BURNCO ROCK PRODUCTS LTD.'S PROPOSED BURNCO AGGREGATE PROJECT HOWE SOUND, BC

PALAEONTOLOGICAL RESOURCE DESKTOP ASSESSMENT

Report No. BBL 2014-011A

March 20, 2014
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Prepared for:
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Executive Summary

The potential impact of construction on the palaeontological resources of the proposed BURNCO Aggregate Project that is located in the McNab Creek valley along the northwest shore of Howe Sound, southwestern British Columbia has been assessed through map, database and literature investigations. A regional inventory of palaeontological resources for Howe Sound has been compiled with 39 sites within the coastal Howe Sound and neighbouring areas that contribute to the understanding of the palaeontological potential. Within the Project area and along the barge routes, five geological units -- three Quaternary (alluvial, Capilano fan delta, and the Capilano to Salish Marine and glaciomarine sediments), and 2 Mesozoic (Bowen Island and Gambier groups) -- are considered to have palaeontological sensitivity. Most Quaternary fossils comprise conifer wood and needles; however, marine shells, pinnipeds, and wormtubes are also included. The rare Mesozoic fossils comprise ammonites and fossil leaf material. Beyond Howe Sound, a wide range of fossils from large marine and terrestrial animals suggests that similar palaeontological resources could occur in the proposed Project area.

A predictive palaeontological sensitivity model for the proposed Project area has been constructed which indicates 7 areas that are considered highly prospective and 26 areas of medium prospect. Several shoreline areas along the barge routes have been identified to include sedimentary units. Most of these would receive low potential negative effects from the project activities. However, the Quaternary sediments at the beach adjacent to the development area at mouth of McNab Creek, and the Cretaceous fossil sites directly across from the project at Ekins Point, Gambier Island are considered to have medium palaeontological sensitivity. Across the Project area several sediment exposures occur along the valley wall faces, the beach, stream channels and the McNab Creek which would be good places for fossil exploration. A total of the 24 palaeontologically sensitive areas have been identified that would benefit from visual inspection. The primary areas are concentrated along the artificial stream, the present beach bluffs, and the palaeobeach bluffs.

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NOTATIONS AND ABBREVIATIONS

Palaeontological Notations:

F### – Known fossil site number
PIA – Palaeontological Impact assessment
PS### – Palaeontological sensitivity area number

Coastal Sedimentary Exposure Notations:

Qu## – Quaternary unconsolidated sediments
EKg## – Gambier Group volcanic and sedimentary rocks undifferentiated
EKs## – Gambier Group sedimentary rock
TJ## – Bowen Island Group sedimentary rocks

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PALAEONTOLOGICAL RESOURCE DESKTOP ASSESSMENT

1 INTRODUCTION
1.1 SCOPE OF THE PALAEONTOLOGICAL ASSESSMENT

The proposed BURNCO Aggregate Project (49° 28' N; 123° 23'W) ("Project") is to be situated in the McNab Creek valley at the mouth of the McNab Creek along the northwest shore of Howe Sound, southwestern British Columbia, 22 km west of the city of Squamish (Figure 1). The BURNCO Aggregate Project is proposed by BURNCO Rock Products Ltd. for the development of a sand and gravel pit, processing facility and a marine barge outlet with associated barge routes through Howe Sound to connect with approved routes to New Westminister and Langley. These approved barge routes beyond Howe Sound are not considered in this assessment, as the study has been limited to within Howe Sound.

The primary mining target is an accumulation of the Quaternary alluvial clastics at a coastal margin. Similar deposits are renowned regionally along the west coast area for their potential to contain palaeontological resources, such as large terrestrial proboscidean and marine pinniped and cetacean skeletal elements, with additional plant and small animal fossils.

The primary objective of this study is to investigate the potential impact of construction on the palaeontological resources through map, database and literature investigations to arrive at a palaeontological sensitivity model which could be tested through field surveys and direct resource assessments. This palaeontological overview report constitutes a preliminary assessment for the Project area from available documents to identify and describe:

- The geological setting with repect to potential palaeontological resources;

- The known palaeontological resources in the local vicinity of the Project that could be directly affected by the Project;
- The known palaeontological resources in the greater region of the Project that have the potential to be encountered or affected by the Project development;
- A predictive palaeontological model for the examination of the Project;
- Potential Project-related effects on palaeontological resources in the development area; and
- The measures to avoid, limit or otherwise mitigate potential adverse effects of the Project on palaeontological resources.

This palaeontological overview does not include ground proofing the potentially fossiliferous areas through pedestrian inspection and assessment in the field. This study has been undertaken by Dr. Edward H. Davies, a professional palaeontologist and geologist.

2 GEOLOGICAL SETTING

The geological setting of the Project area has been reviewed in a technical memorandum (Golder Associates Ltd., 2010). The proposed Project development activities have the potential to affect palaeontological resources, if present, in the following units:

1. The overlying sediments;
2. The target fan-delta sediments;
3. The bedrock formations underlying and surrounding the Project target sediments which could be encountered during mining operations; and
4. The surface stratigraphic formations that could be encountered during construction of the mining facilities and access roads.

2.1 GEOMORPHOLOGY

The project area is set geomorphologically at the lower end of the glaciated U-shaped valley drained by the McNab Creek where it flows into the marine environment of Howe Sound. The valley is flanked by high mountainous slopes which are underlaid primarily by plutonic bedrock with pendant sedimentary rocks with low grade metamorphism and filled with glacial and post-glacial sedimentation. The proposed barge routes would include the flooded glacial fiords of middle to outer Howe Sound including Ramillies, Thornbrough and Queen Charlotte channels from the landing point at McNab Creek.

2.2 BEDROCK GEOLOGY

As illustrated in the BCGS geological map for this area (Figure 2) the geological units (Table 1: upper three units) present in the Project area and locally affected areas encompass a wide stratigraphic range of ages and environments including the Mesozoic Triassic to Jurassic Bowen Island Group and the Early Cretaceous (Albian) Gambier Group that comprises variably metamorphosed sedimentary and volcanic rocks. These occur as pendant deposits to later Cretaceous and Tertiary plutonic intrusives. The plutons, and other smaller intrusive and volcanic rocks that occur along the potential barge route have negligible implication to the palaeontological resource potential.

Table 1: Table of Geological Units affected by the Project

Geological Unit	Context	Age	Lithology	Palaeo-Resource Potential
Marine and Glacio marine Salish and Capilano	Surficial and interbedded	Post-glacial to recent	Thin veneers of marine silts and sands	High
Fan-Delta Capilano fluvial deposits	Surficial and interbedded target beds	Post-glacial	Thick sand and gravel intermixed with silt layers	Medium
Alluvial	Surficial and interbedded target beds	Post glacial	Thick sand and gravel	Low
Gambier Group	Bedrock	Cretaceous (Albian)	Low grade metamorphic sedimentary and volcanic rocks	Medium
Bowen Island Group	Bedrock	Triassic to Jurassic	Metamorphic sedimentary and volcanic rocks, such as slate, quartzite meta-siltsone	Low
Plutonic and smaller intrusives, and volcanics	Bedrock	Jurassic to Late Cretaceous	Granites and granodiorites	Negligible

2.3

2.4 SURFICIAL GEOLOGY

Post-glacial deposits (Table 1: upper three units) have created a thick blanket that covers the glacially carved valley with glacio-fluvial sediments derived from higher up the valley. The alluvial deposition at the mouth of the valley has interacted with the marine environment of Howe Sound producing a fan delta with intercalated beds of marine sediments. The coarse clastic components are the target material source for the Project.

3 PALAEONTOLOGICAL METHODS

3.1 BACKGROUND LITERATURE REVIEW METHODS

Geological, surficial geological and palaeontological maps used for the current research were obtained online through the Mirage website which includes a digital imagery library of maps generated by Geological Survey of Canada, Earth Science Sector, Natural Resources Canada (http://www.geoapps.nrcan.gc.ca/applications/0/mirage) on which known palaeontological sites discovered through field mapping have been plotted. In particular the Squamish Geological Map (Vancouver West Half Map 42 1963 compiled by H.H. Bostock), a local geological map (Lynch 1991) and a field guide map of the east coast of Howe Sound (Monger and Struik 2007). The surficial map of the east coast of Howe Sound (Blais-Stevens 2008) was utilized to refine the distribution of Quaternary sediments; however, an equivalent map for the northwest coast was not available. Additional source materials were reviewed from Branta's in-house palaeontological library.

