Y. BAJARD ASSOCIATES LTD.

REGIONAL PLANNING — RESOURCE DEVELOPMENT

ANALYSIS OF INFORMATION AVAILABLE ON

WATER RELATED ASPECTS OF MINING IN HIGHLAND VALLEY

Our file: 0042

January 23, 1981

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February 9, 1981 Our file: 0042

Dr. W.J. McMillan
Energy, Mines and Petroleum Resources
Parliament Buildings
Victoria
British Columbia
V8V 1X4

LOG NO: 2.12 T3
ACTION:
FILE NO:

Dear Dr. McMillan,

Please find enclosed a copy of our report entitled "Analysis of Information Available on Water Related Aspects of Mining in Highland Valley." It is sent to you on request of the Nicola Valley Stockbreeders' Association, for information. Your opinion on the matter would be appreciated. Also it may be useful for discussion with persons in charge at the Groundwater Section of the Hydrology Division, Inventories and Engineering Branch, B.C. Environment.

Thank you again for the information provided on the geology of the Highland Valley.

Sincerely yours,

Y. Bajard, D.Sc., P.Eng.
President

no maps - hard to assess conclusions

cc. Dr. Foweraker
Guy Rose
Len Marchand
Al Zachodnik

Glacial - see p13

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ANALYSIS OF INFORMATION AVAILABLE ON
WATER RELATED ASPECTS OF MINING IN HIGHLAND VALLEY

I. INTRODUCTION

The object of this report is a review of information prepared by mining firms in Highland Valley and communicated to our firm, re the possible effect of contemplated and recently initiated mining operations in the area on the hydrology of Witches Brook and Guichon Creek Valleys and on water uses in those valleys.

This report is produced as a result of a verbal agreement made on December 11, 1980, between our firm and the Nicola Valley Indian Administration on the one hand and the Nicola Stockbreeders' Association on the other.

Our firm has been engaged during the past three and a half years in extensive data gathering on water resources, their governing factors and their utilization, and processing them towards the establishment of a comprehensive water management system in the Nicola Valley, which includes the Watershed of Guichon Creek and Witches Brook in particular. We have constructed an approximate hydrologic model of the system which was presented in August, 1980, to the Working Committee set up specifically in 1977 for the purpose of improving management of water and related resources in the Nicola Valley.

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Dr. Bajard, while working for Klohn Leonoff Consultants Ltd., had also taken a very active part in 1973-74 to the preliminary study of a then contemplated open pit in Highland Valley (J-A Zone) by Bethlehem Copper Corporation Ltd.

The firm has therefore considerable experience on the matter and knowledge of the specific area.

II. TERMS OF REFERENCE

Terms of reference of the current assignment were:

a) to approach the mining firms in Highland Valley and obtain from them as much as possible the information, reports, studies, monitoring records, etc. relative to surface and groundwater hydrology in the Highland Valley, and in particular the reports dealing with the projected effects of contemplated or recently initiated mining operations in Highland Valley on the overall hydrology of Guichon Creek and on water users in this area.

b) to review the information provided, analyze it and draw conclusions on the matter.

c) to recommend a line of action in function of the conclusions drawn.

III. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations resulting from our analysis can be summed up as follows:

3.1 Conclusions

a) Two large mining firms with large open pits, mills, tailings ponds waste dumps, etc. have been operating in Highland Valley for several years. Apparently their operation will continue for several years. One firm is starting a large open pit at present. Another one is planning to begin shortly. There are other ore bodies in Highland Valley, some of which have been investigated in great detail. Mining of copper and associated metal can therefore be considered (in economic terms) as the vocation of Highland Valley for at least the next thirty years.

i) *Mining undoubtedly affects the hydrologic regime of Witches Brook and therefore of Guichon Creek (and of Pukaist Creek) in the following fashion:*

- *reduction of total flows*, caused by cutting off of parts of the Watershed;
- *changes to the runoff regime resulting from:* changes in ground cover, (open pits, waste dump, logging, road construction, mills, etc.), higher and shorter freshet, relatively lesser recharge to aquifers, reduction of summer flows because of a lesser "sponge effect" of the ground, draining back to the creeks;
- *changes in the groundwater system* because of pumping for water supply or for open pit dewatering) which, although their direct drawdown effect on the regional system may be relatively small, reduce surface flows because they induce higher recharge rates. This causes a reduction of streamflows at all times. In addition, this indirectly affects summer flows (further reduction of the "sponge effect", storage of Mamit Lake, and possibly the recharge to remote aquifers along the system (e.g., alluvial fan near by Shulus and Lower Nicola)

- all this boils down to the simple but valid statement *that it is impossible to take out from a complex hydrologic system, in which surface streams and aquifers are definitely interdependent, a large fraction of the upstream runoff* (29% of annual runoff to Little Divide Lake as per Valley Copper estimates - and this is in our opinion, a relatively conservative figure) *and still larger amounts of groundwater* from various levels. According to figures given in Valley Copper report stage 2 Volume 3, the amounts currently pumped each year are equivalent to 82% of average annual flow (1969-79) of Witches Brook at mouth and to 49% of the cumulated average flow over the same period of Witches Brook and Pukaist Creek[1]. Projected pumping is 3.6 times larger than average annual flow at the mouth of Witches Brook and 2.1 times larger than the cumulated average annual flows of Witches Brook and Pukaist Creek.[2]

b) *There is however a remarkably dense data base, on present and contemplated water uses, surface hydrology and groundwater,* of variable precision and reliability. *This information is however scattered* between the mining firms, who apparently do not pool their water-related information, some government agencies (e.g., B.C. Fish and Wildlife, Water Management, Waste Management, Thompson-Nicola Regional District, Municipality of Logan Lake) and ourselves.

Contact was established with the four mining firms and a reasonable goodwill for cooperation was noticed. Most cooperative was Valley Copper, who communicated without difficulty the information they have. For circumstancial reasons no written documents were communicated by the others but some information was given by telephone. We have in the past three years obtained a large fraction of the information existing in Government agencies (but not all) and done our own investigations in the field over the entire Watershed.

