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Memorandum

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Subject: **Summary of 2011 Activities, PAPA Interim Plan**
Interim Groundwater/Aquifer Pollution Prevention, Mitigation and Monitoring Plan, Pinedale Anticline Oil and Gas Exploration and Development Project, Sublette County, Wyoming

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This memorandum lists key activities completed in 2011 by AMEC Environment & Infrastructure, Inc. (AMEC; formerly Geomatrix Consultants, Inc. and AMEC Geomatrix, Inc.) related to the PAPA Interim Plan. Activities are grouped according to four principal project components:

- Hydrogeologic Data Gaps Investigation;
- Numerical Groundwater Modeling (*note: not required by the 2008 Record of Decision*);
- Evaluation of Potential Sources of Low-Level Petroleum Hydrocarbon Compound Detections in Groundwater; and,
- Draft Final Groundwater/Aquifer Pollution Prevention, Mitigation and Monitoring Plan.

It is our understanding that the Operators will provide this summary to Merry Gamper, BLM Project Lead, to aid in her presentation to the Pinedale Anticline Working Group scheduled for February 7, 2012 in Pinedale, Wyoming.

Hydrogeologic Data Gaps Investigation

The Draft Technical Report on the Hydrogeologic Data Gaps Investigation was issued to the BDE and Operators on October 4, 2011. Thirty study wells ranging in depth from 15 to 795 feet, and 13 shallow piezometers were installed in 2009-2010. Field work consisting of continued well development, additional aquifer testing, water level monitoring and groundwater sampling was performed in 2011. This field work and other key activities associated with the hydrogeologic data gaps investigation, including data analysis and reporting, are summarized below:

1. Field Work

- Data recording pressure transducers installed in 23 study wells and two barometric pressure sensors were downloaded in June. Data were then reduced and used to prepare groundwater hydrographs.
- Submersible electric pumps were used to continue the development of 23 study wells. Other study wells were adequately developed in 2010. Approximately five casing-volumes of water were pumped from each well in June, and water quality parameters were measured and recorded. Groundwater was land-applied using a series of irrigation sprinklers.
- Constant-discharge aquifer tests were completed on an additional eight study wells in June to characterize hydraulic properties of alluvium and sandstone units in the Wasatch Formation. (Note that a constant discharge shut-in test was performed on one artesian well). Four other aquifer tests had been completed in December 2010. Data were then reduced and analyzed to develop hydraulic properties for the hydrostratigraphic units.
- Groundwater samples were collected from all study wells, except for three wells that were dry, and submitted for laboratory analysis in accordance with the Plan of Study in June.

2. Data Compilation and Management – Geodatabase

The PAPA Interim Plan geodatabase has 14 tables that can all be linked to the "All_Wells" feature class (similar to a shapefile) in ArcMap, by linking the "WID" (well ID) field. In 2011, AMEC compiled, formatted, validated and uploaded field and lab data to the PAPA Interim Plan geodatabase. This includes groundwater samples collected in 2010 and 2011 for the both the hydrogeologic data gaps study and the low-level petroleum hydrocarbon investigation. Available 2010 water quality data collected by the Sublette County Conservation District were also uploaded to the geodatabase.

- 2011 uploads of AMEC's groundwater field data included: water levels, LEL, temperature, pH, dissolved oxygen, oxidation reduction potential, conductivity and aquifer testing data. Once in the geodatabase, a 100 percent QA/QC review of uploaded data was performed.
- 2011 uploads of AMEC's groundwater laboratory data included: Gas and isotope data, petroleum hydrocarbon compounds, volatile and semi-volatile organic compounds (and tentatively identified compounds), common ions, inorganic parameters, and metals. Prior to uploading, all analytical data were first verified and then validated using EPA's National Functional Guidelines. As required, qualified data were flagged in accordance with the Plan of Study. A QA/QC review of 100 percent of the uploaded analytical data was performed.
- Other data added to the geodatabase in 2011 included: Wyoming State Engineer's Office and US Geological Survey geology/lithology data, associated data developed for the low-level petroleum hydrocarbon investigation (see below), and updates to the "wells" feature class.

