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Memorandum

Date: August 5, 2011

To: Thomas Cooper

From: Jonathan Myers

RE: Occurrences of Gas Bubbles in KAFB Groundwater Samples

The observation of bubbles in groundwater samples obtained from more than a few tens of feet below the water table is a common and well understood occurrence at many facilities. Groundwater in contact with common carbonate minerals such as calcite ($CaCO_3$) will dissolve these minerals which have moderately high solubilities. The presence of units containing limestone gravel within the Santa Fe Formation provides a source of calcite which is the main mineral composing limestone. Calcite will dissolve in groundwater by the reaction:

$$CaCO_3 + H_2O \rightarrow Ca^{2+} + HCO_3^- + OH^-$$

to yield bicarbonate ions (HCO_3^-) which are a form of dissolved carbon dioxide (CO_2). Concentrations of calcium and alkalinity (an indirect measure of dissolved CO_2) and pH measurements indicate that most of the groundwater samples are in equilibrium with calcite. The observed alkalinity concentrations, which are in the range of 100 to 300 mg/L (as $CaCO_3$) are equivalent to bicarbonate concentrations of 80 to 250 mg/L, so there is a large reservoir of dissolved CO_2 in the groundwater.

The solubility of dissolved CO_2 increases with hydrostatic pressure, which is linearly related to depth below the water table. Deeper water can thus dissolve more CO_2 than shallower water. When a deep water sample that is in equilibrium with calcite is brought to the surface, the reduction in confining pressure causes the dissolved bicarbonate to yield CO_2 gas by the reaction:

$$HCO_3^- \rightarrow OH^- + CO_2$$

which is released as bubbles. Samples obtained from greater depths below the water table will release proportionally more CO_2 gas when brought to the surface. This reaction is

analogous to opening a can of carbonated drink. Prior to opening the can, the fluid is under pressure and the CO_2 is in a dissolved form. Releasing the pressure by opening the can causes the dissolved CO_2 to exsolve as gas bubbles.