

# **FEASIBILITY STUDY AND MARKET ASSESSMENT FOR ARMOUR STONE IN NEWFOUNDLAND AND LABRADOR**

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## ARMOUR STONE

### EXECUTIVE SUMMARY

The term **armour stone** refers to large pieces of angular rock that are used in the building of engineered structures for sheltering harbours and protecting shorelines from erosion by wave and current action. Large pieces of armour stone (i.e., 5 to 10 tonnes) are more expensive and thus often used as an outside protective layer (*hence the name armour*) on top of smaller, less expensive stone. There are no primary full-time producers of armour stone. Large pieces of stone are typically produced as byproduct, or oversize, from a variety of existing quarry operations. When there is demand for armour stone in a large construction project, a local quarry may undergo short-term expansion to meet the demand, and produce smaller stone as a byproduct.

In Atlantic Canada, the demand for armour stone is filled by local construction firms with access to local sources near the project site. Prince Edward Island is the exception as they lack a source of suitable bedrock. The price of armour stone for projects in Atlantic Canada is a function of the total volume required and the proximity of a local source. Prices can range widely, from as little as \$15 a tonne to more than \$100 a tonne, but average in the \$35 range, FOB jobsite.

In the Great Lakes region of Central Canada and the northern USA, there is a ready supply of armour stone from large existing quarries that produce limestone and dolostone for a wide range of industrial demands. These quarries produce a large volume of oversize material that can be sold as armour stone. There is also a steady demand for a wide range of landscaping stone, and a small market for larger, cut-to-size stone that is used for retaining walls and decorative purposes.

The market for armour stone (and related stone products) in the United States is very large, in the range of \$125 million per year. It can roughly be broken down as 45% to the west coast, 45% to the east coast, and 10% Great Lakes region and interior. In order to access the armour stone market on the US Eastern seaboard, a Newfoundland exporter will need to become a registered vendor for government projects, and/or work closely with, and become a supplier to, large American-based construction companies.



Dimension stone producers in Newfoundland and Labrador would have a difficult time exporting their waste rock into armour stone markets in the United States. The cost of shaping, sorting, and transporting the stone to a suitable port would be high, and then there is the cost and logistics of getting the stone shipped when it is needed. A 'stand alone' armour stone producer would need to be selling a full range of high quality stone products into export markets, and they would have to be located at, or very near to tidewater. Seasonal shipping due to ice conditions in some areas of the province would create additional difficulties of supplying stone in a timely manner.

There are a very limited number of ports in Newfoundland and Labrador that are suited for exporting bulk stone, and the general reception to the concept for using small harbours was more often than not, rather negative.

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# ARMOUR STONE

## 1 BACKGROUND

### 1.1 Scope of Work

The objective of this report is to address the feasibility of producing and exporting armour stone from Newfoundland and Labrador (NL). The study looks at (i) the supply and demand for armour stone in NL, the Atlantic Provinces, Central Canada and the Great Lakes Region, East Coast of the United States as well as northern Europe, (ii) issues related to NL ports, transportation and handling of armour stone, (iii) the potential to utilize ‘waste rock’ from existing and future dimension stone quarries in the province, and (iv) the feasibility of a stand-alone quarry at or near tidewater, to produce armour stone and related stone products.

This study will hopefully provide insight for both existing and future dimension stone producers, and will assist regional, provincial, and federal agencies in planning and implementing strategies related to the production and use of armour stone.

### 1.2 Definitions

The placement of large pieces of stone along the shores of oceans, lakes, rivers, and canals to “armour” or protect the shorelines from erosion by waves and currents has been used for centuries. Closely spaced stones can disrupt, absorb and disperse the energy of waves and currents. This prevents the loosening and removal of soft bedrock, as well as the removal of smaller pieces of stone, sand, and clay. The current use of armour stone is highly varied, sometimes controversial, and always ‘site’ or ‘contract’ specific.

The general term **armour stone** includes a wide variety of types, shapes and sizes of rock. There are numerous definitions and regional names for armour stone that exist in the literature, and a partial list is given below with the definitions that will be used in this report. Below this list is TABLE 1, which gives generalized sizes for the various classes of stone.

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**Armour stone** : (Non-specific) large, angular shaped pieces of rock used to protect shorelines against wave or current action; individual pieces typically range in weight from 1 tonne to greater than 10 tonnes,

**Armour stone** : (Specific) Type I stone (1 to 2 tonnes) and Type II stone (~ 100 to 200 kg); terminology for armour stone in construction projects in the United States

**Armour stone** : “Cut-to-size”: large pieces of stone that have been cut/split to specific dimensions (often with squared edges and orthogonal shape) for use in projects where the stones are placed on top, or beside each other, in the construction of a vertical walls (i.e., for bridge abutments, canal walls, etc.)

**Cut-to-size stone**: stone used in the landscaping industry for specific installations or functions (i.e., waterfall stone, stone benches, etc.)

**Jetty stone** : An American term for armour stone used in the construction of jetty structures

**Filter stone** : Stone that is placed between the core stone or rip rap, and the exterior armour stone; filter stone prevents the smaller core stone from ‘filtering out’ between the larger exterior stone, and it helps disperse energy as well; it can range in size from 250 kg to 1500 kg

**Rip Rap**: A general term for very coarse, angular, blasted +/- crushed bedrock that ranges in size from 9 to 90 kg in weight, and 20 to 45 cm in size; it is also referred to as “one man rubble”

**Core stone** : Smaller, less expensive stone used at the core of engineered structures such as breakwaters, artificial reefs, bridge abutments etc.

**Gabion stone** : Stone (10 to 20 cm) placed in wire cages or baskets and used for bank stabilization and drainage

**Coarse aggregate** : Crushed stone, most often considered smaller than 10 cm in size

In general, the price per tonne of armour stone increases with the size of the stone. The cost per tonne, or per kilogram, can increase 10-fold when comparing a 10 kilogram stone to a 10 tonne boulder. This has resulted in the design of structures requiring armour stone, such as breakwaters, having a core of smaller pieces of stone covered by layers of increasingly larger pieces of stone. This is well illustrated by the delivery schedule/contract *Atlantic Minerals Inc. (AMI)* of Corner Brook has with *Palmetto Contractors Group* in South Carolina. *AMI* supplied stone to build two rock islands that protect bridge support towers being built in the Charleston River, (PLATE 1, *Western Star*, September 28, 2002). *AMI* initially shipped 10 boatloads of coarse aggregate from Lower Cove for the core of the islands. This was then followed by 3 loads of rip rap, then shipments of first Type II armour stone, and finally Type I armour stone.



PLATE 1: The Cooper River Project in Charleston, South Carolina, USA showing the two rock islands composed of armour stone supplied by *Atlantic Minerals Inc.* which are designed to protect the bridge support towers.

### 1.3 Specifications

The general specifications of armour stone are, for the most part, similar to those for construction aggregate. “A rock must be hard, durable, free from cracks, and angular in shape” (*taken from* Form 615, Jan. '99, Dept. of Works, Services, and Transportation, Government of NL). Additional specifications unique to armour stone are density and shape. Density must be greater than 2.6, which means that the actual mineral constituents of the stone must have an average specific gravity greater than 2.6. The specifications on shape are that the minimum dimension must not be less than one quarter of the maximum dimension, and the stone must not be rounded, whereby strong current/wave action could cause it to easily roll down-slope.

**TABLE 1:** Generalized Sizes for Armour Stone, Filter Stone, Rip Rap, and Core Stone.

Source	Armour Stone (Jetty Stone)	Filter Stone	Rip Rap	Core (Gabion Stone)
G. Gosse - Dept. of WST*	Min. dimension not less than ¼ max. dimension		≥ 0.0035 m <sup>3</sup> ≥ 9 kg	
D. Stonehouse - Atlantic Minerals Inc.*	Type I: 1 - 2 tonnes Type II: 90 – 200 kg		< 90 kg, 15 cm	
G. Pike – Marine Contractors Ltd.*	≥ 1 tonne	350 – 1000 kg 30 – 60 cm		≤ 30 cm
E. Coy - NB Dept. of Public Works*	Max. dimension not to exceed 2x min. dimension ≥ 1 ton	75 - 1500kg Max. dimension not to exceed 2x min. dimension		0.1 - 100 kg
Walker Industries**	3 >5 tonnes		20 – 40 cm	10 – 20 cm
Tg. Berhala Project**	3 - 10.5 tonnes	250 - 1500 kg		1- 250 kg
Rideau Canal**			10 – 45 cm angular	

\* Interviews conducted in person and/or by telephone, March, 2003.

\*\* Information obtained from websites (refer to Appendix “C”).

There are a number of standard tests designed by the American Society for Testing Materials (ASTM) for proving that a particular type of stone has resistance to abrasion, low absorption, the ability to withstand repeated freeze thaw cycles, etc. (TABLE 2). These tests are carried out on small hand samples that must be representative of the stone being used to source the armour stone. An examination of the quarry and a petrographic examination of the stone should be carried out by a geologist in order to obtain a reliable quality assessment and to produce a Petrographic Number rating which is used in the final evaluation process (Bragg, 1995).

**TABLE 2:** Armour Stone Specifications

<b>REQUIREMENT / TEST</b>	<b>ARMOUR STONE</b>	<b>RIP RAP</b>
Material features*	Clean, hard, durable rock, free of cracks, angular shape, uniform gradation, ratio of min/max dimension $\geq 1:4$	Clean, hard, durable rock, free of cracks
Weight and Size*	Contract specified	$\geq 0.0035 \text{ m}^3$
Specific Gravity and Absorption (ASTM C127)*	$\geq 2.6 \text{ t/m}^3$ $\leq 5\%$ absorption	$\geq 2.6 \text{ t/m}^3$ $\leq 5\%$ absorption
Los Angeles Abrasion (ASTM C131)*	Loss not greater than 35%	Loss not greater than 35%
Magnesium Sulphate Soundness (ASTM C88-76)*	Loss not greater than 15%	Loss not greater than 15%
Petrographic Examination (ASTM C295)**	100-135 - excellent 136-150 - moderate	100-135 - excellent 136-150 - moderate
Freeze and Thaw (CSA A23.2-24A)**	Loss not greater than 10%	Loss not greater than 10%

Sources:

\* NL Department of Works, Services and Transportation Specifications Book, Sections 615 (Armour Stone) and 610 (Rip Rap Treatment).

\*\* Mr. Dan Bragg, Department of Mines and Energy, NL.

In addition to the standard quality assessment procedures listed above, individual armour stone contracts may have additional specifications. There may be a very detailed breakdown of the different sizes, the permissible variation within individual size ranges and variation in shape (dimensions). This requires additional work at the quarries that are producing the stone, both in the sorting and shaping of the various sizes required, and this adds to the cost of production. The final measurement of the volume of armour stone supplied for an individual contract is usually carried out by weighing truckloads of the stone, and mathematically computing the volume (usually  $\sim 2.6$  times the weight).

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## 2 SUPPLY AND CONSUMPTION

A review of the literature, data collected from the world wide web, and information provided by companies indicates that there are few, if any, full-time primary producers of large volumes of armour stone, (i.e., companies that exist simply to produce and market large boulders for breakwaters, etc.). However, armour stone is commonly produced as a byproduct in quarries which may be producing aggregate, landscaping stone, or even chemical grade limestone (e.g., Lower Cove, Port au Port Peninsula, NL). These large boulders are typically produced from quarry operations during the drilling and blasting of bedrock. The boulders that are too big to ‘feed’ into a quarry’s crusher are referred to as ‘oversize’, and they can often be seen in rows lining the upper edges of cliff faces (as a safety precaution) or marking the perimeter of a quarry yard. In these quarry situations, the large boulders are stockpiled until they can be sold. If there is a company carrying out a large marine construction project in an area, then this company may buy up all the ‘oversize’ boulders from a number of local quarries. Large stones that are too big to be crushed for aggregate are also produced as byproduct from many sand and gravel quarries. However in sand and gravel quarries with a ‘glacio-fluvial’ origin, the stones are usually quite rounded and, therefore, do not meet the specifications for angular armour stone. These ‘pleasingly’ shaped boulders can sometimes be sold into either the commercial or residential landscaping market.

When there is a ‘local’ short-term demand for armour stone to carry out a large construction project, a quarry proximal to the construction site typically undergoes rapid expansion/development to meet the short term demand. In these situations, where there is primary armour stone production (on a temporary basis), a large amount of rip rap and smaller stone will be produced as byproduct. Depending on the thickness of bedding, density of jointing, and fracture patterns in the quarry, the recovery of the larger size armour stone may be as low as 10% of the total stone produced. The smaller stone is typically crushed and sold as aggregate over an extended period of time (i.e., months to years)

The other supply option to meet short term demand is to transport armour stone from an outside source to the construction site because there may not be a source of competent stone adjacent to the project area, or the distance to a source may just be uneconomical for trucking. The fact that most construction projects requiring armour stone are on tidewater, along the shoreline of large lakes or rivers, or along the side of canals or other dredged waterways, facilitates the transport of armour stone by water. This is becoming a

more common practice in areas where industrial development or urban sprawl has sterilized the area adjacent to the project.

Statistics on the production and consumption of armour stone are both difficult to find and to interpret. This is because the tonnages for armour stone are often reported along with those for rip rap, rubble, and sometimes even with aggregate. A significant number of quarries that produce armour stone as byproduct don't separate out the large stone material when reporting production to government. Information supplied by personnel with Natural Resources Canada (NRC) gives a breakdown for just rip rap and rubble consumption for all of Canada during 2000 (TABLE 3).

**TABLE 3:** Consumption of Rip Rap and Rubble in Canada during 2000<sup>1</sup>.

Provinces	Tonnes of Rip Rap + Rubble	Value (Cdn \$)	Price / Tonne
NL, NB, NS	698,160	1,390,101	2.00
QC, ON	233,450	1,357,410	5.82
MB, AB, BC	324,911	1,728,016	5.32
Total CANADA	1,256,521	4,475,527	3.56

<sup>1</sup> Jacqueline Paquette, NRC, [japaquet@NRCan.gc.ca](mailto:japaquet@NRCan.gc.ca)

## 2.1 Atlantic Canada

In Atlantic Canada, three of the four provinces produce armour stone for local consumption. The three producing provinces, Newfoundland (NL), New Brunswick (NB), and Nova Scotia (NS), all have extensive coastlines and marine based industries, and thus they have a requirement for breakwater structures, wharf development, and maintenance programs. Prince Edward Island (PEI) does not have any bedrock sources suitable for the production of armour stone (or Class A aggregate) and the province must import stone (primarily from NB) to meet almost all of the province's construction needs.



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### 2.1.1 Newfoundland and Labrador

Armour stone and related stone products are used throughout Newfoundland and Labrador in the construction of breakwaters for harbour protection, in the construction and maintenance of wharves and bridge abutments, for anchoring sewage outflows pipes, etc. Construction companies meet their stone requirements by extracting stone from bedrock quarries, scavenging stone from existing or older, perhaps dormant aggregate quarries, or they buy stone from other quarry producers.

The provincial Department of Work Services and Transportation (WST) reports their own annual consumption of armour stone and riprap, as well as the prices paid. The statistics for the period 2000-2002, are presented in TABLE 4. The data show a yearly consumption of 2,300 tonnes of armour stone at an average installed price of \$28.30/tonne and 6,000 tonnes of rip rap at an average installed price of \$36.00/tonne. For comparison, one anonymous west coast contractor told of a 'one-time-purchase' of limestone boulders from a quarry on the Port au Port Peninsula, for \$8-9 per tonne FOB quarry! However on average, the cost of armour stone in western Newfoundland was quoted at between \$35.00 – 90.00 per tonne installed.

