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North Coast Aggregate Potential Project

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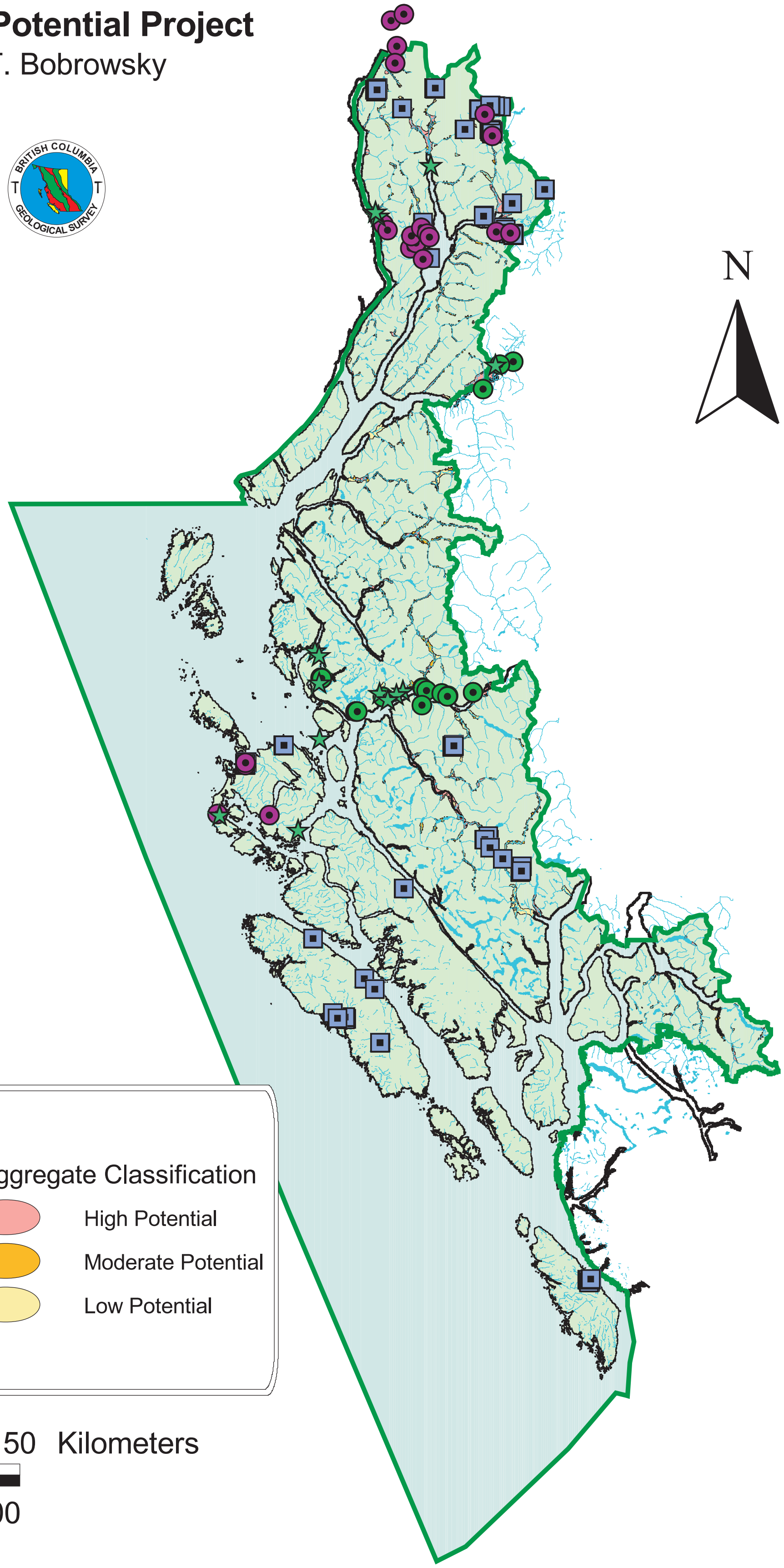

LRMP Boundary

Gravel Pit

Extraction

Drill Holes

Aris Drill Holes

Aggregate Classification

High Potential

Moderate Potential

Low Potential

25 0 25 50 Kilometers

Scale 1: 2,000,000

North American Datum 1983
Universal Transverse Mercator Projection
Zone 9

North Coast LRMP Aggregate Potential Map: Accompanying Notes

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INTRODUCTION

Globally, the aggregate sector has experienced increasing pressure to properly manage aggregate resources in response to accelerated urbanization, which has markedly increased consumption near large urban centers. Municipal expansion, alternate land uses, land sterilization, and public concern are just some of the factors, which have limited the availability of many traditional aggregate sources. Such factors, including the elevated cost of the product due to increased transportation distances, has created considerable concern about the aggregate industry's ability to supply aggregates to meet future demand.

Aggregate is herein defined as naturally occurring, hard construction material, and includes sand, gravel, crushed stone or slag, which can be mixed with cementing material to form concrete and asphalt or can be used separately in road building, railroad ballast or other construction or manufacturing activities (Edwards *et al*., 1985). Aggregate is an essential commodity in urban and suburban areas and despite its relatively low unit value, aggregate has become a major element in most economies. Natural aggregate is the product of unique geological processes (Langer and Glanzman, 1993). As such, this generally restricts the location for aggregate deposits to those areas where suitable environments of deposition either now exist or existed in the past. Understanding processes and suitable environments of deposition, has enabled aggregate geologists to predict those landforms which are most likely to contain aggregate. The North Coast LRMP Aggregate Potential Map project is a reconnaissance level study designed to target locations, within the LRMP boundaries that may potentially host economic aggregate deposits.

