Silurian-aged carbonate rock that has karst development in the immediate area. Water from MW-09 can only migrate to a discharge point that is at lower elevation than its water level (there are no wells in the immediate area). There are lower elevations for the site streams west of the DU impact area, and there are lower elevations in the valley of a stream to the east of the DU impact area, and either stream is a potential discharge point. According to a map of karst features and caves in southeastern Indiana (Powell, *et al.*, 2002), there are surface caves in the Silurian rocks to the east and there are surface caves in the Silurian rocks to the west. Current characterization does not allow a prediction of whether the deeper flow is to the east or the west.

Direct evidence that complex subsurface migration paths can allow DU to bypass monitoring points is found in the site ERM data. With a clear understanding the Army's consultant does not accept this interpretation, my view is that there is evidence in the fall

2005 ERM sampling data, as one example. (The issue of what if anything this evidence shows will be discussed further below in A.021.)

Surface water samples designated as SW-08 are collected where Big Creek crosses out of the DU impact area. Surface water samples designated as SW-02 are collected where Big Creek crosses out of the entire JPG site. (See U.S. Army, 2002b, Figure 2-1, page 2-5.) The bounding approach being taken by Army and accepted by the Staff for site characterization appears to be that, if DU is not observed in the water in Big Creek sampled at SW-08, it is a conservative assumption that DU will not be found further downstream in Big Creek.

In the fall of 2005, the U238/U234 alpha activity ratio of the SW-08 sample from the edge of DU impact area was less than 0.5. There were two SW-02 samples taken at the downstream side of the JPG. The first had a ratio of greater than 1.2 and the second a ratio of 2.9. The higher the alpha activity ratio, the greater the likelihood and the higher the proportion of DU in the sample. The data from the fall 2005 ERM sampling are consistent with the hypothesis that there is a component of DU in the Big Creek water leaving the JPG that is not in the Big Creek water leaving the DU impact area, and therefore enters Big Creek without passing the Army's perimeter monitoring network.

Q.020 Would you expand briefly on your item 2, that there needs to be additional stream gauging activities in the form of seepage run surveys that are not part of the current

FSP?

A.020 Yes. The existing stream and cave gauging is not designed and is not capable of identifying where the streams crossing the DU impact area are gaining flow from groundwater or losing flow to groundwater. Knowing which reaches are transferring which way is fundamental to characterizing when and where the surface water is contaminating or being contaminated by ground water and *vice versa*. Knowing where the recharge/discharge reaches are will also help refine the location of future characterization wells that can be targeted, with additional geophysical work, to test conduit features that were untested in the previous characterization drilling or are invisible to the methodologies that were used to locate the first wells and are known to interact with the surface water flows across the site.

It is important to note that the seepage run survey(s) that are needed are not a substitute for or a replacement of permanent stream gauging/staging stations or stream sampling. They are primarily a tool for identifying the positions and nature of exchanges between surface water and groundwater. They have a secondary value as a tool to help appropriately position permanent or long-term gauging stations analogous to those currently installed as elements of the stream gauging system. One of the purposes of the stream gauging system is to allow an estimate of the portion of the precipitation that infiltrates to become groundwater. The methods for those estimates assume that groundwater within the surface water basin is not transferred out of the surface water basin or into the surface water basin and that surface water above the gauging station

cannot bypass the gauging station and return to the stream below the point of measurement. By relocating the gauging/staging locations to correspond to gaining and losing reaches of the stream, more, and more reliable, interpretations of that data are possible than with the existing system.

Q.021 Would you expand briefly on your item 3, that there needs to be additional remote and contact geophysical programs as part of site characterization?

A.021 Yes. One of the issues I raised in my direct testimony was the use of the EI system to distinguish among linear features identified on the air photos that represented fracture zones likeliest to be water-bearing conduits. My perception from reading the FSP and supporting documents was that the EI technology was being represented as a technique to locate probable water-bearing conduits that were coincident with features identified on the FTA. I originally testified that, as a resistivity device, the EI could be and was likely mapping any number of resistivity contrasts that may have nothing to do with major water-bearing conduits. Based upon the pre-filed testimony of Army witnesses Eaby and Snyder, I apparently did not fully appreciate from the FSP language what these witnesses understand to be the uses and limitations of the EI device. This is one of the issues where I find my current understanding of their geophysical tool of choice is more consistent with their understanding than I perceived at the time of my pre-filed testimony.

