



File: 38050-03/ HONGYANG BOTTLING PLANT

July 30, 2018

To: Murray Allison, RFT, Water Stewardship Officer
Thompson Rivers Natural Resource District
Via email to Murray.Allison@gov.bc.ca

From: David Thomson, P.Geo., Regional Hydrogeologist
Ministry of Forests, Lands, Natural Resource Operations & Rural Development
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Re: Second Peer Review for HONGYANG, Application 20005985

This technical memo is in response to a second peer review request by yourself. There was some confusion in the initial (June 11 2018) review due to there being two applications from the same applicant in the same area. Your primary concerns included:

1. Aquifer confinement
2. Surface water connectivity
3. Pumping test recovery, rate control, discharge water location, observation well responses
4. Absence of basic background hydrologic data, cross sections, well diagrams
5. Connection to Cutoff Valley Creek
6. Recharge from bedrock

Many of the subjects above also speak to the overall sustainability of the withdrawal, which is addressed throughout. The hydrogeological report for this application "Well Drilling, Construction and Pumping Test for Crystal Clinton Bottling Ltd." (Lowen Hydrogeology Consulting Ltd (LHC), 2016) is dated January 12, 2016, prior to the WSA implementation and knowledge of the requirements for a technical assessment (Todd et al, 2016). Subsequent to my initial review of this report, a second report from EHD Consulting, dated July 3, 2015, (EHD, 2015) was made available, titled "Well 41015 Assessment – Proposed Mineral Water Bottling Facility, Clinton, BC." I understand the Qualified Professional (QP) was subsequently made aware of the Technical Assessment Guidelines (Todd, 2016). Also, a supplemental report to the

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2016 report was recently provided in response to comments provided on the basis of the first report (LHC, 2018).

I understand the most recent report (LHC, 2018) is intended to address questions you had regarding EHD's 2016 report, arising in part from it being produced prior to the WSA being enacted. Therefore, the comments below focus mainly on the recent report while also tying into the original analyses.

My ability to address issues you are concerned with as a statutory decision maker (SDM) is sometimes limited with the brief nature of some of the comments, and lack of clarity with respect to assumptions and statements made in that report.

1. Aquifer Confinement

The supplemental report states the unconfined nature of the aquifer in the location where the well was drilled is an "isolated occurrence", noting that the Ministry of Environment mapping describe it as follows: "Well records indicate that clay or till overlies the entire unconsolidated aquifer." (MOE Aquifer Classification Work Sheet for Aquifer 921 accessed online through iMap). The 2007 Work Sheet also noted the aquifer characterization had a "low" degree of certainty.

The other wells drilled for the applicant (WTN 41015, 39847, 39851) in 2014-15 show similar unconfined lithologies. I further note that WTN 86455, east of Duck Lakes at the eastern extent of the aquifer, reports aquifer materials from surface to 36 m when drilling stopped. The provincial observation well near Salt Lake indicates "loose br. clay mixed with crse. sand" in the upper 6 m and then aquifer materials to the bottom of the hole. I interpret the "loose" nature of the clay as non-confining. These lithologies interspersed with the adjacent water bodies and gravel mining almost up to the bank of Cutoff Creek suggest the aquifer may be unconfined across its southern portion, such that a significant part (a quarter?) of the aquifer may be unconfined. Figure 1, attached, shows areas of interest as it pertains to portions of the aquifer that may be unconfined.

Therefore even if the unconfined portion is limited to the area drilled by the four applicant wells, the Hydraulic Connection Guidance (Province of British Columbia, 2016) as it pertains to unconfined sand and gravel aquifers (types 1 through 4a), if applied, indicates one is to assume the lake is hydraulically connected.

2. Surface Water Connectivity

The Well Location Plan shown in Appendix A indicates the production well is on the order of 50 m or less from the east edge of Duck Lake, with Salt Lake approximately 300 m east-southeast. LHC (2018) state elevations are approximate and not surveyed; therefore it is not possible to accurately characterize groundwater flow direction or gain insight into potential surface water flow interactions in the vicinity of Duck Lake.