3.2 PALAEONTOLOGICAL INVENTORY

All nearby and regional palaeontological site locations and their assemblage composition, if available, were recorded to form a baseline level of the palaeontological knowledge in which the proposed Project area is set. From this baseline a palaeontological inventory of known palaeontological sites was compiled for the local Project and regional areas, and then plotted on maps (Figure 3). The shoreline areas around Howe Sound with potentially fossiliferous sedimentary units that could possibly be impacted by wave generation along barge routes were also plotted on the regional palaeontological potential map of the area (Figure 4). Regional palaeontological sites were included if they were derived from stratigraphic units that would be potentially disturbed by the Project.

From this data, the inventory of palaeontological resources is constructed (Table 2) that is used to create a predictive regional model for the various stratigraphic units encountered within and adjacent to the proposed Project.

3.3 PALAEONTOLOGICAL RESOURCE MODELING

3.3.1 Local Sources of Information

Palaeontological assessments are dependent on local sources of palaeontological information to evaluate the probability of finding palaeontological resources on the surface and in the subsurface. The sources include:

- Previous palaeontological studies of the area;
- Previous geological studies that have palaeontologically related observations;
- Surface sediment exposures;
- Previously existing borehole logs; and
- Assessment of the strata in relation to the regional palaeontological inventory.

Palaeontological resources, which are available for observation without further excavation, occur necessarily on the surface as sediment exposures. These exposures are often obscured and degraded contextually by various taphonomic factors, such as:

- vegetation cover;
- extraneous sediment veneers;
- slumping;
- human disturbance;
- weathering; and
- abrasion

These factors can prevent the ability to predict accurately the subsurface palaeontological potential.

In addition the observable resources represent a small fraction of the resources that occur potentially below the surface, as fossils contained within the surficial sediments or bedrock. Thus the prediction of the potential to encounter subsurface palaeontological resources in proposed developments requiring excavations, such as roads, building foundations, mines, quarries and gravel pits, can be assessed most appropriately through pedestrial examination of surface areas in which:

- vegetation is lacking;
- erosion has been recently active;
- slumping is minimal ; and
- exposure cuts across the full stratigraphic interval.

Existing sediment and rock exposures act as predictive “information windows” into the potential palaeontological resources that could be found in stratigraphically equivalent sediments and strata that have been deposited during

similar times and within similar environments. In areas that are to be excavated where there are no exposures or exposures are poorly developed, lateral exposures can serve predictively as the best information source to an area in advance of the proposed excavation, and thus, such exposures can be considered as "proxies" to the less exposed areas. Borehole data, if available, can be used to assess the continuity of prospective strata across the proposed Project.

3.3.2 Palaeontological Sensitivity Zones

GoogleEarth online mapping tools were utilized to evaluate the geomorphic relief within the Project area and approximately 50 m beyond, or other adjacent areas that could potentially be impacted by the Project. Creek banks, bluffs and valley walls have been examined to identify possible exposures of sedimentary rock, which could exhibit fossils on the surface. These exposures were outlined by polygons, numbered for ease of reference (PS001 to PS049; PS represents Palaeontological Sensitivity), and then colour-coded according to the predicted palaeontological sensitivity modeling to produce a map showing the Predicted Palaeontological Sensitivity Model (Figure 5).

The predicted palaeontological sensitivity zones indicate the interpreted potential to find palaeontological resources upon inspection of the ground surface.

These zones were divided into four levels of sensitivity to disturbance:

- High Palaeontological Sensitivity Zones: The red polygons indicate sensitive areas with a high potential to find significant fossil material due to steeper slopes and extensive formational exposure. These areas have significant palaeontological interest. Purple (Quaternary) and green (Cretaceous) flags indicate previously discovered fossil sites with a likely probability for encountering further fossil material. Mitigative actions for these areas could include:
    - Palaeontological field assessment should be required in advance of construction activities;
    - Palaeontological salvage if significant fossil sites are confirmed;
    - The significance of the palaeontological finds should be evaluated; and
    - Palaeontological monitoring of significant fossil sites to record and salvage uncovered fossil material during construction activities to be performed by a qualified palaeontologist.

- Medium Palaeontological Sensitivity Zones: The orange polygons indicate areas which have restricted or intermittent formation exposures with vegetational cover in which fossiliferous sediments or bedrock is expected to be close to the surface and would be disturbed with excavation activities. Mitigative actions for these areas could include:

- Remotely appraised through float-by, drive-by or fly-by review to determine if closer palaeontological examination would be warranted. Predestrian examination of 50% of these areas, if warranted; and
- If palaeontological resources are encountered, the significant area would be delineated and mitigative actions for positive high zones may be proposed.

- Low Palaeontological Sensitivity Zones: The yellow polygons (low impact) indicate areas which have a limited potential to encounter bedrock or Pleistocene fossil material. These are most likely covered with draped colluvium or soil with small patchy exposures. Mitigative actions for these areas could include:
  - A brief palaeontological assessment should be made if it is encountered en route or appraised remotely during field activities. Predestrian examination of 10% of these areas during a project, if warranted; and
  - If palaeontological resources are encountered, the significant area would be delineated and mitigative actions for positive high zones may be proposed.

- Negligible Palaeontological Sensitivity Zones: The remaining black-outlined, uncoloured polygons (negligible impact) indicate areas which have a negligible potential to encounter significant fossil material. These areas have been disturbed through previous industrial activities and would be avoided during field activities.

4 RESULTS

4.1 STRATIGRAPHIC PALAEONTOLOGY & INVENTORY

Few known palaeontological localities are in the Howe Sound area from equivalent strata as those likely to be encountered in the proposed development (Figure 3). The available records of some of these sites did not supply enough location information to pinpoint the exact location and, therefore, are approximately located.

In order to identify the potential fossils to be found in the stratigraphic units within the proposed Project area, the scope was broadened to include fossil occurrences in Howe Sound and the greater Vancouver area. The taxonomic nomenclature is supplied as it occurs in the references. Indefinite taxa assignments are noted by a question mark and the species authorships are omitted.

Table 2. The palaeontological inventory of coastal Howe Sound, and neighbouring coasts for equivalent strata.

Age (years before present)		Locality	Fossil Inventory	Reference
Present - 12000	500-2400	F010[2], F011[3], F012[1], F013[3],	PLANTS Charcoal[1-3]	[1] McNeely and Atkinson 1996 [2] McNeely and Jorgensen 1992 [3] Thurber Engineering/Golder Associates (1993)
	5500-10200	F011[3], F014[1], F015[3] F016[2, 3] F017[3] F018[3] F019[1]	PLANTS Charcoal[2] Conifer needles[1] Gyttja[1] Plant detritus[1] Sticks[1]	[1] Clague et al 2003 [2] Eisbacher 1983 [3] Thurber Engineering/Golder Associates (1993)
	10344-12000	F002[5] F003[3] F004[2] F005[1] F019[4] F021[6] F022[6] F023[6]	INVERTEBRATES Shells[1] PLANTS *Abies* sp.?[6] Charcoal[3] *Pinus contora*[6] *Tsuga heterophylla*[6] Twig[4] Wood[2,4,5]	[1] Blake 1984 [2] Brooks 1994 [3] Brooks and Freile 1992 [4] Clague et al 2003 [5] Friele and Clague 2002 [6] Saunders et al 1987
	Age unspecified	F020[1,4] F033[2] F038[3] F039[3] F040[3]	INVERTEBRATES Shells[2] Shell moulds and casts[3] Crab tracks[3] Chironomids[4] PLANTS *Thuja plicata*, *Thuja* scale leaves[1] *Tsuga herterophylla* needles[1]	[1] Wainman and Mathewes 1987 [2] Stirkland 1970 in Golder Associates 2010 [3] McCammon 1997 [4] Walker 1988