Snyder succinctly confirms (Snyder, A48, p. 31) that his understanding of what the EI is mapping is consistent with my experience,

> Norris also states that "Low-resistivity anomalies may represent the electrical signal of mineral content, not necessarily that of water-bearing conduits." Deposits of clay from karst weathering are actually what is most often mapped by the EI.

Snyder states (p.32), "Although compacted clay has very low permeability, the sediment/bedrock interface and the adjacent fractured bedrock zones are often highly permeable, ..." This is not to say that the EI can identify the sediment/bedrock interface of the fracture trace, or the face of fractured bedrock. Eaby's testimony clarifies that. Although he does not identify what the EI does map, Eaby is clear about what it does not map (Eaby, A34, p.28):

> Mr. Norris is making the mistake in interpretation by considering the EI results as a picture of a cross-section of the subsurface and is considering the edges or boundaries of modeled electrical fields as actual physical surfaces such as bedrock surfaces, solution cavity walls, fracture faces, etc, when this is not the case at all.

The existing characterization wells were positioned along roads at locations where visible linear anomalies, interpreted as fracture traces, coincide with the electrical anomalies from a geophysical technique that primarily maps clay, a material with very low permeability. The expectation is that sufficient clay to produce a resistivity anomaly of interest will not represent the degree of plugging that will prevent a monitoring wells from being installed. The individual and institutional experience with this methodology is that, with the help of a good rig geologist, a "successful" monitoring well can frequently be installed..

The greatest risk to an offsite receptor from contamination in groundwater is not from groundwater migrating through the kind of "conduit" that is being tested by this characterization program. The greatest threat is contamination that migrates through open channels through the carbonate rock, channels that have the least fill and highest proportion of voids. In that kind of karst conduit, transport is fastest, attenuation is least, and impacts are greatest.

Such cave systems under the DU impact area that are shallow are apparently already biologically damaged. An invertebrate survey has been conducted of the caves earlier surveyed by Sheldon. This study (Lewis, *et al.*, 2002) found that invertebrate fauna in caves under the DU impact area are disproportionately impaired, even though the caves were largely physically intact. The researchers observed based upon their investigations the following (p. 64):

> In other caves within the impact zones, a mosaic of presence/absence of fauna was noted. Unlike Isaiah Irwin or Everett Shonk caves, these sites seem to be at least grossly intact. The reason for the absence of fauna remains unknown, but groundwater contamination should be entertained as a cause. In particular, caves in the depleted uranium area (figure 6) appear to have low population densities of stygobiont aquatic species, but quantitative sampling would have to be performed to ascertain this.

Open conduits below the stream bases are the conduits that the proposed characterization should seek to find. With today's level of understanding, a statement that "there is no evidence" for such conduits is only a confirmation that the search for them has not been started, not proof that they cannot be found. Assertions of a dynamic, iterative FSP that

can respond to new data ring hollow because data indicative of that type of karst system are not being sought.

Remote sensing and ground geophysical surveys that are capable of finding these types of conduits, as opposed to finding clay-bearing fracture zones, are needed. The specific surveys and protocols should be selected in consultation with those familiar and experienced with searches for these specific types of features. No technology should be rejected out of hand. That does not mean that all technologies would be used. Pilot implementation of likely candidate technologies should be used prior to design of the full program.

Q.022 Would you expand briefly on your item 4, that there needs to be modification of the existing sampling program to achieve necessary site characterization?

A.022 Yes. I take sampling to be all methods of data collection that influence ones understanding of the site. In that context, remote and ground investigations are forms of sampling, but they have been addressed above, so I turn to other forms.

