Review of Hydrology/Water Resources Portions of the Draft Environmental Impact Review
Idaho-Maryland Mine, SCH No. 2007092017

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The Idaho-Maryland Mining Corporation (IMMC) proposes to reopen the existing Idaho-Maryland Mine in Grass Valley, CA. The City of Grass Valley Planning Department (City) is the responsible agency for preparing a draft environmental impact review (DEIR). This report reviews the hydrology/water resources aspects of the reopening of the mine. To do this, it reviews the DEIR, focusing on section 4.7 but referring to other sections, Knoch (2008), and Todd Engineers (2007).

The existing mine has filled with water since it closed in 1956. A primary environmental issue regarding the reopening of the mine is removing this water, or dewatering and its' associated impacts. Dewatering will lower the water level in surrounding aquifers because they will drain toward the dewatered mine shaft, whose total depth is about 3250 feet below ground surface (bgs). Associated impacts include

- Lowered groundwater tables affecting domestic wells
- Lowered groundwater tables affecting baseflow in streams and springs
- Sediment transport and erosion in Wolf Creek and South Fork Wolf Creek, into which the dewatering will be discharged, due to the additional flow
- Potential downstream flooding
- Dewatering water quality
- Effects of backfilling the shafts on groundwater quality

A primary issue is the accuracy of the analysis of the dewatering effects. This analysis depends on a satisfactory understanding of groundwater flow and the groundwater balance in the watershed. After a summary of recommendations, the first portion of this report reviews the general hydrogeology in the watershed. It considers both general concepts and comments on the presumptions and discussions in the various reports. Then the report reviews the specific impact analysis and mitigations as presented in the DEIR. As part of impact analysis, the report reviews the dewatering analysis and the determination of impacts to wells and streams. The report then reviews the impacts related to discharge and water quality.

Summary of Recommendations and General Comments

1. The DEIR should provide data to verify the assumptions concerning the location of groundwater divides.
2. The DEIR should include seepage runs to determine recharge from the NID canals and recharge/discharge reaches in Wolf Creek.
3. The conceptual flow model must be updated to remove the suggestion of recharge from Wolf Creek and to consider the inflow of groundwater from uphill regions.
4. The recharge estimate using the soil moisture balance should be improved by considering local scale landscape units and separate upland evapotranspiration (ET) from groundwater ET.
5. It should also be completed for a longer time period, preferably 30 years rather than for a single “average” year.
6. The soil moisture balance calculation for recharge should be provided in tabular form.
7. The recharge estimate should be redone by using the HELP model or similar widely used methodology.
8. Hydraulic conductivity should be determined among geologic formations. The relation of hydraulic conductivity with depth should be tested to determine whether the relation is better defined by the absolute elevation of the well screen.
9. The water quality predictions for discharge from the mine should be reconsidered with the assumption that the current water does not reflect the quality of the water that will drain from the shaft walls. The DEIR should consider a reasonable worst case scenario that includes significant oxidation and metals leaching; the nearby Empire Mine should be considered an analog and be considered as to whether the current discharge from that mine is possible at IMM.
10. The IMM mine currently has an illegal, unpermitted “natural” discharge to Wolf Creek.
11. The DEIR should reconsider all of the dewatering analysis which supports the determination of drawdown and risk levels for domestic wells.
12. The very concept of radius of influence is probably incorrect in this watershed.
13. The flow around the shaft violates all assumptions used to derive the equation for the radius of influence.
14. The time to “steady flow” is substantially underestimated.
15. The sensitivity of all of the assumptions in the radius of influence equation should be tested.
16. Many reasonable parameters that could be used in the equation would grossly increase the affected areas.
17. The DEIR should not assume the faults are flow barriers without data to justify the assumption.
18. The dewatering rate estimate should be considered very uncertain. All impact analysis that depends on the long-term discharge equaling 850 gpm should be redone to consider the effects if the rate is much higher than predicted, either temporarily or permanently. The DEIR should consider a reasonable worse case scenario of the dewatering rate being much higher than predicted.

19. The DEIR should consider the dewatering rate in relation to the predicted recharge rate to determine whether the area expected to be affected by dewatering makes sense.
20. The DEIR should complete a series of well tests to reduce the uncertainty inherent in estimating which wells will be affected by dewatering. Details are explained in the text.
21. The DEIR should have a reconnaissance level groundwater model, at a minimum, to vastly improve the predictions of the extent of drawdown. Details are explained in the text. The model would have two purposes. First, it would be used to predict the actual rate of drawdown and time for the flow to approach steady values. Second, it could determine the depth and extent of drawdown around the site. A primary aspect would be the consideration of the sensitivity of various assumptions.
22. APM 7 is not appropriate because it defines the dewatering process as complete when the water level reaches 3250 ft BGS. This is because the drawdown cone, such as it is in a bedrock-fracture system, continues to expand, theoretically until the end of the project.
23. The sediment analysis should include at least a year of baseflow and sediment transport data.
24. The sediment analysis should also include mercury concentrations in the sediment.
25. The increased sediment concentrations at base flow, at either discharge site, degrades water quality and may be impermissible under the Clean Water Act.
26. The sediment analysis should consider a reasonable worst case analysis with a higher long-term dewatering rate.
27. The potential backfill should have had kinetic tests performed before the DEIR was released.
28. Backfill should be allowed only using methods that will result in material at least as impermeable as the existing background bedrock. This would include either paste or concrete rock fill.

Hydrogeology of the Site

This section discusses the hydrogeology of the site watersheds. It reviews the basic hydrologic concepts discussed by Todd (2007), Knoch (2008), and the DEIR, accepting concepts and data where they are correct and rejecting them, with explanation, where they are incorrect. Page et al (1984) is a good baseline report, as far as it goes, but it mostly concerns wells west of this study area.

Conceptual Model and Water Balance of Flow in the Watersheds

Groundwater flows in the Wolf Creek drainage, affected by the proposed mine, from east to west, downhill, in the foothills of the Sierra Nevada. Most groundwater flow is through fractured bedrock; alluvium occurs only near the streams and is very shallow. The groundwater divides are not physical but are based on recharge and discharge points, and are nebulously described in the DEIR. Recharge is distributed and from two canals.

Discharge is to Wolf Creek and the South Fork Wolf Creek and to evapotranspiration (ET) near the creeks.

The DEIR analysis assumes that the groundwater divides coincide with topographic divides "[b]ecause data indicate that" fact (Todd Engineers, 2007, at 11). No data is presented to support the location of the groundwater divide between Wolf Creek and South Fork watersheds (the wells plotted on Todd figure A-1 show that there are none in the Wolf Creek side of the topographic divide), therefore the study should indicate that the location of the divide is based on an assumption. The assumption could be wrong if there is a significant difference in recharge distributed across the area or if the NID canal causes a significant difference in the recharge. There is also no evidence of a groundwater divide on the east side of the Wolf Creek watershed. The DEIR should provide data to verify these assumptions.

Water balance is the change of storage equals the difference in inflow and outflow. At steady state, inflow equals outflow resulting in no change in storage. Steady state is often considered to be that which occurs prior to development if the development adds a significant new outflow, as the dewatering will do here. In reality, steady state does not exist because recharge and evapotranspiration (ET) varies seasonally and annually which causes groundwater storage to naturally fluctuate; it is better to describe the system as being in dynamic equilibrium.

Inflow to the groundwater is distributed recharge and recharge from the NID canals. The distributed recharge probably varies across the watersheds, with a tendency for more in the higher elevations. Due to the relatively small elevation and annual precipitation differences across the watershed, soils and geology probably control the location of recharge more than total precipitation.

