AGGREGATE POTENTIAL MAPPING ON THE SEA-TO-SKY HIGHWAY, BRITISH COLUMBIA

By A.S. Hickin[1], E.D. Brooks, and P.T. Bobrowsky, British Columbia Geological Survey Branch, Victoria, BC, Canada

INTRODUCTION

Aggregate is defined as naturally occurring hard construction material, such as sand, gravel, crushed stone or slag, which can be mixed with cementing material to form concrete and asphalt or can be used alone 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; it has become a major contributor to the economy of most communities.

Globally, the aggregate sector has experienced ever-increasing pressure to manage this resource properly in response to accelerated urbanization, which is marked by increased consumption. Municipal expansion, alternate land uses, land sterilization, and public concern are just some of the factors that have impacted the availability of many traditional aggregate sources. Factors like this, and the cost added by increased transportation distances, has created concern about the ability of the aggregate industry to meet future demand. The Aggregate Advisory Panel held in 2001 evidences this concern in the province of British Columbia, where initiatives like the Sea-to-Sky Aggregate Potential Map Project provide the first step toward ensuring sustainable development of aggregate resources in British Columbia. The methodology used in this study provides a means for planners to efficiently manage land areas with aggregate resources that may be vital to the development and maintenance of municipalities and their infrastructure.

Natural aggregate, such as sand and gravel, is the product of unique geological processes (Langer and Glanzman, 1993), thus potential aggregate deposits are generally restricted to areas where specific environments of deposition exist or once existed (Edwards, 1998). Understanding gained about the geological processes and environments has enabled aggregate geologists to predict qualitatively which landforms are most likely to contain aggregate (for example, Gartner *et al*., 1981). To improve estimates, statistical modeling can be used with landform data to provide quantitative predictions of aggregate volume and area (Bobrowsky and Manson, 1998). Unfortunately, we have not reached a stage where quantitative predictions of location, volume and quality of aggregate resources are possible.

The Sea-to-Sky region, north of Vancouver, is faced with competing land use options that range from development of scarce but economically important aggregate resources, to complete conservation and preservation of the natural resources. However, with continued growth of communities, such as the villages of Whistler and Pemberton and the city of Squamish, coupled with the successful bid for the 2010 Winter Olympics, pressure on the known local aggregate reserves will eventually reach a critical stage. To address these concerns, the Ministry of Energy and Mines, with funding assistance from the Corporate Resource Inventory Initiative (CRII), British Columbia Assets and Lands (BCAL), and Ministry of Transportation and Highways (MoTH), initiated a joint project to assess, at a reconnaissance level, the aggregate potential of the Sea-to-Sky corridor.

LOCATION

The study area is located in southwestern British Columbia, north of the city of Vancouver. The area is best described as a 10-kilometre wide corridor along the major transportation routes, delimited in the south by Daisy Lake and in the north by the head of the Lillooet River Valley near Salal Creek. In more detail, the first part of the corridor extends from Daisy Lake north to the Village of Pemberton, and includes Callaghan and Rutherford Creeks; at Pemberton the corridor divides to encompass the Upper Lillooet River Valley, as well as Birkenhead Lake and D'Arcy on the southern end of Anderson Lake. In total, the corridor covers portions of NTS 1:50,000 map sheets 92J/2, 92J/3, 92J/6, 92J/7, 92J/8, 92J/9, 92J/10, 92J/11, and 92J/12 (Figure 1). The communities of Whistler, Pemberton, Mt. Currie, and D'Arcy all fall within the study boundaries.

PHYSIOGRAPHY AND GLACIAL HISTORY

The study area is centred on the west coast of British Columbia some 40 kilometres north of Squamish (at the head of Howe Sound). This is part of the "Coast

[1] Current Location: Alberta Geological Survey, Edmonton, Alberta

Mountain" morphogeological belt (summarized in Gabrielse *et al*., 1991). Terrain is typified by high, rugged mountains and deep glaciated valleys. It includes the Coastal Western Hemlock, the Mountain Hemlock, and the Alpine Tundra biogeoclimatic zones, each differentiated by elevation (Meidinger and Pojar, 1991).

Most unconsolidated deposits in British Columbia owe their existence to the processes of glaciation and deglaciation. During the past few million years, the entire province has experienced a number of glacial and non-glacial cycles, and the most recent event, the Wisconsinan ca. 25 000 to 10 000 years before present (BP), had the greatest impact on aggregate accumulation and distribution.

