Memorandum

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cc: Ross Micham, Water Division, Underground Injection Control Branch, U.S. Environmental Protection Agency

From: Ann Maest, PhD, Stratus Consulting, Inc. and Robert Prucha, PhD, Integrated Hydro Systems

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Subject: Summary of UIC issues for the KEMC Eagle Project, Michigan

We are currently preparing a report on underground injection control (UIC) issues related to Kennecott Eagle Mineral Company's (KEMC) Eagle Project. The report is prepared on behalf of the Keweenaw Bay Indian Community and will be delivered to your office next week. This memorandum contains a summary of the most important points in our report.

The aquifers that will be impacted by KEMC's discharges are protected underground sources of drinking water (USDWs) because they: contain a sufficient quantity of groundwater to supply a public water system; contain fewer than 10,000 mg/l total dissolved solids; and have not been declared exempted aquifers under the UIC program. Assessing realistic potential impacts to the drinking water aquifer potentially impacted by KEMC's treated water infiltration system (TWIS) requires a thorough understanding of several interrelated hydrogeologic and geochemical issues, including the current and post-discharge groundwater flow systems; water quality and quantity entering and exiting the treatment plant; and the behavior of the TWIS discharge in the aquifer.

Our analysis shows that KEMC has seriously underestimated the potential impacts to the USDWs in the TWIS area. A proper analysis of the potential impacts to the USDWs must consider inflows to the TWIS, wastewater treatment plant (WWTP) issues, and hydrogeologic and geochemical issues downgradient of the TWIS. A summary of the major issues related to these areas is included herein.

1.0 Inflows to the TWIS

The major hydrogeologic issue regarding inflow to the TWIS is that the estimates of mine inflow are too low by several factors to an order of magnitude. This is a critical factor in the overall design of the TWIS, because the largest component of flow at the TWIS derives from inflow to the proposed underground mine. KEMC's modeled estimates of mine inflow are too low for the following reasons:

- Hydrogeologic characterization and conceptualization were inadequate.

- Modeling did not include or consider major water-conducting structural features present throughout the area.
- Modeling assumed that faults in the lower bedrock did not continue into the upper bedrock.
- The effects of crown-pillar failure in the mine or increase of hydraulic conductivity due to dilation of the rock mass were not evaluated as a contingency or as part of the model.
- The effects of mine workings, including the access tunnel, were not considered in the model.
- Simulated flows were actually not high enough to dewater the access tunnel and the lower portions of the mine.

When more realistic assumptions are used as modifications to the Golder FEFLOW model, much higher inflow estimates are predicted. The more realistic higher inflows are supported by actual inflow rates for similar underground mines in the area, which KEMC did not consider.

In addition to underestimating likely mine and WWTP inflow rates, KEMC has underestimated the concentration of contaminants in mine drainage water, and has, therefore, underestimated contaminant concentrations in water entering the WWTP. The following points describe the relevant geochemical issues and briefly explain why we believe KEMC's analysis underestimates input concentrations to the WWTP:

- The Eagle deposit (a massive sulfide ultramafic ore body) is similar to other ore bodies that have produced acidic waters with high concentrations of base metals such as nickel and copper.
- The ore and its host rock, which comprise the vast majority of the managed material at the Eagle Project, clearly have a moderate to high ability to produce acid and contaminants and a low ability to neutralize the acid produced. The surrounding sedimentary rocks also have a high ability to produce acid and leach metals, with somewhat more ability to neutralize the acid produced.
- KEMC's assessment of mine leachate quality is not representative of conditions expected in the underground mine during or after operations. KEMC ignored the presence of development rock in the underground mine and the presence of a larger and more mineralized crown pillar, and underestimated surface area and mine drainage concentrations, including concentrations of nitrate in the underground mine during operations.
- Comparison of our and KEMC's modeled WWTP inputs shows that predicted concentrations of many metals, including aluminum, barium, beryllium, cadmium, calcium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, and zinc, are substantially higher in our

analysis. The higher values are largely the result of the higher predicted concentrations in drainage coming into the underground mine. Therefore, KEMC's predictions of water quality entering the WWTP are very likely underestimated.

