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*Hydrogeology • Mineral Resource Management • Geological Engineering • Mine Hydrology*



April 13, 1987

Mr. Tom Olson
Uranium Recovery Field Office
U.S. Nuclear Regulatory Commission
P.O. Box 25325
Denver, Colorado 80225

Dear Tom:

This letter constitutes my review of the document entitled "Groundwater Model for the Anaconda Bluewater Mill Site Near Grants, New Mexico." The document was prepared by Dames and Moore, Salt Lake City Office. The cover letter was signed by Mr. George Condrat. The document is attached to Volume 3 of the Anaconda Bluewater Mill License Application documents as Appendix B.

The introduction section of Appendix B explains that the appendix presents the details of the groundwater model, the hydrogeologic coefficients used in the model, the model output and the model predictions that were used to evaluate the hydrogeologic impacts of tailings disposal operations upon groundwater in the Grants-Bluewater area, New Mexico. The model is one of the most comprehensive models I have ever reviewed. The model was calibrated to existing data, then used to forecast future groundwater conditions. Dames and Moore made a decision to incorporate the San Andres-Glorieta aquifer and the basalt-alluvial aquifer into a single flow and chemical transport model. They used a model code called TARGET that reportedly was developed by Dames and Moore for the study. According to the report, TARGET has been reviewed and documented in a report cited as Dames and Moore, 1985. Unfortunately Appendix B does not contain a list of references nor does the table of contents make reference to a list of references cited. Consequently I am unable to comment on the validity of the documentation of TARGET as used in Appendix B.

The section of the report entitled "Hydrogeologic Model Parameters" explains that the model TARGET was established as a two-layer model in which the lower layer (Layer 1) is the San Andres aquifer and Layer 2 is the overlying basalt-alluvial aquifer. The model does not differentiate the basalt from the alluvium. This omission impacts the results significantly. The



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model incorporates the Chinle Formation that lies between these two strata as a leakance factor that connects Layers 1 and 2. The grid is oriented parallel to the edge of the San Andres Formation outcrop which is oriented approximately N55°W. The San Andres dips east-northeast from the mill site. The San Andres, the alluvium, and the basalt all crop out beneath the tailings pond. The basalt does not dip in a direction parallel to that of the San Andres Formation. However, the model ignores this difference. The model is regional in scale. It extends from a location 25,000 ft west of the Bluewater mill tailings pond to the city of Grants, New Mexico. Plate B-1 explains the zones of no external discharge and recharge, recharge at 5 percent of the precip rate, recharge at 15 percent of the precip rate, recharge from irrigation, recharge from streams and canals, and recharge receiving seepage from tailings impoundment. Plate B-1 applies only to the San Andres aquifer. A portion of the Bluewater mill tailings pond is treated as a source of seepage but the area apparently does not include the portion of the tailings pond underlain by basalt. In my opinion the basalt would be expected to be the major recharge conduit for seepage from the tailings pond to the San Andres aquifer in addition to the direct contact of the tailings with the San Andres aquifer. This conclusion is based on the fact that the basalt appears to be in direct hydraulic connection with the San Andres via two faults and a thin layer of alluvium.

Plate B-3 describes the nodal characteristics of the alluvial aquifer (combined with the basalt). The primary issue of interest on Plate B-3 is the fact that recharge through the basalt beneath the Bluewater mill tailings pond site is forced into the alluvium above the Chinle Formation that overlies the San Andres aquifer. This treatment means that the basalt beneath the tailings pond is treated as an aquitard with a vertical permeability of only $2.9\times10^{-5}$ ft/day. In reality the basalt beneath the tailings pond should be treated with a much higher vertical permeability and connected directly to the San Andres aquifer beneath. Plate B-3 also is noteworthy in that it ignores seepage from the Homestake impoundments. It treats the Homestake impoundments as though they were receiving recharge at a rate of 5 percent of the total precipitation rate. The Homestake impoundments are known to be leaking profusely. As a consequence of these initial conditions, the Homestake impoundment has no groundwater mound beneath it, as shown on Plate B-19 of the groundwater model output.