As climate began to deteriorate some 25 000 years ago, ice that was previously restricted to high alpine regions gradually expanded. Valley glaciers advanced, eventually over-topping inter-valley ridges and coalescing

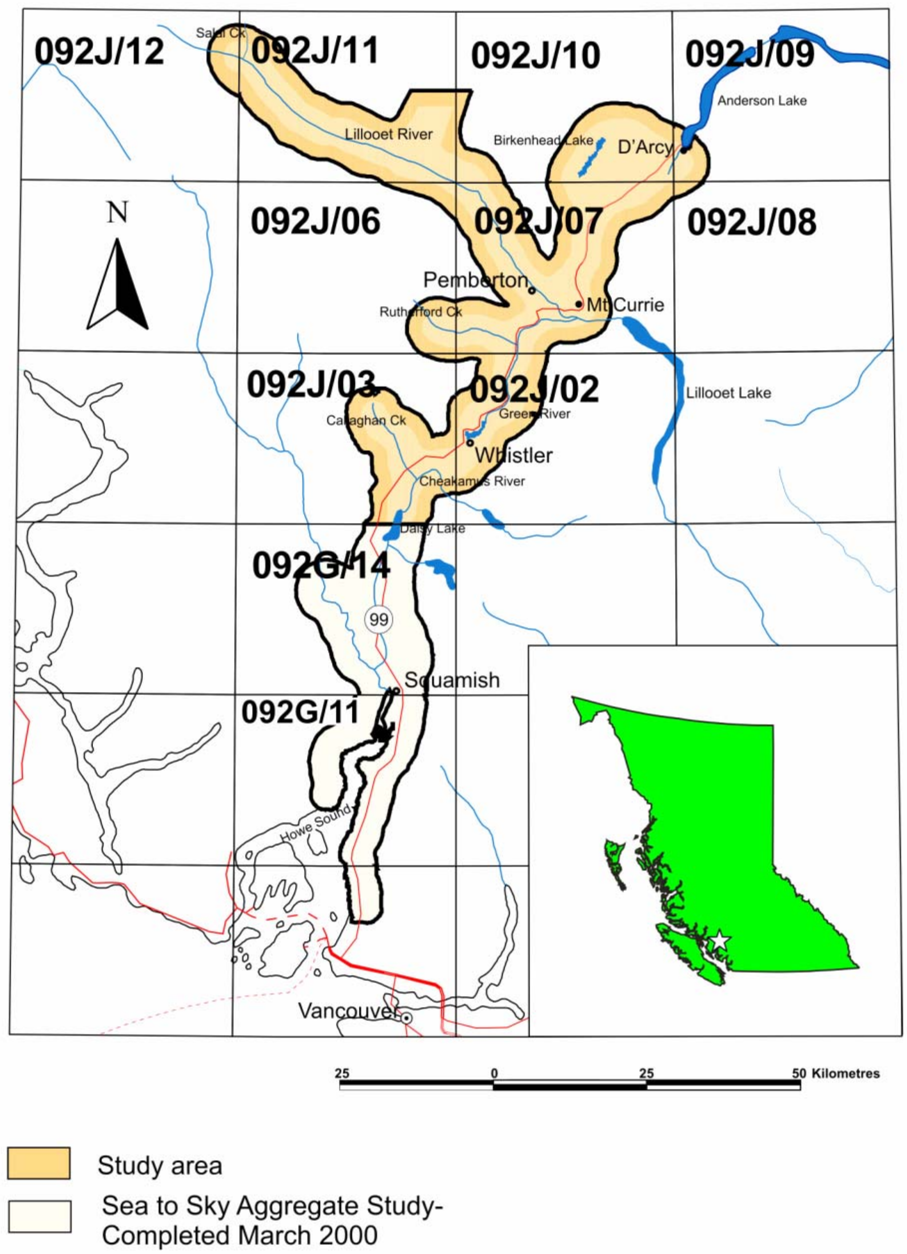

Figure 1. The Sea-to-Sky Aggregate Potential Map Project is located directly north of the City of Vancouver and includes the communities of Whistler, Pemberton, D'Arcy, and Mt. Currie.

to form small mountain ice sheets (Davis and Mathews, 1944). Subsequently, glaciers spread across the interior plateaus and coastal lowlands, covering most of the province and parts of the continental shelf, finally producing the Cordilleran Ice Sheet (Clague, 1986). Minimal effort has been directed toward resolving the chronology of Quaternary events in the study area, but deglaciation history can be inferred from work completed nearby at the head of Howe Sound and the Mamquam River Valley (Friele and Clague, personal communication, 2000). Apparently, by about 14 000 years BP glaciers had retreated from the Mamquam River Valley leaving it ice-free and forested. Deformed glaciolacustrine and diamicton deposits overlying unmodified glaciolacustrine sediments provide evidence for a glacial re-advance about 13 500 years BP. A dated submerged end moraine at Porteau Cove marks the maximum extent of the re-advance and also indicates that ice began to recede shortly after 12 800 years BP. By 11 800 yearrs BP, ice had retreated up the Squamish River Valley as far as the confluence of the Cheakamus River. It is likely that the main trunk glaciers in the Cheakamus, Pemberton, and Birkenhead Valleys continued to decay throughout the Holocene into the high alpine, where remnant ice bodies persist today.

