The large amount of water proposed for extraction from the karst aquifer brought concern that it may dewater the aquifer or draw the groundwater levels down to potentially critical levels. The water is vital to support the areas’ cattle ranching industry. Further, a biological inventory had not been conducted in the caves or in the karst aquifer. Therefore, it was unclear if there were any aquatic troglobitic species that would be affected.

The Bureau of Land Management required a complete biological inventory be conducted to understand more about the affected environment. As a result of that inventory two new aquatic troglobitic species were discovered. The agency in conjunction with the mining company developed a groundwater monitoring plan to track the water levels and detect any significant drops in the aquifer levels. The BLM initiated an adaptive management strategy that set trigger points beyond which alternate water sources would be used for the project.

The Proposal

A proposal for a solution mining project in southeast New Mexico, USA was received by the United States Department of the Interior, Bureau of Land Management (BLM) from the Intrepid Mining Corporation. The proposal is to inject a NaCl brine solution into previously mined workings through injection wells. The injected NaCl brine will fill the lower elevations of the workings and replace the potassium chloride (KCl) from the remaining pillars and edges of the workings via ion replacement. The potash and sodium chloride concentrated solution will then be recovered via extraction wells and pumped through pipelines to solar evaporation ponds covering approximately 230 hectares (570 acres). The KCl/NaCl concentrate will then be harvested from the solar evaporation ponds and processed at a flotation plant (DOI, 2012).
The water needed for the project will require that approximately 10,886 kiloliters (2.88 million gallons) of water per day be pumped for the first 7 years and 5,443 kiloliters (1.44 million gallons) per day for the next 13 years (DOI, 2012). The water source for the proposed project is targeted for a shallow karst aquifer. Sodium chloride will be added to the water.

**The Environment**

**Geology**

The Burton Flats area contains Permian age evaporites of the Rustler Formation being primarily made up of interbedded gypsum, dolomite and anhydrite. The gypsum members occasionally crop out on the surface, which is largely composed of gypsum soils. From the top to the bottom the members are the Forty-niner, the Magenta Dolomite, the Tamarisk, the Culebra Dolomite, and the Los Medaños (Figure 1).

The Forty-niner member is composed of gypsum, anhydrite, siltstone, shale, and clay. The Magenta Dolomite member is 6 to 9 m (20 to 30 feet) thick and identified by its color, weathering to colors from pink to red to purple. It contains open voids and high porosity. The Tamarisk member is largely composed of massive anhydrite. The Culebra Dolomite is a thin-bedded crystalline dolomite that also has high porosity. Below the Culebra is the Los Medaños member. It is composed of siltstone, gypsum, and fine-grained sandstone (Hill, 1996). Both the Magenta and the Culebra dolomite formations are aquifers.

**Climate**

The area has an arid to semiarid climate. The average rainfall is between 25 to 35 centimeters per year. The average monthly maximum temperatures in July range from 34 to 37°C (94 to 98°F) with average monthly minimums of -1 to -2 °C (28 to 30°F) in December and January. Average annual potential evaporation rates far exceed average annual precipitation. Evaporation rates approach 180 centimeters per year in this area, resulting in a large moisture deficit.

**Caves and Karst**

The gypsum karst plain of the Burton Flats area has 79 known caves (Figure 2) and hundreds of dolines in the vicinity of the project. It is estimated to have 50 karst features per square kilometer in this dense karst area. Several of the caves are large and go down to the local water table approximately 26 meters deep. The length of the caves varies from 30 meters to 200 meters. The cave systems and dolines provide for rapid recharge of groundwater during rain events. The caves are formed in the 49er member of the Rustler formation and may terminate in the Magenta dolomite member where they encounter the water table. The caves may go much deeper but no diving has been conducted in any of the caves. Due to significant fracturing there is a high probability that the Magenta and Culebra aquifers are connected.
The inventory was conducted over the course of several months and included the baiting of traps and aquatic areas. Three visits were made to each cave. ZARA Environmental conducted inventories of terrestrial and aquatic subterranean fauna in the three gypsum caves. All three caves showed a broad array of terrestrial invertebrate fauna, including typical cave fauna such as Ceuthophilus crickets, Rhadine ground beetles, Cicurina spiders, and Speorthus millipedes. Groundwater sampling for fauna revealed undescribed new species of Parabogidiella amphipod known only from Skylite Cave (Figure 3), and a new species of copepods. Also identified were ostracods. Terrestrial fauna include an undescribed species of Rhadine beetle that may be a new species or one that is only known from gypsum caves nearby (ZARA Environmental, 2012).

Knowing that unique species may be affected by aquifer drawdown and that the ranching communities depend on the water supplies, it was determined that a very specific groundwater monitoring plan should be developed to track any drops in the aquifer in the Burton Flats karst plain and develop a water monitoring plan to track any critical changes in the aquifer’s stable levels.

The monitoring plan involved the installation of several groundwater monitoring wells as part of the solution mining project. These wells would further define the Magenta Aquifer unit and associated potentiometric surface across the project area. Additionally, they would be used to document and analyze drawdown from the project pumping wells screened in the Rustler Formation (Magenta and Culebra Dolomite Members). An “early warning” water monitoring well was installed between the pumping wells and the monitoring wells in the Burton Flats karst plain.

