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Town of Gibsons
474 South Fletcher Road
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Attention: Mr. Andre Boel, RPP
Director of Planning

Project: Geotechnical Review
Horizon Engineering Inc. Geotechnical Investigation Report – 07 April 2015
Proposed 'The George' Mixed Use Development, Gibsons, BC

Dear Sir:

1. INTRODUCTION

Levelton Consultants Ltd (Levelton) was retained in February 2014 to provide the Town of Gibsons (the Town) with geotechnical consulting services related to the proposed 'The George' Mixed Use Development in Gibsons, BC. The focus of the appointment was to provide a level of professional due diligence in relation to geotechnical considerations associated with the Town's responsibilities in the permitting process. Since the appointment in February 2014, Levelton has interacted with the Town on several occasions as the proponent's design has progressed and additional geotechnical information has been received. The two previous reports that have been generated by Levelton, dated 20 March 2014 and 23 June 2014 are appended herewith for completeness and ease of reference. In conjunction with Levelton's geotechnical review, Waterline Resources Inc. of Nanaimo, BC has been retained by the Town to provide a level of professional due diligence in relation to the hydrogeological aspects of the development.

This report relates to a review of the geotechnical report dated 07 April 2015[1] prepared by Horizon Engineering Inc. (Horizon) for the above referenced project. The Horizon report builds upon and supersedes their earlier reports dated 14 February and 05 June 2014, which were provided to the Town as part of the design process.

[1] Horizon Engineering Ltd 07 April 2015. Geotechnical Investigation Report (revised) Proposed 'The George' Mixed Use Development, Gibsons, BC. Prepared for Klaus Fuerniss Enterprises Inc.

The 07 April report was prepared in support of a rezoning and development permit application for the development. As such, our review is focussed towards geotechnical feasibility and the identification of requirements for future work and/or possible covenants that would be registered on title as part of the Rezoning and/or Development Permit approval. At a subsequent stage, should the re-zoning and development permit be successful, the Town would anticipate separate submissions from the proponent in support of a Building Permit, which would include further detailed supporting documentation.

Our review of the 07 April 2015 Horizon report has been undertaken using a sequential process with the following steps:

- Assess the additional investigative programs, testing, and monitoring conducted in December 2014 and January 2015 with respect to an improved characterization of subsurface conditions; including aquitard thickness, and pore pressure variation in the upper portion of the Gibsons aquifer;
- Consider the identification of geotechnical challenges presented in the report;
- Consider the risk assessment process presented in the report with regard to confidence levels associated with the potential breach of the aquitard as a result of the proposed excavation for the below-grade parkade;
- Consider the modeling effort that simulated the stages of bulk excavation to design subgrade level. Assumptions used to develop soil and seepage models are considered with regard to their representations of site conditions;
- Global stability of excavation slopes considering the indicated soil strengths and variable pore pressure conditions;
- Consider options for a shoring system given the presence of water-bearing soils and weak buried organic materials within and below the proposed excavation slopes;
- Consider the approach used to evaluate flood control levels and tsunami hazard;
- Consider the feasibility of constructing a sea dike with the intended purpose of enabling the development of habitable space below the flood control level;
- Consider the proposed approach to foundation concepts and ground improvement options within the eastern portion (non-excavated) of the development site. The foundation concept should include consideration as to how seismically-induced lateral building loads are transferred into the soil zone;
- Consider seismic performance of foreshore fills and natural soils and potential impact of pile foundations for the proposed over-water structures;
- Feasibility of conceptual design of pile foundations (e.g., depth, type, installation procedures) compatible with site conditions and constraints identified by Waterline;
- Approach proposed for methane control below the building;
- Approach prepared to deal with soft compressible soils below and outside building footprint. Options to deal with ongoing settlement in service corridors and roadways;
- Approach proposed for infiltration of collected groundwater into natural soil deposits; and
- Conditions identified in terms of covenant and indemnification.

