ENTERED

June 29, 2018

Ms. Michelle Hunter, Chief
Ground Water Quality Bureau
New Mexico Environment Department
1190 St. Francis Drive, P.O. Box 26110
Santa Fe, New Mexico 87502-6110

Delivered via email: michelle.hunter@state.nm.us

Re: Initial Assessment of Capture Zone Analysis for the Kirtland Air Force Base Aviation Fuel Cleanup Project, Albuquerque, New Mexico

Dear Ms. Hunter:

This letter report documents the initial assessment conducted by Daniel B. Stephens & Associates, Inc. (DBS&A) of the capture zone analysis being conducted by the U.S. Army Corps of Engineers (USACE) consultant in support of remediation efforts at the Kirtland Air Force Base (KAFB) Aviation Fuel Cleanup Project in Albuquerque, New Mexico. Our assessment is based on a review of documents pertaining to the cleanup project and our attendance at a June 14, 2018 meeting of the KAFB Bulk Fuels Facility (BFF) Modeling Technical Working Group.

Document Review

There are numerous documents and much information regarding the cleanup project. Documents and information are available on federal and state websites and from an FTP site established for the cleanup project. To develop an initial assessment of the approach being used for the capture zone analysis, DBS&A relied primarily on the following documents to obtain an understanding of the site and actions being taken to address impacted groundwater:

- CB&I Federal Services LLC. 2016. *Updated Numerical Groundwater Flow and Contaminant Transport Modeling Report, Bulk Fuels Facility Solid Waste Management Unit ST-106/SS-111*. October 2016.
- Sundance Consulting, Inc. 2017. *RCRA Facility Investigation Report, Bulk Fuels Facility Release Solid Waste Management Unit ST-106/SS-111*. January 2017
- U.S. Air Force. 2018. Letter from Colonel D.A. Nickell to Mr. J. Kieling regarding KAFB response to notice of deficiency dated November 16, 2017 and submission of preliminary groundwater modeling results. March 2018.
- U.S. Air Force. 2018. Letter from Colonel D.A. Nickell to Mr. J. Kieling regarding selection of FEFLOW for groundwater modeling. April 2018.
- EA Engineering, Science, and Technology, Inc., PBC. 2018. *Quarterly Report for January - March 2018, Bulk Fuels Facility, Solid Waste Management Unit ST-106/SS-111*. June 2018.

Daniel B. Stephens & Associates, Inc.
6020 Academy NE, Suite 100 505-822-9400
Albuquerque, NM 87109 FAX 505-822-8877

Meeting Summary

On June 14, 2018, a meeting of the KAFB BFF Modeling Technical Working Group was held in Albuquerque, New Mexico. During the meeting, the U.S. Geological Survey (USGS) gave a presentation on a numerical groundwater flow model they have developed for the area of KAFB. The model is based on the regional groundwater flow model for the Middle Rio Grande Basin, which was developed using a version of the MODFLOW computer code. The USGS has used the MODFLOW-LGR package to refine the regional model domain in the area of KAFB and simulate groundwater flow conditions in this area, including the influence of supply well pumping on groundwater flow direction. A USGS modeling report is expected to be published in September 2018.

The working group also discussed presentation slides to be shown at an upcoming July 2018 public meeting, possible capture zone uncertainty analysis, and the simulation period for capture zone analysis. Prior to the June 14, 2018 meeting, the Albuquerque Bernalillo County Water Utility Authority (the Authority) provided recommended agenda items for the meeting, which included a list of 12 uncertain model parameters and possible parameter values (Attachment 1). Stuart Norton (USGS) provided his opinion on the uncertain model parameters, expressing that effective porosity is one of the more important parameters to consider due to its uncertainty and effect on particle tracking (i.e., modeling used to define capture zones). The working group generally agreed to a simulation period of 6 months for the capture zone analysis.