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(1) Or again respectively to 26% and 13% of the fraction of annual precipitation which is not lost by evapotranspiration (according to figures given in the Water Balance)

(2) or again respectively to 113% and 57% of the same fraction.

c) *The problem is not addressed in a complete, clearly defined manner by the mining firms.* Our understanding of the problem is as follows:

i) are the mines under their current and future level of operation likely to reduce the flows or affect water quality in Witches Brook or the groundwater regime to an extent which would adversely affect other water users beyond acceptable limits?

ii) if so, what can be done to compensate these effects in a most cost-effective manner?

and as a side question, addressed more specifically to the mines?

iii) are they getting their water, dewatering the pits, etc. at least cost?

d) *We have carefully analyzed the information cummunicated by Valley Copper*, i.e., Volume 3 of their Stage 2 report[1]. Our comments on this document are the following:

i) from the structure of this report it appears that:

- *only part of the problem is addressed:* The main effect investigated is remote (regional) groundwater drawdown. Surface hydrology comes as an afterthought in the addendum. No consideration is given to possible larger future water requirements of other activities than mining: the growth of Logan Lake, plans and potential for agricultural and fisheries developments are not taken into account;
- more importance is given to the description of various characteristics of Highland Valley than to interpretation and to development of conclusions;
- because of some confusion in scope, the report deals at the same time with impact assessment and with the design of a pit dewatering system and of diversion ditches of creeks.

ii) in setting the problem, *relatively important and even critical aspects are omitted, making thus the conclusions incomplete:*

(1) which is, as indicated by Valley Copper, to be kept confidential until Government has made a decision on the subject.

- the effects of the operation on freshets, the regime of Mamit Lake, recharge to shallow and deep aquifers and through the "sponge effect", on summer flows are not dealt with.
- no real attention is paid to cost-effectiveness in steps proposed to dewater the pit,supply water to the mine, compensate effects on downstream water users.

iii) *the data base used is incomplete and this again affects the quality of the conclusions:*
- existing geological maps (bedrock and surficial geology) at relatively large scale are not used;
- some information from drill holes is omitted;
- results of a similar study carried out at nearby J-A Zone for Bethlehem Copper (1973-74), and extending well into the Valley Copper area have apparently not been communicated to their consultants;
- data used on water licenses seems to be incomplete;
- some important existing data on climate, water flows and water quality have not been taken into account.

iv) *computation methods are for a large part inappropriate and in fact not applicable to provide sufficiently detailed and representative results.* In particular, this applies to:
- the definition of climatic parameters (general averaging for the drainage area)is not acceptable;
- the definition of water uses (lumping into annual requirements for all the vicinity of Highland Valley) makes it very difficult to identify possible effects ;
- the computation of water balance (and application of average annual values for the basin to a specific location within the basin)is not acceptable;
- the hydrogeological computations (averaging of hydrogeological parameters, assuming rather than measuring those parameters, using a formula which is valid for an homogeneous,infinite half space (180° open)),but not in a complex system as existing in Highland Valley) are disputable;

The method used for surface hydrology is adequate but the results are affected by disputable hydrogeological inputs.

v) *Therefore conclusions drawn are disputable*

- *the statement that ground and surface waters are not related in Highland Valley is not substantiated and in fact contradicted in the report itself.*
- there are discrepancies between our findings on agricultural water requirements (from Water Rights listings) and those stated in the report.
- *the statement that increased pumping rates by Bethlehem Copper have not changed the static level of groundwater since 1967 is based on insufficient evidence and not adequately justified.*
- *distances at which dewatering of the open pit will cease to affect the aquifers in the Valley is based on an incomplete interpretation of the geological structure of the overburden, and the use of disputable computing methods (see above)* (in particular the possibility that some of the aquifers may be "boxed in" between transverse upthrusts of the bedrock and possible discontinuities in the aquifers are not accounted for).
- *the estimates (pit dewatering discharges and subsequently water supply)are disputable for the same reasons;*
- *the proposed layout of dewatering wells is disputable* because it does not take into account the very highly complex structure of the overburden and the possibility of groundwater inflows from the bedrock;
- *the proposal to limit the investigations to the upper 135 m (450 ft.) of the overburden does not take into account the possible dangers to the floor of the pit which hydrostatic pressures in the lower aquifers would cause;*
- *the design of diversion ditches and protection against overland flow does not envisage possible large savings in dewatering (and water supply) which would result from a*

ditch layout and design where seepage losses (recharge) are minimized within the area of influence of pumping at the pit and a selective cutting off from the pit of pervious zones of the top 10 - 15 m (30 - 50 ft.) of overburden

e) From the information available to us, we can conclude, relatively to the other mining operations that the extension of the Lornex, Bethlehem Copper pits and the development of Highmont will probably affect the hydrology of the Guichon Creek system in a manner and to a degree comparable with the effects of Valley Copper.

3.2 Recommendations

We would recommend therefore

a) that action be initiated towards pooling the existing water related information between the mining firms, government agencies at various levels, other water users and ourselves(on Highland Valley and Guichon Creek). This would involve some direct negotiations between the main water users and the mines.

b) on the basis of this more complete information, that an overall, realistic assessment be done of the relative effects of all existing and contemplated activities (mines or others) over a thirty year period, (several alternatives to be taken into consideration),

c) that the problems identified in the alternative retained, if any, be dealt with in a technically acceptable manner(re water supply, treatment after use, and possible compensations to affected users), thus leading to cost-effective solutions. Such solutions would probably consist of

   i) leaving Highland Valley to the mines, with adequate supply systems and pollution control downstream,

ii) joint action to compensate possible reduction of flows in the system elsewhere in the Guichon Creek Watershed, possibly combined with

iii) developments which would increase the safety of water supply and reduce the risk of conflicts to users in the Valley.

This would undoubtedly benefit all parties, not only in avoiding water related conflicts, but in providing cost-effective solutions to water problems. In particular Valley Copper could, through a careful design, documented on all the information available, design a gradual system for pit dewatering and water supply at least cost and minimum adverse downstream effects.

