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Town of Gibsons  
474 South Fletcher Rd  
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**Attention:** Andre Boel, Director of Planning

Dear Mr. Boel,

**RE: Gibsons Aquifer Review of Geotechnical Investigation Report (Revised) for the Proposed "The George" Mixed Use Development at 377, 385 & 407 Gower Point Road, 397 & 689 Winn Road, and Winn Road Right-of-Way, Gibsons, BC**

## **1.0 INTRODUCTION**

Horizon Engineering Inc. (Horizon) completed a revised geotechnical investigation report of the Proposed Mixed Use Development, "The George" (the project site), located at 377, 385 & 407 Gower Point Road, 397 & 689 Winn Road, and Winn Road Right-of-Way, Gibsons, BC (Horizon, April 2015). The Town of Gibsons requested Waterline Resources Inc. (Waterline) to complete a review the Horizon report and consider the proposed commercial development (The George) in the context of the Gibsons Aquifer which has been previously mapped by Waterline and the University of British Columbia (Waterline 2013, Doyle, 2013). In addition to reviewing the above-captioned report, the Town of Gibsons also requested Waterline to oversee drilling and monitoring well installation during supplemental subsurface investigations undertaken by Horizon at the project site. The purpose of field monitoring was to confirm the subsurface geology and groundwater conditions above and within the Gibsons Aquifer beneath property.

The primary objective of Waterline's review was to gain an understanding of the proposed development re-design in relation to the underlying Gibsons Aquitard-Aquifer system. It should be noted that Waterline's expertise is hydrogeology and geotechnical aspects of the proposed development are addressed by Levelton Consultants Ltd. (Levelton) in a separate memo (Levelton, 2015).

## 2.0 REPORT REVIEW COMMENTS

### 2.1 Review Comments on PART A – Background Information and Technical Data and Appendix B Test Hole Data

In general, lithology descriptions and depths presented in the borehole logs provided in Horizon's report (Appendix B and Section 5.0) are consistent with Waterline observations during drilling supervision. However, some clarification of the hydrogeological information and interpretation is needed so that conceptual cross-sections and computer models presented later in the report are clear and the Gibsons Aquifer and Aquitard can be clearly identified. The additional comments are provided below to assist in clarifying the hydrogeological data collected during the test drilling program attended by Waterline.

- Clarification that the "Collar Elevation" of the boreholes is the elevation of the adjacent grade (i.e. ground or seabed elevation).
- Based on the artesian head elevations (artesian groundwater levels) displayed in the water level monitoring data presented in Figures 4 through 6 of the Horizon Report, artesian groundwater levels fluctuate to elevations higher than the "static" elevations presented in the Test Hole Data table (Appendix B). In addition, the monitored pressure in BH14-3 was observed by Horizon to be higher (up to 5.5 psi) than at the time of completion (4 psi) and does not likely represent static conditions.
- Artesian pressure measurements should be presented as metres of head and referenced groundwater elevation. This would allow cross-referencing with the conceptual cross-section and groundwater seepage model presented later in the report.

#### ***Section 5.4.2 Artesian Groundwater Conditions, page 9 and 10:***

##### **Waterline Comment:**

Regarding all references to "stabilized" water levels, artesian groundwater levels included in this section are not likely stabilized in Waterline's opinion. The groundwater levels were measured at the time of drilling or prior to borehole abandonment. Long-term monitoring would be required to determine stabilized or static groundwater levels. As the information in this section is used as input into the groundwater seepage model, a summary table to provide data that was used by Horizon in the groundwater seepage analysis is recommended. This could include the depth to the top of the Gibsons Aquitard and Aquifer (if present) for each borehole/auger hole/test pit, as well as the ranges of groundwater elevations or levels measured presented as geodetic elevation and/or as meters of water above/below grade or well casing.

### 2.2 Waterline Review Comments on PART B – Discussion and Recommendations

***Section 8.1 General, page 16, fourth paragraph:*** "It should be noted that due to the nature of this project and limitations of the subsurface investigations that were carried out, rigorous sampling and laboratory testing program to develop a complex soil model was not practical nor feasible at the time of executing the subsurface investigation. We envisage that the analyses carried out are

*sufficient to provide a reasonable order of magnitude of result, which is considered to be conservative.”*

**Waterline Comment:**

Some clarification should be presented on what is meant by a “*reasonable order of magnitude of result*”. Was a sensitivity analysis completed as part of the groundwater seepage modelling completed by Horizon? Did Horizon consider input parameter and model uncertainty and was this uncertainty considered as the basis for recommended development of the site and marine infrastructure?