			Abies mmabilis needles[1] *Taxus brevifolia* needles[1] *Pseudotsuga menziesii* - needles[1] *Pinus monticola* - needles[1] *Pinus contorta* – needles[1] *Picea sitchensis* - needles[1]	
12000-20000	12000-15305	F001[4] F002[4] F006[3] F007[1] F008[2]	VERTEBRATES Stellar Sea Lion: *Eumetopias jubatus*[2] INVERTEBRATES Serpulid worm tubes[2] PLANTS Stump[3] Wood[1, 4]	[1] Armstrong 1981 [2] Blake 1984 [3] Brooks and Friele 1992 [4] Friele and Clague 2002
	17000-20000	F0024[1] F0025[1]	PLANTS *Abies* sp.[1] Wood[1]	[1]Hicock and Lian 1995
>20000	20000-31000	F009[1] F024[2] F025[2] F026[3] F027[3]	VERTEBRATES Proboscidea tusk fragment[3] INVERTEBRATES Benthic diatoms[1] Marine plankton[1] PLANTS *Abies*[2] Plant fragments[1] Twigs, branchlets and herbaceous leaves[1]	[1] Clague et al. 2005 [2] Hicock and Lian 1995 [3] Hicock et al 1982
	>34000	F026[1]	INVERTEBRATES Marine Shells[1]	[1] Lowdon et al 1977
Quaternary - uncertain		F029	VERTEBRATES Stellar Sea Lion: *Eumetopias jubatus* - immature[1]	[1] Cowan 1941
Mesozoic	Early Cretaceous (Albian)	**F030[1,6]** **F031[2,3,6]** **F032[4]** **F037[5]**	INVERTEBRATES **Ammonite mould[1]** **Ammonite *Cleoniceras*[2,3,4,6]** PLANTS **Fossil Leaf material [5]**	[1] Bostock 1963, [2] Armstrong 1990a,b [3] Haggart pers. com. [4] Monger and Struik 2007 [5] Coyne pers. com, [6] Lynch 1991,1992
	Jurassic	F036[1,	Ammonite: *Arnioceras kwakiutlanus?*[1]	[1] Friedman et al. 1990

4.1.1 Mesozoic Bedrock Geological Units:

4.1.1.1 Plutonic intrusions:

Description: The plutonic intrusions comprise granites and granodiorites.

Age: Lower Jurassic through to Upper Cretaceous

Fossil potential: Negligible, due to the igneous nature of the rocks

Formational Distribution: These rocks form the primary bedrock along the

northwest shores of Howe Sound and along its mid to upper reaches, south to Porteau on the east shore.

4.1.1.2 Bowen Island Group

Description: The Bowen Island Group is a complex unit of sedimentary and volcanic rocks including flows and pyroclastics, chert, sandstone and siltstone that have, in some places, been metamorphosed into gneiss and schist quartzites.

Age: Triassic? to Jurassic; An age of Early to Middle Jurassic (Sinemurian to Aalenian) has been indicated by radiometric dating (Freidman et al. 1990) along with the inclusion of an ammonite. Armstrong (1990a,b) suggests a Triassic age.

Distribution: The Bowen Island Group is distributed across outer Howe Sound from Bowen Island, Keats Island, southwest Gambier Island and on the southwest mainland coast north of Gibsons near Landale and Twin Creeks.

Fossil potential: At present, a single fossil is known from the Bowen Island Group northwest of Jervis Inlet. This paucity is due to its general high-grade metamorphism. However, isolated diagenetic environments could allow the preservation of fossils in the Bowen Island Group within Howe Sound, similar to the Jervis Inlet locality. Close examination of the fine grained slates could produce marine trace and imprint fossils. Siliceous microfossils, such as radiolarians, could also be preserved.

The following is a list of fossils recorded in Howe Sound from Bowen Island Group:

Vertebrates: Not recorded

Invertebrates: Ammonites - *Arnioceras kwakiutlanus*?

Microfossils: Not recorded

Palaeoflora: Not recorded

4.1.1.3 Gambier Group

Description: The Gambier Group is a complex unit of sedimentary and volcanic rocks. The sedimentary rocks comprise argillites, wackystone, sandstones, breccias and conglomerates with minor limestones that have undergone low grade metamorphism.

Age: Late Jurassic to Early Cretaceous; Fossiliferous rocks are dated as late Early Cretaceous (Albian) based on the presence of the ammonite *Cleoniceras*

(F031) near Porteau (Jeletzky *in* Friedman et al. 1990; Lynch 1991, 1992). The age is also constrained by radiometric dating of plutonic rocks between earliest Cretaceous (Berriasian) <145Ma and late Early Cretaceous (latest Albian) >102Ma (Lynch 1991).

Distribution: Gambier Group exposures are located along the west coast of Lions Bay from Horseshoe Island north to Porteau, and continues as a band across Howe Sound over Anvil Island, the middle and northern portions of Gambier Island, across to restricted areas along the northwest shores of Howe Sound including the southwest wall of the McNab Creek valley and possibly underlies, in part, the surficial sediments in the Project area.

Fossil potential: Few fossils are known from the Gamier Group due to low grade metamorphism and lack of palaeontological attention. Known fossil sites (F030, F031) were discovered incidentally during geological mapping by Bostock 1963 and Armstrong 1990b, 2005). Fossil Site F030 occurs directly across from the proposed Project area at Ekins Point on the northeast shore of Gambier Island. Later, H. Tipper (Coyne, pers. com.) collected abundant fossil leaf material (F037) from Cretaceous black slates at Ekin Point in 1972. Close examination of the areas exposing the sedimentary rocks could produce more marine shell fossils as well as trace and imprint fossils. Similar Cretaceous environments are known to produce ichthyosaurs and mosasaurs. Siliceous microfossils, such as radiolarians, could also be preserved.

The following is a list of fossils recorded in Howe Sound from the Gambier Group:

Vertebrates: Not recorded

Invertebrates: Ammonites – *Cleonoceras*

Microfossils: Not recorded

Palaeoflora: Unidentified fossil leaf material

4.1.2 Quaternary Surficial sediments:

The Quaternary surficial sediments are distributed across the proposed Project as indicated by the published statement of the BCGS geologist McCammon (1977): “The most widespread unconsolidated deposits comprise a variety of marine and glaciomarine sediments.” For the purposes of this palaeontological review these sediments are divided into three units with differing palaeontological resource potential based on their depositional environments. The basal sediments are usually ground moraine (McCammon 1977) and its palaeontological potential is considered to be negligible. The potential distribution of these sediments across the project area are schematically interpreted in a

cross-sectional profile through the McNab Creek valley (Figure 6). Within this illustration the number of fan-deltas and marine incursions is interpretative as is the relative thickness, and is meant to demonstrate potential oscillating sealevel events.

4.1.2.1 Marine Sediments

Description: Thin veneers and interbeds of marginal marine fine grained sediments ranging into coarser submerged channels and beach sorted sediments deposited at times of higher sea level.

Age: Post-glacial to recent

Distribution: Marginal marine sediments can be expected to occur in the proposed Project area. This is demonstrated by the observation that shell fragments have been observed in boreholes through the target sediments (Stirland 1970 in Golder Associates Ltd. 2010, p.3) .

Fossil Potential: Palaeontological resources are regionally known from marginal marine sediments, and include mollusc shells (F005) near Shannon Falls and a fossil pinniped (F008) on Bowen Island. The pinniped (stellar sealion) was discovered in a well, situated at 82m above sea level with a maximum palaeowater depth greater than 11m at approximately 12.5 Ka during the retreat stage of Late Wisconsan glaciation (Harington 1996, Harington 2003, Harington et al., 2004). Other marine animals such as cetaceans, birds, fish, echinoderms, gastropods, pelecypods, etc. could be present as in similar environments in the lower Fraser Valley (Cowan) and the east coast of Vancouver Island (Harington and Beard 1992; Harington et al. 2004, Wagner 1959; Kermode 1916). Terrestrial plant fossils, such as wood, would be washed or slumped into the beach, as can be seen on the beach at McNab Creek today (visible on GoogleEarth imagery March 14, 2013). In addition aquatic microfossils such as the chlorophytic algae, diatoms and *Pediastrum,* have been recovered.