IV. CURRENT STATE OF MINING OPERATIONS AND CONTEMPLATED DEVELOPMENTS

4.1 Mining firms in Highland Valley are:

. Bethlehem Copper Corporation Ltd., which began operations in the early sixties in the hills, just North of the Valley, in Witches Brook Watershed: open pits, mill, initial tailings dam on Witches Brook, 1 km West of Bose Lake, later abandoned when BCCL agreed with Lornex to share a larger tailings disposal facility in the upper part of Pukaist Creek Valley (flowing towards the Thompson River). The operation has resulted in large waste dumps on the hill, numerous service roads and logging off of the area.

BCCL draw their water from

a) wells in Shula flats, South of the Airstrip (9 wells drilled)
b) Total flow of Witches Brook under code 04A (Land improvement).

. Lornex Mining Corporation Ltd., which began operations in 1971 in the hills, South of the Valley in Witches Brook (Bethsaida Creek) Watershed: open pit, mill with large waste dump on the hills, and tailings disposal in a large area of Pukaist Creek Valley, numerous service roads, logging, diversion of Bethsaida Creek, etc.

Lornex draw their water mostly from the Thompson River, natural flow to their tailings dam (recycling) and to a minor extent from two wells in the Valley near by Little Divide Lake, 1.5 km West of Shula Flats (BCCL well fields).

- Highmont Operation Corporation Ltd., which is just beginning operations in the hills, 4 km South of Highland Valley. This will result in a large open pit, mill, waste dumps, service roads, tailings operation which will undoubtedly affect the hydrology of the Guichon Creek system.

  Highmont is entirely within the Guichon Creek Watershed. Highmont get their water from wells in the valley of Witches Brook, 7.5 km downstream of BCCL's well field. They also cut off part of the watershed for the purpose of tailings disposal.

- Valley Copper Mines Ltd., is in the final stages of preparation for starting a large mining operation in Highland Valley itself, just West of Quiltanton Lake. This will entail a 360 m deep open pit on the South West side of the Valley, for a part in the bedrock and for another in the Valley overburden fill (some 200 m deep). This will in particular extend over and drain Quiltanton Lake; imply the diversion of several creeks (Trojan Creek, Bethsaida Creek and an unnamed creek to the West which is to be diverted to Pukaist Creek) and cutting off overland flow. In addition to the pit, there will be a mill, service roads, etc. Tailings disposal facilities of Lornex/BCCL in Pukaist Creek will be used.

  Valley Copper plans to get their water (mill and drinking water) from dewatering the open pit.

- There are still significant amounts of ore in the Highland Valley area and mining will certainly continue for a long time (e.g., 30 years).

The existing operations have undoubtedly affected the hydrologic regime of the Guichon Creek system (and of Pukaist Creek also). Their expansion and the development of new operations will certainly result in larger, more important effects on those systems.

V. PROBLEM SETTING

5.1 Hydrology

In hydrological terms, the Valley of Guichon Creek is a complex network of surface streams and lakes of various sizes draining into the Nicola River at Lower Nicola, combined with a no less complex groundwater system. The latter can be characterized in a few words as a network of fossil valleys, filled by a combination of pre-glacial (Tertiary) continental, relatively loose material (sand, silts, clays with coal and lignite intercalations) overlain by a succession of fluvio-glacial material. The fluvio-glacial part of the overburden reflects the Quarternary history of the area, with at least four successive glaciations. It consists of an irregular alternance of impervious glacial tills and post-glacial and interglacial deposits which combined "twined" cords of fluvial and torrential alluvia flood plain deposits, talus, torrential fans, marshes, lenticular lake deposits of various sizes and permeabilities and fluvio-glacial formations (kame terraces, eskers, etc.) left by streams which ran under the glaciers and communicated in various ways with surface runoff of the time. All this is further complicated by relatively recent faulting in the bedrock (late tertiary if not more recent), which in some cases cut through the oldest part of the overburden and added to the discontinuities of the system. This also includes groundwater circulation in the fractures of the rock, with some indications of geothermal water.

5.2 Water uses

The mines in the Highland Valley are using large amounts of water for ore processing and their requirements are increasing. Other activities in the Guichon Creek system also require large amounts of water:

a) Agriculture, which consists mostly of cattle ranching (by white

settlers and Native Indians) uses large amounts of water in the summer, mostly taken from creeks, lakes and dams,for irrigated production of hay and forage. Domestic water for the ranches and watering requirements from the cattle are less important in size and are catered for by groundwater wells and to some extent, by surface flows. As the climate in the Guichon Creek area can be described as very dry in average, with a wide variation of precipitations from year to year, water is a critical limiting factor to the operation of agriculture and its development. The ranches in Guichon Creek are of small to medium size. Potential for agricultural development would be significant if water was available on a regular, safe basis. There is a fair amount of undeveloped Class 2 to 4 land (B.C. Land Commission Classification). Also the policies of the Provincial Government call for a strong increase in agricultural production. Even though very little water is drawn directly from Witches Brook for agriculture, much is drawn from Guichon Creek below Witches Brook's Junction.

b) Communities, some of which (e.g., Logan Lake, Lac Le Jeune and Mamit Lake) are developing very fast because of the intensification of mining and tourism, are also consuming large amounts of water. Most of it comes from groundwater. Effluents however are sent back to the upper layer of subsoil which may drain into the creeks. Demand is significant at all times of the year but again, peak demand is in summer.

c) Fisheries, which at present are compelled to make do with what is left in the streams (they are dry in general for a large part of the summer) but plan to develop the system for migratory Coho salmon and Steelhead trout (these are known historically to have been abundant in the system) and to increase its carrying capacity for Rainbow trout. All this would imply the safe and regular supply of minimum flows to selected streams (to our knowledge, Witches Brook is not one of them, but the main stem of Guichon Creek below its junction with Witches Brook certainly is). Demands would be a minimum supply all year, with peaks in summer and fall. Reduction of floods is also important.

d) Industries, such as sand and gravel operations on Shulus Reserve also require relatively large amounts of water, but their total requirements are relatively small. The potential for industrial development in the Guichon Creek system is not known but, apart from the mines, it does not seem to be significant.

All those activities contribute significantly to the economy of the Province and cannot be ignored.

5.3 Water affecting activities

The activities mentioned above affect the water regime: in one way or another they send effluents which are not as pure as the water they took or they change the runoff and seepage process by clearing land, covering it with asphalt or concrete, excavating it, etc. Other activities, less directly depending on water supply to operate are also affecting the regime: logging, road construction, etc.

