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AGGREGATES FOR EXPORT

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ABSTRACT

This report describes an aggregate resource inventory conducted in the St. George's Bay area of western Newfoundland. The aim of the project was to map deposits of granular aggregate material for potential export markets. The area selected for study is adjacent to an ice-free coast, has the necessary infrastructure (wharf facilities and haulage road) and large volumes of granular material.

INTRODUCTION

Initial interest in aggregates for export came about from the results of a study entitled *Study of Markets for Aggregate Materials Accessible from Nova Scotia and New Brunswick,* prepared for Supply and Services Canada (ADI Limited, 1986). Market areas (accessible through the United States Atlantic seaboard) were evaluated from production records for sand and gravel and crushed stone. Maritime aggregate producers have a competitive advantage in production costs for most of the areas investigated, since aggregates are relatively low-cost bulk materials. Transportation can be a very significant proportion of the cost of the product delivered to the end user. A comparison of costs for different modes of transportation is shown in Table 1.

Table 1. Comparative aggregate transportation costs based on an annual volume of 500,000 tonnes per year (ADI Limited, 1986)

Origin	Destination	Truck	Rail	Marine
Saint John	Boston	$45.28	$32.87	$4.00
Mulgrave	Boston	$93.99	$40.44	$4.74

Aggregate resource field work in 1987 was conducted on a 1:50,000 scale in map areas 12B/7 and 12B/8. This is in the vicinity of the Duntar gypsum mine and extends northwest as far as Black Bank Provincial Park in western Newfoundland (Figure 1). This study area was chosen because of large quantities of granular aggregates and because of the shutdown of the gypsum mine in late 1987. With this shutdown a large amount of machinery was left idle, which could be utilized if a large scale aggregate operation begins. Another valuable asset in this area is a loading wharf capable of handling bulk carriers necessary for aggregate export. A 9-km-long haul-road leads from the mine site to the wharf and the road is in close proximity to many of the aggregate zones in the study area.

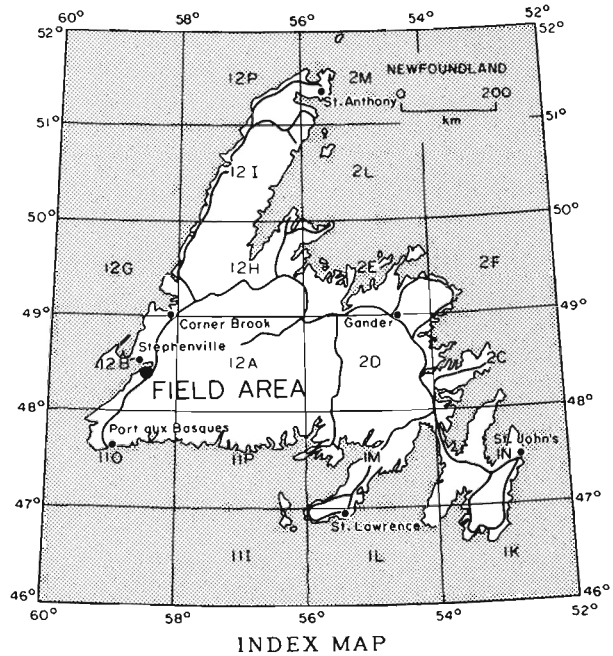

Figure 1. *Location of study area.*

The objective of this project is to locate aggregate deposits and determine their quantity and quality for suitability in the manufacture of portland cement concrete, asphaltic pavements and as highway-base material. These uses account for 80 to 90 percent of sand and gravel utilized in the United States (ADI Limited, 1986).

Deposits sampled are within a 12-km radius of wharf facilities that can be used as a shoreline base for loading raw material. Most deposits are easily accessible by roads leading to this shoreline location. A deposit that can supply 500,000 m^3 annually, for approximately 10 years, is required to make an export venture a profitable one.

This project is a contribution to the Canada–Newfoundland Mineral Development Agreement, 1984–1989.

FIELD PROGRAM

Coloured aerial photographs at 1:12,500 scale were used as a guide to locate potential resource areas. This procedure provided a framework for field investigation by outlining areas of potential deposits.

Quaternary deposits composed predominantly of glaciofluvial outwash and marine material make up much of the area, particularly along coastal shores and river valleys. Tills are located in areas east of the Trans-Canada Highway and at higher elevations (greater than 26 m above sea level) along the shoreline (Brookes, 1974). Exposed bedrock is scarce.

Field sampling was conducted by vehicle and foot traverses. Where possible, samples were taken from natural exposures such as stream cuts, shorelines and gullied areas. Where natural exposures were not available, samples were collected from hand-dug pits, usually greater than 1 m in depth. Sampling provided material for petrographic and grain size analyses to more accurately determine the boundaries of specific deposits. Field sieve and petrographic analyses were conducted on all samples containing +8 mm size material. A 200- to 500-g split of the sand–silt–clay fraction (finer than 8 mm) was retained for laboratory sieve analyses (Kirby *et al.*, 1983).

LITHOLOGICAL STUDY

Pebble lithology studies were conducted to help determine the geotechnical characteristics of the pebble fraction of aggregates. Following a review of the geological literature related to the study area, and the determination of the percentage of each rock type found in each sample of pebbles, data were collected on silt–clay coating, weathering, staining, sphericity, rounding, fractures, mineralogy and texture of various rock types present in a given pebble sample.

A petrographic number was calculated for each sample following procedures similar to CSA standard A23.2.30 (Canadian Standards Association, 1973). The petrographic number, ranging between 100 and 1000, is derived by taking the sum of the percentage of each pebble type present multiplied by a factor (based on soundness and durability) assigned to that rock type (Bragg, 1986). The lower the number, the better the quality of the aggregate material.