We note that the 07 April Horizon report is large and detailed, and includes significant discussion, the results of detailed computer modelling, and multiple appendices of factual information. A number of geotechnical challenges and natural hazards are identified. A number of assumptions or assumed design conditions are presented in the report, including design life, sea level change, and flood control levels. It is not clear from the report if these assumptions have been provided by and/or are endorsed by the proponent or architect. A number of the solutions to geotechnical challenges that are proposed in the report are directly affected by these assumptions. We would recommend that, as an initial item, the Town seek confirmation from the proponent that the Horizon geotechnical report has been accepted and endorsed by their design group.

2. DISCUSSION

Based on our review of the 07 April Horizon report, and in consideration of the above, Levelton remains of the opinion that there are several elements that are key to the technical feasibility of the proposed project that require further development. We would also encourage the Town to have the proponent's team confirm that they have reviewed the proposed solutions put forward in the Horizon report in terms of financial feasibility, particularly in relation to the proposed ground improvement, water-proofing, and foundation concepts that have been advanced. If the solutions put forward in the report are deemed cost prohibitive, it may be necessary for alternative solutions to be considered.

The 07 April Horizon report is extensive in terms of the breadth of scope that is covered. However, only a limited amount of architectural, structural and civil design information appears to be currently available and, therefore, the appropriateness/completeness of certain recommendations is difficult to assess. For instance, detailed and specific foundation recommendations have been developed in the absence of actual structural loading information. In addition, a flood control level has been determined on the basis of a building design life of 50 years, which - if incorrect - would change the hazard review and discussion in the Horizon report. For this reason, it is recommended that the Town confirm that this draft report has been accepted and endorsed by their design group.

On the basis of our review of the work completed to date, we are of the opinion that the critical item of geotechnical/hydrological consequence from the Town's perspective is whether or not the proposed development could have a serious negative impact on the Gibson Aquifer. Given the nature of the proposed development, the potential for a serious impact occurs principally as a result of: a proposed deep excavation at the west side of the property; advancing of deep pilings in the easterly foreshore area; and a proposed dredging operation. Potential consequences from a breach are described in Section 7 of the Horizon report and include the formation of an uncontrolled sinkhole, aquifer depressurization, ground settlement, and potential contamination.

Levelton's previous review (June 2014) identified uncertainty in the evaluation of the risk of a significant breach and recommended that an improved characterization of the aquitard be undertaken within all areas of the development as well as additional pore pressure monitoring. The intent of this recommendation was to demonstrate a better understand of the risk of breaching the aquitard during excavation or foundation installation and to allow mitigative measures to be developed. The three additional land-based boreholes drilled by Horizon in December 2014 have improved this understanding and they have identified artesian groundwater

conditions at the area of proposed deepest excavation which resulted in a recommended reduction to the depth of excavation.

The measured piezometric head of El. 12.9 m at the west of the site (Figure 4 of report) is significantly greater than the revised proposed cut elevation of El. 5 m in this area. Horizon has undertaken computer modelling to assess potential heave in this area. However, their work does not appear to have considered vertical hydraulic gradients in the westerly proximity of the parkade that might result in upward seepage and the potential for soil piping, uncontrolled sinkhole, aquifer depressurization, or ground settlement. As such, we are concerned with the credibility of the statement in the second to last paragraph of the executive summary that Horizon is of the opinion that "*there is no risk of ground heaving or upward groundwater seepage into the excavation (if our recommendations in this report are implemented*)". An uncontrolled loss of ground or piping could be catastrophic; this mode of failure is not considered in the deformation modelling that has been completed and we would expect further commentary on this item.

In light of the uncertainties and elevated risks associated with the above item, we would encourage their design team to consider an option of hazard avoidance, in which the westerly part of the Parkade P2 Level is truncated to avoid the need for the deep excavation. Such a building modification would address not only this large uncertainty, but also a number of other geotechnical issues including global stability of the deep cut, the need for off-site encroachment of anchors, and the potential for off-site settlement as a result of dewatering.