5.4 Problem setting

In general terms the problem is for every water user to get the amounts of adequate water he needs at the appropriate time at least cost.

To that effect the others are to leave enough to him and not to pollute the water or disturb the rivers and groundwater sytem beyond certain limits, more or less well known.

In the Highland Valley and Witches Brook Watersheds specific questions are the following:

a) are the mining operations, current, planned or future possible, as they plan to expand, likely to reduce the flows or affect water quality in Witches Brook (and Pukaist Creek) and the groundwater regime to such an extent that the supply to other users would be affected beyond what can be accepted?

These questions are in fact interrelated because the streams flowing into Highland Valley recharge the aquifers, especially along the sides of the Valley. Also, groundwater, seeping through one or another of the loose sandy layers of the sub-soil may, because of local geological conditions, may end up near the surface and ooze out water diffusely to the soil or to the streams, even if there is no major springs.

An additional question is then:

b) if the mining operations are affecting the surface or groundwater regimes beyond what can be accepted, what can be done to compensate this in a most cost-effective manner?

Finally a side question which is to be addressed is the following:

c) are the mining operations getting their water, dewatering their pits, disposing of their used water at least cost?

VI. WORK CARRIED OUT

6.1 Bethlehem Copper, Lornex, Highmont

Contact was established by telephone with Messrs J. Walmsley of BCCL, Dal Scott of Lornex and H. Hallbauer of Highmont. For various reasons no meetings could be arranged until now. However,some information was provided by telephone by BCCL. Highmont was just starting operation and have not much time available at present. They appeared however reasonably cooperative and a meeting could be scheduled in February.

6.2 Valley Copper

A meeting took place with Messrs R. Taylor and M. McGarry of Valley Copper on December 15, 1980. They were then informed of our mandate. Also, the possible scope of another meeting already scheduled for the next day with their consultants, Messrs W. Brown of Brown-Erdman and Associates and Dr. A.G. Chantler of Crippen Consultants was discussed.

A preliminary discussion took place on December 16 with these consultants. Subsequently, we requested communication of Volume 3, Surface and Groundwater Studies of the Stage 2 Report of the Valley Copper Project.

This Volume 3 was sent to us on January13,1981 by Valley Copper and carefully analyzed.

6.3 Information already available

We had anyway in our office and were familiar with a considerable amount of information on the Guichon Creek Valley and Witches Brook

- Topographic maps (1/50,000)
- Bedrock geology maps (1/25,000)(McMillan, Crado - 1979)
- Surficial geology maps (1/50,000) enlargement of 1/250,000) Fulton, 1975
- Canada Land Inventory Maps (1/50,000)

- Air photos (1/33,000)
- Landsat imagery (1/500,000) - September 1976
- Water rights listings up to date - 1980
- Water rights maps (1" - 20 chains)
- Agricultural Land reserve map (1/50,000)
- Forest cover maps (various scales)
- Land capabilities maps (1/50,000) for Agriculture, Forest, Recreation, etc.

and our Phase I report of the Technical Study of the Nicola Valley Water and Related Resources Management, etc.

We also knew of the existence of several other reports, logs of drill holes, etc. and in particular those existing at BCCL on J-A Zone and the logs of drill holes, foundation and groundwater studies done for Lornex and BCCL which Dr. Bajard had perused in 1973-74, but had not had access to since. Also several surveys have been done by Government and their results not yet released (B.C. Waste Management, B.C. Fish and Wildlife). There is also a development plan for Logan Lake, plans for subdivision near Mamit Lake, etc.

VII. ANALYSIS OF VOLUME 3 - SURFACE AND GROUNDWATER STUDIES VALLEY COPPER PROJECT - STAGE 2 REPORT

The scope of Volume 3 was to assess the impact of Valley Copper open pit, mine and mill operation on the hydrology of Highland and Guichon Creek Valleys.

An analytical summary of Volume 3 and our detailed, point by point, comments were formulated in the course of our work. Our major comments are summarized in the present section.

7.1 Structure of Volume 3

Volume 3 is subdivided into two major sections:

a) the report on the Hydrogeology of Central Highland Valley, dated June, 1980.
b) an Addendum to (a) dated September, 1980.

7.1.1 Hydrogeology report

This report comprizes:

a) conclusions and recommendations, which present in a summary form (1.5 pages)
   - current and future groundwater uses rates in inches over the Highland Valley drainage area
   - total groundwater recharge in similar terms
   - a statement that surface lakes and streams are perched and separate from the subsurface aquifers
   - a statement that 318 l/s (4200 Igpm) of clean dewatering water will be discharged to the mill.

b) an introduction, which

i) explains the mainlines of Valley Copper contemplated operation (1 page)

ii) defines the mandate of Brown Erdman and Associates and the scope of the report (1 page)

iii) defines the location, physiography and drainage of the area (3.5 pages)

iv) gives a brief historical summary of mining in the area and of groundwater development (4 pages)

v) describes the general climatic character of Highland Valley and defines average values of climatic and hydrologic factors (precipitations, evapotranspiration, runoff) (7 pages).

c) a section on present water uses which deals with

i) community water systems (1.5 pages)

ii) private water sources (2 pages)

iii) irrigation (0.5 pages)

iv) Fisheries (0.8 pages)

v) effects of mining on present water use (5 pages)

d) a section of geology, subdivided as follows:

i) regional (1.5 pages)

ii) local (0.5 pages)

iii) surficial geology (regional and local separately) (13 pages)

e) a section on hydrogeology, in turn subdivided as follows:

i) general statement (3 lines)

ii) groundwater geology, in which aquifer coefficients, recharge and discharge are analyzed and a basin water balance proposed (12 pages)

iii) historical aquifers response to pumping (4 pages)

iv) dewatering (2.5 pages)

f) a section on water chemistry (surface and groundwater) (2.5 pages)

g) and a section on the effects of mining (during and after mining) (3.5 pages)

Corresponding maps, plans, sections are put in Appendix.

Comments:

Firstly,the structure of this report is indicative that most probably only part of the subject is covered: nothing is mentioned about surface hydrology, possible future water uses in the vicinity of Highland Valley.