Initial Model Review and Assessment

EA Engineering, Science, and Technology, Inc. (EA) (the USACE consultant) developed a numerical groundwater flow model for capture zone analysis. The model was developed using FEFLOW and is intended to support USACE's implementation of the approach described in the U.S. EPA document titled *A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems* dated January 2008 (EPA 600/R-08/003). Existing model documentation for EA's capture zone analysis consists of groundwater modeling results presented in a slideshow-type format (Attachment 2). Below is a brief summary of the model:

- *Model domain:* The horizontal domain appears to be limited to the area of the KAFB remedial extraction wells and KAFB supply wells. The top of the model is set to an elevation of 4,885 feet above mean sea level (feet msl), which is the elevation of the top of the KAFB-3 well screen. The bottom of the model is represented by the top of the A2 confining layer.
- *Ambient groundwater flow direction:* The ambient groundwater flow direction is specified as toward the southeast at 0.00047 foot per foot (ft/ft).
- *Steady-state:* The model assumes steady-state conditions.
- *Simulated pumping:* The model simulates pumping at the remedial extraction wells and KAFB-3. It is not clear whether pumping at the other KAFB supply wells and the Veterans Administration (VA) well is included in the model; presumably it is not.

- *Calibration:* Model calibration consisted of simulating five scenarios, in which horizontal hydraulic conductivity, vertical anisotropy, and the KAFB-3 pumping rate were varied. It is not clear why the KAFB-3 pumping rate was varied; the simulated pumping rate should be based on actual pumping records.
- *Selected scenario:* The horizontal hydraulic conductivity, vertical anisotropy, and the KAFB-3 pumping rate associated with the scenario with the best fit to observed data are 100 feet per day, 0.03, and 225 gallons per minute (gpm), respectively. Best fit was determined using the normalized root-mean-squared deviation (NRMSD) method. NRMSD of the selected scenario is 13 percent, which is greater than the generally acceptable NRMSD of 10 percent.
- *Capture zone analysis:* The selected scenario was used to conduct the capture zone analysis. Results show steady-state capture zones extending more than a mile to the northwest (Attachment 2).

A limitation of the model is the specification of a steady-state groundwater flow condition with a fixed ambient groundwater gradient. The EPA's systematic approach for capture zone analysis cautions that time-varying influences and transient conditions should be considered, when present, as these affect hydraulic gradients and capture effectiveness. Since the Authority reduced pumping at the Ridge Crest wells, groundwater levels in the area, including KAFB, have risen, and the gradient has shifted from the northeast to the southeast. The rising groundwater levels and change in groundwater flow direction represent a transient condition that should be considered in the capture zone analysis. It was unclear to DBS&A from discussions during the June 14, 2018 meeting whether the Ridge Crest wells are currently operating or will be operated in the future. Any current and future changes in supply well pumping have the potential to have a transient influence on the KAFB groundwater flow regime. Other sources of transient water levels are attributable to pumping from the remediation system wells and KAFB and VA supply wells.

EA appears to attribute the poor fit of their steady-state model to observed data to interim remedy extraction (Attachment 1). The NRMSD of their selected modeling scenario is 13 percent, while the generally accepted criterion is less than 10 percent. Another possible explanation for the poor fit is the transient influence caused by changes in supply well pumping that the steady-state model does not simulate. In general, the EA model calibration is fairly poor. For a relatively small model domain where water levels are prescribed at the model boundary, the 10 percent criterion for NRMSD should be readily achievable.

The working group generally agreed to a simulation period of 6 months for the capture zone analysis; the capture zone analysis would be based on 6 months of groundwater monitoring data, and then results of the analysis would be compared to treatment system operational data (e.g., mass of EDB treated). This approach may assist in evaluating results of the capture zone analysis and prevent overestimation of simulated zones of capture by limiting particle tracking to a 6-month period. The approach may also allow for observed changes in the groundwater flow regime to be simulated. Once the results of the capture zone analysis are compared to

groundwater monitoring and operational data, we can develop a more informed opinion as to whether the 6-month approach is appropriate for mimicking transient conditions that occur at the site.

The initial model review and assessment presented in this letter are based on the documentation provided in Attachment 2. DBS&A would like to obtain the FEFLOW modeling files from USACE so we can further review the model using the FEFLOW reader.