Todd Engineers use measured flow rates from the canal to estimate a canal loss rate equaling 0.069 af/y/ft (Todd Engineers, 2007, page 15). The estimated rate may be accurate for the entire canal reach, but the DEIR should determine the actual locations along the canals where seepage occurs, as could be determined with a detailed seepage analysis.

Todd Engineers calculated recharge from Wolf Creek, which is used to transport some NID water, using the same leakage rate determined for the canals. This is not correct because Wolf Creek and the South Fork of Wolf Creek are discharge sinks, as shown on the groundwater flow map (Todd Engineers, 2007, Figure 11); the groundwater level contours show flow converging at the streams. The conceptual flow model in the DEIR is also incorrect where it discusses recharge from the creeks (DEIR, page 4.7-9).

Outflow is primarily ET and discharge to the streams. Well level hydrographs published by Todd Engineers (2007) show no long-term trend indicating there is likely no long-term overdraft occurring.

Todd Engineers states “data are unavailable to determine the location and quantity of groundwater discharge to surface water in the Study Area” (Todd at 11). This would be easy data to collect; they could have performed a series of seepage runs during baseflow conditions to determine the locations of inflow from the groundwater. Failing to collect this basic data renders the analysis inadequate as a disclosure or public decision document.

The small estimate of domestic pumpage within the watersheds is sufficiently accurate. Pumpage is two orders of magnitude less than natural recharge. Even a large error in the estimate of pumpage would have only a small effect on the analysis. It is unlikely that domestic pumping causes a long-term trend in water levels within the watershed.

Annual ET is estimated with data from the California Irrigation Management Information System. “[CIMIS} has compiled daily reference ET (ETo) and delineated zones sharing the same ETo values. The Study Area is located in CIMIS ETo Zone 13 – Northern Sierra Nevada with an average ETo of 54.30 inches, ranging from 0.93 inches in December to 8.99 inches in July. The amounts represent the **maximum amount of precipitation that can be lost to ET** in the soil moisture balance.” (Todd Engineers, 2007, page 13, emphasis added). This extremely coarse estimate does not consider landscape units more detailed than the regional scale or for elevation, aspect, antecedent moisture, or any other differences among small-scale landscape units. The coarseness of the estimate renders it inadequate for the soil moisture balance and other analyses incorporated for the DEIR.

Todd Engineers used soil moisture balance on an average monthly basis to calculate annual recharge (Todd Engineers, 2007, at 12, 13). Recharge is part of the residual, with all other components independently estimated. The other part is runoff, so they assumed that 75% of the residual became runoff and the remainder recharge. Their analysis was for an average year starting with dry conditions; they assumed this average year would provide average recharge values. However, they did not provide a table to show how it was done or allow the public to review the monthly values.

It is not correct to assume that a monthly water balance analysis starting with dry conditions and using average monthly inputs (precipitation and ET) correctly provides an average annual rate. This is because the process is nonlinear. Todd Engineers’ analysis does not consider this fact. During dry years or months, there may be little recharge but in wet years there may be substantial amounts; the average is simply a balance of extremes. In many locations where fractured bedrock underlies the soil rooting zone, a vapor barrier may prevent small amounts of seepage from reaching the bedrock which could lead to marginally supersaturated conditions or interflow from the site. Once saturation reaches the threshold for flow to the bedrock, that may become the preferred pathway and interflow may shut down. ET varies from year-to-year depending on the moisture conditions. Wet conditions allow the vegetation to leaf out more and be more robust. These conditions increase the potential ET through vegetation. Simple annual water balance modeling does not capture these factors.

The water balance was apparently completed for the watersheds as a whole. This assumption is based on the discussion of cover and interception (Todd at 13) which refers to the meadowlands at lower elevations decreasing the amount of interception expected in the conifer-covered watersheds. The result would be an estimate of uniform recharge across the watersheds, a fallacy at best. For example, Riser (2008) found for a watershed averaging 12.8 in/y of recharge, the range was 0.11 in/y for wetlands to 17.1 in/y for upland forests. Wolf Creek watershed probably has a similar potential distribution between forested and wetland areas. If the larger recharge rates occur further from the site of dewatering, the drawdown will expand further in that direction (again, if the dewatering impact methodology accounts for recharge). A correct analysis would consider the conifer and meadowlands separately and then combine them with areal averaging to estimate the overall recharge within the watersheds.

The method as applied in this study is also incorrect because it does not separate upland ET discharge from groundwater ET discharge (Todd Engineers, 2007, Table 1). Applied across the watershed, as appears to be the case with this analysis, the total ET will include ET from both groundwater and from water that has infiltrated the surface but not yet reached groundwater to be considered recharge. In the type of water balance performed here to estimate recharge, water that percolates beyond the root zone is groundwater recharge.

A more accurate method for simulating the soil water balance would be to use the HELP model (Schroader et al, 1994 a and b). The method has recently been used to estimate recharge in a semi-humid zone watershed with precipitation and ET similar to that in Grass Valley (Risser, 2008). The author of this review has also used HELP to estimate the seasonal variability of recharge in a southeast Idaho watershed (Myers, 2007). Todd Engineers could combine help with measured flow rates on Wolf Creek to improve the calibration (Risser, 2008). With such a method freely available and easily usable, this DEIR is deficient in the simplicity and inaccuracy of its recharge methodology.

The water balance analysis assumes there is no groundwater inflow to the watersheds, other than for a small amount in the mine itself, because the groundwater divides coincide with the topographic divides. This assumption may be wrong, as is apparent on Todd Engineers Figure 11. It appears that a significant inflow to the watershed could occur through the eastern boundary. Todd Engineers should justify this assumption and adjust the water balance number as appropriate.

Summary of Water Balance Values

Table 1 in Todd Engineers (2007) summarizes the water balance for the watershed without adequately separating the groundwater balance from the total watershed water balance. However, total recharge in the Wolf Creek watershed is near 3100 af/y, with almost 2000 af/y being from imported water and just 1100 af/y being from natural distributed recharge. Total and natural recharge in the South Fork is 1165 and 627 af/y, respectively. Even with the potential errors in the water balance discussed above, if the losses from the canals are accurate, it appears that imported water leakage may be a major part of the groundwater flow system in the Wolf Creek and South Fork watersheds.

The area recharge estimated for Wolf Creek basin converts to 5.2 in/y. This is extremely low for an area with 53 in/y of precipitation, especially considering the majority of the precipitation falls during low-evaporation seasons. Using a method commonly employed in Nevada (Maxey and Eakin, 1949), this amount would be the recharge in a watershed with about 20 to 25 inches of annual precipitation. Risser et al (2008) estimated more than 12 in/y and referenced studies with up to 19 in/y for watersheds in Pennsylvania with about 40 in/y of annual precipitation. Based on these few comparisons, Todd Engineers should better justify their water balance calculations.

Hydraulic Conductivity

Hydraulic conductivity is the aquifer property which controls the flow velocity. It depends on the amount and size of pore spaces within the aquifer, and their connectivity. The values determined by Todd Engineers are a bulk conductivity which means they are based on transmissivity based on the entire screened width contributing flow; they represent a certain elemental volume of rock. The actual flow occurs through fractures; the fact that the bulk conductivity values are so high near the ground surface indicates the rock is actually highly fractured decreasing with depth (as shown in Figure 7). There are so few observations at depth, however, that the conclusions may be less accurate than one would hope. Just six wells are 800 feet or deeper and their conductivity values lie within the range of many other wells completed between 200 and 800 feet deep. This range corresponds with the 215 foot depth postulated as a divider between deep and shallow wells (Page et al, 1984).

