April 10, 2019 Reference No. 088877

Mr. Allan Leuschen
Senior Environmental Protection Officer Authorizations – South
Environmental Protection Division Ministry of Environment
2080 Labieux Road
Nanaimo, British Columbia V9T 6J9

Dear Mr. Leuschen:

Re: GHD Response to Waterline's Hydrogeological Review of the Proposed Upland Landfill Upland Landfill
Upland Excavating, Campbell River, British Columbia

1. Introduction

Waterline Resources Inc. (Waterline) was retained by the City of Campbell River (City) to complete a hydrogeological review of technical documents prepared by GHD in support of the Upland Excavating Ltd. (Upland) Waste Discharge Application (Application) to obtain an Operational Certification (OC) for the Upland Landfill. The Upland Landfill is located at 7295 Gold River Highway in Campbell River, British Columbia (Site). Waterline indicates the City's concern with the Upland Landfill "relates to the possibility of contaminant migration via groundwater through the underlying sand and gravel and/or bedrock to McIvor Lake, either directly or through Rico Lake."

The results of Waterline's review is provided in a letter dated February 25, 2019 from Bernadette Lyons, MSc.E, P.Eng and Darren David, M.Sc. P.Geo of Waterline addressed to the City of Campbell River Water Department attention Matt Rykers. As part of the review, Waterline conducted a single walkthrough Site visit on January 22, 2019. During their review, Waterline did not contact GHD to request clarification on any of the information contained in the reports. GHD received a copy of Waterline's review on March 22, 2019.

The technical documents reviewed by Waterline include:

- Technical Assessment Report (TAR). Prepared by GHD on May 27, 2016. Amended on May 31, 2017.
- Hydrogeology and Hydrology Characterization Report (HHCR). Prepared by GHD on May 27, 2016. Amended on May 31, 2017.
- 2017 Design, Operation and Closure Plan (DOCP). Prepared by GHD on May 27, 2016. Amended on May 31, 2017.
- 2016 Geotechnical Investigation. Prepared by GHD on May 27, 2016.
- Technical Addendum, Peer Review Response. Prepared by GHD on October 20, 2017.

- 2018 Technical Work Plan and Schedule. Prepared by GHD on March 7, 2018.
- Technical Response to ENV Review. Prepared by GHD on March 23, 2018.
- Technical Response to ENV Review, Task 8 – Sand and Gravel Aquifer Pumping Tests. Prepared by GHD on October 1, 2018.
- Technical Response to ENV Review, Task 7 – Additional Bedrock Characterization. Prepared by GHD on October 1, 2018. Amendment on December 11, 2018.
- Independent Peer Review of Technical Reports, Prepared by Guy Patrick of Patrick Consulting on September 8, 2017.
- Review of GHD Technical Responses Task 7 and Task 8. Prepared by GW Solutions on behalf of the Campbell River Environmental Group on December 21, 2018.

1.1 GHD's Response

GHD has prepared this letter in response to Waterline's review. GHD responses include correction of factual information and clarifications/explanations in response to Waterline's interpretations of information provided in the technical documents.

In summary, Waterline identifies the following matters of concern in their letter:

a) A change in hydrogeologic conditions that could cause a reversal in groundwater gradient

b) The amount of long term monitoring carried out

c) Insufficient hydrogeological analysis

d) The inclusion of the upper fractured bedrock in the landfill impact assessment

e) Leachate generation modeling

f) The capacity of the leachate collection and treatment system

GHD's response to these matters is provided as follows:

a) The change in hydrogeological conditions that could cause a reversal in groundwater gradient, as presented by Waterline, are highly unrealistic. More specifically it is not realistic to hypothesize lake levels dropping with simultaneous collection of extreme amounts of water in the Pit.

b) Sufficient long term monitoring has been carried out on-Site. From September 2015 to March 2019, GHD has collected ten rounds of water levels, 49 groundwater samples and ten surface water samples to characterize water quality and the hydrologic and hydrogeologic conditions of the Site. Water quality samples and water levels were collected during wet and dry months, including in the month of November, which is considered the wettest month of the year in the Campbell River area based on 1981-2010 Canadian Climate Normals.

c) Sufficient hydrogeological analysis and monitoring has been completed in support of the landfill design. The hydrogeologic analysis demonstrates groundwater flows within a sand and gravel aquifer across the Site in a southeast direction away from McIvor Lake, Rico Lake and the City's drinking water source. It also confirms groundwater levels drop over 25 metres (m) across the Site, the vertical gradient in the shallow bedrock in the western portion of the Site is upwards indicating bedrock recharges the sand and gravel aquifer, and water quality compliance is achieved in the performance compliance model under a range of failure scenarios. The design of the landfill exceeds the requirements of the Landfill Criteria for Municipal Solid Waste (ENV June 2016).