Secondly, the distribution of pages indicates that much more importance is given to description of various characteristics of the Valley than to interpretation and conclusions.

These concerns were confirmed in the course of the analysis.

7.1.2 Addendum

The addendum comprizes

a) a proposal for drilling and testing (5 pages)
b) a proposal for monitoring (1.5 pages)
c) a section on the design of the dewatering system (5 pages)
d) a section on hydrochemistry (2.5 pages)
e) an amplification of the water balance (3 pages)
f) a section on surface hydrology and drainage control, itself subdivided into sub-sections:
    - Hydrology (3 pages and 1 map)
    - Ditch Design (2 pages)
    - Contaminated water treatment (1 page)
    - Downstream hydrological regime (4.5 pages and 2 maps)
    - Historical variation of Witches Brook Regime (1 page)

g) a section responding to miscellaneous comments (3.5 pages)
h) an appendix on the fundamentals of groundwater occurrence, movement and testing (9 pages)

Comments

The structure of this addendum is indicative of some confusions in the scope of the report. Some sections are directly addressing design problems: dewatering system, diversion ditches; some actually provide complements to the hydrogeological study towards an assessment of the effect of Valley Copper operation on the Hydrology of Guichon Creek. There is now a section on Hydrology, but nothing is mentioned about possible future water uses in the vicinity of Highland Valley. The impression that this report is somewhat incomplete and that it does not address the entire problem therefore remains.

7.2 Problem setting

The problem to be solved is set in general terms in the beginning of the hydrogeological report: to assess the impact of Valley Copper open pit, mine and mill on the hydrology of Highland and Guichon Creek Valleys.

However, the report does not fully specify the conditions governing the possible impact of the operation on the hydrology of Highland Valley and Guichon Creek: in which way are the open pit, the mine and the mill likely to affect the hydrologic regime of the area? on what criteria can one judge whether an effect is negligible, acceptable or excessive? In which direction should corrective measures be sought, on what criteria should they be chosen?

Because the systematic analysis of the problem has not been done,a relatively important number of critical aspects are omitted and the conclusions, whatever their individual merits, are incomplete.

7.2.1 Conditions of the problem as per Volume 3

The conditions of the problem, as implied in Volume 3 (they are not explicitely stated) are limited to two:

a) in the Hydrogeological report of June, 1980, the only possible causes of an effect of the open pit, the mine and the mill on the hydrology of the area seem to be
   i) direct remote effect on the regional groundwater system of the drawdown in groundwater levels to result from pit dewatering.
   ii) the contamination of the aquifers by leachates from the tailings pond.

b) in the addendum, another possible cause is added for consideration
   iii) the possible reduction of flows in Witches Brook caused by cutting off part of its watershed, suppressing Quiltanton Lake and diverting several creeks (e.g., Bethsaida and Trojan Creeks).

7.2.2 Samples of omissions

This ignores several other possible effects of the Valley Copper open pit, mine and the mill and in particular:

a) the fact that the open pit and other installations will cut off from Witches Brook,(in addition to the overland flow to Quiltanton Lake the subsurface)flow in the upper aquifer which contributes directly to the flow in Witches Brook with a significant delay: the topsoil, especially in the Valley floor but also on the hillsides is usually soaked by snowmelt, and to a lesser extent, by rains. This interstitial water flows downstream in the shallow ground, much more slowly than runoff. Some of it is lost by evaporation and used by the vegetation. Another part is drained during spring and summer by Witches Brook, therefore contributing noticeably to the low flows. The

possible reduction of summer flows likely to result from such a reduction of the "sponge effect" of the top aquifer is apparently not taken into consideration.

b) the fact that dewatering the pit will have a very important (at least local) drawdown effect in the vicinity of the pit will probably result in a considerable increase of the seepage losses from overland flow and creeks along the sides of the Valley to a significant but unknown distance. In any event this increased trend to recharge the aquifers will be noticeable further East than the limits of the catchment of Trojan Creek and Bethsaida Creek. The residual flows downstream in Witches Brook will be reduced because of this recharge. This will most probably cut a significant fraction of the freshet, and of other possible high flows due to intense showers. This reduction of the high flows in the creek can affect the hydrology of Guichon Creek and therefore the supply to various users in the area on several counts:

   i) reducing the high flows will result in a lesser degree of soaking of the upper aquifer, and therefore a less important "sponge effect" along Witches Brook and the mainstem of Guichon Creek below Witches Brook's Junction, therefore reducing summer flows;

   ii) reducing the high flows will result in a lesser capability for Guichon Creek and Witches Brook to contribute to the possible recharge of deep aquifers at or nearby geological discontinuities (e.g., junction with Guichon Creek Valley, steepening of river bed downstream of Mamit Lake, alluvial fan at Shulus/Lower Nicola, etc.)

   iii) this will also reduce the inflow to Mamit Lake, which can play an important role to regulate flows.

Those aspects of the problem have not been taken into consideration by the authors of Volume 3. They may be more important than the possible extension of the remote effects of drawdown caused by dewatering the pit. It would be of some interest therefore to assess with sufficient precision these possible effects on the hydrology

of Guichon Creek, the corresponding risks of damages to water users[1] in the area of influence of those hydrological changes, resulting losses, and to define the best possible ways to compensate those losses. Remedies, to be effective, may have to be different from the provision of additional storage in Little Divide Lake and imply, for example, a contribution to works outside of Witches Brook Watershed. This might be more cost-effective than the proposed dyking of Little Divide Lake.

7.2.3 Comments

There may be other critical aspects of the problem, and the above possibilities are only examples of what could happen and is not mentioned in Volume 3. Defining all aspects of the problem was not part of our terms of reference. It would require a close review of data available and some more reflexion.

7.3 Data base used

The data base used by the consultants in their analysis does not include significant information, some of which is available to the public and the rest, although belonging to other mining firms in Highland Valley and therefore somewhat restricted, could probably have been obtained because

i) pooling data on groundwater and overburden geology would benefit everyone in the area,

ii) some of it held by Bethlehem Copper, which to my knowledge are also partly owned by Cominco;

As a support to the above statement, a list of data we know exists and could probably be obtained is given below. (This list is not necessarily complete.)

