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Army Snyder Exh. # 5

U.S. NUCLEAR REGULATORY COMMISSION

In the Matter of US ARMY (JEFFERSON PROVING GROUND)

Docket No. 40-8838-MLA Official Exhibit No. ARMY EXH. #5

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Pre-filed Testimony of Army Witness Stephen N. Snyder

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD PANEL

Before Administrative Judges:

Alan S. Rosenthal, Chair
Dr. Paul B. Abramson
Dr. Richard F. Cole

In the Matter of	)	Docket No. 40-8838-MLA
	)	
U.S. ARMY	)	ASLBP No. 00-776-04-MLA
	)	
(Jefferson Proving Ground Site)	)	August 15, 2007
	)	

TESTIMONY OF STEPHEN M. SNYDER
ON STV CONTENTION B-1
BASIS ITEMS "a," "d," "e," AND "f"

SUBJECTS: Electrical Imaging; Selection, Installation, and Purpose of Conduit Well Sites; Installation of Shallow Wells

I. WITNESS BACKGROUND

Stephen M. Snyder ("SMS")

Q1. Please state your full name.

A1. (SMS) My name is Stephen M. Snyder.

Q2. By whom are you employed and what is your position?

A2. (SMS) I work as a Senior Hydrogeologist and Program Manager with Science Applications International Corporation (SAIC) in their Harrisburg, Pennsylvania office. SAIC acts as the Army's technical consultant and expert on selected tasks related to the planned decommissioning of the U.S. Nuclear Regulatory Commission (NRC) materials license at the Jefferson Proving Ground (JPG).

Q3. Please summarize your professional and educational qualifications.

A3. (SMS) My professional and educational experience is summarized in the résumé attached to this testimony as "Exhibit SMS #1." Briefly summarized, I am a Licensed Professional Geologist in Pennsylvania, Alabama, Mississippi, Virginia, Wisconsin, and Tennessee. I have been actively employed as an environmental consultant for 34 years.

I have experience with groundwater characterization for numerous purposes, including water supply development, landfill design and permitting, contaminant transport, and remedial investigation and remedial action. I have worked in most types of geologic environments in the continental United States, but have developed a specialty in fractured rock and Karst aquifers, which underlies the JPG site. Karst aquifers develop in soluble carbonate rocks (limestone and dolomite) and are unique in that groundwater flow pathways are dominated by solution-enhanced pathways along fractures, bedding planes, and other discontinuities in the rock, while blocks of rock between discontinuities may be nearly impermeable, transmitting little or no groundwater.

I have developed a specialty of characterizing fractured and Karst aquifers along preferential flow pathways, using a combination of aerial photo analysis and geophysical surveys. Combined with other tools, such as pumping tests, dye studies, thermal studies, analysis of stream flows, groundwater chemistry, and monitoring of water levels in wells and streams, I have characterized or assisted in the characterization of four large facilities (200 acres or more) with Karst geology in Pennsylvania, Alabama, and Tennessee. In addition, I sited numerous production wells in fractured rock aquifers for water supply purveyors, and sited or developed extraction wells and groundwater remediation systems for six projects.

I received a B.S. in Geology in 1973, from the College of William and Mary and I have completed Continuing Education in Hydrogeology at Pennsylvania State University.

Q4. Please summarize the nature of your professional involvement with JPG.

A4. (SMS) My technical support activities on the Army's JPG facility started in early 2004. I have visited JPG on two occasions and have conceptualized and guided the development of the groundwater characterization studies at JPG. I personally conducted an aerial photo fracture trace analysis of 22 square miles ,including and surrounding the Depleted Uranium (DU) Impact Area, and designed an Electrical Imaging (EI) survey for the purpose of locating monitoring wells on preferential flow pathways, which are the most likely avenues for migration of groundwater and potential migration of DU constituents with groundwater on-site and off-site. Along with the placement of stream gauging stations. I planned studies of DU penetrator corrosion and DU component migration through soils, and shallow/soil/bedrock interface zones. I am the primary author for sections in the Field Sampling Plan (FSP) that deal with DU migration pathways in groundwater and surface water.

Q5. What is the purpose of your testimony?

A5. (SMS) The purpose of my testimony is to address, on behalf of the Army, hydrological and geological issues at JPG as raised by Save The Valley (STV) as part of its Contention B-1 in these proceedings.

STV has asserted in Contention B-1 in a May 31, 2006 filing with the NRC that:

"As filed, the FSP is not properly designed to obtain all of the verifiable data required for reliable dose modeling and accurate assessment of the effects on exposure pathways of meteorological, geological, hydrological, animal, and human features specific to the JPG site and its surrounding area."

In that filing, STV provided 18 supporting bases for their contention, lettered "a" through "r" (basis "p" was withdrawn with this filing of the Final Contentions of STV.

The purpose of my testimony is to provide evidence and expert opinion that refutes the assertions and/or provides clarification to the statements made in Basis Items "a,: "d," "e," and "f".

II. OVERVIEW

Issues Raised By Basis Item "a" to STV Contention B-1

Q6. What is your understanding of the technical issues raised by Basis Item "a" of STV's Contention B-1?

A6. (SMS) STV's Basis Item "a" states:

"The EI geophysical study which will follow the fracture analysis study, as described in section 6.1 of the FSP, is supposed to find all significant karst features and location of the water table. From these studies, 10 to 20 pairs of monitoring wells are proposed to attempt to tie into 'conduits' of ground water flow. This study may help to site monitoring wells, but stream gauging studies should be an early and integral part of the search for likely conduits. The stream reaches of strong gain would be a very strong direct indicator of the discharge points of ground water 'conduits.' EI is an indirect technique and can miss conduits or identify features that are not conduits. The FSP alludes to doing stream gauging in its discussion of well location criteria, but the time table shown indicates stream studies will follow the ground water studies by a year."

STV's Basis Item "a" raises issues relating to the goal and purpose of the EI survey performed by the Army at JPG. By implication, STV asserts that the license amendment should not be approved unless the Army provides significant additional information to assist in positioning wells.

Q7. Do you agree with the assertions contained in Basis Item "a" of STV Contention B-1?

A7. (SMS) No.

III. Discussion

Electrical Imaging; Selection of Conduit Well Sites

Q8. Describe what Electrical Imaging is?

A8. (SMS) EI is a geophysical technique that measures differences in subsurface electrical resistivity at depth. Direct Current (DC) is introduced into the ground, and the resistance of the subsurface material to conducting the electricity is measured. Subsurface materials with low moisture content, like solid rock and dry sand, have high resistivity; weathered rock and silt-sized material have moderate resistivity; and clayey or saturated materials have low resistivity. A profile or cross-section is constructed from the data, showing the distribution of electrically resistant materials and electrically conductive materials. Zones of fracture-induced weathered rock are easily identifiable with EI, since they are usually saturated vertical or sub-vertical zones filled with sand, silt, and clay between blocks of solid rock. Where such features correlate with fracture traces mapped on aerial photographs, the chances are good that a well drilled on that location will intersect the network of conduits that conduct most of the groundwater through the site. The degree to which conduits develop may vary from site to site, but the procedure will locate the most likely conduit features for exploration and sampling.

Q9. Please describe the technical or analytical bases for your disagreement with STV's Basis Item "a".

A9. (SMS) There are two points made by STV in the first sentence of this Basis Item "a" that are inconsistent with the FSP and what is expected to occur as a result of the fracture trace analysis and the EI geophysical study:

- STV states that the EI geophysical study is supposed to find "*<u>all</u> significant karst features and <u>location of the water table</u>.*" The purpose of the investigation is not to locate all significant Karst features, but rather to identify locations where wells can be drilled that will intersect Karst features. These features are the most likely pathways for groundwater migration through and from the site, and by installing wells into these features the groundwater flow network can be monitored and characterized. Therefore, there is no need to identify all significant Karst features in order to adequately characterize the site.

- With respect to locating the water table, it was stated in the FSP (SAIC 2005a), Section 6.1.2.7 Potential Interpretation Techniques, page 6-4, that "The resistivity difference between dry and wet material, if indicated in the observed electrostratigraphy, can represent water table depths." This does not state that the water table will be located, only that, depending on the site conditions, it may be possible, at times, to estimate the location of the water table from the results of the EI testing. Locating the water table with the EI study is not a primary goal of the study, and would not be that significant, since the location of the water table fluctuates in response to recharge. The primary goal is to locate the most likely areas that may have increased potential for preferential groundwater flow pathways so that monitoring wells may be located in zones where groundwater is migrating, and not in Karst blocks (solid blocks of unfractured bedrock with low permeability [capacity of a rock or aquifer to transmit groundwater]) and, therefore, where groundwater migration is minimal.

STV and its consultants contend that surface water gauging along the entire stream reaches of Big Creek and Middle Fork Creek in the vicinity of the DU Impact Area are necessary for the selection of drilling locations for monitoring wells intersecting groundwater conduits with the Karst aquifer. I do not believe that this type of study is necessary for appropriately selecting conduit well locations and that the results achieved from those types of investigations (i.e., gaining, losing stream reaches) may indicate broad areas where groundwater conduits intersect streams, but does not provide accurate enough resolution of the locations or any indication of the orientation of the possible groundwater conduit intersections to appropriately locate conduit well drilling locations.

Furthermore, the surface water gauging study that STV refers to would provide limited information for areas immediately along the streams and provide no useful information as to groundwater flow pathway locations in locations surrounding and inside the DU Impact Area that are not in close proximity to the streams. Fracture trace analysis and EI are certainly a more direct method for designing a groundwater monitoring network in a conduit controlled aquifer. Nine recording stream and cave stream gauges, which are measuring surface water flow continuously for 1 year, and then will continue to measure flow after wells are installed for comparison of groundwater levels to surface water flow, will provide similar and much more substantial information, rather than a one-time snap shot of stream flow, as is proposed by STV.

IV. SUMMARY AND CONCLUSION

As to Basis Item "a"

Q10. Please summarize your testimony with regard to Basis Item "a".

A10. (SMS) My testimony can be summarized as follows:

STV misunderstood the goal of and purpose for the EI survey. The use of stream gauging will not provide significant additional information to assist in positioning wells. The project should continue as presented in the FSP (SAIC 2005a) and FSP Addendum 4 (SAIC 2007a) with the selection of well locations based on the results of the fracture trace analysis and the EI survey. Following the drilling and installation of the monitoring wells, site-specific information will be obtained as to the success of locating preferential flow pathways and the extent of Karst aquifer development at the site in the vicinity of the DU Impact Area.

V. OVERVIEW

Issues Raised By Basis Item "d " to STV Contention B-1

Q11. What is your understanding of the technical issues raised by Basis Item "d" of STV's Contention B-1?

A11. (SMS) In Basis Item "d" STV stated that:

"The FSP specifies in section 6.2.4 that the 'conduit' wells will be paired, but does not describe or explain the reason(s) for the relative positions of the two wells at each well site. Presumably, the objective is to provide a means of measuring vertical gradients at each site, but that is not explained or discussed. Nor is there an indication of whether the 'paired' well will be above or below the 'conduit' well or whether that relative position would change depending upon unspecified geologic or hydrogeologic conditions."

By implication, STV asserts that the license amendment should not be approved unless the Army is required to explain in greater detail the installation of paired conduit wells at the JPG site.

Q12. Do you agree with STV's assertions in Basis Item "d"?

A12. (SMS) No.

VI. DISCUSSION

Conduit Well Sites

Q13. Please describe the technical or analytical bases for your disagreement with STV's Basis Item "d".

A13. (SMS) Monitoring well pairs are two wells constructed in close proximity to each other that are used to measure and sample at different discrete depth intervals in the aquifer. The total depth of the target investigation will be drilled and the information will be used to select the most permeable zones, into which well screens will be placed. Different depths may represent different pathways and source areas, and will be useful in determining the vertical gradient within the aquifer.

Some of the information or details that STV requests is present in other sections of the FSP (SAIC 2005a) (Section 6.2 Groundwater [page 6-4] and Section 6.2.4.3 Installation, subpart Borehole Diameter and Depth [page 6-12]).

As stated in the referenced sections of the FSP (SAIC 2005a), the final depths and screen intervals will be determined following review of the actual location subsurface conditions encountered. In addition, FSP Addendum 4, Section 2.1 Well Locations and Proposed Depths (SAIC 2007b), which was submitted after STV filed their contention, also includes details of the anticipated well depths and states that they will be based on actual subsurface site conditions observed during the drilling and installation. This flexibility to modify and design the well screen intervals based on the actual site conditions is crucial to the appropriate and successful installation of monitoring wells due to the highly variable nature of fractured and Karst aquifers.

VI. SUMMARY AND CONCLUSION

As to Basis Item "d"

Q14. Please summarize your testimony with regard to Basis Item "d".

A14. (SMS) My testimony can be summarized as follows:

Sufficient information is presented in the FSP (SAIC 2005a) and Addendum 4 (SAIC 2007a) regarding the purpose of the well pairs. The project should continue in the fashion presented in the FSP and Addendum 4 to allow the flexibility to make determinations and appropriate selections of well screen intervals based on the actual observed site conditions during drilling.