**Section 8.2 Soil Properties, page 16, Table 1, and**

**Section 8.3 Seepage Analysis (Initial State), page 17, Paragraph 2 and**

**Paragraph 3 which states:**

*“For the seepage analysis, we have used ranges of permeability (hydraulic conductivity) values for some of the soil materials, as listed in Table 1 above. However, for the steady state condition, there are no significant changes in the estimated pore water pressures generated within the model. Based on this modelled steady state condition, a flux of groundwater into the west portion of the proposed excavation was estimated, which is described in Section 14.3. An artesian groundwater pressure was established at the underside of the Gibsons Aquitard with a range of 130 to 160 kPa (2,715 to 3,550 psf)..... “It is noteworthy that these pressures appeared to be affected by the shape of the aquitard’s lower limit; however, for this analysis, the effect of the soil layer shapes was not explored.”*

**Waterline Comment:**

Reference and justification for parameter ranges should be included in Table 1 as these values serve as input into the groundwater seepage model, the output of which is used by Horizon in its re-design of foundation structures which may be encroaching on the Gibsons Aquifer-Aquitard system. This section should clearly indicate how the Gibsons Aquifer is being protected. Waterline has the following specific questions relating to the selection of material properties provided in Horizon’s report:

- Soil permeability ranges are provided but it is not clear if the values were measured by Horizon or estimated. References should be provided to support the permeability values indicated.
- The permeability range used by Horizon for the Silty Sand unit was between  $1.0 \times 10^{-6}$  to  $1.0 \times 10^{-5}$  m/s and for Till between  $1.0 \times 10^{-7}$  to  $1.0 \times 10^{-8}$  m/s. Based on the geological legend provided in Figure 2, both the Silty Sand and Till units inferred to be the Gibsons Aquitard. As part of the regional aquifer modelling study, Doyle (2013) used a bulk hydraulic conductivity of  $2.0 \times 10^{-6}$  m/s for the Gibsons Aquitard which provided calibration to the

groundwater model. How would seepage and stability of the Gibsons Aquifer-Aquitard system be affected if a higher permeability was used for the Till unit?

- “Seabed Sediments” and “Seabed Silty Sand” were combined with “Fill” and “Silty Sand to Sandy Silt to Silt” in Figures 1 and 2 and in Section 5.2. However, the groundwater seepage model appears to separate these units and higher permeability values are used.
- Did Horizon consider the uncertainty of the estimated artesian head elevations at Town Well #1 and in BH14-2, and was this taken into account when applying boundary conditions to the Seep-W model?
- In Paragraph 2, Horizon states that the boundary condition at the eastern edge of the model is 3.2 m of head. Why was a lower total head of 2.2 m applied to areas where ground (grade) elevations were less than 2.2 m?
- Justification of model boundaries and hydraulic data is needed in order for Waterline to further evaluate the groundwater seepage analysis.
- What is the estimated flux of groundwater discharge into the marine environment prior to and post the proposed development? This is important as directly relates to the understanding of how the proposed development considers the protection of the Gibsons Aquifer and incorporates required elements into the engineering design.
- The statement that the model sensitivity to the shape of the aquitard is noteworthy but has not been explored should be supported by model results.

***Section 8.4 Deformation Analysis, page 18, paragraph 6:***

**Waterline Comment:**

Horizon indicates that notable deformation is predicted to occur at 4 m elevation but not at 5 m elevation which is used as the basis for selecting the maximum base of excavation at 5 m elevation. Additional details should be provided to show the predicted deformation of the Gibsons Aquitard for intervals between 4 and 5 m elevation to help support the maximum depth of excavation.

***Section 10.2 Recommended Building Grades, page 21, paragraph 1:***

**Waterline Comment:**

The boundary between the northwest portion of the site where the proposed excavation elevation is 5 m should be clearly identified and distinguished from the remainder of the site where the maximum excavation depth is 0.5 m below existing grades.

***Section 12.0 Ground Improvement, page 23, paragraph 5:***

What monitoring efforts will be conducted during the ground improvement process to detect failures and how will this be mitigated to ensure the protection of the Gibsons Aquifer-Aquitard system?

***Section 17.2 Proposed Foundation Concept, page 28-29:***

**Waterline Comment:**

More information is required to describe the “drilled pipe piles” methodology in order to assess its potential effect on the Gibsons Aquifer-Aquitard system. In addition, groundwater monitoring and mitigation programs that will be implemented during construction should be provided to ensure that the integrity of the Gibsons Aquifer-Aquitard system is maintained.