DATA PRESENTATION

Office Program

Particle-size analyses were conducted on 140 samples and lithological analyses on 68 samples. The results of particle-size analyses were used to plot cumulative graphs (Kirby *et al.*, 1983) for each sample. These graphs show percentages of gravel, sand and silt–clay for each sample. Petrographic numbers are also shown on the graphs.

A review of landform classification data and particle analyses was made and results were drafted on 1:12,500 scale maps. These results include zones of sand and gravel, sample numbers and type of samples collected (sand, gravel, silt and till). It should be noted that the boundaries around designated areas (zones) are determined from air photos and field investigations and may not represent the true extent of any deposit that can be used as a source of aggregate.

AGGREGATE ZONES

A brief description is given for each of the 26 aggregate zones (Figure 2 and Table 2) in the map area. This description includes: estimated reserves (listed in cubic meters) for each zone; exposure types from where samples were collected; cumulative thickness of topsoil and iron oxide layers and obstacles that may affect mining (forest growth and residential development); average percentages of gravel, sand and silt–clay; the average dominant particle size for each zone; and a range of petrographic numbers and their average. In zones with high sand concentrations, pebble content was not extensive enough to conduct detailed petrographic analyses on coarse grained material. Gravel clasts greater than approximately 100 mm could not be accurately sieved using available field equipment, therefore a visual estimate of boulder content was made at each sample site.

Zone Description

Zone 1 contains a terrace deposit situated on the west side of the Terra Transport railway track (formerly C.N.R.) between Little Barachois Brook and Black Bank Provincial Park. Forest growth covers much of the area together with scattered farmland and pastureland. A residential area is located in the southern end of the zone. This zone is approximately 1500 m long, 200 m wide, 12 m high and contains an estimated 2,000,000 m^3 of material.

Topsoil and iron oxide thicknesses average 0.5 m in this area. Particle-size analyses of ten samples collected from shoreline exposures show that the ten samples average 3 percent gravel, 88 percent sand and 8 percent silt–clay. Particles between 0.125 and 0.5 mm are dominant, forming 50 percent of sieved material. Petrographic analyses were not conducted for this zone due to lack of coarse material (greater than 16 mm).

Zone 2 contains a terrace deposit situated on the north side of Route 461, between Turf Point and Barachois Brook. This zone is predominantly forest covered but has an extensive residential area along Route 461 in the southwest section of the zone. However, there is less extensive development along two roads branching off Route 461. It is approximately 2000 m long, 400 m wide, up to 17 m thick and contains an estimated 10,000,000 m^3 of material.

Samples collected came from shoreline exposures (Plate 1) along the north side of the zone and from two quarries near the east end of the zone. Topsoil and iron oxide average 0.5 m thick. Shoreline exposures are predominantly composed of stratified sands, and, in places, are overlain by pebbly gravel up to 0.4 m in thickness. Thicker gravel units (3 to

