Forward Plan Concerning the Protection of Groundwater Resources in the Vicinity of the Uranium Energy Corporation Project near Ander, Texas

Prepared for **Goliad County Groundwater Conservation District**
Goliad, Texas

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Forward Plan Concerning the Protection of Groundwater Resources in the Vicinity of the Uranium Energy Corporation Project

1. Purpose

The purpose of this forward plan is to provide the Goliad County Groundwater Conservation District (the District) a roadmap for moving forward should the Uranium Energy Corporation (UEC) in-situ mining project near Ander, Texas (Figure 1) take place. The District is concerned that the proposed mining operation may have long-term adverse effects on the quality of groundwater in the area. The uranium deposits that will be mined by UEC occur in the same Evangeline Aquifer units that serve as the sole source of water for residents of the area. In addition, groundwater from the Evangeline Aquifer sustains the base flow of Coleto Creek, east of the mine site.

This forward plan provides a brief overview of the nature of the proposed mining, a brief summary of some of the concerns regarding the potential for adverse impacts to groundwater quality in the vicinity of the mining area, and recommendations that the District may implement to monitor long-term water quality. The concerns that the District has concerning groundwater quality are not new and have been raised previously with the Texas Commission on Environmental Quality (TCEQ) and the U.S. Environmental Protection Agency (EPA).

2. Overview of Proposed Mining

The type of mining that will be conducted at the Ander site is referred to as in-situ leach or in-situ recovery (ISR). During the ISR process, the native groundwater chemistry is altered through the injection of an oxygen-rich, pH-controlled fluid called lixiviant. Lixiviant often consists of oxygenated groundwater that may have sodium bicarbonate added to it. The purpose of the lixiviant is to change the hydrogeochemical conditions in the subsurface from reducing (oxygen-poor) to oxidizing (oxygen-rich), thereby creating conditions within the ore body that allows uranium to become soluble and dissolve into the groundwater. The dissolved uranium in the groundwater is then pumped to the surface for extraction and processing.

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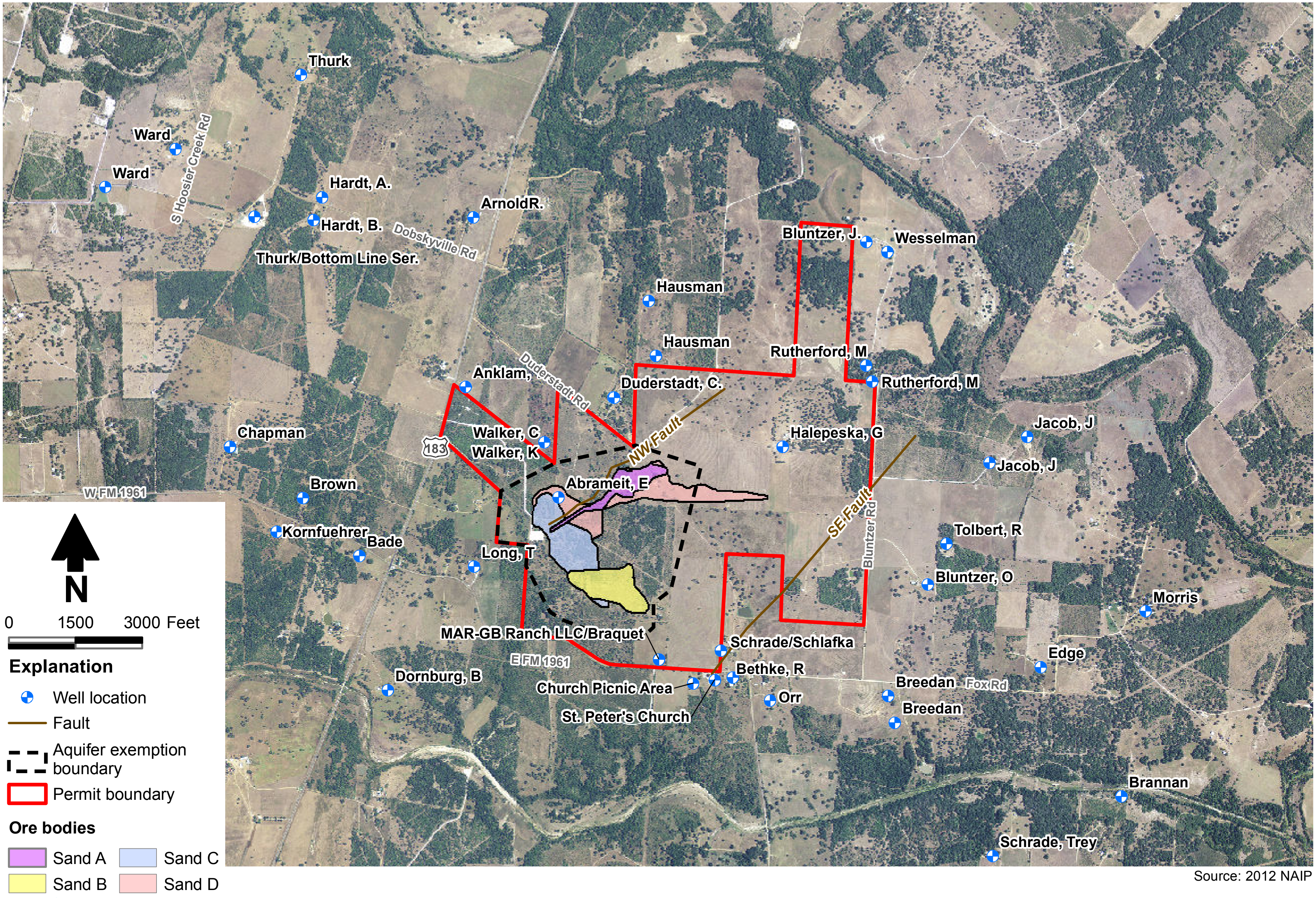