d) The upper fractured bedrock groundwater flow has been included in the pumping test analysis only for determining hydraulic conductivity of the sand and gravel aquifer which is clearly explained in the Task 8 letter. The inclusion of the shallow fractured bedrock groundwater flow results in a lower hydraulic conductivity of the sand and gravel aquifer, which equates to lower groundwater flux and higher modelled downgradient water quality concentrations. The higher modelled concentrations were shown to be less than the BC CSR DW Standards under all scenarios.

e) Leachate generation modelling has been sufficiently completed as described in the DOCP. Leachate generation volumes were estimated using the Hydrologic Evaluation Landfill Performance (HELP) model, which is an EPA approved model developed by the US Army Corp of Engineers. The model considered design parameters under a local climate setting. The climate data used a model input was the Canadian Climate Normals 1981-2010 dataset for Campbell River. This source provided 30-year average daily rainfall data which accounted for climate extremes during the above noted time period. Three HELP models were developed to simulate leachate generation under different cover conditions during Landfill development (daily, intermediate and final conditions).

f) The capacity of the leachate collection and treatment system was designed to meet leachate generation rates under the maximum daily average generation rates. The capacity of the leachate treatment system allows for all leachate generated from high intensity storms (leachate volumes were estimated using the HELP model, as described above) to be collected and treated. Not all precipitation becomes leachate and not all water infiltrating into the waste immediately reaches the leachate collection system. The leachate treatment pond has been designed to manage the maximum annual average leachate generated with 100% redundancy. The treatment pond capacity was also designed to provide sufficient capacity to treat the maximum monthly average leachate generated through the winter months (highest precipitation months) with a potential six percent increase due to climate change.

In Section 2.0 of this letter below GHD has reproduced Section 2.0 – Hydrogeological Review Comments of Waterline's letter verbatim including section titles. GHD has provided specific responses to relevant observations, interpretations and conclusions made by Waterline. **Waterline's review comments are in standard black font. GHD responses are in blue italics within a comment box.**

2. Excerpt from Waterline Report with GHD Response

As noted above, the remainder of this letter contains a reproduction of Waterline's report with GHD's comments.

2. *Hydrogeological Review Comments*

2.1 *Potential Contaminant Pathway to McIvor and Rico Lakes*

As part of our review, Waterline was requested to consider the potential for contaminant migration from the proposed landfill to McIvor and/or Rico Lake. The potential for contamination that reaches either lake to adversely affect the City's water supply is a surface water contaminant mixing and transport study and is out of Waterline's area of expertise.

> *GHD Comment 1: The discussion provided in this section does not focus on potential for contaminant migration, but instead discusses the potential for groundwater gradient reversal under, in GHD's opinion, highly unrealistic scenarios.*

Based on the information reviewed, a hydraulic connection likely exists between the lakes and the aquifers beneath the proposed landfill, however insufficient data has been collected to fully understand this connection. The groundwater flow regime is a gravity driven system and will be influenced by natural landforms, surficial sediment and bedrock structure, watershed geometry (lake and river levels), recharge and surface activities. Bedrock surface mapping in the vicinity of the landfill slopes to the southeast and away from the lakes suggesting that the natural groundwater flow follows a similar pattern.

> *GHD Comment 2: The data clearly supports a hydrogeologic connection between McIvor Lake the sand and gravel aquifer. The Lake is the headwater to the sand and gravel aquifer. Groundwater flows beneath the Pit in a southeasterly direction.*

The limited groundwater level data set collected for the Site indicate that groundwater is flowing from the lakes across the Upland gravel pit property to the southeast, shown on Figure 2. For the gradients to reverse, causing groundwater to flow from the landfill area to the lakes, the hydraulic head in the landfill, infiltration ponds and/or pit area would have to be higher than the water levels in the lakes. Furthermore, for contamination from the landfill to reach the lakes the gradient reversal would have to be maintained for long enough for contaminates to migrate to the lakes. It should also be noted that even if water levels in the pit area build up to a level higher than the lake levels there will likely still be a significant hydraulic gradient moving groundwater primarily to the southeast.

> *GHD Comment 3: GHD agrees that groundwater is flowing from McIvor Lake across the Site to the southeast. GHD also agrees that a gradient reversal is highly unlikely. However, in this paragraph Waterline equates gradient reversal with contaminant migration. Waterline does not speak to or recognize the landfill design includes a double composite liner. Waterline's opinion relies on the failure of the liner system.*

The DOCP notes that water levels in the waste will be maintained at less than 0.3 m above the liner, therefore the maximum head in the landfill should be below 168.3 m AMSL. The design elevation of the top of the infiltration ponds is 170 m AMSL (Figure 3). Section 8.4.3 of the DOCP notes that in the case of a multi-day precipitation event temporarily overwhelming the infiltration areas, excess water will be directed to the pit floor. The pit floor elevation is 172 m AMSL, the pit floor covers an extensive area (Figure 2), and therefore it is assumed that water elevations in the pit would likely not exceed 173 m AMSL. The closure plan presented in Section 8 and 11 of the DOCP, indicates that the long-term infiltration of runoff from the landfill will be to the base of the pit.

