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United States Department of the Interior

OFFICE OF SURFACE MINING
Reclamation and Enforcement
P.O. Box 46667
Denver, Colorado 80201-6667

IN REPLY REFER TO:

January 30, 2004

Utah Division of Oil, Gas, & Mining
Coal Regulatory Program
1594 West North Temple, Suite 1210
P.O. Box 145801
Salt Lake City, Utah 84114-5801

Incoming
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Copy Karen
Bregg

RE: Review of Canyon Fuel Company – "Skyline" Mine – Groundwater Model Report

Dear Mr. Galecki:

In response to a request for technical assistance, The Office of Surface Mining Reclamation and Enforcement (OSM) is providing the attached comments on Canyon Fuel Company's flow model documentation for the Skyline Mine and surrounding area.

Should you have any questions regarding the attached comments, please contact me at (303) 844-1400 extension 1531.

Sincerely,

Paul Clark

Paul Clark
Program Support Division

(Attachment)

cc: Jim Fulton (Chief, DFD)
Ranvir Singh (Branch Chief, PSD)
Rick Holbrook (Branch Chief, PSD)
Mitch Rollings (Utah Mine Team Leader, DFD)

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DIV. OF OIL, GAS & MINING

United States Department of the Interior

OFFICE OF SURFACE MINING
Reclamation and Enforcement
P.O. Box 46667
Denver, Colorado 80201-6667

IN REPLY REFER TO:

An Evaluation of the Skyline Flow Model Findings Prepared by Hydrologic Consultants, Inc. of Colorado

Reviewed by:
Paul Clark
Office of Surface Mining Reclamation and Enforcement
Western Regional Coordinating Center

January 2004

1.0 Purpose of Groundwater Model Development

In response to significant groundwater inflows at Skyline Mine, Hydrologic Consultants, Inc (HCI) developed a hydrogeologically-based numerical groundwater flow model at the direction of Skyline Mine, operated by Canyon Fuel Company (CFC). Understanding of the area hydrology is limited due to the availability of data and the nature of geologic faulting in the area. Therefore, in an effort to refine the conceptual understanding of the groundwater system, the flow model was developed by incorporating the available information in the vicinity of Skyline Mine. The model was then utilized as a management tool for surface and groundwater resources. Of specific significance, the flow model was used to evaluate the Electric Lake surface water and mine inflow water interaction, if any, so that the water resources may be appropriately managed.

2.0 Office of Surface Mining (OSM) Review Objectives

The Utah Division of Oil, Gas, and Mining (the Division) has the regulatory responsibility of protecting the hydrologic balance from significant impacts in accordance R645-301-730. Specifically, R645-301-731.211 requires that the permit application include a ground-water monitoring plan based on the probable hydrologic consequences (PHC) determination required under R645-301-728 and the analysis of all baseline hydrologic, geologic and other information in the permit application. The monitoring plan is required to identify the quantity and quality parameters to be monitored, sampling frequency and site locations, and describe how these data may be used to determine the impacts of the operation on the hydrologic balance. R645-301-726 explains that the use of modeling techniques, interpolation or statistical techniques may be included as part of the permit application, but actual surface- and ground-water information may be required by the Division for each site even when such techniques are used. Therefore, CFC elected to submit a numerical groundwater flow model as supplemental information to the PHC determination.

The Division requested technical assistance from OSM on October 28, 2003 to evaluate the hydrogeologically-based numerical groundwater flow model for the Skyline Mine area. The model code was not provided for review since it was developed with proprietary software, but a Findings Report documenting the model setup and simulated results was submitted to the Division as part of the PHC and is the subject of this technical review.

3.0 Evaluation of Conceptual Model

All models are based upon a conceptual understanding of the hydrologic system. Conceptual models are derived from available data and supplemented with assumptions. Like all models, HCI's model is built upon an assumed understanding of the hydrologic regime in the Skyline Mine area. Assumptions built into the model directly affect model results; therefore, it is important to understand the effects certain assumptions have on the flow model results. For that reason, discussion of the effects of these assumptions chosen in HCI's model, not the appropriateness, is warranted.