VII. OVERVIEW

Issues Raised By Basis Item "e," to STV Contention B-1

Q15. What is your understanding of the technical issues raised by Basis Item "e" of STV's Contention B-1?

A15. (SMS) In its Basis Item "e," STV states:

"The FSP also specifies in section 6.2.4.3 that a boring that does not produce enough water for a well will be abandoned. If lack of production occurs because the system is 'tight' (i.e., impermeable), that makes some sense. However, the nature of karst terrain is such that conduits may not produce water because the flow is highly transient and, unless there is a new flow event at the time of drilling

and/or testing, a well may be dry even though it has been placed in an appropriate and important location. To ensure the problem is a temporary lack of water, rather than a permanent lack of permeability, it is necessary to monitor the boring for enough time to be sure it never produces before abandoning it."

In this Basis Item STV suggests that a borehole be maintained and monitored for an unspecified amount of time above the water table.

Q16. Do you agree with the position asserted in Basis Item "e" by STV?

A16. (SMS) No.

VIII. DISCUSSION

Purpose of Conduit Well Installation

Q17. What is the basis for your disagreement?

A17. (SMS) The context of the statement from which STV developed this contention is a discussion of the anticipated depth of well pairs, which are to be targeted for 50 and 120 feet, for shallow and deep well screens, respectively. Both of these depths would be below the water table and therefore, not be subject to temporary dryness. The only reasonable cause that a borehole would not have "sufficient water to support a functional monitoring well" (quoted from the FSP [SAIC 2005a]) would be the lack of permeability or connection with the flow pathways through the aquifer, which is mentioned by STV.

What STV is intending or suggesting is that a borehole be maintained and monitored for an unspecified amount of time above the water table. Without building a dry well, this is impractical and unnecessary for the site characterization.

The intent of the conduit well installation is to provide a monitoring well network that will be used for characterizing the groundwater and groundwater flow in and immediately surrounding the DU Impact Area, not to build wells above the water table that may flood for days or minutes during storm events, if ever. Features that could possibly flood or fill with water will either drain into the groundwater conduit pathways (proposed to be monitored by installed wells) or flow through the shallow Karst network and eventually discharge to surface water through a cave stream or spring (proposed to be monitored by surface water sampling of cave streams and streams). In other words, the current monitoring well installation plan (FSP [SAIC 2005a] and Addendum 4 [SAIC 2007b]) plus the inclusion of a planned FSP addendum that will address monitoring surface water, which is likely to include sampling locations at the mouths of caves or the confluence of cave springs with creeks/streams, is sufficient to adequately characterize DU migration at the site to develop a Decommissioning Plan that meets the requirements of 10 Code of Federal Regulation (CFR) et seq.

The decision to abandon boreholes based on well yield is further refined in Section 2.1, Well Locations and Proposed Depths, of FSP Addendum 4 (2007b) as stated "The goal is to target high-permeability zones, such as fractures and solution-enhanced zones, with the screened interval.....If adequate permeability is not encountered, abandonment of the borehole will be considered."

IX. SUMMARY AND CONCLUSION

As to Basis Item "e"

Q18. Please summarize your testimony with regard to Basis Item "e".

A18. (SMS) My testimony can be summarized as follows:

STV's request to construct dry wells above the water table that may contain water during storm events is impractical. The project should continue in the fashion presented in the FSP (SAIC 2005a) and addenda (SAIC 2006a, 2006b, 2007a) to allow the flexibility to make determinations and appropriate selections of well screen intervals based on the actual observed site conditions during drilling for appropriate well construction for the <u>purpose of monitoring and characterizing groundwater and groundwater flow.</u>

X. OVERVIEW

Issues Raised By Basis Item "f," to STV Contention B-1

Q19. What is your understanding of the technical issues raised by Basis Item "f" of STV's Contention B-1?

A19. (SMS) In its Basis Item "f" STV states:

"The FSP states in section 6.2 that all new wells to be completed will be in 'conduit' settings in bedrock. This placement is too limited. Certainly, most off-site transport is likely to occur through bedrock karst features. But, the projectiles and the DU reside in the till and/or the weathered bedrock/colluvium. Simply because good, shallow wells were not completed in the original set of JPG wells does not mean that properly located and completed shallow wells are unnecessary to characterize properly the hydrogeology of the site. Such wells should be included in the FSP."

STV is asserting that the license amendment should not be approved unless the Army is required to install these shallow wells.

Q20. Do you agree with the position asserted in Basis Item "f" of STV Contention B-1?

A20. (SMS) No.

XI. Discussion

Installation of Shallow Wells

Q21. What is the basis for your disagreement?

A21. (SMS) As an expert dealing with Karst aquifers, I recognize and STV acknowledges, as stated in this basis, that the most probable off-site transport by groundwater is most likely to occur through fracture zones in bedrock in which Karst features may develop, but the Army and SAIC have never presented or stated that *"...shallow wells are unnecessary to characterize properly the hydrogeology of the site."*

The Army intends to consider the installation of shallow wells completed in the unconsolidated materials if sufficient, saturated permeable materials are encountered and has presented this in both FSP Addendum 4 (SAIC 2007a) and the January 2007 Well Selection Report (SAIC 2007b) completed by SAIC. Section 6.2.1.2, Deep Overburden Well Pair Location (SAIC 2007b) presents the evaluation of overburden materials and the soil/bedrock interface for the presence of permeable materials and potential for groundwater flow and plans to installing at least one well in the unconsolidated materials at this location based on the actual observed site conditions.

The inclusion of this evaluation of the potential for deep soils and permeable unconsolidated materials at this location based on the results of the EI survey demonstrates the intention of the Army to appropriately modify and design successive studies based on the results of the preceding studies and the acquisition of site-specific data. Once again, this is crucial to appropriately and accurately design and install a representative monitoring network.

Section 2.1, Well Locations and Proposed Depths of FSP Addendum 4 (SAIC 2007a) also describes the evaluation for permeable materials at the deep soil location identified with the EI survey and also states "At all sites, if sufficiently permeable saturated materials are identified in the unconsolidated deposits, the installation of a well with a screened interval in the permeable zone will be considered."

Further, it is the intent of this characterization to evaluate the potential for migration of DU penetrator material through the unconsolidated materials (soil, till, loess) as described in Sections 6.7 and 6.8 of the FSP (SAIC 2005a) by sampling soils and analyzing for DU components near deposits of DU penetrators, measuring the rate of corrosion, and conducting leachability tests. If these tests indicate that the DU components are mobile in the unsaturated unconsolidated material, that information might lead to a recommendation for a more rigorous examination of the extent of migration in the shallow saturated unconsolidated materials, where they exist.

Thus, the characterization will evaluate migration near the source in the shallow soils around the DU penetrators; in saturated unconsolidated material above bedrock, if encountered; in cave streams and surface streams; and in solution enhanced groundwater pathways that would be the most likely migration pathway for DU in groundwater leaving the site.

XII. SUMMARY AND CONCLUSION

As to Basis Item "f"

Q22. Please summarize your testimony with regard to Basis Item "f".

A22. (SMS) My testimony can be summarized as follows:

Most probable offsite groundwater migration is through fracture zones, which may develop into Karst features, and thus the greatest emphasis is placed on successful construction of wells in the Karst network. However, wells will be installed, as appropriate, in unconsolidated materials, and other parts of the aquifer that would reasonably be expected to transmit groundwater. The project should continue in the fashion presented in the FSP (SAIC 2005a) and addenda (SAIC 2006a, 2006b, 2007a) to allow the flexibility to make determinations and appropriate selections of well screen intervals based on the actual observed site conditions during drilling for appropriate well construction for the purpose of monitoring and characterizing groundwater and groundwater flow.

XIII. OVERVIEW

Comments and Rebuttal Pertaining to Testimony of Chuck Norris

Q23. Are you familiar with the testimony offered by Charles Norris in this hearing?

A23. (SMS) Yes. I have reviewed his written testimony dated July 13, 2007.

Q24. Do you agree with his opinions and conclusions concerning the adequacy of the hydrogeological characterization program?

A24. (SMS) No, I disagree in a number of respects.

Q25. Please state the general basis for your disagreement.

A25. (SMS) My testimony and my rebuttal of testimony by Charles H. Norris focuses on the processes and conditions that control the potential migration of DU in water. That portion of the Conceptual Site Model (CSM) is being studied at significant points along those pathways:

- DU in its original form is a smooth solid metal rod, not unlike a heavy reinforcing bar. DU is immobile in that form. Once it corrodes, as a result of exposure to the elements, it can be dissolved in water or be transported by water as particles or attached to particles of soil. Thus, the rate of corrosion is important. That process is being characterized in two ways: by exposing a DU rod to a weathering chamber and by exhuming and examining DU projectiles that were test-fired as part of the JPG operation.
- On its way to the groundwater table, DU must migrate through the soils. The rate and extent of migration of DU through the soil will be calculated/measured by collecting soil samples near and beneath the DU projectiles at a number of locations. Different soil types found at JPG may transmit DU at different rates, so those soil properties have been characterized and this testing will be conducted in areas representing those different conditions.
- Most of the unconsolidated materials overlying bedrock are tight glacial tills and residual limestone clay and silt, which do not allow water (or DU) to pass through readily. Where more permeable unconsolidated materials are found, wells will be constructed to sample groundwater for DU. These wells will be located near areas high in DU deposits, as well as up-gradient, in order to examine natural uranium content.
- Once through the unconsolidated mantle of materials, the water pathway migrates to the bedrock. Bedrock underlying JPG is composed of horizontally bedded siliceous limestone and dolomite. Migration of groundwater through this rock is almost exclusively along joints, fractures, and bedding planes in the rock. To some degree, over time, water percolating through these discontinuities may have dissolved portions of the rock and enlarged the pathways. This created a network of relatively higher zones of permeability, which act as avenues for the

majority of groundwater migrating through the site. The FSP (SAIC 2005a) calls for wells to be placed on concentrated zones of fractures upgradient of the DU Impact Area (to measure natural U) and downgradient of the DU Impact Area, to measure the current impact of DU deposits. Great care has been taken to place wells in the most likely areas of high permeability and in all likely directions of groundwater migration from the DU deposit.

- DU may potentially be transported by surface water, either in solution or as particles, along with sediment. Numerous surface streams cross the DU Impact Area. Recent sediment deposits and stream samples, collected at different times of the year, will characterize this pathway.
- Lying somewhere in between surface water and groundwater is a network of sinkholes and shallow caves. Sinkholes can receive surface water runoff and sediment and transport it to caves or to the groundwater table. Groundwater also may discharge to cave channels. Some caves carry streams, either intermittently or perennially. This potential pathway is being characterized by sampling cave streams at the mouths of caves.
- Numerous stream gauging stations have been set up to measure stream flow across the site. The stream flow hydrographs will be analyzed to determine what portion of precipitation that falls on-site goes to direct surface runoff, through the sink holes and caves, and to the water table. That information will allow us to order the most likely potential pathways for DU carried by water.
- All sample points are in close proximity to or within the boundaries of the DU Impact Area. The concentration of DU, if migrating, will be highest and most detectable close to the DU deposits. The pathways are also most predictable closest to the source. By determining the degree to which migration is occurring close to the site, the DU migration processes can be understood. From that point, conservative dose modeling scenarios can be developed and tested.

Throughout the development of the FSP (SAIC 2005a), the physical conditions of the site had to be considered. The DU area contains incised stream channels and a high concentration of unexploded ordnance (UXO), making access to many areas difficult, and in some cases, nearly impossible.

Respecting those access limitations, a characterization plan was developed that will provide sufficient information to satisfy NRC requirements needed to consider license closure.

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 the 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).

Although all of the components mentioned by Mr. Norris in his Answer 11 will be evaluated sufficient to provide input data for the implementation of the RESRAD model, the use of the words *"site-specific input data to the site modeling"* further raises the concern that Mr. Norris is mistakenly expecting a numerical groundwater fate and transport model.

Q26. Do you agree or disagree with Mr. Norris's explanation of karst features and their formation found in his Answers 13 and 14?

A26. (SMS) I disagree.

Q27. Please state the basis for your disagreement.

A27. (SMS) Although all levels of complication and intricate flow patterns have been found in karst aquifers throughout the world, most karst aquifer systems fall into one of a few patterns (Fetter, "Applied Hydrogeology" 2nd edition, 1988, p. 288), and can be effectively characterized. The depth of the karstified portion of the aquifer may be extremely limited, as suggested by local geologic literature (Greeman, "Lineaments and Fracture Traces, Jennings County and Jefferson Proving Ground, Indiana", 1981, p. 12 and 13) and the preferential flow pathways are often very well-connected, particularly in bedrock with well-defined horizontal bedding, as occurs at JPG. One type of carbonate aquifer, called diffuse-flow aquifers, *"have little solutional activity directed toward opening large channels." "Diffuse-flow aquifers, are typically found in dolomitic rocks or shaley limestones,"* such as those that are present underlying and surrounding the DU Impact Area at JPG. *"Water movement is along joints and bedding planes that have been only modestly affected by solution. Moving groundwater is not concentrated in certain zones in the aquifer and, if caves are present, they are small and not interconnected. Discharge is likely through a number of small springs and seeps."* All quotes are from Fetter, 1988, p. 289-290. All of these conditions are consistent with the current observations at the JPG site.