> *GHD Comment 4: In this paragraph Waterline identifies an unrealistic assumption that the water level across the entire Pit floor could rise to 1.0 m above the pit floor. This scenario also assumes complete saturation of the underlying vadose zone which is highly unlikely and unreasonable.*

Page 21 of the HHCR gives the following description of McIvor Lake levels: "The elevation of McIvor Lake is partially controlled by BC Hydro's Ladore Dam located on the northern shore of McIvor Lake approximately 1.7 km northwest of Site. BC Hydro attempts to maintain a preferred water elevation at Ladore Dam between 176 and 178 m AMSL and has established and a minimum operational water elevation of 174 m AMSL (BC Hydro, 2016). Based on BC Hydro records, water elevations at Ladore Dam have fluctuated between 174.5 and 177.9 m AMSL since 2008."

Assuming:

- The proponent is able to address the infiltration and high groundwater table concerns noted in the following sections of this report and any associated design changes do not raise the water level in the landfill area above the minimum operational level of McIvor Lake,
- The landfill design and closure plan remains as described in the DOCP,
- BC Hydro does not change the management plan for the Ladore Dam,
- There is no catastrophic event that damages the dam and significantly lowers the water level in McIvor Lake, and
- The closure plan for the whole site which has not been reviewed does not significantly change the hydraulics of the site.

It is unlikely that contamination from the proposed landfill, as currently designed, would reach McIvor Lake.

> *GHD Comment 5: The water level in the landfill footprint area which is approximately 164 m AMSL, will not rise more than 10 m above the minimum operational level of McIvor Lake (174.5 m AMSL). Under a catastrophic event resulting in the draining of McIvor Lake, the sand and gravel aquifer will be lowered with the groundwater flow direction in the aquifer following the slope of the underlying bedrock surface. The small amount of leachate in the landfill and treated water in the infiltration pond will have no effect on the hydraulics of the Site. The infiltration pond*

covers an area of less than 3% of the Pit floor and is located over a vadose zone that is greater than 10 m in thickness.

It should be noted that the geological continuity of the sand and gravel deposit between the landfill and McIvor Lake is based on regional information and has not been verified since groundwater is not expected to flow towards the lake.

GHD Comment 6: There are 2 boreholes, 8 monitoring wells, 11 test pits, one domestic well and over 0.5 km of open excavation between the proposed landfill location and McIvor Lake all of which encounter sand and gravel. The encountered underlying stratigraphy provides evidence that a sand and gravel deposit is present between the proposed landfill and McIvor Lake.

Rico Lake was formed after the Gold River Highway was built, water from the Rico Lake is thought to seep under the highway toward McIvor Lake though a French drain, the Upland operation uses Rico Lake as a water source (Terry Stuart and Mark Stuart pers. comm). Six Rico Lake level measurements were presented in the reports reviewed, the lake level ranged from 181.2 m AMSL on January 29, 2016 and March 6, 2016 to 178 m AMSL on September 17, 2018. Over the range of measured lake levels, water from Rico Lake in addition to flowing under the highway toward McIvor Lake would likely flow to the gravel pit either though the bedrock aquifer or though the sand and gravel in the recently delineated bedrock trough, shown on Figure 4. The base of the bedrock trough has not been established but based on the geophysical interpretation presented in the Task 7 TRL it is below 172 m AMSL. The HHCR notes that the bottom of Rico Lake is at 168 m AMSL.

There is a possibility that groundwater from the landfill area could migrate toward Rico Lake if the water level in Rico Lake fell below the ponded water level in the infiltration ponds or gravel pit, i.e. below 170 m AMSL under normal operating conditions or below 173 m AMSL if the gravel pit was flooded. In this case the water would only flow west toward McIvor Lake if the McIvor Lake level was lower than Rico Lake level. As noted above BC Hydro's current minimum operational water elevation for McIvor Lake is 174 m AMSL, therefore in a situation where Rico lake levels are low enough to induce groundwater flow from the landfill to Rico Lake the surface water gradient would most likely be from McIvor Lake to Rico Lake.