Vertebrates: *Eumetopias jubatus*

Invertebrates: Shells unidentifed, crab tracks, serpulid worm tubes

Microfossils: Not recorded

Palaeoflora: Wood

4.1.2.2 Fan-Delta

Description: Surficial deposits of thick progradational clastics comprising sand and gravel with thin silt and/or till materials (Golder Associates 2010) that are intercalated with marine incursions. Both marine and terrestrial animals are

potentially found in such units.

Distribution: Fan-deltas, that have been raised, tend to occur at the mouths of glaciated valleys, such as the McNab Creek valley. Similar geomorphic features occur at the mouths of Potluck River, Rainy River, Mull Creek and Squamish River as they discharge into Howe Sound. The 12.5Ka sea level would extend up the Squamish River valley to include portions of the Cheeye fan.

Fossil Potential: Fan-deltas produce regionally good fossil material, primarily plant fossils comprising wood and charcoals often associated with debris-flows, but also in the silts and gravels. Although common, these fossils can be used for radiometric dating, and contribute to the reconstruction of the geohistory of Howe Sound. Similar environments, such as fans and gravels in the lower Fraser Valley and Vancouver Island, have produced fossil proboscideans, muskox, bison, and horse (Bornhold 1997, Cowan 1941, Harington 2003, Kermode 1916, Hicock et al. 1992).

A paucity of highly significant fossils has been previously recorded in Howe Sound as the following list of fossils recorded from similar fan-delta beds indicate:

Vertebrates: Not recorded

Invertebrates: Not recorded

Microfossils: Not recorded

Palaeoflora: Wood (charcoal, sticks, fragments)

4.1.2.3 Alluvial Valley Fill

Description: Thick sand and gravel glaciofluvial outwash sediments which have been eroded, reworked and redeposited by the McNab Creek. Ponded sediments can also occur. In addition, slumped material can originate from higher elevations.

Distribution: These alluvial sediments occur along the length of the McNab Creek and create alluvial fans along the walls of the valley. Similar geomorphic features occur .

Fossil Potential: The fossil occurrences are relatively low comprising primarily wood and various plant fossils such as conifer needles. These have scientific significance in that they are useful to date radiometrically the depositional events. Comprehensive plant and insect assemblages, such as those found at the fossil site F020 at Marion Lake, can assist in defining prehistoric vegetation and climatic patterns (Wainman and Mathewes 1987, Walker 1988). However, similar

stratigraphic units in southern and coastal British Columbia offer further opportunities to discover terrestrial vertebrates, especially the large and exceedingly rare goat, bison, bear, caribou, elk, horse, proboscideans, rodents, sheep and sloth, as well as fish remains (Harington 1996).

A paucity of highly significant fossils has been previously recorded in Howe Sound as indicated by the following list of fossils recorded in Howe Sound from similar alluvial beds:

Vertebrates: Not recorded

Invertebrates: Chironomids (insects) diverse

Microfossils: Not recorded

Palaeoflora: Wood (stumps, charcoal) conifer elements (needles, leaves) of *Abies, Picea, Pinus, Pseudotsuga* and *Thuja*

4.2 PREDICTED PALAEONTOLOGICAL SENSITIVITY MODEL

4.2.1 The Project Area

The McNab Creek valley floor is lined with bluffs and terraces and high valley wall exposures occur. The primary features with exposed potentially fossiliferous sediments are:

- Cretaceous metasediments that are exposed along the west side of the valley wall, especially along the steep shore of Howe Sound as well as road cuts along the west boundary of the project;
- Quaternary slumped and alluvial sediments and possibly fan-delta sediments that have been exposed at meander bends of the McNab Creek;
- An artifical stream that has been carved through the centre of the proposed Project for fish habitat development which exposes the upper fan-delta and/or marine sediments;
- A palaeobeach that has been formed along the south boundary of the pit of the proposed Project and are patchily exposed; and
- Marine sediments that are exposed along Howe Sound beach, the beach bluff (up to 8m high), and possibly along the flanks of the small tidal channels.

A total of thirty four polygons demarking the palaeontological sensitivity zones have been identified across the Project area (Table 3 and Figure 5). Six areas with high sensitivity (red polygons) have been identified that are the most prospective areas for fossils and a further 27 larger areas with medium palaeontological sensitivity are regarded as secondary prospective areas. The

background area across the Project area is considered to be of low sensitivity at the surface; however, wherever excavation is expected to occur, fossiferous strata could be encountered.

In addition 20 polygons (Table 3 and Figure 5) demark sediment exposures around the perifery of the Project area which could be impacted or serve as proxies to subsurface stratigraphy. Igneous or highly metamorphic rock along the east valley wall is considered to be unfossiliferous; therefore, exposures have not been identified in the Project area.

Table 3. The palaeontological sensitivity zones of the Project area. The bold font numbers are within the Project area and the italized font are potential proxies to subsurface stratigraphy.

Area	High	Medium	Low	Negligible
West Valley Wall	**3**/*4*	**2**/*4*	**1**	**0**
Beach Front	**0**	**2**/*5*		**1**
Palaeobeach	**2**	**9**		**0**
Fan-Delta Top	**1**	**7**		**0**
Artificial Stream	**2**	**6**		**0**
McNab Creek	*1*	*6*		**0**
Total = 34/*20*	**7**/*5*	**26**/*15*	**1**/*0*	**0**/*0*

4.2.2 The Barge Routes

Two barge routes are proposed, one north and east of Gambier Island through Ramilles Channel, and the other west and south of Gambier Island through Thornbrough Channel. Both routes connect and proceed through Queen Charlotte Channel. Beyond the Queen Charlotte Channel the routes connect with previously approved routes to New Westminister and Langley. These later route segments are not considered here, although they course by known palaeontological sites.

4.2.2.1 Quaternary Shoreline Areas

Potentially fossiliferous sedimentary rock or Quaternary sediment accumulations lateral to the proposed barge routes of the Project are distributed intermittently along the Howe Sound shoreline areas (Figure 4). The most direct impact would occur along the shore at McNab valley (Qu01). Increased wave action could degrade rapidly the unconsolidated beach bluff and expose fossiliferous shallow marine and beach sediments. These areas are outlined in detail in Figure 3 (PS019 to PS025). Further adverse effects could occur along the coast near Port Mellon (Qu02 and Qu02). There the converging discharge of Rainy River, McNair Creek and Dakota Creek have accumulated Quaternary sediments along the shoreline that could be affected in a similar manner to McNab Creek from barge traffic along Thornbrough Channel. The palaeontological sensitivity to adverse effects of the barge route in these areas is considered to be medium.

4.2.2.2 Cretaceous Shoreline Areas

Shoreline areas lined with Cretaceous sedimentary rocks could also be impacted, although to a lesser extent as the rocks are more resilient to erosion through wave activity. The southwest area (EKs7) adjacent of the Project, has black slates (Golder Associates 2010) which are similar to those directly across Thornbrough Channel on Gambier Island (EKs1). Although fossils have not been previously recorded in the mainland area, the Cretaceous sedimentary rocks on Gambier Island have an ammonite (F30) and abundant fossil leaf material (F37) at Ekins Point. Thus potentially adverse effects of the barge routes could occur on both the Mainland and Gambier Island areas. Two other areas on the south shore of Gambier Island (EKs2, EKs3) are considered to be less sensitve to adverse effects, as they do not have known palaeontological sites, and are well protected at the proximal ends of two long narrow bays. The palaeontological sensitivity to potential adverse effects produced by the barge route in these areas is considered to be low.

Cretaceous ammonites have also been recorded from the area (EKg1) with mixed volcanics and sedimentary rocks along the mainland shoreline of Montagu Channel between Brunswick Point and Porteau (F031, F032) in a shoreline zone that extends south from Porteau to Horseshoe Bay. Although fossiliferous sites are protected from most wave action produced from Ramillies Channel by Anvil Island there is the possibility of similar effects imposed on equivalent strata along Queen Charlotte Channel on Bowyer Island (EKg3) and the mainland shoreline Lions Bay to Horseshoe Bay (EKg1). The palaeontological sensitivity to potential adverse effects of the barge route in these areas is considered to be low.