7.3.1 Water uses

* development plans of Logan Lake
* contemplated time schedule of all mining operations
* updated water rights listings and maps (1" = 20 chains)
* development plans/intents of Fisheries (B.C. Fish and Wildlife).

(1) present and future possible

* B.C. Agricultural Reserve Map
* Canada Land Inventory Land Capability map (and more recent update)(Agriculture, Forestry, Recreation)
* Forest cover maps
* Air photos and satellite imagery
* data recently gathered by B.C. Fish and Wildlife (1980)

7.3.2 Climate:

* Air temperature and preoipitation intensive measurements made for most of the Nicola Valley (including Guichon Creek) by B.C. Environment in 1972-75 and eventual analysis, preparation of normalized maps of seasonal precipitation.
* Precipitation measurements made at Logan Lake, Lac Le Jeune by our firm for Federal Fisheries and the Working Committee in Merritt (1979)
* Work on evapotranspiration made by B.C. Environment/Agriculture Canada at the experimental farm in Kamloops.

7.3.3 Water flows - Hydrology:

* Stream gauging carried out in the Guichon Creek Watershed by B.C. Pollution Control Branch (now Waste Management) in 1978 and 1979 and by our firm in 1979 for the Working Committee.

7.3.4 Water quality:

* Analyses made systematically in the Guichon Creek Watershed by B.C. Pollution Control Branch in 1978 and 1979.

7.3.5 Geology - Hydrogeology:

* Maps of bedrock geology 1/100,000 and 1/25,000 recently done by B.C. Mines, Energy and Petroleum Resources (Crado, MacMillan)
* Map of surficial geology 1/125,000 (R.J. Fulton) (G.S.C. 1975)(1)
* Deglaciation studies in the Kamloops Area (R.J. Fulton)(G. S.C. 1967)
* Glacial geomorphology and Pleistocene history of Central British Columbia (H.W. Tipper) (G.S.C. 1971)

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(1) it is mentioned in Volume 3 but evidence that his information was used could not be found.

* Studies made in 1973-74 for Bethlehem Copper, of dewatering of a then contemplated deep open pit in J-A Zone and in particular
  - . map of surficial geology (large scale, appr. 1/15,000) by J.D. Mollard for Klohn Leonoff
  - . resistivity soundings extending roughly between the divide (Big Divide Lake) and the vicinity of Highmont well field (Klohn Leonoff, Geoterrex)
  - . Geostratigraphic cross-section using the above, the logs of all existing drill holes through overburden and in bedrock (Klohn Leonoff)
  - . pumping tests in boreholes (Golder-Brawner) and other investigation drilling for pit stability
  - . a tentative estimate of pumping discharges for the dewatering of the J-A Zone pit. (Klohn Leonoff)

7.4 Computation methods

Methods used by the authors of Volume 3 are disputable, mainly because they are not sufficiently precise to allow specific conclusions on the magnitude of the effects anticipated.

7.4.1 Definition of Climatic parameters (precipitations, evapotranspiration, runoff)

a) The use, in the hydrogeological report, of annual averages of precipitation and evapotranspiration is not representative of the situation. It would be necessary, if sufficient precision is to be achieved, to use monthly values (as done in the Addendum, hydrological study) and to take into account the very important possible variations from year to year.

b) There are also better - and easy - manners to assess the actual evapotranspiration in the Valley, by using in particular monthly values of air temperature (measured at Bethlehem, Lornex and for which gradients in function of elevation can be defined), solar radiation, etc.

c) "Average" values of precipitations, evapotranspiration for the entire watershed of Highland Valley cannot be accepted as representative of the specific situation in the vicinity of Quiltanton Lake. This can be compared to using statistical data for a specific individual.

d) It is also very difficult to justify the method chosen to represent runoff: dividing the mean annual flows (1969-1979) at the gauging station located at the mouth of Witches Brook by the drainage area of the Brook is not representative

i) of the flows in Witches Brook itself, because interannual variability is not taken into account

ii) of what those flows might have been before mining began in Highland Valley

iii) of the flows (current, future and past) in the area of Quiltanton Lake which, if the same method is applied to Bethsaida Creek, is 2.46 times larger. (this relates again to the point that one cannot use statistical results to a specific individual)

7.4.2 Water uses

a) Agglomerating water uses in one total for the entire vicinity of Highland Valley (Pukaist Creek and Guichon Creek Watersheds) is absolutely not significant of the water requirements which can be affected by mining in Highland Valley. There is no reason why the upper parts of Guichon Creek and Meadow Creek would be influenced by Highland Valley. Rather, in the course of problem setting one should concentrate on those water users which are within the area of influence of flows from Witches Brook and Pukaist Creek and groundwater from Highland Valley. This requires a faily good knowledge of the groundwater potential in the area and a specific definition and localization of water users[1].

(1) This was done in the preparation of the Approximate Hydrologic Model.

b) also water requirements should be subdivided into monthly values. Comparing annual flows and requirements can be very misleading because maximum flows in a year do not occur at the same time as maximum demand.

c) It is also to be noted that water requirements other than those of the mines are not taken into account in the regional water balance (whether when considering present and future uses). This, assuming that the water balance method is valid, is a serious omission given the fact that current "other" water uses are actually larger than the total current and forecast requirements of the mines in the Guichon Creek Watershed and probably of at least the same order in the lower part, influenced by Witches Brook,

7.4.3 Water balance computation

a) The method used for the water balance computation may be valid as a first approximation to represent in a symbolic fashion the balance of mean annual inflows to and outflows from the entire watershed under consideration, in order to assess the downstream effect of that watershed. It cannot however be applied with any chance of being representative of what occurs at any particular point within the watershed. Again this can be compared to applying statistical results to a specific individual of the population contemplated.

b) also, establishing this balance with very uncertain figures, in particular for evapotranspiration, and possibly with the omission of some water uses, does not increase its reliability.

c) finally doing it for average annual values makes it more disputable, because the various elements of the balance do not reach maxima or minima at the same time. Hydrologic variations from year to year, which are a critical aspect of the problem, are not taken into account either.