***Section 17.3 Proposed Foreshore Dredging, page 29-30:***

**Waterline Comment:**

Although some additional cone penetrometer data was collected in the foreshore area, it is Waterline's opinion that insufficient data is available to fully understand the impact of the proposed marine development on the Gibsons Aquifer-Aquitard system. This is evident on Figure 2 where complex geology is shown on the land based areas where borehole density is higher in comparison to the proposed marine development area where simpler geologic interpretation is provided due to the lack of data. Only one borehole was drilled into the proposed dredging area and no data is available in the deepest part of the development area.

***Section 21.2 Temporary Excavation, pages 32-33:***

Horizon states: “Any signs of instability such as tension cracks, excessive sloughing, or ground movements should be reported to Horizon Engineering immediately”

**Waterline Comment:**

This statement is concerning as it suggests that Horizon, who is largely responsible for foundation and excavation design will not be on site to supervise construction activities. If heaving is indicated during construction then it may already be too late for corrective action. Although these details may be more appropriately described during the development permit stages, some understanding of mitigation strategies and contractor preparedness should be provided.

### **3.0 CLOSURE**

It is Waterline's opinion that some clarification and summarization of the subsurface data is required in order for Horizon and the developer to provide assurance that the Gibsons Aquifer-Aquitard system will be fully protected by the proposed development. Waterline's main concern on the land portion of the project site relates to the possibility of an uncontrollable breach of the Gibsons Aquitard caused by the proposed excavation for the parking garage. For instance, a sensitivity analysis of either the seepage or deformation model was not documented in the report to address uncertainty of the model input parameters. As this is effectively a geotechnical concern,

Waterline cannot further advise the Town and would rely on the final assessment by Levelton and Horizon.

In regards to the proposed re-development of the marine environment, it is Waterline's opinion that there is insufficient data to characterize the Gibsons Aquifer-Aquitard system within the proposed dredging area. Based on the conclusions of the Gibsons Aquifer Mapping Study (2013), and the barge-drilling program lead by Horizon in 2014, the Gibsons Aquifer extends into the Gibsons Harbour and has artesian conditions within the vicinity of the proposed marine development. In addition, there is likely existing discharge at an unknown rate from the Gibsons Aquifer into the ocean within the Gibsons Harbour. However, little data has been provided to map the extent and geometry of the Gibsons Aquifer-Aquitard system, the rate, or the points of discharge from the aquifer with any degree of accuracy in relation to the proposed marine development area.

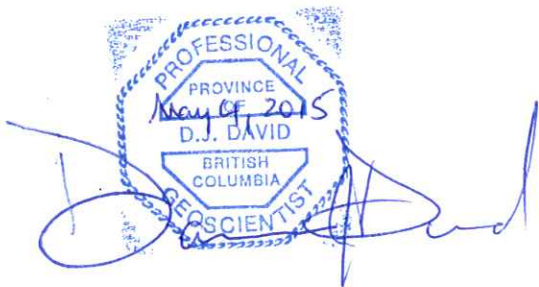
Waterline trust that the information provided in this document is sufficient for your requirements. Should you have any questions or concerns, please do not hesitate to contact the undersigned.

Respectfully submitted,

**Waterline Resources Inc.**



Jessica Doyle, M.Sc., G.I.T.  
Hydrogeologist



Darren David, M.Sc., P.Geo.  
Principal Hydrogeologist

#### **4.0 REFERENCES**

Doyle, J.M., 2013. Integrating environmental tracers and groundwater flow modeling to investigate groundwater sustainability, Gibsons, BC. M.Sc. Thesis. University of British Columbia. 203 p

Horizon Engineering Inc., 2014. Geotechnical Investigation Report (Revised) for the Proposed "The George" Mixed Use Development at 377, 385 & 407 Gower Point Road, 397 & 689 Winn Road, and Winn Road Right-of-Way, Gibsons, BC. April 7, 2015.

Levelton Consultants Ltd., 2015. Geotechnical Review. Horizon Engineering Inc. Geotechnical Investigation Report – 7 April 2015. Proposed "The George" Mixed Use Development, Gibsons, BC.

Waterline Resources Inc. 2013. Aquifer Mapping Study, Gibsons, BC. 111 p.

Waterline Resources Ltd., 2014. Hydrogeological Review of the Revised "The George" Geotechnical Investigation Report, (Draft for Discussion). June 25, 2014.

## 5.0 LIMITATIONS AND USE

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