6. Scofield Reservoir Phase I, 314 Clean Lakes Study, 1980 - 1982, Richard L. Denton, Project Officer; Myron I Cox, Water Quality Specialist; Lavere B Merritt, Ph. D., Brigham Young University in cooperation with the Utah Department of Health, Division of Environmental Health, Bureau of Water Pollution Control, and Brigham Young University

Appendix F October 1, 2002 Internal Correspondence, Expected Water Inflow Rates

Appendix G Petersen Hydrologic Report

Investigation of Fault-related Groundwater Inflows at the Skyline Mine
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HCI HYDROLOGIC COLORADO CONSULTANTS, INC. HCI TASCA an company

Hydrologic Consultants, Inc. of Colorado
143 Union Blvd., Ste. 525
Lakewood, Colorado 80228 USA
telephone: 303-969-8033 fax: 303-969-8357
e-mail: hcico@hcico.com http://www.hcitasca.com

TECHNICAL MEMORANDUM

TO: **Mr. Chris Hansen** **HCI-1787**

FROM: **Roger Howell – HCI**

SUBJECT: **Status of Ground-Water Flow Modeling for Skyline Mine**

DATE: **May 23, 2002**

1.0 INTRODUCTION

Hydrologic Consultants Inc. of Colorado (HCI) is constructing a numerical model for Canyon Fuel Company (CFC) to represent ground-water flow in and around the Skyline Mine. The goal of this project is to develop a hydrogeologically-based model that will describe the hydrologic system in the vicinity of the Skyline Mine, and that can be used to identify potential effects of mining on the ground-water and surface-water resources of the region. The current objectives for the ground-water model are:

- To investigate the relationship between deep ground water and surface hydrology in the vicinity of the Skyline Mine.
- To evaluate various alternative sources and pathways of ground-water inflow to the Skyline Mine.
- To estimate the effect of mine inflow and pumping on surface-water resources.
- To predict future mine inflows and required pumping rate from dewatering wells.

1.1 History of Ground-water Modeling at Skyline

An early version of the Skyline ground-water flow model was completed in May 2002 (the May version) for the limited purpose of predicting dewatering requirements for mining in the Flat Canyon Tract. To save time and costs, the May version of the model did not include surface water hydrology, but modelled a no-flow top boundary to represent the thick, relatively-impermeable Blackhawk Formation above the mine. The assumption of low flow through the Blackhawk Formation was based on results of geochemical and geological studies at other sites in Utah (Mayo, and Morris, 2000) which indicate that the deep ground waters that provide inflows to the mine are much older than, and may not receive a significant amount of recharge from, the shallow ground-water system that draws recharge from precipitation. The results of the May version of the numerical model were presented at a meeting at Skyline Mine on 31 May 2002.

In August 2002 CFC requested that HCI upgrade the numerical ground-water flow model to include surface-water effects (specifically surface recharge to the ground-water system). Consequently, the May version of the model was updated with incorporation of upper stratigraphic units (Blackhawk Formation above the coal seams), more accurate fault locations, surface topography, and surface hydrologic features. Preliminary model runs conducted in October 2002 showed that the deep and shallow ground-water systems could be simulated together. However, the results were very sensitive to geological assumptions, primarily to assumptions regarding the thickness and elevation of the Starpoint Sandstones. At that time very little direct, concrete information about the deep portions of the Starpoint Formation was available.

In October it was decided by CFC and HCI to discontinue further development of the model until a geological compilation could be completed. A comprehensive study was subsequently undertaken by Skyline and their consultants to assess the physical extent of the Starpoint Sandstones, including a regional study of stratigraphy, and of structures (faults) that might limit or enhance the transmissivities of the sandstones. The study examined existing data from diverse sources, including drillhole logs from numerous gas-exploration wells drilled in the region; and

geological studies, including university theses, government investigations, and proprietary industry (mining and petroleum) reports.

2.0 CURRENT GROUND-WATER FLOW MODEL

The geological compilation was largely completed by mid March 2003, and the results have since been incorporated into, and used to constrain, a current ground-water flow model. The current model has been successfully calibrated, and used in preliminary evaluations of ground-water flow and surface-water/ground-water interaction. The current model is described briefly below.

2.1 Area of Study

The hydrologic study area (HSA) of the current ground-water flow model is centered on the Skyline Mine in the northern Wasatch Plateau of central Utah. The area generally lies west of Pleasant Valley and the towns of Scofield and Clear Creek, and east of Gooseberry Valley and Skyline Drive. The HSA extends south to just beyond Electric Lake dam on Huntington Creek, and north to Fish Creek (Figure 1). The HSA is composed mostly of high, somewhat flat-topped mountains with deeply incised, heavily wooded valleys. The area is characterised by considerable relief with elevations ranging from 7,700 ft (NGVD) at the mouth of Fish Creek to over 9,800 ft at the headwaters of Gooseberry Creek. Ephemeral streams on the west and east flanks of the HSA flow northward and discharge through Scofield Reservoir, while streams in the center of the HSA flow southward and discharge through Electric Lake Reservoir.

