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TECHNICAL MEMORANDUM

DATE: February 15, 2011

FROM: INTERA Incorporated

TO: Mr. John Stomp III, PE, Albuquerque Bernalillo County Water Utility Authority
Mr. Rick Shean, Albuquerque Bernalillo County Water Utility Authority
Ms. Barbara Gastian, Albuquerque Bernalillo County Water Utility Authority

SUBJECT: Review of *Groundwater Investigation Work Plan Part I: Field Investigation Activities Bulk Fuels Facility Spill Solid Waste Management Units ST-106 and SS-111*, dated November, 2010

1.0 Introduction

INTERA, Incorporated (INTERA) was retained by the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) to provide technical expertise and analytical support in reviewing the work plans for characterization and remediation of the Kirtland Air Force Base (KAFB) bulk jet fuel spill. INTERA's review is focused on identifying concerns or improvements in the work plan activities or schedule that will help achieve the ABCWUA's objective of minimizing long term damage to aquifer water quality. The significant quantity of fuel released to the vadose zone and aquifer over such a long period is posing a significant threat to soil and water quality and to water supply wells downgradient of the light density non-aqueous phase liquid (LNAPL) lens that extends roughly northward from the bulk fuel transfer and handling areas, underneath Bullhead Park towards the intersection of San Pedro and Gibson Boulevards SE in Albuquerque, NM (Figure 1).

KAFB has contracted Shaw Environmental & Infrastructure Inc (Shaw) to characterize the extent of the contamination in the vadose zone and aquifer and to implement containment and remediation of the soil and groundwater. Shaw and KAFB have submitted four work plans; the most recent version of each is dated November 2010, to the Hazardous Waste Bureau (HWB) of the New Mexico Environment Department (NMED):

1. *LNAPL Interim Measure Containment Work Plan* (LIMCWP), which is directed at establishing temporary containment of the dissolved phase and LNAPL (Shaw, 2010a);
2. *Interim Measures Work Plan, Part I: Field Investigation Activities*, which focuses on removal of near surface fuel-contaminated soils and characterization of the distribution of LNAPL and dissolved phase in the deep vadose zone (Shaw, 2010b);
3. *Groundwater Investigation Work Plan, Part I: Field Investigation Activities*, which focuses on installing 78 wells to establish the extent of the dissolve phase plume (Shaw, 2010c); and
4. *Vadose Zone Investigation Work Plan, Part I: Field Investigation Activities*, which focuses on sampling of soil and soil vapor in and around potential source areas (Shaw, 2010d).

NMED has already reviewed and commented on items 2, 3, and 4, most recently in its notice of partial approval with modification and notice of disapproval, dated December 10, 2010. This Technical Memorandum (TM) will review and summarize item 3 above.

2.0 Summary of the Groundwater Investigation Work Plan

As stated in its executive summary, the primary objectives of the Groundwater Investigation Work Plan (GWIWP) are to characterize LNAPL contamination present in free phase (pure liquid) on top of the water table and dissolved in groundwater:

> *"This Groundwater Investigation Work Plan, together with the Vadose Zone Investigation Work Plan, the Interim Measures Work Plan, and Light Non-Aqueous Phase Liquid Containment Interim Measure Work Plan, were developed in response to April 2 and August 6, 2010 correspondence from the New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB) to the Air Force. In these letters, the NMED HWB required the Air Force to develop and submit work plans to address soil and groundwater contamination at the Bulk Fuels Facility (BFF) Spill at Kirtland Air Force Base (AFB), New Mexico...*

> *This work plan outlines previous investigations performed at the BFF. It also provides the sampling rationale and decision logic for defining the nature of the contaminants and delineating fuel contamination within groundwater.*

Specific goals of the work plan are to:

- *Characterize the nature, horizontal and vertical extent, and fate and rate of migration of groundwater contamination;*
- *Characterize the geology and hydrogeology at and below the water table; and*
- *Characterize groundwater flow and velocity."* (Shaw, 2010c, page ES-1)

The groundwater investigation will proceed as follows:

"Groundwater investigation activities include installation of shallow-, intermediate-, and deep-depth groundwater monitoring wells in accordance with the NMED August 6, 2010 letter; collection and analysis of borehole soil samples; borehole geophysics; and analyses of the groundwater to determine the groundwater quality and to add to the knowledge base of groundwater chemistry. The geophysical investigation and borehole soil samples will provide information on subsurface geology and contaminant location and migration. Groundwater sampling will provide immediate, as well as long-term, sampling data on subsurface contaminant distribution in different horizons within the aquifer." (Shaw, 2010c, page ES-1)

The current work plan provides detail on the first of two phases (Phase I of II). Phase I includes installation, development, and sampling of 78 wells as directed by NMED in their April 2 and August 10, 2010 letters (NMED, 2010a; NMED, 2010b). The focus of Phase II will consist of development of a Conceptual Site Model (CSM), which will describe the nature and extent of contamination, including the spatial distribution of contamination in groundwater, and the physical and chemical processes governing fate and transport of contamination in the subsurface.

2.1 Groundwater Monitoring Plan

To a large degree, the current work plan is based on well locations and construction details prescribed by NMED (NMED, 2010a; NMED, 2010b). The NMED was quite prescriptive in presenting its groundwater sampling locations and the manner in which they should be addressed, and thus Shaw, in developing its work plan, simply followed NMED's requirements. NMED presented specific well locations in their correspondence (NMED, 2010a, Table 5), and Shaw adopted those locations in its work plan. The existing and proposed well locations are presented in Figure 1.

As shown in Figure 1, a total of 78 groundwater monitoring wells will be installed in separate boreholes. Monitoring wells will be clustered in groups of three with shallow, intermediate, and deep wells. Fourteen well clusters designed to characterize the dissolved plume will be installed.

These clusters will consist of three separate monitoring wells installed to depths of approximately 515, 530, and 555 ft bgs, respectively (this assumes the water table is at approximately 500 ft bgs). A shallow monitoring well currently exists at five of the proposed well clusters. Therefore, two monitoring wells will be installed at these locations at depths of 530, and 555 ft bgs, respectively. Thirteen well clusters, designed to monitor the LNAPL plume core, will consist of three monitoring wells installed to depths of approximately 515, 530, and 600 ft bgs, respectively.

Borehole geophysical logging will be performed at 29 existing monitoring wells and 28 new monitoring wells. Induction, neutron, and gamma logs will be run. These logs will help to elucidate lithology and moisture content in the vadose zone and beneath the water table, as well as the extent of contamination. Another goal of geophysical logging is develop a detailed interpretation of the extent of the LNAPL contamination. Identifying clay and silt units may help to highlight areas where LNAPL may pool.

During drilling, soil samples will be collected using split-spoon sampling techniques. Soil samples will be collected for analysis from the deepest soil boring completed at the NMED well locations 11, 12, 17, and 18 (Figure 1). These wells are located within the LNAPL portion of the groundwater contaminant plume. Soil samples will be collected at a frequency of one sample every 10 ft of the first 50 ft of the borehole, and then one sample every 50 ft to 450 ft bgs. Split spoons will be collected continuously 450 ft bgs (approximately 50 ft above the water table) to 510 ft bgs (10 ft below the water table). Collecting continuous split-spoon samples will help more clearly delineate the LNAPL-groundwater interface zone.

Each continuous split-spoon sample will be photographed under ultraviolet and visible light conditions to evaluate water and LNAPL saturation and field screened using a photoionization detector (PID) to detect LNAPL vapors.

Each groundwater monitoring well installed under this groundwater investigation, including monitoring wells installed within the LNAPL plume, will be sampled once under the scope of this work plan.

3.0 Key Findings

In general, the work plan presents a set of generally reasonable first steps towards delineating the nature and extent of dissolved-phase contamination, but falls short in several of its stated objectives, specifically, characterizing the hydrogeology at and below the water table and characterizing the groundwater flow and velocity. Some of the choices made in the work plan appear arbitrarily limited, so that even after this first phase of work is completed, significant uncertainties are likely to remain.