2.0 Water treatment issues

Wastewater from sulfide mining, and the Eagle Project in particular, poses significant treatment challenges. The composite water from the mine (which derives from many sources) is unusual and possibly unique because it includes acid mine drainage, saline water, and the presence of boron, which is notoriously difficult to remove. Individually these types of wastewaters are treated relatively successfully, but the treatment of a combination of such wastewaters is untested and remarkably complicated. The fact that the WWTP contains so many components is an indication of how difficult it will be for KEMC to treat the wastewater generated by the mine to acceptable levels. The salient treatment issues are summarized below:

- The most common type of treatment for acid mine drainage is lime precipitation, and the most common type of treatment for saline waters is reverse osmosis (RO). Because of the unique combination of contaminants, both types of treatment are proposed for the Eagle Project WWTP. While other RO systems have worked for mine drainage, this system is one of the only ones that will be required to work 24 hours a day, seven days a week.

- We expect that the influent volume for the WWTP easily will be one order of magnitude higher than predicted by KEMC. If the water volume is higher than KEMC predicts for the WWTP (350 gpm), the system will fail because it is beyond its design capacity. The only solution would be to increase the size of the treatment system or discharge untreated or only partially treated wastewater. Increasing the size of the WWTP will require a major redesign effort and will require a major increase in the capacity of the TWIS and storage basin facilities on the Site.

- The WWTP influent water quality likely will be substantially more contaminated than predicted, which will have an impact on the first stages of the water treatment system (first RO system), as well as the concentrate reduction process (CRP). When we apply the same removal efficiencies to our higher influent concentrations, we find that a number of contaminants will exceed MDEQ permit limits and Michigan standards for drinking water, and the TWIS discharge would not be protective of the USDW.

- KEMC does not have a contingency plan for treatment of higher than expected volumes of water or water with substantially poorer quality. The main storage contingency for higher WWTP inflows is diversion to the development rock storage area. If water needs to be diverted to the waste rock facility, the water will need to be retreated. The acid generated in this system will require additional treatment to allow for passage through the reverse osmosis system. The additional lime precipitation required will generate additional sludge, and the disposal of sludge has not been adequately addressed by KEMC. In addition, KEMC does not have a clear plan for quality assurance of the treatment process.

3.0 Downgradient TWIS issues

KEMC's characterization of the hydrogeology in the TWIS area is poor. Because of the lack of important characterization information, KEMC is unable to accurately identify the geologic setting, the extent of the hydrogeologic units in the TWIS area, or even the direction of groundwater flow. The major hydrgeologic characterization issues include:

- No boreholes or groundwater monitoring wells were completed in the area from the TWIS discharge point to KEMC's expected venting location. Without this essential information, it is impossible to generate a realistic cross-section of the hydrostratigraphic units in the TWIS area or reliable groundwater contours and flow directions. Available evidence suggests that Quaternary deposit stratigraphy in the TWIS area is complex and significantly different from other areas tested by KEMC to the west/southwest. The very limited available hydrogeologic data suggest that the current natural groundwater flow direction from the TWIS area could be to the north, to the east, or to the south. Additional wells are required to better define the groundwater flow direction.

- The cross-sections provided by KEMC do not accurately reflect geologic information from borehole logs; in particular, important information showing the presence of low permeability strata well above the water table was not transferred to the cross-sections. These low permeability layers will likely cause mounding of the discharge at the ground surface.

- KEMC conducted one "specific capacity" test in the TWIS area to characterize the hydraulic properties in one zone (D zone) of the Quaternary deposit aquifer. These types of tests are inappropriate to use in such a complex aquifer system and will not provide reliable information on hydraulic properties. KEMC's use of the test additionally flawed because most of the requirements needed to use the method were violated by KEMC.

- The standard type of test to use for estimating hydraulic properties is a multiple-well aquifer pump test. KEMC conducted only one multiple-well pump test to characterize hydraulic properties in the aquifer units underlying the TWIS. The test was too far away (>3,000 ft from the TWIS area). In addition, the stratigraphy of the test area differs dramatically from that of the TWIS. In the test area, silt and clay layers (B and C zones) are up to 90 ft thick and occur below the water table. In the TWIS area, these same units are above and below the water table, are much thinner, and are inverted in some cases (e.g., C zone lies above the B zone). Because of these shortcomings, the methods KEMC used to characterize the hydraulic properties of the TWIS aquifer will not provide accurate information on the behavior of the TWIS discharge in the groundwater system.