3. Data Analysis and Reporting

Hydrogeologic data developed since the Interim Plan was issued in December 2008, were analyzed and documented in a Draft Technical Report: Hydrogeologic Data Gaps Investigation. The draft report was issued to the BDE and Operators on October 4, 2011. Key components of the report include:

- A summary of data collection activities (geodatabase development, surface water flow study, river stage, surface water flow characterization, spring characterization, piezometer and study well installation, well surveys and depth to water measurements, groundwater sampling, aquifer testing, compilation of groundwater consumption data and project permitting requirements).
- Surface water flow characteristics (synoptic flow study and hydrographs).
- Groundwater occurrence and flow (depths to water, hydraulic properties, hydrogeologic cross-sections, horizontal and vertical groundwater flow, groundwater recharge and discharge).
- Water quality (surface water, springs, groundwater quality in the various hydrostratigraphic units, quality assurance and quality control).
- Surface water—groundwater interconnection (water levels and heads, surface water gains and losses, water quality).
- Three-dimensional lithostratigraphic geologic model.
- Hydrologic system balance and steady-state groundwater balance.
- Hydrogeologic conceptual model.

After the draft report was issued, the following events occurred:

- Comments were received from the BDE on October 24 and 28.
- AMEC issued a detailed "response-to comments" table to the BDE on December 16.

In early January 2012, the BDE commented on several responses to comments. Currently AMEC is preparing a Draft Final version of the report which is anticipated to be issued to the BDE in late February 2012.

Summary of PAPA Numerical Modeling for 2011

Although not required by the 2008 Record of Decision, a numerical groundwater model for the PAPA was developed in 2011 using data, information and the hydrogeologic conceptual model resulting from the Hydrogeologic Data Gaps Investigation (above). Modeling work completed in 2011 is grouped into the following six categories.

1. Scope of Numerical Modeling, Purpose and Need

- Development of a numerical model allows for more efficient and effective use of available data in the decision making process.
- The model will serve as a framework to help organize field and analytical data and will represent a synthesis of all hydrogeologic information compiled to date.

- The numerical model will greatly aid the process of selecting monitoring points for the long-term water resources monitoring program required by the Draft Final Plan.
- Particle tracking and solute transport analysis will identify those portions of the aquifer most vulnerable to impacts from potential releases to the subsurface.
- The numerical groundwater model will support the water resources monitoring plan being developed for the PAPA.
- AMEC presented the "Proposed Approach for Numerical Groundwater Modeling" to Operators and BDE (Bureau of Land Management, Wyoming Department of Environmental Quality, and U.S. Environmental Protection Agency) in a web meeting (May 11).

2. Model Design, Parameterization, and Calibration Targets

- Two web meeting were held with BDE, Operators and AMEC to discuss model set up, parameterization, and calibration targets (June 23 and July 25).
- Model design was based on hydrologic boundaries and field collected data including lithologic data from well logs and groundwater level measurements.
- Initial model parameterization was based on literature values and field collected data including groundwater level measurements, aquifer testing, and flow data collected for the New Fork River.
- Calibration targets were established using field collected data and estimated flux data based on the conceptual understanding groundwater system of the PAPA.
- A face-to-face meeting between BDE, Operators and AMEC was held in Missoula, MT (July 28-29). The meeting included reviewing model design and parameterization and open discussions regarding how contaminants enter the groundwater system, potential sources and receptors and use of the model for predictive capabilities.

3. Model Calibration and Sensitivity Analysis

- The numerical model was calibrated to field collected data including groundwater level measurements and flow in the New Fork River and estimated flux values.
- AMEC issued the "Draft Numerical Model Calibration" memo to Operators and BDE documenting model calibration results (August 16).
- After discussions between AMEC and BDE regarding model calibration, AMEC issued the “Final Numerical Model Calibration” memo which addressed comments and concerns raised by the BDE (November 17).
- After model calibration, a sensitivity analysis was performed to access uncertainty caused by estimates of model parameters. Results were discussed with BDE and Operators in a web meeting (August 29).

4. **Particle Tracking and Uncertainty Analysis**

    - Particle tracking is used to visualize groundwater flow fields, track actual or hypothetical contaminant paths in an aquifer, and will aid in the process of selecting monitoring points for the long-term water resources monitoring program.
    - Based on discussions between BDE, Operators and AMEC, particle tracking was performed for potential sources and receptors within the PAPA.
    - Preliminary particle tracking results were presented to BDE and Operators in a web meeting (August 29).
    - After particle tracking was complete, an uncertainty analysis was completed to assess uncertainty related to estimated model parameters.