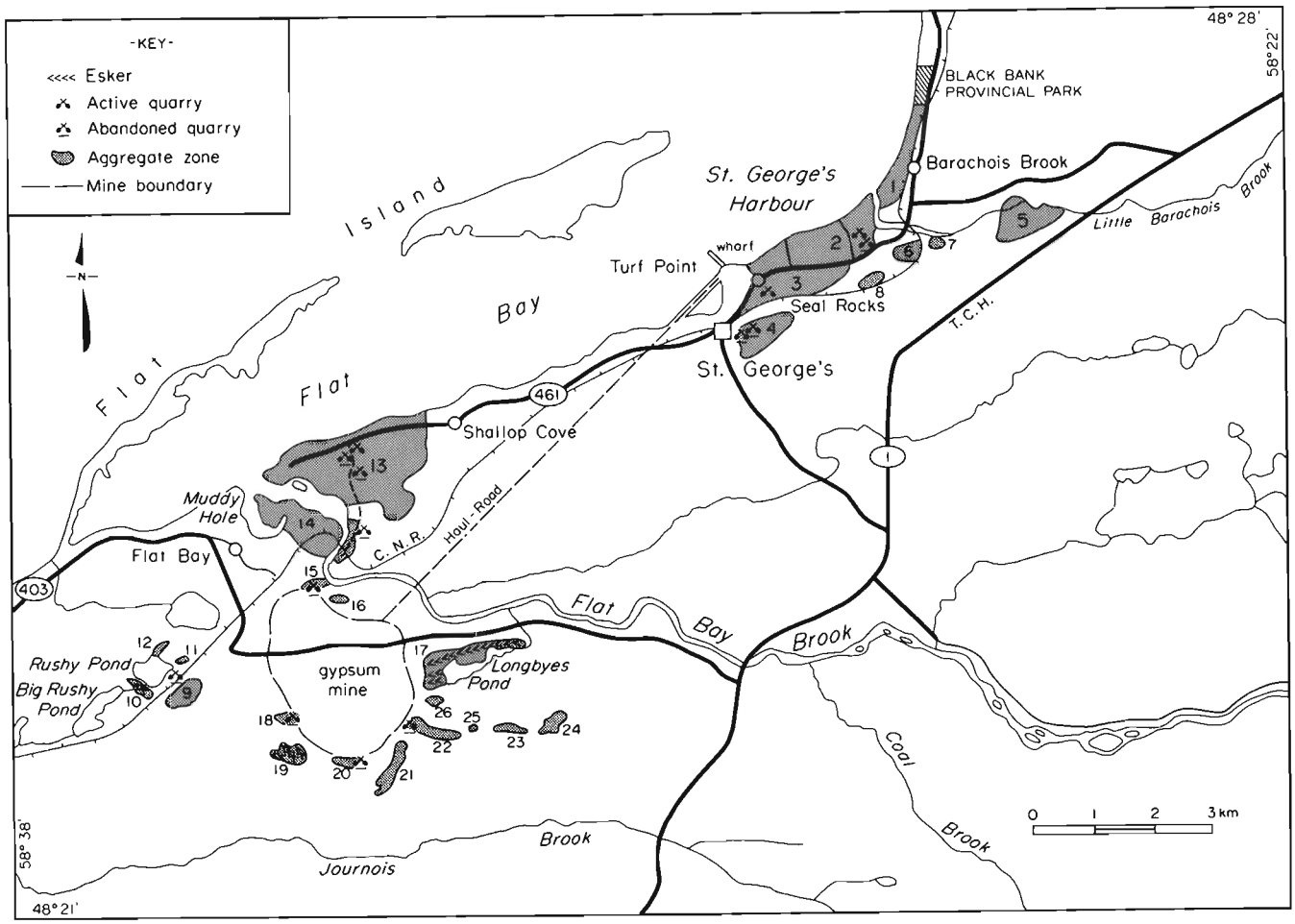

Figure 2. *Study area showing aggregate zones 1 to 26.*

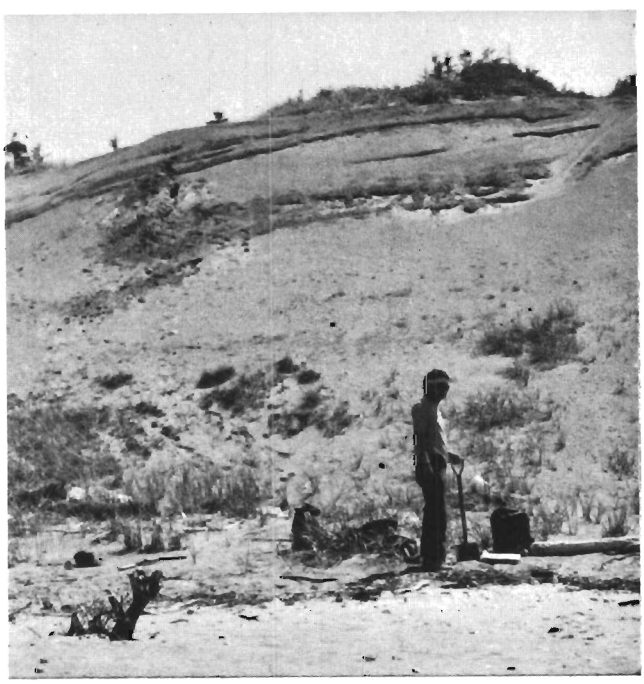

Plate 1. *Eight-m-high sandy shoreline exposure in Zone 2.*

4 m) were noted at one of the quarry sites, however, these are nearly depleted and sand exposures are now common along most of the quarry face. A layer of compacted, stratified silt–clay sediment was also noted in the shoreline exposure. This silt–clay unit is approximately 200 m long and 6 m thick.

Particle-size analyses of 12 samples collected in Zone 2 (excluding the silt–clay unit) show an average of 7 percent gravel, 85 percent sand and 8 percent silt–clay. The dominant particle size occurs between 0.25 and 0.125 mm, forming 31 percent of sieved material. Particle sizes between 0.25 and 0.5 mm account for another 28 percent. Petrographic numbers determined by analyses of three samples are 107, 110 and 147.

Zone 3 is located south of Zone 2, between Route 461 and the Terra Transport railway track. Aggregate extraction will be affected by a residential area along Route 461, which is most extensive in the east and west sections of the zone. The south and central areas are covered by dense forest and scattered cut-overs. The zone is approximately 1500 m long, 300 m wide and contains an estimated 2,000,000 m^3 of material.

Eight of the ten samples collected in this area came from backhoe pits averaging 3 m in depth; the other two were taken

Table 2. Summary and comparisons of aggregate zones sampled in the St. George's Bay area of western Newfoundland

		Petrographic Analyses			Particle Size Analyses			
Zone	Estimated m^3	# of Samples Analyzed	Average	Range	# of Samples Analyzed	% Gravel (+ 5mm)	% Sand (+0.078mm to +5mm)	% Silt–Clay (-0.078mm)
1	2,000,000	0	-		11	3.54	88.22	7.63
2	10,000,000	3	114	107-125	12	7.16	84.95	7.90
3	2,000,000	7	120	102-155	11	26.24	71.51	2.15
4	1,000,000	1	111		6	3.47	92.89	3.61
5	1,280,000	5	116	101-137	8	25.3	73.3	1.3
6	130,000	1	106		1	39.2	60.4	0.4
7	80,000	0	-		1	0.3	77.8	21.8
8	60,000	1	108		1	75.3	24.4	0.3
9	600,000	4	150	120-184	4	71.83	27.8	0.6
10	90,000	1	123		1	40.6	58.9	0.5
11	12,000	1	119		1	60.6	39.0	0.4
12	16,000	1	131		1	67.3	32.5	0.3
13	4,200,000	11	124	104-167	15	46.5	53.27	0.51
14	1,300,000	7	143	100-184	12	47.7	51.39	0.91
15	800,000	1	115		4	18.1	72.68	9.25
16	25,000	1	158		4	16.75	73.68	9.58
17	560,000	9	119	106-128	12	49.43	49.35	1.23
18	270,000	1	113		2	11.7	88.25	.05
19	300,000	4	128	116-151	8	28.18	70.83	1.01
20	300,000	2	147	136-158	4	26.54	72.02	1.44
21	500,000	1	128		6	14.92	81.73	3.32
22	800,000	4	119	109-129	7	33.01	62.58	4.42
23	60,000	2	113	106-121	2	56.1	43.45	0.5
24	500,000	1	140		1	56.4	43.0	0.6
25	1,500	0	-		1	24.6	74.8	0.6
26	36,000	1	118		1	77.6	22.1	0.3