4.2.2.3 Triassic to Jurassic Shoreline Areas

The areas where the Triassic to Jurassic Bowen Island Group forms the bedrock of the shoreline cliff occur in the outer Howe Sound. Fossils, for the most part, are non-existing as the metamorphic grade is high. However, it does not entirely preclude the occasional preservation of certain types of fossils such as ammonites.

Along Thornbrough Channel potential adverse effects could occur at areas at Twin Creeks (Tr13), on the opposite shore on Gambier Island (Tr12), at Langdale (Tr14), the southwest tip of Gambier Island (Tr11), the north shore of Keats Island (Tr09 and Tr10), and the north shores of Bowen Island (Tr04 to Tr06). Along Queen Charlotte Channel the southeast shores of Bowen Island (Tr01 to Tr04) could also receive adverse effects from barge traffic. The palaeontological sensitivity to adverse effects of the barge route in these areas is considered to be low due to the low palaeontological content.

4.2.2.4 Volcanic and Plutonic Shoreline Areas

The areas where the Triassic to Jurassic Bowen Island Group forms the bedrock of the shoreline cliff occur in the outer Howe Sound. Fossils, are devoid in igneous rocks. However, volcanic extrusive rocks can occlude the occasional preservation of fossils in breccia, ash and interbeds of sedimentary clastics.

4.3 PRELIMINARY PALAEONTOLOGICAL ASSESSMENT SUMMARY

4.3.1 5.1 Scientific significance

From a scientific point of view, the Project area holds significant palaeontological value as known fossils are quite rare and it is situated in a geographically-defined information gap. Early palaeontological exploration was performed incidentally by geologists mapping the area with minimal professional palaeontological attention. Evidence to this lies in the fact that the Cretaceous fossil sites have not been published in scientific journals, nor received any external expert identification (Coyne, pers. com). These Cretaceous fossil sites were almost non-evidential except for small markings on a preliminary map (Bostock 1963). However, they are important in dating the sedimentary rock strata, appraising the palaeoenvironments of terranes accreted to form the coastal mountains. Similarly the Bowen Island Group has postulated ages from Triassic to Jurassic. The most current age assignment of Jurassic (Sinemurian to Aalenian) (Friedman et al. 1990) is derived from a single fossil west of Jervis Inlet and is bracketted by radiometric dates from plutonic rocks. Other fossils from the Bowen Island Group would be a welcomed addition to the accumulated scientific knowledge of the area.

The glacial and post-glacial history is written in the terrestrial sands and gravels, and marine silts. During periods of low sea level, large Pleistocene mammals would have had greater access to the Project area. During periods of high sea level, the sea would have inundated the lower McNab Creek valley bringing molluscs and possibly marine mammals. The opportunity exists to find large animals such as extinct bison, mammoth, in the Quaternary sediments. Such discoveries would assist in the reconstruction of glaciation and post-glacial geo- and bio-history. Quaternary fossils from the regional area of the Project are rare. All records would, therefore, be scientifically important, especially if large mammals were to be discovered.

The systematic collection and description of potential fossils in the Project area would fill a gap in the present palaeontological knowledge base and, thus, enhance the current understanding of coastal geology, ancient life and evolutionary processes.

4.3.2 Natural Heritage Significance

Fossils and their study, Palaeontology, are important to the Howe Sound community (Bowen Island Nature Club 2013, Tourism Squamish 2014). These intriguing curiosities draw the attention and imagination of young children and adults alike. The fossils speak to us from the ancient past about the path towards our present existence, ground us to the continual metamorphsis of life, and point to the ever changing environments through the ages and into the future.

A reconnaissance palaeontological survey would augment the identification and qualification of the fossil sites within the Project area and permit the recovery of fossils that would be of interest to museums and other institutions, so that the fossils would be preserved for future generations to contemplate and enjoy.

4.3.3 Educational Significance

A palaeontological field assessment of the Project area could identify fossils and palaeontological sites that would be useful for educational purposes. However, the site is remote for common public visitation. Comments on the webpage of the Bowen Island Nature Club ask a series of intriguing queries on why "curious layers of clay contain marine fossils, yet are high above the sea" and "Our Island rocks formed in the Jurassic Era – could we find dinosaur bones here?" (Bowen Island Nature Club, March 7, 2013). Fossils within the Project area and the barge routes could help to assist in the public education of geohistory of the local area.

4.3.4 Commercial Significance

The fossil sites have the potential to have medium to high commercial values, although any commercial trade or export of fossils needs to be permitted by the government. Large mammals, such as the pinniped on Bowen Island, would be highly sought after and recieve high commercial value.

4.4 KEY PALAEONTOLOGICAL ISSUES OF CONCERN

Palaeontological issues of concern have been revealed through this preliminary palaeontological assessment as follows:

- The published palaeontological knowledge base for the Project area and Howe Sound region is meager and dispersed. Very little is known about what exists there except for a few positive indications. The extensive sediment exposures point towards multiple prospective sites for fossil exploration. Palaeontological field excursion with pedestrian inspection is the primary methodology employed to fill this information gap; and

- Although most relevant local palaoentological sites have likely been considered here, there are limitations to the search. Further intensive literature research and consultation with palaeontological repositories would be necessary to fully document the palaeontological resources of the Project area and within Howe Sound.

4.5 FOSSIL RESOURCE MANAGEMENT RECOMMENDATIONS

The following recommendations are proposed for the adequate fossil resource management of the Project area.

- The Project area is underlaid by sedimentary units which have the potential to produce abundant, diverse and well-preserved fossils. To protect and preserve these palaeontological resources a pedestrian field palaeontological impact assessment (PIA) is recommended in advance of facilities, road and pit construction. The PIA should attempt to intersect as many of the formations as possible;
- Where subsurface sedimentary units are to be excavated, and there are no sufficient sites on the Project area from which to evaluate the fossil potential, the neighbouring exposures of equivalent strata should be inspected as proxies to the subsurface, if possible;
- Attempts should be made to fill the knowledge base through contact with appropriate palaeontologists, palaeontological research institutes and museums, in advance of implementing the PIA; and
- A chance-find procedure should be set up to refer to a professional palaeontologist, the occasional fossils or suspected fossils discovered within the Project area by Project personel such as other professional investigators, the operators of excavators and job supervisors. This would assist in developing a palaeontological inventory and minimize any resource loss during the development of the proposed Project.

4.5.1 Field Assessment Plans

In the event that Burnco considers conducting a pre-development PIA, it is recommended that the field assessment involve pedestrian inspection at:

- Seven Quaternary high palaeontological sensitivity zones within the Project area;
- Thirteen of the medium sensitivity zones within the Project area;
- one proxy site (PS035) to examine correlative sediments to the subsurface fan-delta and alluvium;
- The Cretaceous Gambier Group at PS026 and PS049 at the southwest corner of The Project area and continuing along EKg7; and
- The known sites of the Cretaceous Gambier Group at Ekins point (F030 and F37 in EKs1) on Gambier Island.

It is further recommended that the field work be done on a non-intrusive, reconnaissance basis. Representative fossils would be collected for future identification or if the fossil was prone to damage by weather or water. All types of fossils would be recorded and photographed to build as complete a palaeontological inventory as possible for the proposed Project area and barge routes.