For example, the work plan (as directed by NMED) proposed installing wells in the margin of the LNAPL lens (and specifically intended to determine dissolved-phase extent) to depths no deeper than 55 ft below the water table, whereas wells to be installed within the LNAPL lens are to be constructed with screens no deeper than 100 ft below the water table. ABCWUA (Water Authority) wells in the vicinity of the plume are screened as deep as approximately 3,000 ft bgs, so that deeper screens are more likely to be necessary outside the LNAPL lens, rather than inside, in order to detect the obliquely downward movement of the dissolved phase plume to the supply wells. Thus on first principles, the dissolved phase wells outside the LNAPL lens should have an additional screened interval deeper than 55 ft below the water table if KAFB/Shaw believe there is evidence to require the 55 ft below the water table screen depth.

More importantly, NMED's stipulations of screened interval depths, and the work plan's acquiescence, do not appear to allow for decision-making about screen interval depths based on drilling findings. This could result in well screen locations that do not intercept the transmissive intervals, which contribute significantly to the dissolved-phase plume migration, but intercept intervals that do not contribute significantly to dissolved-phase plume migration. In terms of modifying the well locations during the investigation, there is language related to the data quality objectives (DQOs) that seems to indicate well locations may be modified during the investigation:

> *"DQOs for groundwater samples include the contingency to revise well locations laterally or vertically from the initial plan presented in this Groundwater Investigation Work Plan. Analytical results of well installed during the initial portion of the well installation program will be used to revise locations of subsequent wells installed during the investigation, if necessary. The direction and distance of a revised well location will be dependent on the contaminant concentrations exceeding the MCLs, probable COPC, and contamination migration rates/distances."* (Shaw, 2010c, page 75)

The presence or absence of transmissive zones is lacking from this list. Despite the very prescriptive nature of NMED's requirements with respect to well screen location, enabling the ability to make changes during the investigation sis desirable and should be made part of the work plan.

If any of the proposed deep wells reveal detections of jet-fuel-related compounds, installation of additional wells is recommended. Similarly, the side- and down-gradient boundaries of the plume may not be defined simply by the proposed monitoring wells; however, this will not be known until the proposed wells are installed and sampled.

With respect to soil sampling, the work plan limits soil sample collection to the deepest boreholes at NMED well locations 11, 12, 17, and 18, all within the LNAPL lens. Excluding sampling at the remaining 24 well locations will provide a very limited understanding of the geologic and hydrogeologic properties of the affected aquifer. With such limited information, the work plan is not likely to achieve its stated objective to characterize the geologic and hydrogeologic properties of the aquifer.

Furthermore, collecting samples via split spoon every 50 ft is not likely to provide sufficient vertical resolution to adequately delineate the geology, hydrogeology, presence and mass of LNAPL or associated contamination, or identify potential preferential migration pathways in the soil and aquifer. Given the heterogeneous nature of subsurface lithology and the non-wetting phase's preference for larger pores, LNAPL may be moving through the subsurface via relatively thin, preferential pathways. LNAPL is thought to be following a tortuous, three-dimensional pathway, such as "stair-stepping" from one clay lens to another, as it moves through the subsurface, according to Shaw (2010c page 3-9) and presentations made by CH2M Hill to the ABCWUA Board. Therefore, sampling at intervals of only 50 ft is likely to miss significant amounts of LNAPL mass, such as that contained in "fingers" or lobes of LNAPL, present in the vadose zone.

The work plan does not include any activities to characterize the hydrogeologic properties of the aquifer, especially the screened intervals. No mention is made of measuring porosity, hydraulic conductivity, or storage properties of the aquifer intervals; therefore, the current work plan will not achieve its objective to characterize the aquifer and groundwater flow and velocity.

NMED's recent Notice of Deficiencies (NMED, 2010c) cited the following deficiencies related to sampling frequency and hydraulic properties:

- 22. Revise the Work Plan to provide for the collection and maintenance of representative soil samples encountered during well installations and to indicate that said samples will be made available for NMED inspection upon request by the NMED. Additionally, Section 11.2 of Appendix E indicates that there are 35 wells to be included in the study. Specify which number of wells is correct.

- 23. Revise the Work Plan to specify the frequency that soil samples will be tested for grain size via sieve analysis. Indicate the specific sieve screen sizes that will be utilized for the testing.