Source: 2012 NAIP

GOLIAD FORWARD PLAN

UEC Ander Facility and Nearby Wells

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Figure 1

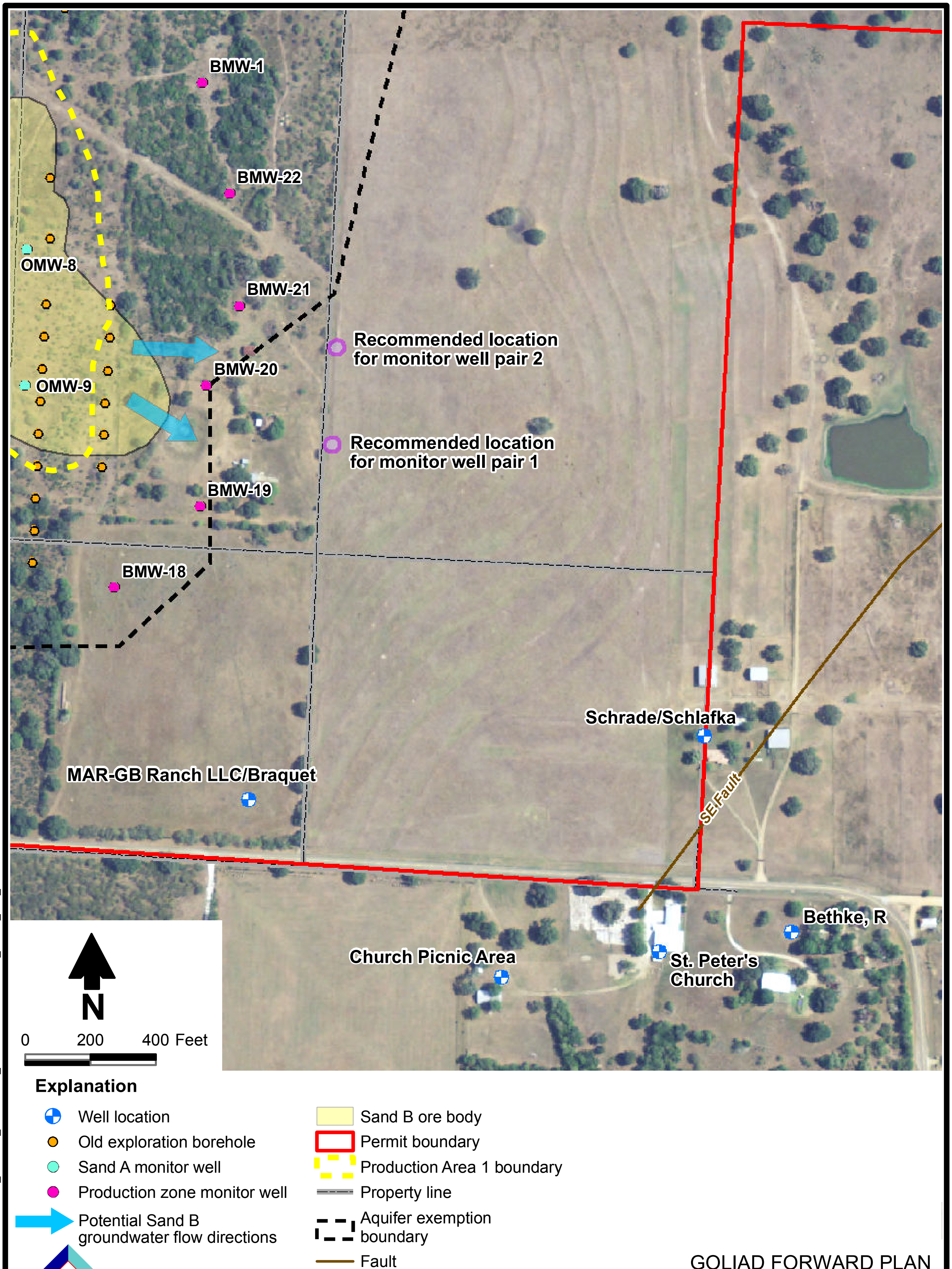
The intent of the mining operation is to capture all of the groundwater with elevated concentrations of uranium and other constituents. However, some groundwater in the lixiviant-affected zone may not be captured by the extraction wells, and this groundwater is likely to have elevated levels of not only uranium, but of daughter products of the uranium, including radium-226 and radon, along with various ions such as bicarbonate, sodium, and sulfate. As this groundwater moves away from the zone affected by the lixiviant and encounters reducing conditions in the aquifer, the dissolved uranium will precipitate back on to sand grains as a solid mineral, and uranium concentrations in groundwater will be significantly reduced. The daughter products such as radium and radon, however, will remain in groundwater even under reducing conditions. When mining is complete, the operator is supposed to restore the groundwater to the quality specified in the TCEQ permit.