A much greater volume of stone is used by private companies, carrying out government projects. A listing of marine construction projects from the Federal Department of Public Works suggests that in NL, the total annual production and consumption of armour stone, rip rap, core and filter stone is in the range of 100,000 tonnes (if one assumes not all projects are reported, and that some of the use of armour stone may be reported as aggregate or other stone products). The variety, size and geographic distribution of projects for 2000-2001 are given in TABLE 5.

The approximate annual consumption of armour stone in NL ranges between 85,000 m<sup>3</sup> to 100,000 m<sup>3</sup>, with an approximate value ranging from \$ 2,405,000 to \$ 2,830,000. There are years, however, when unique storm events may result in increased government spending to repair damage and/or to carry out improvement projects to prepare for future storms. This was the case in January of 2000, when strong storm surges caused serious damage on some of the province's southern coastlines. The result was the spending of approximately \$6,000,000 to replace armour stone which had been swept away, replace old wooden structures with new stone gabion structures, and a variety of bank stabilization projects.

**TABLE 4:** Armour Stone and Rip Rap usage for 2000-2002 by the Department of Works, Services and Transportation, Government of Newfoundland and Labrador\*.

Specifics	Armour Stone	Rip Rap (random)**
Size	Site specific with least dimension not less than ¼ of greatest dimension	$\geq 0.0035 \text{ m}^3$ $\geq 9 \text{ kg}$
Consumed 2000-2002 <sup>(1)</sup>	4,600 tonnes (1800 m <sup>3</sup> )	12,000 tonnes ( 4500 m <sup>3</sup> )
Average cost <sup>(2)</sup>	\$28.30 / tonne	\$36.00 / tonne
Range of cost quotes	\$20.00 - \$45.00 / tonne	\$14.00 - \$65.00 / tonne <sup>(3)</sup>
Usage	Breakwaters, bridge abutments	Culverts, slopes, beds of channels

\* - Quoted from telephone interview with G. Gosse, Newfoundland and Labrador Department of Works, Services and Transportation.

\*\* - Other types of stone, including Hand Laid (\$140.00/m<sup>3</sup>) and Hand Laid with Sod (\$117.00/m<sup>3</sup>)

<sup>(1)</sup> - Total volume of armour stone used by the Department of Works, Services and Transportation for 2000-2002.

<sup>(2)</sup> - Average weighted cost per ton including haulage and site installation.

<sup>(3)</sup> - Range on price depends upon volume of contract (i.e., \$14.00/m<sup>3</sup> for 3500 m<sup>3</sup>, \$65.00/m<sup>3</sup> for 200 m<sup>3</sup>).

In Labrador, there are also requirements for armour stone and riprap to build breakwaters and protect sewer outflows from severe storms and ice. In the vicinity of most communities, there is an adequate supply of suitable bedrock which can be quarried and used in these projects. There are some exceptions however, as a 1985 study by *Newfoundland Geoscience* (Project No. 85-361), suggested that armour stone for projects along the Strait of Belle Isle would have to be transported approximately 10 km to some of the communities. The short shipping season and greater shipping distances suggest that Labrador quarries would have trouble supplying economically competitive armour stone to job sites in the south.

**TABLE 5:** Armour Stone (A), Rip Rap (R), Filter Stone (F) and Core Stone (C) Supplied for the 2000-2001 Marine Projects for Public Works Canada, Newfoundland and Labrador<sup>1</sup>

Tonnage	A	F	R	C	Project	Location	Company
31,241	X	X		X	Breakwater	Grand Bank	Weir's Construction
4,200	X	X			Breakwater	Lawn	Bennett's Construction
6,200	X	X		X	Harbour Dev.	Red Harbour	Trident Construction
1,930	X				Breakwater	Flatrock	Modern Paving Ltd.
400	X				Wharf Extension	St. Brendans	Rogers Enter. Ltd.
6,739	X*				Wharf Construction	Catalina	J&E Enter. Ltd.
2,093			X*		Wharf Construction	Bridgeport	Northeast Builders
3,187		X			Breakwater	Black Duck Bk.	Marine Contractors
3,330	X				Breakwater	Black Duck Bk.	Marine Contractors
2,802				X	Breakwater	Black Duck Bk.	Marine Contractors
1,010	X				Wharf Construction	Forteau	Johnsons Construction
535			X*		Wharf Reconstruction	Miles Cove	Newcon Construction
611			X		Wharf Reconstruction	Jackson's Cove	Northeast Builders
299			X		Wharf Reconstruction	Lushes Bight	Barkers Construction
2,705				X	A.S. Installation	La Scie	Barkers Construction
1,510		X			A.S. Installation	La Scie	Barkers Construction
320	X				A.S. Installation	La Scie	Barkers Construction
3,057	X				A.S. Installation	La Scie	Barkers Construction
240		X			A.S. Repair	Black Duck Cove	Marine Contractors
1,800	X				A.S. Repair	Black Duck Cove	Marine Contractors
130			X		Wharf Construction	Frenchman Cove	Brook Enterprises Ltd.
130			X		Wharf Construction	Griquet	Hann Enterprises Ltd.
74,599					TOTAL TONNAGE		

\* - Rip Rap and Rockfill

<sup>1</sup> William Oldford, Mineral Lands Division, Newfoundland and Labrador Department of Mines and Energy, tel: 709-292-4503.

Note: @ \$28.30/ton x 74,599 = \$2.11 million total for year (28,700 m<sup>3</sup>)

There are dimension quarries located at tidewater in the Nain region of northern Labrador (FIGURE 1). Mr. Fred Hall of the *LIDC* has indicated that the Ten Mile Bay and Igiak Bay anorthosite (granite) quarries could supply between 50,000 – 100,000 tonnes of small and/or irregular shaped block for use as armour stone from their waste piles. However the great distance to market, combined with the extremely valuable nature of this stone, and the opening up of a secondary processing plant in Hopedale, would likely limit the potential for use of this stone in breakwaters.

On the island of Newfoundland, there are several locations close to tidewater that have potential for the development of armour stone quarries. A number of geological formations have been sampled by the Department of Mines and Energy and ASTM testing has been carried out (D. Bragg, pers. comm., 2003; Bragg, 1995). The following areas were prioritized: (1) the Conception Group, Holyrood Pluton and Harbour Main Group volcanic rocks in the Conception Bay area, (2) the Musgravetown Group's Big Head and Bull Arm Formations in the Long Harbour area, (3) the Table Head and St. Georges groups in the Main Brook area, and (4) the Table Head and St. Georges groups in the Corner Brook area. The location, formation name and corresponding ASTM data for these potential sources of armour stone are presented in TABLE 6.

**TABLE 6:** Location, formation & ASTM tests for potential sources of good quality armour stone in NL<sup>1</sup>.

<b>ASTM ? Unit ?</b>	<b>Abrasion (% loss)</b>	<b>Soundness (% loss)</b>	<b>Specific Gravity</b>	<b>Freeze/Thaw (% loss)</b>	<b>Petrographic Number</b>
Conception Group	12.80-18.90	1.828-2.060	2.5-2.6	1.9-8.6	100-125
Holyrood Pluton	14.90-18.60	0.337-0.312	2.6-2.8	0.63-2.4	100-120
Musgravetown Group	11.90-18.70	0.370-0.740	2.6-2.8	No results	110-150
Table Head/St. Georges (Hare Bay)	17.50-23.80	7.5-14.8	2.5-2.7	3.230-4.368	110-130
Table Head/St. Georges (Corner Brook)	18.70-26.58	0.213-0.874	2.6-2.7	2.213-4.368	110-135

<sup>1</sup> Courtesy of D. Bragg, Bedrock Aggregate Geologist, Department of Mines and Energy, NL.



**FIGURE 1:** Map showing the location of the *T.U.C.* Ten Mile Bay and Igiak Bay anorthosite quarries near Nain, Labrador, the *International Granite Corp.* gabbro quarries at Jumpers Brook, central NL and the *Hurley Slateworks Co. Ltd.* quarry in eastern NL.

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A number of reports concerning armour stone in eastern Newfoundland have been written in the past (i.e., Snelgrove, 1987; Miles, 1983). Snelgrove (1987) examined potential armour stone sites in the southern Avalon and concluded that the lithologies in the area are not well suited for the production of armour stone. The rates of recovery were predicted to be low and the size of stone to be generally small (i.e.,  $\leq$  2.5 tonnes). Miles (1983) studied the armour stone potential of rock units in the northeastern Avalon Peninsula for a project requiring 120,000 tonnes of armour and core stone for the construction of the Fisherman's Facilities at Prosser's Rock in St. John's Harbour. He concluded that granite from the Holyrood Pluton was the best (i.e., suitable size rock pieces and good ASTM results) for production of armour stone and core stone for marine projects.

### 2.1.2 New Brunswick and Nova Scotia

New Brunswick has suitable bedrock in many areas of the province for producing armour stone and riprap for local marine construction projects. There are limestone aggregate producers that have oversize production from their operations, and old sandstone quarries at tidewater. The NB Department of Public Works reports shipments of armour stone from NB to PEI. However, the industrial mineral geologist, Mr. Tim Webb, of the NB Department of Natural Resources was not aware of any significant export of armour stone beyond PEI.

There is a large bedrock aggregate quarry near St. Andrews, NB, on the Bay of Fundy, that opened up in 1998 to sell crushed stone into the U.S. eastern seaboard and Caribbean. The quarry is part of the Bayside Marine Terminal and it has the potential to supply granite armour stone from its oversize production of granite aggregate, which will likely build in volume over time. This operation, which is 50% owned by *Florida Rock Industries Inc.*, also trucks in sand and gravel from 20 km away to be shipped from the terminal.

The total quantity (tonnes) of armour stone used by the NB Department of Public Works along the coastline of eastern NB is presented in TABLE 7. The data from TABLE 7 covers the years 1987 to 2003. Of interest is the tremendous range in consumption of the various types of core, filter and armour stone for different years. This variation reflects both the increased demand during storm years and the project-specific nature of marketing armour stone.

**TABLE 7:** Projects Using Core, Filter and Armour Stone in Eastern New Brunswick – 1987 to 2003.<sup>1</sup>

Year	Location	Description	Core Quantity (Tonne)	Filter Quantity (tonne) Size (kg)	Armour Quantity (tonne) Size (kg)
1987	Lameque	Breakwater	51,000	6,400/140-230 2,800/50-100	15,000/1,400-2,300 6,300/500-1,000
1987	Ste. Marie	Breakwater	14,500	12,800/500-1,500	2,500/1,500-3,000 18,300/500-8,000
1988	Bas Neguac	Breakwater			4,700/???
1988	Pte. Verte	Breakwater	6,000	5,000/???	17,200/7,000
1989	Blue Cove	Breakwater	22,500	6,600/500-2,000 14,000/500-2,000	11,200/2,000-6,000 16,300/6,000-9,000
1992	Blue Cove	Wharf repairs		700 /???	1,400 /???
1992	Neguac	Wharf repairs		1,750 /???	3,000 /???
1994	Val Comeau	Gully stabilization	20,000	14,500/400-800 4,200/200-400 4,200/100-200	30,400/4,000-6,000 7,000/2,000-4,000 5,800/1,000-2,000
2000	Escuminac	Breakwater	13,000	8,000 /???	7,500 /???
2000	Les Aboiteaux	Breakwater	1,900	4,670/100-400	1,630/1,000-2,000 6,160/2,000-4,000
2001	Le Goulet	Wharf road protection	4,000	4,500 /???	6,600 /???
2001	Cap Pele	Breakwater	4,400	1,350 /???	3,500 /???
2001	Petite Cap	Breakwater	2,200	3,800 /???	4,100 /???
2002	Cormierville	Breakwater	2,200	350 /???	850 /???
2003	Chockpish	Breakwater	6,500	6,000 /???	6,500/4,000-6,000 1,700/2,000-4,000 1,000/1,000
		Aver. \$ cost based on 40 km haul	\$5.00/tonne sandstone	\$ 20.00/tonne	\$ 25.00/tonne

<sup>1</sup> Ed Coy, Senior Project Manager, NB Department of Public Works.

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The recent burial of a natural gas pipeline from NS through NB and into Maine has provided a one-time source of armour stone. This is because the large boulders dug up in the trench for the pipe are not reburied with the pipe and they remain littered along the pipeline route. The NB Department of Natural Resources industrial mineral geologist noted this as a potential resource of armour or landscaping stone.

In Nova Scotia, armour stone is produced as a byproduct from aggregate quarries for any local projects along its extensive coastline. Much of NS's Atlantic coastline is underlain by metamorphosed sediments, (i.e., Halifax slate of the Meguma Group), which is used in breakwaters and for fill inside the crib structures of new wharfs. Granite is the other common rock type along Nova Scotia's coastline, and it also underlies the highlands to the west and north. During the last major period of glaciation, granite boulders were scoured, transported, and re-deposited all along the coast. These boulders, as well as large broken slabs of granite, are a major source of armour stone for local projects

Mr. Jerome MacGillivray, Project Manager with the Marine Programs of the NS Department of Public Works has reported the following quantities of quarried rock used in NS over the past 2 years as:

Armour Stone: 98,000 tonnes

Filter Stone: 102,000 tonnes

Core Stone: 210,000 tonnes

Rip Rap: 5,000 tonnes

This gives an approximately annual volume of various sized stone as 207,500 tonnes or 79,800 m<sup>3</sup>.

There are at least 6 major producers of crushed stone in NS. The largest exporter of crushed stone is *Construction Aggregates Limited* who operate a massive quarry at Porcupine Mountain (Aulds Cove), adjacent to the Canso Causeway. This quarry was started in 1952 to supply stone for the causeway which connects Cape Breton (CB) to the NS mainland. The quarry was shut down after completion of the causeway project and only used occasionally to supply modest amounts of stone for provincial projects in CB. However in 1978, this quarry was reactivated by *Construction Aggregates Limited*, who recognized the potential of the abandoned quarry with high-quality stone adjacent to a deepwater port. This large quarry operation is often referred to as "one of the pioneers of the long-haul marine transport of aggregate". The operation has changed ownership a number of times, and is currently owned by *Martin*



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*Marietta*, a large producer of industrial minerals based in the USA. The range of products they produce includes concrete aggregate, paving stone, specification sand, road base and surface material, railroad ballast, drain rock, rip rap and armour stone.

*Construction Aggregates Limited* processes a crushed granite stone, with smaller amounts of volcanic stone, from their quarry on top of Porcupine Mountain. The crushed stone is blasted and crushed in the quarry and then fed by conveyor over the edge of the cliff, where it freefalls into the processing yard at tidewater on the Straits of Canso. There is a large storage area and load-out facility with conveyor systems for loading boats and barges. The oversize rock from the quarry is used for rip rap and armour stone and this stone is trucked down from the quarry to the load-out facility.

There are several major crushed stone quarries in the Halifax-Dartmouth area, and they are largely concerned with addressing the needs of local construction projects in a booming economy. There is major loading facility in Bedford Basin on the Dartmouth side, where bulk shipping of gypsum takes place, as well as some shipments of rip rap and other classes of stone.

A massive new quarry development is proposed in southwestern NS, at the mouth of the Bay of Fundy. The proposed site at Digby Neck will process 'basalt', a dense hard rock that would make excellent crushed stone (similar rock to what industry terms "trap rock"). The proponents are planning to produce a variety of products and are targeting the export market in the United States. However, current land and permitting issues may set back the much publicized 2004 opening.