Mr. Norris provides no documentation that a complex condition could or is likely to exist at JPG and, only talks in general about nightmarish conditions that occur in karst aquifers somewhere in the world. Little site-specific investigative work has been completed to date. As the work is completed, the process of characterizing the degree and depth of karstification, the interconnectivity of the karst network, and the potential for accurately characterizing groundwater migration from and through the DU Impact Area will be determined. Fetter (, 1988, p.288) provides this perspective: *"Carbonate aquifers show a wide range of hydraulic characteristics. There are, to be sure, a number of 'underground rivers' where a surface stream disappears and flows through caves as open channel flow. At the other extreme, some carbonate aquifers behave almost like a homogeneous isotropic porous medium. Most lie in between these extremes."*

All local literature and the current observations on-site suggest a modest, lightly karstified aquifer. The extreme measures proposed by Mr. Norris throughout his testimony would support a decade of doctoral thesis projects in full academic research mode. But more to the point, the current understanding of the site does not support this level of investigation, and would frustrate researchers looking for and trying to characterize a complicated system that most likely does not exist.

Q28. Mr. Norris, in his Answer 16, stresses the importance of tracking water chemistry changes along transport paths at JPG. Do you agree?

A28. (SMS) Not necessarily. The statement that "transport of dissolved DU is independent of water velocity" is not entirely accurate. Freeze and Cherry (1979, pages 402-408) describe how "…reactive contaminants…" such as dissolved DU "…will travel at a rate depending on its relative velocity…" The relative velocity is a function of groundwater velocity and "retardation" resulting from the chemical reactions (e.g., adsorption-desorption, acid-base, dissolution-precipitation) and the transfer of dissolved DU to other phases (gas or solid). NUREG 6705 (page 24) states that, "…sorption, dilution, and precipitation are sufficiently effective sinks to limit short-term (years to decades) the advance of artificial U plumes. In long-term situations (thousands to millions of years), weathering processes and secondary precipitation of oxidized uranyl phases appears to limit advance of natural plumes…" How important water chemistry is, within the bounds of the variation of water chemistry across the DU Impact Area remains to be determined, but uranium concentrations will be evaluated along the pathway and will be sampled quarterly to account for seasonal variations. In addition, the concentrations and measurements of other parameters that influence the dissolution and transport of DU in groundwater (e.g., pH, redox) also will be obtained along pathways and at various times.

Q29. In his Answers 17 and 18, Mr. Norris suggests other factors influencing the transport of dissolved DU. Will sampling be conducted to detect entrained sediment and suspended transport of DU?

A29. (SMS) Yes. Since entrainment is a function of velocity, when the velocity is reduced, the mass of entrained-sediments will be dropped and deposited along the path from the source. These samples will be analyzed for DU. If DU is detected in sediments, additional testing to measure the mass flux of entrained sediments may be necessary.

Potential suspended DU will be measured by sampling unfiltered samples of water from streams and cave streams downgradient and upgradient from the DU Area.

Q30. Do you agree with Mr. Norris opinion, expressed in his Answer 19, as to the sources and types of data required for a meaningful DU fate and transport model?

A30. (SMS) No.

Q31. What is the basis for your disagreement?

A31. (SMS) In the first bullet of his Answer 19, Mr. Norris calls for *"Mapped critical pathways, presumably dominantly karst, of groundwater flow from source areas to discharge points, whether such discharge is within or outside JPG."* The mapping of individual groundwater pathways, in the sense that becomes obvious when reviewing his testimony as a whole, is impractical and unnecessary, especially in complex sites involving karst and fractured rock aquifers. Mr. Norris later explains that he feels it is necessary to trace individual conduit pathways, apparently similar to the way a spelunker would map a cave. Once again in bullet 3 Mr. Norris calls for the characterization of individual *"groundwater paths with measurements of chemical parameters."* The characterization of individual groundwater flow pathways is both impractical and unnecessary. What is necessary is the placement of appropriately constructed and designed monitoring wells that intersect preferential flow pathways or groundwater conduits that will facilitate the monitoring and characterization of the groundwater flow network comprising saturated karst and fracture features. The idea of mapping individual groundwater pathways is addressed numerous other times in response to Mr. Norris's repeated discussion of this concept.

In Answer 19, Mr. Norris, for the most part, lists a number of viable pathways for DU transport. He calls for direct measurement of DU concentrations under various conditions, as if one were going to attempt to numerically model all chemical transport from the site. I disagree that all conditions must be measured, which of course is nearly impossible. A blatant example is the call for sampling sediment and dissolved and suspended DU during a *"singular climate event such as a 25-year or rarer precipitation even."* Sampling of such an event would be prohibitively dangerous, not to mention logistically very difficult. Sampling DU concentrations and characterizing the potential for DU mobilization and transport during high-flow conditions will be accomplished by sampling sediment deposited along the surface water pathway downgradient from the DU areas. If the sampling indicates that high surface water flows are a significant mechanism for migration of DU, and it becomes necessary to sample during high-flow conditions to identify or quantify the risk to receptors, the investigation will be amended. In this manner, all pathways will be investigated, and any that indicate active migration of DU will be the subject of sufficient additional characterization to identify and quantify risks to receptors.

Q 32. Starting with his Answer 20, Mr. Norris lists and then discusses what he calls the "seven major elements of the hydrogeologic characterization program." Do you have any comments or responses to offer with regard to his Testimony?

A32. (SMS) Yes. I intend to respond to Mr. Norris's testimony regarding sections on Fracture Trace Analysis, EI Survey, Gauging of Streams and Caves and Staging of Streams, and Well Location Assessment and Selection. My colleague, Mr. Todd Eaby, will respond to Well Installation and Assessment and Surface Water Sampling and Sediment Sampling.

Fracture Trace Analysis

Q33. Do you agree or disagree with his testimony pertaining to deficiencies in the design of the fracture trace analysis for JPG?

A33. (SMS) I disagree.

Q34. What is the basis for your disagreement?

A34. (SMS) Mr. Norris is unfamiliar with even the basic definitions of words commonly used by those who use fracture trace analysis. Lattman (1958) organized the process of using aerial photographs to map linear features by defining fracture traces (straight features up to 1 mile in length) and lineaments (1 to 100 miles in length). But, admittedly, the awareness of that article among general practice geologists is low, although the reference was provided in the JPG FSP (SAIC 2005a). However, the basic college text book by Fetter (1988) provides these same definitions (p. 294). It should be obvious from this demonstrated lack of basic familiarity that Mr. Norris is not in a position to explain *"the complexity of a true fracture trace analysis."*

Q35. Do you agree or disagree with Mr. Norris's statement that fracture trace analysis can only identify fractures that have an expression on the surface of the earth and cannot distinguish fractures that are part of a karst network?

A35. (SMS) I disagree. The connection between fracture trace analysis and its ability to identify zones of preferential flow pathways, particularly in karst aquifers, is well-documented in the literature. One of the first such documentations is by Lattman and Parizek (1964), titled Relationship Between Fracture Traces and the Occurrence of Groundwater in Carbonate Rocks. The following is quoted from the abstract of this article: *"These data support the concept that fracture traces reflect underlying fracture concentrations and are useful as a prospecting guide in locating zones of increased weathering, solutioning and permeability."* I had the privilege of studying under and working with Dr. Parizek and learned his methodology first hand. I have located many successful high-yield production wells using fracture traces. Mr. Norris states that fracture trace analysis *"cannot distinguish between simple fractures and solution-enhanced fractures."* I disagree, in that the soil-tonal and vegetation differences, topographic features, and straight line stream segments overlying a karst aquifer are most often caused by karst activity, are often latent sinkholes or sags (Fetter 1988, p. 294). The question is moot, however, since either condition would represent a potentially significant high permeability condition in the otherwise massive and very low permeability bedrock.

Q36. Do you agree or disagree with Mr. Norris's statement, in his Answer 24, that "unless a bedrock fracture has propagated itself through the blanket of glacial sediments, it cannot be observed"?

A36. (SMS) I disagree. Mr. Norris's statement shows a general lack of familiarity with fracture trace analysis. Even without having the benefit of first-hand experience with fracture trace analysis, there are numerous examples in published literature that fracture trace analysis is effective in areas overlain by glacial sediments. The U. S. Geological Survey (USGS) report by Greeman (1981) for the JPG area quoted elsewhere by Mr. Norris states *"Pleistocene drift, averaging 25-30 feet thick, covers most of the bedrock, but did not restrict the mapping of lineaments and fracture traces from aerial photographs."* (p1, 3rd Paragraph). Page 8, 2nd to last paragraph continues to discuss glacial drift up to 81 feet thick and references studies mapping fracture traces through 350 feet of overburden. Fetter (1988), p.294 states *"The surface features can reveal fracture traces covered by up to 300 feet (100 meters) of residual or transported soils."*

Q37. In the same Answer 24 Mr. Norris's cites previous characterization studies, summarized in the Regional Range Study (USACHPPM No. 38-EH-8220-03, JPG, IN, Sep 02, Sub-section 6.2.3.1, page 4 of 41), in support of his position concerning the limitations of the utility of a fracture trace analysis. Is this citation accurate?

A37. (SMS) No. The referenced sentence actually reads *"Small-scale fractures* *and sand lenses within the till contribute to the higher hydraulic conductivity."* The context is a discussion of the range of hydraulic conductivities measured in the fairly tight tills south of the firing line at JPG. Fractures of the scale discussed in this reference (inches) have nothing to do with fracture traces that may occur in areas overlain by till and be seen on aerial photographs.

Q38. Also in his Answer 24 Mr. Norris criticizes the use of older black and white aerial photographs and advises use of more modern technology in conducting the fracture trace analysis. Do you agree with his criticisms?

A38. (SMS) No, not entirely. I have used color and false color (another name for infrared) aerial photography and satellite imagery in a number of investigations, and they are not without merit. Side looking airborne radar (SLAR) can be effective at locating fracture traces (EPA/625/R-92/007 Eastern Research Group (ERG), Sept 1993 p. 2-3), but ground penetrating radar (GPR) is not a remote sensing technique. Rather, it is an on-the-ground geophysical technique,that, from my experience, can penetrate only a few feet in typical clay-rich residual soils, as typically occurs over carbonate bedrock, like at JPG. My experience is supported by this quote from ERG (1993) p. 6-2 *"Attenuation is particularly severe in clay-rich soils and where water content exceeds 40 percent."* GPR is not used on UXO sites, due to safety hazards, as the induced energy may cause detonation of certain ordnance. The suggestion of the use of GPR on this site 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.

This is not a research project requiring the uses of multiple technologies. Our goal in using fracture trace analysis and EI is to select locations where wells can be placed in zones of high hydraulic conductivity, and thus to characterize the network of preferential flow pathways in the bedrock aquifer. Allow me to quote a few sentences from Fetter (1988), p. 294: *"The selection of well locations in carbonate terrain is one of the great challenges for the hydrogeologist. As the* *porosity and permeability may be localized, it is necessary to find the zones of high hydraulic conductivity. One of the most productive approaches to the task is the use of fracture traces"..."As they represent the surface expression of nearly vertical zones of fracture concentrations, they are often areas with hydraulic conductivity 10 to 1000 times that of adjacent rock."*

Q39. Do you agree with Norris's statement that cave map and sinkhole information must be integrated into the fracture trace analysis?

A39 (SMS) I agree that cave mapping information by Sheldon is important information. It was considered and available to the team, as evidenced by the locations of cave streams selected for gauging in Figure 3-1 of SAIC's Well Selection Report (SAIC, 2007b, p. 3-3). However, locating of well using fracture traces does not require this correlation. Greeman's excellent academic paper (1981) on fracture traces and lineaments in Jennings County and surrounding counties, which makes specific reference to JPG, makes no reference to the occurrence of caves and the correlations with fracture traces and lineaments in the Silurian carbonates of Jennings County and JPG. Greeman indicates fracture traces and lineaments are the best locations to develop the most productive well sites, thus would be useful in finding groundwater flow pathways.

Q40. Do you agree with Mr. Norris's opinion that data from the Greeman study must be integrated into the fracture trace analysis?

A40. (SMS) No, I do not.

Q41. What is the basis for your disagreement?

A41. (SMS) The data from Greeman were reviewed during the fracture trace analysis. The fracture traces mapped as part of Greman's report, which covered 467 square miles, were transferred from the 1:48,000 (1" = 0.76 mi.) map and entered into the Geographic Information Systems (GIS) database. It was determined through this process, that the accuracy of the mapping from this map was insufficient to use in our study. The report data at this scale are of value for considering general trends of fracture trace orientation, but not accurate enough to use to locate wells on karst features. The general trends of fractures mapped by the Greeman study (*"oriented northeast-southwest and northwest-southeast"* Greeman 1981, p. 9) match the mapping conducted by SAIC: *"Seventy percent of the mapped traces were oriented either North 27 to 59° West (33 fracture traces) or North 31 to 56° East 43 fracture traces* (SAIC2007b, p. 4-4).

Q42. Do you agree with Mr. Norris's opinion, in his Answer 24, of the adequacy of the field reconnaissance at the DU area?