4.6 CONCLUSIONS

The following conclusions can be made on the palaeontological sensitivity of the proposed Burnco Aggregate Project:

- The geology and fossil locations were investigated through database, literature and maps for the Project area and the associated barge routes in Howe Sound, southwestern British Columbia;
- Previously known Quaternary fossils within Howe Sound comprise conifer material, wood, and mollusc shells along the eastern coast, while pinniped skeletal elements occur on Bowen Island;
- Previously known fossil marine shells occur in the boreholes within the proposed Project area indicating that the proposed aggregate target is fossiliferous. The maximum sea level, greater than 93m above present day sea level, encompasses the entire Project area and proposed proxy exposures. The marine environments of the present beach, bluffs, palaeobeach and fan-delta could contain significant fossils with scientific, heritage, educational and possibly commercial values;
- Although Cretaceous fossil sites were not identified directly within the proposed Project area, the Early Cretaceous Gambier Group contains fossiliferous sedimentary rocks. Ammonites and fossil leaves that are over 100 million years old (Albian) are known from Ekins Point, Gambier Island directly across Thornbrough Channel from the Project area. These fossils are expected to be encountered in the building of the docking facilities, and, if present, could be adversely affected by wave action produced by the barge traffic. From a palaeontological perspective the Project area is considered to be palaeontologically sensitive and mitigative actions are recommended in advance of construction, initiating with a PIA; and
- Across the Project area, several sediment exposures occur along the valley wall faces, the beach, artificial stream and the McNab Creek which would be good places for fossil exploration. A total of the 24 palaeontologically sensitive areas should be inspected. The primary areas are concentrated along the artificial stream, the present beach bluffs, and the palaeobeach bluffs.

4.7 REPORT AUTHORIZATION

This report has been approved by March 20, 2014:

Dr. Edward H. Davies,
APEGBC (#37854) and APEGA (#44164),
Professional Geologist and Palaeontologist

BRANTA BIOSTRATIGRAPHY LTD.

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6 APPENDIX A
FIGURES

Figure 1. Proposed conceptual site layout and LSA for the palaeontological resources desktop assessment. Burnco Aggregate project in McNab Creek valley, northwest Howe Sound.

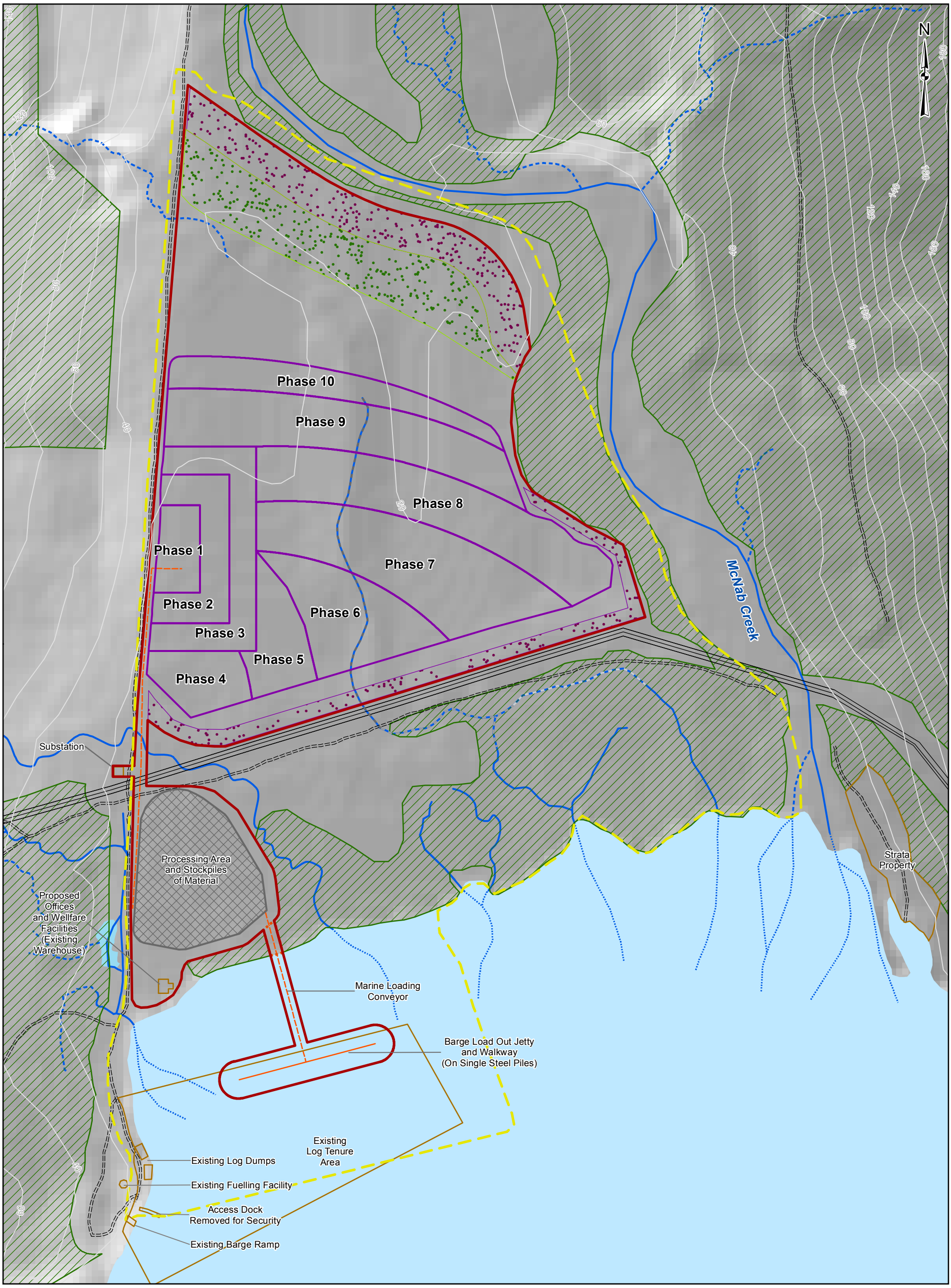
Figure 2. The Geology map of Howe Sound. derived from the Vancouver Geology map *by* Armstrong (1990b, Geological Survey of Canada). The red polygon indicates the outer boundaries of the project. The brown line trace indicates the proposed barge routes.

Figure 3. The Distribution of known palaeontological resources in the vicinity of Howe Sound: Red Sites – Quaternary fossil localities; Green Sites– Cretaceous fossil localities. The numbered labels key into Table 2.

Figure 4. The distribution of potentially fossiliferous sedimentary units along shoreline of Howe Sound which could be impacted by barge transportation: TJ – Bowen Island Group: undifferentiated volcanics and metasediments; EKg – Gambier Group: undifferentiated volcanics and low grade metasediments; EKs – Gambier Group: low grade metasediments; Qu – Quaternary to recent unconsolidated sediments.

Figure 5. The predicted palaeontological sensitivity model: Red Zone– High sensitivity; Orange Zone– Medium sensitivity; Yellow Zone– Low sensitivity; Black Zone – negligible sensitivity.

Figure 6: A schematic geological cross-section of the proposed Project area showing three potentially fossiliferous Quaternary Units (marine, fan delta and alluvium) overlying ground moraine and bedrock. The potential for the ground moraine is considered to be negligible (interpreted after Stirland 1970, Golder Associates 2010, and McCammon 1990).



LEGEND

- Palaeontology LSA
- Project Boundary
- Mature 2nd Growth Forest
- Processing Plant and Product Stockpile
- Berm (Organic + Wash Sediment Mixed and Planted)
- Planted forest (organics and washed fines)
- Proposed Aggregate Pit Area
- Waterbody
- Road (existing)
- Transmission Line
- Barge Load-out
- Conveyor
- Conveyor Buffer
- Permanent / Perennial Channel
- Intermittent Channel
- Intertidal Channel
- Contour - 20m Interval

Constructed Channel

- Phase 1
- Phase 2
- Phase 3

200 0 200

SCALE 1:6,000 METRES

REFERENCE

DEM from Geobase, base data from the Province of British Columbia, contours from TRIM positional data. Additional detailed site features provided by McElhanney. Projection: UTM Zone 10 Datum: NAD 83

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

PROPOSED CONCEPTUAL SITE LAYOUT AND LSA FOR PALAEONTOLOGICAL RESOURCES DESKTOP ASSESSMENT

Golder Associates

PROJECT NO. 11-1422-0046			PHASE No.	
DESIGN	DG	17 Sep. 2014	SCALE AS SHOWN	REV. 0
GIS	DL	22 Sep. 2014		
CHECK	AC	30 Sep. 2014		
REVIEW	DG	30 Sep. 2014		

FIGURE 1

Path: X:\Project Data\BC\McNab\Figures\MXD\Archaeology\BURNCO_PALAEONTOLOGY_Figure_01_Proposed_Conceptual_Site_Layout_and_LSA_For_PRDA.mxd