3.1 Conceptual Model Assumptions

It should be noted that OSM did not evaluate the PHC determination that "the available data suggests the water entering the mine is sourced by the Star Point Sandstone. The water in the Star Point is under potentiometric head and is forced up through faults and fractures encountered during mining" (PHC Addendum, A-19). Therefore, assuming the water from the pumped fault and mine inflow water are primarily derived from groundwater, the impacts of concern are drawdown as it relates to water quantity and the hydrologic balance, and impacts to base flow and spring discharge associated with drawdown. The following sections identify significant assumptions of the conceptual hydrologic model, and discuss the how the chosen assumptions may influence the results of drawdown and associated impacts.

3.1.1 Hydrostratigraphic Units

The Mancos Shale is generally accepted as a confining unit, and appropriately considered the bottom of the flow model due to its low permeability. The remaining geology between the Mancos and the surface was divided into hydrostratigraphic units for flow simulation. Hydrostratigraphic units are typically determined to be zones of similar hydrogeologic properties. Therefore, knowledge of the depositional history and regional water level data are often valuable in identifying the different hydrostratigraphic units.

The development of the hydrostratigraphic unit categories and associated model layers is vaguely presented in the findings report. Most importantly, the findings report details the modeled thickness of some layers, but not others. Therefore, it is difficult to evaluate the significance of each hydrostratigraphic unit on the flow system, and determine if the conceptual model is adequately represented in the numerical model.

In general, it appears sandstone and coal zones were categorized into separate hydrostratigraphic units due to their assumed higher hydraulic conductivity. Likewise, interburden units were categorized based on an assumed low hydraulic conductivity. Hydraulic conductivity is a primary mechanism for controlling groundwater movement.

A primary assumption is that the mine inflow and pumped water originate from deeper Star Point Formation groundwater. Therefore, it is unclear why the upper two model layers are represented. An attempt was made to couple the surface and groundwater flow systems. However, the top layer has a simulated thickness of 150 feet, and assigned a high hydraulic conductivity value to allow recharge to stream baseflow. Although unclear in the documentation, it appears that the second layer is approximately 2000 feet thick, with assigned hydraulic properties consistent to those of the Mancos confining unit. As stated on page 3 of the findings report, "CFC requested HCI to update the [early version] ground-water flow model with additional water-level data, and to incorporate surface-water effects (specifically surface recharge to the ground-water system)." The early flow model version "did not include surface-water hydrology and included a no-flow top boundary to represent the thick, relatively-impermeable Blackhawk Formation above the mine. For that reason, it appears that the current model stratigraphy was updated from the early version by assigning a high hydraulic conductivity value to the upper most 150 feet, then a low hydraulic conductivity value for the next 2000 feet.

Honoring the assumption that the mine water and pumped water are derived from groundwater, this approach is reasonable, and adequately represented in the model. However, if a model were to be constructed to evaluate potential impacts associated with drawdown, coupling surface and groundwater flow would not be advisable, as the coupling only leads to increased assumptions.

3.1.2 Star Point and Blackhawk Formations

The thickness of the Star Point Formation is identified as locally variable, ranging in thickness from 200 feet to 1,500 feet. The interbedded shale/siltstone units were homogenized into simulation of the Star Point Formation by assuming a horizontal/vertical anisotropy ratio of 5:1, and the Star Point Formation thickness varied from 500 feet to 1500 feet.

An isopach map depicting the aerial extent of the simulated Star Point Formation was not provided. Of most interest is the simulated thickness of the Star Point Formation near pumping centers, and area of pumping influence. If the Star Point Formation is modeled inappropriately thick, transmissivity may be higher than normal. If the Star Point Formation is modeled inappropriately thin, transmissivity will be lower than normal. A lower than actual transmissivity will create a steeper cone of depression localized in the area of the pumping well. Conversely, the effects of using a higher than actual transmissivity creates less drawdown at the pumping well, but the effects of drawdown propagate over a much larger area.

Similarly, hydraulic conductivity effects drawdown. When a lower than actual hydraulic conductivity is assigned, a steeper than actual cone of depression localized in the area of the pumping well will result. Conversely, the effects of using a higher than actual hydraulic conductivity creates less drawdown at the pumping well, but the effects of drawdown propagate over a much larger area.