A42. (SMS) I disagree. I conducted a 2-day field reconnaissance of the JPG DU area during the process of writing the FSP, and prior to conducting the fracture trace analysis. This allowed me to get the lay of the land, a feel for the topography, and anticipate how a fracture trace analysis would be conducted.

Mr. Norris's statement that the field proofing *"should be done before, not after the analysis is complete"* demonstrates a general lack of understanding of the fracture trace analysis process. It is necessary to map fracture traces on aerial photographs in order to identify areas in the field that can be field checked. The process of mapping fracture traces is done by viewing aerial photographs one at a time and in pairs to view the images in stereo, which provides a three-dimensional view to the land surface. This is best done in an office or laboratory setting. After the mapping of fracture traces on individual stereo paired aerial photographs, the aerial photographs are georeferenced, and the fracture traces are placed in a GIS and then displayed on a map of the site. At this point, the hydrogeologist can take the map to the field and evaluate the mapped fracture trace.

Regarding Mr. Norris's comment that the walk-over should include areas off-road, this comment ignores the extreme health and safety concern caused by the high concentrations of UXO in the DU Impact area. The existing network of roads allows access to the complete perimeter of the DU Impact area, and crosses the DU Impact area in appropriate intervals and along important hydrogeologic features (like Big Creek). Even on sites where better walk-over access is available, my experience is that the majority of the observations are generally made along the road-ways due to the ability to see the terrain better, which often is extremely restricted by dense vegetation and woods.

Q43. Do you agree or disagree with Mr. Norris's statement that potentially important dipping fractures would not be identified by the fracture trace analysis?

A43. (SMS) I disagree. The previously quoted sentence from Fetter (1988, p. 294) in his discussion of fracture traces indicates that, by definition, fracture traces are vertical features: *"As they represent the surface expression of near vertical zones of fracture concentrations, they are often areas with hydraulic conductivity 10 to 1000 times that of adjacent rock."* Fracture traces are being employed to assist in locating wells in zones of high hydraulic conductivity. Fetter states that fracture traces are *"one of the most productive approaches"* to accomplish this. Mapping nonlinear photographic features is not part of the fracture trace analysis method.

Mr. Norris's opinion that "intersections of fractures that dip are likelier to develop major karst elements than are intersections of vertical fractures" is unsupported in his testimony, and is not shared by me, and to my knowledge is unsupported by published studies. Supporting my opinion is the statement by Greeman in an article previously referenced by Norris: *"Vertical bedrock fractures transmit a large part of the water that is moving through the limestone-dolomite aquifer..."* (Greeman 1981, p.13). This is a study that was conducted on Jennings County and JPG, thus, it represents information on the local conditions around the subject site.

However, the argument is still not significant because the goal of the fracture trace analysis, combined with the EI survey, is to locate areas where wells could be placed with a high likelihood they would intersect the network of preferential flow pathways through the karst aquifer that underlies the DU Impact Area. Any high hydraulic conductivity zones, vertical, subvertical, or horizontal, if sufficiently continuous to be significant for transport of groundwater across and from the DU Impact area, will be interconnected.

Q44. Do you agree or disagree with Mr. Norris's statement as to the significance of the fracture trace analysis deficiencies which he states in his Answer 26?

A44. (SMS) I disagree. All alleged deficiencies mentioned in this summary answer have been addressed in rebuttal to previous answers. Mr. Norris's opinion of the deficiency of using fracture traces to locate high-conductivity zones in karst are not shared by me or by the numerous authors cited or quoted. Mr. Norris raises one new alleged deficiency in Answer 26 that has not previously been addressed. This is his concern that the FSP (SAIC 2005a) may miss karst networks *"whose controlling fractures are too deep to reach the present day surface."* However unlikely this may be, it is inconsequential to the characterization of the groundwater flow system beneath JPG that may potentially transport DU from the site. DU has been deposited on the surface of the DU range and, therefore, the migration must start from there. If it is being transported by surface water or groundwater, it must start on the surface, and migrate downward to the water table. If there is a deep karst network "whose controlling fractures are too deep to reach the present day surface," it would not be in communication with the surface of the DU Impact Area, and therefore could not be a viable pathway for DU migration.

The plan outlined in the FSP (SAIC 2005a) will characterize the pathway from the surface to the streams and to the groundwater beneath, and as it leaves the site. In order to get to real or imagined distant or deep pathways, it must first pass through the shallow system. Characterization of that system is sufficiently scoped in the current FSP (SAIC 2005a) and its Addenda (SAIC 2006a, 2006b, and 2007a). If those investigations result in information that indicates a concern for exposure to receptors, the FSP will be augmented at that time in a focused manner.

Electrical Imaging Survey

Q45. Do you agree with Mr. Norris's opinion, in his answer 27, that the FSP Electrical Imaging (EI) survey needs to be a "grid application" so that three dimensional mapping of results can be done?

A45. (SMS) I do not agree.

Q46. Please state the basis for your disagreement.

A46. (SMS) Mr. Norris arbitrarily states that *"EI surveys are usually performed along a two-dimensional surface grid over an area of investigation."* This methodology is actually referred to as three dimensional (3D) EI. I have been conducting resistivity surveys (the precursor to EI, prior to computer-driven switching systems in the early 1990s) and EI studies for more than 30 years and have been associated with only one project researching the viability of a grid array application. Not until 1996 were data acquisition methods and processing software developed to effectively perform automated 3D resistivity surveys (Dahlin and Loke, 1997). 3D EI methods represent nontraditional method of data acquisition for the purpose of gathering resistivity measurements over a localized area to evaluate complex geologic or subsurface conditions (e.g., caves, sinkhole network, archaeological structures, etc). This method requires a fixed electrode grid be established over the entire area of interest at electrode spacing sufficiently close to meet target objectives. These surveys usually are focused on a few acres or less. Performing such surveys across the entire area of interest at JPG would not be practical and would be cost prohibitive, not to mention extremely dangerous, due to the UXO. These dangers were minimized/avoided during the EI survey at JPG because we took advantage of cleared corridors and used a delayed start to collect data while personnel retreated to a safe area.

Q47. Do you agree or disagree with the deficiencies in the EI survey which Mr. Norris lists in his Answer 30?

A47. (SMS) I disagree.

Q48. Please state the basis for your disagreement.

A48. (SMS) Mr. Norris apparently misunderstands or misrepresented a statement he references on page B-3 of Appendix B of the FSP (SAIC 2005a) regarding the orientation of EI traverses, stating that they should be "oriented normally to geologic features of interest". The actual language states *"The traverse should not be set up running parallel to subsurface utilities or other subsurface conductors."* There is no reference to geologic features of interest stated or implied. I have had the opportunity to test the success of locating wells on EI features that match up with fracture traces that cross both perpendicular and at an angle to the EI line and, in developing my skills, originally insisted that some of the EI survey lines be oriented such that they are perpendicular to the fracture trace. I have experienced no loss of success in placing wells in groundwater conduits using EI survey data that crosses fracture traces at oblique angles. Drilling targets, in most severely karst areas, are actually larger, since the fracture trace is in close proximity to the EI survey line for a greater distance. Given the extreme limitations in the ability to traverse off-road areas caused by the safety problems of UXO throughout the area of investigation, and the experience applying this technology at other sites, there was no concern that the orientation dictated by the existing roads would limit the effectiveness of the characterization study during this phase of the investigation.

Mr. Norris is also critical of what he describes as failing to lay out EI lines in straight lines. It is true that EI results are easier to interpret when lines are straight and that results near the bends in a survey line must be used with some degree of caution. However, segments away from the bends are perfectly fine and are not subject to the effects of the bend. The area covered by D Road, which parallels the course of Big Creek as it takes some gentle bends, was very important to the investigation, and the ability to get off the road to straighten the line was precluded by the existence of UXO. It was understood by the geophysicists and hydrogeologists collecting and interpreting the data, that EI data in the locations of bends in the survey lines should be considered with a relative degree of caution.

The EI survey was never intended to produce a 3D map of potential groundwater conduits, which is impractical and unnecessary. The two dimensional (2D) resistivity methods deployed at JPG covered important perimeter and internal areas along roadways that were safely accessible for the purpose of substantiating results of a fracture trace analysis study in order to optimally site groundwater monitoring wells along accessible roadways.

The purpose of the fracture trace and EI studies is to aid in locating areas with the potential to have increased **groundwater** flow due to the presence of fractures and/or solution enhanced features for use in characterizing potential groundwater impacts and the groundwater flow network. It is not to identify dry conduits that could potentially intermittently transmit water related to precipitation events that may not be related to groundwater. The potential that open solution features could intermittently transmit DU along with water from precipitation events and during high groundwater stage conditions is being investigated using the excellent survey information available from the cave survey work (Sheldon, 1997) that has been conducted on the JPG site. A number of the mapped caves are in the middle of the DU Impact Area and are oriented in such a manner that percolating and runoff water from precipitation that falls on the DU Impact area will be intercepted. Sampling of streams and sediment from these caves will be far superior to constructing dry wells in shallow unsaturated voids in the subsurface.

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. These clay and silt deposits are the insoluble residue left after the soluble (calcium carbonate) portions of the bedrock are carried away by groundwater. Karst weathering is enhanced along zones of concentrated fracturing, due to increased exposed rock surface area and larger volumes of groundwater migrating through the more permeable area. Although compacted clay has a very low permeability, the sediment/bedrock interface and the adjacent fractured bedrock zones are often highly permeable, and provide a location where the network of karst conduits may be characterized and monitored.

Norris also criticizes the EI survey because possible variations in the electrical resistivity may be unrecognized variations in groundwater quality, not variations in hydraulic conductivity of the rock. Variations in the specific conductance of water sampled from the Environmental Radiological Monitoring (ERM) wells could be caused by factors unrelated to insitu groundwater quality, such as turbidity caused by sampling. It also could be a result of the two wells being placed in different geologic materials. The specific conductance of the groundwater has little ability to impact the electrical conductivity of bedrock, since groundwater occupies less than 1/10th of 1 percent of the volume in a typical unfractured bedrock aquifer. It is extremely unlikely that there are small pockets of natural groundwater with different specific conductance that will be mistaken for evidence of weathering along vertical fractures in the carbonate bedrock. Further, that pocket would have to line up with a mapped fracture trace to have a negative impact on the investigation.

Next, in his Answer 30, Mr. Norris discusses the possible effects of slow moving or stagnant groundwater on electrical conductivity. My experience on other sites does not match the conditions in this paragraph, which have most likely been developed from Mr. Norris's imagination and not his experience. A summary of observations from my experience on karst sites and in carbonate aquifers follows:

- Zones of clay that extend vertically down into the bedrock are often indications of weathering along vertical fractures. Although the clay itself has very low permeability, high-permeability zones often accompany these "plugs" of clay, either in the form of open channels through the clay, permeability along the clay-bedrock interface, or deposits of sand and gravel that were deposited in the same feature.

- Since these zones of clay are often formed along zones of concentrated vertical fracturing, well bores that penetrate through the clay often encounter permeable fractured rock.
- Saturated conduits filled with sand and gravel would clearly show in an EI survey as a low-resistivity area and would constitute a detectable and desired target of this investigation.

Finally, Mr. Norris completely misunderstood or misrepresented the concept behind the proposed well location methodology, and misquotes the referenced section in the FSP to help make his point sound viable. In Table 4.1, the EI survey is described as:

> *"Survey, combined with the fracture trace analysis, will be used to identify preferential flow paths and karst features for groundwater. Survey will be conducted to identify entry and exit pathways."*

Rather than indicating that the EI survey will identify entry and exit **points** of groundwater flow, the statement actually means that preferential flow pathways for groundwater up-gradient of the DU area that will naturally migrate into the DU area (entry pathways) will be identified. Likewise, preferential flow pathways for groundwater downgradient of the DU Area that will naturally migrate away from the DU Area (exit pathways) will be identified. This is conducted by running the EI survey along the upgradient and downgradient roads that perimeter the DU Area and matching the anomalies with fracture traces.

Mr. Norris misquotes a study by Wilson et al. (Wilson, John T., *et al.* 2001, An Evaluation of Borehole Flowmeters Used to Measure Horizontal Ground-Water Flow in Limestones of Indiana, Kentucky, and Tennessee, 1999, USGS Water-Resources Investigations Report 014139) in asserting that at most there will be one point well control where a conduit crosses a road and flow direction cannot be determined from a single well.

Mr. Norris compounds the misquote by suggesting that our survey is to *"determine entry and exit points of groundwater flow* ***in conduits****.*" He also must have forgotten that the purpose of the fracture trace analysis/EI survey was to select locations to install wells, since he states that one of the problems with the FSP (SAIC 2005a) is that there has been no verification drilling. The verification will be completed during the well drilling and installation and subsequent water level monitoring. The general direction of groundwater flow will be determined by consideration of the water levels in all wells, not a single well. Although groundwater in karst may take a sinuous pathway, it will generally migrate toward its point of discharge in the network of interconnected flow pathways, which will be determined by considering the water level elevations in all wells and streams on-site. Connectivity between wells will be evaluated by determining responses to precipitation events by measuring water levels and monitoring continuous water level recorders in wells.