Six of the new monitoring wells in the Burton Flats karst plain network would be used to evaluate potential

**The Concern**

The primary concern regarding cave and karst resources was that the amount of water proposed to be pumped from the karst aquifer is greater than the limited recharge that the area can sustain and the aquifer may be pumped dry. This would severely stress the ranching community, which relies on the water for their cattle. Additionally, there had not been a biological inventory conducted in the caves to determine what types of troglobitic species might be present that may be affected by significant lowering of the water levels.

**The Solution**

To address the concerns of impacts to potential biological communities the Bureau of Land Management required the proponent to hire a company to conduct a biological inventory on three of the caves in the project area located in Burton Flat. In this way it could be determined what species were present and if there were any aquatic invertebrate species that could possibly be impacted by the drawdown of the aquifer. The caves to be studied were located at the boundaries of the potentially affected area of the aquifer drawdown. Two of the caves, Banded Pit and Skylight, went down to the local water table at depths of approximately 27 meters. An environmental company, ZARA, was hired to conduct the biological inventory. The inventory was conducted over the course of several months and included the baiting of traps and aquatic areas. Three visits were made to each cave. ZARA Environmental conducted inventories of terrestrial and aquatic subterranean fauna in the three gypsum caves. All three caves showed a broad array of terrestrial invertebrate fauna, including typical cave fauna such as Ceuthophilus crickets, Rhadine ground beetles, Cicurina spiders, and Speorthus millipedes. Groundwater sampling for fauna revealed undescribed new species of Parabogidiella amphipod known only from Skylite Cave (Figure 3), and a new species of copepods. Also identified were ostracods. Terrestrial fauna include an undescribed species of Rhadine beetle that may be a new species or one that is only known from gypsum caves nearby (ZARA Environmental, 2012).

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impacts to the aquifer associated with the three caves: Skylight Cave, Banded Pit Cave and Macha Cave. These wells were installed as pairs adjacent to the 3 caves. One well was completed to the bottom of the Magenta dolomite and a second well was completed to the bottom of the Culebra dolomite. (Figure 4)

The wells were completed in the Magenta and Culebra aquifers using perforated casing in an open hole to allow aquatic wildlife to enter and provide an opportunity for biologic sampling. Each well was equipped with a submersible water pump and a 4 centimeter tube attached to the inside of the well casing, in which an electronic datalogger is installed. The datalogger records stage height, temperature, ph, dissolved oxygen, and conductivity. The monitoring wells are sampled every three months for basic water chemistry and water levels. High volume pump tests will be conducted in the Culebra formation with monitoring in the Magenta to detect drawdown. This will provide information necessary to determine if the two aquifers are connected.

In addition to the requirements for the mining company the BLM installed rain gauges near the cave entrances to collect that data and analyze the correlation of rainfall data to the water levels in the caves. The BLM has also installed data loggers in the lakes within the caves. These data loggers record water height and temperature. This information will be correlated with the monitoring well data to help analyze the reaction of rain events to the water heights in the caves and in turn in the local water tables.

The Bureau of Land Management has initiated an adaptive management strategy for the extraction of water from the Rustler formation. The water level monitoring being conducted before the project pumping wells go into operation will provide baseline data to determine if excessive drawdown is occurring. Water monitoring wells will be logged approximately two years before project pumping begins. A water monitoring plan has been developed identifying a drawdown trigger point. If water levels in the Burton Flats karst plain drop 5 feet (1.5 m) the pumping will stop and the solution mining project will get their water from a different source until the water levels return to baseline levels. Additional biologic samples will be taken in the water wells to look for further evidence of amphipods and other species. This will help to define and establish a range for the new species that were discovered.

Figure 4. Schematic of water monitoring well in karst aquifer.
References

Biography
Jim began caving at 9 years old with his parents and two sisters in central Texas where the “bug” bit him and he was infected with a lifelong desire to explore, understand, and protect underground resources. Much of his 33+ year career with the Bureau of Land Management has been developing their national Cave and Karst Management Program where he currently serves as the Senior Cave and Karst Specialist for the Washington Office. He assisted in writing the Federal Cave Resources Protection Act, their regulations, and implementation procedures and was instrumental in developing their national cave and karst management policies, manual and handbook, cave management training courses, national and local agreements, national cave safety standards, and guidelines for oil & gas drilling in karst areas. Jim is an Honorary Life Member, Fellow, and past board member of the National Speleological Society, a Fellow of the Cave Research Foundation, and a Charter Life Member of the American Cave Conservation Association. His interests, education, and career have led him into all aspects of cave exploration, science, and karst management. Caving and cave management have taken Jim to 16 foreign countries. Jim has authored over 25 publications on cave and karst management and geology. He earned his BS in Park and Recreation Management from Texas A&M University and conducted his graduate studies in Cave/Karst Geology/Geomorphology at Western Kentucky University in 1979-81.