PREVIOUS WORK

Little published aggregate work has been conducted in this region of the province with the exception of studies by Clague and Hicock (1976) for the Terrace, Kitimat, Prince Rupert corridor and Ridley Island by Buchanan (1979). Quaternary studies have been limited to brief excerpts found in bedrock reports detailing reconnaissance work by the Geological Survey of Canada (GSC) in the 1920's. Nonetheless, the glacial history of the Nass (McCuaig, 1997; McCuaig and Roberts, 1999) and Skeena (Clague, 1984; 1985) river valleys do provide a framework for interpreting surficial sediments for the study area. Furthermore, unpublished surficial geology maps by the B.C. Ministry of Transportation and Highways (MoTH) have been produced for the major transportation corridors in the area.

LOCATION

British Columbia has been segregated into land resources management plan (LRMP) areas to facilitate the administration of the provinces vast resources. The study area for the North Coast LRMP Aggregate Potential Map covers an area of approximately 3,670,000 hectares of the west coast of British Columbia, from the southern tip of Aristanzabal Island, north to the head of the Portland Canal. The area within this LRMP covers much of the Hecate depression and extends inland as far as Gardner Channel. It includes the city of Prince Rupert, the municipality of Port Edwards, and the villages of Kitsault, Kincolith, Greenville, Lax Kwalaams, Metlakatla, Digby Island, Port Essington, Kitkatla, and Hartley Bay. Figure 1 is an index illustrating the location and boundary of this study. Table 1 lists the relevant 1: 50,000 NTS map sheets contained within the area.

Figure 1. The North Coast LRMP Aggregate Potential Map Project study area is located on the north coast of British Columbia. The LRMP boundary extends from the head of Portland Canal along the BC-Alaska border, to the southern end of Aristanzabal Island.

Table 1. List of the NTS 1:50,000 map sheets included within the North Coast LRMP Aggregate Potential Map study.

103A/11	103H/12	103I/11	103J/15	103P/11
103A/14	103H/13	103I/12	103J/16	103P/12
103G/10	103H/14	103I/13	103J/2	103P/13
103G/15	103H/2	103I/3	103J/7	103P/14
103G/16	103H/3	103I/4	103J/8	103P/4
103G/8	103H/4	103I/5	103J/9	103P/5
103G/9	103H/5	103I/6	103O/1	103P/6
103H/1	103H/6	103J/1	103O/16	
103H/10	103H/7	103J/10	103O/8	
103H/11	103H/8	103J/11	103O/9	

PHYSIOGRAPHY

The Coast Mountains represent an unbroken chain of mountains trending north-south from the Fraser River in the south to the Yukon Territory in the north. Holland (1976) separates this particular chain into four ranges: the Boundary, Kitimat, Pacific, and Cascade ranges, of which parts of the Boundary and Kitimat ranges lie in this study.

The Boundary Range is located in the northern part of this study and extends from the Nass River to the northwest along the Alaska-British Columbia Boundary. Mountains in this range have been heavily glaciated and extensive ice-carved trunk valleys, hanging valleys, and cirque development has resulted in a rugged over-steepened topography. Large ice fields persist at higher elevations (e.g. Cambria), with numerous glacial tongues extending down distributary valleys. Slopes below approximately 1200 metres are heavily forested with dense under brush.

The Kitimat Ranges extend south of the Nass River to the Bella Cola River. They are flanked to the west by the Coastal Trough and to the east by the Hazelton Mountains. Here, the topography is also the result of valley and cirque glaciations, which produced drowned valleys, cirques that open to marine waters, and long fjords. Generally, the peaks of the Kitimat Ranges were over-topped by glaciers during the Pleistocene glacial maxima and therefore show a more rounded morphology than the peaks to the north.

GLACIAL HISTORY

Most of the unconsolidated sediment in British Columbia owes its existence to glacial processes. The current landscape has developed from repeated cycles of glacial and non-glacial events, the most recent of which (Wisconsinan ca. 25,000 to 10,000 years BP) has the greatest impact on aggregate accumulation and distribution. Therefore, it is always important to correctly recognize the paleo-environment responsible for deposition or erosion features when assessing the aggregate potential of a landform.

At the onset of the Fraser Glaciation some 25,000 - 30,000 years ago climatic cooling and possibly increased precipitation triggered the growth of alpine glaciers (Clague, 1984). Valley glaciers advanced and thickened eventually emerging from the confines of their valleys, and coalescing to form small mountain ice sheets (Davis and Mathews, 1944). Ice continued to accumulate and expand, eventually spreading across the interior plateau and coastal lowland, covering much of the province and parts of the continental shelf, producing the Cordilleran Ice Sheet (Clague, 1986). Large valleys, such as the Skeena, were likely major conduits for the flow of ice from the interior of the province to the Pacific Ocean (Clague, 1984). At the glacial maximum, ice loading caused the underlying land surface to be significantly depressed, resulting in an isostastic sea-level change of up to 230 metres above present conditions (McCuaig, 1997). This transgression is responsible for the many marine deposits found throughout the fjords, and river valleys within the study area.

Destabilization of the Cordilleran Ice sheet marked the initiation of the deglacial cycle. Because this LRMP covers a considerable area, the chronology of events varies from place to place (diachroneity). Deglaciation of the Hectate Lowlands was under way by 12,700 years BP as indicated by radiocarbon dates on mollusks from glaciomarine diamicton at Prince Rupert (Clague, 1985). Glaciers retreated up the valleys facilitated by calving ice fronts as marine waters inundated and drowned the isostatically, depressed valleys. Ice retreated up the Skeena Valley in a non-uniform fashion, with intervals of catastrophic retreat separated by intervals of relative stability and stagnation (Clague 1985). It is during these stable periods that large, localized bodies of sand, gravel, and till accumulated in ice marginal conditions. The Nass Valley basin followed a much different chronology than that of the lower Skeena. Here, ice retreated rapidly and continuously with little or no stagnation (McCuaig and Roberts, 1999). Unlike the Terrace-Kitimat area, the lower Nass Valley is broad, lacking bedrock ridges and narrows that could pin or buttress a glacial snout (Clague 1984). Ice had disappeared from the lower Skeena valley by 10,100 years BP. Ice likely persisted longer in the northern parts of the study, as valley glaciers would have continued to be fed by the Cambia Ice Fields. These glaciers continued to retreat, becoming restricted to alpine elevation, though remnant glacial tongues such as the Sutton Glacier continue to be active today.