UEC plans to mine four delineated ore deposits at the Ander site; these are known as Sands A, B, C, and D. Sand A is the shallowest unit (about 50 to 110 feet below ground surface [ft bgs]) and Sand D is the deepest unit (approximately 350 to 450 ft bgs). The water table occurs in Sand A, and Sands B, C, and D are all below the water table (fully saturated). These designated sand units are the same sand units that comprise the Evangeline Aquifer, which is the sole source of water supply in the vicinity of Ander. UEC Production Area 1 (PA-1) consists of Sand B as delineated by UEC; this is the only sand unit for which a Production Area Authorization Application has been submitted to TCEQ. Sand B, and the portion of Sand A that overlies or is downgradient of the Sand B production area, is the focus of this forward plan for the following reasons:

- Sand B is the first proposed production area at the Ander facility, and it is the only production area currently permitted by the TCEQ.

- The majority of private wells in the vicinity of the Ander facility obtain water from Sand B or the overlying (shallower) Sand A, which is in hydraulic communication with Sand B.

- Existing water supply wells are closer to the Sand B ore deposit than they are to the other ore deposits that occur in Sands A, C, or D. Based on the regional groundwater flow direction of east to southeast (Figure 2), some of these wells are also downgradient of Sand B.



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Proposed Monitor Well Locations

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Figure 2

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- There are existing water supply wells and there may be opportunities to construct new wells to the west of a geologic fault, designated as the southeast fault, relatively close to the mining area (Figure 2).

3. Concerns and Recommendations

Sections 3.1 through 3.3 identify key concerns regarding the potential for long-term water quality impacts due to ISR uranium mining in the Ander area and provide recommendations to the District regarding each of the concerns. The District may request through the regulatory agencies (TCEQ or EPA) that the following actions be conducted by UEC. If this approach is unsuccessful the District can elect to conduct some of the suggested actions independently.