Page B-6 discusses the role of faults in the model. The report notes that (1) faults having minor offsets would have no large effects and could be generally ignored and (2) faults that completely offset the San Andres and the Glorieta Formations would prevent the migration of groundwaters across the fault, and

(3) permeabilities may be locally higher in directions parallel to the fault. The report makes no use of faults in the model because, as stated on page B-6, "Because the San Andres Formation is highly faulted the impact of each fault on groundwater flow cannot be evaluate..." This statement is significant because the nearly vertical normal fault that exists on the south side of the Bluewater mill tailings pond probably acts as a vertical conduit that conducts seepage from the basalt flow down to the San Andres-Glorieta aquifer.

Page B-7 of the report discusses effective porosity. In essence the report notes that effective porosity was not measured but it was assigned a value of 0.02. In my opinion this value is reasonable but it also would be reasonable to assign a value of 0.002 or possibly even 0.2 depending on the characteristics of the karst features in the San Andres limestone. Dames and Moore picked the value of 0.02 for the San Andres Layer 1 in the model because "This value corresponds to two feet of void space throughout the entire thickness of the aquifer due to secondary features of the rock." This procedure is not a very sound one for selecting values of effective porosity. In all fairness, however, the operators of the model could not avoid having to guess at some value because the Anaconda Company probably was not willing to accept the cost of a full-fledged tracer test. Unfortunately, the discussion about specific yield and coefficient of storage presented on page B-8 uses the same value for specific yield as it used for effective porosity. The two values cannot be the same. The model used a value of $5 \times 10^{-4}$ for a coefficient of storage. This value is reasonable and it probably is supported by the pumping test data discussed elsewhere.

Page B-8 also discusses dispersivity. The number used was 100 ft. This number is an absolute guess. No data exist to support the use of it. TARGET computed coefficients of dispersion as the product of dispersivity and groundwater velocity. It should be noted that groundwater velocity is inversely proportional to effective porosity. My previous comment about effective porosity portrays the problems with the uncertainty associated with the calculation of coefficient of dispersion. For the alluvial portion of the model values of 10 and 50 ft were used for dispersivity. As explained above, no rational basis for this estimate exists.

Page B-13 of the report describes pumpage rates. It refers to Appendix A for estimation of pumpage rate from agriculture wells. Pumpage rates used in the model are difficult to determine. Plate B-10 portrays pumpage rates but the figure is almost impossible to interpret. In fact the figure <u>is</u> impossible to interpret. Plate B-1 shows the locations of pumped nodes but the locations of the nodes near the Anaconda mill site do not appear to me to be appropriate, i.e., the pumping stations are not located at the sites of the pumping wells. I am not able to determine the rate at which the Anaconda wells were pumped in the model. This rate is a critical factor in the prediction of the fate of seepage from the mill tailings pond as I will discuss below.

Page B-13 also discusses interaquifer leakage. Leakage is handled automatically by the TARGET model as an input leakance factor. Page B-13 states, "Leakage from units stratigraphically lower than the San Andres aquifer is not believed to be significant." This statement contradicts the analyses of pumping test data presented in other reports. The results of the pumping test data discussed elsewhere in my reviews conclude that the San Andres aquifer is leaky. The other investigators have concluded that the leakage was derived from the rocks underlying it, not the Chinle Formation above it as assumed by this report. I am forced to assume that leakage beneath the tailings ponds from the basalt and from the alluvium downwards to the San Andres is treated as the same as leakage everywhere else in the system, in spite of the fact that the alluvium beneath the basalt is thin and in spite of the fact that the tailings pond is underlain and bounded by two major, nearly vertical faults. Page B-14 of the report describes the tailings impoundment seepage rate. The report notes that seepage rates have been estimated at different times by different people to vary between 1,000 gpm and 40 gpm. For purposes of modeling Dames and Moore was forced to guess at a sequence of seepage rates. They are presented in Plate B-13. These seepage rates indicate that Dames and Moore selected very conservative values. They were forced to do so for reasons that will be discussed below.