Closing

If you have questions regarding our initial assessment, please contact us at (505) 822-9400.

Sincerely,

DANIEL B. STEPHENS & ASSOCIATES, INC.

John Ayarbe, P.G.
Senior Hydrogeologist

John Bunch, P.G.
Senior Hydrogeologist

JA/rpf
Attachments
cc.: Bruce Yurdin (bruce.yurdin@state.nm.us)
Dennis McQuillan (dennis.mcquillan@state.nm.us)

Attachment 1

Recommended Agenda for June 14, 2018 Meeting

Recommended agenda for June 14th groundwater modeling meeting

Uncertainty Modeling for Capture 9:15 to 12:00

1. Choose time period for capture zone analysis: 3 month or 6 month

2. Select important uncertain parameters and their minima and maxima

   a. Horizontal hydraulic conductivity (ft/d): [70, 100, 150, 200, 250, 300]
   b. Vertical to horizontal hydraulic conductivity ratio (-): [0.001, 0.01, 0.1]
   c. Gradient direction (azimuth degrees where 0 = N): [0, 22.5, 45, 77.5, 90, 112.5, 135, 157.5, 180, 212.5, 225, 247.5, 270, 292.5, 315, 337.5,]
   d. Gradient magnitude (ft/ft): [1E-06, 1E-05, 5E-05, 1E-04, 5E-04, 1E-03]
   e. Effective porosity (ft^3/ft^3): [0.10, 0.15, 0.20, 0.25]
   f. Pumping rates for KAFB remediation wells (gpm): [average rate for each of 4 wells over capture zone time period = total volume extracted over time period divided by capture zone time period]
   g. Injection rate for KAFB-7 (gpm): [total volume injected over time period divided by capture zone time period]
   h. Fraction of KAFB production well pumping rates extracted from unconfined aquifer (-): [0, 0.25, 0.5, 0.75, 1]
   i. Fraction of VA production well pumping rate extracted from unconfined aquifer (-): [0, 0.25, 0.5, 0.75, 1]
   j. Fraction of Ridgecrest production well pumping rate extracted from unconfined aquifer (-): [0, 0.25, 0.5, 0.75]
   k. Water table distance above top of remediation well screens (ft): [-20, -10, 10, 20] or use average of observed nearby formation water levels
   l. Aquifer thickness (ft): [120, 240, 360]

3. Determine required reporting elements

   a. Radius and area of common capture zone and volume pumped for each extraction well
   b. Estimated benzene and EDB concentrations within each common capture zone
   c. Estimated mass of benzene and mass of EDB removed from each common capture zone for each extraction well
   d. Comparison with benzene and EDB masses observed at treatment center manifold (ideally also report individual benzene and EDB masses for each remediation well]
   e. Maps of common capture areas for each remediation well

4. Hand over preliminary FEFLOW model files for review and schedule for handover of each update

5. Discuss head data available to define north model boundary

Develop Objectives and Specifications for Future Fate and Transport Modeling 1:00 to 2:30 PM

Each stakeholder to submit objectives and required specifications prior to meeting and then work on a defining the objectives and drafting lists of draft required specs and draft desired specs.

Prep for July 2018 Public Meeting 2:45 to 4:30 PM

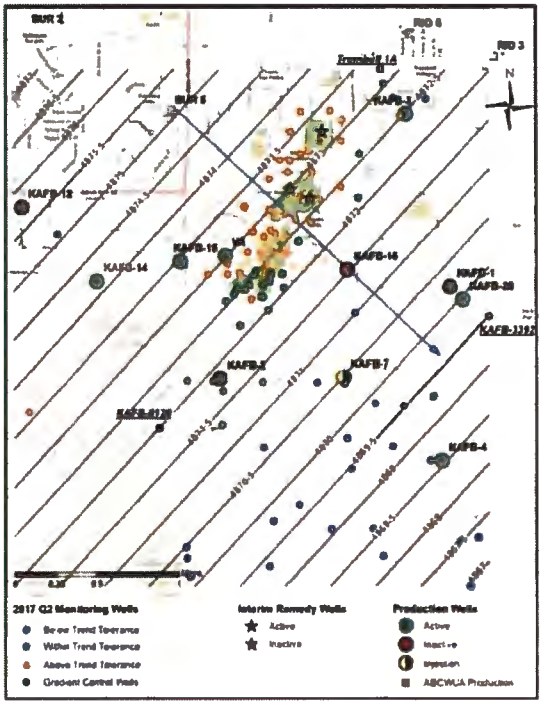
Each stakeholder to submit objectives and required specifications prior to meeting and then work on a defining the objectives and drafting lists of draft required specs and draft desired specs.