3.1 Time Frame for Water Quality Monitoring

Concern: UEC is required in their PA-1 permit to monitor the water quality in monitor wells for a period of 2 years after the cessation of mining operations (TCEQ requires 1 year and UEC has committed to 2 years). The proposed time frame for monitoring is too short to definitively determine whether degradation in groundwater quality will occur at off-site wells.

Recommendation: The District should continue to monitor existing wells, and new dedicated monitoring wells if constructed, for a period longer than 2 years. Existing information indicates ambient (unaffected by mining) groundwater flow rates on the order of 40 feet per year. Monitoring should continue, therefore, for a period of about 10 to 15 years after reclamation ceases if existing monitor wells can be used, or for a period of 20 to 25 years if new monitor wells are constructed (Section 3.2.1). If mining begins and more information is obtained about the aquifer properties at the site, existing estimates of the direction and rate of groundwater flow may be updated, and estimated time frames for monitoring may be revised accordingly.

3.2 Sand B Groundwater Quality Monitoring

Concern: To comply with TCEQ monitoring requirements in the PA-1 application, UEC constructed 22 monitor wells (BMW-1 through BMW-22) in a ring around the Sand B ore body. Each of the BMW series wells is 400 feet from the portion of the Sand B ore body targeted for mining (the PA-1 boundary shown in Figure 2). The 400-foot distance is the maximum allowable distance from the ore body according to TCEQ rules. However, based on the hydraulic properties of the Sand B aquifer and the proposed time frame for mining, it is unlikely that fluids not contained by the extraction wells would be observed at the Sand B monitor wells, because the wells are too distant from the ore body. Consequently, given the lack of monitor wells between the ore body and the BMW wells, groundwater quality in this region will not be known at the cessation of groundwater restoration efforts.

Recommendations: To ensure that residual impacted groundwater, to the extent that it occurs, does not adversely affect adjacent water supplies, Sand B water quality downgradient of PA-1 should be monitored long-term, as described in Sections 3.2.1 and 3.2.2.

3.2.1 Monitoring Locations

If access can be obtained, the District should continue to monitor existing Sand B monitor wells BMW-1 and BMW-18 through BMW-22 after UEC ceases groundwater monitoring under its PA-1 permit. The purpose of the monitoring would be to maintain a record of groundwater quality relative to known baseline conditions.

If access to the existing monitoring wells cannot be obtained, it is recommended that the District install and monitor dedicated monitoring wells as close as possible to the eastern and southeastern edge of the PA-1 monitor well ring, as indicated in Figure 2. Two monitor well pairs are recommended, with one well at each location completed in Sand A and the second well completed in Sand B. Suggested locations for the two recommended well pairs are labeled as locations 1 and 2 on Figure 2.

Sand B monitor wells should be completed to a depth of about 175 feet or less, with the final depth determination made in the field during drilling. Sand A monitor wells are discussed in Section 3.2.

3.2.2 Indicator Constituents for Monitoring

Prolonged monitoring for all constituents sampled and reported under the application for PA-1 would be costly if conducted on a regular basis. A more cost-effective approach that uses an indicator parameter to trigger more comprehensive analyses as warranted is therefore proposed. As described in Section 2, during the ISR process the groundwater chemistry is altered to create conditions within the ore body that allows uranium to become soluble and dissolve into the groundwater. If groundwater with elevated constituent concentrations is not captured by the extraction wells, it is likely to have elevated levels of various constituents that will be indicated by elevated levels of total dissolved solids (TDS), which is closely correlated with the field parameter electrical conductivity (EC).

If new monitor wells are constructed, several initial groundwater samples (probably 3 to 5 samples, spaced 3 to 6 months apart) should be collected to establish the baseline water quality (including EC) for each well. If the BMW wells can be monitored over the long term, water quality reported by UEC can be used as a baseline. Over the long term, once baseline water quality has been established at the available monitoring locations, EC should be measured periodically (at least biannually) to determine if an increasing trend is evident in consecutive sampling events. In the event that increasing trends are evident at a given monitor well, then a laboratory sample can be collected for analysis of a full analytical suite (defined below) and results of the sample can be compared to baseline conditions. Sampling events for a full analytical suite of constituents should also be completed on a regular basis, such as every 2 years.

