EXECUTIVE SUMMARY

Gold Creek presently has three certified water rights for a total of 144.8 cubic feet per second (cfs), although this amount is not used all the time. AEL&P has certified water rights for 137 cfs for hydroelectric generation and the City and Borough of Juneau (CBJ) has two certified water rights totalling 7.8 cfs for municipal water supply. The CBJ has applied to DNR to increase their water rights to 18.6 cfs, and Echo Bay Exploration has applied for up to 20.6 cfs (on an annual basis) for mining related operations. The purpose of this memo is to provide hydrologic information to facilitate adjudication of these requests by the Water Management Section of the Division of Water. This adjudication will include re-examining the historic water use rates and existing rights to use water by all water rights holders and current applicants for Gold Creek water (G. Prokosch, Alaska Div. of Water, oral commun., 1993). The average annual flow in Gold Creek is approximately 116 cfs, and during winter low flows Gold Creek flow generally decreases to less than ten cfs. Currently, during low flow events, Gold Creek may not be capable of supplying sufficient quantities of water to existing users.

This report summarizes the effects of proposed diversion of water on existing water rights holders and applicants. To determine the effect of diverting water draining through the AJ mine away from Gold Creek, a study was completed by Echo Bay’s consultant and the Alaska Hydrologic Survey. It was determined from both a computer model and field data collected in this study that during low flow events the CBJ well field in Last Chance Basin can be pumped at approximately the same rate that Gold Creek flows. Because of this, estimating Gold Creek flows is critical in determining impacts to the CBJ after diverting the mine drainage water.

The amount of water proposed to be diverted away from Gold Creek is significant because it may unduly effect the CBJ current and future pumping plans. At the end of mining the probability of a shortfall during any given year is estimated to increase from 30 percent to 48 percent at the present CBJ certified water right of 7.8 cfs. This estimation represents a 60 percent increase in the expected number of years that the well field would experience a shortfall under a 30-day low flow scenario.
If Echo Bay were to return two cfs to Gold Creek, upon mine start-up and initial diversion the probability of an impact on the well field due to mine operations would not change unless the CBJ pumped the well field at rates greater than 15 cfs. At the end of mining, the probability of an impact on the well field due to mine operations would not change unless the CBJ pumped the well field at rates greater than 7.8 cfs.

The estimates presented in this report are adequate for characterizing the approximate magnitude of the impact of the proposed diversion. Uncertainties in the data may cause actual impacts to be somewhat lesser or greater than described herein.

INTRODUCTION

This memo is in response to your request for hydrologic information on Gold Creek and Last Chance Basin for adjudication of water rights applications from the City and Borough of Juneau (CBJ) and Echo Bay Mines (EBM). We have examined the relevant information pertaining to the proposed AJ mine and Gold Creek hydrology, and have estimated the effects of tunnel diversion on Gold Creek. Our analysis is based on independent DNR data contained in Noll (1992), USGS stream flow data, and information supplied by EBM through your office (IT Corporation, 1992). Other information sources include USGS reports dating back to 1906 and recent engineering evaluations done for the city.

This memo contains a brief description of the hydrologic and geologic setting of Last Chance basin, the methods used to analyze the available data, and a summary of findings. Although IT Corporation (1992) (hereafter referred to as IT) performed a similar analysis of Last Chance Basin for EBM, their work is not sufficiently complete to answer all of your questions. Where IT's work is relevant to our analysis, we cite their results and include a discussion of key issues regarding the useability of their work.

GEOLOGIC SETTING

Last Chance Basin is a small geologic basin in the Gold Creek drainage located about 1.5 miles from tide water. It is approximately 4000 feet long, and attains a maximum width of about 1000 feet. There are two aquifers in Last Chance Basin, an upper unconfined aquifer separated from the production (lower or semi-confined) aquifer by a silty sand deposit. The upper aquifer is recharged by direct infiltration of rain and surface runoff, snowmelt, ground water flow from the talus and colluvial deposits on Mt. Juneau and infiltration from Gold Creek. The unconfined aquifer supplies base flow to Gold Creek below the slope change at the approximate location of TW-3 (Figure 1). The production aquifer is recharged mainly from Gold Creek in the upper 2000 feet of Last Chance Basin starting just below the confluence of the mine tunnel discharge. A secondary, but important recharge source is ground water flow from the talus deposits on Mt. Juneau.
During well field pumping, the unconfined aquifer supplies water to the production aquifer through the semi-confining layer as observed in the February 1991 pump test. Under non-pumping conditions, water in the production aquifer flows to the land surface under artesian pressure west of PW-3.

Gold Creek discharge has been recorded near the upper end of Last Chance Basin since June 1984. At this point, Gold Creek drains an area of 8.41 square miles. For water years 1985-1991; the annual mean flow is 116 cfs, the highest daily mean flow was 1600 cfs, and the lowest daily mean flow was 3.5 cfs (USGS, 1990). Although no periods of no flow have been recorded at the present stream gage, in January 1991 when Gold Creek was flowing at approximately seven cfs at the USGS gage, Gold Creek completely infiltrated and went dry approximately 1,000 feet below the salmon bake bridge (Figure 1). Base flow back to Gold Creek started just below the slope change near TW-3. Periods of no flow were recorded at the lower USGS gage located near AEL&P's diversion in water years 1951, 1956, 1974, and 1982 (USGS, 1990).

APPROACH

The analysis of the Last Chance Basin aquifers requires a combined ground water and surface water approach because the two systems are closely interconnected. IT's computer model of the ground water system in Last Chance Basin is used to quantify the ground water portion of the analysis. The model is used to estimate how much water is available through recharge, Gold Creek infiltration, and aquifer storage and relate these quantities to probable well yields. The results of the model appear to be within reasonable bounds of how the ground water flow system functions, based on all available field data. We have not independently confirmed the accuracy and validity of the model; however, a discussion of these issues is presented at the end of this section.

From field data and the model output, it was determined that stream flow in Gold Creek is the principle factor controlling potential well field yield during low flow events. Because of this, the surface water analysis is very important, and will determine when the well field should be impacted.

Two different methods of analyzing Gold Creek flow data are available. IT used a flow duration method applied at both annual and monthly time scales. IT's use of flow duration curves combine incremental data of daily average flow with integrated or averaged events (30 day well field yields). When asked if this method was statistically valid, IT's representative said he did not know if it was (oral communication at the 4 October 1991 meeting). IT's Figure 5-5 (monthly flow duration curve for December, Appendix A) demonstrates the statistical quandary IT's method presents. IT's Figure 5-5 indicates that ten percent of the time in December (three days) Gold Creek will flow at nine cfs or less. However, the nine cfs from IT's model is a 30 day average streamflow that is being related by IT to an
event of only three days duration. To circumvent these problems, DNR's method is to estimate what the probability is of a seven-, 14-, or 30-day low flow event of a specified magnitude happening anytime during a given year.

Probabilistic methods are used because streamflow is inherently variable as a result of irregular climatic events. Another reason for selecting probabilities is that most people are familiar with the concept intuitively, or from experience (such as coin-tossing where a probable outcome is 1/2 or 50-50 each try). Probabilities are also the inverse of recurrence intervals, another concept that most people have a natural feel for. A probability of .10 (10%) has a recurrence interval of once in ten years (1/.10 = 10). It should be remembered that the theoretical distributions represented in the probability graphs are not an exact representation of the natural process, but only a description which approximates the phenomenon and describes the observed data we presently have (Gilbert, 1987).

Low flow probability curves are constructed from the lowest average flow recorded during consecutive periods of time (usually three-, seven-, 14-, or 30-days) for all years of record. The curves are used to determine the probability that a certain average low flow rate, persisting for a given duration, will occur during any given year. This analysis looks at seven-, 14-, and 30-day periods at your request.

To evaluate the effect of tunnel water diversion on the Last Chance Basin well field, assumptions based on the available information or standard hydrologic parameters were used. These assumptions are detailed in specific sections. The general method used is outlined below:

1. construct low flow probability curves from existing USGS data and DVSTAT statistics program for seven-, 14-, and 30-day continuous events;

2. establish two regression equations between Gold Creek flows and tunnel flows, for all Gold Creek flows less than 19 cfs and 145 cfs. The regression equation for all flows less than 19 cfs is used for estimating low flow event impacts on the CBJ well field, and the equation for all flows less than 145 cfs is used for estimating impacts to AEL&P's hydroelectric generating potential.

3. determine how the expected future mining subsidence will effect flow through the tunnel;

4. determine probabilities of well field shortfalls for different well field demands and various low flow events; and

5. compare shortfalls with and without mine development to determine the effect of mining.
The impacts on AEL&P’s hydropower generation is determined from a regression equation between Gold Creek and tunnel flows as outlined in the Regression Equation Determination section.

Model Accuracy and Validity

The accuracy and validity of the ground water model is important to this analysis because:

1. the analysis cannot be reasonably performed without it;
2. the analysis is only as good as its weakest link; and
3. the model contains significant uncertainties that cannot be quantified.

Ultimately, the decision of whether or how to use IT’s model for solving the problems of Last Chance Basin will be made by decision-makers such as yourself.

Goodrich (1992) from IT’s Albuquerque, New Mexico office provides an interesting and timely discussion of model validity (appendix A). He asserts that a model cannot be declared valid, only "invalid" or "not invalid", and declaring a model not invalid does not guarantee the model is valid. According to Goodrich (1992), validity "only provides the modeler a means to demonstrate reasonable assurance that the model is not incorrect. According to Goodrich (1992) "To ignore those site-specific uncertainties in data and parameters when evaluating a model could lead to an incorrect conclusion about model performance".

IT’s model is missing key data with which to evaluate the accuracy of the model, used data with large measurement errors, and used a number of simplifying assumptions about Last Chance Basin hydrology and geology that illustrate the lack of closeness of the simulation to reality. The most important missing data are data on recharge from Mt. Juneau and Mt. Roberts and permeabilities of deposits in Last Chance Basin. In lieu of these data, the modelers adjusted recharge rates and permeabilities in their calibrating simulation until water level elevation from the model matched observed test well values, and simulated streamflow losses and gains matched measured values.

Regarding permeabilities, even if IT’s understanding is correct, permeabilities of natural earth material range over about 14 orders of magnitude, giving modelers latitude to adjust them to produce reasonable water level and flow rate matches. IT’s authors have used values that are not field verified, and that are not related to the geologic development of the basin, including placer mining activity. As detailed in a DNR letter to EBM (15 October 1991), IT modeled a placer mined area of 400,000 square feet with a high hydraulic conductivity. Maps and photos shown in Spencer (1906) indicate that the actual placer mined area is closer to 60,000 square feet. For these reasons, the accuracies of the permeabilities assigned throughout the ground-water flow system are questionable.
IT also failed to measure infiltration of streamflow below the salmon bake bridge and gain in streamflow above the old USGS gage. These data would have greatly improved the comparison of measured stream losses and gains with model results. As a result, the comparisons presented in IT’s report do not fully reflect all stream losses and gains.

The IT streamflow data used in the model has errors much larger that those estimated by IT. IT estimated that all streamflow measurements were within ± eight percent, with most measurements from Last Chance Basin ± five percent. The only check on these data is at the USGS continuous recording station at the head of Last Chance Basin. When compared with the USGS measurements, IT’s measurements during the five well pump test vary from less than a five percent difference to over 30 percent difference (Appendix B). This error may have come about because IT did not routinely check their meter for proper operation prior to measurements. Only four spin tests were done in 35 measurements by IT, and this is not in accordance with standard USGS procedures requiring spin tests before every measurement (Buchanan and Somers, 1969; Rantz, 1982).