BEDROCK GEOLOGY

Quarried and crushed stone can be an alternate source of aggregate where sand and gravel deposits maybe scarce, therefore, bedrock geology of the study area has been included in the evaluation of aggregate potential. The geology of the area consists of rocks differentiated into seven groups, including the Bowser Lake, Hazelton, Karmutsen, and Stuhini groups, as well as the Coast Plutonic Belt, Gravina Assemblage, and Alexander Terrane (MacIntyer *et al*. 1994). The location and distribution of these units is shown in Figure 2 with a summary and description listed in appendix A.

Figure 2. Bedrock lithologies within the study area. The rocks can be differentiated into the Bowser Lake, Hazelton, Karmutsen, and Stuhini groups, as well as the Coast Plutonic Belt, Gravina Assemblage, and Alexander Terrane.

Rocks of the Bowser Lake group, are represented by Upper Jurassic sedimentary units interbedded with volcanics. The sedimentary rocks consist of sandstone, siltstone, shale, and argillite, with minor coal and carbonaceous units. The volcanic units are typically epiclastic volcanic conglomerate. The Hazelton Group consists of a number of different facies, though generally the rocks are dominantly Jurassic volcanic tuffs, breccias, andesitic porphyries and pillow basalts with sandstones, siltstones, argillite, and limestone. The Karmutsen Group is represented by a Triassic massive pillow basalt. Two units of the Stuhini Group are present in the study area, and consist of Upper Triassic volcanic porphyries and pillow basalts, with sandstone, conglomerate, silitstone, argillite, shale and limestone. The dominant rock in the southern half of the area belongs to the Coast Plutonic Belt. These rocks are generally intrusive diorite, granodiorite, and gabbro with local metamorphic phases such as schist, amphibolite, and gneiss. The Gravina Assemblage is restricted to a single unit containing marine argillite, and greywacke with interbedded andesitic and basaltic volcanic and volcanoclastic rocks metamorphosed to amphibolite grade. Rocks of the Alexander Terrane are highly variable and include felsic volcanics, metasediments, mafic plutons, sills and dykes, as well as quartzite and limestone.

Given that this LRMP has limited sand and gravel resources, bedrock sources of crushed aggregate become increasingly important. With this in mind, the utility of a rock for aggregate will depend on the inherent mechanical and chemical properties of the unit. Therefore, before costly quarries are established, the unit should undergo significant testing to assess the usability of the rock for crushed stone aggregate.

METHODOLOGY

The North Coast LRMP Aggregate Potential Map follows the provincial standards and criteria for a Level IV aggregate potential study (Bobrowsky *et al.*, 1996) (Table 2). This is a reconnaissance level map used primarily to target location for further investigation. The mapping relies on air photograph interpretation, where landform selection and identification is constrained by the scale of photographs. The size, quantity, or inherent physical properties of the surficial deposits have not been considered in this investigation. The onus is, therefore on the user of this database to ground truth and evaluate surficial materials and landforms, identify the precise boundaries of polygons, and determine the economic significance of a deposit. <u>It is important to remember that none of the landforms, deposits or aggregate pits discussed in this Level IV map for the North Coast LRMP were ever ground-truthed. All the interpretations provided on the map and in this accompanying text are open to revision.</u>

Table 2. Summary of data reliability, cost and suitability of level I to level V aggregate potential maps in British Columbia. The North Coast LRMP Aggregate potential map generally follows the level IV mapping criteria.

	I	II	III	IV	V
Map scales	1:100 to 1:10,000	1:10,000 to 1:50,000	1:50,000 to 1:100,000	1:100,000 to 1:250,000	1:250,000 to 1:500,000
Surficial (landform) data	yes	yes	yes	yes	yes
Field verification of polygons	yes	minimal	no	no	no
Air photo interpretation	new, detailed	new and pre-existing	as required	minimal	none
Water well data	yes	yes	yes	no	no
Use of existing geotech. data	yes	yes	minimal	no	no
Drilling and/or trenching	yes	minimal	no	no	no
New laboratory tests	yes	minimal	no	no	no
Literature research	detailed studies included	detailed studies included	regional studies	basic to regional studies	minimal
Verification of agg. pit locations	yes	yes	yes	minimal	no
Geo. mapping of agg. pits	yes	yes	yes	minimal	no
Product reliability	very high	high	moderate	low	very low
Avg. cost / map sheet	\$100,000 to \$1,000,000	\$50,000 to \$100,000	\$10,000 to \$50,000	\$5,000 to \$15,000	\$1,000 to \$10,000
Suitability of maps	site construction purposes	city planning to municipal planning	municipal to regional planning	broad, regional planning	provincial planning

Given this study represents a reconnaissance level mapping project (Level IV), the methodology is relatively simple. The primary objective of this investigation is to identify those landforms (polygons) most likely to host accumulations of sand and gravel at a scale of 1:100,000 and classify those polygons as high, moderate, or low for aggregate potential. This was achieved using a three phase process consisting of: a) air photograph interpretation, b) literature and data compilation, and c) a polygon-by-polygon assessment of the landforms.

The air photograph interpretation was completed using either 1:60 000 or 1:70 000 scale photos depending on the availability of coverage. This information was then transferred to 1:50,000 scale map sheets, which were then digitized to a 1:100,000 scale base projection.