EC can be determined either through traditional water quality sampling methods or by using transducers. Transducers are more cost-effective over the long run, but they need to be checked and may require recalibration from time to time.

Routine monitoring would consist of the field parameters EC and pH only; a full analytical suite would consist of these two field parameters plus the following laboratory analytes:

- Alkalinity (including bicarbonate)
- Arsenic
- Bromide
- Chloride
- Calcium
- Fluoride

- Iron
- Sodium
- Sulfate
- Potassium
- Magnesium
- Manganese
- Molybdenum
- Nitrate
- Selenium
- Silica
- TDS
- Uranium
- Radium-226

3.3 Sand A Groundwater Quality Monitoring

Concern: Sand A, which overlies Sand B, is hydraulically connected to Sand B across the sandy clay confining unit of approximately 20 to 40 feet. Although the confining unit has significantly lower permeability than the sand units, it is not impermeable, and groundwater can and will migrate through this unit given sufficient time. Even more important than the natural permeability of the confining unit are potential pathways created by exploration boreholes completed in the 1980s, prior to UEC's acquisition of the property (Figure 2). Plugging and abandonment records for these boreholes are not available, and if typical practices of the period were followed, the boreholes were likely plugged near the surface but not at depth. UEC contended in their testimony in the administrative hearing for Permit No. UR03075 for Aquifer Exemption and PA-1 authorization that these boreholes have collapsed and are therefore not potential conduits for preferential fluid migration.

Implicit in UEC's assumption is that the confining unit materials (sandy clay) filled the portion of the borehole adjacent to the confining unit, and sand filled the portion of the boreholes adjacent to Sands A and B. This interpretation, however, does not consider the possibility that the exploration boreholes were filled primarily with sand upon their collapse. This outcome is likely, because the clay units are cohesive and less prone to collapse than the unconsolidated sand units; consequently the portion of the borehole adjacent to the confining unit could be filled predominantly with sand that collapsed into the borehole from the overlying Sand A, thereby forming a conduit of relatively high permeability through the confining unit (Figure 3).

It is possible, therefore, that at least some of these older exploration boreholes could serve as pathways for impacted water to migrate from Sand B upward into Sand A, under both ambient (pre- and post-mining) conditions, as well as during active mining operations, when hydraulic head in Sand B will be increased in the vicinity of injection wells used to introduce lixiviant to the ore body.

Recommendation: To ensure that residual impacted groundwater, to the extent that it occurs, does not adversely affect adjacent water supplies, Sand A water quality overlying PA-1 should be monitored long-term, as described in Sections 3.3.1 and 3.3.2.

3.3.1 Monitoring Locations

If access can be obtained, the District should continue to monitor existing Sand A monitor wells OMW-8 and OMW-9 (Figure 2) after UEC ceases groundwater monitoring under its PA-1 permit. If access to the existing monitor wells cannot be obtained, it is recommended that the District install the dedicated monitor well pairs (one well completed in Sand A and the other in Sand B) described in Section 3.2.1 and shown in Figure 2. Sand A monitor wells would be completed to a depth of about 100 feet or less, with the final determination to be made in the field during drilling. To increase the likelihood of detecting potential changes in water quality attributable to uranium mining in the underlying Sand B, the Sand A monitor wells should be screened in the bottom 10 to 20 feet of the Sand A producing interval.

3.3.2 Indicator Constituents

The same monitoring approach as outlined in Section 3.2.2 should be implemented for Sand A monitor wells.