N

Squamish

Woodfibre

Project Area

Thornbrough Channel

Ramillies Channel

Montagu Channel

Anvil Island

Port Mellon

Gambier Island

Lions Bay

Gibsons

Shoal Channel

Barfleur Passage

Collingwood Channel

Bowen Island

Queen Charlotte Channel

West Vancouver

LEGEND

Quaternary Sediments and Garibaldi Volcanic Rocks

- Salish Sediments
- Sumas Drift, Fort Langley Formation, Capilano Sediments
- Vashion Drift, Pre-Vashon Drift

Pre-Quaternary Sedimentary, Volcanic and Granitic Rocks

- Coast Intrusions
- Gambier Group, Bowen Island Group

- Project Boundary
- Proposed Barging Route
- Existing Barging Route

4,000 0 4,000

SCALE 1:150,000 METRES

REFERENCE

Geological surfaces from Geological Survey of Canada. Parks/protected areas and sensitive areas from BC LRDW, elevation and aboriginal lands from Geobase, base data from CanVec10.
Projection: UTM Zone 10 Datum: NAD 83

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

THE GEOLOGY MAP OF HOWE SOUND

Golder Associates

PROJECT NO. 11-1422-0046			PHASE No.	
DESIGN	DG	18 Sep. 2014	SCALE AS SHOWN	REV. 1
GIS	DL	23 Sep. 2014		
CHECK	AC	30 Sep. 2014		
REVIEW	DG	30 Sep. 2014		

FIGURE 2

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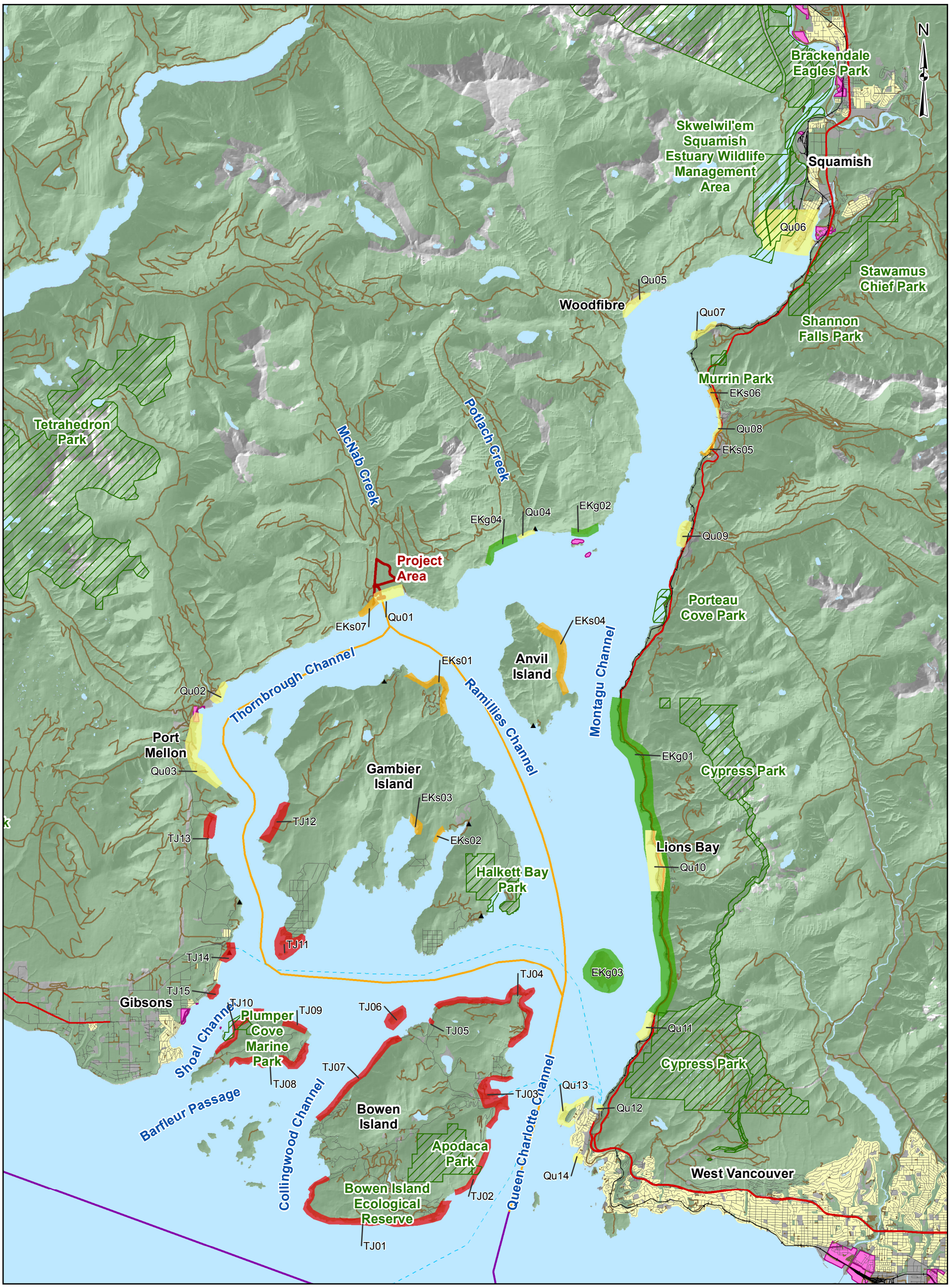


LEGEND

Potentially Fossiliferous Sedimentary Units

- TJ - Bowen Island Group: undifferentiated volcanics and metasediments
- EKg - Gambier Group: undifferentiated volcanics and low grade metasediments
- EKs - Gambier Group: low grade metasediments
- Qu - Quaternary to recent unconsolidated sediments
- Project Boundary
- Parks / Protected Area
- Vegetation
- Residential Area
- Indian Reserve
- Highway
- Road
- Resource Road
- Railway
- Ferry
- Proposed Barging Route
- Existing Barging Route
- Camp

REFERENCE

Parks/protected areas and sensitive areas from BC LRDW, elevation and aboriginal lands from Geobase, base data from CanVec10.
Projection: UTM Zone 10 Datum: NAD 83