- 24. Table 6-2 lists only two soil samples each to be collected for grain size, residual LNAPL saturation, Water/LNAPL Drainage Capillary Pressure and Water LNAPL Relative Permeability and only one LNAPL sample each for testing for viscosity, fluid density and surface and interfacial tension. Revise the Work Plan to describe why these few numbers of samples are sufficient for the range of conditions at the site. Also, clarify in the table if the column titled "No. of Field Samples" is correct, and if the column "Total No. of Samples to Laboratory" is correct.

- 25. Saturated hydraulic conductivity and porosity are important variables in groundwater flow considerations. Specify field or laboratory tests that will be conducted to arrive at a range of site specific values. Revise the Work Plan to indicate how values for saturated hydraulic conductivity and porosity will be assessed.

However, responses to these deficiencies are not due back to NMED until March 31st, 2011, roughly two-thirds of the way through the proposed drilling program.

Appendix E of the work plan discusses installation of the groundwater wells for monitored natural attenuation (MNA). NMED also requested clarification about the intent of the appendix in introducing MNA (NMED, 2010c). As no mention is made of this remedial option in the work plan, the appendix may be erroneous. If so, we recommend that all mention of MNA should be removed; otherwise, the work plan should be revised to explain KAFB's intentions regarding selection of MNA as a remedial option.

4.0 Recommendations

As drilling is now beginning, it is critical that KAFB and Shaw revise their sampling plan to increase the number of wells sampled and the frequency of sample collection with depth. Limiting collection of soil samples to the four well locations within the LNAPL lens is will characterize only a small volume of the contaminated area and overall area of interest. Samples should be collected from every well location, including those located outside the LNAPL lens. For wells outside the LNAPL lens, samples should be collected at 5 or 10 ft intervals beginning at a suitable distance above the water table (50 ft is cited in the work plan) and continue down to the total depth. For well locations within the LNAPL lens, soil samples should be collected every 5 or 10 ft through both the vadose zone and the aquifer.

Wells located outside the LNAPL lens should have screened intervals for at least one more depth interval below 55 ft beneath the water table to ascertain the vertical distribution of dissolved phase contamination.

Well screens should be targeted on the most transmissive intervals identified by the split spoon samples and drill cuttings. The work plan should be revised immediately to allow such targeting.

Logging of split spoon samples should include identification of potential fast paths within the aquifer. Particle size distributions should be measured at all well locations for each significant lithologic unit identified.

The work plan should be revised to include testing of each screened interval to determine hydraulic conductivity, porosity, and storage properties. Wherever possible, aquifer testing should be conducted; otherwise slug tests should be made.

Consider a phased approach that includes provisions for additional monitoring well installations if the plume boundaries are not effectively delineated via the current set of proposed wells.

Clarification of Shaw's intentions regarding the groundwater wells and monitored natural attenuation in Appendix E is required.

5.0 References

New Mexico Environment Department (NMED), 2010a. Letter from James P. Bearzi, NMED to Colonel Michael S. Duvall and Mr. John Pike, Kirtland Air Force Base. Dated April 2, 2010.

New Mexico Environment Department (NMED), 2010b. Letter from James P. Bearzi, NMED to Colonel Robert L. Maness and Mr. John Pike, Kirtland Air Force Base. Dated August 6, 2010.

New Mexico Environment Department (NMED), 2010c. Letter from James P. Bearzi, NMED to Colonel Robert L. Maness and Mr. John Pike, Kirtland Air Force Base. Dated December 10, 2010.

Shaw, 2010a. LNAPL Interim Measure Containment Work Plan for the Bulk Fuels Facility Spill, Solid Waste Management Units ST-106 and SS-111, November, 2010.

Shaw, 2010b. Interim Measures Work Plan, Part I: Field Investigation Activities for the Bulk Fuels Facility Spill, Solid Waste Management Units ST-106 and SS-111, November, 2010.

Shaw, 2010c. Groundwater Investigation Work Plan, Part I: Field Investigation Activities for the Bulk Fuels Facility Spill, Solid Waste Management Units ST-106 and SS-111, November, 2010.