Rock sampling occurs in the process of advancing the borings and completing the wells. Drilling would not include automatic casing advancement with drilling. It would be considered at an individual boring where drilling conditions allowed no other method. In

my present work in karst and fractured Silurian dolomites and limestones that are overlain by glacial sediments, such drilling procedures are very seldom necessary. Boreholes, both vertical and angled, are routinely drilled with either rotary bit or continuous coring without persistent drilling and completion problems. This is clearly a different experience than that expressed by Army's consultants, but there is also a fundamentally different drilling objective, which may account for the different field experiences.

A major characterization advantage of this approach over the FSP approach is that the boreholes will be open after drilling allowing for geophysical investigations of the rock around the boring to supplement and quantify the observations of the trained rig geologist. Upon completion of each well, it would immediately be tested for hydrologic properties and its water levels would be routinely measured, in order to provide maximum information to guide subsequent characterization efforts as soon as possible.

Stream flows would be measured using the same methods and protocols of the FSP. There would almost certainly be a difference in the sites of staging locations, based upon the results of seepage run surveys. Cave flows would be measured similarly to the FSP methods and protocols but locations would likely be different. Conduits that support spring discharge, whether or not large enough to enter, would be considered. Conduits whose discharge includes or originates with sinkhole infiltration would be sought and those whose flow originates in areas of heavy radioactivity would be given priority.

Tracer surveys would likely be used to assist in such identification.

Sampling schedules for groundwater and surface water would be designed to test media at times and places designed to find contaminants that are migrating, both radiological and chemical. Sampling under average conditions provides less information about geologic processes, particular with respect to transport processes, than sampling under conditions specifically related to a particular transport process. For example, uranium in the impact area will likely often be closely associated with clay minerals and organic soils. Light rains may allow uranium-contaminated soils to wash into sinkholes, where the sediments accumulate until there is a major rain, which flushes the accumulated soils from the cave. Sampling the cave water quarterly for the sediments suspended in the discharge without consideration of that cave's flow patterns is unlikely to identify the transport contribution of the cave. Each medium and sampling station needs to be evaluated to ensure that the timing and methodology employed will actually collect the necessary information. Evaluation of each sampling medium and station individually does not mean separate sampling schedules and procedures for each sampling location.

Radiological sampling protocols and procedures are particularly important for this site, of course. The objective should be to push the envelope to ensure that if DU is moving, the sampling program finds it and finds it at its peak concentrations. Since a characterization program has distinctly different purposes than a compliance program, sampling objectives and methodologies appropriately are different. First arrival and detections at

low concentrations are key objectives in characterizing a site with known contaminations. Sampling and, as discussed below, analytical procedures should be coordinated to meet those objectives.

Data collected in the characterization of the site will be the only way to "truth" whatever model is used to evaluate radiological and environmental performance of the decommissioning plan. The conditions being observed today are virtually the birth of the evaluation. If conservative, bounding values for parameters predict no dose from a particular medium at the midpoint of the evaluation, and there is a finite, measurable dose today, there is an input error. If high resolution methods are not being used to detect low concentrations, the truthing process can't be done.

Q.023 Would you expand briefly on your item 5, that there needs to be modifications made to the analytical and evaluation protocols and procedures, at least for the characterization period?

A.023 Yes. At this stage of site evolution, DU concentrations will likely be low, they will vary temporally and they will vary among media. Quantifying that variability is not simply a choice of analytical technologies, *e.g.*, AS vs. ICP-MS; it may require both depending upon the medium, and it may require customized laboratory procedures, rather than off-the-self, standard procedures. Given these variabilities and the "chameleon" chemistry of DU among various media, creative innovation in design of the laboratory procedures is called for.

In my pre-filed testimony I discussed the need for high resolution at low concentrations for detecting DU presence and understanding DU migration. Uranium isotope data is presently being analyzed in the site ERM program using alpha-spectroscopy. Using standard laboratory procedures, many samples from each medium have low activity concentrations and high uncertainties. The result is that the ability to determine isotope concentrations, and thereby, the DU fraction, in the soil, sediment and water is limited or not possible.