Todd Engineers discusses the different geologic formations in the watersheds, but assumes there are no differences among those formations as far as concerns flow. "On a regional basis, fracturing in these units is the likely controlling factor in determining the hydraulic properties of the bedrock aquifers. Given that, it seems reasonable to assume **no significant differences in hydraulic properties among specific bedrock units**." (Todd Engineers, 2007, at 6, emphasis added). This assumption is not supported by any facts. Different bedrock would fracture differently resulting in different transmissivities. Todd Engineers should analyze the transmissivities by formation.

There should be an analysis of whether the deep level conductivity varies depending on the elevation of the ground surface at the well. As noted (Todd Engineers, 2007, at 8), the depth to water is greater at higher elevations, which reflects surface topography more than the underlying groundwater. Higher elevation wells are deeper because they must reach water; a question remains whether the conductivity depends more on the well depth or the elevation through which the well is screened.

Review of Impacts, Chapter 4.7

Impact 4.7-2: Proposed project operation and reclamation activities, including mine dewatering, may violate water quality standards or waste discharge requirements or could substantially degrade water quality within Wolf Creek and South Fork Wolf Creek. *Less than Significant with Mitigation (Class II)*.

Mitigation Measure 4.7-2: The applicant shall design and construct its wastewater treatment system to effectively treat the liquid waste associated with the gold mill process, including residual sodium cyanide, flotation reagents, by-products from the gold mill process, and residual sodium chemicals present from the neutralization of sodium cyanide sludge material. The treatment process can either be designed as an integral component of the overall wastewater treatment system or be designed as a separate, in-line pre-treatment process. The applicant shall demonstrate to the RWQCB and the City of Grass Valley that the proposed treatment system effectively treats mine discharge water, storm water, and gold mill process water to applicable water quality standards and discharge requirements. The City of Grass Valley and its consultants shall participate in the review process with the RWQCB, and the RWQCB must approve the treatment strategy prior to implementation by the applicant. Changes to the applicant-proposed treatment system that result from this mitigation measure shall become part of the project and the applicant shall provide the City of Grass Valley and the RWQCB with detailed plans and narratives describing the wastewater treatment system and the required upgrades to the currently or design changes.

Dewatering will initially remove water currently in the shaft and then will remove groundwater that flows into the shafts to keep them dry. As noted, the long-term dewatering rate depends on the rate the groundwater flows to the shafts. The initial rate, 2700 gpm, is chosen by IMMC. The water quality in the mine is relatively good and consistent with depth (DEIR, Knoch, 2007), therefore the initial pumping can probably be treated without difficulty.

The existing water quality should not be considered the water quality to be expected during operations. The water quality results obtained from samples in the mine, regardless of the depth, probably reflect only the water quality from the most conductive zones intersecting the mine. As the mine filled with water after dewatering ceased in 1956, the majority of water would have come from the most conductive zones near the surface and flowed down through the shaft. It is therefore likely that the water quality regardless of depth reflects the water quality from the most productive formations intersecting the shaft. The high pH reported by Knoch (2008, page 9) may reflect the primary water source and current reducing conditions. Once oxygen becomes available, the drainage entering the shaft at depth may be acidic.

Walker and Assoc (2008) also suggest the dewatering water quality will be good. However, neither the DEIR nor other documents explain why water discharging from the Magenta Drain on the Empire Mine, which practically abuts the Idaho-Maryland Mine on the south, is so bad but the predicted water quality from the IMM is so good.

The City should not have confidence in predictions of water quality at depth based on these measurements.

The Clean Water Act applies to the proposed discharge of dewatering water from the mine to Wolf Creek (DEIS, page 4.7-14). However, the mine currently appears to have illegal, unpermitted "natural" discharge points from the mine to the creek (DEIR, Fig 4.7-1).

The DEIR states that the "proposed project would result in a significant impact to surface hydrology, groundwater resources, or water quality" if it violates "water quality standards". This is wrong. From a CEQA perspective, it is significant if it has the potential to degrade water quality; degradation is the diminution of the existing water quality. In fact, the relevant standard is probably degradation – the project may not degrade existing water quality if it exceeds the quality of the existing stream.

> **Impact 4.7-3: Mine dewatering activities proposed under the project could reduce groundwater levels or entirely dewater certain high risk domestic groundwater supply wells in the vicinity of the Idaho-Maryland mine site. Well dewatering would lead to a reduction of domestic water supply. *Less than Significant with Mitigation (Class II)*.**
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> **Mitigation Measure 4.7-3a:** The applicant shall utilize the High, Moderate, Low, and Very Low Risk well group categories as redefined by this EIR for all APMs developed as part of the proposed project.
> **Mitigation Measure 4.7-3b:** Within 14 days of the identification of dewatering impacts within the High to Moderate Risk Well areas, the applicant shall connect the affected well owners home to the NID system. If agreed upon through negotiations with the affected well owner, alternative supplies of water supply and/or a longer time frame for connection to the NID system may be negotiated.
> **Mitigation Measure 4.7-3c:** In the event that dewatering impacts occur at a currently operable domestic water supply well, which is considered a High to Moderate Risk Well but that is not currently part of the groundwater monitoring program, the applicant shall ensure that the property is provided with NID water supply.
> **Mitigation Measure 4.7-3d:** In the event that dewatering impacts occur at domestic water supply well(s) after the initial mine dewatering process is considered complete (current estimates indicate that initial mine dewatering will take between 8 to 12 months), and after the 12 month period defined under APM 9, the applicant shall remain responsible to provide a temporary water source to the affected well owner prior to the installation of a permanent water source. Determination of whether the well loss was due to mine dewatering or a related activity shall be made by a qualified third party consultant selected mutually by the City and the applicant. The temporary water source shall be in place and operational within 10 working days after the first conclusive sign of impact, while ample well water is still available. Should an impact occur in the form of an unexpected and sudden failure of a well before the temporary supply is established, the affected resident shall be provided an immediate source of water supply by the applicant. The costs of all immediate and temporary water supplies and storage facilities shall remain the burden of the applicant.
> **Mitigation Measure 4.7-3e:** In the event that dewatering impacts occur and the property of the affected well owner is included into the NID water service system, the well(s) that

> are no longer in service shall be decommissioned and/or destroyed within six months of the establishment of NID water service system connection for the property. All costs associated with the decommissioning/destruction of unused water supply wells shall be the responsibility of the applicant.

This is the primary hydrologic impact associated with reopening this mine. The analysis of this impact involves a substantial analysis of the dewatering analysis both in the DEIR and Todd Engineers. The result of the review is the fact that the analysis grossly underestimated the effects of the dewatering.

Conceptual Model of Flow to/from the Shaft

A mine shaft is a large diameter conduit constructed through the bedrock surrounding the mine. Groundwater flows downgradient toward the shaft, just as it does towards a well; the hydraulics are very similar to those controlling flow to a large-diameter well. The IMM mine is much more complicated than a single or multiple well bores because of the overlapping shafts.