## **2.2 Central Canada, USA and Eastern Europe**

According to Ron Hewitt, Marine Engineer with the Ontario Department of Public Works, the volume of armour stone and related stone products used in the Ontario and the Great Lakes Region is, in general, very limited. Over the last decade, only a few relatively large jobs have required significant volumes of armour stone. For example, during 2002-2003, their department was involved in only one major breakwater project located in the Lake Erie region. This project required 30,000 tonnes of various sized armour stone at an average price installed of \$50.00 – 60.00/tonne. In general, only a very small amount

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of armour stone is utilized on an annual basis due to the fact that most large structures have already been built along the Great Lakes shoreline, and only limited storm damage has occurred to existing structures over the years. Within Ontario and the Great Lakes region, the largest market for small and larger pieces of stone (rough and cut-to-size) belongs to the residential and commercial landscaping business.

A similar situation exists along the US eastern seaboard, with the consumption of armour stone being relatively limited (with respect to the large population) due to the fact that there are only a small number of new marine construction projects. Most of these projects are carried out by, or supervised by, the U.S. Army Corp of Engineers, and supply of armour stone is generally from local sources. The supply and consumption of armour stone is greater in the south-eastern US where until recently the economy was booming. Armour stone has been obtained for many years from limestone quarries in Missouri and the Yucatan Peninsula, in Mexico.

### 2.2.1 Central Canada - The Great Lakes Region

According to the industrial mineral geologist with the ON Ministry of Northern Development and Mines, Myra Gerow, the bulk of armour stone produced in ON is a byproduct of existing aggregate quarries. Many of these quarries are located along the Niagara escarpment and utilize the very hard Paleozoic dolostones.

The flat-lying carbonate rocks of southern Ontario and northern Michigan are host to a number of large stone quarries; many of which are located at or near the Great Lakes. These quarries have supplied chemical-grade dolostone (dolomite) for the steel industry, limestone for the cement industry, and road aggregates.

Dolostone and limestone (also marble) quarries operated by companies such as Amsen Quarries Ltd., Bruce Peninsula Stone Ltd., Ebel Quarries Ltd., Eisen Quarries Inc., Georgian Bay Marble and Stone Inc., Haliburton Stone Works, Flamboro Quarries Ltd., Owen Sound Ledgerock Ltd., Redstone Quarries, Rockleith Quarry Ltd., and Ruby Lake Marble Ltd., each supply dimensional, armour and landscaping stone. There has no doubt been a large volume of armour stone ('oversize') sold from these quarries over

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the past years for use in breakwaters and harbour development, as rip rap for protecting shorelines and even as ‘cut-to-size’ stone for use in building the extensive canal system. However, at present, only a limited volume of armour stone is used each year for shoreline stabilization and breakwater structures in the province of ON (R. Hewitt, 2003, pers. comm.).

In addition to the carbonate rock quarries, there are numerous dimension stone producers of granite and granitic gneiss in ON (i.e., Algonquin Stone, Allstone Quarry Products Inc., Belmont Rose Granite Corp., Birkendale Granite Quarry Ltd., Boothby Quarry, Fowler Construction Co. Ltd., Fraser Quarry, Granimar Quarries Ltd., McDonald Quarry, Rock Lake Quarry, Tazzo Lake Stone, and Upper Canada Stone Co.) who sell some armour stone by-product as well as a wide range of landscaping stone, and even crushed stone aggregate from their quarry waste.

Information from southern Ontario stone producers indicates that limestone has traditionally been the preferred type of armour stone due to the less expensive production costs. However, granitic/gneissic rock is gradually gaining more recognition as a superior armour stone, despite the price. It should also be noted that in today’s market, the volume of stone sold as armour stone is minor in comparison to that sold for cut-to-size and landscaping stone. Ms. C. Proud of *Belmont Rose Granite Corp.* has indicated a large market potential for rough block, shaped stone (i.e., hydraulically split stone with rough surfaces and no drill holes), and cut-to-size stone for export into the northern US marketplace as well as central Canada. Pricing of cut-to-size products is highly competitive, with limestone priced at generally less than half that of granite.

The price for various ON armour stone and landscaping stone products is quite variable and a partial list of prices is presented in TABLE 8. The variation in prices depends upon a number of factors including the type of stone, number of hydraulically split sides, size of individual pieces, total volume of contract, and location of quarry.

**TABLE 8:** Examples of prices quoted for various Armour Stone, Cut-to-Size Stone and Decorative Landscaping Stone Products in Ontario.

Source	Rock Type	Thickness / Size	Price (per tonne) FOB
Public Works Canada - Ontario	Armour stone	>1 tonne	\$ 50.00 - 60.00 <sup>1</sup>
QE & ON (1989) <sup>2</sup>	Armour stone	unspecified	\$ 6.63 - 36.62
QE & ON (1989) <sup>2</sup>	Armour stone	unspecified	\$ 24.12 (average)
Walker Ind. – Vineland Quarries	Armour stone	3 -5 tonnes	\$ 35.00
	Rip Rap	20 – 40 cm	\$ 12.00
	Gabion stone	10 – 20 cm	\$ 13.00
Belmont Rose Granite	Granite - rough	60 x 60 x 60 cm	~ \$ 60.00
	split	60 x 60 x 90 cm	~ \$ 80.00
		60 x 60 x 122 cm	~ \$100.00
	Limestone - rough		~ \$ 25.00 - 30.00
Birkendale Granite Quarry Ltd., Muskoka, ON	Granite	4 - 6.5 cm thick blast	\$ 75.00
		1 split side	\$ 150.00
		2-3 split sides	\$ 180.00
		4 split sides	\$ 225.00
John Eisen Ltd.	Dolostone	30 cm – 50 cm	\$ 140.00 – 155.00
		< 30 cm	\$ 160.00 - 76.00
		Gabion	\$ 140.00 – 155.00
		1 tonne	\$ 140.00 – 155.00

<sup>1</sup> Average price for armour stone installed at job site (R. Hewitt, Marine Engineer, Public Works Canada).

<sup>2</sup> Range in prices of armour stone installed at job site in ON and QE during 1989 (from Carter et. al., 1989).

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### 2.2.2 United States

The United States Army Corps of Engineers (USACE) provides many government services including the planning, designing, building and operation of water resources (i.e., navigation, flood control, environmental protection etc.). The USACE has been indirectly or directly involved with shoreline projects along the U.S. Eastern Seaboard and Great Lakes regions over the last 30 years. They report that the vast majority of armour stone supplied for these projects has been sourced from the major existing stone producing centers within the USA (Y. Yatsevitch, *USACE*, pers. comm., 2003). Shoreline protection projects such as the Great Lake Basin Program and the Minnesota - Silver Cliff Shoreline Project, that were carried out during the early 1990s, reported limited use of armour stone (i.e., 2,700 m<sup>3</sup>) in the construction of rock buttresses with the stone being obtained from local construction sites.

According to Y. Yatsevitch and J. Winmill, USACE, the present yearly demand for armour stone for shoreline protection and related uses is generally low. This is due primarily to the fact that most breakwater and shoreline structures have already been built. No major projects requiring armour stone have been undertaken within the New England States in the last few years (Y. Yatsevitch, *USACE*, pers. comm., 2003). Most of the work requiring armour stone is related to small repairs and local stone suppliers meet that requirement. An increased demand for armour stone would require the occurrence of a major storm that results in significant shoreline damage. Again, it was indicated that an abundance of local suppliers with existing long term business relations are already in place to meet most foreseeable demands, particularly in the New England States region (J. Winmill, pers. comm., 2003).

A summary of the information available from the USGS regarding the national production/consumption of armour (jetty) stone, filter stone, rip rap and core (gabion) stone is presented in TABLES 9, 10 and 11. The breakdown of production by stone type shows how the lower cost of limestone is inversely related to the higher volume consumed. It is reported in phone interviews that one company alone, *Chemlime Ltd.*, sells 6 to 12 million tones/year of rip rap and armour stone to the USACE through the *Tower Rock Stone Company*. The limestone boulders are used in federal programs which include the building of artificial reefs in the Gulf of Mexico to promote the development of marine habitat for the recreation fishing industry.

**TABLE 9:** Rip Rap or Jetty Stone Sold or Used by Producers in the U.S.A for 2001.<sup>1</sup>  
(quantity in thousand metric tons, value in thousands).<sup>2</sup>

Rock Type	Quantity <sup>3</sup>	Value	Unit Value (USD / ton)
Limestone	9,890	59,400	6.00
Dolomite	301	2,450	8.14
Marble	23	206	8.96
Granite	3,380	33,700	9.97
Traprock	976	9,500	9.73
Sandstone	2,210	13,600	6.16
Quartzite	126	787	6.25
Miscellaneous	525	3,830	-

<sup>1</sup> Data compiled from [www.usgs.gov/minerals/pubs/commodity/stone\\_crushed](http://www.usgs.gov/minerals/pubs/commodity/stone_crushed)

<sup>2</sup> Data are rounded to no more than three significant digits

<sup>3</sup> Increase by 50% to incorporate reported and unspecified production without a breakdown by end use.

**TABLE 10:** Rip Rap or Jetty Stone Sold or Used by Producers in the U.S.A for 2000.<sup>1</sup>  
(quantity in thousand metric tons, value in thousands)<sup>2</sup>

Rock Type	Quantity <sup>3</sup>	Value	Unit Value (USD / ton)
Limestone	10,400	64,000	6.15
Dolomite	755	5,300	7.02
Marble	-	-	-
Granite	2,370	24,800	10.46
Traprock	1,500	13,500	9.00
Sandstone	801	8,550	10.67
Quartzite	67	502	7.49
Miscellaneous	1160	8,190	-

<sup>1</sup> Data compiled from [www.usgs.gov/minerals/pubs/commodity/stone\\_crushed](http://www.usgs.gov/minerals/pubs/commodity/stone_crushed)

<sup>2</sup> Data are rounded to no more than three significant digits

<sup>3</sup> Increase by 50% to incorporate reported and unspecified production without a breakdown by end use.

**TABLE 11:** Rip Rap or Jetty Stone Sold or Used by Producers in the U.S.A for 1999.<sup>1</sup>  
(quantity in thousand metric tons, value in thousands)<sup>2</sup>

Rock Type	Quantity <sup>3</sup>	Value	Unit Value (USD / ton)
Limestone	8,420	49,300	5.85
Dolomite	617	4,390	7.12
Marble	43	469	10.91
Granite	3,380	29,300	8.67
Traprock	1,580	13,400	8.48
Sandstone	511	5,540	10.84
Quartzite	134	1,010	7.54
Miscellaneous	300	2,060	-

<sup>1</sup> Data compiled from [www.usgs.gov/minerals/pubs/commodity/stone\\_crushed](http://www.usgs.gov/minerals/pubs/commodity/stone_crushed)

<sup>2</sup> Data are rounded to no more than three significant digits

<sup>3</sup> Increase by 50% to incorporate reported and unspecified production without a breakdown by end use.

The total production of all stone types in the USA for the years 1999-2001 is tabulated in TABLE 12. It is projected that the consumption is roughly split between the east and west coast of the USA, with 45% to each coast, and the remaining 10% being used in the Great Lakes region and the interior (i.e., river systems, dams, etc.)

**TABLE 12:** Total Rip Rap or Jetty Stone Sold or Used by Producers in the U.S.A for 2001, 2000  
and 1999.<sup>1</sup> (quantity in thousand metric tons, value in thousands)<sup>2</sup>

Year	Quantity <sup>3</sup>	Value	Unit Value (USD / ton)
2001	17,400	124,000	7.08
2000	17,100	125,000	7.33
1999	15,000	106,000	7.03

<sup>1</sup> Data compiled from [www.usgs.gov/minerals/pubs/commodity/stone\\_crushed](http://www.usgs.gov/minerals/pubs/commodity/stone_crushed)

<sup>2</sup> Data are rounded to no more than three significant digits

<sup>3</sup> Increase by 50% to incorporate reported and unspecified production without a breakdown by end use.

Note: Filler Stone prices in 2000-2001 at \$6.70 /metric ton.

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### 2.2.3 Europe

Larvik, Southern Norway

The sale of waste rock from dimension stone quarries has been carried out in Europe for 10s of years, if not longer. The most notable example is the sale of granitic dimension stone “waste” from Sweden and Norway to the south coast of England, where the soft chalk cliffs are very susceptible to weathering from wave action. It is ironic that some of the world’s most prized (and expensive) dimension stone (Blue Pearl and Emerald Pearl) is used to protect the White Cliffs of Dover from shoreline erosion! To protect these cliffs, a linear ridge of armour stone up to 10 metres high is constructed parallel to the shoreline, approximately 20 meters from the base of the cliffs. The armour stone is transported by barges which can carry up to 20,000 tonnes, and which are towed by supply ships similar to those which operate on the Grand Banks servicing the oil production platforms. The barges are beached at high tide, and then at low tide the boulders are bulldozed off the barges and later taken away by loaders for incorporation into the breakwaters. In some years, as much as 200,000 tonnes of armour stone was barged to various parts of south and east coasts of the U.K.

It should be noted that the situation in the Larvik region of Norway is unique in that there are dozens of closely spaced quarries at a reasonable distance from tidewater, which favours the economics of such an operation. Two additional points to consider are that, (i) the granite blocks being produced and sold as dimension stone command a very high price, and (ii) there is a huge problem with ‘waste rock’ because of the very close spacing of the quarries. One of the authors (SMD) visited the Larvik region in 2000, and was told by one quarrier that the sale of the armour stone reduces the quarry waste piles; however, the price merely covers the transportation costs.

One of the largest suppliers of armour stone in northern Europe, *Woodstock Deering Ltd.*, has indicated that for armour stone, they obtain ~300,000 tonnes from Larvik, Norway; ~50,000 tonnes from France and ~100,000 tonnes from inland quarries. This company charges around the equivalent of \$ 68.00 CDN delivered cost for armour stone. The main markets are coastal defence with occasional jetty and breakwater contracts. The main product size is 3 to 10 tonne pieces.



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United Kingdom

Armour stone is produced as a byproduct from granite quarries on the Cornwall Peninsula, in southwestern England. The quarries are operated by *Imerys Minerals Ltd.*, formerly *English China Clays (ECC) International*. It is somewhat surprising that these quarries are used because they are in kaolinized granite (*hydrothermally altered granite*), that are quarried to supply soft kaolin clay to the fine china market. The kaolin is separated from the granite under extremely high water pressure (hydraulic mining) allowing the producers to advertise their granite as being “washed”. The waste granite is then sorted by size and shape using an excavator, and separated into 5 basic sizes: rip rap, 1–3 tonnes, 3–6 tonnes, 6–10 tonnes, and greater than 10 tonnes. The company reports output in the range of 500 to 1000 tonnes per day, and they transport their stone either by truck, or by truck and ‘sea freight’. Despite the fact that the granite armour stone is a by-product from a successful kaolin operation, it still faces stiff competition for coastal work projects in southern England from the waste granite armour stone from Larvik.

### 3 MARKETS

The markets for armour stone are difficult to assess with complete confidence. There are many reasons, but probably the greatest factor is the lumping of different sizes of stones into one category when reporting stone consumption for construction projects. Also, reported project requirements change in the middle of some projects due to a lack of available large size armour stone. Production statistics on stone kept by governments are not always well defined, with armour stone often not separated from other types of stone such as rip rap and the all encompassing term “rubble” (see definitions). In fairness to government record keepers, the quarries that supply the statistics do not always report the oversize stone that accumulates in piles off to the edge of their production areas, and sales may not be reported accurately. Finally, there are conflicting reports from the marketplace itself on whether there is a growing demand, a lack of demand, or a lack of supply for large pieces of armour stone in marine construction projects.