5. **Solute Transport**

    - Solute transport simulations help identify vulnerable areas within the aquifer and will aid in the process of selecting monitoring points for the long-term water resources monitoring program.
    - Based on discussions between BDE, Operators and AMEC, five hypothetical solute transport simulations were conceptualized.
    - Initial parameterization was completed for all solute transport simulations.

6. **2011Summary**

    - The numerical model is well calibrated to field measured groundwater level and flux data and estimated flux data.
    - Particle tracking is complete including uncertainty analysis.
    - Solute transport scenarios have been conceptualized and parameterized.
    - Model documentation and reporting has begun.

Low-Level Petroleum Hydrocarbon Compound Study

In 2011, AMEC continued executing the Sampling and Analysis Plan which included completing various sampling events, data compilation and validation, and evaluation of the data.

1. **Data Collected in 2011**

    - Confirmation samples of groundwater at T-3-SW and T-3-RW and well casing gas at T-3-SW (February 1-3).
    - Flowback fluid sample from an Operator (Ultra) pad where hydraulic fracturing was occurring (February 18).
    - Flowback fluid sample from an Operator (Shell) pad where hydraulic fracturing was occurring (February 28).

- Flowback fluid sample from an Operator (QEP) pad where hydraulic fracturing was occurring (March 17).
- Groundwater samples from study wells T-1-SW, T-1-RW, T-2-RW, T-3-SW, T-3-RW, T-4-SW, T-4-RWa, T-4-RWb, and T-5-RW (June 14-16).

2. Data Compilation and Validation

- Field data associated with samples collected in November and December of 2010 were validated in January and February 2011. Sample collection information, water level data and groundwater quality parameter data were uploaded into the geodatabase. Laboratory data associated with groundwater, gas and potential source material samples (> 75 samples) collected during November and December 2010 were validated and uploaded into geodatabase.
- Between mid-March and mid-June 2011, field and laboratory data associated with samples collected in February and March 2011 (see item #1 above) were validated and uploaded to the geodatabase. We also began tabulating and compiling data collected for LLPHC evaluation.
- Field and laboratory data associated with groundwater samples collected in June 2011 were validated during June through August 2011. The validated field and laboratory data were then uploaded to the geodatabase. We also continued tabulating and compiling data collected for the LLPHC evaluation.

3. Data Evaluation

The following describes AMEC's LLPHC data evaluation process between August and December 2011. During this time period as well, AMEC prepared key sections of the draft LLPHC report.

- Assessed type, magnitude and location of parameters detected in groundwater, gas and potential source material samples.
- Performed correlation analysis between petroleum hydrocarbon compounds in groundwater and inorganic constituents and methane.
- Identified analytical indicators of potential sources based on unique chemical signatures (e.g. chromatograms).
- Evaluated general water quality trends in groundwater (e.g., Stiff/Piper diagrams) and by location in PAPA.

Draft Final Groundwater/Aquifer Pollution Prevention, Mitigation and Monitoring Plan

Work on the certain sections of the Draft Final Plan was performed during 2011 including:

- Discussing AMEC's inventory of the Oil and Gas Industry's Standard Procedures and Practices during a meeting with the BDE and the Operators in Cheyenne, Wyoming on February 2.
- Issuing a revised Technical Memorandum concerning the inventory to the BDE on February 23.

- Providing the series of five Operator Practice Mitigation matrices for oil and gas development (i.e., planning/design, construction, drilling/completion, production, closure/reclamation) to BLM as requested during the February 2 meeting.
- Reviewing the BLM-revised matrices which were received November 10.
- Preparing the draft version of the Quality Assurance Project Plan (QAPP; a component of the Draft Final Plan) in November and December. The draft version of the QAPP is mostly complete and includes procedures for field documentation, sample shipping, QA/QC, and database management. Remaining work includes specifics regarding various topics including sampling design, personnel, etc.
- Preparing sections of the Sampling and Analysis Plan which will become a key component of the Draft Final Plan. These include standard groundwater and surface water monitoring procedures, field forms, and a proposed health and safety plan.