Note: Estimated m^3 of material are based on air photo analyses and field investigations.

from a 5-m face in an abandoned quarry (Plate 2). Topsoil and iron oxide layers at these exposures averaged 0.8 m in thickness. Textures of sampled material vary greatly in the east and west parts of this zone. Gravel content in the west section ranges from 41 to 70 percent whereas in the east it ranges from a low of less than 1 to 26 percent. Gravels taken from backhoe pits in the east section of the zone may be underlain by sand because a 1-m-thick layer of gravel was observed to overly sand at the quarry site, and by extensive sandy shoreline exposures in Zone 2.

Sampled material averages 26 percent gravel, 72 percent sand and 2 percent silt–clay. The dominant particle size occurs between 1.0 and 0.5 mm forming 25 percent of sieved material. A silt–sand lens noted in a backhoe pit in the east section of Zone 3 contained 7 percent gravel, 61 percent sand and 32 percent silt–clay. The lens, ranging up to 1.2 m in thickness, appears to be localized, tapering off toward the central part of the zone. A study of 7 samples shows petrographic numbers ranging from 102 to 155 and an average of 120.

Zone 4 is located east of St. George's and south of the railway track. It is a terrace deposit, predominantly forest covered with a residential area, ballfield and playground located on the west side. It is approximately 700 m long by 500 m wide and contains an estimated 1,000,000 m^3 of material.

Samples collected in this area came from two quarries (thickness exposures of 4 and 8 m), a 1.2-m-deep trench and from two hand-dug pits with depths of 0.6 m. Topsoil and iron oxide layers in this zone average 0.5 m in thickness.

Sand is the dominant component of this zone; particle-size analyses show an average of 3 percent gravel, 93 percent sand and 4 percent silt–clay. The dominant particle size occurs between 0.5 and 0.25 mm comprising 43 percent of sampled material. The petrographic number of one sample has a value of 111.

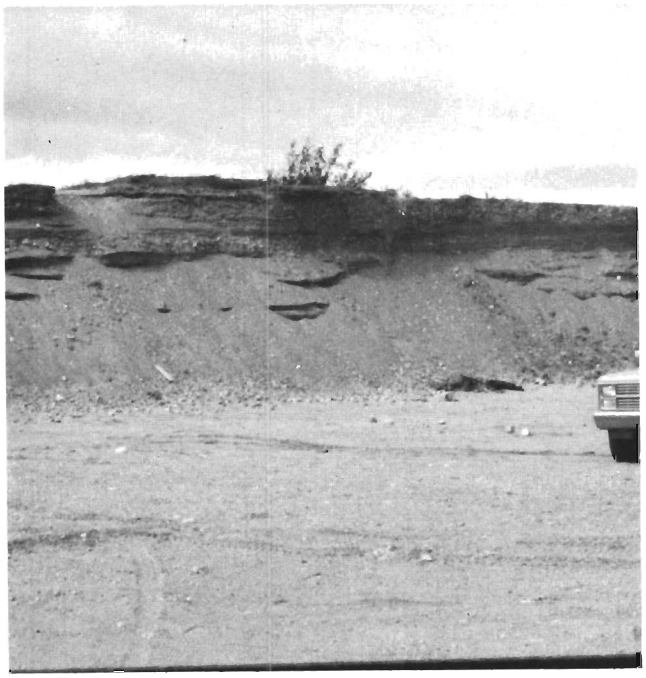

Plate 2. *Quarry with 5-m-high exposure of stratified sand and minor pebble gravel.*

Zone 5 borders the south side of Little Barachois Brook on the north side of the Trans-Canada Highway (T.C.H). It consists of an esker ridge and terrace material in an area overgrown by dense forest and with minor bog and barrens. The zone is 800 m long, 500 m wide and contains an estimated 1,280,000 m³ of material.

Samples were collected from three stream exposures with thicknesses of 14 m, 6 m and 4.5 m and two hand-dug pits with depths of 1.8 and 1.9 m. Topsoil and iron oxide layers measured at these sites had an average thickness of 0.6 m.

Particle-size analyses of five samples show 25 percent gravel, 73 percent sand and 1 percent silt–clay. The dominant grain size occurs between 0.5 and 1 mm, forming 26 percent of sieved material. Petrographic numbers range from 101 to 137, with an average of 116.

Zone 6 is situated near the south bank of Little Barachois Brook, between Route 461 and the railway track. It is covered by dense forest except for a small developing residential area at the northwest end. This zone is approximately 500 m long, 200 m wide and contains an estimated 130,000 m³ of material.

One sample was collected in this zone from a 1-m-high road exposure containing 0.7 m of topsoil and underlying iron oxide layer. Particle-size analyses of sampled material indicate that this zone contains 39 percent gravel, 60 percent sand and less than 1 percent silt–clay. The dominant particle size occurs between 0.5 and 1 mm, forming 18 percent of sampled material. A petrographic number of 106 was calculated from the plus 16 mm pebble fraction.

Zone 7 borders the south bank of Little Barachois Brook east of the railway track. It is covered by dense tree growth and a section of abandoned farmland. The zone is 200 m long, 150 m wide and contains an estimated 80,000 m³ of material.