The potential for groundwater to be a pathway for contamination of Rico Lake could be mitigated by ensuring that the lake level is maintained above the water level in the infiltration ponds and gravel pit. Ongoing monitoring of water levels in Rico Lake and the bedrock and sand and gravel aquifer would help clarify the nature of the hydraulic connection between the lake and the proposed landfill.

GHD Comment 7: The scenario described in the above paragraphs is unrealistic and misleading. The base of Rico Lake is reported to be between 168 m AMSL (CREC, August 2016) and 172 m AMSL (GHD, September 2018). If the surface water elevation of Rico Lake fell below the infiltration pond elevation (<170 to 173 m AMSL), a reverse gradient would not result. The water from the infiltration pond infiltrates to the underlying vadose zone and aquifer. The highest groundwater elevation in the Pit measured east of Rico Lake is 165.2 m AMSL at MW4B-15. As indicated by the recorded elevation data, surface water in Rico Lake remains higher than the *groundwater elevation to the east. Under this scenario, Rico Lake would continue to recharge the shallow aquifer and fractured bedrock to the east.*

Further, the landfill is not connected to the aquifer and the infiltration ponds have been designed to discharge treated water that meets BC CSR Schedule 3.2 DW Standards. Waterline's unrealistic gradient reversal scenarios continue to inaccurately equate an unrealistic gradient reversal between the aquifers and the Lakes with contaminant migration from the proposed landfill, which again ignores the landfill design and leachate treatment.

2.2 Long-Term Water Level Monitoring

In Waterline's opinion, insufficient baseline groundwater and surface water data has been collected by GHD to fully characterize the local and regional hydrogeological system in relation to the proposed landfill project. The landfill design and aquifer characterization presented in the HHCR and DOCP rely largely on groundwater level monitoring data collected on April 6, 2017. It is not possible to assess the effect of seasonal and long-term variability on groundwater flow using a single groundwater monitoring event. At the request ENV, GHD collected supplemental data in an attempt to help understand the seasonal variability in groundwater levels (GHD 2018d). However; this only included two additional rounds of groundwater measurements and sampling conducted on June 7, 2018 and September 17, 2018. The most complete groundwater level data for the Site are shown on Table 5.1 in the March 23, 2018 TRL, reproduced here as Figure 5.

GHD Comment 8: Waterline is incorrect in stating that the landfill design largely relies on groundwater level monitoring data collected on April 6, 2017. Water levels have been collected on Site between September 2015 and March 2019 (nine separate events).

In GHD's Technical Response to ENV Review, March 23, 2018, Section 4 – Updated Groundwater Compliance Prediction Modeling, GHD presents the results of groundwater modeling for four separate scenarios that model seasonal variability. The groundwater flux beneath the pit floor used in the modeling ranged from 500 m^3 to 865 m^3 per day for the dry and wet scenarios. The range in flux corresponds to a range in saturated thickness of 4.45 to 6.42 m as inputs to the model. The range of the saturated thickness is based on water level measurements from taken at the Site from 2015 to 2017 (seven separate events).

In addition, GHD adjusted the surface water infiltration rates to further investigate seasonal variability. Modeled infiltration rates corresponding to the precipitation rates for the wettest month (November - average 232 mm) and the driest month (July – average 39 mm) were used as inputs to the model resulting in downgradient infiltration rates of 432 m^3 down to 69 m^3 per day.

The work carried out to investigate seasonal variability demonstrates water quality compliance would be achieved under all scenarios.

The standard hydrogeological practice for collecting long-term groundwater and surface water data is to install data loggers in monitoring wells and surface water bodies (lakes, creeks, ponds). This would allow for an ongoing analysis of the hydraulic inter-connections and relationship between the groundwater levels in the sand and gravel and bedrock aquifers to the changes in water levels in Rico and McIvor lakes. This data should also be compared to the local climate data (i.e.: precipitation) to improve the understanding of infiltration and recharge at the Site which is a critical factor in landfill design and operation.

GHD Comment 9: GHD agrees that data loggers installed in monitoring wells and surface water bodies (lakes, creels, ponds) provide on-going water level data. However, it is GHD's opinion that long-term continuous water level data is not necessary under the context of the proposed Upland landfill since the Site is not sensitive to changing hydraulic gradients. Refer to GHD Comments 5 and 7 for further information relative to gradients. GHD is also of the opinion that a "standard hydrogeological practice for collecting long-term groundwater and surface water data" does not exist. It is the duty of the Qualified Professional to gather information and determine what types of regulatory approved data collection methodologies are appropriate for a given Site under investigation.