2.2 Description of Numerical Model

The term "model" or "numerical model" refers to a specific combination of a code, a finite-element mesh, hydrologic data, and boundary conditions that describe a specific set of site conditions. The term "code" or "numerical code" is used to refer to a computer program that solves a system of equations that describe a ground-water flow problem. The term "numerical

model" should not be confused with the "conceptual hydrogeologic model" which is a qualitative description of the physical ground-water flow system simulated by the numerical model.

2.2.1 Numerical Code used in Current Model

The numerical modelling described in this letter report utilises the numerical code MINEDW which solves three-dimensional ground-water flow problems with an unconfined, or phreatic, surface using the finite element method. This code was developed and copyrighted by HCI (Timothy J. Durbin, P.E., is the primary author) to solve problems related to mine dewatering. MINEDW has several special attributes that specifically address conditions common to mine dewatering (Atkinson and others, 1992). MINEDW also utilises a variable flux boundary condition as an alternative to generating unnecessarily large model grids.

2.2.2 Model Mesh and Discretization

The current model grid is shown in Figure 2. Other physical properties of the model are listed in the table below.

Discretization of Model	
Number of Layers	13
Number of Nodes	29,316
Number of Elements	53,040
Number of Hydrogeologic Units	32
Model Area (mi^2)	88

2.3 Inputs to the model

The basic data that have been compiled for use in the ground-water flow model are listed below.

1) Geology, including a comprehensive compilation of the structure and stratigraphy of the Starpoint Sandstones.

2) Water level data from 21 piezometers, including pre-mining records from archived records, and current recordings of water-level changes.

3) Mining history, including a panel-by-panel chronology of the excavation of the Skyline Mine.

4) Total mine inflow, and timing and discharge rates of individual mine inflows

5) Pumping schedules and rates from the James Canyon Wells.

6) Stream baseflows and precipitation records.

7) Measured and estimated hydraulic parameters of the principal formations.

8) Boundary Conditions.

9) Constraints of geochemistry and reservoir operations

2.3.2 Hydrogeologic Units

Eight major hydrogeologic units have been identified in the HSA. The units are shown graphically in Figure 3. In general, from shallowest to deepest, they include overburden, upper coal (LOA) and lower coal (LOB), Storrs and Panther Sandstones, and Starpoint Sandstone, with interburden units between all.

Overburden comprises the top 3 layers of the model. Multiple layers of overburden are necessary both to model a surface zone more open and porous than rocks below, and to model the propagation of fractures upward through the lower overburden as mining progresses. Initial hydraulic conductivities (pre-mining) are relatively low compared to all other hydrostratigraphic units in the model, and horizontal/vertical anisotropies are high (100:1).

Both coal units (LOA and LOB) initially are assigned relatively high horizontal hydraulic conductivity (similar to a sandstone) with anisotropies of only 1:1, representing heavily-cleated coal. The upper coal is differentiated in order to account for early mining and mine inflows.

The Starpoint Formation is modelled with two layers for numerical reasons. Both layers include, conceptually, multiple sandstone units and shales interbedded with the sandstones. Consequently, the Starpoint layers are assigned properties that account for the anisotropy imparted by the interlayering.

Interburden layers occur between the coal and sandstone layers. The interburden layers initially are assigned properties similar to the lower (pre-mining) overburden.

The Mancos Shale, beneath the Starpoint Formation, is implicitly modelled as a no-flow boundary at the base of the model.

2.3.3 Surface-Water Flows

Streams in the HSA were simulated using drain nodes along the courses of the streams. The drain nodes were assigned heads taken from U.S.G.S-based topographic data. Fluxes through the drain nodes were then summed to yield a value for streamflow, from which recharge rates could be checked.

Electric Lake was simulated with constant head nodes. A head of 8,545 ft represents the mean reservoir stage over the last 28 years.

2.3.4 Pumping and Mine Inflows

Pumping from JC-1 and JC-2 is simulated explicitly in the model as a pumping well node located on the Diagonal Fault. Mine inflows are implicitly simulated using drain nodes, with leakance matched to estimated inflow rates through time. The inflow nodes are also located along the appropriate faults.