A 2.3-m-high stream exposure in this area showed 0.8 m of topsoil and iron oxide overlying 1 m of sandy, cobbly pebble gravel which, in turn, is underlain by an undetermined thickness of stratified sand–silt sediment. Particle-size analysis of one sample collected from the lower unit shows less than 1 percent gravel, 78 percent sand and 22 percent silt–clay. The dominant grain size occurs between 0.065 and 0.125 mm, making up 30 percent of sampled material. Due to the fine grained nature of sediment in this zone, no petrographic work was conducted.

Zone 8 is located in a forested area between zones 3 and 6 bordering the north side of the railway track. The zone is 100 m long, 600 m wide and contains an estimated 60,000 m³ of material.

A topsoil and iron oxide thickness of 0.5 m was measured at a 1-m-high road exposure. Particle-size analyses of sampled material show an average 75 percent gravel, 24 percent sand and less than 1 percent silt–clay. The dominant grain size occurs between 31.5 and 63 mm, forming 24 percent of sieved material. A petrographic number of 108 was calculated from analysis of this material.

Zone 9 is located on the east side of the railway track, east of Rushy Pond. It is situated in an area of dense forest and cut-overs. This zone is 600 m long, 400 m wide and contains approximately 600,000 m³ of material.

Samples collected in this area came from 4 backhoe pits, averaging 2.9 m in depth. Topsoil and iron oxide layers at these sites ranged from 0.2 to 1.8 m in thickness, averaging 0.93 m. Particle-size analyses of sampled material show an average of 72 percent gravel, 28 percent sand and less than 1 percent silt–clay. The dominant particle size occurs between 16 and 31.5 mm, and forms 21 percent of sieved material. Another 20 percent falls within the 31.5 and 63 mm size range. At two site locations visual observations determined that approximately 30 percent of material is greater than 200 mm (material that is too large for sieving). Petrographic numbers determined from analyses of four samples range from 120 to 184 and average 150.

Zone 10 is situated in a forested area bordering the south side of Rushy Pond, west of the railway track. It is composed predominantly of an esker deposit, dissected by a stream running from Rushy Pond to Big Rushy Pond. The zone is approximately 500 m long, 100 m wide, up to 5 m high and contains an estimated 90,000 m³ of material.

A four-meter road cut through the east end of this zone showed a 0.7 m thickness of topsoil and iron oxide. Sampled material from this exposure indicates this deposit contains about 41 percent gravel, 59 percent sand and less than 1

percent silt–clay. The dominant grain size occurs between 0.5 to 11 mm and 4 to 8 mm; each of these intervals contains 17 percent of sieved material. Another 16 percent was retained between 8 and 16 mm. A petrographic number of 123 was calculated from analysis of one sample.

Zone 11 is a small zone located in a forested area northeast of Rushy Pond, bordering the west side of the railway track. It is 100 m long, 70 m wide and contains an estimated 12,000 m^3 of material.

Material was sampled from a 3.4-m-high road exposure, showing 0.9 m of topsoil and iron oxide overlying gravel. Particle-size analyses show an average of 60 percent gravel, 39 percent sand and less than 1 percent silt–clay. The dominant particle size occurs between 31.5 and 63 mm, forming 23 percent of sieved material. A petrographic number of 119 was calculated from analysis of one sample.

Zone 12 is another small zone located near the northern tip of Rushy Pond. It is covered by dense forest and surrounded by bog. This zone is 250 m long, 15 m wide and contains approximately 16,000 m^3 of material.

One sample was collected from this deposit from a hand-dug pit with an exposure thickness of 2.1 m. This exposure showed 0.8 m topsoil and iron oxide overlying 0.5 m of unsampled sand. Below the sand, a sample was collected from a gravel unit of undetermined thickness. Particle-size analyses of this material shows 67 percent gravel, 33 percent sand and less than 1 percent silt–clay. The dominant grain size occurs between 16 and 31.5 mm, composing 27 percent of sieved material. A petrographic value of 131 was calculated from sampled material.

Zone 13 is located southwest of Shallop Cove and borders the north side of Flat Bay Brook. Approximately 40 percent of this area is overlain by bog with a variable thickness (up to 1.5 m). Dense forest growth, cut-overs and farmland cover the remainder of this zone. This zone is the second most extensive in the study area, covering an area 1500 m long, 100 m wide and containing an estimated 4,200,000 m^3 of material.

Eight of the fifteen samples collected in this zone came from quarry exposures ranging from 1.8 to 7 m in thickness. Five other samples were taken from backhoe pits averaging 3 m in depth, and two samples were collected along a 6-m shoreline exposure. Sampling in the bogland area was limited to one sample due to difficulty in operating the backhoe machine in wet marshy areas. Average topsoil, iron oxide and organic layers were calculated to be 0.7 m thick, from a range of 0.5 to 1.7 m. Stratified sand and gravel (Plate 3) make up this zone. The upper 0.7 to 4 m contain most of the gravel content whereas the underlying unit (undetermined thickness) is predominantly sand (approximately 75 percent).

Particle-size analyses show an average of 47 percent gravel, 53 percent sand and less than 1 percent silt–clay. The dominant grain size occurs between 0.5 and 1 mm, accounting for 16 percent of sieved material. Petrographic numbers show a range from 104 to 167 with an average of 128.