Attachment 2

EA Model Documentation

2017 Q2 Gradient Input to Model

- Extraction from KAFB and interim remedy water-table aquifer wells has equaled or exceeded extraction from Ridgecrest wells resulting in a shift in flow direction across the AOI
- Only when Ridgecrest extraction greatly exceeds KAFB extraction does flow at Trumbull 1A shift towards Ridgecrest wells
  - Periodic shift
- Combined drawdown associated with KAFB-3, 4, and 20 extraction has become the controlling factor for AOI gradient
- Linear Gradient Model
  - Gradient = 0.00047
  - Flow Direction = S47°E (317°)
  - Goodness of Fit
    - Measure head range (difference)
      - 4,869.3 to 4,875.9 NAVD88 (6.7 ft)
      - Trend fit = residual -0.67 to 0.67 ft
    - NRMSE = 21%
      - The poor fit of the linear trend model to measured head data across the AOI is due to interim remedy extraction.
      - Poor model fit in south of AOI due to gradient across this area is towards the east and the combined KAFB-4 / KAFB-20 drawdown.

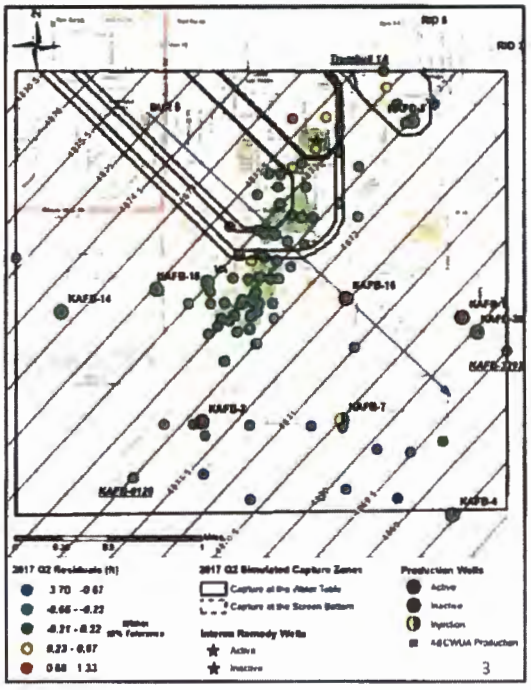


Gradient Flow Model Design

- Purpose: supporting line of evidence for Interim Remedy Capture Analysis
- Incorporates:
  - Aquifer properties:
    - Horizontal hydraulic conductivity
    - Vertical anisotropy
  - Magnitude and direction of the local gradient
  - Interim Remedy extraction rates
- Design:
  - Finite element numerical flow simulation using FEFLOW
  - 3D, 2-layer, phreatic, steady-state model
    - Top of model elevation set at 4,885 ft amsl
      - Top of KAFB-3 screen
    - Top of layer two set at bottom of Interim Remedy extraction well screen elevations
      - Assures extraction wells are fully penetrating with respect to layer one
    - Bottom of model equals top of A2 confining unit elevation
      - Extracted from CB&I flow model
  - Mesh refined down to less than 3 feet at three Interim Remedy extraction wells and KAFB-3
  - Well screen casing radius assigned to well boundary
  - Approximate node spacing equals 50 ft
    - 74,530 nodes per layer (223,590 total)
    - 148,034 elements per layer (296,068 total)