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Duck Lake, similar to Salt Lake, does not appear to have a natural outflow as it is topographically constrained to the west and south, and a gravel pit exists to the north of the lake. There are other water bodies west of Duck Lake that also have a partial whitish appearance around the edges, that may reflect increased salinity.

Surface water connectivity can be explored at a basic level, as suggested before, through cross-sections, surveyed water elevations, evaluation of water chemistries, and more thorough analysis of the pumping test data for potential boundaries. The above comments are not intended as inclusive instructions for future work, they are just standard analyses that may assist the applicant.

The suggestion that water be diverted from the well to the lake to make up any potential loss of “10-50 m³/d” has no net benefit due to the (assumed) hydraulic connection, so the water would just be recirculated. The calculation of the 10-50 m³/d begins with a statement that the “sand-silt-clay” lake sediments have a hydraulic conductivity of 0.0001 m/d, but there is no support for this, such as a laboratory test, so it is assumed that is an assumption. That value converts to $\sim 10^{-9}$ m/s, which is in the expected range for relatively impermeable clay. If the estimate in this case is low by one or two orders of magnitude – not uncommon for assumed values - the calculated loss could easily be 10 or 100 times larger, potentially exceeding that of the proposed abstraction (397,926 m³/yr or 1090 m³/d).

The applicant’s assertion that withdrawing 6.8% of the aquifer ‘flow’ is sustainable uses uncertain calculations, and also assumes the aquifer does in fact flow somewhere, and that hasn’t been established.

3. Pumping Test

The pumping test is indicated to begin at 0900 on November 27, 2015 at 300 US gpm, then turned down to 170 US gpm after 3 minutes, and then turned up to 200 US gpm after 300 minutes for the duration of the test. Software packages for interpretation of pumping tests with variable rates exist, but were not used for this interpretation. It is difficult to verify the results for correct interpretation since the range of drawdown as plotted occupies about 10% of the 11 inch paper.

In my previous response (Thomson, 2018) I replotted the data showing the test does not appear to reach steady state until more than a day of pumping, approximately 2000 minutes onward. A more correct fit would result in a greater projected 100-day drawdown, which I have not calculated. The applicant will need to supply an interpretation that is reviewable. That interpretation could use derivative analysis to confirm the period of steady state flow as interpreted by the QP.

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The drawdown and recovery data in the other three wells monitored could also be used to provide insight into potential aquifer boundaries and address decision-maker concerns with issuing a license.

- Further analysis of the plotted recovery data in the pumping and observation wells may help understand the aquifer and potential boundaries, as it should reduce or eliminate the effects of variable pumping
- The water level should recover to 90% of the pre-pumping level within the recovery period, but this data was not provided, if it was recorded.

4. Absence of Data

Additional information was provided in a July 11, 2018 memorandum. Combined with the original report, the additional data does not provide adequate understanding of the local hydrogeology and address the concerns, as I understand them, of the Statutory Decision Maker (SDM). Additional concerns may arise through further consultations with other parties.

5. Connection to Cutoff Valley and Creek

It was stated before that hydrogeologic cross-sections to scale (with surveyed elevations of wells and water measuring points) would help understand the potential for connection and probable groundwater flow direction. A single section was provided, to approximate scale. I question the interpretation for the following reasons:

- There is no subsurface data at the creek crossing to suggest the geology as shown
- Geology at WTN 20593 is described as 'loose clay with sand' which does not suggest fully confining to me especially given more definitive descriptors such as till and hardpan are common in area logs
- The section is drawn through several wells that have no well logs to substantiate the interpretation
- WTN 78126, through which the section is drawn, indicates sand and gravel through to 40 m depth (more than shown on section at adjacent WTN 109358)
- Aerial photos in the Water Resources Atlas show apparent gravel mining in the immediate vicinity of 112536 and between 112536 immediately east of the creek.
- Aerial photos in the creek valley also appear to show agricultural fields, which typically require some thickness of permeable sediments.

The applicant's cross section does appear to show a groundwater divide between Salt Lake and Duck Lake on the basis of three water levels, the source and date of measurement which are not known. The single section does not provide strong evidence regarding the relationship between the aquifer, the aquifer flow direction, and Cutoff Creek.