A high hydraulic conductivity of 1 ft/day was assigned to the Storrs and Panther Sandstones of the Blackhawk Formation based on the results of pumping in the James Canyon wells. If the James Canyon wells are drilled into a high conductivity fault zone, there appears to be a poor basis for making the assumption that there is a uniform hydraulic conductivity throughout the Storrs and Panther Sandstones equal to that of the fault zone.

Additionally, HCI used several analytical techniques to evaluate long-term pumping and monitoring data to estimate hydraulic parameters for the Star Point Formation. The techniques are not described in the findings report; therefore, were not evaluated for reasonableness. The techniques were used to develop a value for specific storage. A low storatively value will induce a broad and deep cone of depression, and a high storatively value will induce a shallow and localized cone of depression.

3.1.3 Boundary Conditions

Model Boundaries

Page 21 of the Skyline Mine flow model discusses that the high hydraulic conductivity for the Blackhawk Formation is justified being increased up to 4 orders of magnitude since the laboratory permeability tests do not take into account highly conductive fractures. Yet, page 24, Section 3.2 discusses how "the faults juxtapose relatively permeable Starpoint sandstones against the lower-permeability Blackhawk Formation. Consequently, these model-bounding faults are assumed to prevent lateral groundwater flow throughout the entire model thickness, and are assumed to be no-flow boundaries." There appears to be a contradiction in the rational for the boundary conditions.

If the predictive drawdown reaches the model boundaries, and the boundaries are inappropriately constraining the model, the effect will be an exaggerated drawdown and associated cone of depression at the pumping centers.

Recharge

It is unclear how the deep aquifer system recharges to compensate for the mine inflow and pumped water. The Skyline Mine flow model indicates that "The model is constructed such that all ground water within the model domain is generated by recharge from precipitation" (Page 32, Section 4.3). It appears that the model has been set up such that recharge from precipitation infiltrates the upper 150 feet of the assumed highly permeable overburden, hits the underlying 2000 feet of low permeability overburden, creating discharge to the streams with measured base flow.

Additionally, it is presented that the Pleasant Valley and Fish Creek faults are no-flow boundaries, but the faults are able to discharge water from the deep aquifer to the streams. It appears that the no-flow fault boundaries have a considerable amount of water originating from the fault boundary. Since the model was developed using proprietary software, the water budget cannot be reviewed. A detailed water budget should be included.

Constant Head Boundary

Based on the objectives of this model, assigning a constant head boundary to Electric Lake appears appropriate since the model developer is able to review water gained and lost from the constant head boundary. Once again, since the model was developed using proprietary software, the water budget cannot be reviewed, and information pertaining to the water budget of Electric Lake should be provided. Caution of assigning Electric Lake as a constant head boundary is advised if the objective shifts to evaluating predictive drawdown. Use of the constant head boundary for Electric Lake may mask the effects of drawdown.

Additionally, it is stated, "During the predictive runs, the pumping node is converted to a constant head node when the calculated water level reaches the elevation of the top of the Panther Sandstone. This numerical approach enables the reduction in the pumping rate of JC-1 due to dewatering of the deep ground-water system to be replicated" (Page 38, Section 4.6). The rationale for this approach is not clear, but may be reasonable to meet the objectives of this model. However, during predictive simulations, this may prematurely establish steady state. It may be more reasonable to change the pumping rate within a set of time steps for long-term drawdown predictions.

Sources and Sinks

JC-3 is not simulated in the model. Once again, it may be reasonable to take this approach given the current objectives, but it is not reasonable for predictive drawdown simulations.

Page 38, Section 4.6, states "The major ground-water inflows are all explicitly simulated by specific drain nodes." This setup is confusing. Are the drains taking water out of the system? If the drain nodes simulate groundwater draining into the mine, and JC-3 pumps the groundwater that has drained into the mine, shouldn't JC-3 be simulated as pumping in the model since that water is coming directly from the groundwater system, or are the drain nodes taking water out of the system?

3.2 Appropriately Translating the Conceptual Model to a Numerical Model

After the conceptual model of the flow system is developed, a numerical model can be constructed by assigning physical processes that occur within in the system to governing flow equations. The validity of the numerical model and its depiction of the conceptual

model are often verified through a process of calibration, sensitivity analysis, model verification, and post audit, and are the topics of this section.