The landfill design presented by GHD (2018a) is reproduced as Figure 3 for reference purposes. It shows the base of the landfill sloping from an elevation of 168 m AMSL on the south side to a sump elevation of 164 m AMSL at the center of the northern edge of the landfill. As referenced in GHD's DOCP report, the Landfill Criteria for Municipal Solid Waste (ENV 2016) requires that the landfill base be maintained at a minimum height of 1.5 m above the groundwater table at all times. Insufficient water level data has been collected to demonstrate that groundwater levels will remain 1.5 m below the base of landfill. In fact, groundwater levels at MW4A-15 was measured at 165.9 m AMSL on the 6 April 2017, and at 165.2 m AMSL in MW4B-15 on the 11 September 2015 which are above the design elevation of the sump and likely do not meet the ENV landfill criteria. It should be specifically noted that no groundwater level measurements have been collected in the months of November or December which are generally the two wettest months of the year in the Campbell River area based on the historical precipitation record (Government of Canada 2018).

Given the lack of long-term groundwater monitoring data, it is not possible to assess the following:

- The highest historical groundwater level that occurred on site over the monitoring period,
- How the groundwater elevations change (or don't change) in response to changes in the water level in McIvor Lake which is controlled by BC Hydro at the Ladore Dam, and
- The hydraulic response in the sand and gravel and fractured bedrock beneath the Site to significant precipitation events or unusually wet periods.

A better understanding of the hydrological conditions on site are necessary to estimate the highest groundwater elevation expected over the life of the landfill, to ensure that groundwater remains 1.5 m below the base of the landfill during the operating and the estimated post closure contaminating lifespan of the landfill.

GHD Comment 10: Waterline makes a misleading comparison between groundwater conditions on Site and landfill design criteria. In Section 1.1 of Waterline's report, the stated scope of work is "to review reports submitted by GHD to provide comments on the site hydrogeology and hydrology characterization, groundwater divide and risk to the drinking water supply"; however, the Landfill Criteria requirement that the landfill base be placed at a minimum distance of 1.5 m above the groundwater at all times is an engineering requirement. This design criteria outlined in Section 5.3- Landfill Base Design of the Landfill Criteria is relevant to a number of design and performance considerations including the stability of the geomembrane components of a composite liner system to minimize the risk of hydrostatic uplift of the liner. The 1.5 m distance applies to the landfill base liner. Depending on the specific design, the inclusion of a leak detection system can be placed within the 1.5 m distance.

Waterline makes an incorrect comparison of the groundwater table elevation below the leachate collection sump (lowest point) with a water level measured in a monitoring well over 100 m upgradient (MW4B-15). Waterline is also incorrect in stating that no groundwater level measurements have been collected during November and December. Groundwater levels have been measured in November 2017 and 2018. Refer to GHD's letter summarizing groundwater and surface water monitoring data (GHD, April 9, 2019) provided in the various technical reports.

2.3 Fractured Bedrock Characterization

The bedrock at the site is described by GHD (2107b) as a Karmutsen Formation basalt with a varying degree of weathering and fracturing. The hydrogeological characterization of the bedrock beneath the Site has been largely focused on assessing the potential hydraulic connection between the proposed landfill and Rico Lake. An annotated copy of the GHD's bedrock surface contour map is included as Figure 4 (GHD 2018d). The update bedrock contours (Figure 4), show that the southwest corner of the proposed landfill will be at or near the bedrock surface.

GHD Comment 11: The updated bedrock contours as shown on Figure 7.1A of the Task 7 letter report, GHD December 11, 2018, are estimates of bedrock surface elevations when interpolating between bedrock elevations measured in boreholes/outcrops etc. Figure 7.1A indicates that the bedrock contours in the southwest corner of the landfill are inferred. BH5-15 located along the southern limit of the landfill, as shown on Figure 2.8 and presented on Table 1.0 of the 2017 HHCR, indicates bedrock to be below 167 m AMSL.

The geologic/hydrogeologic conditions beneath the landfill footprint including the bedrock surface and bedrock groundwater elevations will be further defined as part of completing the detailed design. The elevation of the base of the Phase 2A landfill cell, although not expected, can be adjusted based on the detailed design field investigation. Refer to the borehole log for BH5-15 which illustrates the bedrock to be below the base in the central portion of Phase 2A.

Groundwater level data collected by GHD from monitoring wells completed in bedrock show groundwater level elevations consistently being measured above the top of the bedrock and above groundwater levels measured in the sand and gravel aquifer (Figure 5). This information indicates the presence of an upward gradient from the bedrock to the sand and gravel aquifer. Considering the updated bedrock surface present by GHD (GHD 2018d) and the observed groundwater levels in the bedrock, the piezometric surface of groundwater in the bedrock would likely be above the base of the landfill in the southwest corner of the proposed landfill. The bedrock groundwater level data do not appear to have been considered by GHD in relation to the ENV landfill criteria requirement of that groundwater levels be maintained 1.5 m below the base of the landfill.