Q49. Do you agree or disagree with Mr. Norris's opinion, given in his Answer 31, of the significance of the deficiencies that he finds in the EI survey?

A49. (SMS) No, I disagree. The basis for my disagreement is as follows:

Section 6.2.1.1 of the Well Location Selection Report (SAIC 2007b, p. 6-1, 6-2) lists five criteria for the selection of proposed well pair locations, rather than a single criterion purported by Mr. Norris's statement. All other alleged deficiencies have been sufficiently refuted in previous rebuttals to individual questions in this section.

Mr. Norris apparently has developed a site conceptual model that involves isolated independent tubes that carry groundwater from the DU Area to receptors within or outside the DU Area. This is unrealistic and unsupported by local and regional geological publications, as well as a general understanding of karst hydrogeology. Rather, it is more likely that groundwater flow in bedrock is controlled by vertical fractures and bedding planes (Greeman 1981, p. 13).

The depth of the water-bearing zones is relatively shallow, as supported by this statement by Greeman: *"Data from the Jennings County area indicate that drilling below 125-150 ft has increased well yields at only a few sites."* Water-bearing zones in the aquifer beneath JPG may even be shallower because the lower sequence Silurian limestones and dolomites are *"extremely resistant to* *dissolution along vertical fractures and horizontal bedding planes"* because of the siliceous dolomite that caps this unit *(Greeman 1981, p. 12)*. Further to the west, where the majority of Jennings County lies, adequate domestic water supplies are commonly obtained due to the area being underlain by the upper sequence Silurian limestones and dolomites (Greeman 1981, pp. 12-13) Verification of the interconnectivity of the flow pathways will be verified by monitoring water level responses to precipitation (recharge) events in the multilevel wells.

Stream/Cave Gauging and Stream Staging

Q50. Does Mr. Norris in his Answer 34 correctly identify all of the major design elements of the stream/cave gauging and stream staging?

A50. (SMS) Mr. Norris incorrectly states that the Middle Fork Creek Cave is dropped from the FSP (SAIC 2005a) with the FSP Addendum 3 (SAIC 2006b). In Section 2. Monitoring Equipment Installation and Monitoring Plan (SAIC 2006b, p. 2-1) of the FSP Addendum 3, second paragraph it is stated that three cave spring stage gauging stations will be constructed and references Figure 2-1 of the Addendum, which illustrates the proposed locations of the gauging stations including the cave location JPG-MF-02 (identification nomenclature adopted from Sheldon, 1997) along Middle Fork Creek.

Q51. Do you agree or disagree with Mr. Norris's criticism of the stream/cave gauging and stream staging activities found in his Answers 35 through 37?

A51. (SMS) I disagree.

Q52. Please state the basis for your disagreement.

A52. (SMS) Mr. Norris's testimony on the FSP (SAIC 2005a) with regard to stream and cave stream gauging makes little sense. He begins his objections by stating that the original (pre-FSP) site conceptual model did not consider the potential that the DU Area is underlain by a karst aquifer. To prove that, he quotes SAIC's Well Location Selection Report (SAIC 2007b). I am, of course, in agreement with my report, had no control over the original work that was conducted at the site prior to SAIC's involvement, and have clearly taken the position that karst conditions on-site must drive the characterization investigation.

Much of his remaining discussion describes all of the problems that can be caused by not considering a site conceptual model that includes karst, which is bazaar, since that has been the basis for all of the work proposed on-site since the beginning of my involvement.

Mr. Norris then further confuses the issue (and this reader) by stating "The deficiency in the surface water gauging and staging tasks is that the premise of the current conceptual model is that there *is* karst flow underlying the JPG DU site." How this supports his argument is not clear to me. He then describes the potential that water in streams could be dropping into conduits (into the groundwater), resurging into the stream, and/or resurfacing into some other distant basin. This is highly speculative and is not shown or suggested to occur in any studies of the JPG area, including the extensive cave study by Sheldon or the local fracture trace analysis by Greeman. He indicates that this condition would not be detected by the FSP surface water gauging study, which is certainly incorrect. The gain or loss of water from Big Creek, the primary tributary through the middle of the DU Area, would certainly be detected by the location of the three gauges located at the upgradient and downgradient boundaries of the DU Area (SGC-BC-01 and 03) and one in between (SGC-BC-02). In addition, gauges on the northern tributary to Big Creek, where it exits the DU Area and four gauges on Middle Fork Creek and its tributaries, will allow the comparison of unit area recharge values between the basins and sub-basins. If there would be any inter- or intra-basin losses or gains, they would be detected by this comparison, and at that time would possibly require further investigation.

The method of measuring stream flow proposed by Mr. Norris, which is often called a seepage run survey, calls for numerous instantaneous (one-time) stream measurements along a stream course. The entire stream, or at least the portions of the stream that one wants to compare, must be conducted under the same hydrologic conditions. It requires a team of technicians to walk the stream courses and select and measure profiles and stream velocities at numerous points along the course of the stream. If it rains during the survey (which would take at least two weeks to complete the streams at JPG), the before and after measurements cannot be accurately compared. For small streams, like those at JPG, measurements will be drastically impacted by evapotranspiration (plant uptake), such that measurements made in the morning cannot be compared to measurements made in the afternoon during any time of the year when leaves are on trees. Since, as Mr. Norris stresses, the conditions we would be trying to define are transient (the influx of groundwater can range from no flow to large flows, depending on recharge conditions, and may reverse and take water from the stream at other times) this procedure would have to be performed during different seasonal conditions.

Trying to define these transient conditions without continuous readings is often not successful. In my experience, having recently conducted two such studies in karst terrain, in the most favorable conditions, general sections of streams can be identified as gaining or losing. Claiming to be able to actually pinpoint a small area on a stream that is a part of a conduit system to the degree that information would be useful for tracing subsurface conduits or positioning wells shows Mr. Norris's lack of first-hand experience with this technique. Only once have I successfully located sinkholes taking water from a stream using the method described by Mr. Norris, and that was in a stream that was flowing within a few hundred feet of a 200-foot-deep limestone quarry that was being dewatered to support a mining operation, a unique and extreme case.

The use of continuous stream and cave stream gauges, as proposed in the FSP (SAIC 2005a) and its' addenda (SAIC 2006a, 2006b, and 2007a), is a far superior method of evaluating the hydrologic properties of the site, than the instantaneous (one time) seepage run survey measurements described by Mr. Norris. Continuous gauging allows the comparison of stream water level and flows to other portions of the basin and other adjacent basins or sub-basins. It will permit the use of baseflow separation techniques that will allow us to understand and quantify what percentage of precipitation that falls on the DU Area runs off across the surface, what portion drops into vadose caves, and what portion reaches the groundwater table and travels to streams through the aquifer.

Well Location Assessment and Selection

Q53. Do you agree with the major elements of the Well Location Assessment and Selection as stated by Mr. Norris in his Answer 39.

A53. (SMS) No. Mr. Norris suggests that the selection criteria for proposed well locations among potential locations are changed to prioritize "... locations that are anticipated to provide coverage in possible flow directions from the DU Impact Area." when in fact this was an added selection criterion. We did not change the consideration of the previously stated selection criteria in the FSP or in the Well Selection Report pages 6-1 and 6-2, which considered the following:

- fracture trace locations,
- EI anomalies indicating the possible location of fractures or weathered bedrock,
- correlation of the presence of a fracture trace and EI anomaly,
- located along these identified features in a suspected down gradient direction from the areas suspected to have the highest density of DU penetrators,
- so that good site coverage is achieved in all possible down gradient flow directions (i.e locations not concentrated in one portion or side of the study area).

He also states that depth of bedrock was no longer among the selection criteria, but he himself states that "One location of paired wells is added to investigate an area of unusually thick unconsolidated sediment overlying the bedrock." This location was selected based on results of the EI survey where it identified the potential for an area of unusually thick unconsolidated sediment overlying the bedrock to be present. This also is presented in Section 6.2.1.2 Deep Overburden Well Pair Location (p. 6-2) of the Well Selection Report (SAIC

2007b). Depth to bedrock was obviously a selection criterion since this location was selected.

Q54. Do you agree or disagree with the deficiencies in the design for the well location assessment and selection that he lists in his Answer 41?

A54. (SMS) I disagree.

Q55. Please state the basis for you disagreement.

A55. (SMS) It is the intent to install wells into permeable materials if they are encountered in the unconsolidated materials as presented in Section 2.1 Well Locations and Proposed Depths (p. 2-5) of the FSP Addendum 4 (SAIC 2007b), which states "At all sites, if sufficiently permeable materials are identified in the unconsolidated deposits, the installation of a well with a screened interval in the permeable zone will be considered. A final determination for the installation of a well in permeable unconsolidated materials will be made based on discussion between the Army and SAIC's project hydrogeologist, project manager, and rig geologist." Discussion between the Army, SAIC's project hydrogeologist, project manager, and rig geologist does not constitute simply relegating the installation of these wells to the discretion of the licensee, as suggested by Mr. Norris.

Mr. Norris's argument that the wells that are drilled will not be characterization wells because of the methodology used is speculative and in his very argument he indicates that the methodologies that we are using to locate wells "may" be relevant to finding groundwater conduits at the site. To use numerous alternate methods for locating wells on conduits as suggested by Mr. Norris is not necessary, is not commonly practiced, wastes of both money and time, especially when we are applying tried and proven methods that are very well supported within the scientific community and USGS, as evident in their fracture trace report Greeman, 1981) which was completed on an area including JPG. Mr. Norris's statement that the wells are not characterization wells is inappropriate as they will be used for both verification of the well location selection process as well as characterization wells. The extent of the use for the wells as characterization wells will be determined following the completion of the Conduit Intersection Confirmation described in Section 6.2.3 of the Well Location

Selection Report (p. 6-7). All wells drilled at JPG are expensive regardless of their purpose due in part to the hazards presented at the site by the presence of UXO. The installation of expensive wells, used for the purpose of verification and/or characterization, would have to be installed following the well selection process presented by both the FSP and modifications to the process that Mr. Norris is calling for regardless of which process was completed, so to criticize the installation of these wells based on their cost is irrelevant. Mr. Norris once again implies in the final sentence above that "all of the active groundwater conduits at this site" need to be located for the characterization of the site, which is impractical, unnecessary and may be impossible, especially considering the time constraints that have been imposed for completing the characterization and submission of a decommissioning plan. Karst conduits, if effective at controlling the migration of groundwater across the site, will form an interconnected network (Mr. Norris apparently agrees with this concept, since he uses the word network or karst network eight times in CN Q&A 36 and 37 alone). The degree of interconnection of the wells and streams will be established by monitoring of water levels and analyzing responses to precipitation (recharge).

His errant insistence that each individual conduit pathway needs to be mapped to satisfy the criteria for license termination has been addressed. That a paleo-karst system, no longer part of the contemporary conduit system, may be important to the characterization of the DU site has been addressed. The whole concept is geologically absurd in that if DU deposited on the site may move through this karst network, it must be active and thus part of Mr. Norris's so-named "contemporary conduit system."

Mr. Norris suggests using his description of a flow survey on JPG streams as part of conduit mapping to identify points or reaches of streams where the streams are receiving flow from or losing water to the groundwater conduits. Mr. Norris presents a very simplified interpretation of the results of this type of flow study and his application of the results to the location of groundwater conduits. Complications with this method have been discussed previously.

Mr. Norris use of language such as "mouths and headwaters of active groundwater conduits" indicates a severe unfamiliarity with typical and accepted practices and concepts of fractured rock hydrogeology. This language is more appropriate for surface water, and I could understand a temptation to use of these words to describe vadose caves or even deeply karstified systems like Mammoth Cave. It is, however, inappropriate for characterization of fracture-controlled flow pathways in groundwater. Flow of water through vadose caves will be adequately characterized, and there is no evidence of a deeply karstified system at JPG. If such a system exists, it will be discovered by drilling of wells of fracture traces.

Mr. Norris simply makes a statement that "The cave survey that was performed at JPG in the mid- to late 1990s is not fully and appropriately incorporated into the location and selection process" and goes on to state facts or findings presented in the referenced report, with no supporting details as to the appropriate use of that report with respect to the well selection process. In fact, the report referenced has and continues to be evaluated during the planning and implementation of the site characterization efforts. For instance, the report data were used to help in locate and select appropriate cave stream monitoring locations and will be further used to help select water and sediment sampling locations.

The occurrence of recorded caves and sinkholes in the DU Impact Area provides a narrow strip of information through the center of the site, approximately 450 to 900 feet wide. These locations (there is some obvious error in the reported locations, since the given coordinates do not match basic descriptions of some caves, like "on the bank of Big Creek") and the extent of the mapped sections of the caves have been shown in Figure SMS-1 (attached as Exhibit SMS #2), in context with the extent of the entire DU Impact Area. To properly locate wells in an effort to characterize the migration of groundwater through the site, wells must be located across the entire site, similar to distribution of the candidate well locations shown on my figure. Use of the caves provides information on such a small portion of the site (2 percent of the designated DU Impact Area) that it is obvious that an additional method must be used to place wells on preferential flow pathways. One of the most productive approaches identified in the literature is the use of photogeologic fracture traces (Fetter 1988,, p. 294), which has been utilized on this site. The distribution of mapped fracture traces is also shown on my figure.

