THE UNIVERSITY OF ARIZONA
COLLEGE OF SCIENCE
Hydrology & Atmospheric Sciences

Harshbarger Building
Room 122
1133 E. James E. Rogers Way
P.O. Box 210011
Tucson, AZ 85721-0011
Ofc: 520-621-7120
Fax: 520-621-1422

Physics and Atmospheric Sciences Building
Room 542
1118 E. 4th St.
P.O. Box 210081
Tucson, AZ 85721-0081
Ofc: 520-621-0275
Fax: 520-621-6833

Kerwin Dewberry
Forest Supervisor of the Coronado National Forest
300 W. Congress St.
Tucson, AZ 85701

June 1, 2017

Dear Kerwin Dewberry,

I am writing to provide new information about the hydrogeology of the Cienega Creek watershed that may be relevant for your decision about the proposed Rosemont Copper Mine. The results attached came from an on-going study that my graduate students and I have been conducting, since 2014, with other scientists from the Nature Conservancy and Desert Botanical Garden. Please let me know if you have any questions.

Sincerely,

Dr. Jennifer C. McIntosh
Associate Professor, UA Distinguished Scholar
Department of Hydrology and Atmospheric Sciences
University of Arizona
Email: mcintosh@hwr.arizona.edu

Personal Matters / Ex. 6

Key results from Upper Cienega Creek watershed study:

- The study in the Upper Cienega Creek Watershed was conducted by a team of scientists from the University of Arizona, the Desert Botanical Garden, and The Nature Conservancy. Study funding was provided by the BLM through a cooperative agreement with the Nature Conservancy designed to improve understanding of dynamics of shallow groundwater in the basin.

- The research area is bounded by the Santa Rita mountain front to the west, Empire Gulch in the north, Cienega Creek to the east, and Gardner Canyon in the south. Water samples from precipitation collectors, wells, springs, piezometers, and cienegas (wetlands) were collected from 2014 to 2017 and analyzed for major ion chemistry, stable water isotopes, and radioactive isotopes.

- Groundwater across the basin was mostly recharged prior to the 1950's, with a small component of modern recharge in a few locations, based on the age tracer results. The majority of groundwater samples analyzed for tritium (n= 34) contained no detectable tritium (<0.5 tritium units (TU)), indicating they were recharged prior to the 1950's, while 10 samples contained low, but measurable tritium (up to 2 TU), indicating a small portion of modern recharge mixed with older waters. Carbon-14 values ranged widely from 3.33 to 84.7 percent modern carbon (pMC). These values correspond to uncorrected radiocarbon ages of ~1,400 to 28,000. The relatively long residence time of basin groundwater is likely related to the presence of a thick clay confining unit across the basin.

- Mountain block recharge is the source of shallow groundwater near the mountain front based on age tracer results. Tritium values measured in a well and spring at the mountain front are 0.8 TU and 0.9 TU, respectively, near the detection limit. Carbon-14 of dissolved inorganic carbon in groundwater sampled from the well was 84.7 pMC. The carbon-14 and tritium results in groundwater at the mountain front imply a mixture of mostly older water with a minimal component of modern recharge. The limited recharge of ephemeral stream water beneath washes at the Santa Rita mountain front is in contrast to what has been observed in the Tucson Basin.

- Stable isotope ($\delta^{18}O$ and δD) samples were collected biannually, at the end of the rainy season, from precipitation buckets across a 5000-foot elevation gradient. Based on the range of values, season collected and short record, an altitude and seasonality affect in the isotopic composition of the precipitation could not be identified.

- Sulfur isotope ($\delta^{34}S$) values in basin groundwater are consistent with meteoric precipitation. The sulfur isotope values range from 3-10‰, which indicate an atmospheric signature. The sulfur isotope values and low sulfate concentrations indicate the groundwater did not encounter sulfur-bearing rocks along its flowpath through the basin.

- The cienegas and shallow groundwater in the Las Cienegas National Conservation Area are dependent on basin groundwater. The SO_4^{2-} to Cl^- ratios of water in the cienegas and underlying shallow groundwater in alluvial aquifers are similar to basin groundwater

throughout the year. Unlike in the San Pedro Basin, there was no evidence of monsoon floodwater recharge into the shallow alluvial aquifers during the study period.

- The combination of relatively old groundwater and limited modern recharge indicates that groundwater resources across the basin are vulnerable to over-extraction from unregulated groundwater use with resulting depletion of connected surface water resources.