GHD Comment 12: GHD and Waterline are in agreement that there is an upward gradient within the shallow fractured bedrock. As outlined in GHD Comment 10 and 11, the final elevation of the landfill base will respect the requirements of the Landfill Criteria. As a result, the piezometric surface of groundwater in the bedrock is not relevant for discussion. Based on the groundwater elevation data collected at MW3-14, the groundwater in the sand and gravel aquifer will be below 1.5 m below the base of the landfill.

GHD appears to have repeatedly mischaracterised the hydraulic connection between the bedrock aquifer and the sand and gravel aquifer in the pit area. The following paragraph is an excerpt taken from page 7 of GHD's March 17, 2018 TRP but was previously noted in the HHCR and DOCP:

"Significant fracturing has been noted in the boring advanced within the Pit (MW4A-15), including evidence of weathering (i.e. iron staining) and secondary mineralization observed in some fractures. Analysis of hydraulic conductivity testing of the weathered zone gives a K ~ $2x10^{-2}$ cm/s, which is very permeable and essentially an equivalent porous media. As a result, the upper weathered bedrock zone and overlying sand and gravel aquifer can functionally be considered the same hydrogeologic unit."

If the upper portion of the bedrock aquifer and sand and gravel aquifer were essentially the same hydrologic unit as GHD suggests, then groundwater levels in the nested wells MW4A-15 (completed in the top 3 m of fractured bedrock) and MW4B-15 (completed in the overlying sand and gravel) should have the same elevation when measured at the same time. However as can be seen in GHD's water level summary table (Figure 5) groundwater levels in the bedrock well MW4A-15 are consistently 0.2 to 0.3 m higher than in the nested well completed in the sand and gravel aquifer, MW4B-15. This clearly shows that the bedrock and sand and gravel aquifer are not acting as a single hydraulic unit at this location.

GHD Comment 13: The presence of mild vertical gradients between hydraulically connected strata at different depths in a layered system is not uncommon and does not mean that the units are not hydraulically connected. The hydraulic monitoring data collected at the Site supports GHD's interpretation that the upper fractured bedrock and the sand and gravel share a hydraulic connection. In particular, the drawdown observed at MW4A-15 (completed in the upper bedrock) in response to pumping at MW4B-15 (completed in the sand and gravel) verifies the presence of this hydraulic connection.

Further, the similarity in seasonal fluctuations in static groundwater elevations observed between the upper bedrock and sand and gravel, and the similarity between water levels at well nest MW4A/B-15 further supports GHD's interpretation. The verified connection and similarity in static elevations not only support the interpretation that the direction of horizontal movement of groundwater is likely common between the two units, but a component of vertical mixing between the two units is also occurring.

Notwithstanding the above, the mild vertical gradient between the two units has no bearing on the landfill base design or the anticipated future performance.

Based on this incorrect assumption, GHD included the top 3 m of the bedrock aquifer as part of the sand and gravel aquifer in the pump test analysis presented in the Task 8 TRL. This information was also used to assess groundwater flow beneath the landfill and subsequent leachate dilution calculations presented in Section 13 of the DOCP. Therefore, these analyses cannot be relied upon as a basis for landfill design or environmental impact assessment and should be revised.

GHD Comment 14: Waterline appears to not understand how the pump test results were used to estimate the hydraulic conductivity of the sand gravel aquifer which was then used as a conservative input in the groundwater compliance prediction modelling. Only drawdown data for MW4B-15 (the overburden well) was used to estimate hydraulic conductivity of the sand and gravel aquifer. GHD provided this information in the Task 8 report.

GHD stated the following:
"Since MW4A-15 is screened within the shallow bedrock aquifer, drawdown data from this monitoring well is not suitable for use in determining hydraulic properties of the sand and gravel aquifer. Drawdown data from MW4A-15 was used to verify the presence of a hydraulic connection between the sand and gravel and shallow bedrock aquifers only".

A saturated thickness of 16 m was used to calculate the hydraulic conductivity from the transmissivity values interpreted from the pumping test analysis. This thickness represents the total saturated thickness of the sand and gravel aquifer and the upper 3 m of the bedrock aquifer combined that contributes recharge in response to the pumping of MW4B-15 (as demonstrated by the drawdown observed in MW4A-15). Although only minor contributions to the recharge rate of the pumped well are likely occurring from the upper bedrock (i.e. due to the upward gradient), using the full thickness of 16 m is conservative in estimating the hydraulic conductivity of the sand and gravel aquifer.

The lower or conservative hydraulic conductivity estimate for the sand and gravel aquifer, equates to a lower groundwater flux, which provides for lower dilution rates. The lower hydraulic conductivity estimate was used as a conservative input into the groundwater compliance prediction modelling.