The importance of identifying DU, even at low concentrations, is addressed in my rebuttal testimony in A.020. With the current methods, results in the ERM data that are indicative of the presence of DU to one reviewer are rejected by another, due in large part to different perspectives of what interpretations are reasonable and conservative. I firmly believe that the surface water passing eastward off the JPG facility in Big Creek contains DU in rising proportion to total uranium:

> In spring 2005, the U-238/U-234 ratio was 1.1, more than 2X the minimum values seen in other streams.
>
> In fall 2005, the U-238/U-234 ratios were > 1.2 and 2.9, from duplicate samples
>
> In spring 2006, the U-238/U-234 ratio was 3.7, more than 7X the minimum values seen in other streams.

Army witness Anagnostopoulos testifies passionately and at length (A28, pp. 11-22) on details of uranium isotope analysis and concludes that, because of the total propagated uncertainty, the spring 2006 water sample of Big Creek leaving the facility "cannot be used for decision making." Anagnostopoulos is silent as to whether he thinks there is DU in the sample.

It is important to identify DU, even at low concentrations, as part of site characterization. It is, therefore, important to identify it with a precision that allows all stakeholders to accept the analyses and agree on what is there, even if not agree on what to do about it.

In my pre-filed direct testimony I suggested that the analytical resolution of uranium isotopes and DU identification could be improved by increasing sample size (*i.e.*, mass) and/or increasing the count time for the analysis. Anagnostopoulos and Staff witness Condra have testified that while increasing mass (but not necessarily sample size) and count time reduces analytical uncertainties, there is very limited gain that can be achieved using standard procedures at commercial labs. It seems reasonable, then, that for the DU site characterization program, that alternative methods, laboratory, and/or custom, non-standard procedures be used to allow DU to be detected and quantified.

I also suggested in my pre-filed direct testimony that custom analytical procedures that are developed should be sufficiently precise to detect DU that constituted as little as 25 % of the total uranium. In response, Condra testified,

> In my laboratory, the only method used to determine the isotopic ratio of U-238/U-234 is a statistical method of dividing the U-238 concentration by the U-234 concentration and then propagating the uncertainties. I am not aware of a methodology that permits one to determine if part of the sample is natural uranium or DU. The concentrations in the analyzed aliquot are reported in either natural uranium or DU. I have never observed uranium concentrations reported in any sample as a percentage of natural uranium and a percentage of DU.

With the exception of the projectile itself or fragments of projectiles every medium sampled that contains DU will be a mix of natural uranium and DU, since natural uranium is virtually ubiquitous in its occurrence. Expressing the relative abundance as percentages is an immediately understandable method of describing the uranium chemistry of a sample. The idea of reporting DU as a percentage is also neither original nor unique. DU assessments performed by the United Nations in Bosnia and Herzegovina (UNEP, 2003) reported the uranium with the various isotope ratios commonly seen as well as converted to a percentage DU, by combining the results of the the U-238/U-234 alpha activities with the U-235/U-238 mass ratio from (high resolution) ICP-MS analysis. The percentage reporting method was used for soils, water, and air.

The results for this method provided some interesting insights when compared to U-238/U-234 activity ratios. A water sample with 73.4% DU had an activity ratio of only 1.72, compared to the water leaving the JPG site in Big Creek with an activity ratio of 3.7. Another water sample with 14% DU had an activity ratio of 1.12. These examples come from Tables E-2 and E-5, UNEP, 2003. Soil similarly showed the problem with assuming significant DU contamination is evidenced by high activity ratios. DU

compositions of between 33% and 45% had activity ratios of only 1.3 to 1.6.

In my pre-filed direct testimony I suggest that there is evidence that chemical fractionation may be modifying the U-238/U-234 activity ratios and that the nature of that fractionation is such that U-234 is disproportionately mobile and U-238 is disproportionately attenuated. The result of this fractionation would be that residual soils would have high activity ratios and water media dominated by dissolved species would have low activity ratios. In addition to discussing field evidence for such fractionation, I provided a laboratory study showing quantifiable fractionation in the laboratory. Chemical fractionation is problematic because it would reduce the chance that a mix of natural uranium and DU in water dominated by dissolved uranium would have the expected high activity ratio normally used to identify DU and make the task of identifying and tracking DU even more difficult.