Finally, IT simplified the modeling process by leaving out some key natural processes in Last Chance Basin. For example, the model does not simulate any flow from Mt. Roberts, precipitation or snowmelt in the bottom of the basin, or flow from the talus slope at the base of Mt. Juneau.

These missing data, inaccuracies, and simplifying assumptions in the model help illustrate that the model results should be viewed as approximate and that they contain unquantifiable errors.

DNR LOW FLOW PROBABILITY ESTIMATIONS

Low Flow Probability Graphs

This analysis uses data collected from 1985 to 1992 at the USGS gage at upper Last Chance Basin. DNR’s probability curves use 33 percent more data than IT used in their graphs because of the longer period of record now available. At your request we are also evaluating seven- and 14-day low flow events. Probability graphs were constructed for seven-, 14- and 30-day consecutive low flow periods from data supplied by the USGS DVSTAT (DAILY VALUES STATISTICAL) program (Figures 2-4). Data points for water years 1985-1991 were contained in the DVSTAT program, and the value for water year 1992 was calculated from provisional data supplied by the USGS. The Weibull plotting position formula (Viessman, et al, 1977) was used to determine the plotting position and rank for the data (Table 1). Graphs, including confidence intervals, were plotted using SigmaPlot, version 4.1.
Table 1

Lowest Mean Value and Ranking for the Indicated Number of Consecutive Days for Gold Creek at the upper USGS Gage Water Years 1985-1992

<table>
<thead>
<tr>
<th>Rank</th>
<th>Percent Probability m/(n + 1)</th>
<th>7-Day Event (cfs)</th>
<th>14-Day Event (cfs)</th>
<th>30-Day Event (cfs)</th>
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<td>4.00</td>
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</tr>
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<td>4.94</td>
<td>5.16</td>
<td>6.94</td>
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<td>4</td>
<td>44.4</td>
<td>6.67</td>
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<td>8.89</td>
</tr>
<tr>
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<td>9.89</td>
</tr>
<tr>
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<td>8.06</td>
<td>8.46</td>
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</tr>
<tr>
<td>7</td>
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<td>9.09</td>
<td>9.93</td>
<td>11.9</td>
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<tr>
<td>8</td>
<td>88.9</td>
<td>12.9</td>
<td>14.9</td>
<td>21.9</td>
</tr>
</tbody>
</table>

n = the number of years of record  

m = the rank
GOLD CREEK 7-DAY FLOWS

Figure 2  % Probability that in any one year, the 7-Day low flow event will be less than or equal to the indicated value.
GOLD CREEK 14-DAY FLOWS

Recurrence interval (years)

% Probability that in any one year, the 14-Day low flow event will be less than or equal to the indicated value

Figure 3

95% Confidence Interval
Figure 4

% Probability that in any one year, the 30-day low flow event will be less than or equal to the indicated value.
Regression Equation Determination

Regression equations were determined for paired Gold Creek and tunnel flow data. Two equations were developed, one for Gold Creek flows less than 19 cfs, and the other for Gold Creek flows less than 145 cfs. The regression equation for flows less than 19 cfs is used in evaluating potential low flow impacts on the CBJ well field, and the equation for flows less than 145 cfs is used in evaluating impacts on AEL&P’s hydroelectric water use.

The correlation coefficients ($r^2$s) are low for these regression equations, especially when compared to the regressions done by Easton (1992) and IT (1992) (Table 2). From the regression equations in Table 2, it is apparent that as the number of data points used in the regression increases, the correlation coefficient of the regression equation decreases. Easton set an arbitrary upper Gold Creek flow limit of ten cfs for his data, and was limited to only 14 data pairs. This use of censored data may be the reason his correlation is so high. IT used a transformation that follows the idea of the central limit theorem. This states that the mean of a number of sets of random samples taken from any population will be normally distributed (the mean of a group of means approximates the true mean of the population) (Davis, 1986). IT used the monthly mean values for both Gold Creek and the tunnel for 16 months and did a regression of these values. This process decreases the variance and provides for a higher apparent correlation as seen in Table 2. However, IT’s work appears to violate two key statistical methods. These are: 1) for months where the tunnel data are incomplete (for example, Gold Creek had 31 measurements and the tunnel had 15 for January 1991) IT averaged all the Gold Creek values (31) not just the values paired with tunnel data (15); and 2) for most winter months in water year 1989 no tunnel data were collected (Appendix A), so either IT generated the data for 25 percent of their regression points by a method unknown to us, or they have access to data that Echo Bay and DNR do not. IT’s higher correlation between the variables may not reflect the relationship between them, but is probably induced by the transformation performed on the data. As a result of these problems with IT’s regression analysis, it will not be used further in this report.

Table 2

<table>
<thead>
<tr>
<th>Item</th>
<th>Equation</th>
<th>$r^2$</th>
<th>n</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easton</td>
<td>$y = 0.2077x + 0.0464$</td>
<td>.94</td>
<td>14</td>
<td>all &lt; 10 cfs Gold Ck flows</td>
</tr>
<tr>
<td>IT</td>
<td>$y = 0.0660x + 0.7459$</td>
<td>.85</td>
<td>16</td>
<td>winter monthly averages</td>
</tr>
<tr>
<td>DNR &lt; 19</td>
<td>$y = 0.0902x + 0.5778$</td>
<td>.42</td>
<td>165</td>
<td>all paired flows &lt; 19 cfs</td>
</tr>
<tr>
<td>DNR &lt; 145</td>
<td>$y = 0.0399x + 1.941$</td>
<td>.40</td>
<td>747</td>
<td>all paired flows &lt; 145 cfs</td>
</tr>
</tbody>
</table>

Central limit theorem. This states that the mean of a number of sets of random samples taken from any population will be normally distributed (the mean of a group of means approximates the true mean of the population) (Davis, 1986). IT used the monthly mean values for both Gold Creek and the tunnel for 16 months and did a regression of these values. This process decreases the variance and provides for a higher apparent correlation as seen in Table 2. However, IT’s work appears to violate two key statistical methods. These are: 1) for months where the tunnel data are incomplete (for example, Gold Creek had 31 measurements and the tunnel had 15 for January 1991) IT averaged all the Gold Creek values (31) not just the values paired with tunnel data (15); and 2) for most winter months in water year 1989 no tunnel data were collected (Appendix A), so either IT generated the data for 25 percent of their regression points by a method unknown to us, or they have access to data that Echo Bay and DNR do not. IT’s higher correlation between the variables may not reflect the relationship between them, but is probably induced by the transformation performed on the data. As a result of these problems with IT’s regression analysis, it will not be used further in this report.
To estimate the impact of diverting the present tunnel water on AEL&P water availability (assuming no interference from the CBJ well field, i.e., no pumping), the DNR regression equation EQ-4

\[ \text{Tunnel Flow} = (0.0399) \text{Gold Creek Flow} + 1.941 \]

needs to be rearranged. The equation needs to be rearranged because in its present form, Gold Creek flow at the USGS gage site includes that portion of present Gold Creek flow from the tunnel. After the diversion, the gage will only measure that portion of Gold Creek flow that has not flowed through the mine. After rearranging (see Appendix C), the regression equation reduces to:

\[ \text{Tunnel Flow} = (0.0416) \text{Post-Diversion Gold Creek Flow} + 2.02 \]  \text{EQ-5}

This equation can be used for all flows less than 145 cfs as measured by the USGS gage to estimate the amount of water that is diverted out of the drainage and is no longer available to AEL&P for hydropower production. For Gold Creek flows greater than 145 cfs, initial tunnel diversion will not reduce Gold Creek flow below AEL&P’s water right certificate amount of 137 cfs.

**EXPECTED FUTURE SUBSIDENCE AND WORST CASE CAPTURE**

Present surface runoff and snowmelt flow into the existing glory holes that developed due to subsidence from past mining. The water flows through old AJ mine workings and is discharged back to Gold Creek from a tunnel just above Last Chance Basin (Figure 1). During proposed mine operation this tunnel will usually be plugged and water that enters the mine will be diverted out of the Gold Creek basin through the Bradley Adit (Figure 5).

The increase in subsidence was estimated by Steffen, Robertson, and Kersten Inc. (SRK), consulting Engineers from Vancouver, B.C. Their estimations are contained in two documents, AJ Mine-Surface Response to Underground Mining (May 1990), and AJ Mine-Surface Response to Underground Mining-1st Update (July 1991). These estimations appear to contain a significant amount of uncertainty. In the first update (July 1991) introduction, the authors caution that "Even though the details given in this report are a specific response to the mining activities planned, they may differ from what actually occurs above the mining area if unexpected geologic structures, changes in geologic structure orientation, or changes in material strength parameters are encountered". In SRK’s first update, they used portions of three different models to analyze different portions of the mine. It is unlikely that the SRK engineers perfectly predicted the geologic structures, orientation, and material strength for each block, and that the model used perfectly
See Figures 1 and 6 for glory hole and current mine discharge locations.

Figure 5: Schematic cross-section through AJ mine workings showing present and proposed diversions through the mine.
predicts future subsidence. The text in SRK's report suggest that the lines drawn on SRK's map showing future subsidence areas are not as definitive as shown on the map. The authors also conclude that although numerical methods would likely give the best results, more information is needed. Because of this lack of information they used "empirical engineering solutions" to solve the problem, and state "the results may well include some inaccuracies". SRK also refers to the "preliminary nature of the work" it did in 1991, and state "Subsidence removed from the actual area of the gloryholes is difficult, if not impossible to quantify at this point, given the available data".