OBJECTIVES

The Sea-to-Sky Aggregate Potential Map Project has four main objectives:

- Locate, compile and review all existing and readily available geological and geotechnical information housed within government, academia, and industry.
- Through fieldwork, identify and accurately record (using GPS and UTM grid references) the location of both currently and previously active sand, gravel, and crushed stone aggregate extraction operations.
- Generate a Level III Aggregate Potential Map at a scale of 1:50 000 using surficial landform polygons as a base-map in accordance with a methodology that most closely approximates provincial standards for this procedure (Bobrowsky *et al*., 1996).
- Create a multi-layered comprehensive digital map and interactive database in a GIS format (ARCVIEW) that is readily accessible by means of the Internet to government, industry, and the public.

METHODOLOGY

This study follows procedures and provincial standards established and detailed elsewhere (Bobrowsky *et al*., 1996). The process consists of data acquisition and compilation, fieldwork, and polygon ranking. Data from a number of sources was first identified, located, compiled and evaluated as part of producing an integrated interpretive map product. Geotechnical reports, surficial and bedrock geology maps and reports, water-well logs, drill reports, and consulting reports, were used to evaluate the surficial geology landform data (illustrated in polygon style). Sources of this information included various levels of government, crown corporations, municipalities, and industry.

The following layers of data were compiled for the Sea-To-Sky study:

- surficial materials (primary and secondary components of landform polygons in map form; 1:50,000 scale)
- texture of surficial materials (primary and secondary modifiers of landform polygon labels in map form; 1:50,000 scale)
- landform expression (primary and secondary modifiers of landform polygon labels in map form; 1:50,000 scale)
- quality (qualitative) and thickness (quantitative) of identified aggregate resources
- surficial unit polygon area (map form; 1:50,000 scale)
- bedrock geology (map form; 1:50,000 scale)
- presence/absence of aggregate operations
- overburden thickness (quantitative)

The base map used to classify aggregate potential relies on polygon data denoting surficial geology/terrain/landform information plotted in accordance with British Columbia provincial Resource Inventory Committee (RIC) standards. For the purposes of this study, a 1:50,000-scale terrain map was prepared from air photo interpretation of surficial landforms, materials, and textures following the mapping methodology of Howes and Kenk (1997) and RIC (1996). This information was then digitized according to RIC (1997) digital standards. Finally, all the polygonal data was analyzed on a polygon-by-polygon basis for aggregate potential. Individual parameters were scored from 0 (low importance) to 5 (high importance) for data within each polygon. Final ranking for individual polygons was achieved in a 3-step process. First, undesirable polygons, such as those containing water and ice, were eliminated from the final polygon rankings. The second step was to generate a weighted algorithm, which includes at varying levels of importance, all the individual parameters for each polygon. Because some parameters are considered more important with regards to aggregate potential than others, these are given a weighting factor that increases their influence in the final value scored by the polygon. The following algorithm was used to evaluate polygons in this study:

Total Polygon Value = 3(Primary Surficial Material Rank) + 3(Secondary Surficial Material Rank) + 2(Quality A Rank) + 2(Primary Texture Rank) + 2(Overburden Rank) + (Secondary Texture Rank) + (Primary Landform Expression Rank) + (Secondary Landform Expression Rank) + (Minimum Thickness Rank) + (Maximum Polygon Rank) + (Thickness Rank) + (Quality B Rank) + (Quality C Rank) + (Area Rank) + (Bedrock Rank).

For a definition of the algorithm terms, weighting logic and details of the calculations, see Hickin *et al.* (2001). In addition, polygons that host current or historic extraction operations (that is, pits) were further evaluated. Pits were assessed to show their potential for further aggregate production, which generated another layer of data that designated a production potential rank to the host polygon. A rank of 1 indicates a high potential, 2 a moderate potential, and 3 a low potential. High potential was assigned to any active commercial pit with additional reserves. A moderate potential was applied to smaller commercial operations, operations producing less desirable material, and/or operations with moderate reserves. Lastly, a low potential was assigned to inactive, non-commercial, borrow, and/or pits with limited or no reserves. A polygon with more than one operation would receive the highest pit rank to represent the potential of the polygon.