Condra did not address the fractionation issue. Anagnostopoulos discussed anomalous alpha activities in terms of alpha recoil fraction, a largely physical phenomenon, that would not account for the relative activity ratios between background deer samples and the deer collected around the DU impact area, as chemical fractionation would. Staff witness McLaughlin dismissed the concept as an academic curiosity performed in the lab based upon the review of the paper provided in disclosure. There is no indication field evidence was evaluated.

Q.024 Would you expand briefly on your item 6, and discuss what you mean by a "sea change" and how it impacts the FSP and site characterization?

A.024 Yes. The implementation of the FSP currently is a wait-and-see implementation. There seems little interest in acquiring data that may change perceptions or interpretation of the site geology or hydrogeology. The FSP is touted as a dynamic, iterative characterization program, but that dynamic, iterative potential is not realized when the data necessary to trigger new activities are not part of the data-collection tasks of the FSP. For example, Staff witness Peckenpaugh discusses how the FSP will dynamically respond to site conditions to determine which of the characterization wells to put in the monitoring system. After listing a single water level measurement and a number of physical and construction details of the wells as evaluation and selection criteria for selection of the monitoring wells, he states (A25, p. 24), *"If the groundwater levels are significantly impacted by climatic conditions, additional water levels will be needed before the monitoring wells can be selected."* One can't identify significant impacts to groundwater levels by climate conditions without having recorded multiple water level readings. But, multiple water level readings aren't warranted until significant climatic impacts are evident. Army witness Snyder (A31 on page 21) appears caught in a similar endless loop when addressing the conditions under which high-flow surface water samples will be collected.

Based upon more than two decades working on a broad range of characterization, remediation, and water development projects, the most effective and most efficient

projects are those where aggressive data acquisition and assessment were the rule. Projects with a don't-ask, don't tell approach, as the current FSP is in many aspects, get in trouble, in my experience. If the Army wants a successful characterization project by the end of its five-year program, one that openly evaluates who will be impacted to what degree as a result of its restricted-release decommissioning plan, I would recommend it review its tactics and take a more aggressive approach to learning how this site behaves.

Q.025 Would you expand briefly on your item 7, and discuss what you see as the issues related to modeling uranium mobility and the use of the Kd approach?

A.025 Yes. Although the issue of using a distribution coefficient or Kd to model the uranium mobility characteristics was not raised by STV witnesses in pre-filed direct testimony, it was introduced in one of the original bases to STV Contention B-1 and addressed by a number of Army and Staff witnesses to some degree. Staff witness Ridge was the witness who best discussed the merits of the method and rebutted the criticism brought by STV when it filed its original contentions, so I will primarily address her rebuttal testimony.

STV's Basis J of its original contention lodged a number of criticisms related to the Kd approach. These included discussing some of the underlying assumptions for Kd computations that are known to be wrong, and offering alternative ways to approach the problem of uranium mobility and how to characterize it. I will address Ridge's major points in sequence.

Two of the underlying assumptions for using Kd computation are that of a linear Kd isotherm and that of local or rapid equilibrium. (Ridge does a very good job of discussing these terms and, for those interested, I refer them to her testimony beginning on page 5.) Ridge acknowledges that neither assumption is valid, but believes each can be worked around by bounding inputs to conservative values. The representation that this is appropriate because everyone else is doing it is non-persuasive.

The discussion of local equilibrium and its impacts is disturbing. When the assumption of local equilibrium does not occur, the computed peak concentration is delayed in time and suppressed in magnitude. Ridge acknowledges both problems and discusses weak work-arounds. She suggests that NRC staff may look at times beyond 1000 years, so the delayed-in-time problem may not be a severe issue. Ridge did not, however, attempt to deal with the issue of peak suppression.

Among the rationales for using the validity-plagued Kd approach, Ridge described how the Army would develop site-specific coefficients from site groundwater and the various site specific soils so the Kd used could be conservatively bounded. It is unclear whether she is aware that the Soil Verification Study consolidated all of the soil series into just two groups, so the variety is now a population of two. Further, any comfort Ridge gets from the concept of using site-specific groundwater for the Kd development is premature. The FSP does not yet have the sampling addendum published and it is not at all clear how, or if, they will be sampling the vadose water that should be used for such work, or

whether they will substitute groundwater from some monitoring well. Assurances of reliability of coefficient development should be withheld until all applicable addenda have been issued and reviewed.