KEMC's prediction of groundwater flow direction ignores the existing hydrgeologic information and is highly uncertain.

- KEMC assumes, based on very little information, that groundwater will flow in a northeasterly direction from the TWIS. However, their own cross-sections through the TWIS indicate very high gradients towards the southeast, or 90 degrees from the direction they indicate on their inferred groundwater level contour maps.

- The Quaternary aquifer thickens and the bedrock surface declines to the east/southeast, which is consistent with the strong gradients to the southeast shown on their cross-sections. Yet KEMC assumes that groundwater flows to the northeast, despite having no wells in this "downgradient" direction.

KEMC failed to consider the effect of major hydrogeologic basin features (dikes, faults, major surface drainage features) on groundwater flow conditions in the TWIS discharge area and in areas potentially affected by this discharge.

- A major dike occurs directly beneath the TWIS. This feature can drain groundwater from the overlying glacial aquifers to the underlying bedrock aquifer. The dike is oriented southeast, and groundwater can easily flow along the elongated brecciated margin of the dike in a southeastern direction, rather than to the northeast as KEMC assumes. Groundwater flow to the southeast is consistent with the strong groundwater gradients shown on KEMC's own cross–sections through the TWIS.

- KEMC has not considered the potential for movement of TWIS discharge into the bedrock aquifer and has no wells in the bedrock in the TWIS area.KEMC failed to consider the effects of significant low permeability strata in the unsaturated zone beneath the TWIS. These strata were encountered in all but two of the nine borehole logs in the area. We conducted simple two-dimensional unsaturated zone flow modeling using the available information from the logs. Results from the modeling showed that infiltrating discharge from the TWIS will mound up to the ground surface beneath the TWIS, even using KEMC's assumed mine inflow rates. Our modeling also shows that the degree of mounding above low permeability material beneath the TWIS depends to a large degree on the lateral extent and configuration of the low permeability material. KEMC has not characterized the extent or configuration of these low permeability strata.

The proposed design of the TWIS groundwater monitoring well network is flawed because it does not account for the effects of shallow low permeability material in the unsaturated zone beneath the TWIS, or the magnitude of rising water levels in the Quaternary glacial aquifer or the direction of groundwater flow.

- KEMC proposes to screen monitoring wells (using 10-ft screens) across the current water table. However, discharge at the TWIS will cause water levels to rise by tens of feet. Post-discharge monitoring wells must be screened at higher levels in the aquifer to be representative of water discharged at the TWIS.

- The prevalence of shallow low permeability material well above the water table in all but two of the nine boreholes beneath the TWIS will cause infiltrating TWIS discharge to mound over these units. As a result, wells screened over the current water table directly beneath the TWIS will likely miss most if not all of the infiltrating TWIS discharge. At a minimum, KEMC should have proposed a monitoring network that screens across these important low permeability zones.

- As TWIS discharge infiltrates beneath the TWIS and then mounds up over low permeability units, it will start to flow laterally. Lateral flow will continue until the low permeability material pinches out. Whether the mounded discharge water actually reaches the current water table depends on the three-dimensional configuration, lateral extent, and hydraulic properties of the low permeability strata. This type of information must be collected and analyzed before a protective monitoring system can be designed.

The MDEQ'groundwater discharge permit is not protective of groundwater quality.

- Unless EPA requires a UIC permit for the TWIS discharge (and requires compliance with relevant health-based water quality standards), the only groundwater standards that will apply are the State's groundwater discharge permit limits.

- Our analysis shows that the discharge will likely violate the prohibition of fluid movement. Using the expected higher TWIS discharge concentrations, a number of metals and nitrate will likely exceed relevant drinking water standards.

- MDEQ's reporting requirements allow violations of a number of metals, including arsenic, beryllium, boron, cadmium, nickel, and thallium.

The MDEQ'groundwater discharge permit is not protective of surface water quality.

- Although the UIC rules do not address surface water impacts, the groundwater that discharges at the TWIS will eventually vent to surface water.

- MDEQ's permit limits and reporting requirements allow violations of surface water quality standards for cadmium, copper, silver, and zinc.

We will present a more detailed analysis of the points above in our complete report. We look forward to your response after reviewing our analysis.