Polygons were only established around those landforms, which were likely to contain a significant accumulation of sand and gravel. This would include, but is not restricted to glaciofluvial, fluvial, colluvial, or notable isolated morainal or marine deposits. Excluded landforms where extensive morainal and marine blankets.

A number of sources provided information to better assess the selected polygons. Data were acquired from published reports, Ministry of Energy and Mines (MEM) assessment reports, the MEM aggregate pit database, unpublished MoTH reconnaissance mapping, MoTH geotechnical reports, and water-well drill logs. Information was generally limited, as populated areas are not common and little aggregate or geotechnical work has been done within this LRMP. This information provided the framework for selecting and assessing individual polygons.

Table 3. General scores applied to the surficial material and landforms classified in the North Coast LRMP Aggregate Potential Map. Fluvial and glaciofluvial material is the most desirable material and, therefore, receives a high score, in contrast to morainal or organic material which has limited aggregate potential and receives a lower score.

Score	**3**	**2**	**1**
Surficial Material and landform	Fluvial Plain	Marine Ridge (High Energy Beach)	Morainal Ridge
	Fluvial Fan	Colluvial Cone	Marine Plain
	Fluvial Terrace	Colluvial Fan	Marine Blanket
	Glaciofluvial Plain		Marine Terrace
	Glaciofluvial Terrace		Organic Blanket
	Glaciofluvial Fan		Organic Plain

The final step in the process, once the polygons had been identified, was to assess the aggregate potential of polygons as high, moderate, or low potential. This was accomplished by applying a "numeric value" to the surficial material and landform that each polygon would likely represent. The scores are summarized in Table 3. Those polygons containing more than one surficial material and/or landform, received scores that reflect either the dominant material, or a value estimated to represent the combine relative aggregate potential of the polygon. If it was possible to establish a fine-grained texture for the polygon (e.g. estuaries), then the polygon would automatically will receive a low rank.

RESULTS

A total of 920 polygons were established ranging in size from 0.4 to 1083.6 hectares. Of these, 260 (28.3%) of the polygons were ranked high, 371 (40.3%) were ranked moderate and 289 (31.4%) were ranked low for aggregate potential. Some 517 ARIS drill logs were evaluated, to provide an estimate of the thickness of the sediment cover (depth to bedrock). In addition, 36 water wells and geotechnical well logs were used; these contain detailed information with respect to thickness and texture of the sedimentary units drilled. Little aggregate extraction activity occurs in the study area, however, 14 notices of work for aggregate operations are on record with the British Columbia Mines Branch (Smithers). Two of these operations (Hastings Arm and Marcus Passage) are dredge locations and plot along water ways.

Because this study covers such a large area, specific descriptions are provided in groups corresponding to the appropriate 1:50,000 NTS map sheets. This general summary reviews those polygons considered significant for hosting aggregate and guides the user through the mapped sections (refer to Figure 1 for 1:50,000 NTS map locations).

<u>103O/16 & 103/P13</u>

The head of the Portland Canal is in the vicinity of the Cambria Ice fields and is dominated by modern glacial processes. Much of the alpine is covered by glacial ice with the highest peaks emerging as nunataks. Surficial sediments are discontinuous and restricted to the lower elevations, and are clearly related to the retreat of the ice fronts. The only materials of significance are the small glaciofluvial and fluvial deposit (fans and plains) found in valleys near the Portland Canal. Moderate deposits of moraine occur in some valleys and cirques, although the economic value is likely minimal due to inaccessibility, and poor quality. Colluvial cones and fans cover many of the lower slopes of the valley wall. The cones result form erosion and collapse of the over-steepened valley walls.

103O/9, 103P/12, & 103P/11

Farther south, ice fields diminish and more of the terrain is exposed. Minor fluvial fan deposits can be found to the west near Portland Canal, particularly where larger creeks empty into the fjord. To the east, three valleys suggest potential to host significant grade and/or quantities of material. These include the Sutton, Kshwan, and Kitsault river valleys. The valleys trend north-south and are fed by melt water from retreating glaciers. The Sutton and Kshwan rivers have developed a valley sandur extending from the river mouth at the head of Hastings Arm, to approximately 7 km to the north at the confluence of the two rivers. From this point, incised glaciofluvial terraces and braided modern fluvial sediments occur to the ice fronts. The Kitsault River also drains a modern glacier and glaciofluvial and fluvial silt, sand and gravel occupy the valley bottom from Homestake Creek to the delta at the head of Alice Arm. The two sandurs show the highest potential for aggregate in this region of the study area.

103P/5, & 103P/6

As with the previous map sheets, the terrain in these sheets is the result of glacial processes with little suitable aggregate still remaining. On the coastal areas, small fans and cones prograde into the fjords, however, development of significant deltas is hindered by the small sediment discharge and deep water. Many of the valleys have well-developed colluvial cones which cover the valley floors, hence fluvial sediments in the valleys appear to be rare or covered by the colluvium. The head of Alice Arm contains abundant sediment, which is present as a result of the progradation of a large delta, and the coalescing of a number of fluvial fans. At the distal end of the exposed delta, sediments are likely fine-grained and muddy with considerable organics. Marine processes also presently influence this material, which is likely to diminish the potential quality of the aggregate.

103O/1, & 103P/4

There is very little aggregate potential in these two map sheets, with the exception of the small glaciofluvial deposits on the Kincolith (Mission Valley) and Ikouk rivers near the mouth of the Nass River. The Nass Valley contains significant quantities of aggregate, although at the surface, sediments are likely to be fine-grained consisting primarily of overbank silt and mud. Nass River sediments include stranded glaciofluvial deltas and terraces, in addition to modern fluvial gravel, however, the bulk of the valley lies outside the study area boundary. A thick terrace at the south end of Greenville Creek may contain favorable material and is proposed a target of further investigation.

