United States Department of the Interior

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September 30, 2014

Jim Upchurch, Forest Supervisor
Coronado National Forest
300 W. Congress St. 85701
Tucson, AZ

Dear Mr. Upchurch:

As requested, our hydrologists Stan Leake, Jesse Dickinson, Don Pool have conducted a technical review of Hydro-Logic Technical Memorandum "Simulated Empire Gulch Spring Discharge and Stream Flows based on the Tetra Tech (2010) Groundwater Flow Model." The Memorandum documents a modification of the Tetra Tech (2010) groundwater flow model (the original model) to simulate the Upper Empire Gulch Spring discharge and Empire Gulch streamflows. These features were not explicitly simulated in the original model. The Memorandum also describes model predictions of streamflow changes over time. Our comments, listed below, are limited to the modification to include the spring and streamflow at Empire Gulch, as specified in the Scope of Work for USGS Technical Support to Rosemont Copper Project Hydrology Working Group - Federal Agency Subgroup.

1. Our first comment is on the assumptions about the sources of water to the spring and how those assumptions lead to the modeling approach for simulating the spring discharge at Upper Empire Gulch. It was assumed in the model that the water that discharges at the spring comes from what is called the "bedrock aquifer" in the Technical Memorandum. To simulate spring discharge from the bedrock aquifer, a boundary feature that represents a drain was added to the model. The drain removes water from the model from model layer 12, which represents the upper part of the bedrock aquifer. That is, flow to the spring is simulated as coming directly from the bedrock aquifer. The simulated head in the bedrock aquifer is about 70 ft below the elevation of the actual spring.
   The actual mechanism for discharge of groundwater at the location of Empire Gulch Spring is unknown; however, discharge at that location from the bedrock aquifer would likely require 1) a head in the bedrock aquifer that is higher than the spring elevation, 2) an overlying confining layer in the area near the spring but missing at the spring, and 3) a conduit or a zone of higher vertical hydraulic conductivity that allows water to flow upward from the bedrock aquifer to the land surface at the spring location. A well log for

a nearby flowing well indicates the presence of a clay confining layer in the general region near the spring. If that clay unit is present over a larger area around the spring, it could serve as the confining unit outlined in requirement 2 above. Gravity data show a NW trending structural high in the bedrock in the area of the spring, which indicates that bedrock might be shallower at the spring location than in some adjacent areas. If bedrock that is more permeable than surrounding clay extends upwards to the alluvial aquifer in the area of the spring, then condition 3 above might be met. That such a framework exists, however, is speculation at this point. The model would be improved by a better understanding of the hydrogeologic framework in the area of the spring and recalibration with a revised framework that simulates a reasonable representation of the spring.
Our hydrologists recognize that more work would be needed to better understand the mechanism for spring discharge as well as representation of that mechanism in the model and recalibration of the model. Furthermore, changes to the model structure in the area of the spring might not have a large effect on the timing of computed depletion of spring flow in relation the timing of depletion presented in the Hydro-Logic Technical Memorandum. We would expect that to be the case if the simulated aquifer properties between the proposed mine location and the Empire Gulch spring remain largely unchanged in the updated calibration. One caveat, however, is that the timing of when the spring is simulated to dry up is controlled by the difference between the simulated head in the model cell with the spring and the specified spring elevation. Increasing values of difference means that more simulation time would be needed for head at the cell to fall to a level at or below the spring elevation.

2. Our second comment relates to how the spring was simulated in the tests conducted by Hydro-Logic, as described in the technical memorandum. In addition to the documented work in the Technical Memorandum, further insight on how the spring was simulated was gained by a phone conversation with Grady O'Brien, Stan Leake, and Jesse Dickinson on September 9th, 2014. The original computed pre-mine head at the cell with the added drain was about 4527 ft and the drain elevation was set at 4499 ft. Actual land surface elevation at the Empire Gulch Spring is approximately 4597 ft. The drain elevation had to be set lower than land surface elevation because of the low computed water level at this location. Grady indicated on our call that the drain elevation was assigned to be about 28 ft below the head in a nearby artesian well. The pre-mine computed head at the cell after adding the drain was 4500 ft, resulting in a head loss of 1.5 ft across the drain. That head loss is largely a function of the simulated drain conductance, which was 1077 ft^2/day. If the groundwater model is linear in the area of the spring, then computed declines in drain flow may be insensitive to the specified elevation of the spring, particularly if head always remains above the specified drain elevation. The specified drain conductance, however, might play a minor role in the computed timing of effects of the proposed mine on spring flow. The effects of