2.4 Infiltration Capacity and Groundwater Monitoring

No infiltration capacity testing has been done to determine if the native soil has the capacity to infiltrate the treated leachate at the design rate of 60 mm/hr (GHD 2017a) or if groundwater mounding will occur. Section 8.4.5 of the DOCP states that the infiltration rate applied for the design and sizing of the infiltration ponds was based on book values for gravel and sand materials and compared to hydraulic conductivity estimates presented in the HHCR. GHD notes that infiltration testing will be done during the detailed design phase of the project (GHD 2017a).

To date all hydraulic conductivity testing undertaken at site, including slug tests and one low rate pumping test, have largely evaluated the horizontal hydraulic conductivity of the sand and gravel aquifer. Infiltration capacity is limited by the vertical hydraulic conductivity of the aquifer which is typically an order of magnitude less than the horizontal hydraulic conductivity due to the layered deposition of sedimentary systems. Distinct near horizontal layering observed in the south pit wall (Figure 6), indicates that vertical hydraulic conductivity maybe significantly less than horizontal hydraulic conductivity at the Site.

During Waterline's January 22, 2019 site visit, significant ponding was noted in the base of the pit (Figure 7). The Upland staff indicated that the pond remains for most of the winter but the area is consistently dry in the summer (Terry Stuart and Mark Stuart pers. comm.). The cause of ponding in the pit needs to be further investigated as it appears to contradict GHD's interpretation of high infiltration capacity. The layered structure of the sand and gravel aquifer visible in the south pit wall, should have prompted in-situ testing to determine the site-specific infiltration capacity even for the preliminary landfill design.

> *GHD Comment 15: The ponding at the southern end of the Pit floor has been observed periodically by GHD following significant rainfall events. As shown on Figure 5.1 of the Technical Response Task 7, the Pit floor is graded from north to south with a low point that is focused to the west of monitoring well MW3-14, where ponding first occurs. Fines carried by storm water will occupy the soil pore space of the sand and gravel. In addition, the Pit floor has experienced considerable compaction through vehicular traffic over the 20+ years of Site operation, which has reduced the hydraulic conductivity of the sand and gravel exposed at surface. This reduces the ability of surface water runoff to infiltrate through the compacted layer at surface, particularly after significant sustained rainfall events.*
>
> *GHD agrees with Waterline that further infiltration testing should be completed and confirms that this testing will be completed as part of the detailed design phase of the infiltration pond on granular soil that has not be highly disturbed by Site operations.*

2.5 Leachate Generation and Groundwater and Surface Water Impact Assessment

Section 9 and 13 of GHD's DOCP report provides an estimate of leachate volumes, groundwater flow beneath the landfill and contaminant travel times over the life of the landfill. The estimates were based on very limited data do not appear account for the variability or complexity in the aquifer as discussed above.

GHD modelled leachate generation based on monthly precipitation taken from Canadian Climate Normals (1981 – 2010) for Campbell River. It appears that no design storm analysis was undertaken to assess possible climate extremes. Rather, GHD suggests that 0.3 m of storage is available in the waste pile to manage a potentially large volume of leachate generated during a storm event. Scientifically defensible data is needed to verify site conditions and to determine if the adaptive management strategies presented are suitable. Specifically, leachate volumes generated by design storms needs to be estimated and compared to available storage in the waste at various phases of operation and closure to confirm that adequate storage is available.

GHD Comment 16: Leachate generation volumes were estimated using scientifically defensible data and the HELP model, which is an EPA approved model developed by the US Army Corp of Engineers. The HELP model requires climatologic data, soil characteristics, and design specifications to perform the analysis. The Canadian Climate Normals 1981-2010 data set provides 30-year average daily rainfall data which accounted for climate extremes during the above noted time period. Climate normals provided by Environment Canada, the HELP model default soil characteristics and design specifications are scientifically defensible inputs into the HELP model.

Based on the input data, the HELP model synthetically generates daily rainfall data for a 100-year period, and evaluates both the peak and average infiltration rate through each of the modelled landfill layers. The HELP model outputs are provided in Appendix D of the DOCP and Appendix A of GHD's Technical Response to ENV Review. The outputs of peak daily values for years 1 through 100 provide the maximum daily leachate generation and maximum head on the liner under extreme condition. At modelled peak infiltration, the landfill provides more than sufficient capacity to ensure the head on the liner remains below 0.3 m.

Leachate generation estimates were based on the phase of landfill development with the highest leachate generation potential, which is the largest area of landfill exposed to infiltration through daily cover.

The groundwater flow beneath the landfill, dilution calculations, contaminant travel times and leachate pond volumes will all need to be reconsidered if a portion of the landfill sits directly on bedrock, and once the implications of the ponding are understood and the infiltration capacity is investigated.