103J/16, 103J/15, & 103I/13

On the west side of the map sheets, lies Pearse Island, which is essentially devoid of any sediment accumulation. The lowest elevations were likely submerged during the last glaciation, hence a veneer of marine sediments drapes the bedrock. To the east, four locations contain significant sediment accumulations, the Iskheenickh River floodplain, Chambers Creek, Kwinamass River, and Lachballach Lake. The Iskeenickh River floodplain is generally of poor quality as it is dominated by fine-grained material and organics. However, some of the terraces and deltaic areas may consist of coarser sediment, therefore, this large floodplain is recognized as a target for further investigation. Sediment from Chambers Creek has accumulated in a depression between the Mylor Peninsula and the mainland, separating Iceberg Bay and Nasoga Gulf. The material here is likely a combination of fluvial material capped by stranded marine terraces. Though the area has been designated low potential, more desirable material may be present at depth. The Kwinamass River is generally of poor quality due to fine-grained sediments and considerable organics, however, some of the modern terraces and fluvial deposits away from the marine influence may host aggregate reserves. Finally, the Lachballach Lake fen generally has little or no aggregate potential, as it is almost exclusively organics, silts and clays. There is some evidence of kame terraces on the east end of the fen (outside the study area) and could prove to have some limited aggregate value.

103J/9 & 103I/12

Generally, most of the area consists of steep, rugged, extensively cirqued mountains and glaciated valleys. Surficial deposits are rare, and occur mostly as colluvial cones in the valley bottoms. Such cones may cover fluvial or morainal deposits, however, due to the volume of material and the frequency of the cones, accessing the underlying material is unlikely to be economically viable. Tsimpsean Peninsula and the neighboring islands are covered by marine deposits at elevations below approximately 150 m (~500ft). This material is unlikely to have a significant aggregate potential as it appears in air photographs to be predominantly mud and sand. Terraces and the alluvial plains at the head of Khutzeymateen Inlet may host sand and gravel, particularly near the confluence of the Khutzeymateen and Kateen rivers. Another area of interest is the fluvial deposit along the Exchamsiks River, although the economic value is questionable, given that they are both small and inaccessible.

103J/8 & 103I/5

A detailed study of the Kitimat, Terrace and Prince Rupert corridor was conducted by Clague and Hicock (1976). They identified the Skeena River Valley as a particularly important source of aggregate. During deglaciation, the lower Skeena River Valley was inundated by marine waters, and large deltaic deposits formed where sediment laden meltwater emptied into the marine environments. In addition to these glaciofluvial deltas, extensive sand and gravel deposits of unknown thickness underlie the floodplains of the major rivers. Unfortunately, the bulk of the desirable deposits lie outside the study. The area near Prince Rupert is considered to have no sand and gravel deposits of any significance (Clague and Hicock, 1976). Peat overlies bedrock throughout much of the Prince Rupert region, and marine sediments deposited after ice retreat are common. Historic gravel operations have been opened in small accumulations of till, outwash, raised beach deposits, and in colluvium. However, not only are the pits are small, the material mined is considered difficult to work and of low quality. In the past, aggregate has been dredged from the sea-floor west of the city and may be an alternative source if environmental impact is minimized.

103J/1, 103J/4 & 103I/3

The coastal islands on the west side of the map sheets were likely submerged during the glacial maximum, therefore a veneer of marine sediments covers most elevations below 150 m. Many glacially carved valleys are now exposed to marine settings, and those with elevations below the glacial marine limit contain substantial organic deposits (a result of the accumulation of clay, silt and fine sand). Fluvial deposits do occur at the mouth of McNeil Creek, as well as Khyex, Lachmarch, and Scotia rivers. However, these deposits are likely fine-grained (resulting in visibly poor drainage) and overlie marine sediments. The east side of the map sheets is generally rugged with high elevations and mountainous terrain, and limited aggregate potential. Despite this, two locations may contain some usable aggregate. The confluence of Magar Creek and the Gitnadoix River contains a braided fluvial plain, which may be usable but limited in its access. Similarly, though much smaller, is an outwash plain near the head of Gilloyees Creek.

103G/15, 103G/16, 103H/13 & 103H/14

The islands on the outer coast are also draped with marine sediments, although the unprotected beaches on the seaward side may host beach sand and gravel, reworked and washed by wave action. Examples of these deposits are located on the west side of the Porcher Penninsula and Goshen Island and are marked as moderate potential. The inner coast (Ogden Channel, Kitkatla Channel, north Greenville Channel, etc.) have little aggregate potential as surficial sediments here are thin, absent, fine-grained (marine) or organic. The most promising area for aggregate occurs within the fluvial terraces and bars of the lower Ecstall River, particularly towards the mouth of the river. Overbank sediments, or tidal influence may have deposited finer material on the surface of the fluvial material, however, these landforms do warrant some further consideration. Farther inland, organic deposits progressively dominate overlying fluvial plains or terraces; reflecting poor drainage as a result of finer sediments. The upper Ecstall River consists primarily of colluvial cones with marshes and bogs. The fluvial deposits along the lower Golttoyees Creek may also be of some interest, as the deposit is relatively accessible by water at the head of Golttoyees Inlet.

103G/10, 103G/9, 103H/10, 103H/11 & 103H/12

North Banks Island and McCauley Island are devoid of any significant aggregate deposits. Some of the bays and small inlets may have minor accumulations of modern marine sediments, although most of these appear to be fine-grained and unlikely to be of any value. Topography changes from relatively flat lowlands on the outer west coast islands to higher relief with glaciated and cirqued valleys on the east side of Pit Island. Despite the change in relief, the mountains in the Kitimat Range have been over-topped with ice and are distinctly more rounded than the peaks to the north (Boundary Range) (Holland, 1976). Here, the valley bottoms are occupied by lakes, fjords, and marine inlets. Little of the terrain around Greenville Channel contains aggregate deposits of any significance, although colluvial fans and cones are common on the lower slopes of the over-steepened valleys. Quail River is the only notable exception, where a large floodplain has developed south of Ecstall Lake towards Douglas Channel. The floodplain has been marked as low potential due to significant accumulations of organics and fine-grained sediments. This floodplain does, however, show a multitude of fluvial terraces, and outwash morphology, and further investigation may reveal a more favorable material within the terraces or at depth.