Three items control the flow to a shaft: the surface area of the shafts, the bedrock conductivity, and the flow gradient. The shaft density, the number of shafts per volume of bedrock, controls the total shaft surface area, through which flow into the shaft can occur. Because of the decreased conductivity, the flow to the shafts will decrease with depth. The gradient will be controlled by the difference in head between the bedrock aquifer and the water level in the shaft. During the initial dewatering, this gradient will increase, or reach 1.0 once the hydraulic connection is broken, as will occur throughout the shaft after dewatering. The total discharge to the shaft at any given elevation therefore depends on the effective conductivity of the bedrock, the density of the shaft, and gradient driving flow to the shaft.

As the shaft is dewatered, the gradient controlling the discharge to the shaft below the current water level, 2500 feet amsl, would increase and therefore increase the discharge to the shaft. This increase in discharge will cause a drawdown in the groundwater table draining to the shaft. It is this drawdown that could affect surrounding domestic wells and groundwater discharge to springs and streams.

Todd Engineers (2007) and the DEIR cite an earlier study by IMMC which determined the inflow rate to the shaft once dewatered will average 850 gpm, or about 2 cfs, with a range from about 500 to 1200 gpm. The study was not reviewed, therefore the methodology cannot be verified. Based on the range and the vast uncertainties in all estimates that go into the calculation, the estimate should be considered very uncertain. All impact analysis that depends on the long-term discharge equaling 850 gpm should be redone to consider the effects if the rate is much higher than predicted, either temporarily or permanently. The DEIR should consider a reasonable worse case scenario of the dewatering rate being much higher than predicted.

Based on the water-volume-depth relationship within the mine, most of the water resides below the most conductive bedrock zone, which ranges from the ground surface to the

215 to 300 feet below ground surface level (Page et al, 1984; Todd Engineers, 2007). If the deeper bedrock is as nonconductive as implied (a three to five order of magnitude difference in conductivity between above and below 300 feet below ground surface (Todd Engineers, 2007, Figure 7), most of the groundwater flow to the shaft likely occurs in the upper several hundred feet. Given a constant gradient for flow to the shaft, the flow from equal thickness layers above and below 300 feet bgs would also differ by orders of magnitude. The calculation table used by Todd Engineers to determine average transmissivity for the entire shaft showed that 95% of the transmissivity occurred in the top 400 feet of saturated bedrock (Todd Engineers, 2007, page 21), which verifies the suggestion that most flow would be from the upper portions of the aquifer.

Tritium dating suggests the water in the shaft, and therefore reaching the shaft, is relatively young (Todd Engineers, 2007, page 10). This supports the idea of much more discharge reaching the shaft from higher elevations, from near the ground surface.

Todd Engineer's Assessment of Drawdown Impacts

Todd Engineers (2007, pages 19 and 20) estimated the area affected by drawdown caused by dewatering the shaft by treating the mine shaft as a large diameter well assuming that the interconnected system of shafts emulates a pumping well centered at the centroid of the mine volume. Treating the interconnected matrix of shafts as a single, large-diameter well is dubious and Todd Engineers should justify their assumption much better. One major difference between the mine and any well flow equation is that flow to the mine is not horizontal whereas well flow equations are derived assuming the Dupuit-Forcheimer assumptions for horizontal flow apply (Bear, 1979). In this case, with drawdown approaching 3250 feet at the mine, the flow is not horizontal.

They used a standard equation for determining the radius of influence, the maximum point they assumed would be subject to drawdown effects. The radius of influence is, technically, the point at which the drawdown in the Thiem equation equals 0; it is said that at this point the influence of the well is zero (Bear, 1979, page 306). However, it is only a theoretical concept because "steady flow cannot prevail in an infinite aquifer" and should therefore be considered as the distance beyond which the drawdown is negligible (*Id.*). Also, the equations are based on horizontal flow which does not occur near these shafts.

The DEIR incorrectly states the "radius of influence" is synonymous with "cone of depression" (DEIR page 4.7-31). The cone of depression is a three-dimensional surface formed by lowering the water table and the radius of influence is the maximum areal extent of the cone of depression; radius of influence does not describe the depth of drawdown at all whereas the cone of depression describes it throughout.

Todd Engineers (2007) used a standard formula for determining the radius of influence. As noted by Bear (1979), such formulas are either semi-empirical or empirical; he presents five such formulas. "Empirical" means that the formulas were derived using laboratory or field data and should only be used for conditions similar to those for which it was derived. The formula used by Todd Engineers does not appear in Bear (1979), but is of similar form and probably correct. Todd Engineers should explain how the conditions at the IMM mine are similar to those used to derive the formula; until they do so, the DEIR is inadequate because its results and mitigations are based on unjustified assumptions. They should explain how an equation derived for homogeneous and isotropic conditions, assuming an infinite aquifer (Bear, 1979), can be used for high heterogeneous bedrock fracture aquifers in which secondary permeability controls.

They predicted the radius of influence equals 710 feet with steady flow occurring after 200 days. Their most troubling assumption is that steady flow conditions occur after 200 days, the amount of time estimated to pump the entire 532,000,000 gallons out the shaft into Wolf Creek. They base the estimate on a previous estimate that 850 gpm will be the flow rate into the shaft once it is dewatered and assume that rate will occur by the time the shaft is emptied (Todd Engineers, 2007, page 21).

The 200-day assumption is critical. The radius of influence as determined with their equation becomes larger with time; if the time to equilibrium exceeds 200 days, the radius of influence would be much larger. The DEIR acknowledges that the 200-day estimate is a major assumption, and calculates the additional radius of influence that would result if steady flow did not occur for two years (DEIR, page 4.7-33); it would be about 620 feet further from the mine. However, this was another guess. After 10,000 days, approximately the length of the project, the radius of influence is closer to 5000 feet (Figure 1).

As a way to justify their 200-day assumption, Todd Engineers state that if the drawdown were to continue to expand, it would bump against natural boundaries. These boundaries would be faults, which have not been shown to actually be boundaries. The DEIR acknowledges that this is just an assumption and that the faults may actually be conduits for flow (but does not refute the idea that the faults will limit the effect) (DEIR, page 4.7-33). The DEIR considers that the Weimar fault may act as a conduit to expand the potential drawdown along the fault (*Id.*).