#### 3.1 Current Markets Overview

The market for armour stone consists mostly of contracts to build public infrastructure that is funded either directly or indirectly through government. In many ways this market can be compared to that for

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road construction, (i.e., the market does not have a large consumer driven component). Instead, the market expands and contracts in response to the presence or absence of government's large, multiyear infrastructure programs, such as the US government's Transportation Equity Act for the 21<sup>st</sup> Century (TEA-21). There are occasions where large weather events impact negatively on existing infrastructure and a federal or regional government may dedicate new funds to rebuild or replace damaged structures. As an example, the recent (i.e., April 2003) storm damage to road and bridge structures in western Newfoundland resulted in repair costs estimated to range in the order of \$3,000,000 dollars. Storm events are even more dramatic in coastal environments, and the various hurricanes that batter Florida and the Gulf coastline cause damage in the range of 100s of millions of dollars.

The building and maintenance of coastal facilities, harbours, marinas, breakwaters, and shore protection structures is often planned years in advance. Therefore, it is critical to constantly research for new and proposed projects and become a registered vendor for the various organizations such as port authorities or provincial and state transportation departments. In the US, in order to be awarded a federal contract, all contractors doing business with the federal government (such as with the Corp. of Engineers) must be registered in the Central Contractor Registration (CCR). The CCR web site is <http://www.ccr.gov>.

There are numerous construction associations that publish weekly bulletins or newsletters that will notify members of upcoming tenders, requests for proposals (RFPs), etc., (e.g., Newfoundland and Labrador Construction Association). The internet is used extensively to publicize projects and bids, and registered vendors can perform most functions on the relevant web site such as downloading bid documents (generally, only registered vendors can download bid documents) and submit questions about an invitation to the project manager. In many cases, if bid documents are downloaded for a solicitation, the company will automatically receive e-mail notification when the bid results and contract award are posted. In addition, registered vendors will automatically be notified of new business opportunities that match their capabilities as outlined in their registration.

There is a small landscaping market for armour stone about which it is difficult to find details. This market is consumer driven and it has strong regional variations. There is a limited demand for large or unusual shaped pieces of stone for high-end construction projects and residences. There is even a unique vocabulary for these products with descriptive names like "waterfall stone".

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The potential for unique armour stone markets (e.g., large cut-to-size, stackable blocks, unique naturally weathered / sculptured boulders for landscaping, etc.) is difficult to assess. According to Ms. C. Proud, *Belmont Rose Granite Corp.*, there exists a vast market for the sale of cut-to-size and unique landscaping stone pieces into the US and central Canada. However, information from Mr. C. Johnson, a US stone marketing specialist, indicates that the demand for this type of product seems to be infrequent and therefore, it would be a hard market to develop. Representatives from *Stone World* magazine were interviewed by Mr. C. Johnson during the recent “Coverings” trade show held in Florida during March, 2003. They indicated that examples of large stone landscaping pieces they had seen were very rare, and usually sourced only from local suppliers given the freight constraints. They also felt that the price would be too low since there was no large value-added component through manufacturing expertise, and that the cost of long distance freight would make it non-competitive with local sources of similar stone product. The overall opinion from a marketing perspective is that this type of stone product is a relatively rare item because there are either no sales people out there pushing this type of item, or there is so small a demand for it.

The use of smaller cut-to-size stone pieces and various sized rough slabs and wall rock for use in residential and commercial landscaping projects has been on the rise for the past decade. Although a review of the supply and demand for landscaping stone is beyond the scope of this study, it is interesting to note that local NL producers of landscaping stone are currently marketing their product to other parts of Canada.

### **3.1.1 Newfoundland and Labrador**

In NL, the market for armour stone is small, being as little as 50,000 tonnes per year. The statistics are open to interpretation depending on how one breaks down the Federal tonnages quoted for Atlantic Canada (which are reported together), and how one separates out the statistics on the types of stone used by the NL Department of Works, Services and Transportation (WST), (that is, armour, filter, and core stone are often reported together, along with rip rap). However, even if the total market doubled by including all types of stone, it is still a small market. Add to this the lack of ability for one quarry to supply the two dozen or more projects scattered around the province, and there does not appear to be a

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provincial market with enough demand to warrant a large quarry operation. The types of projects in NL are mostly breakwater construction and wharf construction and repair (see TABLE 5).

### 3.1.2 Maritime Canada

In NS, the market for armour stone is approximately 50,000 tonnes per year and in NB the market is approximately 10,000 tonnes per year. Both of these estimates are from provincial statistics. It is estimated that PEI has a market demand somewhere in between the two other provinces. Thus in terms of export markets for NL armour stone suppliers, the Maritimes does not appear to have great potential. There is also the problem of widely dispersed marine construction projects and local construction companies most likely have the ability, and a decided transport advantage, in filling these markets.

With respect to competing with the Maritimes for export markets, there are two issues. The first is the transportation distance to market, and this is addressed in Section 4. The other issue relates to the fact that the largest quarry in NS supplying export markets is owned by an American company, *Martin Marietta*. This creates a very competitive synergy when bidding on contracts in the US and it allows the company to take advantage of unloading and distribution markets already in place.

There is a large new quarry in NB at Bayside, near St. Andrews on the Bay of Fundy, and a proposed quarry on the opposite side of the bay at Digby Neck, NS. Both of these sites have excellent igneous rock from which to make armour stone and they would have transportation advantages when addressing markets to the south. Armour stone is not being sold from the Bay of Fundy region into the US at this time.

### 3.1.3 Central Canada and the Great Lakes Region

The demand for armour stone in central Canada is not large. In ON, and throughout the Great Lakes region, most of the necessary harbour development and breakwater construction has been carried out over the last 100 years. There are demands for maintenance and repairs after storms, but as indicated in the

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Section 2, there is sufficient supply of oversize byproduct from a variety of aggregate and landscaping operations to meet the local demand.

There is a modest to strong demand for landscaping stone of all shapes and sizes, and for cut-to-size stone in central Canada. However, there are currently three dozen producers of granite, marble, limestone, and/or dolostone supplying some combination of landscaping stone, cut-to-size stone, and armour stone in ON. The potential demand for cut-to-size stone for carrying out maintenance work along canals and waterways in ON is very small. The current strategy for maintaining shorelines along inland waterways is to use bioengineering techniques (basically vegetation) or lay rip rap over geotextile fabric and maintain the existing slopes. Studies have shown that vertical walls have much higher potential to degrade, they reduce fish habitat, and they reflect wave energy back into the waterway, often with an erosive effect which may lead to undermining of the wall itself.

There is a market in QE for a limited amount of armour stone for marine structures along the St. Lawrence River, Gaspé Peninsula, and the north shore of the Gulf of St. Lawrence. However, it is very difficult to get access to QE government contracts as there is a strong preference to use local suppliers, and there are numerous granite quarries along the St. Lawrence valley with abundant reserves of waste rock.

#### **3.1.4 Markets in the United States**

Initially, it was postulated that there could be excellent potential for a significant increase in the use of armour stone and rip rap on the US eastern seaboard to protect against the erosion of shorelines. This assumption was made because of the perceived increase in number of intense seasonal storms coupled with the increase in coastal development. The increase in urban development along coastlines, particularly resorts and private residences is illustrated by a 2002 study that showed an average of 3,600 people in the US move to the coast every day (Erosion Control magazine, Forester Publication, G. Northcutt, 2002). This study also pointed out that the development in high-risk coastal areas increased more than 60% over the last 20 years. This increased development leads to increased problems associated with shoreline erosion. The problem is further enhanced by the relatively flat profile of the Atlantic Coast of the US and the fact that the Atlantic Ocean is in places rising gradually at a rate of approximately 2 mm a year.

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Shorelines are temporary geological features that undergo gradual seasonal changes and rapid storm-related changes. Initially, the sediment (clay and sand) is carried from inland to the ocean by the flow of rivers (if there are no dams) and then transported parallel to coastlines by wave-driven currents. Sand can be carried out to deepwater in the winter and washed back in to shallow water in the summer. Nature establishes a temporary equilibrium that gradually modifies with time. Such is the dynamic nature of coastal systems. When ‘hard structures’ are built to prevent erosion (i.e., to protect private property or roads), the natural processes are interrupted and a new equilibrium is established. Unfortunately the desired results are not often achieved, and it has been well documented that the erosive forces are often just refocused to a different area, sometimes with much worse results.

The increased understanding of coastal processes and awareness of how man’s structures affect these processes has dramatically changed the response to coastal erosion. In Florida, the response is no longer to build more breakwaters in order to try and preserve beaches and protect private residences or resort properties. Instead, beach nourishment programs have been developed whereby sand is brought in to rebuild the eroded beach. This process works best in coastal areas where beach erosion is modest. However, it does not guarantee long-term survival of a beach. The Florida legislature is investing \$30 million a year in these types of programs. It should also be noted that the states of Maine and North Carolina have now banned the use of engineered hard structures to control the erosion of shorelines. Alternatives to the use of natural rock armour stone are presented below.

It was also noted by personnel from the USACE that there is distinct decrease in the demand for new structures to be built along the US eastern seaboard for harbour protection. Harbour development is at a mature phase with most of the requirements having been met in previous decades. The largest demands now are for shoreline erosion control using alternatives to hard structures, and the dredging of existing harbours and inland waterways.

There are some demands for hard structures along the southern Gulf coastline but these demands are more often for the construction of artificial reefs to improve marine habitat and create opportunities for recreational diving enthusiasts. The stone for artificial reef work is sourced from large US industrial mineral producers like *Vulcan Minerals* who have quarries on the Yucatan Peninsula. It was also reported by the US Geological Survey (V. Trepordi, pers. comm., March, 2003) that there is considerable transport

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of aggregate, and to a lesser degree rip rap and armour stone, by barge downstream along the Missouri and Mississippi River systems. The armour stone companies often make use of favorable backhaul rates from barges that have carried product “upstream”.

### 3.1.5 European Markets

The market demand for armour stone in Europe is for shoreline erosion control, as discussed in Section 2.2.3. There is additional demand for stonework along inland waterways, especially canal systems in the Netherlands. Irish limestone is marketed in the form of cut-to-size pieces for work along these canal systems.

## 3.2 Alternatives to Natural Rock Armour Stone

There are many alternatives to using natural rock armour stone for the protection of shorelines from erosion. Where the shoreline slope is low and wave or current action is weak to moderate, it is possible to use bioengineering techniques. These may include the construction of temporary wave barriers to promote re-vegetation, and the creation of oyster reefs which will act as natural wave breaks. In contrast to low slope rip rap revetments, these techniques absorb or dampen wave activity as opposed to reflecting wave energy. However their use is limited to moderate and low energy environments, as would be the case inside of barrier reef complexes along inland waterways to protect against ship’s wakes, etc.

Beach nourishment programs have already been mentioned as alternatives to hard structures. Sand trucked in from afar, or dredged from offshore waters, can help restore eroded beaches, and help create near shore sand mounds/bars which can dampen wave and current activity. These programs serve a useful purpose in coastal areas where communities rely heavily on the tourist trade for their financial wellbeing. They are, however, very controversial as millions of dollar’s worth of sand can be swept away in one storm event. Beach nourishment programs are practical approaches for maintaining shorelines in areas where there are large-volume dredging programs which can be used to supply sand. This is the case in Texas where approximately 40 million m<sup>3</sup> of sand is annually dredged from navigational channels.

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A unique beach preserving technique that competes with nourishment programs is called beach face dewatering. This concept involves installation of a network of buried pipes and a pumping system to artificially lower the water table in the beach. When waves impact on the beach, the water drains down through the sand rather than washing back out to the ocean. This reduces erosion and can actually cause beach accretion in some instances in the Caribbean.

Undercurrent stabilizing systems are also used to protect, or even restore eroded coastlines. In principal, this technique involves altering the dynamics of underwater currents by placing structures perpendicular to the coastline of lakes and oceans to create low energy beaches. These systems may consist of geotextile tubes filled with sand or concrete, or one of many types of concrete structures that will dampen current and/or wave activity. The stabilizers may extend out from the beach for 100 m or more, and vary according to the local wave and current dynamics.

The greatest competition for natural rock armour stone comes from a variety of concrete structures that were largely designed by the USACE, but also some that came out of private company investigations. The USACE has carried out studies for decades to address the ongoing maintenance problems, as well as the occasional complete failure, of structures constructed from natural rock armour stone. One of the major issues is the movement of large rocks during storm conditions. The manmade armour was designed with the concept of being able to make the pieces interlock to some degree, or even form large mats tied together with cables. Early concrete structures (i.e., tetrapods, tribars, and dolos) were sometimes reinforced with steel rebar but met with limited success due to breakage or movement of pieces. Dolos, or large dolosse structures were designed to be placed on the moderate to steep slopes in a partially interlocking fashion. The individual devices look like a pair of giant interlocking concrete crosses, forming a structure up to 3.5 m high and weighing 15 tonnes. However these structures tended to rock in storm conditions, creating sufficient stress to cause breakage of the long slender concrete legs.

Core-Loc concrete structures are an evolution of the dolosse structure, and are designed to be laid right over top of the dolosse when necessary. These multi-legged structures are an improvement over dolosse as they have an extra 'fluke' or arm, and very much resemble giant concrete jacks (PLATE 2). The extra fluke gives the structure extra weight and strength, is a little bit shorter, and the Core-Loc structure does not require steel reinforcing bars. Despite the "open nature" of these concrete structures, they can still





PLATE 2: Multi-legged, massive concrete shore protection armour stone units fronting a resort in Japan.

weigh in the range of 10 to 20 tonnes, although smaller ones are certainly being tested. Initial tests on the large structures have shown that they do not rock in strong wave action, and just a single layer of these Core-Loc pieces can sufficiently armour the underlying breakwater to protect it from erosion. This single layer concept is touted as a major cost savings over other concrete structures.

A company in Kentucky called *Armortec*, also produces similar concrete structures called A-Jacks. They are essentially the same type of erosion control device but they are more aggressively marketed and have a wide range of sizes. A 60-cm-high A-jack weighs less than a tonne and costs approximately \$150, and is used in stream and river bank protection. Larger 3-meter-high A-jacks weighing 5 tonnes are used in very high energy environments, they can be also stacked on each other or on older structures. In comparison to solid, natural rock armour stone, the open structure of A-Jacks (and Core-Loc) is beneficial for the

development aquatic life habitat. *Armortec* also produces ArmorFlex articulating concrete block (ACB) mats, for quick installation over uneven terrain and pipes, such as sewage outflows, and for shoreline protection and bank stabilization. These mats consist of kiln-dried concrete blocks (similar looking to those that are used in wall construction for warehouses and basements) that are specially coated, and then laced together with polyester cable. They are flexible units, can be sized for individual jobs, and can be vegetated.

The negative features for these concrete structures are the fact that they are expensive, with costs depending on the construction parameters. A construction yard is needed along with access to raw materials for the production high quality concrete that is resistant to saltwater conditions. The forms for the Core-Loc are expensive and the fabrication is labor intensive. Handling of these structures is more delicate than armour stone as they must be carefully placed to avoid initial breakage, and located to provide uniform coverage of the area to be protected.

## **4 TRANSPORTATION AND HANDLING OF ARMOUR STONE**

The costs involved in the economic transportation of armour stone from the quarry site to the port of loading can be divided into two primary stages:

- (1) the inland costs associated with loading, transporting and unloading the armour stone from the site of origin in the quarry to the dockside or stockpile, and
- (2) the shipping related costs of loading the vessel, steaming and discharging the armour stone at the port of destination.