According to SRK (1991), expected future glory hole capture will increase approximately double its present area. Calculations from the maps supplied by SRK (1991) show that the area of capture will double from approximately five percent of Gold Creek's total basin area to 11 percent. The worst case would be if subsidence or fractures from the mine system capture the flow from the abandoned Nowell placer (Figure 6). The unnamed stream that drains this area is supplied with water from Icy Gulch and springs from the Silverbow Basin aquifer. The unnamed stream exits Silverbow Basin through a tunnel, reentering Gold Creek approximately 2,000 feet downstream of Granite Creek (Spencer, 1906). On 4 November 1991 I measured the flow of the unnamed stream (8.31 cfs), Gold Creek out of Silverbow Basin (1.08 cfs), and Granite Creek (9.82 cfs) during a low flow event to determine what percent of total Gold Creek flow was supplied by this unnamed stream (Noll, 1992). On that day this unnamed stream supplied approximately 27 percent of the total Gold Creek flow measured at the USGS gage (31 cfs). When combined with the recorded tunnel flow for that day (3.2 cfs), the potential capture is 37 percent of total Gold Creek flow. This is important because the springs draining the Silverbow aquifer now supply Gold Creek during cold-weather low flow events. SRK does not expect this stream to be captured, but does state that "Creep along foliation and other geologic structures as the cave mass compacts will cause subsidence away from the glory hole proper as time progresses". With time, SRK expects the rock mass in the glory holes to settle, and "This settlement may increase the depth of the glory hole. However, collar sloughing may well keep pace with this settlement". Because of SRK's uncertainty, and the unnamed creek's close proximity to the existing glory holes (approximately 380 feet measured 12 June 1991), the potential for collar sloughing and capture exists. This hypothetical capture could occur at a time after "end of mine life". Impacts of this capture would depend on which basin the drainage through the mine is routed to after closure. Therefore, a reduction of approximately 37 percent, although not expected during mine operation, is considered the worst case scenario. Echo Bay has said in the past that if this stream is captured, they would engineer a solution to keep the water out of the mine. This solution is not incorporated into IT's analysis, or this analysis. Future winter mine interception of Gold Creek is one of the major areas of disagreement between this analysis and the IT report. IT concludes that for low flow periods, "the impact under future mining scenarios is the same as the impact under existing tunnel flow conditions". In other words, doubling the size of the glory holes will not increase the capture of water otherwise supplying Gold Creek during winter low flows. IT believes that winter Gold Creek flow is "derived from upstream storage in the alluvium and talus along the creek and from ground water".
FIGURE 6 LOCATION MAP
After: CBJ Draft Well-Head Protection Plan, 1992
flow into the creek through fractures in the underlying bedrock". IT believes that because there is no talus and alluvium upslope from the existing and projected glory holes, there should be no decrease in base flow to Gold Creek other than what is presently flowing through the mine. From the USGS surficial geology map of the Juneau area (Miller, 1975), fan deposits (from five to 80 feet thick) and talus deposits (greater than ten feet thick) are mapped in the expected future glory hole area. Large areas of drainage in the potential capture area upslope of the future glory holes are unmapped by Miller (1975), but vegetative cover identified from air photos suggest that a talus slope has developed over portions of the upslope basin that are expected to be captured. Spencer (1906) identifies two placer deposits upslope from the existing glory holes. At present Icy Gulch is not completely captured by the existing glory holes, but is expected to be after glory hole expansion (SRK, 1991). Hydrographs of current flow through the mine compared to hydrographs of Gold Creek flow suggest that the source for the tunnel water is similar to that of Gold Creek during low flow events. According to IT (1992), the tunnel hydrographs "show that changes in tunnel discharge closely parallel changes in Gold Creek flow during the winter months". This similarity suggest that some amount of talus or alluvium is supplying flow to the mine even during winter low flow events. IT states that most of the tunnel flow during the winter "originates as ground water flow into the mine through fractures in the bedrock". If this is valid, these fractures are probably recharged by water stored in the fan, talus, and placer deposits mantling the bedrock.

IT estimates an end of mine life worst case reduction in Gold Creek flow by using only changes in area. IT's method ends up with more flow in Gold Creek after doubling the size of the glory holes than before mining. IT states "This apparent discrepancy results from the method that was used for this analysis". This apparent discrepancy indicates that an improper method was probably used.

This analysis uses the regression equation for present Gold Creek flows to determine what present tunnel diversion would be for Gold Creek flows from five to 35 cfs. These flows are assumed to be the "best" case for end of mine life capture (in other words, IT is assumed correct, and during winter there is no increase in tunnel flow except for snowmelt). The 37 percent of Gold Creek that includes both present tunnel flow and the unnamed stream draining the Nowell placer represent the possible worst case capture. A family of curves for Gold Creek flows between five and 35 cfs was constructed (Figure 7). From this graph, the midpoint value was assumed to be the "most representative" end of mine life capture, and percentages of present Gold Creek that would be diverted were determined for the five through 35 cfs Gold Creek flows (points a-d, Figure 7). A final graph estimating the percent of Gold Creek that will be diverted through the mine for
Figure 7  Percent of present Gold Creek that will be diverted at end of mine life for "best" to "worst" case scenarios
flows less than 35 cfs is shown in Figure 8. Because of the large uncertainties associated with predicting end of mine life capture, the midpoint capture method was used. This method minimizes potential errors that could result from relying on either endpoint scenario.

The estimated future capture in tunnel flows for various Gold Creek flows range from 25 percent (4.56 cfs) at 18.6 cfs to 32 percent (.96 cfs) at three cfs, and are summarized in Table 3. This represents estimated increases in mine capture of .11 cfs when Gold Creek flows are three cfs, to 2.30 cfs when Gold Creek flow is 18.6 cfs.

Table 3

Estimated Change in Tunnel Flow with "Most Representative" Future Subsidence

<table>
<thead>
<tr>
<th>GOLD CREEK FLOW</th>
<th>PRESENT FLOW</th>
<th>PRESENT PERCENT</th>
<th>FUTURE FLOW</th>
<th>FUTURE PERCENT</th>
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ALL FLOWS IN CUBIC FEET PER SECOND

PRESENT TUNNEL FLOW REGRESSION: Y=0.0902X + 0.5778

FUTURE TUNNEL FLOWS ESTIMATED FROM FIGURE 7
Figure 8 Most representative Gold Creek Capture at end of AJ mine life.
GOLD CREEK FLOWS VERSUS WELL FIELD YIELD

The following discussion is based on average and constant Gold Creek and tunnel flows, CBJ pumping rates, and aquifer recharge. In reality, none of these will be constant, but will be changing with respect to each other in a dynamic process.

During cold periods when Gold Creek flow is typically low, other sources of recharge (surface flow along Mt. Juneau talus slope or direct infiltration) are frozen or non-existent. During these cold periods, Gold Creek and talus slope storage become the only available source of recharge to the Last Chance Basin aquifer system. When Gold Creek flow decreases below the CBJ pumping rate, aquifer storage must make up the difference. Depending on the duration and rate that the aquifer is pumped, water yield from the basin can be substantially augmented by aquifer storage. IT (1992, p. 22) performed model simulations that allow calculation of the amount of water that can be pumped from storage during low flow conditions. Depending on Gold Creek flow rates, and assuming pumping at 18 cfs, this number ranges from 28 to 36 million gallons. Assuming 32 million gallons is available from storage, Table 4 shows pumping rates that should be sustainable by water in storage for seven-, 14-, and 30-day periods of zero Gold Creek flow. These numbers should be viewed as approximate because of the simplifying assumptions used for the calculations.

Because Gold Creek flow is not expected to be zero for any significant length of time, aquifer storage should be able to augment water available from Gold Creek. For 30-day periods, aquifer storage could be depleted if the CBJ well field pumping rate remains over one cfs greater than Gold Creek flows. Because of the small size and high permeability of the aquifer, and the distribution and pumping capacity of the wells, most Gold Creek water recharged to the ground water system during winter low flows should be available to the well field.

Table 4

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<th>TIME PERIOD</th>
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<th>14-Day</th>
<th>30-Day</th>
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<tr>
<td>PUMPING RATE (cfs)</td>
<td>7.1</td>
<td>3.5</td>
<td>1.0</td>
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</table>

Seven- and 14-day calculations based on results from IT’s computer model (IT Report Section 4.7.2 and Table 4.3) and 30-day estimation based on IT’s Figure 5-27.
The minimum flow in Gold Creek needed to maintain the well field production will be the pumping rate minus the maximum rate water can be pumped from storage in the aquifer. For example, if the CBJ wants to pump the well field at 10 cfs for 14 days, Gold Creek flow can decrease to 6.5 cfs for that two week period (10 cfs pumping - 3.5 cfs from storage = 6.5 cfs flow in Gold Creek). To use Figures 2-4 to determine what the probability of a shortfall will be, the well field production rate and available aquifer storage are used to determine what Gold Creek flows are required. Once the needed Gold Creek flow is determined, this amount must be adjusted to take into account the amount of water that will flow through the mine and be diverted away from Gold Creek. For example, if the CBJ wants to pump the well field for 30 days at ten cfs, utilizing all available storage in the aquifer (one cfs pumped from the aquifer), Gold Creek must be flowing at nine cfs. This nine cfs figure must be adjusted upward by adding the mine diversion flow rate to account for the fact that the probability graphs are made with pre-diversion data. A nine cfs post-diversion flow is equivalent to a 10.4 cfs pre-diversion flow (9.0 cfs (post-diversion flow) + 1.4 cfs (calculated present tunnel flow from regression equation EQ-3) = 10.4 cfs). The 10.4 cfs is the flow that should be used with the graphs to determine the probability of an impact to the well field, absent new subsidence.

Impacts were evaluated for CBJ pumping rates of 7.8, 11, 15 and 18.6 cfs. The reason for evaluating at these rates are:

- **7.8 cfs**: this is the present CBJ water right and is slightly greater than the average winter area-wide water use (W. Joiner, oral communication);
- **11 cfs**: this is approximately the maximum winter time area-wide water use for the CBJ (W. Joiner, oral communication);
- **15 cfs**: this is an intermediate value to evaluate the impacts of diversion on CBJ's pending water right applications, and;
- **18.6 cfs**: this represents the upper limit of CBJ's pending water right application.

**QUESTIONS**

Now that we have outlined the assumptions, calculations and methods used to determine the effects of tunnel diversion on Gold Creek, we will answer your questions as outlined in your memorandum to Bill Long (Appendix A). Remember that the answers are in terms of probability of a well field shortfall for any one year, and high probabilities of occurrence may not happen just as low probabilities may happen more frequently than predicted. A well field shortfall is defined as a failure of the wells to deliver the expected or designed flow rate. The shortfalls are calculated to occur at the end of the seven-, 14- or 30-day period for the given
probability of occurrence. Early failure due to dynamic conditions is possible, and for this reason we have evaluated multiple low flow events.

Question 1:

Is the source sufficient to supply the Last Chance Basin well field so that it will yield from 7.8 cfs up to 18.6 cfs under present and future subsidence diversion conditions?

We have compiled the probability of the effect of diversion upon the well field for various pumping rates, low flow periods, and diversions for both total out of basin diversions of tunnel flow, and out of basin diversion of tunnel flow except two cfs returned to Gold Creek (Table 5). The impact is the difference between the no-mining shortfall and the mine-induced shortfall. From the table, it is evident that even without diversion, the probability of well field shortfall is up to 95 percent in any year if the well field is pumped at the maximum rate requested of 18.6 cfs. With initial diversion the probability of a shortfall only increases to 97 percent, and to 98 percent with final mine diversion. Under present conditions, all pumping rates greater than 11 cfs could be impacted every other year for durations greater than seven days. To put this into estimated flows, for initial diversion it is estimated that when Gold Creek flow is five cfs, the tunnel will divert approximately one cfs (Table 3), and when Gold Creek flow is 18.6 cfs, the tunnel will divert approximately 2.26 cfs. Future estimated diversion will increase these flows to 1.45 and 4.56 cfs respectively.

In estimating the impact to the well field, you should look at the change in probabilities. In almost all flow/duration events outlined in Table 5, there is some probability of well field shortfall. Probabilities that exceed 50 percent could be grouped together for planning purposes because they represent recurrence intervals of less than two years. From Table 5, probabilities of shortfall over 50 percent generally represents a CBJ pumping rate greater than 11 cfs, even for present undiverted Gold Creek flows.

From the above discussion, the source is probably not sufficient to supply the CBJ with 18.6 cfs during extended low flow periods, even without diversion of water passing through the mine.
### Table 5

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<th>PUMPING RATE (cfs)</th>
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<th>14-DAY LOW FLOW EVENT</th>
<th>30-DAY LOW FLOW EVENT</th>
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<td>18.6</td>
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<td>96</td>
<td>98</td>
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</tbody>
</table>

Probabilities of impact if 2 cfs (or all of present tunnel flow if <2 cfs) are returned to Gold Creek from the mine.