7.4.4 Geological interpretation and representation methods

No map of the surficial geology of the area is given and the method used for geological interpretation is somewhat disputable. "Fence" diagrams linking comparable lithological levels of boreholes are a valid first step in geological or stratigraphic interpretation. However this should be complemented by transverse cross-sections which would incorporate other informations such as ground and bedrock profiles, surficial geology, land forms, bedrock geology, etc. Also lateral variations in a given unit should be indicated in order to qualify the interpolation. This may seem complicated but is, in our opinion, indispensible; it can be compared with any type of investigations where the principle of action is:

i) to make use of all the information available,

ii) to place it on a common grid, whatever its origin, with qualifications as to the specific value of each item and,

iii) at this point only to try and see if some sense can be made out of the gridded information, and in particular,to define and assess alternative interpretations.

This apparently was not made in the Hydrogeological study.

7.4.5 Hydrogeological computations

The method used for hydrogeological computation is apparently the Cooper and Jacob formula applied to an assumedly homogeneous confined aquifer characterized by one value of transmissivity and one value of storage coefficient, assumedly located in a 180° wide open infinite "half-space". The "boundary" follows the NW - SE contact between bedrock and overburden across the pit and extends to infinity in the contemplated open space. The method is used to define a radius of influence of the drawdown and to assess the effect of the said drawdown on an assumed regional potentiometric level.

This method is not applicable to the situation in the Highland Valley for several reasons:

a) Water bearing "twined" cords and lenses of fluvial, fluvio-glacial and lacustrine alluvia intercalated between impervious or semi-pervious layers on lenses of till, lacustrine silts and clays, etc. contained within a narrow bedrock trough broken by faults as encountered in Highland Valley, do not lend themselves to averaging into a semi infinite homogeneous aquifer.

   This is compounded by the fact that the bedrock boundary is not vertical, and may not be impervious.

b) For the same reasons, which are valid throughout the entire Guichon Creek system, one is not justified in assuming the existence of an overall even regional potentiometric level. There are in fact several distinct groundwater units along the valleys, and in the hills where thick overburden fills exist in buried glacial or tectonic depressions and also a completely distinct hydrogeologic situation in the bedrock.

c) The hyrogeological parameters used in the computations are also difficult to justify. They do not correspond to any measured value (in particular storativity) and could not be accepted as representative of localized measured values(ranging for example for transmissivity from 35% of to 12 times the average value assumed).

d) Also, it is assumed that the only effects of the Valley Copper operation will result from open pit dewatering. This, as already indicated in Section 7.2, is not the case.

7.4.6 Surface Hydrology

Generally the methods chosen are much more to the point than in the hydrogeology section of Volume 3. Mean monthly values of rainfall and runoff are taken into consideration rather than annual values and some care is taken to differentiate runoff coefficients in function of the morphology of the catchment: What happens in the Valley bottom

and Quiltanton Lake is clearly differentiated from the runoff from the hills and this is good. It can be regretted however that the interrelations between surface flows and groundwater, especially the changes in seepage/recharge rates to be expected from dewatering of the open pit could not be taken into account, because of the absence of a map of the surficial geology and adequate cross-sections. Also, minor comments can be made on the choice of the critical design flood used to dimension the ditches, in particular for the probability of combined rainfall and snowmelt.

If these aspects of the problem had been taken into account the computations made would provide a far more reliable estimate of the hydrologic situation than the hydrogeological computations.

7.5 Conclusions and recommendations expressed

In view of the comments made on the other aspects of Volume 3 (Structure, Problem setting, Data base used, Computation methods) one should expect a significant risk that some of the conclusions made are disputable and/or insufficiently substantiated.

7.5.1 Water uses

a) The statement that ground and surface waters in Highland Valley are not related is not substantiated and in fact contradicted in the report itself.

b) The amount quoted as licensed for irrigation ($5.5 Mm^3$) or 4460 Acft. in the vicinity of Highland Valley are much smaller than the total extracted by us from water rights listings in 1979 in Guichon Creek (17 million m^3) or (20960 Acft.).

c) The statements that pumping by Bethlehem Copper at Shula Flats has not affected the aquifers by more than a 6 m (20 ft.) drawdown and that the system has now stabilized is not based on sufficient

data: three measurements of the static level taken at various moments of widely separated years over a 17 year period do not allow any valid conclusions to be drawn. Even if the aquifer has stabilized this is not due to a situation of "no recharge" but to larger annual recharge than what is pumped out. This might change if the pumping increases significantly.

Also the statement that pumping at Shula Flats does not affect the Highmont well field is not substantiated. Even if this is eventually confirmed, it could have several reasons: distance, or discontinuity between the aquifers, or again sufficient annual recharge.

d) The estimates of distance at which dewatering of the open pit will affect the groundwater regime in the system are very disputable. It is probable that this distance will not be very important. However, this would not be due to the reasons invoked in the report, but rather to discontinuities in the aquifers. Actually it is possible that part of the water bearing system to be dewatered for the opening of Valley Copper pit is "boxed" in between the bedrock (sides of the Valley and transverse upthrusts (horsts)).

This would possibly result in lesser amounts of water to be pumped out and therefore a lesser cost to Valley Copper, provided that

- the overland flow and streams are conveniently rerouted in ditches which would avoid the recharge area of the Valley Copper zone or be lined where the intersect it
- the surficial aquifer, relatively shallow (10 - 15 m or 30 - 50 ft.) is at least partly cut off from the pit, preventing seepage

In such a case the effect of dewatering the pit would be very local and would not reach very far in any direction towards Guichon Creek or Pukaist Creek.

e) The dewatering discharge indicated is highly disputable as it is based on hydrogeological parameters and computation methods which in our opinion are not representative or valid. This should be checked more precisely. Incidentally, the investigations proposed in the September 1980 Addendum would not be sufficient to define dewatering discharges with any safety. It is also surprising that no attention is paid at present to dewatering of the deeper levels. Hydrostatic upward pressures in the lower aquifers might exceed the weight of the soil remaining after excavation and cause serious problems of stability of the pit floor. This, according to engineering practices should be investigated without delay.

f) Given the above there is a significant uncertainty as to the amount of water which could be provided to Valley Copper mill on a sustained supply basis. The investigations mentioned above and also in (f) below would provide this information. They would also help defining additional water requirements and possible alternative or complementary sources which would not affect the hydrology of the Guichon Creek system or would be easily compensated.

g) The proposed layout of wells to dewater the pit does not take into account the very complex nature of the overburden, and the possibility that significant seepage could come through the bedrock. This should be carefully investigated before opening the pit. Again, the drilling and testing program proposed is insufficient to achieve this. A detailed interpretation of <u>all</u> existing information would be required, and possibly combined with light geophysics and a very limited number of exploration boreholes in the area (overburden and bedrock)(we presume that such boreholes will be necessary anyway for pit stability computations). This should then be synthetized in model form to obtain a reliable assessment of the situation and the design of a cost-effective dewatering system. Given the information available, we would think that all this could be achieved in a few months.