2.3.5 Mining

Ground-water inflow induced by mining is simulated by assigning drain nodes to the area being mined. We have incorporated lower node leakance values (0.0001) for room and pillar areas than for longwall mining areas (1.0) to be able to simulate the lower inflows that are known to have occurred in the room and pillar areas.

In the numerical simulations, the hydraulic conductivity of the approximately 100-ft thick zone above a panel that is mined is increased by a factor of 10 (as described in Section 3.0). The longwall operation is simulated on a yearly basis based on existing and proposed mine plans provided to HCI by Skyline.

2.4 Model Boundaries

As in earlier versions of the model, the boundaries for the Skyline model have been selected to coincide with natural hydrologic boundaries, where possible, to limit the amount of ground-water and surface water flow that naturally enter and exit the HSA. The east and west boundaries of the model, as before, are defined by the Pleasant Valley and Gooseberry Faults, respectively. Both regional faults juxtapose the Starpoint Sandstones against thick sequences of low-permeability sediments. The north model boundary coincides with the south fault of the Fish Creek graben, in Fish Creek Canyon. The final boundary, at the south end of the HSA south of Electric Lake, is also defined (though only approximately) by surface-water divides. With the exception of the southern boundary, all boundaries are treated as no-flow boundaries in both steady-state and transient simulations.

The southern boundary of the current model is not as well constrained as the other boundaries. The southern boundary west of the Connelville Fault, for steady-state calibration, is defined with constant-head nodes in order to match the sloping piezometric surface seen in well data. The nodes are then assigned a constant flux (measured during steady state) for transient simulations. East of the Connelville Fault the southern boundary is set as no-flow partly as a default condition. Specified flux will not work to the east as it does to the west because of the exposures of Starpoint Sandstone in Huntington Canyon. The no-flow boundary in this reach forces ground water to discharge from the sandstones into Huntington Creek, as seen in the numerous springs along the canyon walls.

3.0 RECOMMENDED EXPANSION OF CURRENT MODEL

The ground-water flow model described above calibrates very well to pre-mining water levels measured and projected in regional piezometers. The transient calibration closely matches local drawdown of water levels, and mine-inflow rates. It is HCI's opinion that the current model provides an accurate characterization of ground-water flow in the vicinity of Skyline Mine.

However, preliminary simulations have shown the ground-water flow around the south end of Electric Lake to be very sensitive to the southern boundary conditions. Because of the intense interest that has developed recently in the interactions between surface water and ground water near Electric Lake, this model may be used more to simulate those interactions than for any other use. Consequently, HCI recommends that the uncertainties due to the current southern boundary be removed.

The assignment of the current southern boundary conditions follows standard modeling techniques. However, the boundary location, reasonable when the model was to be used for mine-dewatering scenarios, may now be inappropriate for scenarios involving surface-water bodies – especially Electric Lake. To provide a more robust and less potentially controversial model solution, the boundary should be moved to a more definitive topographic or hydrogeologic divide. HCI suggests expanding the model domain southward, and setting the eastern portion of the southern boundary in Left Fork of Huntington Creek. There the nodes can be assigned constant head values equal to the elevation of the bottom of the Starpoint Sandstones in that canyon. The western portion of the southern boundary might be moved as far south as the divide between Scad Valley and Joes Valley, and the nodes assigned a no-flow condition coinciding with the surface-water divide.

Expanding the model domain will require collection of additional geologic and hydrologic data to cover the new area. A preliminary search has shown very little available geologic data in this area. Consequently, some time will be needed to conduct field mapping of the major strata and structures. During that period a search will also be made for any records of deep drilling in the area of interest, as well as for any water-level and useable stream flow data. HCI estimates that

the additional field work and data search will take until mid August, 2003, at which time modeling can resume. A final report of model findings, therefore, will be prepared by September 30, 2003.

4.0 REFERENCES

Atkinson, L.C., Durbin, T.J., Azrag, E.A., 1992, estimating the effects of non-darcian flow on inflow to a pit and slope stability: Annual meeting, Society for Mining, Metallurgy, and Exploration, Phoenix, Az., February 25, 1992.

Mayo, A.L., and Morris, T.H., 2000, Conceptual model of groundwater flow in stratified mountainous terrain, Utah, USA *in* Groundwater – Past achievements and future challenges, Sililo, O., et al., eds., Proceedings of XXX IAH Congress on Groundwater, Cape Town, South Africa, 26 November - 1 December 2000, A.A. Balkema, Rotterdam, pp. 225-229.