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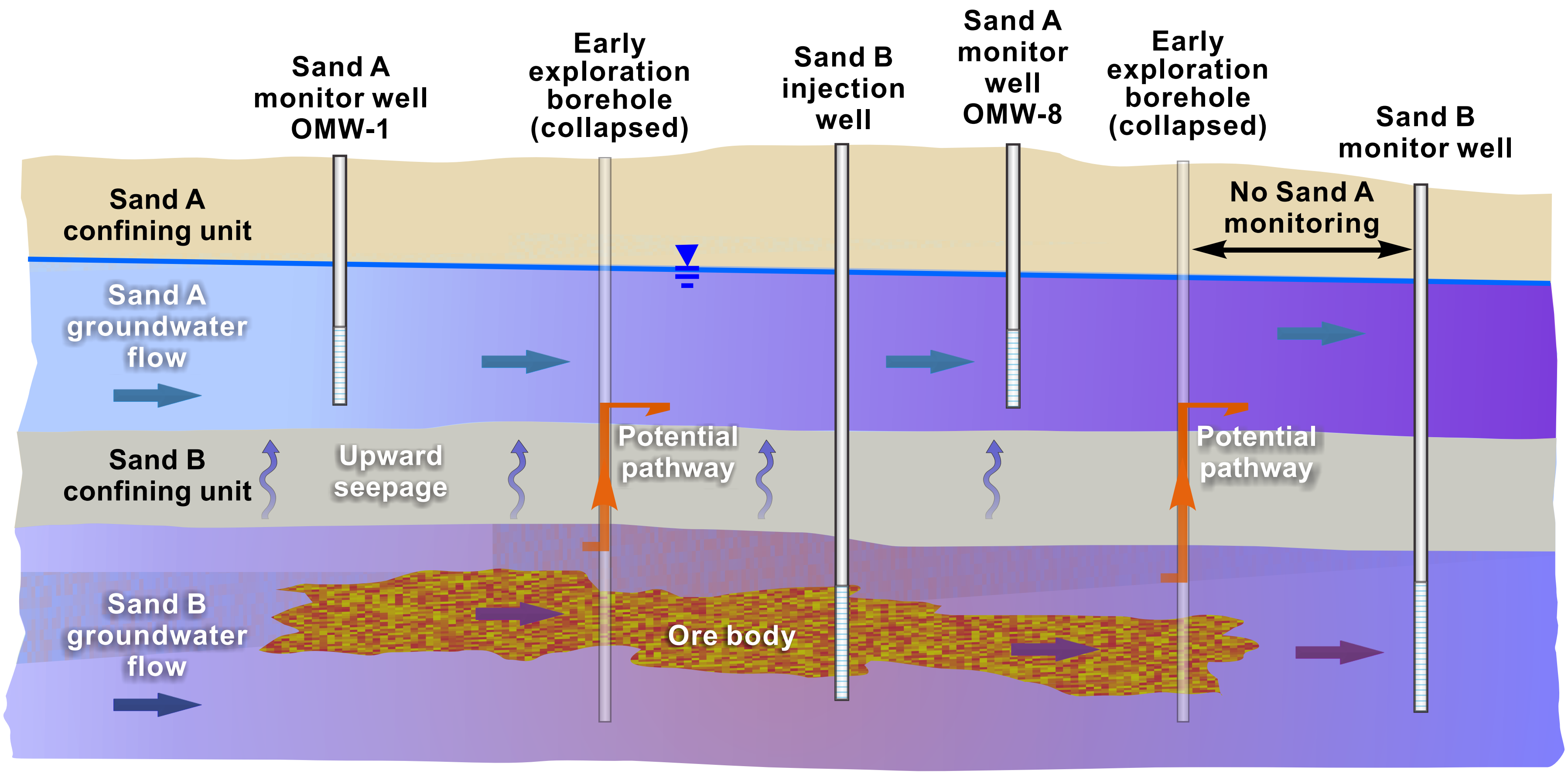

Not to Scale

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Schematic Diagram of Groundwater Flow Through Sands A and B

Figure 3

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4. Summary of Recommended Actions

In summary, the following actions are recommended to address the concerns detailed in Section 3:

1. Seek the ability to continue monitoring the following wells for an extended period of time (15 to 25 years) after groundwater restoration has been deemed complete by the TCEQ and UEC has discontinued groundwater monitoring.
    - Sand A: OMW-8 and OMW-9
    - Sand B: BMW-1 and BMW-18 through BMW-22

2. If continued monitoring of existing wells cannot be achieved, construct one or two monitoring well pairs at the locations indicated on Figure 2. At each location one well should be completed in Sand A and the other in Sand B.

3. After baseline water quality has been established at each well (either through UEC monitoring or, for new wells, through several rounds of initial sampling), monitor water quality using the field parameters EC and pH. If a significant upward trend is observed in EC at any well, then a full analytical suite should be run on a groundwater sample, and the nature and extent of additional monitoring should be determined based on the results of those analyses. Full analytical suites should also be conducted on a regular basis, such as once every 2 years, regardless of field parameter trends.