It has not, at this point, been demonstrated that caves overlie or constitute the locations of groundwater conduits. Since the caves have been explored, they are obviously above the water table for much of the year. Whether the streams that flow from some of these caves are supported by groundwater, or are simply the result of perched or percolating surface water, will be determined by long-term stream and cave stream monitoring in conjunction with groundwater level monitoring in wells. Groundwater flow in the shallow karstified zone of the aquifer may be a significant, even dominant, migration pathway or potential migration pathway for DU. This will be determined by baseflow separation of cave streams and surface streams, and by comparing flow responses to storm and precipitation events. This portion of the potential migration path for DU carried by water is well-represented by the network of caves and, particularly, the three caves that underlie the DU Area, two of which have been fitted with continuous gauging stations.

Whether the caves mapped at JPG are related to groundwater pathways is speculative. It was not expected that EI would necessarily identify the caves, since the dry portions of a cave above the water table would not be electrically conductive. The existence of a cave does not indicate the location of a groundwater flow pathway, since it is above the water table. If fractured and weathered bedrock and water- or sediment-filled solution channels are associated with the cave location, perhaps below the cave, as a result of formation along a zone of vertical fracturing, EI would identify such a feature and show a low-resistivity anomaly at that location. This, of course, would constitute a potential groundwater flow pathway, subject to verification by drilling.

I believe that the point that Mr. Norris is trying to make concerning the wells being "nine Isolated data points" is that he feels it is necessary to map individual groundwater flow conduits, as if they are isolated pipes, open to deposits of DU at the site, but sealed to any interaction with the groundwater, until they surface at a stream. There is no indication that such a system exists. Rather, the system acts more like an interconnected network, as illustrated by these points:

- Fracture-controlled aquifers have zones of relatively higher permeability along discontinuities in the bedrock, surrounded by more impermeable blocks of unfractured rock.
- Indications from Greeman (1981,, p. 9), and the fracture trace analysis conducted under the FSP (SAIC 2005a) are that fractures are oriented in two prominent directions: northeast-southwest, and northwest-southeast. This intersecting pattern of vertical fractures is superimposed on horizontal bedding planes. Migration of groundwater in the bedrock aquifer is along a combination of these interconnecting vertical fractures and the bedding planes.
- In a soluble carbonate rock, some of these discontinuities (joints, fractures, bedding plane partings) tend to capture more groundwater flow, and are enlarged by solutioning (Fetter 1988, p. 286).

Positioning characterization wells on the intersecting vertical fracture patterns, in close proximity to DU deposits, is the best way to determine if migration of DU is occurring, and to characterize the potential that it could be a migration pathway in the future. Interconnections and responses to precipitation and interaction with surface water will be determined by continuous water level monitoring. If migration is indicated by the characterization, that information will be used to develop potential pathways and exposure scenarios of dose modeling. That, in turn, may lead to more detailed studies or specific investigations of distant pathways, such as to Indian-Kentuck Creek.

Q56. Do you agree with Mr. Norris, as stated in his Answer 42, as to the significance of the well location and selection deficiencies he believes exist?

A56. (SMS) No. My concern that Mr. Norris mistakenly believes that numerical groundwater modeling is required for license closure was previously discussed in my earlier testimony. The lack of value in mapping the course of individual groundwater conduits to locate wells also was discussed. The practical problems and likely failure of a conduit mapping program as described by Mr. Norris are also discussed in my testimony. The unlikely potential that such conduits exist at JPG based on local studies was discussed.

The effectiveness of the methods employed to locate wells in carbonate rocks (fracture trace analysis and EI) also is discussed. The ability to characterize the interconnectivity of the aquifer by monitoring water levels in wells and streams is discussed. Development of potential pathways and exposure scenarios of dose modeling also is addressed.

These previous discussions in my testimony form the basis of my disagreement here.

Interactive considerations

Q57. Do you agree or disagree with Mr. Norris's opinion, in his Answer 60, that the deficiencies in the hydrologic sampling will not define or develop the critical inter-relationships needed for effective decommissioning?

A57. (SMS) I disagree.

Q58. Please state the basis for your disagreement.

A58. (SMS) For Mr. Norrris to suggest that the FSP (SAIC 2005a and its addenda (SAIC 2006a, 2006b, and 2007a) will not evaluate "critical inter-relationship" of the various tasks is refuted by the activities to date. The FSP, as modified by the various addenda, exemplifies this very process. The SAIC team has been very careful to plan each of the individual tasks in general, and then modify the details of the plans with addenda as more information becomes available. Each task was designed to build on the previous task, such as the use of fracture trace analysis, followed by EI, which is used to locate multi-level characterization wells. Wells will be installed and data collected from the wells will be used in many ways to refine the conceptual site model (CSM). Water samples from the wells will be used to evaluate the current potential for migration of DU from the site. Water levels in wells will be recorded, and compared to surface water levels. Water level responses to precipitation events will determine the interconnectivity of the aquifer.

On a separate track, DU corrosion rates will be measured in the laboratory and estimated from observation of recovered projectiles. Concentrations of DU beneath projectiles will be measured to determine the rate of migration through the soil. Shallow wells in saturated unconsolidated materials will be established to further track the potential DU pathway. This pathway then links up with the shallow karst system represented by the vadose caves and the fracture controlled groundwater flow system. The surface water pathway is likewise characterized by sampling of recent deposits of sediment and surface water.

Mr. Norris is correct that the FSP does not attempt to verify the pathway of individual conduits, particularly the shallow vadose caves that connect with sinkholes on the very limited portion of the site that is not covered with glacial till. This provides insight into only a small strip of the site, leaving no viable methodology to investigate the remaining 98 percent of the site that is superior to fracture trace analysis followed by EI. Fracture trace analysis is described by Fettter as "one of the most productive approaches…to the selection of well sites in carbonate terrane." (Fetter, 1988, p. 294). Mr. Norris provides no references that indicate anyone has successfully utilized his proposed methods for determining exact flow paths on a micro scale, as proposed. He does not even provide unpublished experiential verification that he has attempted, let alone succeeded to accomplish any of the tasks that he says are essential to appropriately understanding the potential for DU migration from the site. He ignores the tremendous safety concerns due to UXO that are involved for personnel that go off of the cleared corridors. Such entry is extremely slow, but will be done for critical tasks such as the recovery of DU projectiles and soil sampling beneath and around projectile points.

Locating wells on fracture traces verified by EI along the upgradient and downgradient perimeters of the DU Area is the best method available to characterize groundwater migration through the DU Area, considering all site conditions. These will not be disconnected isolated points, but the degree of interconnectivity of the aquifer will be determined by monitoring water levels.

The use of continuous stream and cave stream gauges is a far superior method of evaluating the hydrologic properties of the site, than the instantaneous (one time) seepage run survey measurements described by Mr. Norris. Continuous gauging allows the comparison of stream water level, flows, and recharge rates to other portions of the basin and other adjacent basins or sub-basins. It will permit the use of baseflow separation techniques that will allow us to understand and quantify what percentage of precipitation that falls on the DU Area runs off across the surface, what portion drops into vadose caves, and what portion reaches the groundwater table and travels to streams through the aquifer.

The method of measuring stream flow, proposed by Mr. Norris requires numerous instantaneous stream measurements, which are difficult to compare. Trying to define transient stream flow conditions without continuous readings is often not successful. In my experience, having recently conducted two such studies in karst terrain, only general sections of streams can be identified as gaining or losing. Claiming to be able to actually pinpoint a small area on a stream that is a part of a conduit system to the degree that information would be useful for tracing subsurface conduits or positioning wells shows Mr. Norris's lack of first-hand experience with this technique.

In some severely karstified aquifers, where there is significant channelization of groundwater flow, I have used seepage run surveys or thermal surveys, that detect the inflow of groundwater into a surface water by temperature differences (groundwater is warmer than surface water in the winter,and cooler than surface water in the summer). I will not hesitate to suggest this methodology at JPG if there appears that such conditions exist, and the information is necessary to appropriately characterize the potential for DU to be transported by water. I would not use these techniques to site wells or attempt to map conduits.

With respect to surface water and sediment sampling, as described by my colleague, Mr. Todd Eaby (TDE Q&A62), I quote the following: "The presentation of the surface water and sediment sampling locations in the FSP (SAIC 2005a) was completed for planning and budgeting purposes for providing a framework and starting point for initiating the site characterization. This task is not scheduled until after the first year of the plan and as stated in the FSP "...plans for this project are defined in detail for this FSP (SAIC 2005a) and the HASP (SAIC 2005b) for the first year (FY 2005-2006) of the project. Subsequent year tasks and associated activities will be planned and detailed as addenda to the FSP and HASP." Additional detail for surface water and sediment sampling will be further detailed in an FSP addendum.

Q59. Do you agree with Mr. Norris analysis, in his Answer 61, as to what is required to correct the deficiencies he lists?

A59. (SMS) I disagree.

Q60. Please state the basis for your disagreement.

A60. (SMS) Toward the beginning of his answer, Mr. Norris uses the phrase *"A simpler, more practical approach..",* showing a lack of experience in karst terrain studies. There is nothing simple about tracing or mapping underground conduits. Only rarely is this attempted, for projects such as evaluation of bridge or building foundations.

All components of Mr. Norris's proposed actions have been addressed previously, and summarized in these five bullets:

- Locating wells on fracture features located on the upgradient and downgradient perimeters of the DU area, as well as in the center, and along the creeks provide monitoring of groundwater as it enters and exits the DU Area. Comparison of up-gradient and down-gradient results will provide a characterization of the impact of the DU Area on the groundwater quality.
- Shallow vadose caves (above the water table) should not be detectable by EI, unless accompanied by deep fracturing and weathering. If deep fracturing and or weathering are present, the area would be a viable target identified by the EI. The locations of the caves as reported by Sheldon are not precise enough to adequately compare them to the fracture trace and EI work. These caves and associated sinkholes are probably an important pathway for shallow near surface

migration of precipitation runoff from the DU area to Big Creek, which will be determined by baseflow separation of stream hydrographs, but they are not conduits for groundwater flow. Monitoring of cave streams will adequately characterize this shallow water pathway, and additional wells on these pathways are not required.

- The use of vintage aerial photographs (prior to construction of JPG) to map fracture traces has the advantage of avoiding cultural interference and is a proven technique.
- Detailed mapping of individual conduits is nearly impossible, and in the best of conditions very time consuming and incomplete. Further, it is unnecessary to establish the circuitous route that groundwater may take through the aquifer, to characterize the potential for DU migration in groundwater. It is sufficient to characterize the upgradient and downgradient groundwater quality as it moves through the DU area. The use of 3D EI is impractical under any conditions at the scale of this project, seismic and GPR may trigger detonation of UXO. This is not a research project where untested methods can be developed. The safety conditions at the site are serious, and require the use of known, tested methods, which require minimal invasion off of roads and safe corridors.
- Tracer studies often are used in the study of karst terrain. To be effective, they must be done after considerable characterization of the karst network is completed in order to appropriately design and implement a successful study. As stated in numerous discussions previously, dye studies will be considered in the future if the information gained would be helpful to the characterization of the hydrogeologic flow regime.

XIV. SUMMARY AND CONCLUSION

As to Testimony of Charles Norris

Q61. Please summarize your testimony with regard to your disagreement with the testimony of Charles Norris herein.

A61. (SMS) My testimony can be summarized as follows:

STV, through their consultant, Mr. Charles H. Norris, has objected to numerous components of the FSP through 81 pages of written testimony, but his meaningful points are few and those can be summarized in just a few points:

1. Mr. Norris painstakingly presents each modification to each component of the FSP, presenting it as an inconsistency. These improvements or refinements are evidence of our iterative process at work. He fails to acknowledge that later phases of work will be modified as new site-specific data are collected and analyzed.

2. Mr. Norris wants to utilize numerous technologies, many of which he is obviously unfamiliar, to accomplish a single task. For instance, he calls for the use of multi-spectral remote sensing, side-looking airborne radar, GPR, color and false-color imagery, 3D EI, seismic surveys, electrical induction, as well as field-intensive measurements and inspections within the UXO-littered DU Impact Area to trace the "mouths and headwaters" of groundwater conduits in order to locate groundwater characterization wells to determine if DU is migrating from the site.

The Army selected a proven method of positioning characterization wells in carbonate rocks using a combination of fracture trace analysis conducted on pre-construction (to avoid cultural interferences) aerial photographs and EI to pinpoint likely fracture features in the bedrock. The EI was conducted on an excellent network of roads surrounding and passing through the DU Impact Area. These roads are safe corridors where UXO has been cleared, allowing safe data gathering and eventual access for drilling equipment.

3. Mr. Norris expresses concern that there is a DU migration pathway to a remote area (possibly a paleo-karst channel or network) that will go undiscovered and undetected. The geologic conditions at the site (flat-lying Silurian-aged siliceous dolomitic limestone) are not likely to host such a condition, and local geologic literature makes no reference to such a condition or potential. However, there is currently no indication that DU has even reached the groundwater table. If that condition is established, and there appears to be a potential for DU migration in groundwater, the pathway will be investigated further.