RESULTS

The study area consisted of 2289 polygons. From this total 111 represented water and ice and were removed from the algorithm. The remaining 2178 polygons generated final score values that range from 8 to 82. High values indicate high potential. Table 1 summarizes the classification and distribution of the ranked polygons. Figure 2 shows a portion of the final product, including primary, secondary, and tertiary polygons with drill holes, pits and pit potential. pits, and pit potential.

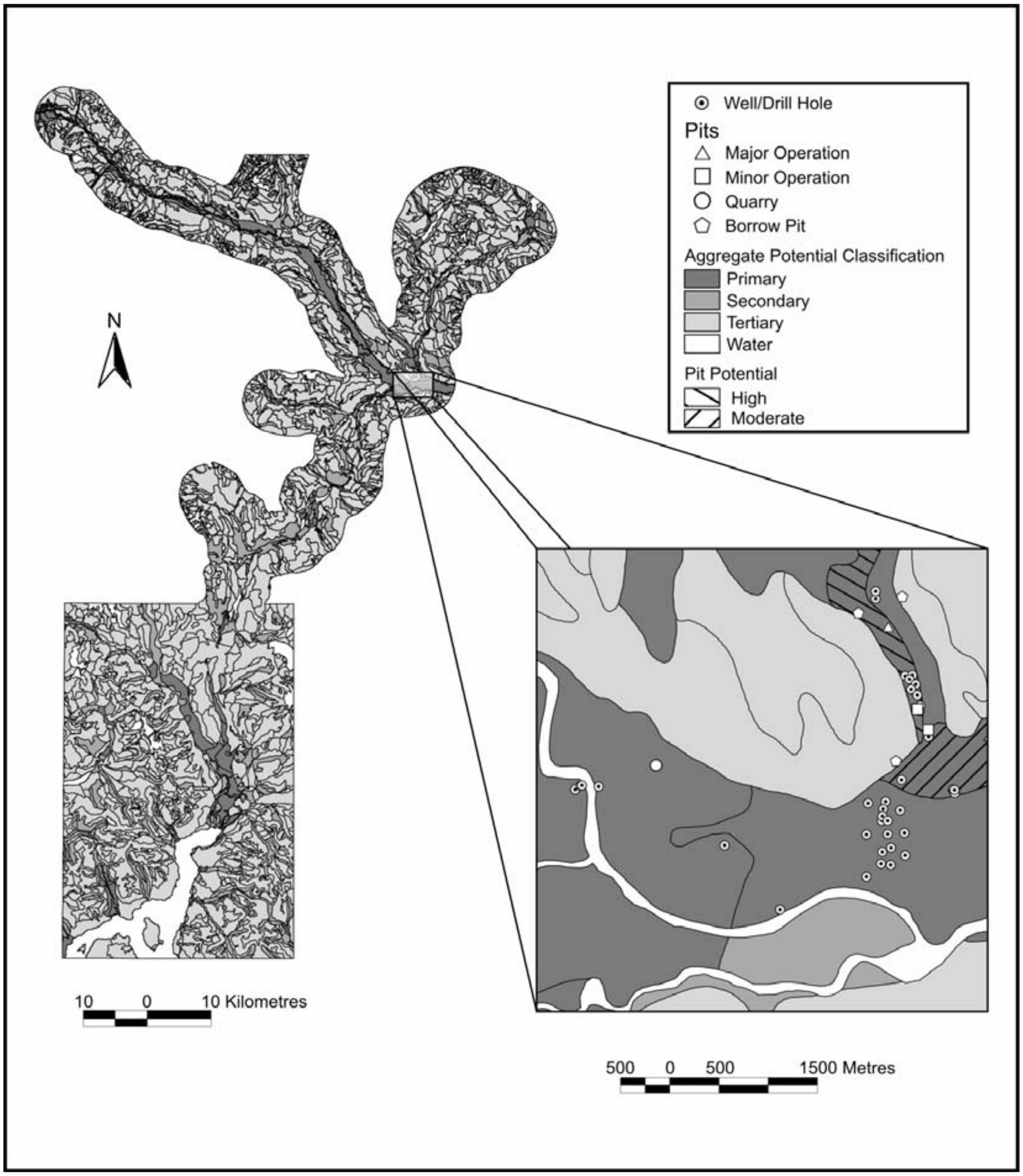

Figure 2. The final Sea-to-Sky Aggregate Potential map displays the distribution of the three polygon classes (primary, secondary, and tertiary). The insert is a magnified portion of the study area showing the additional information included in this project (Lillooet River, east of Pemberton). This information consists of drill hole and pit locations, as well as the pit potential for polygons hosting historic or active aggregate operations.