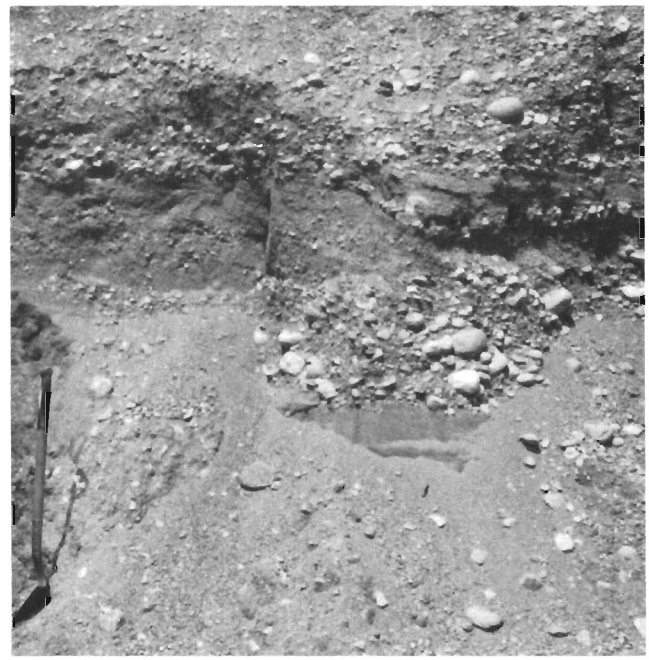

Plate 3. *Stratified pebble–cobble gravel and sand along 3-m-high exposure in Zone 13.*

Zone 14 is a glaciofluvial terrace deposit located east of Muddy Hole at the mouth of Flat Bay Brook. It is covered by forest, barrens and bogland, and includes an area 1000 m long, 600 m wide and an estimated 2,000,000 m^3 of material.

Samples were collected from three river channels (height of exposures–3 m, 8 m and 8 m), two abandoned quarries (exposures of 2.5 m each) and from one 3-m-deep backhoe pit. Topsoil and iron oxide layers averaged 0.8 m in thickness at these sample sites. Particle-size analyses of twelve samples collected in this zone show 48 percent gravel, 53 percent sand and 1 percent silt–clay. The dominant grain size occurs between 0.5 and 1 mm, composing 16 percent of sampled material. Petrographic results of five samples show a range of petrographic numbers of 100 to 184 and an average of 143.

Zone 15 borders the west bank of Flat Bay Brook in a forested area at the north end of the gypsum mine. It is composed of a glacial moraine deposit approximately 1200 m long, 100 m wide and contains an estimated 800,000 m^3 of material.

Four samples were collected in this zone; from a 5-m-high quarry face (Plate 4) and from a 12-m-high river cut. Topsoil and oxide layers average 0.6 m in thickness. Particle-size analyses show 18 percent gravel, 73 percent sand and 9 percent silt–clay. Silt–clay percentages varied from 2 to

Plate 4. *Five-m-high exposure of sandy, silty till in abandoned quarry at Zone 15.*

19 percent. The dominant grain sizes occur between 0.25 and 0.5 mm, comprising 22 percent of sampled material. A petrographic number of 115 was calculated from analysis of one sample in this zone.

Zone 16 comprises a small esker ridge located in a forested area near the south bank of Flat Bay Brook, north of the gypsum mine. It is approximately 60 m long, 20 m wide and varies from 1 m to 8 m high. It contains approximately 25,000 m³ of material overlain by an average topsoil and iron oxide thickness of 0.8 m.

Particle-size analyses of four samples collected from two backhoe pits show an average 17 percent gravel, 74 percent sand and 10 percent silt–clay. The dominant grain size occurs between 0.125 and 0.25 mm, comprising 20 percent of sampled material. Another 18 percent was retained in the sieve fraction between 0.5 and 0.25 mm. A petrographic number of 158 was calculated from analysis of one sample.

Zone 17 is located south of Route 403, bordering the north and west sides of Longbyes Pond. It comprises an esker ridge complex overlain by barrens and dense tree growth. Topsoil and iron oxide layers range from 0.5 to 2.1 m in thickness with an average of 1 m. The major part of this zone consists of a 2000-m-long esker ridge having varying widths of 10 to 35 m and heights 3 to 8 m. The remainder of the zone includes smaller esker ridges less than 300 m long and 5 m high plus outwash material bordering these eskers. This zone contains an estimated 560,000 m³ of material.

Sampling in this zone was conducted entirely by backhoe. These pits were usually dug along the sides of the esker due to difficulty in getting the backhoe machine over the steep sided ridges. Eleven pits were dug, averaging 3 m in depth.

The granular composition of this zone, determined by particle-size analyses of sampled material, showed 49 percent gravel, 49 percent sand and 1 percent silt–clay. Sieves greater than 0.25 mm contained an average of 10 to 13 percent whereas those below 0.25 mm accounted for less than 2 percent of total sieved material.

Although the average percentages of major textural groups were fairly even, the particle-size composition of the zone does vary. The east section is composed of an estimated 30 percent of unsievable boulder–cobble material, noted in four of the backhoe-dug pits. The west half had more noticeable pebble–cobble material. Sand lenses (less than 1 m in thickness) were noted at two sample sites plus outwash sands along the base of the esker deposits. Petrographic results of nine samples show numbers ranging from 106 to 128 with an average of 118.

Zone 18 is located south of Route 403 in a forested area bordering the west side of the gypsum mine. It is approximately 200 m long, 200 m wide and contains an estimated 270,000 m³ of material.

Material in this zone is overlain by 0.1 m of silt and 1.5 m of pebble–gravel having root debris throughout. Particle-size analyses of two samples collected from a 9-m-quarry exposure (Plate 5) indicate that this zone contains approximately 12 percent gravel, 88 percent sand and less than 1 percent silt–clay. The dominant particle size occurs between 0.5 and 1 mm, containing 38 percent of sieved material. A petrographic number of 113 was calculated from analysis of one sample.