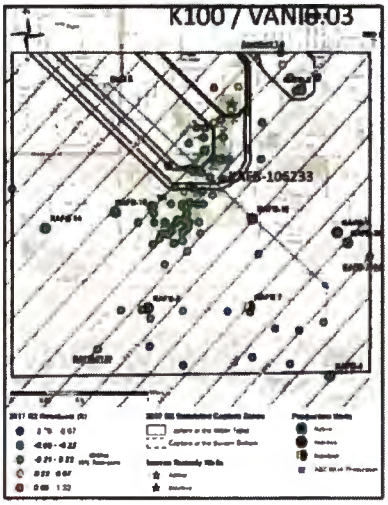
Gradient Flow Model Calibration

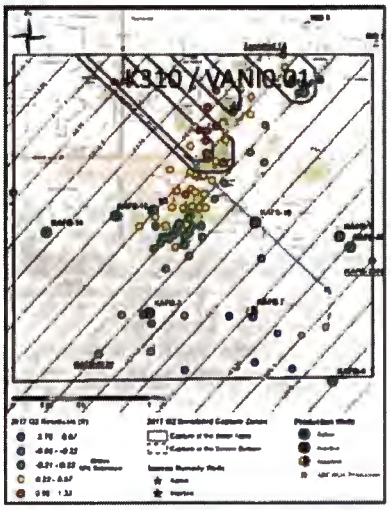
- Five KAFB-106228 aquifer test scenarios simulated to determine aquifer parameters resulting in best-fit to measured head data
  - Homogeneous hydraulic conductivity (K)
  - Homogeneous vertical anisotropy (VANI)
  - Model boundary assigned as constant head
    - Boundary head extracted from 2017 Q2 linear gradient model
  - Starting heads assigned by extracting the heads from the gradient model at each flow model node
- Scenario Assignments:
  - KAFB-106035 (shallow obs. well)
    - K = 170 ft/day; VANI = 0.003; KAFB-3 = 400 gpm
    - K = 180 ft/day; VANI = 0.001; KAFB-3 = 450 gpm
  - KAFB-106022 (shallow obs. well)
    - K = 310 ft/day; VANI = 0.01; KAFB-3 = 650 gpm
  - KAFB-106036 (intermediate obs. well)
    - K = 150 ft/day; VANI = 0.04; KAFB-3 = 375 gpm
  - **KAFB-106037 (deep obs. well)**
    - **K = 100 ft/day; VANI = 0.03; KAFB-3 = 225 gpm**
- Scenario Calibration
  - KAFB-106228 = 145 gpm (fixed)
  - KAFB-106233 = 177 gpm (fixed)
  - KAFB-106234 = 161 gpm (fixed)
  - KAFB-3 extraction rate was modified to give a best-fit to monitoring well KAFB-106201 for each scenario (see above)
    - All scenarios but K=310 simulated measured head at 201 within 0.05 ft
    - Simulated head at 201 off by +0.14 ft using max KAFB-3 pump rate



Scenarios Simulations VS Measured

- Goodness-of-fit was analyzed using standard Normalized Root-Mean-Squared Deviation (NRMSD) method
  - Generally acceptable NRMSD is <10%
  - NRMSD was calculated for the 60 REI 4857 dissolved EDB plume monitoring wells
- Scenario NRMSD
  - K310/VANI0.01 = 26%
  - K180/VANI0.001 = 16%
  - K170/VANI0.003 = 16%
  - K150/VANI0.04 = 17%
  - **K100/VANI0.03 = 13% (Includes southern wells [blue] outside of AOI**
    - Best Fit
    - Most Reasonable KAFB-3 extraction rate
      - Since the beginning of 2015
      - Average monthly KAFB-3 extraction rate - 14 to 361 gpm
      - Three-year mean – 213 gpm
      - Three-year median – 204 gpm





Gradient Flow Model Results

- The K 100; VANI 0.03 Scenario best fits the measured head data
- The K 100; VANI 0.03 Scenario produces the most reasonable KAFB-3 extraction rate
- The K 100; VANI 0.03 compares well with the horizontal capture analysis based on only measured head data