7.5.3 Hydrology

a) The assessment of possible effects of the Valley Copper operation on the hydrology of the Guichon Creek (and Pukaist Creek) system is very disputable because it overlooks significant aspects of the problem (See points 5.2 and 7.2 above). In particular the probable effects of a reduction of the freshet (because of recharge to the deep aquifers) and of cutting of part of the flows from the surficial aquifer on summer flows in Witches Brook are not taken into consideration.

b) Therefore the proposal to compensate the reduction of summer flows by increasing the storage in Little Divide Lake is probably inadequate. Other possibilities should - and could easily - be taken into account, such as cost sharing in the construction of low cost structures at Lac Le Jeune, Walloper Lake, Paska Lake, Face Lake and/or Mamit Lake which were identified as priorities in our Phase I report.

This would in a way fence off Highland Valley, leave it to the miners and provide a clean, cost-effective compensation from elsewhere in The Guichon Creek Watershed.

c) The design of diversion ditches and their layout does not take into account the increased seepage losses through pervious material in the area of influence of the dewatering of Valley Copper pit. This should be corrected. The investigations mentioned in 7.5.2 above would provide the necessary data.

7.5.4 Water quality

The statements made are probably correct but they are not based on sufficient information.

VIII. COMMENTS ON THE OTHER MINING OPERATIONS

Although relevant information and in particular the various groundwater studies and monitoring data (discharges, static head readings) in the various well fields of Lornex, Bethlehem Copper and Highmont and the hydrologic assessment of the tailings disposal open pit and other works at Highmont were not communicated to us, we can venture a few comments relative to the effect of these operations on the hydrology of Guichon Creek, on the basis of professional experience in Highland Valley and of our analysis of Volume 3 of the Valley Copper Project State 2 Report.

8.1 Mining (open pits and waste dumps, tailings

The extension of the Lornex, Bethlehem Copper pits and the development of Highmont open pit, mill, waste dump and tailings disposal are certainly going to affect the hydrology of the Witches Brook and Guichon Creek systems: the runoff pattern will be affected in that natural water retention in the soil, vegetative cover and actual evapotranspiration will be reduced, runoff, especially at snowmelt and during intense rainfall will be increased. On the other hand a section of the Watershed will be cut off by Highmont tailings dam.

How much?

The balance of those changes and their effects on downstream summer flows and through the "sponge effect" in the alluvia of the flood plains, of Witches Brook and lower Guichon Creek are not known but presumably would be similar to those to be expected from the changes caused by Valley Copper. Also the effect of the changes in the freshet on the regime of Mamit Lake are not known. Neither is the effect on the recharge of the aquifers pumped by Lornex, Bethlehem Copper and Highmont.

8.2 Groundwater exploration

From the figures given in Volume 3 it appears that Bethlehem Copper, Highmont and Lornex are or will shortly be drawing from their respective

well fields a total amount of groundwater of the same order of magnitude as Valley Copper's estimated open pit dewatering discharge. This, for the same reasons as indicated in Section VII above will probably affect, not so much the regional groundwater situation in a direct fashion than,because of an increase in the recharge gradients, surface flows, further reduction of runoff in creeks, overland flows) from the hills. This in turn will cause corresponding reduction of the retardant "sponge effect" in the lower parts of the Valley and of summer flows as well as an unknown effect on the regime of Mamit Lake.

8.3 Comments

a) These two points would warrant some investigations and, if studies on the matter have been done by or for the respective firms, their communication for assessment, comparison with one another, and definition of a specific line of action.

b) A surprising aspect of our findings to date is that the mining firms apparently do not pool effectively the information they obtain from hydrologic studies they are carrying out in the preparation of their operation. This results most certainly in a considerable waste of effort, time and money for each of them at a time or another.

We do not see too clearly, why this information, which does not deal in any way with ore contents or other possible information which those firms could wish to keep confidential, is not exchanged between them.

c) Also, the antagonistic attitudes, which a similar secretive attitude generates with the other water users (who are not communicated in general the information on surface and groundwater obtained by the mining firms) are in the end very counter-effective and result more often than not in delaying the mines themselves. On this subject I would like to commend the very cooperative attitude of Valley Copper who communicated the most up-to-date information without difficulty.

d) As, from professional experience, most water related conflicts result from this type of communication gaps, we would suggest that action be undertaken with the mining companies in order to

i) pool all water related information relative to Highland Valley, and possibly the rest of the Guichon Creek Watershed so that

ii) an overall realistic assessment of the relative effects of all activities upon one another can be made and

iii) the problems, if there are, can be dealt with in a technically acceptable manner, thus leading to a cost-effective solution.

Such a solution, intuitively, would consist, most probably of

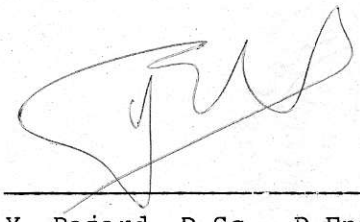
i) leaving Highland Valley to the mines, with adequate precautions to avoid pollution to the outside, and

ii) a joint action to compensate the resulting changes in runoff and groundwater somewhere else in the Guichon Creek Watershed, if possible in combination with

iii) developments which would increase the safety of water supply to the users in the Valley and reduce the risk of water related conflicts.

Vancouver, January 26, 1981

Y. Bajard Associates Ltd.



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