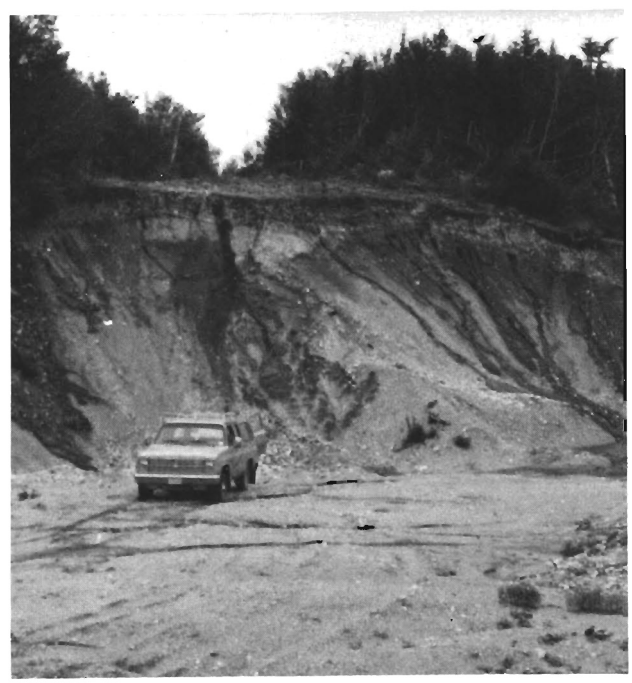

Plate 5. *Nine-m-high quarry exposure in Zone 18.*

Zone 19 is located in a forested area near the southwest border of the gypsum mine. It comprises an esker complex containing an estimated 300,000 m³ of material. Several kettle holes are located between the eskers.

Samples were collected from three backhoe pits averaging 3.8 m in depth and from one 10-m-lake-shore exposure. Topsoil and iron oxide layers have an average thickness of 0.5 m. Particle-size analyses of eight samples show an average 28 percent gravel, 71 percent sand and 1 percent silt–clay. The dominant particle size occurs between 0.5 and 1 mm, comprising 27 percent of sieved material. Petrographic results of four samples show numbers ranging from 116 to 151 with an average of 128.

Zone 20 is located in a forested area bordering the south end of the gypsum mine. This zone is 600 m long, 200 m wide and contains an estimated 300,000 m³ of material. Samples collected in this area came from three quarries with exposed thicknesses of 3, 6 and 7 m. Topsoil and iron oxide thickness at these sites averaged 0.8 m.

This is basically a sand deposit with minor pebble content and pebble–cobble lenses. Particle-size analyses of four samples averaged 27 percent gravel, 72 percent sand and 1 percent silt–clay. The dominant particle size occurs between 0.25 and 0.5 mm, forming 33 percent of sieved material. Petrographic numbers obtained from analyses of two samples are 136 and 158.

Zone 21 is a glaciofluvial terrace located in a forested area near the southeast corner of the gypsum mine. It is approximately 700 m long, 100 m wide and contains an estimated 500,000 m³ of material. Samples were collected from four backhoe pits with average depths of 3.6 m. Cave-in of loose sandy material prevented digging deeper pits at two locations. Topsoil and iron oxide layers average 0.6 m in thickness at these sample sites.

Particle-size analyses of six samples show, on average, 15 percent gravel, 82 percent sand and 3 percent silt–clay. The dominant particle size occurs between 0.25 and 0.5 mm, forming 29 percent of sieved material. Over 60 percent of all sieved material from this zone falls between 0.125 and 1.0 mm. Petrographic results of one sample from this zone had a number of 128.

Zone 22 is located in a forested area southeast of the gypsum mine. It is approximately 700 m long, 70 m wide and contains an estimated 800,000 m³ of material. Sample sites in this area include a 14-m-high quarry face, two backhoe pits (3 m and 4.9 m in depth) and a 2.5-m stream-cut. Topsoil and iron oxide layers measured at these sites averaged 1 m in thickness.

Particle-size analyses of seven samples show 33 percent gravel, 63 percent sand and 4 percent silt–clay. The silt–clay percentage is predominantly due to a sample taken from a 4-m-thick unit, containing approximately 30 percent silt–clay, near the base of a 14-m-high quarry exposure. The dominant grain size determined by averaged sample analyses occurs between 0.25 and 0.5 mm. This interval forms 15 percent of the sampled material. The top two meters of this zone are overlain by a cobble–pebble layer showing 67 percent gravel-size clasts. The remainder of the exposure has alternate layers of finer grain gravels, sand and sand–silt material (Plate 6). Petrographic results of four samples show numbers ranging from 109 to 129 and an average of 118.

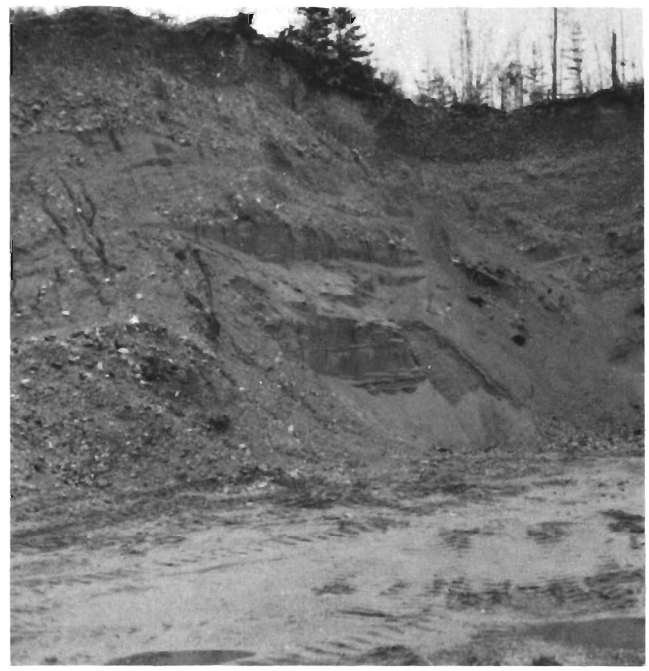

Plate 6. *Fourteen-m-high quarry exposure showing stratified gravel and sand in Zone 22.*