### **4.1 Inland Costs of Transporting Armour Stone from Quarry to Loading Port**

The costs incurred during the movement of the armour stone from the quarry to a designated place for stockpiling can be divided into two main components: (1) the major costs associated with the loading and unloading the armour stone boulders for storage/stockpiling, and (2) the lesser costs involved in the actual trucking of the boulders from quarry to stockpile (near dockside).

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It is assumed that the shipping vessel will be capable of self-loading the armour stone and that this cost is part of the freight rate.

#### **4.1.1 Estimated Cost of Loading and Unloading Armour Stone**

The armour stone is generally loaded on to a flatbed or high-bed truck with a strengthened deck and attached cradle built to prevent the stone from rolling during transportation. The trucks typically carry loads of up to 30 tonnes; composed of 2 or 3 large, 3 to 6 medium, or up to 10 small boulders. The larger boulders are loaded by using a crane or with a large excavator equipped with a hydraulic thumb (orange peeler) on its bucket, which prevents the boulder from rolling out and eliminates the need for chains or straps. The smaller riprap armour stone (i.e., rock pieces up to 30 cm-60 cm in length) is typically loaded with a bucket attached to a 30-tonne machine. The information from contractors in the business of supplying armour stone has indicated a range in the cost of loading and unloading armour stone from between \$6.00 and \$10.00 per tonne. One contractor indicated a high price of \$16.00 per tonne to load/unload. Basically, the more organized the operation is the lower the cost to load/unload.

#### **4.1.2 Estimated Cost of Transporting the Armour Stone from Quarry to Port**

Once the armour stone is loaded on to the high-bed truck, the costs involved in trucking the material to the dock or stockpile area will depend upon: (a) total distance to haul, (b) time it takes to unload, and (c) the total tonnage of the contract (i.e., larger contracts can result in a lower overall rate). The trucking rate can be calculated as the price per tonne per km or as an hourly rate. The information from two of the main experienced local trucking firms indicates trucking rates in the range of \$65.00 / hour plus a 4% to 15% fuel charge. Given a trucking rate (including fuel costs) of \$71.50 / hour, a 10 km trip (20 km round trip), traveling between 65-80 km per hr, with a 40 minute loading/unloading time, carrying a load of 30 tonnes; would give an approximate rate of \$0.25/tonne/km. Similarly a distance (quarry to port) of 20 km would yield a rate of \$0.16/tonne/km, and a distance of 30 km would yield a rate of \$0.13/tonne/km.

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## 4.2 Provincial Ports Suitable for Armour Stone Export

The vast coastline exposures and the correspondingly large numbers of various sized ports which are situated all along the shorelines of NL would seem to indicate a relative ease in locating adequate sites for unloading, stockpiling and loading volumes of armour stone destined for export via ship or barge to foreign markets.

The research conducted during this present study has, however, indicated that only a few of these ports contain the array of optimum conditions required to support the stockpiling and efficient loading of materials for an economically feasible, large-scale armour stone operation.

### 4.2.1 Requirements of Port Infrastructure to Support Armour Stone Export

A number of specific port criteria must be met in order to provide the type of facility needed to allow for the economic stockpiling and loading of armour stone. These preferred conditions include, but are not limited to:

- (1) proximity to significant potential armour stone deposits
- (2) sufficient length and width of wharf or finger pier to accommodate the berthing of large sized (>10,000 tons load capacity) barge or bulk cargo ship, and the movements of heavy equipment to deposit materials at dockside for loading
- (3) sufficient low tide water depths (draft) to easily accommodate large vessels
- (4) adequate wharf load capacity to accommodate loading of vessel at dockside
- (5) sufficient proximal lay-down area for stockpiling of armour stone prior to commencement of loading on vessel
- (6) proximity to major shipping lanes to provide better opportunity for connection with available bulk carriers or barge tugs
- (7) the use of an ice-free harbour facility is critical if shipment is required during the winter season

(8) adequate road access for easy and safe transport of armour stone from the quarry site, through any existing population centers, to the lay-down area

#### 4.2.2 Newfoundland Ports Most Strategically Suited for Armour Stone Export

Information obtained during interviews with representatives of Transport Canada, Small Craft Harbours, Canadian Coastguard and private wharf operators indicates that the list of NL ports most capable of providing the necessary conditions to support the economical export of armour stone would include (from west to east): (1) Stephenville, (2) Corner Brook, (3) Botwood, (4) Long Harbour, (5) Long Pond, and (6) Argentia (refer to FIGURE 2 and TABLE 13). Geographical positioning of these ports covers the west, central, and east coast of NL (FIGURE 2). The coast of Labrador is currently very limited as a potential locale for armour stone shipment due to the lack of adequate port infrastructure and the short ice-free shipping season. The only exception to this case might be the potential to export armour stone by barge from the *LIDC's* Ten Mile Bay quarry site.

The conversations with authorized representatives from each of the six main ports indicates that the management in each of these port authorities would be actively supportive of any proposed business involving armour stone stockpiling and shipment from their respective facilities. The only exception to this would be the port of Corner Brook where there is limited storage available along the loading dock, and where associated stevedoring costs would be incurred.

A summary of the positive factors for each major port is presented as follows (also refer to TABLE 13):

##### (1) Port of Stephenville

The Port Harmon / Stephenville Port is currently in the process of divestiture from Transport Canada to a privately run Port Harmon Port Authority. The Port of Stephenville would provide a very favorable site for potential armour stone export. The existing infrastructure is excellent, with a high load capacity wharf measuring 293 m x 19 m in top surface, and an immediately adjacent 6500 m<sup>2</sup> storage area for stockpiling

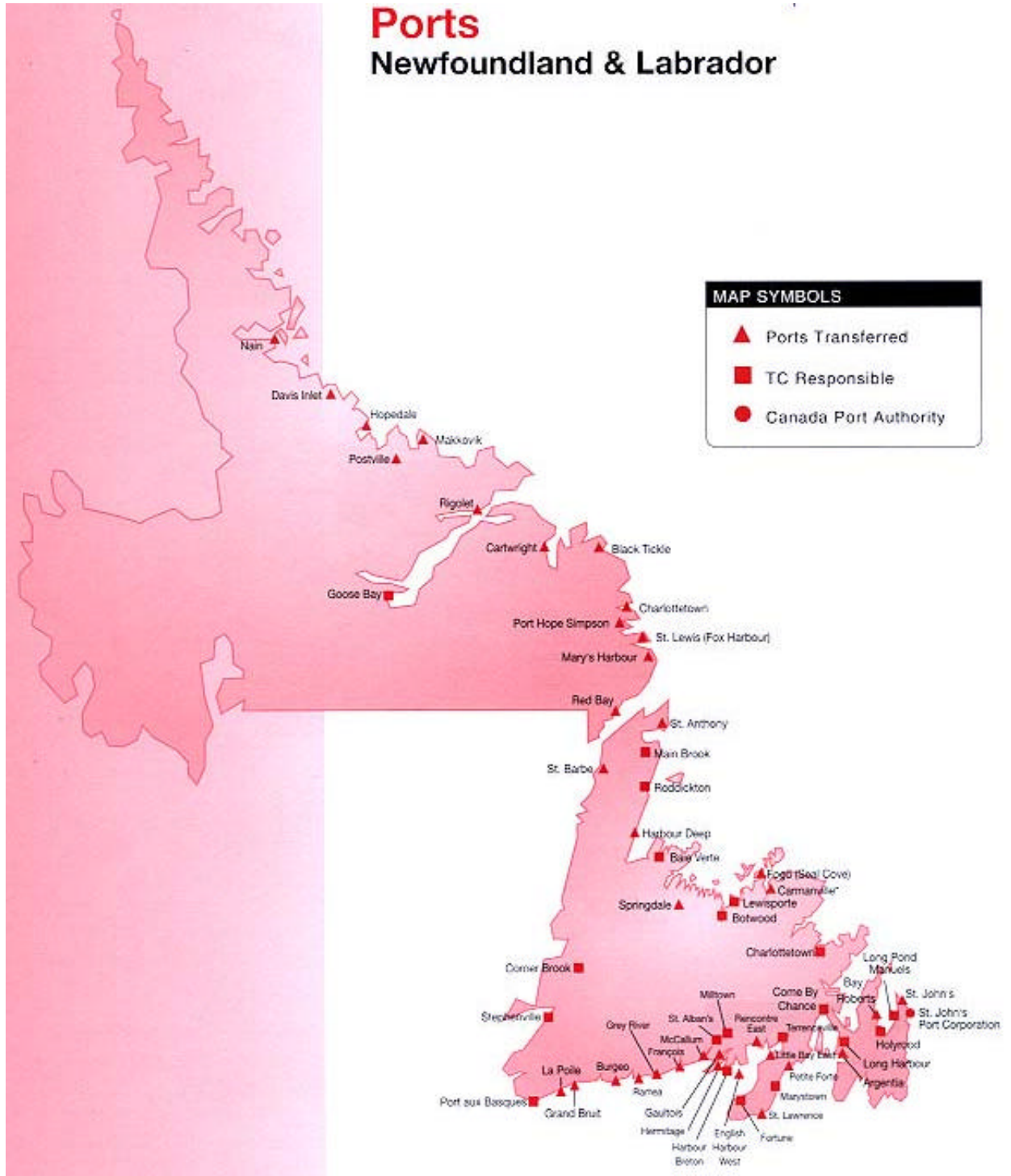


FIGURE 2: Location map of ports throughout Newfoundland and Labrador.

**TABLE 13:** Ports Suitable for Armour Stone Stockpiling and Loading in Newfoundland.

Port	Ownership	Infrastructure
Stephenville	Transport Canada*	Pending transfer to private ownership; wharf (293 m length x 19 m width), storage 6500 m <sup>2</sup> , load capacity MS 250-24 kPa, draft 7.8-9.1 m
Corner Brook	Transport Canada*	Wharf (361 m length x 25-85 m width), load capacity MS 250-50 kPa, two-220 ton cranes, winter ice, draft 9.1 m
Botwood	Transport Canada*	Transit wharf (83 m length x 32 m width), load capacity -MS 150-24 kPa , draft 7.4 m; Oil dock finger pier (45.7 m length x 10 m width – some restricted area), load capacity – MS 150-10 kPa, minimum draft 5.9 m; old ASARCO wharf unsafe; some winter ice, upstream lay down, non-unionized.
Long Harbour	Long Harbour Dev. Corp. (leased to Mahers Rigg Services Ltd.)	Wharf (Berth 1 – 204 m x 19.2 m, 13 m draft; Berth 2 – 198 m x 19.2 m, 13 m draft; Berth 3 – 160 m x 19.4 m, 10 m draft), accommodate ships up to 290 m and 70,000 tons, heavy load capacity, private, large lay-down area, ice free
Long Pond	Transport Canada*	Wharf (245 m length x 13 m width), load capacity, one-220 ton crane, no lay-down area, load capacity MS 250-24 kPa, adjacent private land , and draft 7.0-8.2 m
Argentia	Argentia Port Corp.	Fleet Dock: Berth 1 – 150 m x 70 m, Berth 2 – 155 m x 70 m, Heavy-lift pad up to 200 ton capacity, 11 m draft; Navy Dock: Berth 8- 105 m length, Berth 9 – 105 m length, draft 7.4-11.0 m; ice free harbour, non-unionized, vessels up to 200 m.
Ten Mile Bay	LIDC	Wharf suitable for large barge, large capacity crane, production of armour stone in quarry adjacent to wharf

\* In accordance with the Federal Government's National Marine Policy, Transport Canada is pursuing the transfer of ownership of these ports to local interests.

Note: MS 150 (GVWt 27,500 kg) 2500 kg/m<sup>3</sup> (500)UDL

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of armour stone materials. The low tide water depths range 7.8 m – 9.1 m. The port has a long history of bulk cargo transportation, good road access, is non-unionized, and is located close to an established armour stone deposit (Indian Head anorthosite). A representative from the new port authority indicated that any new business, such as regular or episodic stockpiling and shipment of armour stone, would be strongly supported and actively pursued.

### (2) Port of Corner Brook

The Port of Corner Brook is operated by Transport Canada and would provide a favorable facility for limited shipment of limestone and marble armour stone from this west coast city. This containerized port has a high load capacity, large wharf (i.e., 361 m in length x 25 m to 85 m in width) that provides superb berthing for multiple large vessels. The low tide water depth is 9.1 m. Two large 220-ton cranes are available on site. Limited stockpiling of granite gang saw blocks (up to 25 tonnes) has occurred on site in the recent past. Several shipments of marble armour stone, obtained from the old cement quarry located just above Corner Brook, were shipped through the port last fall for *Atlantic Minerals Ltd.* enroute to Charleston, South Carolina. The limited access of proximal storage space, extra costs associated with stevedoring, and the variable winter ice conditions need to be considered in accessing the regular scheduled use of this port for armour stone export.

### (3) Port of Botwood

The port of Botwood has experienced a long history of shipping bulk and break bulk cargo (i.e., newsprint, mineral ore and oil). Presently, there is little activity at the port. A marketing study charting the course for port development stated in 1991 that the major deficiencies at the port included shallow water depth, limited fenced lay-down area, and generally poor wharf conditions. Transport Canada representatives have indicated that the Transit wharf (83 m length x 32 m width) has a limited load capacity, shallow draft at 7.4 m and is in moderate to poor condition, requiring a significant upgrade. The Oil dock finger pier (45.7 m length x 10 m width) has very limited load capacity with a restricted area and draft of only 5.9 m. The old *ASARCO* wharf is considered unsafe. The work force is non-unionized and there is both proximity to a storage area and good road access to the port. However, the often heavy winter ice conditions in the harbour as well as in the outer Notre Dame Bay area necessitates ice breaker support for shipping. The port of Botwood would be strategically located for shipment of rough and cut-to-size armour stone from the from *International Granite Corporation's* Jumpers Brook gabbro quarries



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which are located approximately 25 km south of Botwood. The shipment of armour stone from the port of Botwood would best be suited to tug and barge given the present wharf and draft conditions.

#### (4) Port of Long Harbour

The port of Long Harbour is well situated to provide an excellent ice-free port facility for large volume export of armour stone. The wharf is owned by the *Long Harbour Development Corp.* and leased for 99 years to *Mahers Riggs Services Ltd.* The site was originally developed for bulk shipment of phosphorous from the *ERCO* plant. The finger dock facility can accommodate ships up to 290 m in length and 70,000 tons. Water depths range 9.1-13.0 m. The wharf was constructed with concrete caisson and concrete deck to support a heavy load capacity (300 psi). A large lay-down area occurs adjacent to the wharf. Potential sources of good quality armour stone were identified by D. Bragg (pers. comm., 2003) in the Big Head and Bull Arm Formations of the Musgravetown Group located in the general vicinity of Long Harbour as well as proximal to the wharf facility. A representative of *Mahers Riggs Services Ltd.* indicated that the facility is in excellent condition and currently in active use for large vessel loading/unloading and servicing. The company has been in contact with large quarry operators (e.g., *LaFarge*) and the facility is available for shipment of armour stone.

#### (5) Port of Long Pond – Manuels

The Transport Canada controlled port of Long Pond has sufficient water depth (i.e., 7.0-8.2 m) and long wharf (e.g., 245 m length x 13 m width) to accommodate multiple vessels and local usage. The wharf structure is rated for heavy load capacity and one-220 ton crane is available for loading. The port has a history of handling bulk commodities (i.e., feed grain, crushed rock, lumber, road salt); however, there is no lay-down area for stockpiling armour stone and winter ice conditions can negatively affect shipping. Land located adjacent to the facility is privately owned and might be available for lease/sale. Rocks of the Conception Group, Holyrood Pluton and Harbour Main volcanics, which outcrop in the vicinity of Long Pond – Manuels, have been rated as potential sources of armour stone (D. Bragg, pers. comm., 2003).