3.2.1 Calibration

Calibration for HCI's Skyline Model was a process of adjusting the conceptual model parameters and boundaries to reasonably replicate field observed conditions for pre-mining water levels and estimated stream baseflows. A traditional method of evaluating a successful calibration is creating a scatter plot comparison of measured water levels to simulated water levels. Ideally, the data will plot on a straight 45 degree line passing through the origin, indicating that the model simulation was able to adequately represent field measured values. Deviation from the straight line should not be biased above or below the line. Most measurement data has some error associated with it. Therefore, all the data plotting on a perfect line would lead to some suspicion about the calibration.

HCI provided a comparison scatter plot as part of the model documentation. Overall, there appears to be an unbiased distribution based on the scatter plot provided. However, it is unclear what hydrostratigraphic units the various water levels represent. There may be a bias in a particular hydrologic zone. It is recommended that the comparison scatter plot be color coded to represent all the water levels of each unique hydrologic zone.

In addition to a graphic of the simulated water levels plotted against the measured water levels, several other graphics could easily be constructed with the residual water level data. A residual water level is the result of the measured water level minus the simulated water level. However, HCI did not provide this critical information in the findings report. It is strongly recommended that HCI provide, at a minimum, a table of the observations, simulated values, residuals, and weighted residuals. Since the nature and level of uncertainty associated with observation measurements may vary, the modeler may "weight" certain measurements due to increased data confidence. HCI should disclose if any measurements or data were weighted, and the procedure for inclusion into the model.

3.2.2 Sensitivity Analysis

A sensitivity analysis evaluates uncertainty of the parameters in a calibrated model. Typically, parameters for recharge, hydraulic conductivity, storage, and boundary conditions are changed to assess the degree of influence the parameters have on hydraulic heads. The degree of change should stay within reasonable conceptual model limits. For example, recharge may not be very well known for the area. Therefore, recharge may be doubled as part of the sensitivity analysis. If by doubling recharge, little effect is observed on the head targets, then one might be able to say that the model is insensitive to recharge.

Based on the Skyline Mine model documentation, it is unclear how in depth HCI performed a sensitivity analysis on the flow model. The sensitivity analysis appears

specifically focused on hydraulic conductivity of the Blackhawk Formation and the diagonal fault. Several other sensitivities should be evaluated and documented.

3.2.3 Model Verification

Groundwater models may also be evaluated for reasonableness and acceptability through model verification. Verification for the Skyline model may be performed by using the steady-state model to simulate known drawdown based on the known pumping rate.

HCI appears to have used the drawdown information as part of the transient calibration. Although using drawdown for transient calibration is reasonable, it is unclear if there are two separate calibrated models: one for transient and one for steady-state. Regardless, it does not appear that the drawdown data was used for model verification.

4.0 Assessing the Confidence and Validity of Model Findings

HCI identifies "The most significant finding of the model simulations is that it is possible to account for essentially 100 percent of the inflow to the Skyline Mine by depletion of storage in the deep groundwater system" (Page 44, Section 5.1). This statement was derived from (1) gross assumptions in the conceptual model, (2) a lack of understanding of groundwater recharge and discharge, (3) insufficient documentation to evaluate model calibration, (4) insufficient documentation to evaluate the sensitivity analysis, and (5) a lack of model verification. Therefore, the above finding statement and use of the model for predictive purposes are extremely questionable.

The following excerpt from the Skyline Mine model documentation fully discloses the unreliable nature of the Skyline model for predictive purposes:

> Consequently, the conceptual hydrogeologic model of the Skyline Mine area is still being developed. Although some components such as recharge or stratigraphic thicknesses can be reasonably well defined by the available data, other major components such as the vertical hydraulic conductivity of the overburden units or the hydraulic characteristics of faults can only be evaluated from the reasonableness of the results of preliminary numerical simulations using assumed values. As such, the Skyline model is still in a [exploratory] stage in which it is being used to learn about the characteristics of the regional ground-water flow system. Nonetheless, it is also being used at the same time to predict hydrologic outcomes under alternative assumptions. (Page 5, Section 1.2)

For these reasons, OSM finds HCI's groundwater model incomplete. Revising the model documentation to satisfy the comments above would result in a more complete model, which would warrant a further review of the model's reliability and predictive capability.