**Example:** (11 cfs pumping) (1 cfs storage) + (2.83 cfs diverted) = 12.83 cfs calculated pre-diversion Gold CK flow.

**From Figure 4, 12.8 cfs = 80% probability.**
Question 2:

What will be the effects of the initial diversion and of the full mine development diversion upon the water rights of the CBJ in Last Chance Basin?

From Table 5, for a 7.8 cfs pumping rate, the probability of shortfall to the existing water right in any one year will vary from less than one percent during 7-day events, to 48 percent for end of mine life diversions over a 30-day period. It should be noted that the present probability of well field shortfall pumping at 7.8 cfs for 30-days is 30 percent. In other words, the probability of a shortfall for a 30-day period pumping at 7.8 cfs increases from 30 percent without diversion, to 41 percent with initial diversion (from a one in three year return period to two years of shortfall every five years). At the end of mine life, the probability of shortfall is expected to increase to 48 percent, or approximately every other year. This end of mine life estimation represents a 60 percent increase in the expected number of years that the well field would experience a shortfall under the 30 day low flow scenario.

Question 3:

What would be the effects of the initial diversion and of the full mine development diversion upon AEL&P's water rights of record of 137 cfs?

Initially the diversion would reduce the water available by:

\[ \text{Tunnel Flow} = (0.0416) \times \text{Post-Diversion Gold Creek Flow} + 2.02 \quad (\text{EQ-5}), \]

as outlined in the section on Regression Equation Development. For example, if upon initial diversion the USGS daily average Gold Creek flow is 100 cfs, then the amount of Gold Creek water diverted away from potential AEL&P use will be:

\[ \text{Tunnel Flow} = 0.0416(100) + 2.02 = 6.2 \text{ cfs}. \]

As subsidence increases, the amount of water diverted will increase. During the operating life of the mine, water flowing out of the Gold Creek basin could be measured in the mine to determine what the actual diversion amount is. More detailed analysis is beyond the scope of this investigation.

Question 4:

What would be the effects of granting the CBJ an additional water right for up to 18.6 cfs upon the water use of AEL&P for hydroelectric generation?

For days that the flow in Gold Creek was less than 155.6 cfs (137 cfs + 18.6 cfs) post diversion Gold Creek flow, the amount that the CBJ pumped would need to be
subtracted from the USGS average Gold Creek flow to determine the approximate amount of AEL&P's water used by the CBJ. For example, if over one day the CBJ pumps 16 cfs, and Gold Creek averages 148 cfs, then 148 cfs - 16 cfs = 132 cfs available to AEL&P. Therefore the CBJ will have used approximately five cfs of AEL&P's water right of record amount for that day. When Gold Creek daily mean flow is less than 137 cfs, the amount CBJ pumped would decrease the water available to AEL&P by approximately that amount.

Question 5:

Review the methodology and results of the synthesis of stream flow data for Sheep Creek.

Time limitations prevent us from reviewing Sheep Creek basin information.

**SUMMARY**

The estimations contained in this report are adequate for characterizing the approximate magnitude of the impact of the proposed diversion. We have discussed in the text most areas of uncertainty contained in this and IT's analysis. The probabilities in Table 5 give a relative estimation for changes due to mining, and can, with some caution, be converted to projected Gold Creek flows after diversion for discussion purposes. The major areas of uncertainty are:

1) IT’s model;

2) regression equations used to relate tunnel flow to Gold Creek flow. Correlation coefficients, \( r^2 \) values, of 0.4 indicate that only 40 percent of the variance of the data is accounted for by tunnel and Gold Creek flow variables; and

3) the mid-point capture analysis. The extent of future glory hole subsidence and possible capture of the unnamed stream draining the Nowell placer is a major source of uncertainty in this analysis.

cc: Ric Davidge, DOW, Director
    Gary Prokosch, DOW, Chief, Water Management Section
REFERENCES CITED


PERCENTAGE OF TIME STREAMFLOW EQUAL TO OR GREATER THAN VALUE SHOWN

GOLD CREEK
MONTHLY FLOW DURATION CURVE
DECEMBER 1985-1991
PREPARED FOR
ECHO BAY MINES
JUNEAU, ALASKA

PERCENTAGE OF TIME STREAMFLOW EQUAL TO OR LESS THAN VALUE SHOWN

INTERNATIONAL TECHNOLOGY CORPORATION
The model proposed by Siegel (this issue) may apply over the aquifer as a whole; however, the study presented by Weaver and Bahr (1991a and 1991b) indicates that other processes affect the flow regime in this aquifer on a local scale. The authors remain convinced that, rather than resulting from a previous flow regime, the ground-water chemistry present in the sandstone aquifer of the study area near the boundary between unconfined and confined conditions (Weaver and Bahr, 1991a) results primarily from processes occurring in response to the current ground-water flow regime as described in Weaver and Bahr (1991b).

References

by Michael T. Goodrich, International Technology Corporation, 5301 Central N.E., Suite 700, Albuquerque, New Mexico 87108

Tsang presented a good overview of the model validation process. I agree that studies like HYDROCOIN (Grundfeld, 1987) and INTRAVAL (Nicholson, 1990) are valuable, but results are often slow to reach the average professional. I also agree with his premise that we need to make a greater effort to publish geospheric model validation theories in the open literature. However, there are several key points that I feel Tsang misstated or overlooked.

First, Tsang stated that models can be validated with respect to a physical process or a site-specific system. I would argue that model validation must be a site-specific endeavor. Models that are able to accurately simulate processes will never be very useful in the waste disposal field if they can be shown to correctly depict those same processes using site-specific hydraulic and geologic data. We know in our hearts that the world is not deterministic and that the concept of a homogeneous and isotropic media is a myth that simply doesn't exist in reality. To ignore those site-specific uncertainties in data and parameters when evaluating a model could lead to an incorrect conclusion about model performance.

Second, Tsang overlooked what I feel is a key component to model validation: purpose. Davis et al. (1991) argued that model adequacy can only be demonstrated for the given purpose of the model. For example, most regulatory definitions of validation include vague phrases requiring the model to "provide a good representation of" (IAEA, 1982), or "reflect the behavior of" (DOE, 1986) that particular agency's view of reality. These are all very general, nonquantifiable, descriptors that must be considered when the purpose of the model is to support a regulatory decision. It is easy how any of a number of models could be interpreted to meet these criteria. The primary discriminator then becomes the purpose of the model. When acceptance criteria are unclear (and let's face it, they often are in the regulatory arena), then ascertaining whether the model fulfills the stated purpose becomes a critical issue. In fact, the same model could be valid for one purpose but invalid for another. Hence, model validation is not only site-specific but also purpose-specific.

Tsang also ignored a basic question of model validation that he debated at every INTRAVAL meeting I ever attended. That is, can models ever really be validated? Davis and Goodrich (1990) said that models could only be shown to be "invalid" or "not invalid" but never "valid." They contend that the scientific method requires us to propose a hypothesis and then design tests to disprove that hypothesis. They cited an analogy from the U.S. judiciary system where the hypothesis is that the individual is "not guilty." A jury must either fail to reject the hypothesis (the individual is "not guilty") or reject the hypothesis (not "not guilty"). Clearly, just because an individual is judged not guilty does not mean that he or she is innocent. It simply means that there was enough evidence for the jury to fail to reject the hypothesis of nonguilt. Similarly, declaring a model not invalid does not guarantee validity. It only provides the modeler a means to demonstrate reasonable assurance that the model is not incorrect. Hence, a model can never be declared "valid," only "invalid" or "not invalid."

Finally, many of the statements made thus far reflect my personal opinions about model validation. Experience has taught me that there are others who have very different views. The process of testing the validity of a model is no different. If I were a regulator and evaluating a model prior to making a regulatory decision, my conclusions could easily be quite different from those of a colleague. Hence, model validation is ultimately a subjective decision. No matter how many performance measures and quantitative acceptance criteria we may select to evaluate a model, eventually humans, with all our imperfections and biases, have to make the final decision on whether or not to accept the results.

References


REPLY TO the preceding Discussion by Michael T. Goodrich of “The Modeling Process and Model Validation”

by Chin-Fu Tsang

I appreciate Goodrich’s alternative ideas as he expressed in his Discussion. I do not consider what we are discussing to be mistranslations or overlooked points whether they be his or mine. It is by discussions of alternative ideas or ideas with alternative emphasis that we can improve our understanding.

There are certainly two alternative viewpoints when Goodrich states that model validation must be a site-specific effort, while I stated that model validation can be with respect to a physical process or with respect to a site-specific system. I am certainly not ignoring site-specific questions of uncertain data and parameters. It is a subject of interest to me (see, e.g., Cook and Tsang, 1990). However, it is my opinion that in addition to those model validation efforts on site-specific problems, one can also discuss model validation efforts on particular processes. The latter include most model validation studies using laboratory experiments and data. For example, it would be extremely useful to validate models to ensure that they can accurately simulate buoyancy flows, heat pipe effects, coupled hydro-mechanical processes, etc. Actually for a given site-specific problem, a number of physical processes may be involved. It would be the proper procedure that submodels are first validated with respect to these processes, and then the total model is validated for the site-specific problem with data uncertainties and geologic structure uncertainties.

Second, I have not overlooked the question of purpose of the model as Goodrich indicated. This is included in Step 3 of the modeling process: “Performance Criteria” in Table 1 of my paper. As I indicated in the text on Modeling Process, “performance criteria are quantities of interest that the model is asked to predict.” This is Goodrich’s so-called “purpose of the model.” It is correct that the model validation is purpose-specific. But I added a further point that sometimes the performance criteria may be overly demanding and we should consider modifying specific performance criteria while still satisfying the overriding concern of safety of waste disposal.

Thirdly, it is common knowledge to workers in this field that models can never be absolutely validated. I stated in the second section of my paper that “one can never have a validated computer model without further qualifying phrases.” The qualifying phrases may include specifications of range of applications and accuracies or uncertainties on predictions.

Finally, I agree with Goodrich that, indeed, acceptance of models is eventually a subjective human decision. The decision should be made not just because a model has gone through model validation, but also it has been used correctly to obtain the particular predictions under consideration. For this the experience and qualifications of the modeler as well as collaborative studies and results are important points to take into consideration.

Model validation is a difficult issue. It is a terrible mistake to assume that a model “has been validated” and then blindly accept all its results. On the other hand, we cannot ignore model validation altogether, because no one should trust results from models that have not gone through validation studies. It is like a medical doctor with an M.D. degree. The M.D. implies that the person has gone through a rigorous program of study and examinations. A sick person should not go to a person without an M.D. degree for treatment. On the other hand, an M.D. degree does not guarantee that you can be healed right away. Often alternative opinions from more than one M.D. should be consulted.

Reference


Short-Course Series

Applied Ground-water Modeling

March 23-27, 1992
April 20-24, 1992

Instructors:
P. Andersen (GeoTrans, Inc.)
L. Konikow (USGS)

This course provides ample opportunity (through lectures and extensive hands-on computer sessions) to become acquainted with the well-documented, thoroughly tested groundwater models, MODFLOW (3D flow) and MOC (2D solute transport), developed at the U.S. Geological Survey.

For more information contact the IGWMC.