Zone 23 is located in a barren and forested area east of the gypsum mine and east of Zone 22. It consists of an esker ridge approximately 200 m long, varying in width from 5 to 35 m, not greater than 5 m high and contains an estimated 60,000 m³ of material. Topsoil and iron oxide thickness, measured from a 1.4-m hand-dug pit and a 3-m backhoe pit averaged 1 m. Particle-size analyses of two samples show, on average, 56 percent gravel, 43 percent sand and less than 1 percent silt–clay. The dominant grain size occurs between 31.5 and 63 mm and between the 1 and 2 mm sieve fractions. Each of these contain 17 percent of sieved material. Petrographic numbers of 106 and 121 were calculated from analyses of two samples.

Zone 24 is located in a dense forested area 2 km east of the gypsum mine and 1.5 km south of Route 403. It is composed of two esker ridges with a total length of approxiamtely 3000 m, up to 40 m wide and a maximum height of 13 m. This deposit contains in excess of 500,000 m³ of material. Due to dense forest growth and the distance from roads, less time was used to define the boundaries of this zone. Topsoil and iron oxide thickness measured in a

1.8-m hand-dug pit was 0.6 m. Boulders at the base of the pit prevented further penetration by pick and shovel. Silt layers covered some of these boulders and water seepage into the pit occurred at a depth of 1.6 m.

Particle-size analyses of sampled material show an average 56 percent gravel, 43 percent sand and 0.6 percent silt–clay. The dominant grain size occurs between the 2 and 4 mm sieve fractions, comprising 17 percent of sieved material. A petrographic number of 140 was calculated from analysis of this sample.

Zone 25 is situated in a barren area between zones 22 and 23, east of the gypsum mine. It is the smallest zone sampled in the study area, containing approximately 1,500 m^3 of material. It consists of an esker ridge 150 m long, 10 m wide and 4 m high. One sample, collected from a 2.7-m backhoe pit, showed 1 m of topsoil and iron oxide overlying 1 m of compacted, unsampled sand and pebble–gravel. A 0.7-m-thick sand–pebble material at the base of the pit contained 24 percent gravel, 75 percent sand and less than 1 percent silt–clay. The dominant grain size occurs between 0.5 and 1 mm, comprising 28 percent of sieved material. No petrographic analysis was conducted due to lack of material between 16 and 32 mm.

Zone 26 is located in a forested area near the east side of the gypsum mine, between zones 17 and 22. It is another small deposit, approximately 200 m long, 60 m wide and up to 6 m high. This zone contains an estimated 36,000 m^3 of material, overlain by 0.7 m of topsoil and iron oxide. Particle-size analysis of one sample collected from a 6-m-high stream exposure indicates that the sample contains 78 percent gravel, 22 percent sand and less than 1 percent silt–clay. The dominant grain size occurs between 8 and 16 mm, comprising 19 percent of sieved material. Another 18 percent occurs between the 31.5 and 63 mm sieve fraction. A petrographic number of 118 was calculated from sampled material in this zone.

SUMMARY

Potential aggregate extraction areas were sampled in 26 locations to locate a source of material for export. Approximately 500,000 m^3 is required on a annual basis for almost ten years to ensure economic viability. Many of the zones sampled are small and cannot support such a large mining operation.

Aggregates are a high volume, low-cost material. Some of the smaller zones can be utilized if larger nearby zones are put into production. Several smaller zones bordering the gypsum mine are within one kilometer of each other and, because of the road network around the mine, these zones are easily accessible. The added expense of constructing access roads to more distant areas such as zones 23, 24 and 25 would make them less profitable.

Particle-size analyses indicate a high sand content in many zones, usually greater than 70 percent. Zones with a higher gravel content are small and do not have the required volume of material to support a large extraction operation for coarse aggregate. If only coarse material is required, the sand content must be screened and dumped. This would greatly reduce deposit potential and result in wastage (unless another outlet can be found) of high quality sand-sized material.

Petrographic analysis was only conducted on samples with particle-sizes between 16 and 32 mm. Sand-size material will usually have high petrographic numbers because lighter deleterious materials are washed away as coarser material is broken down leaving behind higher percentages of hard silicate minerals. Most petrographic numbers of samples analyzed are within the range (less than 130) required for use in high quality concrete.

Zones 2 and 13 appear to be the most suitable sites for the aggregate export market. Both zones have large volumes of material and good petrographic characteristics. Zone 2 is less than 1 km away from the loading wharf. A conveyor system could easily be used to transport aggregate over this distance, avoiding potential problems with local traffic. Zone 2 is in close proximity to zones 3 and 4. These two smaller zones could also be utilized to sustain production over a longer time period if necessary.

Zone 13 is located 0.5 km from the haul-road and another 3.5 km from the loading wharf. Although it contains less than half the volume of material of Zone 2, it is still a substantial deposit. Its proximity to Zone 14 plus easy access to many smaller zones around the gypsum mine increases its potential.

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