Page B-16 discusses water quality parameters. The report explains that each source of groundwater recharge to the model was assigned a chemical quality. The quality values assigned to each of these recharge sources are shown in Table B-2. All the water quality parameters were held constant throughout the duration of the model except for seepage from the tailings pond. In the tailings pond the water quality parameters were allowed to vary in time as inputs to the model. The variations are presented in Table B-2 also. Several problems exist with the water quality input from the tailings pond but the most significant problem exists with sulfate concentration. Data in other reports show that the sulfate concentration in the tailings liquid as obtained from samples collected from piezometers within the tailings ranges in the order of 20,000 mg/L to 25,000 mg/L. Dames and Moore input essentially a steady state value of 3,500 mg/L, almost one order of magnitude below the true value. The Anaconda mill is an acid leach circuit. The sulfate concentration in the tailings solution from an acid leach circuit cannot possibly be as low as 3,500 mg/L. It contradicts all available data. Dames and Moore was forced to choose the 3,500 mg/L value for reasons that will be discussed below. They justified the choice in the following way, 'These later high concentrations are possible only in acidic water. pH measurements of groundwaters from monitoring wells located near the tailings impoundment indicate that discharge from the tailings impoundment are neutralized very close to the impoundment. The value of 3,500 mg/L was based upon the fact that concentrations of sulfate would be reduced due to the precipitation of gypsum as the tailings liquids are neutralized. The value used is much higher than normally found in nature..." It is true that the sulfate concentration of uranium mill tailings solution decreases as it becomes neutralized but the use of 3,500 mg/L is unreasonable as a source. The seepage plume of any acid leach mill tailings pond should contain values far in excess of 3,500 mg/L even <u>after</u> neutralization by alluvial deposits. The situation that exists at the Anaconda mill is anomalous for reasons that will be described below. The Dames and Moore model biases the source toward the lower concentration ranges because it was forced to do so in order to match the data that exist in the field adjacent to the site. The report goes on to explain model calibration against the existing head data base and water quality data base. The model is in fact calibrated against the existing data base satisfactorly. However, the calibration occurs for incorrect reasons.

In my opinion the correct interpretation of the hydrogeologic situation that exists at the Bluewater mill site must recognize the anomalously low concentrations of sulfate, chloride and TDS in the alluvium and in the underlying San Andres aquifer in the vicinity of the tailings pond. The concentrations of sulfate in particular are much lower than would be expected if some unusual hydrogeologic phenomena were not operating at the site. The sulfate concentrations in both hydrostratigraphic units are much lower than they should be for either alluvium or fractured rock, but particularly for fractured rock (in this case karst rock). This statement is based on observations of uranium mill tailings seepage plumes all over the western United States. Once it is recognized that the values are anomalously low then hydrogeologic explanations can be sought. The geology at the site is reasonably well understood. The western half of the tailings pond is underlain by basalt. Observations of the basalt in the field and from familiarity with basalts elsewhere lead the experienced hydrogeologist to conclude quickly that it in essence is a drain for the seepage from the tailings pond. For that reason very little of the seepage ever entered the alluvium to the east of the tailings pond. The seepage either followed the basalt flows down the valley southeast of the site or it moved vertically downward through it, then through the fault to the underlying San Andres aquifer. Comparison of the seepage plumes for the alluvial aquifer and for the San Andres aquifer will substantiate what happened in the subsurface. The existence of a pod of sulfate and a pod of chloride southeast of the ponds also lends credence to the fact that some of the seepage may have moved horizontally through the channel in which the basalt flow was deposited (the movement may have been preferential). The next key factor in understanding the anomalously low concentrations is the Anaconda water supply wells. These water supply wells were located in the San Andres aquifer south and east of the pond. These water supply wells clearly created a cone of depression in the San Andres aquifer. Water pumping rates for these wells are essentially nonexistent (as Dames and Moore notes in their modeling report). However, water quality data for the wells are available. These data show that during the period of operation of the mill, the pumpage from the Anaconda well 2, for example, contained high values of sulfate and chloride. Consequently one is led to the conclusion that the anomalously low concentrations of sulfate and chloride in both aquifers is a function of the hydraulic sink created by the Anaconda wells (not of low seepage rates or of low input concentrations of the seepage). Quite clearly the plume at the Anaconda Bluewater mill site is relatively clean because the seepage was recycled through the cones of depression of the Anaconda commercial water supply wells.

If you have any questions, please call.

Sincerely,

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