International ground water modeling center
Institute for Ground-Water Research and Education
Colorado School of Mines
Golden, Colorado 80401-1887
Phone: 303/273-3103
August 20, 1992

Mr. Rick Noll
Hydrologist
State of Alaska (DNR)
Division of Water
400 Willoughby Ave., Suite 400
Juneau, Alaska 99801

Re: Gold Creek Tunnel Data

Dear Rick:

In response to your letter of July 29, 1992, attached are the mean daily flow data for the Gold Creek Drainage Tunnel. Winter data were lost due to a frozen stilling well when an F type recorder was in use. From mid-February to mid-May repeated F recorder failures resulted from corrosion. At that time the recorder was replaced with an Omnidata data pod and transducer.

If I can be of further assistance please call.

Sincerely,

ECHO BAY ALASKA, INC.

Frank W. Bergstrom
Manager/Environmental Compliance

Enclosure
GOLDCR  
Gold Creek Tunnel near Juneau

Thompson Parshall Flume in Mine Drainage Tunnel

**DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR Oct 1988 TO Sep 1989**

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<td>29</td>
<td>6.7</td>
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<td>17</td>
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<td>5.0</td>
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<td>4.5</td>
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<td>2.4</td>
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</tr>
<tr>
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<td></td>
<td>2.3</td>
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<td></td>
<td></td>
<td>3.7</td>
<td>5.0</td>
<td>4.5</td>
<td>3.2</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL** | 311.1 | 137.3 | 149.8 | 105.3 | 135.4 | 102.4 | 53.5 | 152.9 |
**MEAN** | 10.0 | 4.58 | 4.83 | 6.73 | 4.51 | 3.30 | 2.43 | 5.66 |
**MAX** | 15  | 17  | 13  | 19  | 13  | 5.6 | 6.7 | 22  |
**MIN** | 6.0 | 3.2 | 2.3 | 1.1 | 2.3 | 1.9 | 9.2 | 1.7  |
**AC-FT** | 617 | 272 | 297 | 209 | 259 | 203 | 106 | 303 |
Table 5.2 Regression of Tunnel Discharge on Gold Creek Flow

<table>
<thead>
<tr>
<th>GOLD CREEK FLOW (CFS)</th>
<th>AJ MINE TUNNEL FLOW (CFS)</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.91</td>
<td>1.01</td>
<td>MAR 89</td>
</tr>
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<td>7.57</td>
<td>1.23</td>
<td>FEB 89</td>
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<td>11.5</td>
<td>2.00</td>
<td>FEB 90</td>
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<td>13.0 est.</td>
<td>1.45</td>
<td>DEC 90</td>
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<td>1.59</td>
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<td>16.0 est.</td>
<td>1.79</td>
<td>JAN 91</td>
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<td>1.98</td>
<td>MAR 88</td>
</tr>
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<td>21.9</td>
<td>1.39</td>
<td>FEB 88</td>
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<td>3.48</td>
<td>MAR 90</td>
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<td>2.00</td>
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<td>APR 89 est.</td>
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<td>4.83</td>
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</tr>
<tr>
<td>61.8</td>
<td>4.71</td>
<td>APR 90</td>
</tr>
</tbody>
</table>

Regression Output:

| Constant       | 0.745868   |
| Std Err of Y Est | 0.494441  |
| R Squared       | 0.847262   |
| No. of Observations | 16        |
| Degrees of Freedom | 14        |
| X Coefficient(s) | 0.066058  |
| Std Err of Coef.  | 0.007496  |
MEMORANDUM

STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
Southeast Regional Office
Division of Water

To: Bill Long, Chief
Alaska Hydrologic Survey

Thru: Gary Prokosch, Chief
Water Management Section

Thru: Terry W. Rader
Water Resource Officer

From: John Dunker
Water Resource Officer

Date: July 30 1992
File No: LAS 13128
LAS 13129
LAS 13044
ADL 43152
Telephone No: 465-3400
Subject: Information
AJ/Gold Creek & Sheep Creek
Adjudication

As you know, the time for adjudication of the water right applications from Echo Bay Mines for the A-J Project is almost upon us. BLM’s FEIS has been completed, and the ACMP review is expected to begin soon. The available hydrologic information on Gold Creek and the Last Chance Basin has been augmented by the submission by Echo Bay of the final report from its consultant, IT Corporation.

The adjudicators in the Water Management Section will rely to a large extent on your interpretation of all of the relevant hydrologic information, including but not limited to information provided by the applicant, as this information applies to our adjudication of Echo Bay’s applications. We have prepared a list of questions that follow from our statutory requirements for adjudication under the Water Use Act and from our understanding of how these requirements apply to the proposed project and the existing water rights. These questions are cast here in regulatory as well as hydrologic terms so that you will understand the context; however, we will assume the burden of regulatory interpretation.

As we have discussed before, questions of impacts (effects) or sufficiency of a source to meet needs should be answered in terms of probabilities (and recurrence intervals). Confidence limits and error bars would be welcome where possible. Your judgements of the reliability of the data and its analysis are essential, as are your suggestions for acquisition of additional data where it would solve key problems.

All Gold Creek questions need to be answered with reference to their pertinent diversion conditions. There are three conceptual diversion conditions: the present undiverted condition, the initial mine development diversion condition, and the full mine development diversion condition. Within each of these you may have more than
one hypothetical estimate of diversion amounts, or a range of amounts, depending on various assumptions as to area and location of subsidence and other mining-induced interception and as to hydrologic and hydrogeologic characteristics influencing seasonal flow/area relationships. We will need to understand the assumptions you use in quantifying these conditions.

Please provide your best estimates of subsidence area and location, and interception from subsidence and other mining-induced interception, under the initial diversion and full mine development diversion conditions. If you wish, express this as a range with advice for its application. Please provide your judgement as to data adequacy and reliability, with recommendations for further data acquisition if advisable.

All Gold Creek questions should be answered for two scenarios. EBM has indicated that it can probably segregate up to 2 cfs from the mine drainage and furnish it as clean mitigation water to the Sheep Creek hatchery. In effect, this is water proposed to be diverted from the Gold Creek drainage that it would be feasible to ultimately not divert, and to return to the Gold Creek drainage instead. Therefore, each quantification of diversion condition should have a parallel estimate based on a scenario of 2 cfs less of diversion (or, 2 cfs more of Gold Creek stream flow). This will enable us to estimate the effects of the diversion whether we do or do not approve the transfer of the 2 cfs out of the drainage.

Although not needed in your response to these questions, your recommendations for monitoring stream flows, diversion flows, subsidence, precipitation, etc. will be requested at a later date.

---------------------------------------------------

- Is the source sufficient to supply the Last Chance Basin well field so that it will yield from 7.8 cfs (5 MGD) up to 18.6 cfs (12 MGD) under the proposed initial diversion condition (Gold Creek Drainage Tunnel plugging with no additional diversion from subsidence), and under the full mine development diversion condition?

This question is intended to allow us to determine a preference for public water supply under AS 46.15.090. 7.8 cfs is the current certified water rights of CBJ; 18.6 cfs is the total of the certified water rights and CBJ’s pending water rights application. (You may combine this question with the one below for a range of well field yields from 0.0 cfs to 18.6 cfs.)

Please present for each diversion condition a series of well field yield probability/recurrence interval curves for the 7, 14, and 30-day low flow events, if possible (corresponding to USGS DVMET ranked low flow events).
you deem advisable. Also please note any existing hydrologic or hydrogeologic limitations on CBJ's ability to obtain up to 18.6 cfs from the Last Chance Basin, independently of EBM's proposed diversion.

========================

- What will be the effects of the initial diversion and of the full mine development diversion upon the water rights of CBJ in the Last Chance Basin?

We must determine whether the rights of prior appropriators are "unduly affected" by the diversion. To determine effects, we must know current condition probabilities, to which we will compare estimated future condition probabilities. Effects on CBJ's certified water rights amount of 7.8 cfs (5 MGD) as well as on maximum and average monthly usages should be estimated. As noted in the first question (above), you may choose to answer these two questions concurrently; the above-requested analysis applies here also.

Please summarize the effects (estimated changes from current conditions to both future conditions) in a summary table or graph(s). Please provide any other interpretation you deem advisable.

========================

- What would be the effects of the initial diversion and of the full mine development diversion upon the water rights of AEL&P in Gold Creek?

This will require estimates of the present and future flows in the range usable for hydroelectric generation. Effects on AEL&P's certified water rights amount of 137 cfs as well as on maximum and average monthly usages should be estimated.

If necessary, please enlist the help of AEA staff in verifying the usable range of flow and other aspects of AEL&P's water use/power generation records. Please determine the necessity for the continued availability of low flows, and characterize the impacts to low flow turbine operation in terms of power production and power system operation.

========================

- What would be the effects of granting CBJ an additional water right for up to 18.6 cfs upon the water use of AEL&P for hydroelectric generation?

(See preceding question.)
IMPACTS ON AEL&P

At present the regression equation for Gold Creek flows less than 145 cfs is:

\[ \text{Tunnel Flow} = (0.0399) \times \text{Gold Creek flow} + 1.941. \quad \text{EQ-4} \]

The Gold Creek flows presently being measured by the USGS at upper Last Chance Basin include both the tunnel flow and that component of Gold Creek that does not flow through the mine. To determine the relationship between tunnel flows and Gold Creek flows that bypass the mine, the above equation must be rearranged such that all tunnel flows are on the left side of the equation. In reality, the above equation could be written as follows:

\[ \text{Tunnel flow} = (0.0399)(\text{Bypass Gold Creek Flow} + \text{Tunnel Flow}) + 1.941. \]

Multiplying the slope of the equation (.0399) through the equation becomes:

\[ \text{Tunnel Flow} = (0.0399)\times \text{Bypass Gold Creek Flow} + (0.0399)\times \text{Tunnel Flow} + 1.941. \]

Subtracting (.0399)Tunnel Flow from both sides, the equation becomes:

\[ (0.9601)\times \text{Tunnel Flow} = (0.0399)\times \text{Bypass Gold Creek Flow} + 1.941 \]

Dividing both sides by .9601, the final equation becomes:

\[ \text{Tunnel Flow} = (0.0416)\times \text{Bypass Gold Creek Flow} + 2.022 \]

The flow that bypasses the mine is the post-diversion flow that will be measured by the USGS gage.

And the final equation used in the text is:

\[ \text{Tunnel Flow} = (0.0416)\times \text{Post-Diversion Gold Creek Flow} + 2.02 \]
Comparison of Streamflow Measurements by IT and the USGS

<table>
<thead>
<tr>
<th>Date</th>
<th>IT Measured Flow</th>
<th>**USGS Gage Flow for the Same Period IT Flow was Made</th>
<th>Percent Difference</th>
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<td>21 Dec 90</td>
<td>6.6</td>
<td>6.9</td>
<td>4</td>
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<td>10 Jan 91</td>
<td>3.3</td>
<td>3.6</td>
<td>8</td>
</tr>
<tr>
<td>12 Feb 91</td>
<td>34</td>
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<td>5 Apr 91</td>
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<td>9</td>
</tr>
<tr>
<td>17 Apr 91</td>
<td>24</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

'IT stream flow measurements generally took 30 to 60 minutes to complete. USGS flow was determined for the midpoint of the IT measurement period from continuous USGS records.