conductance could be further tested by running the model with conductance increased by factors of 1 or 2 orders of magnitude. With very large conductance values, the drain cell will behave as a specified-head cell as long as computed head remains above the specified drain elevation

3. Stream flow in Empire Gulch was simulated by directly adding water to the channel at the head waters of Empire Gulch spring. The amount of added water is the amount that is removed by the simulated drain in the deep part of the aquifer. Another approach would be to allow the model to compute the discharge of water from the aquifer to the stream by using a stream feature at the land surface. This would allow for the spring discharge to come from both deep and shallow parts of the aquifer. However, discharge to the simulated stream would occur if the water table is above the stream channel at some point so that groundwater could discharge to the stream channel. The approach taken by Hydro-Logic doesn't allow dynamic changes in the shallow parts of the aquifer to affect the spring discharge. Another consideration is that there may be a possibility of discharge from the bedrock aquifer directly to the alluvial aquifer in the area of the spring. That water might not show up as surface water, but might be available as a source of down-valley flow in the shallow aquifer and for use by riparian phreatophytes. The observed flow at Empire Gulch Spring should be considered to be a lower limit of upward movement of water from the bedrock aquifer, if that aquifer is the source of water to the spring. Relating back to our previous two comments, the low simulated head values at the location of the spring may not have a large effect on computed timing of *changes* in outflow from activities at the proposed mine, but the inability of the model to simulate the direct discharge from the lower aquifer to the upper aquifer and the spring limits its usefulness for more detailed studies of groundwater-surface water interaction in the area of the spring. Ideally, the model would simulate water levels in the deep aquifer that are above the spring elevation, and the spring would be represented with a stream segment that allowed water from the bedrock aquifer to discharge directly to the stream channel and to the shallow aquifer. Such a configuration would be more useful for studies that link hydrologic effects to the possible taking of biological species.

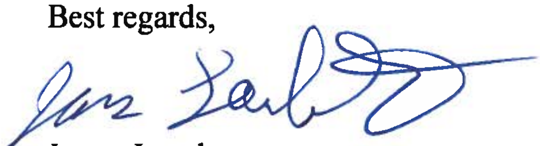
4. On our call on September 9th, Grady indicated that his conceptual model of spring flow at Empire Gulch was that the discharge at the spring occurs because of high pressure in the bedrock aquifer. In the modified model, changes in spring discharge are directly linked to changes in head in layer 12, which has the drain. The Technical Memorandum states that flow to the spring would cease if the drawdown exceeded 28 feet. It may be possible that a small drawdown of head in the bedrock aquifer could have an equivalent head drawdown near the spring. That is, it is not clear if the spring would cease flowing only if the head in the well dropped 28 feet. It may be that a smaller change of head near the spring may cause the spring to cease flowing. This could be investigated by having a

model that simulated higher heads near the spring, and by assigning a drain cell at the land surface with a drain elevation that matches the land surface at the spring.

5. In addition to the drain conductance sensitivity tests suggested in comment 2, our hydrologists suggest that the drain experiment described in the Hydro-Logic Technical Memorandum be repeated with model perimeter boundary conditions switched from constant-head to constant-flow. A graph showing computed capture at the drain location using both boundary conditions would help explain whether or not perimeter boundary conditions have any effect on capture at the location of Empire Gulch Spring.

Thank you for requesting the input of our groundwater-modeling staff to help with some of the challenging technical issues facing the Coronado National Forest. Providing scientific information and expertise to benefit resource management decisions is an important part of the USGS mission. If you or your staff has technical questions regarding these review comments, please contact Stan Leake, Jesse Dickinson, or Don Pool.

Best regards,



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