ydrometrics, Inc.

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July 11, 1991

Tom Reid
Water Quality Bureau
Department of Health and
Environmental Sciences
Cogswell Building
Capitol Station
Helena, MT 59620

RE: Alternative 8 Groundwater Inflow - Estimation
SPGMR East Boulder Project

Dear Bruce;

The following is an analysis of groundwater inflow rates associated with Alternative 8 - Twin Production Adits, for the East Boulder Project. In the proposed action, Stillwater PGM Resources proposes a 16 foot diameter main access adit (East Boulder Adit) which would be driven for a distance of approximately 18,550 feet. In addition, a second 16 foot diameter adit (Brownlee Creek Adit) would be driven approximately 5,640 to a breakout near Brownlee Creek. Total adit length for the two adits is 24,190 feet. Steady state underground groundwater inflow rate for the adits and associated workings has been estimated to be 500 gpm (SPGMR East Boulder Plan of Operations, p3-10) based on experience at the Stillwater Mine, analysis of the known fault systems along the adit drive, and imposing the inflow limitations that sealing and grouting would provide. Based on the relative length of each adit, it is estimated that approximately 384 gpm would flow into the East Boulder Adit and 116 gpm into the Brownlee Creek Adit for a total of 500 gpm.

In Alternative 8, the 16 foot diameter adit would be replaced by two parallel 13.5 foot diameter adits and the Brownlee Creek adit would be eliminated. The twin adits would be closely spaced (approximately 25 to 50 feet apart) and would be driven sequentially. Estimation of the groundwater inflow rate for the twin adit alternative is based on predicted inflow rate of the single adit and on steady state flow equations for tunnels and wells. Because the twin adits would be closely spaced, the adits would essentially behave hydraulically as a single larger adit with an effective area equal to the sum of the area of the dual adits. In the case of two, 13.5 foot diameter adits, the equivalent adit would have a diameter of 19 feet. The following are inflow estimates based on analogies of the adit(s) functioning as 1) a tunnel acting as a steady state drain, and 2) a well under steady state pumping conditions. In general, inflow to tunnels or pumped wells is proportional to the logarithm of the radius of the tunnel or well.

Analysis of Tunnel as a Steady State Drain

An analytical solution for a tunnel acting as a steady state drain was derived by Goodman et al. (1965) and described by Freeze and Cherry (1979). In a homogeneous, isotropic media with hydraulic conductivity K, hydraulic head H, and radius r; inflow rate Q per unit length of tunnel is given by:

$$Q = \frac{2\pi KH}{2.3\log(2H/r)}$$

To solve this equation, it is necessary to know the variables K and H. These can be determined based on the estimated inflow rate (Q=500 gpm or 29.8 gpd/ft for the 24,190 feet of adit length) for the 16 foot diameter adit. Expressing the relationship between K and H :

$$29.8 = \frac{2\pi KH}{2.3\log(2H/8)}$$

$$K = \frac{10.9\log(H/4)}{H}$$

Based on a range of H values, the equation yields the following set of values for K:

K (gpd/ft^2)	H (feet)
0.434	10
0.152	100
0.026	1000

For the given effective diameter of 19 feet for the twin adits, inflow rate can be calculated based on the range of hydraulic conductivity (K) and hydraulic head (H) values by substitution into the initial equation:

$$Q = \frac{2\pi KH}{2.3\log(2H/r)}$$

Substitution yields the following estimated inflow rates for a tunnel with a diameter of 19 feet (equivalent to two 13.5 foot diameter tunnels):

K (gpd/ft^2)	H (feet)	Q (gpd/ft)	Q (gpm)*
0.434	10	36.7	472
0.152	100	31.5	394
0.026	1000	30.7	384

* Based on 18550 feet of adit length.

Analysis of Adit as a Steady State Pumped Well

Discharge from a well is related to the radius of the well by the Thiem equation:

$$Q = \frac{K(H^2-h^2)}{2.3\log(R/r)}$$

where Q = discharge
K = hydraulic conductivity
H-h = drawdown
R = radius of the cone of depression
r = radius of the well

An estimation of adit inflow rates can be made by assuming that an adit acts as a horizontal pumped well with inflow rate analogous to discharge. Assuming that hydraulic conductivity, radius of the cone of depression, and drawdown are equal for both the twin adit and the single adit scenarios; then adit inflow rates are proportional to the logarithms of the radii of the adits. The Thiem equation can be rearranged as:

$$\frac{Q_{9.5}}{Q_8} = \frac{\log(9.5)}{\log(8)} = \frac{0.9777}{0.9031} = 1.083$$

$$Q_{19} = Q_{16} \times 1.083$$

where: Q_{19} = inflow rate for effective diameter of 19 feet,
Q_{16} = inflow rate for 16 foot diameter adit.

For the single 16 foot diameter adit, discharge (Q_{16}) has been estimated to be 384 gpm. This yields an estimated discharge rate for the twin adits (effective diameter of 19 feet) of 415 gpm (384 gpm X 1.083).

Conclusions

The twin adit alternative is estimated to result in a net decrease in groundwater inflow to the underground workings due to the elimination of the Brownlee Creek Adit. Estimated inflow rate for the single adit alternative (16 foot diameter adit) is 500 gpm. Estimated inflow rate for the twin adit alternative range from 384 to 472 gpm based on analogy of the adits with tunnels and wells.

These quantitative estimates also agree with our conceptual model of the adits. Because the twin adits would be closely spaced they would essentially drain the same area and the second adit would be in the radius of influence of the first adit. In contrast, the Brownlee Creek Adit would drain a different area than the

East Boulder Adit which otherwise would remain untapped. Because the Brownlee Creek Adit is approximately one third the length of the East Boulder Adit, elimination of the Brownlee Creek Adit would be expected to result in the elimination of substantial groundwater inflow.

Water quality of mine discharge water associated with Alternative 8 is expected to be similar to Alternative 2 (Proposed Action) and Alternative 7 (Proposed Action with Modifications). As in Alternatives 2 and 7, Alternative 8 would employ a tunnel boring machine (TBM) to drive the adits. Any nitrogen load in discharge water would be derived from active mining areas. Since, Alternative 8 would not modify the proposed mining areas, the nitrogen loads associated with Alternative 8 will be similar to that predicted for Alternatives 2 and 7, and described in the East Boulder Mine Project Draft Environmental Impact Statement, and the Petition for Modification of Quality of Ambient Water - Stillwater PGM Resources. Because of similar mining methods and rock units encountered, concentrations of metals and other chemical parameters in discharge water associated with Alternative 8 also are expected to be similar to Alternatives 2 and 7.

Please contact me if you wish to further discuss this issue.

Sincerely;

Scott Mason

Scott Mason
Geochemist

SM:jy

c: Jo Stephen, MT Department of State Lands
Sherm Sollid, Gallatin National Forest
Bruce Gilbert, Stillwater PGM

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SUMMARY OF ACTIVITY:

$$Q = \frac{2\pi K H}{2.3 \log (2H/r)}$$

$H = 500'$

2.33×10^{-5} cm/s $= K = .5$ gal/day/ft^2

$r = 8$

Tunnel 500 feet

$$Q = \frac{2(3.14) .5 \cdot 500}{2.3 \log [2 \cdot 500/8]}$$

$$Q = \frac{1570}{4.823} = \text{~~1x~~ 325 gpd/ft} \cdot 500 \text{ ft}$$

~~607750~~ 162,761 gal day = ~~422 gpm~~ = 113 gpm

48 gpm at 1×10^{-5}

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