Aside from the principal geotechnical issue of a potential breach of the aquifer, a number of other geotechnical concerns were identified during our review, some of which relate to potential development permit considerations, while others are more appropriately considered to relate to a building permit level of detail. We have identified these in bullet form below and would be available to provide greater discussion if needed:

- The report presents the rationale for a Flood Control Level (FCL) that is based on a number of factors that include a sea level change projected over a 50 year design life. This FCL becomes critical in future parts of the report in regards to floor slab elevations, tsunami protection, volume of ground improvement, etc. Based on the approach taken, the FCL would be higher if a 100 or 200 year period were considered, as opposed to the 50 year design life. This has several implications, including height variance calculations. We recommend that further consideration be given to this critical item and how the Town might incorporate this long term constraint into a covenant. Confirmation that a registered land surveyor has established the elevation of the natural boundary is also recommended.
- Section 9.3 of the report indicates that the development is not subject to tsunami hazard because of the elevation of floor slab of the marine portion. Notwithstanding the above discussion, we should point out that the entire structure is proposed to be supported on piles that are directly subject to hydrodynamic loading and impact from debris from a tsunami event. We would recommend that further design rationale be provided in support of the development permit application.
- The proposed sea dike features heavily in terms of a potential solution to protect portions of the building constructed below the FCL. Given the high natural water table, the presence of artesian groundwater, and the difficulty in the sea dike establishing an effective below grade cut-off, we have concerns that this approach would not be reliable in the long term and that the Town should be cautious in considering

that this approach could be relied upon to provide protection. Clarity is needed from the proponent in regards to the proposed use of areas like Parkade P3 and whether or not such portions of the building are actually considered 'habitable'. We would expect the use to be somewhat linked to the degree of protection required. We are concerned with the request from Horizon raised in Section 14.3 of the report to seek an indemnification for themselves related to building use below the flood control level.

- The currently proposed shotcrete shoring design necessitates off-site encroachment for ground anchors. The requirements for encroachment are not identified and it is not clear if encroachment is limited to public property or will need approval from private property owners. This item requires restrictive conditions to be identified with the permit.
- The proposed groundwater management program consists of in-ground infiltration in the lower east side of the site. We are concerned that an option to infiltrate water year round will fail due to the high natural water table, saturated soils, and the proposed construction of the sea dike (down gradient of the infiltration area). Ground/stormwater disposal requirements should be re-assessed if they are to form part of the approval process.
- One of the options identified for the sea walk is a floating concept. We would point out that there will be ongoing maintenance with such an option. The Town may wish to define maintenance responsibilities for any off-site/public walkways/utilities as part of development conditions.
- The Horizon discussion on dredging to develop the marina indicates that the material that would be removed would be unconsolidated sediment that could be removed using a vacuum and that there would not be any need for mechanical excavation. Since the marina is an integral part of the development, it should be confirmed that, if actual conditions will not allow removal of sufficient material by vacuum, that this will be acceptable to the proponent. The Town may wish to have Horizon 'tighten up' the basis of their statement that they envisage that blow-out would not be expected to occur. This is a high consequence item that warrants greater certainty.
- Although not specifically geotechnical, we are aware that parts of the site have historically been used for petroleum hydrocarbon storage. We would recommend that the Town request confirmation that consideration has been given to dealing with soil/groundwater contamination that might be encountered within the inherent limitations of a conventional excavate and replace option at this site.
- With consideration to the Local Government Act, the Town should request a statement that the site is considered to be safe for the use intended, subject to conditions that may be specified. We would suspect that there would be some discussion related to the definition of "safe".

A number of items are outlined below that may not be directly pertinent to the re-zoning and Development Permit, but that could impact feasibility due to cost or other perspectives. At a minimum, we would expect that further consideration would be given to these items during detailed design and in support of the Building Permit application.