Ridge's response (A17, pp. 11, 12) to STV's suggestion that alternative modeling technologies are available and are superior is a bit puzzling. She seems to be suggesting that while thermodynamic equilibrium models can with a great deal of effort duplicate the Kd approach there doesn't seem to be any benefit to them. That discussion doesn't seem consistent with a paper she co-wrote as principal author; Ridge, A.C., Cady, R.E., O'Donnell, E., Randall, J.D., Reed, P.R., Veblen, L.A. (2005), *Use of Thermodynamic Sorption Models in Reactive Transport Modeling: Advantages for U.S. Nuclear Regulatory Commission Licensees and Staff and Areas of Research*, at Waste Management, Tucson, Arizona, February 27-March 3, 2005. I am uncertain whether this work has been officially disclosed, but it is referenced in her resume and would seem relevant here.

Q.026 Would you expand briefly on your item 8, and discuss the modeling issues you see introduced by implementing the FSP in a manner to address all characterization requirements for restricted-use decommissioning?

A.026 Yes. Implicit in item 1 above, is an expansion of the FSP beyond simply data collection for RESRAD input. RESRAD is incapable of modeling all of the complexity of the site hydrogeology. It is certainly incapable of modeling all of the key considerations relevent

for purposes of environmental assessments. If it is used for purposes of human radiological exposure, its results will not be defendable without confirmatory monitoring from a program with the capability to model site complexity. The selection of the partner program is necessarily dependent on being further along with the characterization process. Thus, whether or not RESRAD is also used, a alternative model is needed for dose assessment, too. If that model is identified early, the data streams appropriate for that model can be incorporated into the FSP and no time need be lost.

VI. Summary

Q.027 In view of the multiple, significant differences you have identified in detail with the Army and Staff witnesses in your rebuttal testimony, would you summarize for the Board your position on the most critical matters in dispute?

A.027 There are three core elements of adequate site characterization that are not incorporated in the FSP and will not be incorporated in the FSP regardless of its "iterative" design unless the Board intervenes. There are other issues I have mentioned, but ultimately they can be resolved by addressing the three core issues.

The first is the failure in the FSP to design sampling programs to adequately characterize

the complex karst geology and hydrogeology of the site, particularly with respect to the existing evidence on and around the site of a karst system that is deeper than that presently envisioned and, therefore, capable of transporting site contaminants, including DU in unanticipated directions, by pathways invisible to the existing or FSP-modified monitoring net, to discharge at unidentified locations. The "iterative" design of the FSP cannot address this issue because even the possibility, let alone the evidence, of a larger karst system is denied. Because of that denial, there are no data to be collected that will drive a change in the FSP to characterize the system.

The second is the perception of the FSP as adequate if it merely collects a handful of data values that allows a standard RESRAD model to be run, in lieu of a model that captures the real character of the site. The NRC does have responsibility at this site for assessing the environmental impacts of any proposed decommissioning plan. That charge entails the characterization, assessment, and modeling of the site for a far wider and different set of conditions and receptors than the simple RESRAD task. If the FSP objective and design is not altered, and soon, there will be no chance to present and assess a finished decommissioning plan in the time frame of the alternative schedule. Not only will time lines be erased, the inefficiency in the performance of site characterization activities will increase their cost considerably.

Finally, there is the issue of sampling and analysis of media on, under, and around the DU Impact area. No matter how the task is performed, projecting the mobility patterns of

the uranium in the DU Impact area from the projectiles, into and through the soils and subsequently through groundwater pathways, over a period of a thousand years, to receptors on and off-site is necessarily an educated guess. When estimated variables are acted upon by exponents, or are themselves exponents, even a good educated guess may not be close to reality.