103G/8, 103H/5, 103H/6, 103H/7 & 103H/8

Again, the outer coastal islands have limited or no significant aggregate deposits and sediment accumulations are likely fine-grained marine deposits related isostatic depression from glacial loading. Notable aggregate accumulations begin to appear east of Ursula Channel where fluvial deposits occur at Ochwe Bay, Goat Harbour, upper Triumph River, along sections of an unnamed creek north of Aaltanhash River, and south of Alan Reach in Gardener Channel (103H/7). Sections along the Kiltuish River may host desirable fluvial material as well as a promising glaciofluvial terrace, which lies approximately seven kilometres from the mouth of the river at Kiltuish Inlet.

103H/4, 103H/3, 103A/13, 103A/15 & 103A/11

The islands in the southern region of the study area have no significant aggregate potential. Therefore, exploration for this resource should focus to the north, particularly where higher relief has prevented the land from being submerged during deglaciation.

CONCLUSION

The North Coast LRMP Aggregate Potential Map provides a mechanism for identifying target areas for further aggregate investigation. In general, there is limited aggregate potential within the North Coast LRMP, as access and availability of material is relatively restricted. However, a number of possible aggregate locations were identified in this project that, with further investigation, may prove to be economic for either local use or export. Almost all locations will have to rely on transportation by water, as the existing road network infrastructure does not extend beyond Prince Rupert and the Skeena River corridor.

Landforms (polygons) of interest are primarily of a fluvial or glaciofluvial origin with those nearest to the coast being of higher priority due to better access. Such deposits are more common in the northern region of the study area, particularly near larger creeks and rivers that originate at glacial termini or in the high alpine.

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REFERENECES

Bobrowsky, P.T., Massey, N.W.D., and Matysek, P.F. (1996): Aggregate Forum, developing an inventory that works for you! Report proceedings March 30-31, 1995; *BC Ministry of Energy Mines and Petroleum Resources*, Information Circular 1996-6.

Buchanan, R.G. (1979): Highway 16 - Ridley Island aggregate resource study*; BC Ministry of Transport, Communications and Highways*, Geotechnical and Materials Branch.

Clague, J.J. and Hicock, S.R. (1976): Sand and Gravel Resources of Kitimat, Terrace, and Prince Rupert, British Columbia; *Geological Survey of Canada*, Paper 76-1A.

Clague, J.J. (1984): Quaternary Geology and Geomorphology, Smithers-Terrace-Prince Rupert area, British Columbia; *Geological Survey of Canada*, Memoir 413, 71 pages.

Clague, J.J. (1985): Deglaciation of the Prince Rupert-Kitimat area, British Columbia; *Canadian Journal of Earth Science*, 22, pp. 256-265.

Clague, J.J. (1986): The Quaternary stratigraphic Record of British Columbia-Evidence for Episodic sedimentation and erosion controlled by Glaciation*; Canadian Journal of Earth Sciences*, volume 23, pp. 885-894.

Davis, N.F.G. and Mathews, W.H. (1944): Four Phases of Glaciation with illustrations from southwestern British Columbia; *Journal of Geology*, volume 52, pp. 403-413.

Edwards, W.A.D., Hudson, R.B., and Scafe, D.W. (1985): Aggregate Resources of the Edmonton/Lloydminster Region; Alberta Research Council, Natural Resource Div. *Alberta Geological Survey*, Bulletin No. 47.

Holland, S.S. (1976): Landforms of British Columbia a physiographic outline*; BC Department of Mines and Petroleum Resources*, Bulletin 48.

Langer, W.H. and Glanzman, V.M. (1993): Natural aggregate building America’s future; Public Issue in Earth Science, *US Geological Survey*, Circular 1110.

MacIntyre, D., Ash, C., and Britton, J. (1994): Geological compilation Skeena-Nass area west central British Columbia*; BC Ministry of Energy, Mines and Petroleum Resources*, Open File 1994-14.

McCuaig, S.J. (1997): Quaternary geology of the Nass River region, British Columbia; Current Research 1997-A, *Geological Survey of Canada*, pp. 183-189.

McCuaig, S.J. and Roberts, M.C. (1999): Surficial geology drilling results, Nass Valley, British Columbia; Current Research 1999-A, *Geological Survey of Canada*, pp. 25-34.

Appendix A

Summary and description of bedrock units present in the North Coast LRMP Aggregate Potential Map area.

Symbol	Association	Sub-Association	Description
lJAr	Alexander Terrane		Moffat rhyolite, light grey to white metarhyolite or rhyodacite, generally with well developed strongly contorted flow banding and breccia composed of angular lapilli to block sized rhyolite clasts (103J).
OTrAgb	Alexander Terrane		Gabbro sills and dykes, considered to be the plutonic phase of OTrAv; includes mafic plutonic rocks on Dundas Island.
OTrAl	Alexander Terrane		Limestone and marble; coarsely crystalline, massive, grey and greyish buff weathering, in general thickly bedded.
OTrAs	Alexander Terrane		Light to dark green phyllite composed mainly of chlorite, sericite, albitic plagioclase and minor epidote; elongated, flattened clasts of green volcanic rock common; locally the unit is intercalated with beds of stretched pebble conglomerate.
OTrAsa	Alexander Terrane		Metasedimentary rocks of predominantly amphibolite facies: includes siltstone, mudstone, shale, mafic and felsic volcanics, limestone, quartzite and conglomerate.
OTrAsg	Alexander Terrane		Metasedimentary rocks of predominantly greenschist facies; includes clack to dark grey graphitic schist, intercalated pale and dark schists and intercalated chlorite and sericite schist.
OTrAsq	Alexander Terrane		Thin to thickly bedded impure to micaceous quartzite with thinner interlayers which may include crystalline limestone, skarn, garnet-biotite schist and quartz-feldspar biotite schist. Locally limestone interbeds are dominant.
OTrAv	Alexander Terrane		Volcanic rocks; weakly metamorphosed; includes tuff, agglomerate and volcanic breccia, rhyolite tuffs and flows, chlorite schist and greenstone; also includes mappable intercalations of both OTrAs and OTrAl
uJKB	Bowser Lake Group	Undivided	Interbedded epiclastic feldspathic and volcanic conglomerate, sandstone, siltstone, shale and argillite; minor coal