- Discussion related to the foundation concept will need to be expanded to address seismically induced uplift and lateral loads - once these become known. Base shear resistance requirements could impact ground improvement needs, associated costs and, therefore, economic viability. Liquefaction will not be mitigated within the marine area under the current program and therefore the foundation system will need to consider lateral spread of loose soils as well as lateral load transfer from the structure. The 07 April report contains interchangeable discussion in reference to the use of shallow footings or a raft foundation, which is not the case in terms of costs. Water-proofing and methane control requirements should be factored into the selection of foundation design and associated potential costs. Clarification should be given as to whether the stated ultimate bearing values given in the report are factored.
- Drilled pipe piles are presented as a favoured solution in the marine area. The creation of a void space through drilling appears to counter the mitigation of the potential geological hazard relating to the existing aquifer. We would suggest that a closed-ended driven pipe pile be considered as an option as the design progresses.
- The western portion of the building currently identified as being in cut comprises only two levels of parkade with no superstructure. We would recommend that the foundation slab design carefully consider potential hydrostatic uplift and any mitigative measures that might be necessary.
- Lateral earth pressure calculations provided for the buried west wall should identify hydrostatic design pressures. The current design loading would appear to assume some deflection to mobilize lower earth pressures. Assuming that this wall is braced by several slabs and that it is designed as a tight water proofed structure, we would suggest that the assumption of wall rotation be revisited in the final determination of lateral earth pressures.
- Ground improvement options and costs should be factored into the overall budget. We note that the proposed ground improvement methodology is intended to address primary foundation support. While the report discusses *"the elimination of the seismic hazard"*, there will in fact be a liquefaction hazard in the non-improved marine area as well as the non-improved areas between the zones of primary foundation support. Further commentary is needed for the over-water design as well as seismic resilience needs for civil/mechanical pipework that traverse the non-improved areas (especially the proposed fuel supply pipeline).
- It is expected that the proposed ground improvement works will create buried "dams" and will impede the natural flow of groundwater across the site. The presence of a positive upward vertical hydraulic gradient would further complicate drainage between improved cells. The design will need to address these complications.
- The proposed ground improvement works will create a series of hard points/lines within an otherwise soft soil setting. As such, there is the potential for long term settlement in areas away from improved ground both within and beyond the building footprint. The potential for differential settlement and "sag" should be considered in the design and layout of buried utilities, grade supported structures and roadways.
- The report identifies a methane hazard and recommends the installation of methane control measures. We would anticipate that the proposed ground improvement works will complicate this design. Non-improved areas under the structural slab may have a tendency to settle and create void space.

- The recent drilling identified a zone of peat or buried topsoil towards the base of the proposed excavation cut at the west side of the site. Horizon should confirm that they have considered this potential weak layer in the global stability of the temporary cut and shoring design. We note that a deeper seated failure at this location could directly impact the adjacent roadway.

The list given above is not intended to exhaustive. It is intended to highlight our opinion that there will need to be some further interaction/assessment within the design team as the project progresses through to detailed design.

3. CLOSURE

In closing, it is our opinion that the 07 April 2015 supplemental report prepared by Horizon has provided an improved assessment of site conditions and has further identified geotechnical challenges and development constraints. We have recommended that the Town confirm that the report is endorsed and accepted by the design team and the assumptions given in the report are valid. Changes in those assumptions would necessitate further review.

We would advocate discussion within the proponent's team related to hazard avoidance through reduced excavation at the west side of the property. We would further prompt the architect/proponent to undertake sufficient financial feasibility review of the proposed geotechnical solutions to be comfortable with the approaches being developed.

We are not at this time in a position to advise the Town that the report, as submitted, has adequately addressed the potential geotechnical issues or provided a suitable confidence level as to the adequacy of proposed site preparation and foundation concepts.

This report has been prepared for the Town of Gibson in accordance with the attached Terms of Reference for Geotechnical Reports. We thank you for the opportunity to be of further service ad would be pleased to discuss any questions you may have regarding the above or related matters.

Yours truly,
LEVELTON CONSULTANTS LTD.

Reviewed by:

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Per: Carl Miller, M.Sc., P.Eng.
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Attachment: Appendix 1. Previous Levelton Reports (20 March and 23 June, 2014)
Appendix 2. Terms of Reference for Geotechnical Reports.