4,000 0 4,000

SCALE 1:150,000 METRES

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

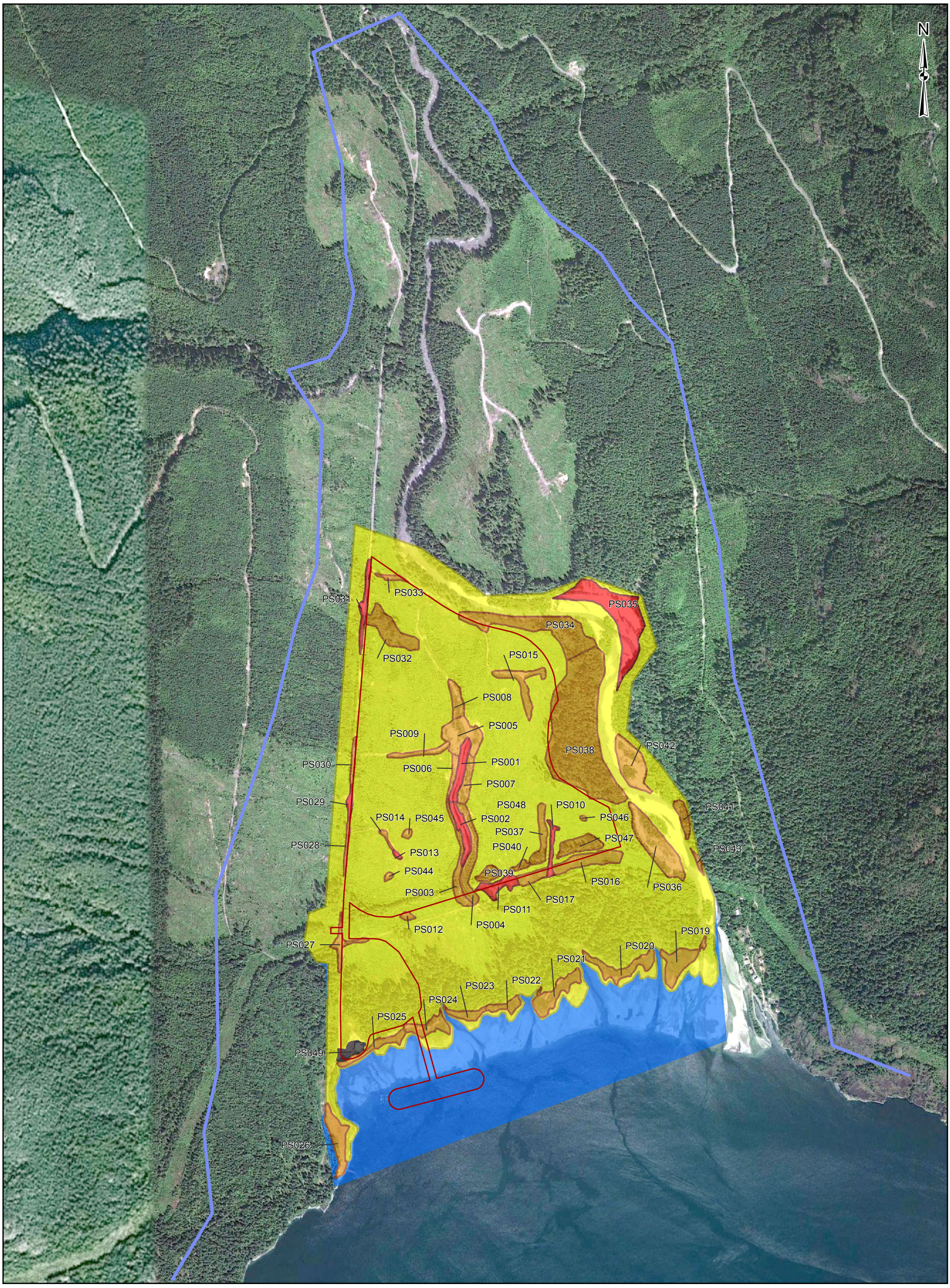
TITLE **THE DISTRIBUTION OF POTENTIALLY FOSSILIFEROUS SEDIMENTARY UNITS ALONG SHORELINE OF HOWE SOUND WHICH COULD BE IMPACTED BY BARGE TRANSPORTATION**

Golder Associates

PROJECT NO. 11-1422-0046			PHASE No.	
DESIGN	DG	18 Sep. 2014	SCALE AS SHOWN	REV. 0
GIS	DL	23 Sep. 2014		
CHECK	AC	30 Sep. 2014		
REVIEW	DG	30 Sep. 2014		

FIGURE 4

Path: X:\Project Data\BC\McNab\Figures\MXD\Archaeology\BURNCO_PALAEONTOLOGY_Figure_04_Distribution_of_Potentially_Fossiliferous_Sedimentary_Units.mxd



LEGEND

- Project Boundary

Predicted Palaeontological Sensitivity Zones

- High Sensitivity
- Medium Sensitivity
- Low Sensitivity
- Negligible Sensitivity
- Sealevel ~12.5Ka
- McNab Area of Consideration

REFERENCE

DEM from Geobase, base data from the Province of British Columbia. Additional detailed site features provided by McElhanney.
Projection: UTM Zone 10 Datum: NAD 83

360 0 360

SCALE 1:11,000 METRES

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

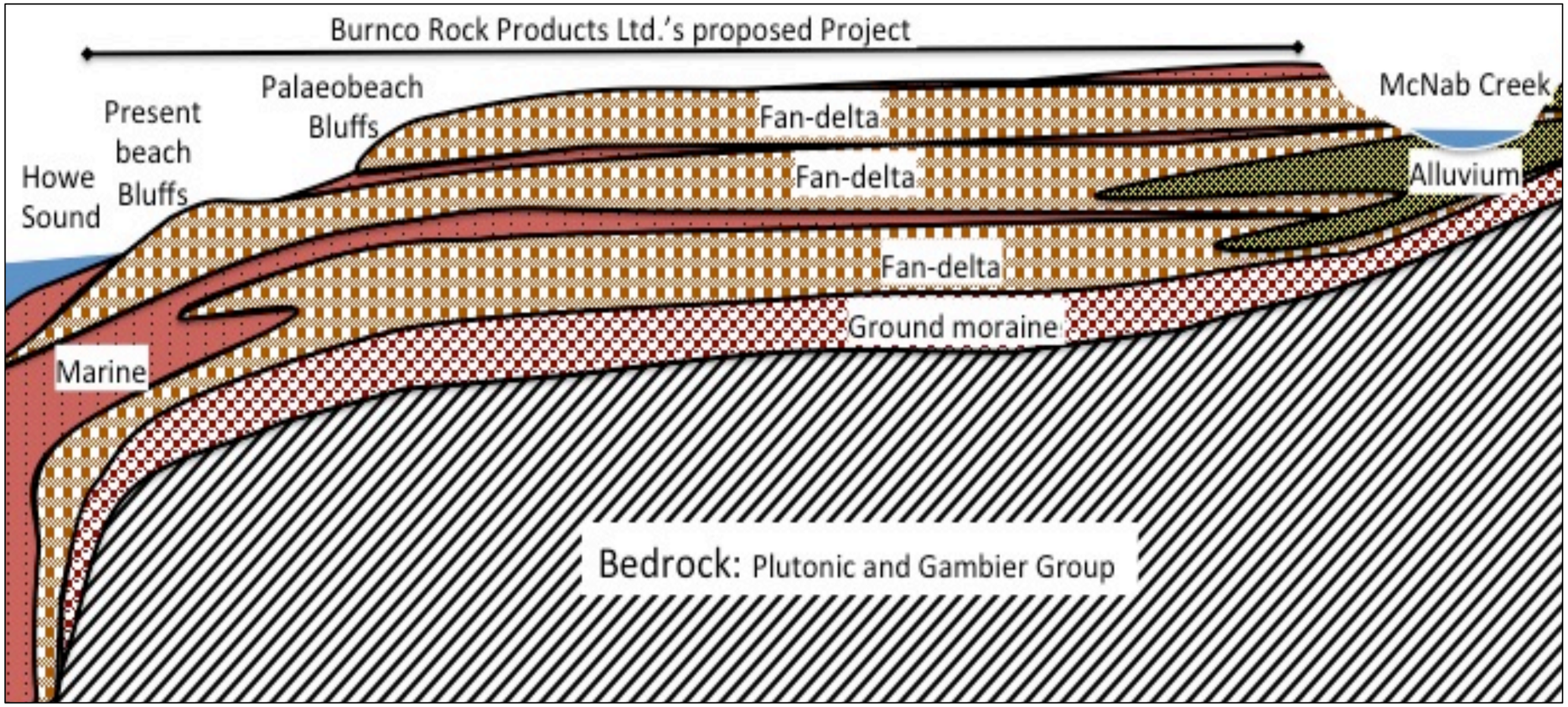
TITLE

THE PREDICTED PALAEONTOLOGICAL SENSITIVITY MODEL

Golder Associates

PROJECT NO. 11-1422-0046			PHASE No.	
DESIGN	DG	18 Sep. 2014	SCALE AS SHOWN	REV. 0
GIS	DL	22 Sep. 2014	FIGURE 5	
CHECK	AC	30 Sep. 2014		
REVIEW	DG	30 Sep. 2014		

Path: X:\Project Data\BC\McNab\Figures\MXD\Archaeology\BURNCO_PALAEONTOLOGY_Figure_05_Predicted_Palaeontological_Sensitivity_Model.mxd



LEGEND

- Water
- Marine sediments
- Fan-delta sediments
- Alluvial sediments
- Ground moraine sediments
- Bedrock: Plutonic and Gambier Group

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

SCHEMATIC GEOLOGICAL CROSS-SECTION ACROSS PROJECT AREA

Three potentially fossiliferous Quaternary Units (marine, fan delta and alluvium) overlying ground moraine and bedrock. The potential for the ground moraine is considered to be negiigible (interpreted after Stirland 1970, Golder Associates 2010, and McCammon 1977).

FIGURE 6