#### (6) Port of Argentia

Argentia is a well developed containerized port with existing facilities to service bulk cargo. The port provides an excellent facility for potential armour stone storage and loading with its ice-free harbour,

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deep draft (7.4 m – 11.0 m), large wharf space with 4 berths that can accommodate vessels up to 200 m in length and 55,000 tons, heavy load capacity, abundant storage area, and good road access. These facilities combined with the proximity to potential good quality armour stone deposits rates Argentia as a very favorable port for armour stone export. Break bulk carriers, presently delivering 20-35 tonne blocks of granite to the Argentia-based *Epoch Rock Inc.* gang saw plant, may potentially offer favorable back-haul rates. However, an extremely well co-coordinated scheduling of block delivery and armour stone loading would be imperative.

#### 4.2.3 Newfoundland Ports Less Suited for Armour Stone Export

The remainder of Newfoundland's ports were determined to be either less suited or having no possible sites for potential armour stone export. The main reasons are summarized in the following:

(1) The numerous harbour facilities controlled under Small Craft Harbours, Department of Fisheries and Oceans (DFO) do not appear to have potential for armour stone storage and/or loading. Conversations with various representatives from DFO indicate that the characteristically limited wharf size, small load capacity, and continuous usage by local fisherman, combined with limited to non-existent upland storage and restricted road access, are factors which taken together essentially eliminate many of these ports. In addition, there was a strong overall negative opinion expressed by representatives from DFO (Small Craft Harbours) on the potential use of these harbor facilities for anything outside of the fishing industry.

(2) The port of St. John's has a limited accessible stockpiling area that is already in use by container shipping companies, ship repair and maintenance companies, and ship supply companies. Road access would require that heavily loaded transport trucks drive through congested areas that are already often fighting the heavy flow of commercial traffic. Large vessels would also incur extra costs due to requirements for a harbour pilot to guide the ship through the Narrows.

(3) The Bull Arm – Mosquito Cove site, which is operated by the Bull Arm Site Corporation (Government), has indicated that the entire top-side area, including wharves and access road, will soon be leased to *M&M Engineering Ltd.* and *G.J. Cahill & Co. Ltd.* for a one-year contract with potential

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extension. This site may have potential if stone adjacent to the docking facilities could be used, and if a satisfactory working arrangement could be negotiated with the unionized facility.

(4) The existing wharf at St. Lawrence, which is owned by *Grand Atlantic Seafoods*, has a limited load capacity, narrow width and is limited to vessels <6,000 tonnes. Of interest is the current plan by *Burin Minerals* and future partner, to build a large loading facility just outside of St. Lawrence, in the Blue Beach area. This facility would provide a deep water port with a capacity for 45,000 tonne vessels. *Burin Minerals* has indicated plans to open pit as well as underground mine fluorite with the potential to stockpile the waste granite for use as armour stone for future shipment to a suitable market.

(5) Come By Chance and Holyrood handle only bulk fuel shipments.

(6) Charlottetown has a high load capacity due to the mass crib structure. However, the approach is narrow (i.e., 7.6 m) and depths are shallow (i.e., 6.4 m) with a large rock off the end of the wharf.

(7) *Glovertown Marine Limited* controls the wharf facilities at Glovertown and does provide barge storage to the *LIDC*. However, the facility is limited to 100-foot-long vessels and there is a limited wharf size, shallow draft at 7.6 m. and winter ice conditions.

(8) The Port of Lewisport is unionized and the workforce is primarily focused upon *Marine Atlantic Ltd.*, although that is changing with government's intention to use a southern Labrador ports to service Labrador. The site has a very narrow lay-down area so as to require stockpiling and moving of the stone at time of vessel loading. The transport of rock through the town could be an issue and the winter ice conditions could restrict shipping to less than 9 months.

(9) The Transport Canada controlled ports of Roddickton and Main Brook, on the Northern Peninsula, have been the sites for loading industrial minerals. However, both ports have load restrictions and relatively shallow drafts (i.e., Roddickton - 5.1 m – 6.7 m and Main Brook - 7.6 m). The extra shipping distances from this area to markets in the USA and winter freeze-up are major constraints.

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(10) The port of Port aux Basques is owned by *Marine Atlantic Ltd.*, and formerly provided space and docking privileges to Hope Brook Mines. There is no storage area at the terminal and the docking of any ships would have to fit within the busy ferry schedule.

### **4.3 Costs of Bulk Shipment of Armour Stone to Discharge Port**

#### **4.3.1 Introduction to Estimating Costs of Shipping Armour Stone**

The two types of vessels that are best suited for transporting armour stone are: (i) a bulk carrier (ship), and (ii) a tug and barge. Both of these vessel types can carry their own cranes which can be used to load and unload the cargo (at extra cost), but it is more likely that a ship would have the ability to load and discharge armour stone.

A ship owner or the operator of a tug and barge calculates a rate to move the armour stone based upon two primary factors: (a) the length of the voyage, and (b) the costs incurred during the voyage. In calculating the estimated costs, the vessel owner considers how long it will take to:

- (1) get to the port in which the armour stone will be loaded
- (2) load the armour stone
- (3) navigate to the discharge port, taking into account the weather the vessel is likely to encounter during the voyage (season)
- (4) unload the armour stone at port of discharge

Once these various time factors are estimated, the vessel owner then multiplies the number of days the vessel will be in service by the daily cost of the vessel and the daily cost of fuel. To this amount, the vessel owner then adds the port costs at both the load and discharge ports, as well as any other costs associated with the voyage (i.e., extra insurance if there is a risk of ice conditions).

The rate per tonne for carrying the armour stone is then calculated by dividing the total of these costs by the quantity of armour stone the vessel expects to carry.

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An armour stone exporter can control some of these variables, and thereby reduce the cost of water transportation by:

- (1) being flexible in the loading dates to take advantage of any suitable vessel that may be nearby (advantage of proximity to ports where suitable ships unload their cargoes)
- (2) avoiding the November to April period when the weather and ice conditions in the Gulf of St. Lawrence and the North Atlantic can be at their worst (depends upon timing of demand at discharge port) – some NL ports are not “ice free” so there may be additional insurance when using those ports
- (3) making sure that all of the armour stone is ready and waiting on or immediately adjacent to the dockside before the vessel arrives (efficient loading reduces costs)
- (4) making sure that the dock is in good condition, that dock surface protection (i.e., layer of sand and gravel, cover plate) is in place prior to vessel arrival, and that any shore equipment required for loading is on the dock and properly serviced before the vessel arrives in port.

The NL armour stone shipper can minimize his ocean freight costs by making sure that there are no delays in loading the ship because: (a) of running out of armour stone to load, (b) the shore equipment needed to load the armour stone breaks down, or (c) there are “hidden” extra charges levied on the ship or its cargo, perhaps by the port authorities.

If an armour stone exporter can find a ship owner who has suitable ships (i.e., good size hatch openings, good cranes, “banana peel” grabs, shallow draft) and whose trading pattern fits this movement of armour stone, then the exporter can negotiate a better price by signing a contract for multiple shipments (a contract of affreightment). Otherwise, you will have to use the “spot” market and take whatever ships may be available when cargo needs to be moved.

The importance of the logistics - in coordinating the whole supply chain, cannot be over emphasized to the potential shipper of armour stone. The real savings come in the ability to load and discharge quickly. As mentioned, the ship owner calculates his freight rate on the basis of time (ballasting time, load port time, steaming time, and unloading time) and costs (crew, fuel, ship and ports costs). If the vessel spends extra time in port waiting for stone to arrive or because of crane breakdowns, then the costs will quickly escalate beyond what the exporter has budgeted.

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The port costs are relatively easy to calculate, but the ship owner will “pad” the estimate if he is not familiar with the port the vessel is entering. In order to establish long-term business, the shipper must be upfront with load port costs. Any attempt to “ambush” the ship owner with “hidden” costs will cause freight rates to rise.

#### **4.3.2 Ship versus Tug / Barge for Transport of Armour Stone**

There are many factors to consider when comparing a ship versus a tug and barge combination to transport armour stone. A ship travels faster than a tug and barge, it can navigate better in rough seas, but it usually costs more per day to hire. A ship is usually a one-way steaming cost whereas a tug and barge usually has to make the return trip to the port of origin, often without a cargo. The amount of cargo the vessels can carry varies according to the vessel’s size, weather conditions, and water depths at the load and discharge ports. The vessel of choice has to “fit” the type of cargo, the load port, the ocean conditions, and the discharge area.

After interviewing several companies that have had experience in transporting armour stone from ports in Eastern Canada to the US east coast and the Caribbean, the following conclusions can be drawn regarding the feasibility of tug and barge as a means of transporting armour stone:

- (1) Tug and barge is a feasible means to move armour stone from NL ports to the US east coast.
- (2) Tug and barge is only feasible during the “summer” sailing season, from mid-April to mid-September; after the winter storms and ice floes and before the hurricane season. For example, a tug/barge service moves cement from Halifax to US East Coast from late April to early November and then a ship is used during the intervening five month period of rough weather.
- (3) There are very few barges on the East Coast that are capable of carrying 10,000 tonnes or more of armour stone.
- (4) A purpose built 10,000 DWT barge could be built in China for USD 2.5 to 3 million and repositioned to the East Coast. Financing a new barge would require a long-term contract with sufficient volume per year to justify the investment.

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(5) If tug and barge is used to carry armour stone rather than a ship, then there must be suitable cranes at the load and discharge ports. The freight rate for the tug and barge must be low enough to offset these extra costs. (NOTE: mentioned earlier that the barge and ship would both be self-loading. ~p. 46)

Carrying armour stone causes damage to ships and barges. The vessels used are usually at the end of their working lives when they are put into the armour stone trade. In order to provide some protection to the ship's steel and to protect the stone, a 15 cm layer of one-half-inch minus aggregate is put in the hold of the ship before the armour stone is loaded. A layer of wood beams and double deck steel may be put on the deck of a barge to prevent the deck of the barge from being punctured and to minimize damage to the armour stone.

In the case of local transportation of armour stone within the province of NL, it is of interest to note that Carter et al. (1989) suggested that where both truck and barge are physically feasible over similar distances, trucking is often the more economic and convenient method.

### **4.3.3 Estimated Freight Rates for Transport of Armour Stone**

The steaming times estimated to travel by ship from a number of major NL ports to the US east coast are presented in TABLE 14. The data shows that all of the steaming times to the US east coast, whether from the east or west coast of NL, are all within hours of each other; the exception to this being the port of Botwood which would require an extra day of steaming. Therefore, all of the NL ports except Botwood should get the same freight rates to the US east coast and Caribbean destinations for armour stone assuming that the loading terms (i.e., speed of loading and the draft to which the ship can be loaded) are the same. Note that ocean freight prices will vary depending on the freight market and the price of fuel.

A comparison of the calculated time required by ship versus barge to travel from various armour stone loading ports to unload ports is presented in TABLE 15. Note the assumed speed of a ship traveling at 13.5 knots (325 nautical miles per day) and a tug/barge traveling at 6 knots (150 nautical miles per day), with no added time consideration for bad weather or other delays. The speed of barges would be more reduced by bad weather conditions than the speed of ships.

**TABLE 14:** Steaming Time from Ports in Newfoundland to the US East Coast

Load Port	Proxy For	Distance in Nautical Miles	Steaming Time at 13.5 Knots
St. John's	Long Pond	893	2 days 18 hours
Argentia	Bull Arm	791	2 days 10 hours
	Long Harbour		
Corner Brook	Stephenville	788	2 days 10 hours
St. Lawrence			< 2 days 10 hours
Botwood		1,126	3 days 11 hours

**TABLE 15:** Distances\* to Discharge Ports from Various Armour Stone Loading Ports\*\*

By ship & by tug/barge	Boston, USA	Hamilton, Bermuda	Charlestone, South Carolina	San Juan, Porto Rico
Belle Dune, NB	877 nmiles	1,101	1,568	2,013
Ship	2 days 16 hr	3 days 9 hr	4 days 20 hr	6 days 5 hr
Tug/barge	5 days 20 hr	7 days 16 hr	10 days 11 hr	13 days 10hr
Aulds Cove, NS	515	722	1,206	1,660
Ship	1 day 14 hr	2 days 5 hr	3 days 17 hr	5 days 2 hr
Tug/barge	3 days 10 hr	4 days 19 hr	8 days 1 hr	11 days 2 hr
Corner Brook, NL	788	995	1,479	1,921
Ship	2 days 10 hr	3 days 1 hr	4 days 13 hr	5 days 22 hr
Tug/barge	5 days 6 hr	6 days 15 hr	9 days 21 hr	12 days 19 hr
Long Pond, NF	791	1,035	1,494	1,841
Ship	2 days 10 hr	3 days 7 hr	4 days 14 hr	5 days 16 hr
Tug/barge	5 days 6 hr	7 days 4 hr	9 days 23 hr	12 days 6 hr
Halifax, NS	386	757	1,077	1,580
Ship	1 day 4 hr	2 days 8 hr	3 days 7 hours	4 days 21 hr
Tug/barge	2 days 13 hr	5 days 1 hr	7 days 4 hr	10 days 12 hr

\* Source: BP "Port –to-Port Distance Software"

\*\* Assumes a ship traveling 13.5 knots, tug/barge at 6.25 knots, no time added for bad weather or other delays.



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In comparing the competitive advantages and disadvantages of shipping from a NL port (i.e., Corner Brook) versus other Atlantic Canada ports which have in the past shipped aggregate and armour stone; the port of Corner Brook is about 8 hours further away by ship than Auld's Cove, NS (Martin-Mariette), but is 6 hours closer than Belle Dune, NB. The added travel time for shipping from NL versus northern NS has minimal effect on the overall cost of shipping armour stone. The Port of Halifax, however, is significantly closer to the US East Coast ports than all of the NL ports. That means that the ocean freight rate disadvantages would have to be offset by: (a) a better quality stone (for which the NL shippers get paid more), (b) faster loading terms in NL ports, (c) lower cost of transporting the stone to the loading dock, or (d) NL armour stone producers would have to take a lower price for their armour stone. Adverse weather conditions such as ice or severe winter storms or delays in loading and/or unloading of the armour stone are of prime concern. For example, adverse ice conditions in Corner Brook resulted in a shipment of armour stone being shipped from Halifax rather than Corner Brook in early 2003.

The estimated cost of moving 10,000 tonnes of armour stone from Corner Brook to Boston by tug/barge, using assumed time and costs, would result in a charge of about USD \$16.75 per tonne (that is, \$25.13 CDN per tonne) FIO (free in and out) on a *round trip* basis). In addition, the shipper would be responsible for the costs of loading and unloading the stone at about 3,300 metric tonnes (~ 1,270 m<sup>3</sup>) per day.

The estimated cost of transporting armour stone by ship from either Long Pond, NF or Corner Brook, NF to Charleston, SC would be approximately USD \$12.50 (CDN \$18.75) per metric tonne (plus an adjustment factor for current fuel prices), including the cost of loading the stone from the dock and unloading the stone onto barges. Demurrage would be payable if the guaranteed amount of stone was not waiting on the dock for loading to the vessel. Any time lost or expenses incurred due to breakdown of the ships cranes would be to the account of the vessels owners. Ocean freight for armour stone destined for the Caribbean would be about USD \$13.50 (CDN \$20.25) per metric tonne (plus an adjustment factor for current fuel prices). Again, the ship's gear and crew would load and unload the stone with the armour stone exporter being charged if there was not the minimum amount of armour stone on the loading dock.