GHD Comment 17: The landfill will not sit on bedrock so this work is not required.

GHD reiterates that the bedrock contours as shown on Figure 7.1A of the Task 7 letter report, are estimates when interpolating between bedrock elevations measured in boreholes/outcrops etc. Figure 7.1A indicates that the bedrock contours are inferred. The geologic/hydrogeologic conditions beneath the landfill footprint including the bedrock surface and bedrock groundwater elevations will be further defined as part of completing the detailed design. The elevation of the *base of the Phase 2A landfill cell, although not expected, can be adjusted based on the detailed design field investigation.*

For an explanation of the ponding at the southern end of the Pit floor, refer to GHD Comment 15.

2.6 Baseline Water Quality Assessment

Only two rounds of baseline groundwater quality sampling were completed to date which is not sufficient to provide statistically meaningful baseline water chemistry, especially since possible seasonal differences in groundwater chemistry were noted in the HHCR. The standard tool used to assess hydrochemistry from groundwater with various sources of recharge (bedrock aquifer, sand and gravel aquifer, surface water/precipitation) is to plot major ion chemistry on trilinear diagrams (e.g.: Piper Plots). The grouping of water samples on the Piper Plots allows for a visual assessment of recharge source and seasonal changes in groundwater chemistry, helping to better understand aquifer and groundwater-surface water interactions.

GHD Comment 18: Waterline is mistaken that only two rounds of baseline groundwater quality sampling were completed to date. GHD' summarized all monitoring data in the "Groundwater and Surface Water Monitoring Data" letter dated April 9, 2019. Key monitoring wells located within the immediate vicinity of the landfill footprint have been sampled seven or eight times between September 2015 to March 2019. The Site operations have not changed in over 40 years; as such, sampling wells numerous times over a 3 year period is reliable in characterizing baseline (pre-landfill) water quality. Waterline's comments again suggests that it has not been reviewed all available data.

GHD is also of the opinion that a "standard tool used to assess hydrochemistry from groundwater with various sources of recharge" does not exist. It is the duty of the Qualified Professional to gather information and determine what types of data analysis tools are appropriate for a given Site under investigation. For the proposed Upland landfill, it is abundantly clear that McIvor Lake is the dominant recharge source for the sand and gravel aquifer. It is also clear that Rico Lake and the upper fractured bedrock are secondary sources of recharge to the sand and gravel aquifer. It is GHD's opinion that Piper Plots are not needed to understand that these aquifer and groundwater-surface interactions are occurring on-Site. GHD is also of the opinion that collecting water quality samples from wells installed on-Site is an appropriate method to characterize baseline water quality prior to landfilling.

2.7 Proposed Environmental Monitoring Program

The recommended environmental monitoring program is presented in Section 14 of GHD's DOCP. Given the lack of continuous baseline groundwater monitoring, the mis-characterization of groundwater in the fractured bedrock (i.e.: water levels in bedrock wells indicated to be higher than in sand and gravel wells), and observed ponding in the pit area, the proposed groundwater monitoring program will need to be re-considered.

GHD Comment 19: The environmental monitoring program described in Section 14 of the DOCP has been designed to sufficiently monitor surface water and groundwater quality following the construction of the landfill. Waterline's statement above discusses baseline water quality monitoring which occurs prior to the construction of the landfill. It is unclear why the collection of baseline water quality samples would limit the effectiveness of the proposed environmental monitoring program. Baseline water quality samples collected to date will allow for a more robust assessment of potential landfill-derived impacts to the surrounding water quality as compared to the numerous landfill sites across the province where baseline data is unavailable.

In addition, a "lack of continuous baseline groundwater monitoring" data and "the mis-characterization of groundwater in the fractured bedrock" are incorrect statements. Refer to GHD Comment 8 and GHD Comments 11 to 13, respectively, for further explanation. The observed ponding in the Pit area has been explained under GHD Comment 15.

The frequency of groundwater and Rico Lake level monitoring was not specified; long-term, continuous monitoring using pressure transducers and data loggers calibrated to manual readings is recommended. Installation of data loggers that measure water level, temperature and electrical conductivity should be considered for establishing trends and seasonal fluctuations as an indicator of groundwater infiltration and recharge. More frequent groundwater quality monitoring using field test kits to assess indicator parameters (e.g.: electrical conductivity/total dissolved solids) should also be considered and verified with lab analysis.

GHD Comment 20: It is unclear to GHD why Waterline is suggesting continuous monitoring of the Rico Lake water level. McIvor Lake is the primary source of water to the aquifer. GHD disagrees that the collection of the data recommended above is required to complete the landfill design, landfill performance assessment, and water quality compliance assessment.

Sincerely,

GHD

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