**USGS measurements from H. Seitz, U.S. Geological Survey, oral communication
John Danner

not need to be further described by minor

John, and be submitted with the same and problem. We understand the impact does

information shown in the record. We need to share. Because this is a major in

coordinates provided by either and in.

We agree with the USGS conclusion that those decisions do not affect the overall

coordinates. Some data on above site can be viewed at site.

information in the report material. Others are described in the manual. We agree

crack and tuned by Peshken. The low-conjunction crack is only one source of

The means that any source of pollution or visitation is accounted for by the crack

coordinates. We would suggest that both coordinates are still below the

information provided by site. In some cases, the request to retrieve or

We assume that the coordinates may not be valid below the lower data. And edge of

government the cost in analysis time possible. For some measurement purposes in the

cases where that is 15 cm and 1.5 cm, respectively, we choose to exclude the data in

coordinates have been described as to be extended to expand the coordinates. The

another manner that the resulting data and its application are provided by our site

coordinates shown the coordinates that the coordinates read. As expected, these data

coordinates should be incorporated

not included. Those data were used for the documentation that the coordinates are

coordinates are obtained. This is evident to discuss the documentation for readers, but we

Subject: USGS Review of AL Memo

Telephone: NO-465-3400

Date: 27 April 1995

MEMORANDUM

State of Alaska, Division of Water, Hydrologic Survey

FROM: J. MacLeod - ADN, Division of Water

TO: MR Danner

DIRECT

FILE: NO

REVIEW

FROM: Blue Nail

REVIEW

FROM: John Danner

DATE: 27 April 1995

ATTN: Ok, Q&A - A check to full memo.

PR-17-95 201c 15:32
PPH-29
PP. 01/10
MEMORANDUM
DEPARTMENT OF NATURAL RESOURCES

TO: John Dunker
Water Resource Manager

DATE: March 2, 1993

FROM: Gary Prokosch
Chief, Water Management
Division of Water

TELEPHONE NO.: 762-2571

SUBJECT: AJ Mine Water Rights

The attached report from Rick Noll, Alaska Hydrologic Survey will go a long way in addressing the availability of Gold Creek water for use by Echo Bay, CBJ, and AEL&P. What is not addressed by this report is the evaluation of water now being used and the quantification of future water use.

As you are aware, CBJ and AEL&P are currently using Gold Creek water and have received Certificates of Appropriation (water rights) in the amounts of 7.8 cfs and 137 cfs respectively. Alaska water law states that the water rights are valid only if water is used in the quantity certificated. Any water not being beneficially used is subject to revocation for nonuse. Because Gold Creek waters are limited during low flow period an evaluation of CBJ's and AEL&P's actual water use is necessary in order to determine if water rights will be affected by the diversion of Gold Creek water for the AJ Mine project during low flow conditions. In addition, CBJ's application for additional water and Echo Bay's applications for water, need to be quantified with respect to actual water needs over the next 15 years (proposed length of a permit, if one is issued).

Our water use evaluation will provide an accurate picture of current water rights based on past water use and an accurate evaluation of future water needs. With this information and the Gold Creek hydrology report we should be able to address the water rights issues and present the options in case of water rights disputes during low flow events.

I know that you are currently working on this evaluation. If you need assistance please let me know.
March 15, 1993

Mr. Ric Davidge, Director
Alaska Division of Water
P.O. Box 107005
Anchorage, AK 99510-7005

Dear Mr. Davidge;

You asked that we review the attached memo from Jim Munter and Scott Noll to John Dunker. I gave the analysis to Stan Jones, who reviewed it for technical content. His remarks are contained in the attached note and in comments written in the margins of the memo. If you or the authors have questions, they may contact him directly at 786-7100.

Although Stan had some minor reservations about certain aspects of the report, these concerns do not affect the overall conclusions reached by Munter and Noll.

Sincerely,

Gordon L. Nelson
Assistant District Chief
I reviewed the surface water part of the report A. J. Hydrology. The methods of analyses are appropriate considering the short period of streamflow data available. I would suggest using methods described in Stedinger and Thomas, 1985, for future low-flow frequency estimation where base-flow measurements are used.

I would use one regression equation for estimating tunnel flows for discharges below about 28 cfs at the Gold Creek site. Table 2 shows two diverging regression equations below 19 cfs. These equations may not be valid below the lowest daily mean flow of 3.5 cfs recorded at the Gold Creek site. Equation 3 indicates as the flow in Gold Creek approaches zero the tunnel flow reaches a limit of 0.58 cfs. Equation 4 indicates as flows in Gold Creek approaches zero the tunnel flow reaches 1.94 cfs. Are these equations hydrologically valid?

Sites discussed in the text should appear on the figures 1 or 6. The location of figure 5 should be plotted on figure 6.

Attached are two references which are related to low-flow analysis. I will send the reference by Stedinger and Tasker under separate cover.
APPENDIX B
May 11, 1993

Mr. Andy Pekovich
Alaska Department of Natural Resources
400 Willoughby Ave., Suite 400
Juneau, AK 99801

SUBJECT: Revised AJ Mine Water Right Application, LAS 12264

Dear Mr. Pekovich:

As we have discussed, a slightly revised water right application for the Gold Creek water resource is enclosed. The application has been modified to reflect the needs of the State and the CBJ that have been identified during discussions on the water issue. These include:

- Complete diversion of the Gold Creek diversion tunnel to preclude any chance of spill contamination of the CBJ water supply.
- Removal of any operational process water use from the water right application. Instead, additional water will be recycled to make up for the reduced process water right for Gold Creek.

Please note that the CBJ and AEL&P are in the process of negotiating a mutual agreement regarding water rights to meet their needs. This agreement may impact this application. We have been notified that the results of the negotiation will be available soon.

The revised application reflects these modifications. A copy of the previous application has been modified to clearly identify the changes. Large and underlined type has been used for any modification in the application form and on Figures. Deleted portions of the application form, accompanying text, and Figures are crossed out. Modifications on the text is shown in bold type.
Please call me if you wish to discuss these modifications or the overall DNR permitting process and schedule.

Sincerely,

ECHO BAY ALASKA, INC.

[Signature]

Frank W. Bergstrom
Manager/Environmental Compliance

FWB:mf

cc: Greg Sparks
    Gabrielle LaRoche
    Cheryl Easterwood

Enclosure
APPLICATION FOR WATER RIGHT

Revised LAS 12264 (DATED 5/93)

Instructions: You will need (1) a map showing the location of your source of water and the area of use, (2) a copy of your property ownership document, i.e. deed, patent, lease agreement or an easement agreement if you do not own the property involved, (3) a copy of your driller's well log, if application is for an existing well, (4) Statement of Beneficial Use Of Water (Form 10-1003A) if this is an existing water use, and (5) Application for Permit to Construct or Modify Dam (Form 10-1015) if you will be constructing a dam over 10 feet high or over 50 acre feet of storage. Please type or print in ink.

1. Full legal name of Applicant(s) ECHO BAY ALASKA, INC.

Attention: Frank W. Bergstrom

2. Mailing Address 3100 Channel Drive, Suite 2

Juneau, Alaska 99801

Home Phone N/A Business Phone (907) 586-4161

3. Source of Water Supply:

(a) □ Well

□ Drilled □ Hand Driven □ Dug □ Other _____________________________

If existing well, attach copy of driller's well log.

If existing well, and no log, supply all known information

Total depth ___________ Drawdown ___________

Intake Depth ___________ Screened Yes ___ No ___ Unknown ___

Static level ___________

(b) □ Surface Water

□ Stream □ River □ Lake □ Spring

Give geographic name (if unnamed, state so) Icy Gulch Turner Creek
Water will be taken from surface water source by:

- Pumping
- Diversion (Altering a watercourse) - Attach sketch and plans giving dimensions and specifications.
- Damming - Attach sketch and plans giving dimensions and specifications. If dam is over 10 feet high or over 50 acre feet storage, MUST file Application for Permit to Construct or Modify Dam (Form 10-1015).
- Other: Please refer to attached text and figures.

4. Location of point of WITHDRAWAL, DIVERSION, or IMPOUNDMENT:

MUST attach copy of map or subdivision plat and indicate location

(a) Fractional part NE 1/4 NE 1/4 Sections 19 and Section 20 Township 41S, Range 68E, Copper River Meridian.

(b) If applicable, Lot, Block, Subdivision; U.S. Survey No. N/A

(c) Does applicant own or lease the property at point of withdrawal and over which water is transported? Yes [X] No [ ] Leases. (Note: Some of the transport route is on proposed state lease land.)

If "Yes," MUST attach copy of ownership document (i.e. deed, patent)

See attached response.

If "No," MUST obtain an easement or right-of-way and supply copy. Give name, mailing address and phone number(s) of legal owner.

Name ________________________________

Mailing Address ________________________________

_________________________________________ Zip ____________

Home phone ____________________ Business Phone ____________________

5. Location of point of USE: If same as question 4, check and go to question 6. [X]

MUST attach copy of map or subdivision plat and indicate location.

(a) Fractional part NE 1/4 NH 1/4 Section 5 Township 62S, Range 68E, Copper River Meridian: Outfall point.

(b) If applicable, Lot, Block, Subdivision; U.S. Survey No. N/A

(c) Does applicant own or lease the property at point of water use? Yes [ ] No [X]

Application for Outfall lease and right of way to DNR submitted, Nov. 1990.

If "Yes," MUST attach copy of ownership document (i.e. deed, patent)
If "No," MUST obtain an easement or right-of-way and supply copy. Give name, mailing address and phone number(s) of legal owner.

Name: Alaska DNR - Divisions of Lands
Mailing Address: 400 Willoughby Avenue, Suite 400, Juneau, Alaska

Home phone: N/A  Business Phone: (907) 465-3400
Lease and right of way pending (Nov. 1990 application)

6. Type of water use and Quantity of water needed: Please fill in the attached Water Use Chart indicating the quantity of water and months of use for each type of water use. Standard quantities and definitions are provided for your convenience. If water use is for a Commercial/Industrial purpose or Other Use not on the Water Use Chart, refer to question 7.SEE CHART AND ACCOMPANYING DISCUSSION.

7. Commercial/Industrial and Other Uses:
Explain in detail the basis for quantity of water requested. Use additional sheet of paper if needed. Indicate type of operation including structures and methods used. Include a sketch or engineering drawings. Enter quantity requested and months of use on attached Water Use Chart.

Please refer to attached text and figures.
(SEE REVISION OF USES)

SOUTH 1995

8. Date when water use began or is expected to begin South 1995. If water use is existing, fill out Statement of Beneficial Use of Water (Form 10-1003A).

HAVE YOU ATTACHED?

| X | Deed, patent, lease, etc. | NA | Driller's log (if existing well) |
| X | USGS or Subdivision map | X | Diversion sketch and plans |
| X | Filing Fee: dated attached | NA | Dam sketch and plans |
| X | Water Use Chart | | |
| | Statement of Beneficial Use of Water (Form 10-1003A) (if existing water use) |

Statements appearing herein are to the best of my knowledge true and correct.