These freight rates are intended to give an overall sense of the range in costs involved in transporting armour stone from Newfoundland to ports along the US east coast and into the Caribbean. Actual costs will vary depending upon variables such as the total volume of armour stone contract, conditions and

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speed in loading and unloading the cargo, conditions of the vessel, size of armour stone pieces, size of individual vessel loads, fuel costs, labor charges, port costs (i.e., services of tugs, harbour dues based upon vessel weight x 0.0249 for Canadian and 0.0503 for non-Canadian vessels, top wharf rates at \$0.52 per tonne at federal wharfs, berthage rates of \$1.39/m/day or if <12 hours then the rate is \$0.13/m/hour), ice breaker assistance, Institute Warranty Limits (IWL) surcharge during higher risk shipping season, as well as port and weather conditions.

The costs associated with getting the armour stone from the quarry site to the port, stockpiling and storing the armour stone proximal to the port, and time involved in loading the stone are factors which by far outweigh the variation in steaming costs from different ports of loading throughout NL.

A shipment of armour stone was recently loaded in Halifax harbour on a ship destined for Charleston, SC. *Dexter Construction Ltd.* had been accumulating their armour stone for several years, and made the sale. The stevedoring and ocean freight was arranged by a Halifax stone broker and a ship-owner named *SMT* moved the armour stone in its own geared bulk carriers.

A recent example of a 100,000 short ton shipment of armour stone from NL to the US East Coast involved the *Atlantic Minerals Limited* sale of limestone armour stone to Charleston, SC. The contract of affreightment involved five 20,000-ton shiploads of armour stone from the port of Corner Brook. The contract terms involved FIO (free in and out), 5,000 tons (1900 m<sup>3</sup>) per day load, and 6,000 tons per day discharge SHinc (Sunday and holidays included). The ship was responsible for its own stevedoring with the ship's crew handling cranes to load from dock and unload into barges. The bottom of the ship's cargo holds were lined with 15 cm (~ 1,800 tons) of dolomite and soft loading of the armour stone was utilized to prevent damage to both the cargo and the ship. There was a guarantee of 6,000 tons of armour stone on the dock at load port every day (SHinc) or pay a penalty of USD \$10,000.00.

#### **4.3.4 Competition from Norway – on US East Coast and in Europe**

A large volume of armour stone product is produced and shipped from areas such as Larvik, Norway into northern European destination markets such as Dover, England. A comparison of the distances and time

required in shipping from Larvik, Norway to Dover, England versus to New York, US, as well as Long Harbour, NL to Dover, England, is presented in TABLE 16. This information pertains to ships since barges would not be suitable for regular North Atlantic crossings.

The information indicates the significant time (cost) advantage in shipping directly from NL to the east coast USA/Caribbean rather than from a European source. It likewise shows the time disadvantage in shipping armour stone from NL to any European destination. Note that the rates from North America to Europe are usually “head haul” (higher) rates and rates from Europe to North America are “backhaul” (lower) rates. However, ships dedicated to carrying armour stone are not likely to do trans-Atlantic voyages on a regular basis.

**TABLE 16:** Distances\* from Long Harbour, NL and Larvik, Norway to Dover, England and Larvik, Norway to New York, USA \*\*

Load Port	Destination	Distance (nmiles)	Time (@ 13.5 k)
Long Harbour, NL	Dover, England	2,268	7 days
Larvik, Norway	Dover, England	574	1 day 18 hr
Larvik, Norway	New York, NY, USA	3,531	10 days 21 hr

\* Source: BP “Port -to-Port Distance Software

\*\* Assumes a ship traveling 13.5 k (knots), no time added for bad weather or other delays.

## 5 QUARRY SITE ASSESSMENT, INFRASTRUCTURE AND EQUIPMENT REQUIREMENTS

### 5.1 Site Assessment

A source of armour stone may be available from an existing quarry operation, a disused quarry or a new site. A detailed assessment of an armour stone source is essential prior to expending money on

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infrastructure or equipment. The evaluation of a quarry site as well as the selection of samples to be tested should be conducted by a professional geologist or other qualified personnel (Hendrick, 1981; D. Bragg, pers. comm., 2003).

A comprehensive assessment should include: (1) a review of existing geological information relating to the rock formation, quarry site and performance of the rock if used in previous armour stone installations, (2) detailed mapping of outcrop, (3) evaluation of the rocks lithological and structural characteristics (i.e., primary planes of weakness, porosity, organic inclusions, joint patterns, fracture density, weathering and alteration), (4) assessment of overburden removal, (5) possible diamond core drilling, (6) evaluation of potential yield (i.e., size of armour stone and volume), (7) representative test trenching and sampling for ASTM and petrographic number specifications, (8) evaluation of potential water conditions (i.e., surficial and groundwater), and (9) infrastructure requirements and rehabilitation. Note that the selection of truly representative samples for testing is essential. Otherwise, a good quality rock material might suffer from poor selection, and a poor quality rock material be receive erroneously positive test results.

The 1989 report to Public Works Canada (Carter et al., 1989) attempted to develop a set of guidelines to assist in the assessment of armour stone rock quality and availability for quarries. This report focussed upon situations where a potential quarry was within easy transport to a project site as well as the situation where no armour stone was available within economic haulage distance from a project site and high cost pre-cast concrete units would have to be used. Carter et al. (1989) suggested that the costs of completing a site evaluation for a small project (i.e., < 5,000 tonnes) in an existing or disused quarry might cost \$3,000 - 5,000; while a larger project (>10,000 tonnes) in a new site might cost \$50,000 – \$70,000) to complete the appropriate assessment work. These authors also noted the price of breakwater projects generally ranged \$100,000 to \$1M to \$2M. Therefore, the cost of developing a new quarry for a small project would, of course, be prohibitive. For smaller projects it may be more appropriate to haul longer distances from an existing armour stone source or use more costly manufactured armour blocks (i.e., dolos, tetrapods, etc.). Four points to consider when systematically assessing the viability of producing adequate quantities and qualities of armour stone from a site were outlined by Carter et al. (1989) as: (1) defining economic transportation distance, (2) locating a quarry (quarries) within this distance, (3) assessing the macro and micro characteristics of the rock to check suitability, and (4) determining the yield of acceptable sized stone from site.

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## 5.2 Infrastructure and Equipment Requirements

Once a site has been assessed and identified as a suitable site for armour stone production, then the actual infra-structure requirements for the site are quite straightforward, consisting primarily of an adequate access road, a large enough area to accommodate the maneuvering of heavy equipment, and a lay-down area to sort and stockpile the armour stone.

In terms of equipment, the quarrying of any stone is damaging to all mechanical equipment. As a result, most contractors make use of the oldest machinery that can still be operated safely and efficiently with adequate minimum maintenance. Large-volume quarries might need more specialized equipment such as quarry bar hydraulic splitters.

The typical heavy equipment that is needed for most small armour stone quarry operations might consist of:

- (1) one or two excavators (e.g., a CAT 235, 320 or 330) with forks, a breaker attached for shaping the stone and a “grab” for handling and loading larger armour stone (second hand might cost ~ \$50,000-\$75,000)
- (2) a loader (second hand might cost ~ \$45,000) +/- a boom-mounted dual hammer quarry bar (second hand might cost ~ \$30,000), also for loading smaller rip rap and armour stone pieces with a bucket
- (3) air track drill(s), compressors, and explosives
- (4) a bulldozer may be used to push waste and generally clean the debris from the working area.

The production of armour stone from a bedrock quarry will require air track drills and blasting materials to liberate large and small pieces of armour stone from the solid outcrop. Two or three excavators may be operating for 2 or 3 shifts per day, depending upon the time constraints of the contract. Materials would be separated, rough shaped and sorted into various sizes piles of riprap, 1-2 tonnes, 2-4 tonne, 4-6 tonnes, 6-8 tonnes, 8-10 tonne and >10 tonne armour stone. A number of contractors have indicated that the price of producing and sorting the armour stone from bedrock would range between \$14.00-\$18.00 per ton, depending upon the required size of armour stone material, the hardness of the rock type (i.e., gabbro, granite, sandstone, limestone) and the degree of jointing or zones of weakness for easy separation.

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Production generally ranges in the order of 10% usable armour stone. The cost includes equipment rental and/or maintenance, consumables and labour costs. Higher costs are associated with working a granitic versus a limestone rock type. Gabbroic rock would add another ~25% over the cost of a granite.

The equipment requirements for a dimension quarry require the additional of quarry bars, slot drills, plugs and feathers or hydraulic wedges and/or splitter to shape the blocks, possibly wire saw(s) and perhaps a crane for moving the large blocks (up to 30 tonnes).

### **5.3 Estimated Costs of Production, Transport and Shipping**

The estimated total cost of producing limestone or granite armour stone from a bedrock quarry, transporting the stone 10 km to a port, and shipping from NL to the US East Coast would range from between approximately CDN \$47.25 to \$70.60 per tonne ( refer to TABLE 17). If the armour stone is a by-product of an existing aggregate or dimension stone quarry, transported a distance of 10 km and installed at a local job site, then the price per tonne would range as low as between CDN \$14.50 to \$27.50. Note that these prices reflect no profit margin. A minimal 25% - 50% mark-up of prices could be suggested in order to obtain a profit margin from the sale of the armour stone. Remember, however, that large quarry operators often sell their armour stone material at cost in order to rid themselves of waste piles, thereby gaining valuable working space within their quarry site.

A comparison of the prices for various sized armour stone in NL versus the US is presented in TABLE 18. The information indicates average prices of armour stone at the US quarry (FOB) in the range of between \$7.00-\$22.00 CDN/tonne, depending upon rock type and size of material. Prices for granite armour stone are at the higher end of the price scale. The prices quoted by the USGS are consistently somewhat lower than the prices quoted by private US companies and probably reflect the lower end of the price scale. The cost of armour stone at the US quarry site appears to be, in general, the same to slightly lower than the estimated cost in NL to produce armour stone as a byproduct of an existing quarry operation.

**TABLE 17:** Estimated costs (CDN \$) of producing, transporting and shipping armour stone from NL to Charleston, SC.

<b>Activity</b>	<b>Lower price/tonne</b>	<b>Higher price/tonne</b>
Extraction from bedrock	\$14.00	\$18.00
Sorting, shaping and grading	6.00	8.00
Load/unload to/from truck	6.00	16.00
Truck transportation to port*	2.50	3.50
Freight rates (NL – USEC)	18.75 (by ship)	25.10 (by barge)
Total	47.25	70.60

\* Price per tonne for a 10 km distance from quarry to port.

Based upon this information, in order for NL armour stone to be competitive with local US armour stone producers, the NL stone would have to be either of a superior quality in order to demand a higher price or the overall production cost (i.e., lower sorting/shaping, load/unload and trucking) would have to be lower in order to offset the significant extra cost associated with the shipping of product from NL to the US east coast (i.e., approximate quote of \$18.75 for ship and \$ 25.10 for barge). Many additional factors could affect the overall marketability of a NL armour stone product (i.e., securing business alliances with major US construction companies involved in armour stone installment, a temporary shortage of armour stone in a local market could favour imported products with a higher price, etc.).

The average price of armour stone delivered and installed within NL ranges from \$20.00 - \$60.00 (and upwards to \$125.00) CDN/tonne, depending upon the size of stone and distance from source to destination. These quoted prices correspond well with the estimated costs for NL armour stone produced as byproduct of existing quarry operations (TABLE 17). The higher quoted prices are a reflection of the difficulty in obtaining a suitable quality armour stone proximal to a project site.

**TABLE 18:** NL versus USA Prices per Tonne for Armour Stone, Filter Stone, RipRap, and Core Stone  
(Prices in CDN\$. Currency Exchange = 1.5000)

Source	Rock Type	Armour Stone	Filter Stone	Rip Rap	Core Stone
NL - Local contractor <sup>1</sup>	Boulders	8.00-9.00**			
NL - Local Contractor <sup>1</sup>	Unspecified	35.00-90.00**			
NL - Local Contractor <sup>1</sup>	2 - 4 tonnes	20.00-40.00*			
	6 - 8 tonnes	40.00-60.00*			
	10 - 12 tonnes	30.00-125.00*			
NL - W. Oldford - Dept. of Mines and Energy	10+ tones	40.00-50.00*	15.00*		10.00-12.00*
	6 - 10 tonnes	35.00*			
	4 - 6 tonnes	30.00*			
	2 - 4 tonnes	25.00*			
NL - G. Gosse - Dept. of WST	Unspecified	20.00-45.00* (28.30 aver.)		14.00-65.00* (36.00 aver.)	
Holcim Cement, USA <sup>2</sup>	Limestone - 1 - 5 tonnes	15.00 **			
	6 - 10 tonnes	22.00**			
V. Tepordei, USGS <sup>2</sup>	Unspecified	7.03-7.33**	10.05**	7.03-7.33**	
	Limestone	8.78 - 10.05**		8.78 - 10.05**	
	Dolostone	10.53-12.21 **		10.53-12.21**	
	Marble	13.44-16.37**		13.44-16.37**	
	Granite	13.00-15.69**		13.00-15.69**	
	Traprock	12.72-14.60**		12.72-14.60**	
	Sandstone	9.24-16.26**		9.24-16.26**	
	Quartzite	9.38-11.24**		9.38-11.24**	

<sup>1</sup> The information was sourced from anonymous local contractors during March, 2003. The limestone armour stone boulders from Lower Cove for \$8-9 per ton correlates with the same price as FOB quarry in USA.

<sup>2</sup> Refer to Appendix "C" for reference.

\* - Stone delivered and installed

\*\* - FOB quarry



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## 6 BARRIERS AND OPPORTUNITIES

There are significant barriers to producing armour stone in Newfoundland and Labrador for export to foreign markets. The market is small, there is strong competition, the transportation is expensive, and the cost of preparing waste rock from dimension stone quarries is high. There is potential for the development of stone quarries at tidewater if a company can produce a wide range of high quality stone products. To develop export business a company would need to carry out aggressive marketing or align itself with established producers who have infrastructure and established market contacts.

### 6.1 Barriers to Export Markets

The potential export markets for NL armour stone are on the US eastern seaboard and southern US coast along the Gulf of Mexico. The market itself, however, is not large as much of the harbour infrastructure has already been built. Maintenance and storm repairs do not require significant amounts of stone and these small quantities can often be locally supplied, especially in the New England States. When larger quantities are required, the companies that already import stone have existing contacts and/or infrastructure close to the site to facilitate unloading and placing of the stone. There are very large quarries on the Yucatan Peninsula that are exporting aggregate to the Gulf Coast, and the Mississippi River system provides a large transportation network often with backhaul possibilities. There are a few very large integrated stone producers in the US and they use these transportation networks very effectively.

Competition for armour stone also comes in the form of alternative products and techniques. Portable concrete structures can replace armour stone, and often with superior performance, albeit at a higher cost. There is also a growing awareness of the dynamic nature of coastlines and the problems that have been created by allowing development to take place too close to the water. This has led to programs of beach nourishment and much more subtle approaches to minimizing coastal erosion. But increasingly there is public pressure to utilize coastal resources for tourism without building directly “on the beach”.

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The provinces of NS and NB have large aggregate quarries at tidewater that ship aggregate into American markets. These operations are also capable of exporting their “oversize stone” into these markets, with a shorter shipping distance. Two of these quarry operations are controlled by American-based companies, thus giving them advantages in the marketplace. There have been recent shipments of stone from NL into the US marketplace, but these contracts were relatively unique situations and more focused on rip rap and coarse aggregate rather than on armour stone. It does show, however, that there are possibilities particularly if advantageous company alliances can be made.