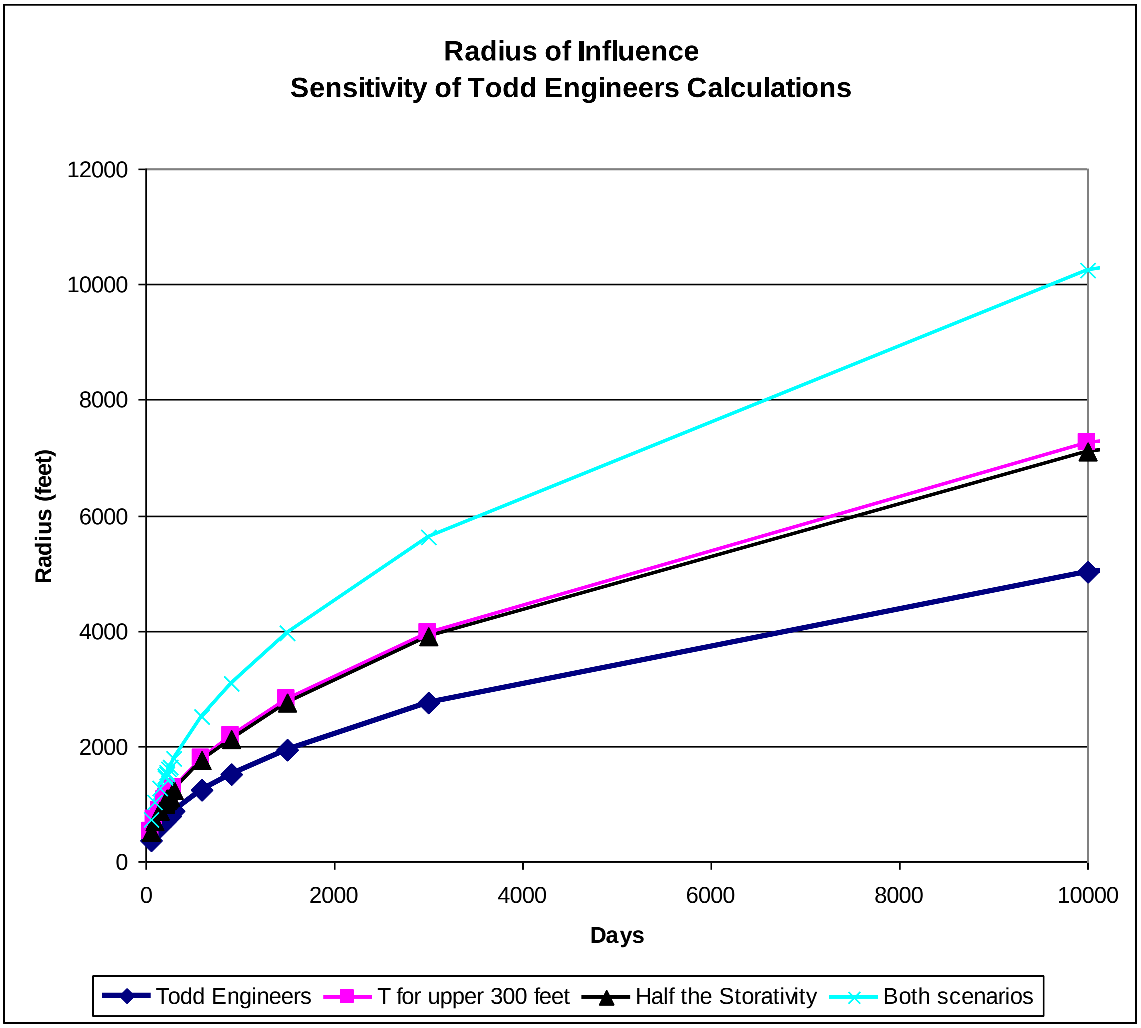

Figure 1: Radius of influence using the equation and assumed hydraulic properties from Todd Engineers (2007). The graph shows clearly that the radius of influence depends on the number of days assumed for steady flow to occur.

Todd Engineers (2007) also claims that its analysis is conservative, even in the same sentence in which they introduce potential uncertainties which would allow the calculation to underestimate the radius of influence. "Although the analysis is **considered conservative in methodology**, several complexities in the groundwater system could potentially result in a larger or smaller radius of influence. Although **large impacts seem unlikely**, it is difficult to prove that aberrations in the system do not exist" (Todd Engineers, 2007, page 22, emphases added). It is standard in environmental analysis, in the experience of this reviewer, for the proponent or its consultants to claim conservatism without justifying the claim or their statement that larger impacts seem unlikely.

The time to steady flow has been questioned as has the appropriateness of the equation used to determine radius of influence, but an analysis to determine the sensitivity of the radius of influence to the assumed transmissivity and storativity would help to bracket the uncertainty of the estimate. Todd Engineers averaged conductivity over the entire depth of the mine to determine transmissivity. Because much of the inflow to the mine shaft probably occurs in the upper few hundred feet, the radius of influence should be based on a transmissivity for just the shallow portions of the bedrock. Transmissivity for the upper 300 feet is about 175 gpd/ft for which the radius of influence is about 44% larger (Figure 1). Halving the storativity increases the radius of influence by about 41% (Figure 1). Changing both parameters increases the radius of influence by more than 100%. This simple sensitivity analysis shows that Todd Engineers' analysis is anything but conservative and likely underestimates the radius of influence, if the concept of radius of influence is reasonable in this usage.

Two aspects of this analysis provide a check on its results and show that the analysis must be wrong. First, the gradient created by the project if the radius of influence is just 710 feet with a 3250 foot drawdown over the mine footprint exceeds 4.0. It is questionable whether a gradient in excess of 1.0 is even possible while maintaining a hydraulic connection (Hart et al, 2008). Because of the fractures controlling the flow, there will likely be areas where the hydraulic connections are broken. Most importantly, steady flow would be unlikely with such a gradient. Because of the changing conductivity with depth and the fact that the flow is fracture controlled, most of the flow that reaches the shaft will be groundwater reaching the edge of the shaft and draining downward in the shaft until it is collected. The controlling gradient would likely be 1.0 unless isolated volumes of bedrock fractures drain out into the shaft and become dry. Additionally, the steep gradients cause the flow near the shaft to completely violate the horizontal flow assumptions required for well flow equations, proving that the equation was applied incorrectly.

The second check is the implausibility of the results with the water balance results. Total groundwater recharge in the Wolf Creek and South Fork watersheds was 3191 and 1165 af/y, respectively. The total dewatering rate for flow to the shaft was assumed to equal 850 gpm, which equals 1371 af/y. The long-term dewatering rate is 31% of the estimated total recharge for both watersheds. It is infeasible that a sink for groundwater, 3250 feet deep, in the middle of the bedrock aquifers of these watersheds, causes a drawdown over such a small area.

It is therefore essential that Todd Engineers provide a better justification for their radius of influence analysis.

Dewatering Impacts to Domestic Wells

The DEIR determines three levels of risk to wells and specifies mitigation based on the pre-determined risk level. High risk wells are those within the footprint of the mine and the 710-foot "radius of influence" as determined by Todd Engineers. Moderate risk wells are those which could lie within the radius of influence if the time to steady flow is actually two years; it adds an additional 646 feet on all sides of the 200-day radius. Low risk wells occur within 710 feet of the surface trace of the Weimar fault. Extremely low risk wells are the others.

Even though the DEIR acknowledged that more wells could be at risk than did Todd Engineers, it is still insufficient. Expanding the radius of influence to 1356 feet still results in a groundwater flow gradient toward the mine of greater than 2, which is still impossible. Adding the low risk wells along the Weimar fault does not increase the confidence in the protections given to the well owners.

Because amount of water expected to be withdrawn is so high in proportion to the local recharge, the radius of influence is probably much larger and may not be reached for the entire project life. The Weimar fault may or may not impede its expansion; as noted above, there is no data to assess it either way.

The DEIR admits it was not possible to accurately determine the effects of dewatering. "Due to the **uncertainties** regarding the complex geology, groundwater flow, flow dynamics in the mine, and the presence of faults, dewatering impacts to domestic water supply wells cannot be **accurately** predicted" (DEIR at 4.7-34, emphases added). The City should have attempted to reduce the uncertainties by requiring pump tests which could accurately determine which wells are connected by observing the effects of pumping one well reflected in another well. The DEIR is inadequate because it fails to collect and present data which could be easily obtained.

Banner Mountain Domestic Wells

The analysis has limited the impacts to approximately the location of the Weimar fault. As shown, the impacts could extend significantly beyond that point. The DEIR should consider whether the impacts could extend further east into the Banner Mountain area. Several factors suggest that drawdown could affect the wells to the east.