4. Plans to characterize surface water and sediment transport of DU are not satisfactory to Mr. Norris. This work is not scheduled to occur until after the installation of wells, so that concurrent sampling of all media can occur. Therefore, details of that program have not yet been prepared.

Implementation of the FSP (SAIC 2005a), including the practice of providing modifications to the FSP through addenda, should be allowed to continue so as not to impede the schedule of the application for license closure.

XV. REFERENCES

Q62. In your testimony you referred to several documents. Would you specifically identify those documents?

A62. (SMS) Yes.

1. Dahlin, T., and M. H. Loke. "Quasi-3D Resistivity Imaging – Mapping of Three Dimensional Structures Using Two Dimensional DC Resistivity Techniques", Proceedings of 3rd Meeting Environmental and Engineering Geophysics, Aahus, Denmark, 8-11 September 1997. Attached as Exhibit SMS # 3.

2. Eastern Research Group, 1993. Use of Airborne, Surface, and Borehole Geophysical Techniques at Contaminated Sites, EPA/625/R-92/007, Sept 1993.

Attached as Exhibit SMS # 4 .

3. Fetter, C. W., 1988, "Applied Hydrogeology", Merrill Publishing Company, Columbus, Ohio. Attached as Exhibit SMS # 5.

4. Greeman, T. K., 1981, "Lineaments and Fracture Traces, Jennings County and Jefferson Proving Ground, Indiana", Open-File Report 81-1120, United States Department of the Interior Geological Survey, Indianapolis, Indiana.

5. Lattman, L. H. 1958, "Techniques of Mapping Geologic Fracture Traces and Lineaments on Aerial Photographs", Photogrametric Engineering, Volume 24, pp. 568-576.

6. Lattman, L. H. and Parizek, R. R., 1964. "Relationship Between Fracture Traces and the Occurrence of Groundwater in Carbonate Rocks", Journal of Hydrology 2(1964) 73-91; North-Holland Publishing Co., Amsterdam

7. Freeze, R. A., and Cherry, J. A. 1979. Groundwater, Prentice-Hall, Inc. Englewood Cliffs, New Jersey. Attached as Exhibit SMS # 6.

8. SAIC (Science Applications International Corporation). 2005a. Field Sampling Plan. DU Impact Area Site Characterization, JPG, Madison, Indiana. Final. May.

9. SAIC. 2005b. Health and Safety Plan, Depleted Uranium Impact Area Site Characterization, Jefferson Proving Ground, Madison, Indiana. Final. May.

10. SAIC. 2006a. Field Sampling Plan Addendum 2, Depleted Uranium Impact Area Site Characterization – Soil Verification, Jefferson Proving Ground, Madison, Indiana. Final. July.

11. SAIC. 2006b. Field Sampling Plan Addendum 3, Depleted Uranium Impact Area Site Characterization – Other Monitoring Equipment Installation, Other Monitoring (Precipitation, Cave, and Stream/Cave Spring Gauges), and Electrical Imaging Survey, Jefferson Proving Ground, Madison, Indiana. Final. July.

12. SAIC. 2007a. Field Sampling Plan Addendum 4, Depleted Uranium Impact Area Site Characterization: Monitoring Well Installation Jefferson Proving Ground, Madison, Indiana. Final. January.

13. SAIC. 2007b. Well Location Selection Report, Depleted Uranium Impact Area Site Characterization: Soil Verification, Surface Water Gauge Installation, Fracture Trace Analysis, and Electrical Imaging, Jefferson Proving Ground, Madison, Indiana. Final. January.

14. Sheldon, R. 1997, "JPG Karst Study Report"

15. Wilson, J. T. , et. al. 2001. "An Evaluation of Borehole Folwmeters Used to Measure Horizontal Ground-Water Flow in Limestones of Indiana, Kentucky, and Tennessee, 1999. U.S.G.S. Water Resources Investigation Report 01-4139.

Q63. Does that conclude your testimony?

A63. (SMS) Yes, it does.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD PANEL

Before Administrative Judges:

Alan S. Rosenthal, Chair
Dr. Paul B. Abramson
Dr. Richard F. Cole

In the Matter of	)	**Docket No. 40-8838-MLA**
	)	
U.S. ARMY	)	**ASLBP No. 00-776-04-MLA**
	)	
(Jefferson Proving Ground Site)	)	**August 15, 2007**
	)	

AFFIDAVIT OF STEPHEN M. SNYDER

RE STV CONTENTION B-1, BASIS ITEMS "a", "d", "e", AND "f"

County of Dauphin)
State of Pennsylvania)

I, Stephen M. Snyder, being duly sworn according to law, depose and state the following:

1. I work as a Senior Hydrogeologist and Program Manager with Science Applications International Corporation (SAIC) in their Harrisburg, Pennsylvania office. My business address is 6310 Allentown Boulevard, Harrisburg, Pennsylvania 17112.

2. I am providing testimony, dated August 15, 2007, on behalf of the U.S. Army, Licensee, in the above captioned proceeding, entitled "TESTIMONY OF STEPHEN M. SNYDER ON STV CONTENTION B-1, BASIS ITEMS BASIS ITEMS 'a',

'd', 'e', AND 'f' SUBJECTS: Electrical Imaging; Selection, Installation and Purpose of Conduit Well Sites; Installation of Shallow Wells."

3. The factual statements and opinions I express in the cited testimony are true and correct to the best of my personal knowledge and belief.

4. I declare under penalty of perjury that the foregoing is true and correct.

Further, the affiant sayeth not.

Stephen M. Snyder

Stephen M. Snyder

Subscribed and sworn to before me
this 15 day of August, 2007.

Diana L. Peters

Notary Public

My commission expires 11/14/07

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Diana L. Peters, Notary Public
Lower Paxton Twp., Dauphin County
My Commission Expires Nov. 14, 2007
Member, Pennsylvania Association Of Notaries

SNYDER TESTIMONY

Exhibit SMS # 1

Résumé

STEPHEN M. SNYDER, P.G.

Project Director

Education:	B.S. in Geology, 1973 College of William and Mary Continuing Education, Hydrogeology Pennsylvania State University
Registrations/ Certification:	Professional Geologist - VA #2801-000170; PA #PG-000169-G; TN #TN-3622; WI #240; AL #830; MS #0370 OSHA-certified for Hazardous Waste Operations

Mr. Snyder has 32 years of experience as a project manager, principal investigator, or project hydrogeologist on more than 200 groundwater development, site characterization, environmental remediation, and waste disposal projects. He has managed and conducted investigations of aquifer contamination and designed and implemented remediation at dozens of landfills, lagoons (waste pits), Department of Defense (DOD) facilities, and industrial sites in Pennsylvania, New Jersey, Alabama, Tennessee, and Texas. He has managed major Comprehensive Environmental Responses, Compensation and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) remediation projects for United States Environmental Protection Agency (EPA) and private industry. He has provided hydrogeologic expert witness testimony for wastewater spray irrigation and groundwater development (well interference) projects and has provided expert litigation support services for an industrial contamination dispute, all of which were settled or decided in favor of his client.

He has developed a specialty in fractured and karst bedrock aquifers, utilizing aerial photo and remote sensing analysis, geophysical testing, and dye trace studies, as well as geologic mapping and aquifer pumping tests to develop groundwater supplies or characterize and design remediation for these sites.

Mr. Snyder serves as technical advisor, client representative, contract administrator, and regulatory liaison. He has a working knowledge of key environmental legislation including Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)/Superfund Amendment and Reauthorization Act (SARA); RCRA; Clean Water Act (CWA); National Environmental Policy Act (NEPA); Safe Drinking Water Act (SDWA); Toxic Substances Control Act (TSCA); and Pennsylvania's Act 2 (Land Recycling) Program. He has worked extensively with the Susquehanna River Basin Commission on behalf of clients requiring groundwater and consumptive use allocations.

Mr. Snyder applies his experience to the investigation and remediation of hazardous waste sites. As project director for Superfund projects, Mr. Snyder has been responsible for management of investigative activities as well as developing remedial design solutions. His Superfund experience is supported by his design, operations, and remediation work on more than 30 landfills in Pennsylvania and New Jersey. He joined SAIC in 1979.

PROJECT EXPERIENCE

Project Director, BMY, Inc., York, PA - Directed development and implementation for the closure of an RCRA-permitted wastewater treatment lagoon containing listed hazardous waste (F019). Directed excavation of waste and contaminated soil. Oversaw design, permitting, and construction of an EPA-approved, double-lined (minimum technology requirements) hazardous waste landfill to contain the stabilized waste, saving the client over $2 million in disposal costs had the materials been disposed off-site. Also directed the design, construction, and operation and maintenance (O&M) of two groundwater remediation systems and a mobile soil gas extraction system on the 135-acre industrial facility. Led development of post-closure monitoring plans.

Carroll County, Maryland, Water Resources Study - Assisted in the development of the hydrogeologic framework of various community planning areas of Carroll County, preparing baseline inventories of available water sources in these areas during this eight-year project. Assisted in the completion of a county-wide evaluation of groundwater development potential. Conducted a study of six small municipal water systems.

Project Director, Chambersburg School District, Chambersburg, PA - Oversaw the hydrogeologic evaluation and recovery of fuel oil resulting from a leaking heating oil tank. Designed remedial program including recovery of free product, pumping and treating of contaminated water, and construction of a new water supply well in fractured carbonate rock.

Peer Reviewer, Ciba-Geigy Oversight and Advisory Committee, Ocean County, NJ - Provided peer review and comment on the EPA's Remedial Investigation Report on Toms River Chemical Plant Superfund site.

Technical Advisor and Peer Reviewer, Combe Fill South Landfill, Morris County, NJ - Evaluated the areal extent and migration pathways of contamination in the subsurface. Evaluated the installation of monitoring wells, piezometers, pumping and slug tests. Developed preliminary remedial alternatives during feasibility study (FS) and evaluated the recommended alternative which included gas venting, an aquifer pumping system, and on-site groundwater treatment.

Project Director, Cumberland County Landfill, Cumberland County, PA - Expansion and cell closure.

Project Scientist, Delaware River Basin Commission (DRBC) - Completed lineament mapping from Lansat imagery for two different study areas.

Project Director, Grove Worldwide, Shady Grove, PA - Has directed and managed numerous investigative and remedial activities at this 330-acre industrial facility where hydraulic cranes and man lifts are manufactured. Mr. Snyder directed the investigation of a solvent still spill and the design and implementation which involved excavation and removal of contaminated soils and soil gas extraction system with thermal fume treatment. Led the site-wide investigation to collect information to defend Grove in federal and commonwealth courts against suits by neighboring property owners regarding groundwater flow and groundwater contamination in this karst fractured rock environment. Provided hydrogeologic expert opinions and report regarding the source of groundwater contamination, which resulted in an out-of-court settlement in favor of Grove. The use of advanced geophysical methods to trace groundwater pathways resulted in convincing evidence that led to the favorable decision.

Project Director, Harley-Davidson Motor Company, York, PA - Directed investigative and remediation activities at a 200-acre former naval ordnance plant site involving contamination of groundwater and soils with metals, volatile organic compounds (VOCs), and cyanide. Investigative activities included aquifer testing, characterization of fracture flow and karst aquifer, groundwater and soil sampling and laboratory analyses, geophysical surveys, historical aerial photograph analysis, soil gas surveys, and off-site source assessments. Also led the design and installation of a groundwater extraction and treatment system, remediation of fuel-contaminated soils using bioremediation and soil gas extraction, and four major metals-contaminated soil removal and disposal projects. Much of the remediation work was carried out inside existing buildings, making building integrity and subcontractor scheduling and management a critical component. Work continues with O&M of the 17-well, 300-gpm groundwater pump-and-treat system, including a thermal fume incinerator, major construction projects in contaminated and potentially contaminated areas, and in the development of continued site-wide remedial investigations. This project has recently joined Pennsylvania's "One Cleanup Program", a cooperative initiative between the state and the USEPA.

Project Director, Harmony Grove Landfill, Waste Management, Inc., York County, PA - Led hydrogeologic investigation/design/installation under Superfund guidance of a groundwater extraction system in fractured rock aquifer. Wells in low-yielding shale aquifer were successfully hydraulically fractured, resulting in a cost savings.

Project Director, Harris Corporation/Brault Lagoon, Clinton County, NY - Directed a hydrogeologic investigation to determine the extent of contamination resulting from disposal of solvents in an unlined disposal pit. The investigation involved characterizing the fracture-controlled pathways in the sandstone bedrock and aquifer testing and modeling to design the placement of extraction wells and to establish design criteria for the treatment and conveyance system. A network of monitoring wells was established and monitored to demonstrate capture of contaminated groundwater. Subsequently oversaw design and implementation of a 20-well groundwater pumping system and treatment plant and continues to perform annual monitoring to evaluate system effectiveness. Special O&M procedures for the air stripping tower and wells/pumps, which are subject to biofouling, have been developed for this project.