			and carbonaceous units (93M, 103P, 94D).
DCdg	Coast Plutonic Belt	Delta River Pluton/ Swede Point Pluton	Mylonitic granodiorite
DCg	Coast Plutonic Belt	Delta River Pluton/ Swede Point Pluton	Granite
DCgb	Coast Plutonic Belt	Delta River Pluton/ Swede Point Pluton	Gabbro
Eg	Coast Plutonic Belt	Coast Plutonic Complex, Great Glacier Pluton, Hyder Plutonic Suite	Granitoid batholith and stocks. Medium to coarse grained
Egn	Coast Plutonic Belt	Coast Plutonic Complex	Gneissic rocks of the Coast plutonic Complex (103P)
EJFo	Coast Plutonic Belt	Foch Lake Body	Weakly to strongly foliated medium-grained epidote-bearing, biotite +/- hornblende tonalite orthogneiss.
EJJo	Coast Plutonic Belt	Johnson Lake Body	Weakly to strongly foliated medium-grained epidote-bearing, biotite +/- hornblende tonalite orthogneiss.
EKd	Coast Plutonic Belt	McCauley Island Pluton	Diorite
EKdn	Coast Plutonic Belt	McCauley Island Pluton	Mainly foliated meta-diorite.
EKgb	Coast Plutonic Belt		Mainly gabbro
EKgbdn	Coast Plutonic Belt		Mainly foliated meta-diorite and gabbro.
EKgd	Coast Plutonic Belt	McCauley Island Pluton	Medium to coarse-grained, massive, isotropic to weakly foliated, hornblende-biotite granodiorite.
EKqd	Coast Plutonic Belt	McCauley Island Pluton	Quartz diorite
EKqm	Coast Plutonic Belt	McCauley Island Pluton	Quartz monzonite.
Eqm	Coast Plutonic Belt	Erin Stock, Bitter Creek Stock, Hyder Batholith, Lee Brant Stock	Granodiorite to quartz monzonite.
ETg	Coast Plutonic Belt	Strohn Creek Pluton, Mt. Bolom, Ear Lake Pluton	Massive medium grained hornblende-biotite monzogranite with very coarse fK-feldspar phenocrysts; grey to pink porphyritic to equigranular granodiorite, quartz monzonite, granite.
ETgd	Coast Plutonic Belt		Mainly granodiorite.
ETqd	Coast Plutonic Belt		Mainly quartz diorite.
ETqm	Coast Plutonic Belt		Quartz monzonite, quartz-eye porphyry and felsite. Equivalent to Kastberg Intrusion.
JKd	Coast Plutonic Belt	Poison Pluton	Leucocratic biotite-hornblende quartz diorite or gabbro. Greenschist facies diorite-tonalite complexes with lesser metavolcanic rocks unfoliated to weakly foliated.
JKqd	Coast Plutonic Belt		Quartz diorite, tonalite, brittle to ductile deformation commonly intensively to

			weakly foliated.
JKum	Coast Plutonic Belt	Mafic-Ultramafic Complex	Coarse-grained, locally weakly lineated hornblende diorite and gabbro and associated rusty weathering coarse hornblendite; contains xenoliths of foliated country rock, possible Alaskan-type affinity.
KTd	Coast Plutonic Belt		Diorite, gabbro, microdiorite, syenodiorite, partly equivalent to Kasalka intrusions.
Ktgd	Coast Plutonic Belt	Quottoon Pluton	Granodiorite.
KTqd	Coast Plutonic Belt	Quottoon Pluton	Quartz diorite .
LKgd	Coast Plutonic Belt		Mainly granodiorite.
LKqm	Coast Plutonic Belt		Mainly quartz monzonite
MJd	Coast Plutonic Belt	Three Sisters Plutonic Suit/Mount Choquette Pluton	Medium to coarse-grained gabbro, diorite and syenite; hornblende diorite, locally with bladed plagioclase porphyry phases.
MJqd	Coast Plutonic Belt		Mainly quartz diorite.
MKd	Coast Plutonic Belt	Ecstall Belt	Diorite
MKdk	Coast Plutonic Belt		Dyke complex of garnet aplite and leucocratic pegmatite; fine grained leucocratic garnet biotite quartz monzonite and granodiorite, titanite-epidote-biotite quartz diorite and amphibolite.
MKdn	Coast Plutonic Belt		Lineated and foliated gneissic metadiorite.
MKg	Coast Plutonic Belt	Ecstall Belt	Granite
MKgb	Coast Plutonic Belt	Axelgold Intrusion	Layered gabbro and minor plugs of gabbro and diabase.
MKgd	Coast Plutonic Belt	Ecstall Belt	Unfoliated to strongly foliated quartz diorite
MKqd	Coast Plutonic Belt		Quartz diorite, granodiorite, leuco-granodirite, minor granite; includes Johanson Creek stock, Kliyul Creek pluton, Fleet Peak stock, stock west of Hogem batholith.
MKqm	Coast Plutonic Belt	Ecstall Belt	Quartz monzonite
MLJd	Coast Plutonic Belt		Diorite.
MLJdn	Coast Plutonic Belt		Metadiorite.
MLJgd	Coast Plutonic Belt	Banks Island Belt	Granodiorite.
MLJqd	Coast Plutonic Belt	Banks Island Belt	Medium to coarse-grained, unfoliated to well foliated quartz diorite.
MLJqm	Coast Plutonic Belt	Banks Island Belt	Quartz monzonite.
MLTrdn	Coast Plutonic Belt	Captain Cove Pluton	Weakly foliated massive with a well-developed foliation near their margin.
MLTrqd	Coast Plutonic Belt	Captain Cove Pluton	Medium- to coarse-grained hornblende biotite quartz diorite.
MLTrqm	Coast Plutonic Belt	Captain Cove Pluton	Quartz monzonite.
PPn	Coast Plutonic Belt	Nisling Terrane??	Layered gneiss; epidote-hornblend-biotite quartz diorite and granodiorite gneiss and garnet amphibolite; some epidote +/- garnet pods; medium