In order to better review the area topography, I have used Google Earth to construct several elevation profiles from various points north of Cutoff Creek through to Salt Lake (Figures 2 – 5, attached). These do not show the subsurface geology, but do illustrate that D-D' is the only

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section showing an overall elevation decrease from the Salt Lake area toward Cutoff Creek. Based on the elevation profiles the Salt Lake and Duck Lake area could reside in a closed basin, which has no natural surface water outlet. The presence of consistent water quality throughout the aquifer would be a key piece of information that could lead to a better understanding of aquifer connectivity and groundwater flow direction.

Surveyed elevations of surface water features and accurate groundwater elevations (taken the same day preferably) are a common way I'm aware of that may substantiate inferences about groundwater flow direction, hydraulic connectivity, etc. This basic information typically would be part of a new groundwater use application, and more complex methods can be employed to investigate potential connection to surface water.

6. Aquifer Recharge

The applicant (LHC, 2018) indicates recharge is from direct precipitation, "mountainside creeks that flow to the edge of the aquifer then infiltrate into the soils", and from bedrock (mountain block recharge). Recharge by the first two means is not consistent with a fully confined aquifer, excepting where the applicant wells are drilled, so the calculations may not be accurate. If the lower portion of the aquifer is not confined, then some portion of the aquifer may be recharged by this means. Also, I see the aquifer is listed as 4.6 km², not 4.1 km².

Recharge by bedrock is possible. The catchment area outlined as "Aquifer groundwater shed" is rectangular and the rationale for its boundaries is not clear, so it can not be evaluated thoroughly.

Bedrock recharge is a common part of the hydrologic cycle in much of British Columbia. The water quality in this aquifer (total dissolved solids (882 mg/L), sulphate (300 mg/L) and chloride (86.6 mg/L)) is uncommon.

The water quality may be natural, or a function of evaporative concentration of surface waters that are in hydraulic connection with the groundwater, and receive limited recharge. The water quality has been consistent with all but the first sample taken at the Province of British Columbia's Observation Well in 1993. Subsequent to 1993 samples have had chloride concentrations ranging from 80-120 mg/L. These results are publically available through the Province of British Columbia's EMS database. The water quality results are attributed to bedrock recharge by the applicant, with a very coarse level of assumptions. The basis for the assumptions is not clear.

In my review of the subsurface geology, the aquifer is underlain primarily by the Chilcotin and Cache Creek groups, the latter of which is described as containing marine sedimentary rocks, which in turn could be related to the water quality. The marine bedrock subcrops only below half or less of the aquifer, which suggests there should not be consistent poor water quality throughout the aquifer if the system is recharged from different bedrock types. To further

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investigate the potential for recharge from bedrock to be the source of the relatively poor water quality, the water quality software Aquachem's Rock Source Deduction feature was used.

Based on the water chemistry and ion ratios of calcium, bicarbonate, sulphate, magnesium, sodium and chloride, it deduced the following:

- Plagioclase weathering unlikely
- Reverse softening, seawater (ie, sodium source other than halite)
- Dolomite dissolution, calcite precipitation or seawater
- Calcium removal through ion exchange or calcite precipitation
- Carbonate weathering (vs silicate weathering) or brine or seawater (based on TDS)
- Rock weathering (based on chloride ratio)
- Carbonate weathering, and Seawater or brine (based on bicarbonate ratio)

The conclusion of 'brine or seawater' several times, along with calcium removal/reverse softening, is more consistent with a hydrologically closed basin than a bedrock source recharge (presuming the marine sedimentary rock recharges sufficient volumes of water to be responsible for the high chloride). Chloride would also accumulate and concentrate over time in an evaporative basin. It is noted that arsenic concentrations are low; high arsenic concentrations are sometimes also associated with marine shale.

Recharge is presumed to increase over time due to climate change. However the calculation of 112,500 m³ surplus water annually does not seem to have included the 10% infiltration factor, so does not lend support to the sustainability of the application.

Summary

One of the requirements of Todd (2016) that is consistent with much professional practice in the field of hydrogeology is the generation of a conceptual model for the site. That is absent. Through my review of the report and the two potential conceptual models took shape. They are briefly described below.