Shaw, 2010d. Vadose Zone Investigation Work Plan, Part I: Field Investigation Activities for the Bulk Fuels Facility Spill, Solid Waste Management Units ST-106 and SS-111, November, 2010.

FIGURES

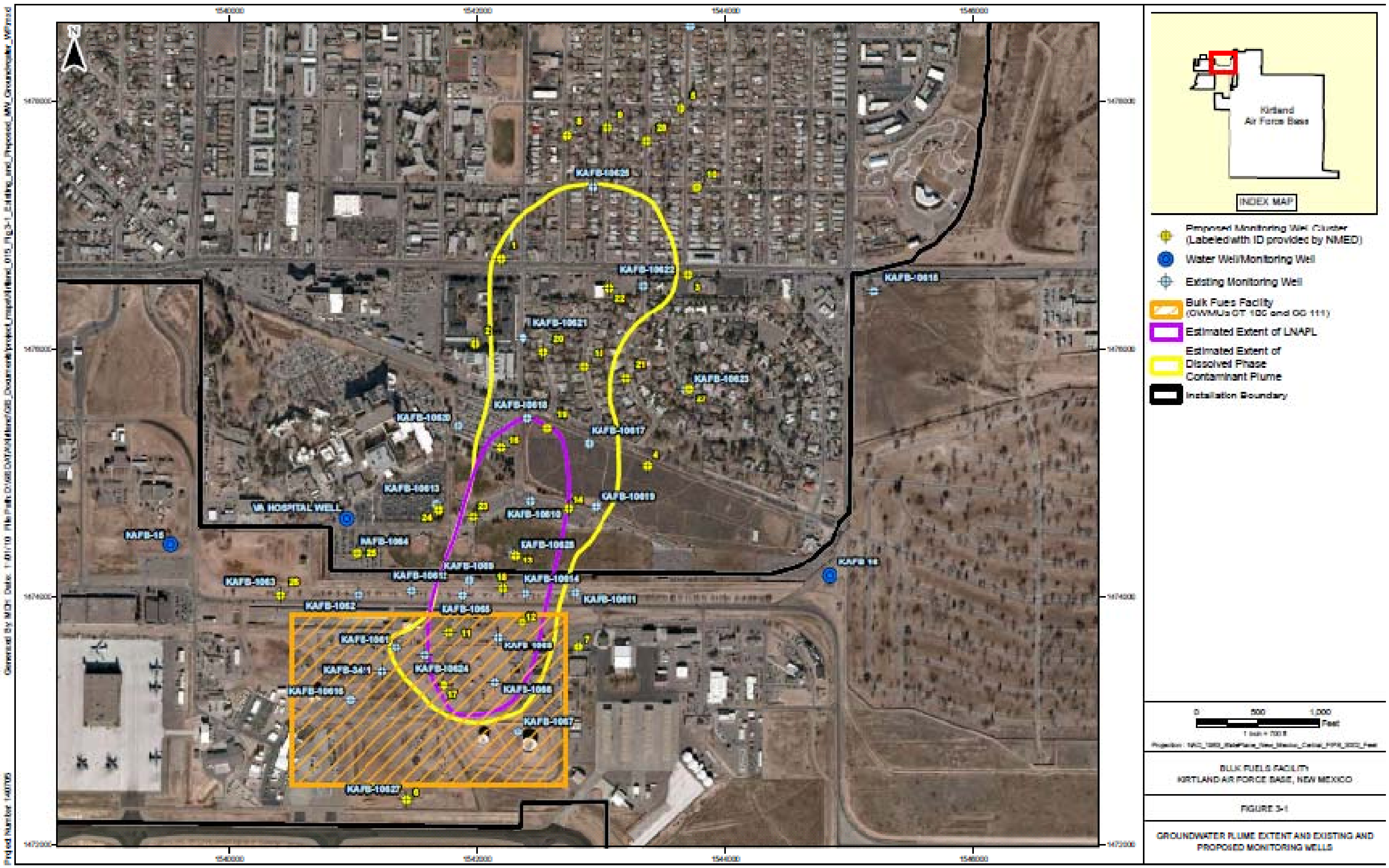

Figure 1. Existing and proposed monitoring well locations (Figure 3-1 from Shaw, 2010c).