The only reality check for that educated guess is the ability to test that guess against observation - calibration of the model. The site is early in its radiological history, and it will still be young 1000 years from now. Any DU migrating from the site now is likely minimal in terms of short-term publlic health effects. But, if it can be detected at measurable concentrations, it provides a reality check on RESRAD or any model that is used. If the model says not in 1000 years for groundwater, and it can be found in groundwater today, the model can be reparameterized to duplicate the observation, and, thereby, improve its projection 1000 years hence. That kind of resolution cannot be achieved with the sampling and analytical procedures that are used for performance monitoring. Performance monitoring does not require that level of discrimination. So the sampling protocols and the analytical methods in the FSP should be modified - customized if necessary – to allow the right data properly collected and evaluated to constrain the models upon which the NRC relies to protect public health and the environment over the longer term..

Q.028 In your testimony, you have referred to a number of sources of information. Are

those listed in a reference section, and has each been disclosed as part of these procedings?

A.028 Yes, they are listed in the reference section, designated section VII. References. I believe each of them has been previously disclosed.

Q.029 Does this conclude your testimony?

A.029 Yes, it does.

VII. References

Hoover, Rick A., 2003, *Geophysical Choices for Karst Investigations*, prepared for 9th Multidiciplinary *[sic]* Conference on Sinkholes & the Engineering and Environmental Impacts of Karst, Huntsville, Alabama, September 2003.

Lewis, Julian J., Salisa T. Rafail, 2002, *The Subterranean Fauna of the Big Oaks National Wildlife Refuge*, Final Report to U. S. Fish and Wildlife Service, Natural Heritage Program Division of Nature Preserves, Indiana Department of Natural Resources, April 2002

Plotnick, Roy, 2007, *Exceptionally Well-Preserved Sub-Absaroka Paleokarst and Lower Pennsylvanian Fill: a Window into Early Pennsylvanian Paleoenvironments*, Paper No. 28-1,

Joint South-Central and North-Central Sections, Geological Society of America, 41st Annual Meeting, at University of Kansas, Lawrence, Kansas, April 11-13, 2007.

Powell, R.L., S.S. Frushour, and D. Harper, 2002, *Distributions of Sinkholes, Sinking-Stream Basins, and Cave Openings in Southeastern Indiana*, Indiana Geological Survey Miscellaneous Map, MM64, 1 pl., Bloomington IN, 2002.

NRC, 2004, *Request for Additional Information (RAI) to Support NRC's Evaluation of the Proposed Changes to the Environmental Radiation Monitoring (ERM) Plan for Jefferson Proving Ground (JPG).* Letter from Thomas McLaughlin (NRC) to Colonel Michael Mullins (Department of the Army). May 20.

SAIC, 2004, *Identification of Key Site-Specific Data to Enhance the Accuracy and Reliability of the RESRAD modeling of the Depleted Uranium Impact Area, Jefferson Proving Ground, Indiana*, a Technical Memorandum prepared for U.S. Army, Aberdeen Proving Ground, Maryland, by Science Applications International Corporation, Reston, Virginia, September 2004

UNEP, 1999, The potential effects on human health and the environment arising from the possible use of depleted uranium during the 1999 Kosovo conflict, A preliminary assessment, UNEP/UNCHS Balkans Task Force (BTC), October 1999.

UNEP, 2003, *Depleted Uranium in Bosnia and Herzegovina, Post-Conflict Environmental*

Assessment, United Nations Environmental Programme, Published in Switzerland, 2003.

U. S. Army, 2002a, *Final Decommissioning Plan for License SUB-1435, Jefferson Proving Ground, Madison, Indiana*, U.S. Department of the Army, Soldier and Biological Chemical Command, Aberdeen Proving Ground, Maryland, June 2002.

U. S. Army, 2002b, *Final Environmental Report, Jefferson Proving Ground, Madison, Indiana*, U.S. Department of the Army, Soldier and Biological Chemical Command, Aberdeen Proving Ground, Maryland, June 2002.

U.S. Army, 2003, *Environmental Radiation Monitoring Plan for License SUB-1435, Jefferson Proving Ground.* Prepared by SAIC for the U.S. Army Installation Support Management Agency. September 2003.

VIII. Verification

I declare, under penalty of perjury, that the foregoing testimony is true and correct to the best of my knowledge, information and belief.

September 18, 2007