SIGNED [Signature] 11/14/90
(Applicant)  DATE
MODIFIED
WATER USE CHART

<table>
<thead>
<tr>
<th>Office Use SIC</th>
<th>Type(s) Of Use</th>
<th>Standard Quantities</th>
<th>Quantity Requested</th>
<th>Months of Use From To (Inclusive)</th>
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</thead>
<tbody>
<tr>
<td>NO OTHER USES:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(7) Commercial
(Industrial)

(8) Other: Mill/Drilling
(See Note)

(See Note)

(See Note)

NOTES:

0 DIVERSION (EQUALIZED) SEE TABLE 1 IN RESPONSE TO QUESTION 7

- AVERAGE ANNUAL DIVERSION (8437 gpm)
- RANGE OF DIVERSION (1526 to 17,458 gpm)

- SEE NOTES BELOW

0 PEAK DIVERSIONS MODIFIED SINCE ALL GOLD CREEK DIVERSION TUNNEL FLOW IS REQUIRED TO BE DIVERTED BY THE CB

0 THE Icy GULCH WATERSHED COULD BE CAPTURED AND DIVERTED THROUGH THE MINE AND INTO GOLD CREEK WITHOUT COMING INTO CONTACT WITH ACTIVE MINE WORKINGS. SUCH A DIVERSION, REALISTICALLY UP TO 10 CFS WOULD REDUCE AVERAGE AND PEAK FLOWS OUT OF THE BRADLEY ADIT SIGNIFICANTLY. SEE DISCUSSION IN RESPONSE TO QUESTION 7.

DEFINITIONS:

GPD - gallons per day
MGD - million gallons per day
AFY - acre feet per year
CFS - cubic feet per second

(1) SINGLE FAMILY - Water use necessary for a single household and the irrigation of up to 10,000 sq. ft. of yard and garden.

(a) Fully plumbed - Water piped into the residence for domestic uses. Hot water heater and water flush toilet included.

(b) Partially plumbed - Water piped into residence for limited domestic uses. Generally no hot water heater and no water flush toilet included.

(c) Unplumbed - No water piped into the residence. Water is hand carried for limited domestic use.

(2) DUPLEX - Water use necessary for two single households and the irrigation of up to 20,000 sq. ft. of yard and garden.

(3) MULTI-FAMILY - Water use necessary for three or more households. Apartment units included.
Response to Question 4.(c).

The mining unit agreement between Alaska Electric Light and Power, the City and Borough of Juneau, and BPC Alaska Corporation is recorded at the Juneau District Recorders office in book 235, pages 500-517. Attached is the assignment agreement yielding BPC Alaska Corporation interests to Echo Bay. This lease covers the area at which withdrawal is to be made.

A copy of the entire lease agreement is available upon request.
Response to Question 7.

Upon initial discussions with DNR, Echo Bay contracted with IT Corporation to study the Last Chance Basin water supply. The first report was finished in May 1990 and submitted to DNR. Upon review of this report with DNR, additional studies were outlined and performed. DNR was directly involved and has copies. These studies quantified the source and characterized the diversion.

Basically, water would be diverted from the existing A.J. Mine Gold Creek Drainage Tunnel through the mine to a discharge at the Gastineau Channel. At the request of CBJ, the Gold Creek drainage tunnel will be completely plugged and all flows routed through the mine to a channel discharge. The overall site layout figure illustrates the project, diversion and discharge point. The flow would be equalized and settled for turbidity removal within the mine and in surface facility sediment ponds as necessary.

A typical cross section showing the old underground workings is included (Figure 1). The opportunities for surface flow intercepts are illustrated on the cross section.

A process diagram (Figure 2) showing water distribution system components, diversions, equalization basins, sedimentation basins, and outfalls are also included to help display the water supply concept. Changes are shown. NOTE: The Gold Creek diversion water will not be utilized for process uses. The water will be diverted to remove any chance of interface with the CBJ water supply. A temporary use permit will be filed for use of water in the mine workings for drilling purposes during exploration and construction. During operation, drilling water and other process water will be from recycle flows from the tailings pond.

As an option to the total diversion of maximum potential area runoff intercepted by the expanded AJ Mine, an option exists to reduce average and peak diversion quantities. The Icy Gulch watershed could be intercepted above any potential subsidence area. Icy Gulch may account for approximately 1/3 of the watershed. It may be feasible to intercept and divert flows up to 10-12 cfs from Icy Gulch. During low runoff periods all the Icy Gulch Flow flow could be intercepted. During peak runoff events, flows over 10-12 cfs from Icy Gulch would overflow to the A.J. Mine diversion system and out the Bradley Adit.

Water successfully intercepted from Icy Gulch could be routed through the mine and into Gold Creek without coming into contact with the active mine workings. This potential condition to the water rights permit could reduce average and peak diversion flows as illustrated in Table 2. Diversion out of the watershed could be reduced from 16.4% to 11.5%. 
Hydroelectric Power Generation

The renewed operation of the A.J. Mine will reduce the quantity of water available for hydroelectric power generation at the Alaska Electric Light and Power facility on Gold Creek for a period of approximately 12 years. The extent that power production will be reduced will be directly proportional to the area of the upper Gold Creek watershed which drains into the mine. Presently, approximately 0.7 square-miles or 8 percent of the Gold Creek watershed drains to the glory hole. Once mining operations begin, surface runoff from this portion of the watershed will be diverted to Gastineau Channel, and flows in Gold Creek will be reduced on the order of 8 percent on a monthly or annual basis. This percentage will increase as the mining activity proceeds. When the mining nears completion, it is estimated that 1.6 square-miles of the upper Gold Creek watershed could be diverted. This would represent a 20 percent reduction in the flow of Gold Creek on a monthly or annual basis. Peak average equalized flow would be up to 18,000 gpm from the mine. Flow would vary in proportion to rainfall/runoff as illustrated in the following Table 1. Average equalized flow from the mine will be approximately 8500 gpm. The diversion and resulting loss of power production will continue until after mining operation cease and the quality of the mine drainage is improved enough to allow resumptions of the return flow to Gold Creek.

However, the loss of power production would not be as great as the loss of streamflow. Only 70 to 80 cfs can be used by the power plant while mean monthly flows are greater than 100 cfs for the six-month period of May through October. Thus a significant percentage of the flow in Gold Creek is expected for the May through October period. Because much of the annual power production at the Gold Creek facility occurs in these same months, the percentage loss of annual power production will be much less than the percentage loss in streamflow of Gold Creek.

An initial estimate of the percentage of power loss has been made on the basis of actual power production and stream flow for the 1985 to 1987 period. The following assumptions were used for the calculations.

- A 20 percent power production loss occurred when the mean daily flow was less than 80 cfs.
- The actual monthly power production figures were reduced by 20 percent for the percentage of day when the mean daily streamflow was less than 80 cfs.

According to these assumptions, annual power production could be reduced by 4.5 to 14 percent. As would be expected, in the analysis using flows from past years, the decrease in production would have been lowest in 1987, the year having the most runoff. The largest power production loss would have been estimated to occur for 1985, the driest of the three years used in the analysis.
Discussions have occurred with AEL&P, the owner/operation of the powerplant on Gold Creek and CBJ, another user of Gold Creek water. The AEL&P position regarding water supply and power production will be summarized and submitted upon completion of negotiations. Discussions and negotiations are currently in progress between EBA, CBJ and AEL&P to resolve water use issues in the Gold Creek watershed. Since AEL&P has the largest and most senior water right, it was proposed that EBA option water from AEL&P for CBJ and project use. CBJ has determined that they would rather negotiate directly with AEL&P and are currently in the process of working out a water use agreement. In the interim, EBA has made an effort to reduce Gold Creek uses by reducing process use and to increase recycle for process use.

DNR will be kept informed regarding CBJ/AEL&P negotiations as details become available.
### TABLE 1<sup>(2)</sup>

Maximum Diversion From Gold Creek

<table>
<thead>
<tr>
<th>Month</th>
<th>Gold Creek Flow (cfs)</th>
<th>Diversion through Mine (cfs)&lt;sup&gt;(1)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>41</td>
<td>7.0</td>
</tr>
<tr>
<td>February</td>
<td>23</td>
<td>3.9</td>
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<td>3.4</td>
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<td>April</td>
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<td>4.25</td>
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<tr>
<td>May</td>
<td>114</td>
<td>19.4</td>
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<tr>
<td>June</td>
<td>229</td>
<td>38.9</td>
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<tr>
<td>July</td>
<td>219</td>
<td>37.2</td>
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<tr>
<td>August</td>
<td>188</td>
<td>32.0</td>
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<tr>
<td>September</td>
<td>162</td>
<td>27.5</td>
</tr>
<tr>
<td>October</td>
<td>200</td>
<td>34.0</td>
</tr>
<tr>
<td>November</td>
<td>53</td>
<td>9.0</td>
</tr>
<tr>
<td>December</td>
<td>53</td>
<td>9.0</td>
</tr>
<tr>
<td>Annual Average</td>
<td>115</td>
<td>18.8 (8437 gpm)</td>
</tr>
</tbody>
</table>

Notes:

<sup>(1)</sup> Assumes 17% diversion. Actually the maximum diversion is less than 16.4%.

<sup>(2)</sup> See excerpts from FEIS attached for discussion of water source and diversion.
References


3.1.3.2 Gold Creek Watershed

Gold Creek is a perennial stream draining approximately 10.5 square miles of mountainous terrain and terminating at tidewater along the Gastineau Channel. The stream is approximately 6 miles long. It heads on the northwest face of Sheep Mountain, drops steeply to Silverbow Basin, runs over Ebner Falls to Last Chance Basin, through downtown Juneau (after channelization) to tidewater. Average channel slope is approximately 3 percent. Major tributaries to Gold Creek include Lurvey Creek, Icy Gulch, and Granite Creek.

Extensive placer and lode mining has occurred in the Gold Creek watershed, including past operation of the A-J Mine. One result of this mining activity is that several large areas of ground subsidence called glory holes have formed in Silverbow Basin at the upper end of the Gold Creek watershed. Other remnants of mining activity are the Gold Creek drainage tunnel which was built to prevent surface runoff that entered the mine from reaching lower mine levels, adits, and railroad tunnels.

The glory holes and a vertical raise in Icy Gulch capture surface runoff from an approximately 0.7 square mile area on the north side of Gastineau Peak. About 60 percent of the Icy Gulch drainage is diverted into the mine through the raise, with the remaining 40 percent entering through the glory holes (Ott 1989a). However, CBJ (Mueller 1992) reports that during field observations during the summer of 1991, that little of Icy Gulch itself was captured by either glory holes or the mine. Surface drainage entering the mine eventually discharges into Gold Creek via the Gold Creek drainage tunnel at the upper end of Last Chance Basin.

Wells in Last Chance Basin supply domestic water for the CBJ. The water is diverted directly to the CBJ system via the old Jualapa Tunnel or to a water storage tunnel (the Old Mill Tunnel) that was converted from a mine rail tunnel. The Jualapa Tunnel is used as a chlorine contact facility (see Section 3.3.4.5 for a detailed description of the CBJ water system). An AEL&P hydroelectric diversion exists at the lower end of the Gold Creek. AEL&P has a water right of 137 cfs (ADL 43152). Because there are certain periods in a given year when only the AEL&P water right can be satisfied, ITC (1991b) did its analysis of the Last Chance Basin on the basis of annual flows. ADNR will resolve this apparent conflict between existing water right appropriations and the new CBJ and EBA water right applications. Watershed features are shown in Figure 3-7.