First, a more realistic analysis using Todd Engineers' methods showed the radius of influence could extend up to a mile, rather than 710 feet. That methodology is fraught with problems however, the biggest of which is that the derivation of the equation assumes a homogeneous, infinite aquifer. As pointed out throughout Todd Engineers (2007) and the DEIR, the aquifer is fractured rock. Connections are poorly understood. If the mine intersects a fracture zone at depth which extends east, connections with shallow wells could cause dewatering to shallow aquifers even in Banner Mountain. Until the fracture system and their connection to the mine are better understood, the wells in the Banner Mountain area should also be considered at risk and IMMC should be required to plan for mitigating losses within that area. If the wells suffer loss of water, the City should assume the mine is the cause unless baseline monitoring has shown that seasonal or drought cycles cause the wells to dry prior to the mine dewatering.

Recommended Additional Analyses

Two additional, potentially related, analyses would improve the reliability of the DEIR.

The DEIR analysis did not include any well tests (DEIR at 4.7-30), but the DEIR uses Todd Engineers' analysis of drillers well yields to estimate transmissivity and conductivity (*Id.*). Unfortunately, IMMC did not actually perform the necessary well tests that would allow an actual assessment of the aquifer properties beyond the nebulous statements of fracture flow found in the DEIR. The City's failure to require the collection of this data renders the analysis inadequate. The project proponent should establish a series of pump tests which could be used to improve transmissivity and storativity estimates and to determine which wells are connected. Such a program could occur as follows.

IMMC could pump one domestic well while monitoring well levels in other domestic wells. A series of tests could cover the entire area. IMMC would have to pump the wells long enough to observe impacts on surrounding wells. Additionally, IMMC should monitor wells on opposite sides of the fault to determine whether stress propagates across the fault. The results of this would have to be interpreted carefully however, because a fault may impede stress propagation without stopping it. The impedance may also vary with depth which may just increase the flow path without preventing the stress propagation.

The second analysis should be a reconnaissance level groundwater model to vastly improve the predictions of the extent of drawdown. The model could use the hydraulic data for each well, supposedly determined by Todd Engineers. The model would, of necessity, assume homogenous properties for model cells, but a model would allow those vary among cells; the current analysis assumes the same properties throughout the aquifer. New data could improve the quality of the existing data. Vertical conductivity gradients as determined by Todd Engineers could be used to estimate conductivity at depth where there are no wells. Geostatistical analysis (kriging) should be used to estimate conductivity values in areas where there are no wells. Properties of the fault would be estimated using newly collected data. If no such data is available, the sensitivity of the model results to varying fault properties should be estimated using standard sensitivity procedures.

The model would have two purposes. First, it would be used to predict the actual rate of drawdown and time for the flow to approach steady values. Second, it could determine the depth and extent of drawdown around the site. A primary aspect would be the consideration of the sensitivity of various assumptions.

This recommended modeling would vastly improve the estimated effects of the dewatering. Failing to do this renders the DEIR inadequate.

Most of the mitigation measures concern the applicant proposed measure which are reviewed in the next subsection. However, one mitigation claims that "[d]etermination of whether the well loss was due to mine dewatering or a related activity shall be made by a qualified third party consultant selected mutually by the City and the applicant". The implication of this statement is that the City represents the interests of the homeowner. This is likely incorrect. It would be more appropriate for the proponent to pay for the homeowner to hire a consultant and then for the three parties to meet to determine the cause of any well loss.

Review of Applicant Proposed Measures

The applicant proposed eleven measures to mitigate the dewatering issues. Most of these issues involve connecting to alternative water supplies, which are not reviewed here. This includes timing and engineering issues. The problem is the APMs assume that it is acceptable to replace a domestic well water source with other water, without considering water quality. This is not appropriate because most well owners do not want an alternative source.

APM 7 is the only measure concerning a significant hydrologic issue. It is not appropriate to define the dewatering process as complete when the water level reaches 3250 ft bgs because the drawdown cone, such as it is in a bedrock-fracture system, continues to expand, theoretically until the end of the project. The technical details of this were discussed above concerning the radius of influence.

> **Impact 4.7-4: The proposed project would require the discharge of mine water into Wolf Creek (from the Idaho-Maryland site) and South Fork Wolf Creek (from the New Brunswick site). Such an action would alter the natural drainage pattern of the project site, potentially inducing substantial erosion and downstream sedimentation, and/or resulting in a violation of existing water quality standards. *Less than Significant with Mitigation (Class II)*.**
>
> **Mitigation Measure 4.7-4:** The discharge location for the dewatering operations at the New Brunswick site shall be moved to the location on South Fork Wolf Creek designated on Figure 4.7-4, which is approximately 1,500 feet downstream of the proposed discharge location. The proposed energy dissipation features for this discharge shall remain the same.
>
> **Mitigation Measure 4.7-4a:** In addition to the discharge pipe extending from the treatment plant at the New Brunswick site to the new discharge location specified in Mitigation Measure 4.7-4, the applicant shall install a small diameter pipeline from the treatment location at the New Brunswick site to the discharge location on South Fork Wolf Creek originally proposed as part of the project. This small diameter pipe shall supply a continuous low flow (i.e., 1-2 cfs) at this location on the creek to supplement potential surface water loss if it were to occur as a consequence of mine dewatering. Installation of the pipe is not contingent on whether or not surface water losses are observed in the creek; this low flow supply shall be installed, maintained and energized concurrently with the main discharge pipe from the water treatment plant.
>
> **Mitigation Measure 4.7-4b:** The applicant shall place abutments, footing, access ways and other facilities associated with the treatment plant discharge pipe well outside the riparian areas of the two streams the pipe alignment would cross. Proposed locations of the abutments, footings and other facilities shall be verified by the City of Grass Valley prior to pipeline construction.

The discharge to South Fork Wolf Creek is a large increase to the baseflow in the receiving waters. It could cause additional sediment movement, particularly during low flow periods if the stream flows across erosive soil, as described by the DEIR.

There is insufficient data concerning the sediment concentrations on Wolf Creek and the South Fork of Wolf Creek. The description (DEIR page 4.7-4) merely references an overall watershed study and calculates sediment load based on the area draining to the location in the watershed. Using this as a base estimate for sediment concentration is inappropriate because watershed sediment yield is not the same as sediment transport within the stream. Sediment transport depends on the erosive capacity of the stream at the site while watershed yield depends on watershed area, underlying soils and geology, and watershed vegetation cover. The DEIR correctly calculates the potential change in sediment transport due to changed flow rates but incorrectly compares it to the watershed sediment yield.

The analysis includes channel bed sediment data for 2000 feet downstream from the proposed discharge site (DEIR, page 4.7-40). The DEIR assumes that the difference in drainage area through this reach would increase the average flow in the stream. That is correct only if tributaries enter the stream in that reach; the DEIR should verify whether this is correct.

The DEIR analysis of sediment transport and erosion considers only the discharge locations and a short reach below the discharge site. Increased flow due to dewatering discharge will affect flow rates throughout the entire stream length and could increase erosion at any point downstream. The DEIR is inadequate because it does not consider whether changes in flow at downstream sites could cause more erosion than the discharge at the proposed or mitigation discharge site.

The DEIR apparently accepts that increasing the sediment concentration up to a level potentially not harmful to salmonids is acceptable. "At the alternate discharge location, the resulting sediment concentration is estimated to be approximately 90 ppm over the initial dewatering period. Though this represents a relatively large increase over the ambient concentration during baseflow conditions (which is essentially zero, or less than 1 ppm), the resulting concentration would still be moderately protective of resident salmonid species (as determined by Lloyd, 1987)." (DEIR, page 4.7-42) The DEIR should reconsider this assumption, because the Clean Water Act has anti-degradation requirements that streams with water quality better than the standard keep the better water quality. Approving this proposal as presented in the DEIR may be approving an illegal project.