Project Director, Hazleton City Water Authority, Hazleton, PA - Provided investigation and report on groundwater development potential for over 120 square miles of area surrounding the greater Hazleton area. Directed project to quantify the amount and availability of good quality groundwater and to select and locate sites for development of high-yield groundwater supply wells. Established an emergency groundwater development program and determined the leakage potential of nearby reservoirs. Evaluated the threat of area pollution to an existing production well, as well as the extensive underground drainage tunnels connecting the mine workings within the Hazleton area. Resulted in the development of new water supplies for the City Authority.

Project Manager, Helen Kramer Landfill Superfund Site, Gloucester County, NJ - Project manager and senior hydrogeologist on this $1 million remedial investigation/feasibility study (RI/FS) to characterize the site, assess its threat to human health and the environment, and evaluate remedial alternatives.

Project Manager, Kelly Air Force Base Remedial Design, San Antonio, TX - Developed and directed studies to obtain remedial design parameters for this $3 million effort. Coordinated data-gathering efforts with design team. Effort involved design of 8 small groundwater extraction systems and approximately 60 soil operable units.

design, operations, and remediation work on more than 30 landfills in Pennsylvania and New Jersey. He joined SAIC in 1979.

PROJECT EXPERIENCE

Project Director, BMY, Inc., York, PA - Directed development and implementation for the closure of an RCRA-permitted wastewater treatment lagoon containing listed hazardous waste (F019). Directed excavation of waste and contaminated soil. Oversaw design, permitting, and construction of an EPA-approved, double-lined (minimum technology requirements) hazardous waste landfill to contain the stabilized waste, saving the client over $2 million in disposal costs had the materials been disposed off-site. Also directed the design, construction, and operation and maintenance (O&M) of two groundwater remediation systems and a mobile soil gas extraction system on the 135-acre industrial facility. Led development of post-closure monitoring plans.

Carroll County, Maryland, Water Resources Study - Assisted in the development of the hydrogeologic framework of various community planning areas of Carroll County, preparing baseline inventories of available water sources in these areas during this eight-year project. Assisted in the completion of a county-wide evaluation of groundwater development potential. Conducted a study of six small municipal water systems.

Project Director, Chambersburg School District, Chambersburg, PA - Oversaw the hydrogeologic evaluation and recovery of fuel oil resulting from a leaking heating oil tank. Designed remedial program including recovery of free product, pumping and treating of contaminated water, and construction of a new water supply well in fractured carbonate rock.

Peer Reviewer, Ciba-Geigy Oversight and Advisory Committee, Ocean County, NJ - Provided peer review and comment on the EPA's Remedial Investigation Report on Toms River Chemical Plant Superfund site.

Technical Advisor and Peer Reviewer, Combe Fill South Landfill, Morris County, NJ - Evaluated the areal extent and migration pathways of contamination in the subsurface. Evaluated the installation of monitoring wells, piezometers, pumping and slug tests. Developed preliminary remedial alternatives during feasibility study (FS) and evaluated the recommended alternative which included gas venting, an aquifer pumping system, and on-site groundwater treatment.

Project Director, Cumberland County Landfill, Cumberland County, PA - Expansion and cell closure.

Project Scientist, Delaware River Basin Commission (DRBC) - Completed lineament mapping from Lansat imagery for two different study areas.

Project Director, Grove Worldwide, Shady Grove, PA - Has directed and managed numerous investigative and remedial activities at this 330-acre industrial facility where hydraulic cranes and man lifts are manufactured. Mr. Snyder directed the investigation of a solvent still spill and the design and implementation which involved excavation and removal of contaminated soils and soil gas extraction system with thermal fume treatment. Led the site-wide investigation to collect information to defend Grove in federal and commonwealth courts against suits by neighboring property owners regarding groundwater flow and groundwater contamination in this karst fractured rock environment. Provided hydrogeologic expert opinions and report regarding the source of groundwater contamination, which resulted in an out-of-court settlement in favor of Grove. The use of advanced geophysical methods to trace groundwater pathways resulted in convincing evidence that led to the favorable decision.

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Project Manager, Helen Kramer Landfill Superfund Site, Gloucester County, NJ - Project manager and senior hydrogeologist on this $1 million remedial investigation/feasibility study (RI/FS) to characterize the site, assess its threat to human health and the environment, and evaluate remedial alternatives.

Project Manager, Kelly Air Force Base Remedial Design, San Antonio, TX - Developed and directed studies to obtain remedial design parameters for this $3 million effort. Coordinated data-gathering efforts with design team. Effort involved design of 8 small groundwater extraction systems and approximately 60 soil operable units.

Project Director, Lancaster Area Refuse Authority, Lancaster, PA - Completed electromagnetic conductivity and seismic refraction survey of carbonate terrain to determine site suitability for a proposed solid waste resource recovery facility. Utilized geophysical surveys, aerial photograph analysis, and soil and rock borings.

Project Director, Lebanon County Redevelopment Authority, Lebanon, PA - Worked with the Authority and private industry to encourage and permit the redevelopment of a former steel manufacturing facility.

Project Director, Lehigh Portland Cement - Conducted hydrogeologic evaluation to reduce stream infiltration to a quarry via sinkhole collapses. Responsibilities included site investigation, remedial design and permitting, and construction monitoring.

Technical Advisor, Lipari Landfill Superfund Site, Pitman, NJ - Served as technical advisor for the hydrogeologic RI/FS investigation. Developed drilling and sampling procedures. Conceptualized and evaluated remedial alternatives. Prepared specifications for long-term maintenance of the recommended impervious cover. Peer reviewed RI/FS text.

Project Director, Mercersburg Borough, Franklin County, PA - Directed evaluation of hydrogeology for suitability for spray irrigation.

Project Director, Spectron, Inc., Superfund Site, Elkton, MD - Responsible corporate officer and project director for this investigation of a four-acre fuel blending/solvent recycling site near Elkton, Maryland, where VOCs were present in the groundwater. Aquifer was fractured metamorphic granodiorite. The project evaluated mass flux of methylene chloride, trichloroethane (TCA), methyl ethyl ketone (MEK), acetone in the creek and evaluated the effectiveness of an existing groundwater extraction facility. Remedial technologies were evaluated for site application.

Project Director, Sunny Farms Landfill, Waste Management, York County, PA - Led hydrogeologic investigation and determination of impact on two closed landfill areas totaling 15 acres. Oversaw piezometer installation, permeability measurements, mapping of soils and geology, water quality impacts, and determination of groundwater flow directions. Directed construction of leachate collection trench and containment facility.

Project Director, United Defense, L.P., York, PA - Served as Responsible Corporate Officer in directing the development and implementation for the closure of a RCRA-permitted wastewater treatment lagoon containing listed hazardous waste (F019). Directed excavation of waste and contaminated soil. Oversaw construction of an EPA-approved, double-lined hazardous waste landfill to contain the stabilized waste. Led development of post-closure monitoring plans.

Project Hydrogeologist, United States Army Corps of Engineers (USACE)/Alabama Army Ammunition Plant, Childersburg, AL - Developed and implemented a work plan for this complex RI/FS to identify conduits of groundwater flow at a site with complex karst geology. Applied and integrated several analytical methods and technologies, such as fracture trace analysis using historical aerial photographs, electrical imaging (geophysics) to confirm and pinpoint the locations of conduits, and thermal imaging and sounding to locate groundwater discharges to surface water. Designed and implemented a dye trace study to demonstrate conduit-controlled groundwater flow direction and point of groundwater discharge to surface water. Thermal and dye test results were used to pinpoint surface water and sediment sampling locations, and to assess environmental impact. Constructed a GIS project to manage and interpret data. Results are supporting cost-effective remedial alternatives analyses.

Project Director, Waste Management, Inc. - Harmony Grove Landfill, York County, PA - Led hydrogeologic investigation/design/installation of a groundwater extraction system in fractured rock aquifer. Wells in low-yielding shale aquifer were successfully hydraulically fractured.

Project Director, Waste Management, Inc. - Modern Landfill, York, PA - Performed a detailed hydrogeologic analysis of subsurface conditions to determine potential for sinkhole activity within a proposed 21-acre lined landfill area.

Project Director, Waste Management of North America - Modern Landfill, York, PA - This project evaluated remedial alternatives and resulted in design and construction of a 30-well groundwater extraction system to prevent off-site migration of leachate for this Superfund site. Design parameters for the extraction system and treatment plant required extensive pumping tests, well efficiency tests, measurement of directional permeabilities in the aquifer, chemical concentrations, and maximum and minimum flows. O&M of the extraction wells subject to biofouling required development of chemical and physical treatment procedures. Also directed solid waste permitting activities for two major expansions (over 60 acres) of landfill area.

Project Director, Waste Management - Pottstown Landfill, Pottstown, PA - Directed hydrogeologic investigation/design/installation/O&M of a groundwater extraction system in fractured rock aquifer. Wells in low-yielding shale aquifer were successfully hydraulically fractured. The pump-and-treat system was monitored and annually evaluated for performance. Well treatment procedures for iron bacteria were also implemented.

Waste Management of North America - Overall responsibility for the design of a groundwater monitoring plan in conjunction with a groundwater assessment and pump-and-treat remediation for an entire 60-acre landfill site. Plan involved 36 monitoring wells, 30 groundwater extraction wells, and 12 surface water points.

Project Director, Constellation Power, Inc. (Division of Baltimore Gas and Electric) - Conducted a modified Phase I environmental assessment of a portion of the former Marietta Air Force Station, Marietta, PA.

Project Hydrogeologist, RI/FS Anniston Army Depot, Alabama USACE Mobile District - Provided expertise in fracture flow and karst hydrogeology for identification of potential groundwater flow pathways. Integrated fracture trace analysis, electrical imaging results with seismic reflection, refraction, and borehole geophysics to identify a fault zone for the purpose of evaluating the potential for contaminant transport along the fault. Constructed a GIS for display and analysis of data.

Project Hydrogeologist, Loring Air Force Base, ME - Conducted fracture trace analysis of plume area in fractured rock aquifer. Interpreted results of electrical imaging survey and located monitoring wells for the purpose of tracing contaminant migration. Data were managed and displayed on an ArcView GIS project.

Delivery Order Manager, SI, FUSRAP, Wayne, NJ, USACE New York District - Led $1.1 million characterization study of the former W.R. Grace fuel processing facility. Developed work plan integrating USACE, EPA Region II, and NJDEP protocols. Completion of field activities and report on an aggressive schedule allowed New York District to meet its excavation schedule.

Project Manager, RD, A-E Environmental Services, Kelly AFB, TX - Developed and directed studies to obtain remedial design parameters for this $3 million effort. Coordinated data gathering with design team. Effort involved design of groundwater extraction systems and soil operable units.

Project Hydrogeologist, Tyco Electronics Corporation, Former Manufacturing Facility, Selinsgrove, PA - Developed, directed, and evaluated groundwater and source area characterization of chlorinated solvents in this fractured rock aquifer, using geologic field mapping, historical aerial photo analysis, fracture trace analysis, passive and active soil gas surveys, and installation and testing of multilevel piezometers/monitoring wells. Data and analysis were managed using ArcView geographical information system.

Project Hydrogeologist, Tyco Electronics Corporation, Former Terminix Facility, Harrisburg, PA - Developed, directed, and evaluated groundwater and source area characterization of chlorinated solvents in this karst aquifer, using historical aerial photo analysis, fracture trace analysis, passive and active soil gas surveys, and installation and testing of multilevel piezometers/monitoring wells. Data and analysis were managed using ArcView geographical information system. A fate and transport study is currently underway.

Project Manager and Hydrogeologist, Volunteer Army Ammunition Plant, Chattanooga, TN - Developed and implemented a work plan to identify conduits of groundwater flow at a site with complex karst geology. Applied and integrated fracture trace analysis using historical aerial photographs, and electrical imaging to support the characterization of the groundwater regime and predict contaminant transport.

Senior Hydrogeologist, Jefferson Proving Grounds, Madison, IN - Work plan development and implementation to characterize the depleted uranium (DU) impact area to support license termination and decommissioning. This project involves use of fracture trace analysis and geophysics, stream gauging, precipitation monitoring, and groundwater stage monitoring, as well as analytical testing to characterize migration of DU in the soil, groundwater, and surface water. Area is highly karst, and efforts are complicated by unexploded ordnance (UXO).

Project Director, Gaumer's Chassis Engineering, Chambersburg, PA – Characterized fill areas and developed closure plans for three unpermitted foundry sand landfills. Work was done for counsel, assisted in negotiating fines, scope of services, closure plan requirements. Construction is scheduled for summer 2006.

Project Director, Principle Investigator, Spring Creek Groundwater Resources Plan, Dauphin County, Pennsylvania – Work is in progress for Hershey Entertainment and Resorts to satisfy Susquehanna River Basin permit requirements. Work involves quantifying basin boundaries, recharge, discharge, and groundwater surface water usage for the karst basin.

Project Director, William Dick Lagoons Super Fund Site, OU-2 (Groundwater), Chester County, Pennsylvania – Design and construction of an interim groundwater pump and treat system using SAIC's patented Ozinox system for ex-situ treatment. Fractured rock aquifer contaminated by chemicals from tanker truck washing operation disposed into unlined lagoons. Work involves baseline characterization of three square mile area, design, construction and operation of a groundwater extraction system, followed by evaluation of performance and recommendations for further action. Work is in progress.