Discharge data (Table 3-8) for Gold Creek are available for the period 1984 to 1988 from USGS gage No. 15049900, located on the left bank of Gold Creek at the head of the Last Chance Basin. 0.6 miles upstream of the Basin Road bridge (USGS 1989). An 8.41 square mile area contributes to this gage. Data are also available for the period 1910 to 1982 from USGS gage No. 15050000 located on the left bank of Gold Creek 150 feet upstream from the AEL&P dam and diversion (USGS 1983). A 9.76 square mile area contributed to this gage.

A rainfall-runoff analysis similar to that conducted for the Sheep Creek basin was performed. The mean annual Gold Creek discharge of 115 cfs at gage No. 15049900 over a 8.41 square mile drainage area implies an average annual precipitation of 185 inches within the watershed for the period 1984 to 1988. According to ITC (1991b), only this upper station can be directly related to water availability in the aquifers supplying the CBJ well field. This is because only this station is located where a majority of the groundwater recharge for the well field takes place.

The Gold Creek drainage tunnel discharges into Gold Creek near the head of the Last Chance Basin. A weir has been used since September 1987 to measure the rate of flow through the Tunnel which discharges upstream of USGS gage No. 15049900 and the CBJ well field. Average flow through the tunnel is 7.2 cfs, and the
The Last Chance Basin lies in a steep-walled glaciated valley, and ranges in altitude from approximately 260 to 330 feet. It is about 4,000 feet long and has a maximum width of 700 feet. The major axis of the basin runs east-west, and Gold Creek roughly divides the basin into northern and southern halves. Unconsolidated sediments reach a depth of at least 236 feet on the north side of the basin, but are less than 100 feet deep on the south side (USGS 1959 and ITC 1991b). The CBJ well field is located at the downstream (west) end of the Last Chance Basin. Investigations by USGS (1959) and ITC (1991b and 1992) indicate that the major water-bearing formations in the Last Chance Basin are sand and gravel deposits within the upper 100 feet of the sediments. Sand and gravel have been found to occur in two distinct zones separated by a layer of clayey silt. The layer of clayey silt is a confining bed that creates artesian pressures in the lower aquifer. In places, the upper aquifer is also confined. The piezometric surface of the aquifer responds to changes in the stream stage of Gold Creek, indicating that the stream has immediate access to recharge the lower aquifer in the downstream part of the Last Chance Basin (USGS 1959 and ITC 1991b). The combined storage of both aquifers is estimated to be 381 million gallons (JMM 1985).

According to ITC (1991b), the upper part of the Last Chance Basin groundwater is recharged by leakage from Gold Creek and from precipitation through talus on the north side of the basin. Residence time for groundwater in the basin is short, with recharge essentially zero unless the well field is being pumped. ITC (1992) notes the well field cannot be pumped at maximum rate for approximately 68 days a year. This restriction coincides with times in the five month low flow period of December through April when flow of Gold Creek is less than 18 cfs.

### Table 3-8
**AVERAGE MONTHLY DISCHARGE FOR GOLD CREEK**

<table>
<thead>
<tr>
<th>MONTH</th>
<th>DISCHARGE (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>41</td>
</tr>
<tr>
<td>February</td>
<td>23</td>
</tr>
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<td>March</td>
<td>20</td>
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<td>April</td>
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<td>May</td>
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<td>June</td>
<td>229</td>
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<td>September</td>
<td>162</td>
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<tr>
<td>October</td>
<td>200</td>
</tr>
<tr>
<td>November</td>
<td>53</td>
</tr>
<tr>
<td>December</td>
<td>53</td>
</tr>
</tbody>
</table>

**AVERAGE ANNUAL**

115


a At USGS Gage No. 15049900, based on 5 years of data.

The highest daily recorded flow was 20.4 cfs. Concurrent measurements of streamflow are available from USGS gage No. 15049900. Both discharge records were compared for the 1987 water year (October 1986 to September 1987). During spring, summer, and fall months, when precipitation is predominantly rain augmented by snowmelt, flow through the drainage tunnel was 5.0 to 6.5 percent of the streamflow in Gold Creek. In the winter and early spring, when a significant portion of the precipitation is snow and when freezing conditions predominate, the flow through the tunnel was 11 to 14 percent of Gold Creek streamflow. This diversion has little effect on flow characteristics other than to change the timing of discharge from the affected subbasin. Neither hydroelectric power generation nor recharge of the aquifer pumped by CBJ wells is reduced by the capture of surface water in the existing mine workings (OTT 1989a). ITC (1991b) evaluated discharges from the Gold Creek drainage tunnel for selected winter months between 1988 and 1991. During that period the maximum average monthly discharge was 4.88 cfs (April 1990) when Gold Creek had 61.8 cfs. The minimum average monthly discharge was 1.01 cfs during March 1989 and February 1990 when Gold Creek had 4.91 cfs and 11.5 cfs, respectively. During the 5 month low flow period of December through April, an estimated 3.9 percent of the total flow above the well field came through the drainage tunnel (ITC 1992).
Gold Creek Watershed

The impacts of the proposed action on the hydrology of Gold Creek watershed would be moderate. The primary adverse impacts to this watershed would be reduction of flows caused by interception of runoff by ground subsidence and diversion of the return flow from the Gold Creek drainage tunnel.

Average annual flow in Gold Creek would be reduced by about 7.2 cfs when the Gold Creek drainage tunnel is closed. During the low flow period, flow would be reduced 3.9 percent, for a total of 174 acre feet. During the later years of operation, there is potential that up to an additional 12.6 cfs of the average annual flow could be diverted from Gold Creek as a result of increased subsidence in the headwater areas. This represents a 17 percent reduction in the total average annual flow of 115 cfs at the well field.

The ITC (1991b, 1992) studies on groundwater hydrology of the Last Chance Basin confirm earlier conclusions (Waller 1959; Anderson and Kelly 1986; JMM 1984) that there is a close relationship between streamflow and recharge to the aquifers. During the summer time, when flows are high, the closure of the drainage tunnel would produce no noticeable change in the amount of water in Gold Creek downstream from the drainage tunnel. During the winter, most available streamflow potentially would be reduced below the well field. This reduction would be in direct relation to the amount being pumped and the streamflow when the streamflow is less than 18 cfs. Under the existing condition, the winter time flows would be reduced by recharge to the well field approximately 45 percent of the 5 month low flow period of December through April. With closure of the drainage tunnel, the available flows for recharge at the well field would be under the maximum sustained pumping more than 50 percent of the time. New subsidence in combination with closing the drainage tunnel would further exacerbate the existing shortage of surface flows downstream from the well field during the low flow period an additional 18 percent (from 50 percent to 68 percent). Therefore, the overall impact to the hydrology of Gold Creek would be moderate, but probably not noticeable to the casual observer. For purposes of the FEIS analysis, it has been assumed that almost all of Icy Gulch (a tributary to Gold Creek) would be captured by projected subsidence (see Figure 4-1). For a discussion of the impacts from proposed closure of the drainage tunnel and new subsidence on water supply, see Section 4.1.3.4.

ITC (1991b) found:

"...From the basin geometry and streamflow data, it appears that the majority of the low flow discharge is derived from basin storage in the upstream talus, alluvium, and fractured bedrock. Therefore, it is concluded that the impact under future mining scenarios is the same as the impact under existing tunnel flow conditions on a mean annual basis."

The mine might also impact the Last Chance Basin as a result of overflow storm discharge from the Gold Creek drainage tunnel. When surface runoff rates exceed the 10-year/24-hour storm magnitude, the proposed project would allow excess flow to re-enter Gold Creek via a floodgate in the Gold Creek drainage tunnel. During these extreme events, discharge from the Gold Creek drainage tunnel would be carrying elevated levels of turbidity and suspended solids that could have an impact on the Last Chance Basin aquifer.

Flows exiting from the Gold Creek drainage tunnel as a result of extremely high flows inside the mine have been estimated as follows, using Sheep Creek data correlations (EBA 1991a):

<table>
<thead>
<tr>
<th>Storm</th>
<th>Discharge from Gold Creek Drainage Tunnel</th>
</tr>
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<tr>
<td>10-year/24-hour</td>
<td>0 cfs</td>
</tr>
<tr>
<td>50-year/24-hour</td>
<td>39 cfs</td>
</tr>
<tr>
<td>100-year/24-hour</td>
<td>54 cfs</td>
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<tr>
<td>500-year/24-hour</td>
<td>89 cfs</td>
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The actual duration of the peak flows would be on the order of 1 or 2 hours during a 24-hour event. Since sediment basins and water passages in the mine would be overloaded during these events, normal water quality standards would not be met. Turbidities as high as 50 to 200 NTUs, and suspended solids as high as 100 to 300 mg/l are expected for short periods of time. Since the ore reduction process occurs at an elevation much lower than the Gold Creek drainage tunnel, and at a considerable distance from it, the chances of any reagent contamination of the Gold Creek drainage tunnel discharge occurring from that source are negligible.

Gold Creek itself would be flowing at anywhere from 10 to 40 times the rate of the discharges coming from the Gold Creek drainage tunnel during these storm events. Since it, too, would be carrying high levels of turbidity and suspended solids, the impact of the discharge from
the Gold Creek Tunnel on the quality of the water flowing in Gold Creek at flood stage is considered to be negligible.

For additional discussion of municipal water supplies, see Section 4.1.3.4.

Under the proposed action, the Gold Creek drainage tunnel would be plugged to prevent water affected by active mining from reaching Gold Creek. Only when flows exceed the 10-year/24-hour storm event would drainage be allowed to flow through the Gold Creek drainage tunnel to Gold Creek itself. These flood flows would be equalized by basins in the mine to the 7,700 to 10,000 gallon per minute (gpm) rate. Existing average annual discharge from the Gold Creek tunnel is approximately 7.2 cfs, or about 6 percent of the total annual flow of Gold Creek. This flow would not be available to Gold Creek under the proposed action (see Table 3-8). Unless CBJ, ADEC, ADNR, or EPA directs otherwise, the majority of mine drainage would again be diverted back through the Gold Creek drainage tunnel to Gold Creek when mine water meets Alaska water quality standards after mine closure.

Reduced total Gold Creek flows of 17 percent under the upper reasonable case scenario would have a negligible direct impact on hydroelectric generating facilities at the lower end of Gold Creek. On the average, no loss of power production would be expected during May through October, when Gold Creek discharge is generally high. Since most hydropower production also occurs in these months, the percentage loss of annual power production would be less than the total 17 percent loss of Gold Creek streamflow. It is estimated that annual power production at this facility would be decreased by approximately 2.5 to 8 percent (see Section 4.1.3.4).
WITH SIMILAR DATA SETS SHOULD BEexplored IF NOT
INCLUDED IN THIS ANALYSIS.

SEKNWEIGHTING

BASED ON 47 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW = .198
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW = .302

FINAL RESULTS

FREQUENCY CURVE - 01-1505 Gold Creek 9.76 SQ.MI. 1915-92

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<th>.95 LIMIT</th>
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FREQUENCY CURVE STATISTICS

MEAN LOGARITHM 3.1446
STANDARD DEVIATION .1651
COMPUTED SKEW .9446
GENERALIZED SKEW .2000
ADOPTED SKEW .6000

FINAL RESULTS

FREQUENCY PLOT - 01-1505 Gold Creek 9.76 SQ.MI. 1915-92

BASED ON COMPUTED VALUES, FLOW IN CUBIC FEET PER SECOND

10000

x x x x x

100

x x x x x

x x x x x