PETERSEN HYDROLOGIC

5 June 2003

Mr. Chris Hansen
Environmental Coordinator
Canyon Fuel Company, LLC
Skyline Mine
HC 35 Box 380
Helper, Utah 84526

Chris,

At your request I have prepared this summary of the ongoing dye tracing study at Electric Lake. The dye placement activities, dye monitoring locations, sample collection procedures, and study results to date are summarized in this letter report. It should be noted that this information is preliminary in nature. Details regarding PacifiCorp's dye placement activities are based largely on communications from PacifiCorp personnel. PacifiCorp is also placing and retrieving dye collection packets, but we are unaware of their procedures and results.

In mid-February 2003, PacifiCorp personnel injected an unknown quantity of fluorescent dye into the substrate of Electric Lake near three inferred fault locations. It was thought by PacifiCorp that significant quantities of water were leaking from Electric Lake through these faults. The specific type of dye used is not known, although it was apparently a type of fluorescein dye.

Subsequent to the initial dye emplacement, a second dye injection took place on 1 April 2003. It is reported that on this date approximately 35 pounds of fluorescein dye was injected into the southernmost north-south trending fault, and approximately 50 pounds of eosine dye was injected into a northerly east-west trending fault in the lake bottom. At both locations, the powdered dye was mixed onsite with lake water in plastic containers. The liquid dye mixture was then pumped though a PVC pipe into the sediments at the bottom of the lake.

A dye-monitoring program was initiated by Petersen Hydrologic on 5 March 2003 to monitor for the presence of dye in surrounding groundwater and surface-water bodies. Dye monitoring stations included locations within the Skyline Mine, JC-1 discharge, locations in Huntington Creek and its tributaries below Electric Lake, springs and wells in the Huntington Creek and Mud Creek drainages, and locations in Mud Creek and its tributaries. Dye monitoring locations are shown on Plate 1.

2695 N. 600 E. LEHI, UTAH 84043 (801) 766-4006

Monitoring for fluorescent dye was performed by placing laboratory-supplied packets containing activated charcoal into a water source for a period of time. The activated charcoal packets were wired to heavy objects and placed in actively-flowing portions of the spring or stream substrate. At each monitoring event the charcoal samplers were collected and new packets were placed. New latex gloves were worn during each monitoring event to prevent sample contamination. The collected sample packets were double bagged and kept under refrigeration until delivery to the laboratory. Samples were shipped to the laboratory under refrigeration via overnight service in new, sealed shipping coolers.

Fluorescent dye accumulates on the activated charcoal if a pulse of dye passes by the sampling device. Using the charcoal packet sampling method, continuous monitoring for dye is achieved, and dye detections at the parts-per-trillion level are possible. Laboratory detection of dye on the activated charcoal samplers was performed by Ozark Underground Laboratory, Inc. of Protem, Missouri. It is our understanding that this same laboratory is being used by PacifiCorp for their laboratory dye analyses.

Dye monitoring results are listed in Table 1. It should be noted that the laboratory reported dye concentrations listed in Table 1 are concentrations of dye in the eluant solution associated with the extraction of the dye from the charcoal samplers. The reported values are not representative of instantaneous dye concentrations in the water source.

It is noteworthy that no dye has been detected in JC-1 discharge in the 2½ months since the dye was placed in the lake. As anticipated, dye has been detected in the outflow of Electric Lake and at downstream locations. Low concentrations of both fluorescein and eosine dye have also been detected in other locations in the study area (Table 1)[1].

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[1] In addition to the dye monitoring program described above, an investigation was performed to determine the extent to which the use of antifreeze could be responsible for the trace concentrations of fluorescein dye detected in the vicinity of the Skyline Mine (Table 1). Antifreeze is widely used in mine vehicles and equipment, both underground and at the surface. Employee and vendor vehicles parked at the mine parking area and vehicles traveling on State Highway 264 adjacent to Eccles Creek also utilize antifreeze.

A sample of antifreeze of the type used in mine equipment was obtained from the mine shop for analysis. The antifreeze was diluted with dye-free distilled water to a concentration of approximately 1.2%. A charcoal sampler was placed in this solution for a period of 2.75 hours. Laboratory analysis of this charcoal sampler indicated a positive detection for fluorescein dye at 505 ppb. To determine whether fluorescence is present in runoff from the mine facilities, charcoal samplers were placed in two surface-water drainage collection systems at the mine. Laboratory analysis indicates that both of these charcoal samplers tested positive for fluorescein (9.76 ppb and 2.24 ppb; Table 1).

The results of this antifreeze investigation suggest that fugitive antifreeze may be responsible for trace fluorescein detections, particularly those in areas where water could have been influenced by water coming from highways or areas where mine equipment was operated.

Please feel free to contact me if you have any questions in this regard.

Sincerely,

Erik C. Petersen, P.G.
Principal Hydrogeologist