TABLE 1. SUMMARY OF THE DISTRIBUTION OF POLYGON CLASSES FOR THE SEA-TO-SKY AGGREGATE POTENTIAL MAP. CLASS WAS DETERMINED BASED ON THE AREAL DISTRIBUTION OF RANKED POLYGONS.

Class	Final Values	% of Polygons*	% of Map Area
Primary	≥50	7.0	5.8
Secondary	≥ 31 - <50	23.8	13.2
Tertiary	<31	69.9	75.2

*% of Polygons does not include polygons of ice or water.

CONCLUSIONS

Aggregate is often restricted to unique geologic settings which favour the deposition of sand and gravel. This is clearly evident by the distribution of primary aggregate potential polygons in this study. Almost without exception the most sought after material is located in the major valleys, particularly the upper Lillooet River, Birkenhead River, Squamish River and Pemberton, Valleys. This material is generally within glaciofluvial and fluvial deposits varying from moderately poor to well-sorted sand to boulder gravel. Current commercial operations are generally mining glaciofluvial and modern fluvial terraces along Highway 99 between Whistler and D'Arcy. Outside this corridor, land sterilization (agricultural land reserves) and hauling distance has restricted development. The present study exemplifies a global trend, which relies on GIS, multi-parameter data and fieldwork to generate maps of use to a wide range of user groups (see Kelly and Bobrowsky, 2001 for a review).

REFERENCES

Aggregate Advisory Panel (2001): Managing Aggregate, Cornerstone of the Economy; Report to the Minister of Energy and Mines, Province of British Columbia. Unpublished report, 48 pages. (available as downloadable pdf. file on the British Columbia Ministry of Energy and Mines website)

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; *British Columbia Ministry of Energy Mines and Petroleum Resources*, Information Circular 1996-6.

Bobrowsky, P.T. and Manson, G. (1998): Modeling sand and gravel deposits and aggregate resource potential, *In* P.T. Bobrowsky, Editor, Aggregate Resources: a global perspective, *A. A. Balkema Publishing*, Rotterdam, The Netherlands, pages 231-254.

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, pages 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, pages 403-413.

Edwards, W.A.D. (1998): The geology, exploration characteristics and resource potential of sand and gravel deposits in Alberta, Canada, *In* P.T. Bobrowsky, Editor, Aggregate Resources: a global perspective, *A. A. Balkema Publishing*, Rotterdam, The Netherlands, pages 101-112.

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.

Gabrielse, H., Monger, J.W.H., Wheeler, J.O., and Yorath, C.J. (1991): Part A. Morphogeological belts, tectonic assemblages, and terranes, *In* H. Gabrielse and C.J. Yorath, Editors. Chapter 2 of Geology of the Cordilleran Orogen in Canada, *Geological Survey of Canada*, Geology of Canada, no.4, pages 15-28 (*also in* Geological Society of America, The Geology of North America, Volume G-2).

Gartner, J.F., Mollard, J.D. and Roed, M.A. (1981): Ontario Engineering Geology Terrain Study Users' Manual; *Ontario Geological Survey*, Northern Ontario Engineering Geology Terrain Study 1, 51 pages.

Hickin, A.S., Brooks, E.D., and P.T. Bobrowsky (2001): Sea-to-Sky Aggregate Potential Map; *British Columbia Ministry of Energy and Mines*, Open File 2001-12.

Howes, D.E. and Kenk, E. (1997): Terrain classification system for British Columbia (revised edition); *British Columbia Ministry of Environment, Lands, and Parks*, Survey and Resource Mapping Branch, MOE Manual 10.

Kelly, R.I. and P.T. Bobrowsky (2001): Aggregate Potential Mapping, *In* P.T. Bobrowsky, Editor, Geoenvironmental Mapping: method, theory and practice, *A. A. Balkema Publishing*, Rotterdam, The Netherlands. (in press)

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

Meidinger, D. and Pojar, J. (1991): Ecosystems of British Columbia; *Ministry of Forests*, Special Report Series, No. 6.

Resource Inventory Committee (RIC) (1996): Guidelines and Standards to Terrain Mapping in British Columbia; Province of British Columbia, Publication #12.

Resource Inventory Committee (RIC) (1997): Standards for digital terrain data capture in British Columbia; Province of British Columbia.