The mine proponent should have collected flow data on the creek at the proposed discharge sites. This data should have been complemented with sediment transport data. The analysis of the potential effects of changing flow rates on sediment transport would therefore be more than speculation. The lack of data in the DEIR, when it was readily and easily collectible, renders the DEIR inadequate. The city should require the proponent to collect a minimum of 12 months of baseflow and sediment data **before** beginning the dewatering operation.

The DEIR essentially ignores the potential presence of mercury in the streambottom sediments which could be mobilized due to the additional discharge. Mercury in the Wolf Creek water column is an issue because the mercury concentrations are high, ranging from 4.6 to 11 ug/l (DEIR, page 4.7-7). These concentrations are from 2.3 to 5.5 times the drinking water standard of 2 ug/l. The DEIR should acknowledge that these concentrations exceed the standards and identify Hg concentrations in the sediment of the creeks which would help to identify locations from which Hg could be mobilized by high flows. The DEIR is inadequate without this easily-obtained data.

The DEIR dismisses the idea of Hg in the sediments by stating "There is no indication that the sediments within either of the creeks are laden with mercury. Furthermore, samples collected from historic mine tailings in the area do not exhibit mercury as a common contaminant; therefore, it is unlikely that sediment in Wolf Creek and South Fork Wolf Creek would be laden with mercury." (DEIR at 4.7-21). They have not collected sediment or analyzed its chemistry, so there is no way to know whether the first sentence in the quote is correct. As for the second sentence, the DEIR needs to define the area and provide a reference to and/or table of the samples that have been collected. Otherwise, the DEIR presents an inadequate analysis.

The mitigation proposal may subject part of the creek to dewatering caused by the lowering of water tables. The DEIR analysis implies this is uncertain. If the groundwater contours (Todd Engineers, 2007, Figure 11) are correct showing the groundwater discharge to the creek, there is no question that surface water flows will be affected by the dewatering. The stream bed between the point of discharge and the uppermost reach that experiences drawdown could be affected. For this reason, it is desirable to discharge the water into the creek as far upstream as possible.

> **Impact 4.7-5: The proposed project would require the discharge of mine water into Wolf Creek (from the Idaho-Maryland site) and South Fork Wolf Creek (from the New Brunswick site). The increased flows could increase the potential for flooding downstream.** ***Less than Significant with Mitigation (Class II)*****.**
>
> **Mitigation Measure 4.7-5:** The 75 percent critical flow depth (as summarized in Table 4.7-3) shall be permanently marked (e.g., with a staff plate) at each of the four culvert locations. During the period of initial dewatering, these locations shall be monitored by the applicant during periods of high flow (e.g., storm events). Discharges from the mine operation shall cease upon the water surface elevation reaching the 75 percent capacity mark at any of the four culverts; discharges may commence once the water surface elevation is below the 75 percent capacity mark at all four culvert locations.

The mitigation for this concern is probably acceptable because the discharge rate is a small proportion of the stream flow.

> **Impact 4.7-7: The proposed project may generate 1,200 tons per day of mine development rock, gold mill tailings, and other solid waste that would be used as**

backfill in the underground mine workings. Groundwater contact with backfilled waste rock and mine tailings could lead to degradation of groundwater quality. *Less than Significant (Class III).*

Mitigation: None required.

The DEIR was released before sufficient data had been collected to determine whether mitigation would be necessary. Kinetic tests have not been conducted and have only been recommended. Unfortunately, the DEIR does not present any of the test data to which it refers (DEIR, page 4.7-50, 51). Neither does the analysis in Appendix F (Walker and Assoc., 2008). It discusses the basic geochemistry in the area, but presents few measurements regarding the potential backfill. It recommends tests that would be performed on any material before it is backfilled; this discussion is also rewritten and provided in the DEIR. The basic contention is that the testing would provide sufficient certainty that seepage through the backfill will not be contaminated by leaching metals or oxidation products.

Walker and Assoc (2008) refer to "backfilling of mine workings" as a novel concept in California and refers to other mines which have used it. .
Walker and Assoc (2008) justify backfilling by noting that the waste is just rock originally removed from the shaft and all they are doing is putting it back. The really big difference, that the industry and their consultants usually forget, is that the process of removing it involves breaking it into small pieces which can leach contaminants much easier. The conductivity is much higher, as is the porosity.

DEIR section 2 describes the mining method as "cut and fill" which requires some form of backfill because the backfill provides the wall or floor for additional mining. The DEIR describes four different types of backfill which could be used in this proposal, with hydraulic backfill being the primary method. The different methods would have significantly different effects on groundwater quality because they would result in different permeabilities in the backfill. Hydraulic backfill is unacceptable because groundwater and water draining into the pit will seep through or saturate the backfill, leaching contaminants. This is why it is essential to use backfill methods that restore the pre-mine conductivity. For this reason, only the cemented or paste methods are acceptable. At the Meikle mine in Nevada, a paste method is being tested to replace the current concrete backfill to prevent groundwater seeping through the backfill to prevent the leaching of contaminants into the groundwater. The Nevada Division of Environmental Protection is currently reviewing for renewal the water pollution control permit for the Barrick Goldstrike North Block Project, including its paste backfill program. The following passage from a renewal permit document for that project explains the type of analysis that should be used in the IMM DEIR, at a minimum

> In December 2007 and January 2008, Barrick conducted tests of paste backfill using mining tailings to evaluate the performance as a replacement for the CRF [concrete rock backfill]. **Critical to this proposal was whether monitored constituents could migrate into the wall rock during curing and the ability of the paste to immobilize monitored constituents after curing**. These initial tests

(Phase I of the paste backfill program) showed good performance of the paste in both of these aspects over the 28-day test period and Barrick was given approval by the Division to proceed with Phase II of the program consisting of the conduct of long term testing of paste in simulated underground, inundated conditions. Final approval of Phase III, the full scale introduction of paste backfill in the underground areas, is contingent upon Division acceptance of Permittee's test report for Phase II showing the successful completion of the long-term tests and **presentation of data showing that the paste does indeed immobilize the monitored constituents, preventing degradation of local groundwater**…

The paste backfill proposal would utilize tailings produced during the roasting process which is used to oxidize refractory ores mined from the surface and underground mines, making them more amenable to cyanide leaching. Gold is then leached with cyanide and adsorbed onto activated carbon for recovery. Tailings are the slurry of oxidized ore remaining once this process is complete. Under the current paste backfill proposal, the roaster tailings will be treated to remove cyanide, cycloned for size distribution, thickened and filtered. The tailings slurry will be mixed with cement and fly ash to create the paste backfill slurry. Paste backfill will be pumped underground through a pipeline, eliminating the need for heavy equipment to place the backfill and filling void spaces more completely than the CRF. Approximately 5000 tons per day (tpd) of roaster tailings will be used at full capacity of the proposed facility….

The anticipated **environmental advantages** of paste backfill over CRF include:

The paste backfill operations will include an above-ground surface batch plant adjacent to the existing roaster and the underground backfilling facility wherein all ingredients of the paste will be treated, combined, and prepared for delivery to the stopes and drifts. Once complete, the facility will include:

- Cyanide Destruction Tanks
- Paste Tailings thickener
- Clarifiers
- Lixiviant (LIX) Kill Tank
- Disc Filter System
- Cement and Fly Ash Feeders
- Paste Mixer
- Associated Pumps, Conveyors, Piping, etc.