One model is the closed basin model. In this model aquifer recharge is roughly in balance with evapotranspiration, and the surface water bodies and hydraulically connected aquifer(s) have no natural outlet. This situation gives rise to naming of "Salt" lakes around the world as various ions either concentrate or precipitate out of solution over time. Support for this model is provided mainly by major ion analysis of groundwater chemistry analyses, lack of an obvious outlet, and lack of information to the contrary.

The second model is the conventional one, in which an aquifer is recharged by a combination of surface infiltration and runoff, and mountain block recharge. In this case the marine sedimentary bedrock partially underlying the aquifer may supply the relatively saline groundwater found in it, and explain the white precipitate that appears to be in air photos

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within Salt Lake and around the edges of Duck Lake and the other nearby unnamed surface water bodies. The aquifer may be found to have a conventional hydraulic gradient, and discharge downgradient beneath Cutoff Creek.

Further to the above, the single cross section with 4 water levels plotted is not sufficient to reasonably establish groundwater flow direction within the aquifer. At its most basic level this would require accurate surveying (ie, to the cm) of measuring points used to record groundwater elevations in local wells (applicant's, Ministry Observation Well, others) and surface water to establish gradient.

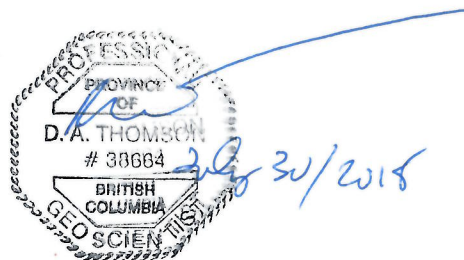
Aquifer recharge mechanisms and estimates remain unclear with the present level of investigation. An aquifer can not be fully confined excepting a small 'window', but at the same time have precipitation infiltrating the entire surface area of the aquifer. Aerial images show several other surface water bodies west of Duck Lake, a relatively large gravel pit mine north of Duck Lake extending almost to the banks of Cutoff Creek, and numerous well logs also show unconfined aquifer conditions. While not corrected for topography, the information available collectively suggests much of the southern portion of the aquifer, in the area of interest, may be in an unconfined state. Some – but not all – well logs close to Cutoff Creek indicate a confined aquifer, with some showing sand and gravel above the confining unit as well.

A conceptual model for the site has not been proposed by the applicant, and should incorporate the unusual water chemistry results.

The pumping test did last for 72 hours but was not a constant rate test until 300 minutes in, and no data or statements indicate water level recovered to pre-pumping levels. Monitoring data is only provided for 24 hours, and observation well data is not fully explored. Recovery to pre-pumping levels is especially important when there is the level of uncertainty about aquifer recharge sources and flow direction.

In short, there isn't enough information provided by the applicant to be able to respond to your questions with much certainty or accuracy.

Signed,



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Attachments:

- Figure 1: Areas of Interest
- Figure 2: Cross-Section A-A'
- Figure 3: Cross-Section B-B'
- Figure 4: Cross-Section C-C'
- Figure 5: Cross-Section D-D'

References

EHD Consulting. Well 41015 Assessment – Proposed Mineral Water Bottling Facility, Clinton, BC. Report prepared for Jane Wang of Clinton Hongyang Zhengong International Investment Inc. July 3, 2015.

Thomson, David (MFLNRORD). Groundwater License Peer Review for HONGYANG, Application 20005985. Intergovernmental letter from David Thomson, Regional Hydrogeologist to Murray Allison, Water Stewardship Officer, June 11, 2018.

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Province of British Columbia, 2016. Determining the Likelihood of Hydraulic Connection – Guidance for the Purpose of Apportioning Demand from Diversion of Groundwater on Streams. Version 1.0. Water Science Series, WSS2016-01. Province of British Columbia, Victoria BC.

Todd, J. M. Wei, M. Lepitre, 2016. Guidance for Technical Assessment Requirements in Support of an Application for Groundwater Use in British Columbia. Water Science Series, WSS2016-08. Province of BC, Victoria, BC.