			grained; well defined compositional layering on a scale of tens of cm; strongly foliated and locally lineated.
PPsc	Coast Plutonic Belt	Nisling Terrane??	Metasedimentary rocks; locally clastic, epidote rich, hornblende-biotite gneiss; fine to medium grained; locally contains epidote-rich and granitoid clasts; well developed foliation and lineation
PPsq	Coast Plutonic Belt	Nisling Terrane??	Quartzite unit: white to grey, locally pyritic quartzite interlayered with lesser amounts of biotite-hornblende gneiss, fissile mica schist, black phyllite to meta-argillite, semipellitic schist; minor amphibolite bands, probably dikes; well foliated.
PPv	Coast Plutonic Belt	Nisling Terrane??	Mafic and intermediate metavolcanics, minor metasedimentary and felsic metavolcanic layers, locally pyritic, strongly foliated, fine grained amphibolite +/- chlorite schist.
PTCa	Coast Plutonic Belt	Central Gneiss Complex	Amphibolite, varies from coarse-grained amphibolite to amphibolite gneiss commonly gradational into well foliated diorite (103J/I)
PTCb	Coast Plutonic Belt	Central Gneiss Complex	Grey biotite +/- hornblende gneiss; dark grey layered amphibolite, minor sillimanite +/- garnet gneiss (103J/I)
PTCg	Coast Plutonic Belt	Central Gneiss Complex	Granitoid gneiss, gneissic quartz diorite, rusty fine-grained gneiss and schist, migmatite; minor garnet-sillimanite-biotite schist, crystalline limestone, dioposidic skarn, garnet-staurolite-kyanite schist (103I/J)
PTClg	Coast Plutonic Belt	Central Gneiss Complex	Buff-grey leucongneiss and migmatite (103J/I)
PTCm	Coast Plutonic Belt	Central Gneiss Complex	Marble, calcsilicate rock
JKG	Gravina Assemblage		Marine argillite and greywake: interbedded andesitic to basaltic volcanic and volcanoclastic rocks, metamorphosed to amphibolite grade; depositionally overlies Alexander Terrane rocks (103I/J).
JH	Hazelton Group	Undivided	Calcalkaline volcanics, mainly andesite and dacite pyroclastics, flows and derived volcaniclastic sedimentary rocks.
lJHB	Hazelton Group	Betty CreeK Formation	Hetrogeneous, purple, maroon, grey and green massive to bedded pyroclastic and sedimentary rocks.
lJHs	Hazelton Group	Sedimentary Unit	Black siltstone, limestone, green and purple volcanic breccia, sandstone, polymictic conglomerate.

lJHu	Hazelton Group	Unuk River Formation	Green and grey intermediate tuffs and flows (feldspar +/- hornblende porphyritic) with locally thick interbeds of fine-grained immature sedimentary rocks; minor conglomerate and limestone.
lJHvf	Hazelton Group	Epiclastic and Felsic Volcanic Unit	Maroon and green volcanic conglomerate, breccia and minor sandstone; black siltstone, argillite, wacke and limestone; dacite pyroclastic rocks and feldspr-porphyritic flows.
lJHvi	Hazelton Group	Intermediate volcanic Unit	Green and maroon andesitic pyroclastic rocks; feldspar +/- hornblende andesite porphyry; maroon siltstone, sandstone and conglomerate; minor limestone.
lmJHpv	Hazelton Group		Pillow basalt and thinly bedded black and white siliceous tuff; pillow lava, broken pillow breccia; andesitic and basaltic flows; mainly pillow lava, pillow breccia, minor mudstone.
lmJHs	Hazelton Group	Smithers Formation	Marine, shallow-water feldspathic sandstone, siltstone, argillite, greywacke; local glauconite and limy; minor ash, crystal and lapilli tuff, volcanic breccia, volcanic-pebble conglomerate, limestone; very fossiliferous.
TrK	Karmutsen Group		Fresh, dark grey, massive pillow basalt with epidote and quartz filled vugs and stringers.
Qvb	Quaternary		Basalt; flow, breccia, plugs and dikes (94D); basaltic flows tuff, scoria, olivine, and plagioclase porphyritic (103P).
uTrSs	Stuhini Group		Thick, poorly bedded augite-bearing volcanic tuffaceous sandstone, common sharpstone conglomerate; black siltstone, argillite, shale, black wacke, sandstone, limestone.
uTrSvm	Stuhini Group		Mainly mafic volcanic rocks; olivine and augite porphyry basalt flows, pillow volcanics and breccias, minor siltstone, wacke and limestone.
Jgn			Gneiss, minor hornfels; possibly an alteration zone
JKqd			Quartz diorite, tonalite, brittle to ductile deformation commonly intensely to weakly foliated (103I E1/2).
Jph			Phyllite, schist, semischist; possibly an alteration zone