During the batch process, samples will be taken from three locations and tested to insure the proper make-up and consistency of the paste:

- Samples will be taken from the Filter Cake and **tested for levels of WAD Cyanide**;
- Paste samples will be taken prior to pumping and subjected to slump measurement procedures;

- Cylinders of the paste will be made and allowed to cure for 28 days, after which they will be **characterized by MWMP testing** at a NV certified lab. [1]

The point of adding this long passage from the permitting process of another mine is to show the amount of design that goes into the backfill with the objective of preventing the movement of contaminants into the surrounding groundwater. It should also be noted that the processing of oxide ore is similar to that likely at IMM and also that the ore is not acid-producing, therefore the motivation behind this care is not the prevention of acid mine drainage.

IMMC should clearly do much more homework on the subject of their backfill prior to proceeding with this proposal; the City should require them to come forth with a much better plan than currently proposed. IMMC could start with articles such as Belm and Benzaazoua (2004).

Review of Geosolutions Report

Geosolutions prepared a report concerning hydrogeology in the study area (Knoch, 2008); the report was presented in DEIR Appendix F. The study purports to be a "technical analysis of area hydrogeology and potential impacts of dewatering the mine" to be used in development of the DEIR (Knoch, 2008, page 1). It is based on a review of previous reports; it also claims to be a "thorough peer review of the new hydrogeologic investigation prepared by Todd Engineers" (***Id.***). However, throughout Knoch's (2008) technical memorandum, Todd (2007) is used as a reference rather than being seriously peer-reviewed.

Knoch (2007, page 2) discusses "infiltration" to the watersheds. Knoch (2007) apparently confuses infiltration with recharge. Infiltration is the movement of water through the ground surface to the soil zone where it contributes to soil moisture; if it exceeds soil moisture, and does not ET back to the atmosphere, it moves past the soil zone toward the saturated zone. Once it reaches the saturated zone, it becomes recharge. Knoch (2007) then reports the same values for infiltration that Todd reported as recharge.

There are no water quality measurements for domestic wells (Knoch, 2007, page 4). This is a particular problem, for example, because he indicates the wells in the "westerly group" have a "very unique geochemistry" (Knoch, 2007, page 11). Without data, or a reference, this statement has no support and merely represents the author's views or his opinions of the area.

Knoch reports that domestic wells in the westerly group have water levels almost 90 feet on average above the water level in the shaft. He also reports on several deeper wells that may be close to the level of some of the mine workings. This should not be considered

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[1] Nevada Division of Environmental Protection, Bureau of Mining Regulation and Reclamation. Fact Sheet – Draft. Barrick Goldstrike Mines Inc., Goldstrike Mine – North Block Project, NEV0091029. Emphases added.

an indication of a lack of connection with the water level in the mine workings for the following reason: the difference in water level in the fractured rock aquifer and the mine workings reflects a quasi steady state condition with flow from the aquifer to the mine workings. Discharge from the mine to the surface controls the water level in the mine. Discharge from the groundwater to the mine is controlled by the gradient between the aquifer and mine (if there is a hydraulic connection, it is based on the aquifer groundwater level and water level in the mine) and conductivity of the aquifer. Discharge into the mine above the water level, as has been observed by mine personnel, would flow down to the mine water level; the controlling gradient equals 1.

Knoch also provides a detailed discussion as to why he believes the Weimar fault, and others, may be significant flow barriers. The entire discussion is provided without reference or data. While repeated a couple of times, he basically describes the argument concerning the Weimar fault as follows:

> **Little is known** about the conditions of materials on the interfacing surfaces of rock located along the Weimar Fault… It is likely that oblique thrusting caused the grinding and crushing of materials at the interface of the structure producing mylonite consisting of a fine grained laminated clayey type material formed by extreme microbrecciation due to movement of adjacent rocks along the fault surface. Because of this pulverization the mylonite will likely behave like clay with a very low permeability and hydraulic conductivity. Therefore, it is likely the **migration of fluids through this structure is limited, if not highly channeled**, thus developing what could be considered a hydrogeologic barrier … (Knoch, 2008, page 14, emphases added)

As Knoch admits, little is known about the conditions around the fault, but that does not prevent him from a detailed description of the faults leading him to conclude the fault could be a hydrogeologic barrier. It is difficult to follow how the migration of fluids is limited if it is highly channeled – these imply different things. As Faunt (1997) describes for faults in a variety of rock near the Death Valley Flow System, faults that were constructed in compression could be barriers in at least one direction. But thrusting, especially if it has a tensional component, could significantly increase the permeability. Faunt (1997) emphasizes the need for significant hydrologic data which Knoch does not discuss here nor does he have. In fact, two bits of data suggest the fault does not affect the flow downgradient through the Wolf Creek watershed.

First, there is no "step" in the groundwater contours for the area (Todd Engineers, 2007, Figure 11). If a fault added a significantly impermeable barrier to the flow, the gradient would have to change across the fault to drive any flow through it. There is no evidence of this, and there certainly are enough well observations from which to observe it. Second, faults often control the location of springs (Page et al, 1984). "Springs in [southwest Nevada county] may lie along zones of saturated fractures, or they may lie along contacts between different rocks types" (Page et al, 1984, page 22). There is no spring system or increase in flow in Wolf Creek where it crosses the fault that reflects damming caused by the fault. As noted by Bredehoeft (1997), faults often support upwelling in the groundwater; in the Wolf Creek watershed this would certainly lead to springs.

He also reports on well 201 which appears to be very close to historic mine workings that are above the water level of the mine. The distance from well to shafts is less than 10 feet horizontal. The way Knoch (page 18) states this gives the impression the well bore is within ten feet of breaching the mine wall; this is unclear. The well hydrograph (Todd Engineers, 2007) shows significant fluctuations with levels actually dropping close to the water level in the mine. It has one of the most variable water level hydrographs reported on by Todd. Perhaps, the well does not intersect fractures that are significantly connected to the mine workings. The extreme fluctuation in water level could result from a very low storage in the fractures connected to the well. In other words, the effective aquifer used by well 201 could be very small so that pumping it adds significant fluctuation on top of the seasonal changes. Alternatively, there is a limited connection which does drain to the shaft. The lack of connection however suggests the well was not completed in highly fractured rock as implied occurs for most of the shallow wells (Knoch, 2008; Todd Engineers, 2007). This anecdotal evidence is not significant with respect to interpreting the overall potential impact of dewatering the mine on the domestic wells.

Knoch's (2008) suggestion that dewatering will not draw water from the streams is incorrect because it ignores the current discharges to the creeks. Groundwater level maps (Todd 2007, Figure 11) show contours with discharge to the creek from both north and south; this also reflects the observation that depth to water and fluctuations of the water levels in the wells becomes less nearer the creek (DEIR, page 4.7-9). The lower part of the contour trough is the elevation of the creek. Clearly, Todd contemplates discharge to the creek (not recharge from the creek as Todd suggested and we discussed elsewhere). The upper couple hundred feet of the mine below the creek would also have been constructed through fractures as were the wells; this is indeed likely the source for much of the water in the mine. There is little question these water levels will be lowered (as contemplated for the high risk wells) which will decrease the discharge to the creeks by decreasing or even reversing the gradient driving the flow. If the gradient reverses, the discharge will be from the creek to the aquifer. This could affect the creek above the discharge point during low flows. This is a significant impact and by not providing for a mitigation, the DEIR is inadequate.

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