## **6.2 Barriers to Producing Armour stone as Byproduct from Existing Dimension Stone Quarries**

Dimension stone quarry sites are selected on the basis of (i) marketable stone from an aesthetic standpoint, and (ii) the potential to produce large blocks. Quarries typically have recovery rates of between 10% - 20% because of visual defects in the stone, and because some blocks are too small or irregularly shaped. The resulting unsorted waste rock is stockpiled outside the working area in a quarry. These waste piles can be problematic in some areas of the world, such as the Larvik region in Norway, where the waste rock is sold practically at cost to avoid congestion at the quarry site (see Section 2). In NL, the waste stone is either discarded “into the woods” adjacent to the quarry (e.g., *International Granite Corp.*) or pushed into the ocean to extend the floor of the quarry, creating additional storage at tidewater (e.g., *Hurley Slateworks Co. Inc., T.U.C. quarry at Ten Mile Bay*).

There are barriers to producing armour stone from the waste rock in dimension stone quarries in NL. One of these barriers is the cost of sorting, selecting, and shaping the stone from the waste piles. Large excavators and bulldozers are required to move stone around in a waste pile thereby adding significant cost especially in the case of the very large pieces (i.e., >10 tonnes). The initial shape of the waste rock may not be suitable for armour stone and will require additional drilling and splitting of the large rock pieces to achieve the required dimensions. The stone in a high quality gabbro monument quarry may have poorly developed rift characteristics (i.e., the ability to split easily in preferred planar direction). In this case, the sorting and shaping of each individual piece of armour stone would take significant time and make the economics of the activity marginal, at best. The ability to economically produce small, lower value pieces of armour stone (i.e., < 3 tonnes) would be even more difficult. The cost of producing rip rap or aggregate would require higher than average prices to make it economically viable.

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In a typical aggregate quarry, the site is usually selected because of orthogonal jointing, and favorable blasting and breaking characteristics for the production of stone that is suitable for feeding into crushers to economically produce small stone. The “oversize” pieces may be approximately equidimensional and suitable for armour stone without significant shaping. In addition, the sorting is carried out immediately after a blast and cuts down on the handling costs. In a dimension stone quarry, the required characteristics are for the production of very large stone blocks, and typically the very angular waste rock is not readily suited for feeding into a crusher. The preparation of orthogonal-shaped gang-saw-size blocks produces variably-shaped waste rock which, again, is often not suited for direct feed into a crusher.

### **6.3 Barriers for Stand Alone Production of Armour Stone**

There are no full time primary producers of armour stone because the markets are too small and the production of only armour stone is not profitable. The rates of recovery for armour stone are comparable to dimension stone quarries (i.e., 10%-25%); however, the unit value is much lower. Quarries that are brought into production in hopes of marketing armour stone must also market all of their other size ranges (i.e., rip rap, aggregate, etc.). A NL operation marketing stone of only one size in the US will face stiff competition from NS, NB, Mexico and US interior (through the Mississippi and Missouri water systems). Stone from Labrador would not be able to compete due to the distances and winter ice conditions. NL's north and west coast would also have to contend with winter ice conditions. In February, 2003, *Atlantic Minerals Ltd.* had to subcontract one load of armour stone from a NS stone company for a sale into South Carolina because ice conditions prevented the vessel from entering Corner Brook harbour.

### **6.4 Opportunities for Stand Alone Production of Armour Stone**

The current market for aggregate, rip rap and armour stone is very price competitive. However, the USACE has carried out studies looking into the premature deterioration of armour stone and they have suggested that higher quality stone may be cost competitive over a longer period of time. Aggregate is facing increasingly rigorous testing for use in asphalt for top surfaces in highway construction. Testing for skid resistance, degree of polishing and abrasion is very common in Europe where roads are built to higher standards. These factors suggest that in the future, producers of high quality aggregate may be able

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to negotiate a higher price for their stone. These markets may offer enhanced opportunities for tidewater quarry operators producing a full suite of high quality stone products.

There is a company currently trying to develop a large aggregate quarry operation in Digby, NS. This would suggest that there is a market for aggregate and associated stone products. However, this NS company is facing major permitting problems and issues with private lands. These types of issues may be easier to avoid or deal with in NL due to the lower population and less residential development along the coastlines. Current economic conditions in the US may indicate caution in planning developments that are relying strictly on the US marketplace. However, the number of locations available in other provinces in Atlantic Canada for development of a competing quarry development at tidewater would be few in number.

## **6.5 Opportunities for Marketing Waste Rock from Dimension Stone Quarries**

The opportunities for marketing waste rock from existing dimension stone quarries are not within the armour stone market. Instead, the opportunities lie within the higher end landscaping and specialty stone market.

The waste rock from the LIDC (TUC) Ten Mile Bay anorthosite quarry is already being used for sculpture work and small-scale fabrication in the stone craft industry. The LIDC is currently running training and trial programs in a secondary processing plant in Hopedale, where furniture, unique headstones, and smaller products will be fabricated. The anorthosite (i.e., labradorite granite) is a unique stone and warrants additional small-scale processing more so than other stones. However, it does point to a different direction which will produce jobs and higher value products. This stone also has potential for landscaping work especially in applications involving water (i.e., fountains, pond surrounds, waterfall stone, etc.).

Dimension stone waste from other quarries may not have the same value as the anorthosite, but may still warrant secondary processing for furniture and arts and craft work. The waste stone that has not been

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blasted is of high quality for this type of value-added secondary processing. While this type of secondary utilization of waste stone does not consume large volumes of stone, it can add significant value.

The landscaping market is also worthy of investigation and the processing of stone with hydraulic splitters to produce exceptionally handsome landscaping stone products should be pursued. There are an increasing number of local, national and international “Landscaping and Lawn & Garden” trade shows, and these could be used to promote this type of product.

## 7 CONCLUSIONS AND RECOMMENDATIONS

The development of a large scale export market of rough natural stone armour stone from NL into the US and regions of Atlantic Canada will be a difficult venture with tight profit margins. The US demand for armour stone products for harbour development has been on the decline for a number of years due primarily to the fact that this type of work has entered a mature stage of development with present efforts focused upon maintenance and repair. Local supplies of armour stone can usually meet this demand.

The majority of new projects involve shoreline protection which often utilizes a number of new alternatives to the traditional hard structures, (i.e., bioengineering, beach nourishment, beach water defacing, undercurrent stabilization, geotextile tubes and man-made interlocking concrete pieces).

When there is a demand for armour stone, the producer must have a ready supply of stone, have established business relations with any one of the major US construction companies, and be ready to compete in a highly competitive spot market. This market will be characterized by fluctuating prices and strong competition for numerous existing aggregate or dimension stone quarry operations within the US as well as Mexico.

The total cost (break-even price) for producing and transporting armour stone from NL to the US east coast is approximately CDN \$47.25 - \$70.60/tonne (TABLE 17). This cost may be reduced by up to 25% if the armour stone is collected from an existing waste pile. In order to economically compete with the US

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quarry prices for armour stone (ranging CDN \$7.00-\$22.00/), (TABLE 18); a NL stone exporter will have to either reduce production costs (i.e., by locating at tidewater, producing a multiple stone-product line, and tightly monitoring logistics) and/or supply a superior quality produce (higher value per tonne).

The demand for armour stone to supply local project sites throughout NL is generally low. Export to PEI has some potential. The growing market for cut-to-size and unique landscaping stone within NL, as well as other provinces and the US, could be exploited. The key is to provide “unique” stone products. That is, stone products made of high quality and unique material (i.e., anorthosite with iridescent feldspar, black gabbro, etc.), with esthetic appeal to help drive both the selling price and the market demand.

The following recommendations are intended to help local armour stone and landscaping stone producers with their search for new stone resources, product development and marketing.

(1) Assessment of the potential for armour stone (and related stone product) deposits in areas with suitable development criteria, (i.e., proximity to tidewater, access to shipping infrastructure, etc.), is needed in NL. A program to aid stone companies in obtaining this type of information would provide direct and meaningful information to the business development plans of the industry participants.

(2) Local aggregate and armour stone producers need to be “in the loop” in order to be aware of upcoming major construction projects, develop business liaisons with US construction companies and be able to submit meaningful bids for work to supply stone product from NL. A program to help stone companies become listed with US government and private industry registries could provide a linkage between US demand and an alternative source (e.g., NL stone). In addition, some type of assistance (e.g., financial) to attend major US construction trade shows with a focus on stone usage, could provide NL stone companies with a chance to make direct contact with US companies, help build business connections and provide a better sense of the present day dynamics of the construction stone industry.

(3) A significant potential exists for increased export of value-added landscaping and unusual large stone pieces for both residential and commercial usage. NL companies working in the area of landscaping and related products need to gain access to that export market. In order to work towards achieving that

market penetration, NL stone producers need to develop an increased understanding of the unique niche markets to be filled, the opportunities for product development, and an increased awareness of the of the industry and the competition. Attendance at major landscaping trade shows in Canada and the US could provide these stone producers with the opportunity to make business contacts, examine their competitor's products, compare prices, assess market potential and gain that all important perspective on the industry as a whole.

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**APPENDIX “A”****LIST OF DEFINITIONS AND ABBREVIATIONS**

**Aggregate:** Composed of a mixture of sand, gravel, shells, broken stone, etc.

**Apron:** Portion of a wharf or pier carried on piles beyond solid fill.

**ASTM:** American Society for the Testing of Materials

**Basalt:** An extrusive volcanic rock composed primarily of plagioclase and pyroxene minerals +/- olivine.

**Batholith:** A body of intrusive rock at least 40 sq. km in area.

**Breakwater:** A substantial structure, located at the outer limits of a harbour or anchorage, to protect the inner waters against the effects of heavy seas.

**Bulkhead:** A retaining wall to prevent sliding of earth or fill into water. Also an upright partition in a ship.

**Caisson:** (a) A supporting foundation (dam) formed by pouring concrete, driving steel lock piling, or forming other material into a hollow box or cylinder; allows maintenance and repair work to be done below water level, (b) a controlled submergence floating hull used as a watertight entrance closure for a graving dock.

**Dolos:** A concrete armour unit used for riprap.

**Dolostone:** A rock consisting entirely of the mineral dolomite.

**Dolomite:** A magnesium limestone mineral-CaMg(CO<sub>3</sub>)<sub>2</sub>.

**Estuary:** A water passage where the tide meets a river current, especially an arm of the sea at the lower end of a river.



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**Filter blanket:** A layer or progressively graded series of soil layers, or plastic cloth filter woven of synthetic fibers, separating material of different grain size. The separation prevents the fine soil from entering into the open spaces of the coarser layer.

**FIO:** free in and out

**FOB:** free on board

**Glaciation:** Alteration of the earth's solid surfaces through erosion and deposition by glacier ice.

**Glacio-fluvial:** Alteration of the earth's solid surface by processes related to glacier ice and river action.

**Gneiss:** A coarse-grained rock in which bands rich in granular minerals alternate with bands in which schistose (planar +/- linear) minerals predominate.

**Granite:** A plutonic rock consisting essentially of alkali feldspar and quartz with plagioclase +/- small amounts of muscovite, biotite, hornblende, or pyroxene.

**Groin:** A narrow structure projecting out, usually close to right angles, from the shoreline. It is designed to influence offshore currents and wave action in a manner that will minimize erosion of the shoreline.

**Hydrothermal alteration:** Phase changes resulting from the interaction of hydrothermal stage fluids with preexisting solid phases (i.e., kaolinization of feldspars), also includes chemical and mineralogical changes in rock due to additional/removal of materials by hydrothermal fluids (e.g., silicification).

**Jetty:** A structure (such as a mound or wall) at or near the entrance to a harbour or river constructed to confine the flow of water due to the currents and tides, and to maintain the entrance free of sandbars; a small pier or wharf

**Kaolinization:** The hydrothermal process of altering rock-forming minerals to clay minerals.

**LIDC:** Labrador Inuit Development Corporation

**Limestone:** A bedded carbonate sedimentary deposit consisting chiefly of calcium carbonate ( $\text{CaCO}_3$ ) which yields lime when burned; the consolidated equivalent of limy mud, calcareous sand or shell fragments.

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**Lithology:** The physical character of a rock .

**Littoral drift:** Movement of sediment by underwater currents and tidal action, usually resulting in formation of sandbars.

**Marble :** A metamorphic rock composed essentially of calcite and/or dolomite.

**Mound:** An artificial embankment or ridge composed of sand, gravel or cobbles and constructed on the ocean floor by dumping the material from scows and barges.

**Petrographic number:** Petrographic analysis to identify potentially deleterious features of a rock such as clay content, presence of unstable or frost susceptible minerals, fractures lengths and intensities which bear upon durability of a stone.

**Pier:** An open- or closed-type structure usually extending perpendicular from the shoreline into sheltered navigable water designed for berthing, loading or unloading cargo, repair, fueling, and general servicing of vessels; it normally provides berthing space on both sides for its entire length.

**Pile (piling):** A long, slender timber, steel, or reinforced concrete structure element driven, jetted or otherwise embedded into the ground to support a vertical load, to resist a lateral force, or to resist water or earth pressure.

**Pluton:** A body of igneous rock that has formed beneath the surface of the earth by consolidation of a magma.

**Quartzite:** A granulose metamorphic rock consisting essentially of quartz; sandstone cemented by silica overgrowths on quartz grains.

**Rip rap:** Stones, boulders or concrete armour units of miscellaneous sizes placed without order on the surface of an earthen structure or embankment to act as protection against erosion.

**Rough finish:** Stone hydraulically split with no drill-hole traces on surface.

**Rubble :** Rough and uncut stones, irregularly shaped and of various sizes ranging up to 100 cu ft each and up to 90 tonnes each.

**Sandstone :** A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains (sand).

**Seawall:** A massive gravity-type structure built along, and generally parallel to, the shoreline; designed to protect the shore against erosion resulting from wave action.

**SHinc.:** Sunday and holidays included

**Surficial:** Occurring on the earth's surface.

**Tetrapod:** A non-reinforced concrete armour unit used for rip rap.

**Traprock:** Dark- coloured dike and flow rocks, chiefly basalt and diabase.

**Tribar:** A reinforced concrete armour unit used for rip rap.

**USACE:** United States Army Corps of Engineers

**USGS:** United States Geological Survey

**Volcanic:** Made of materials (rock) derived from volcanoes.

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**APPENDIX “C”**

**LIST OF CONTACTS**

***Port Corporations, Authorities and Related Port Companies:***

Atlantic Pilotage Authority- 709-637-4455

Argentia Port Corporation – Ken Browne – 709-227-5502

[www.noianet.com/infrastructure/8.argentia.php](http://www.noianet.com/infrastructure/8.argentia.php)

Bull Arm Construction Site – 709-729-0114

[www.bullarm.com](http://www.bullarm.com)

Glovertown Marine Ltd. – Bob Davies – 709-553-6792

Long Harbour Development Corp. – 709-228-2233

[www.longharbour.net](http://www.longharbour.net)

Mahers Rigg Services Ltd. – Ed Maher – 709-228-2036

McKeil Marine Ltd. – Lewisport – Richard Brown – 709-486-2486

Port of Botwood

[www.nf.sympatico.ca/botwood/info.htm](http://www.nf.sympatico.ca/botwood/info.htm)

***Construction, Transportation and Quarry Companies:***

Atlantic Minerals Ltd.- Dave Stonehouse – 709-638-8255

Belmont Rose Granite Co. – 1-866-621-1281

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Burin Minerals – 709-873-3331

D & D Transportation Ltd.: 1-888-822-1773

Eisen Quarriers – 1-519-843-2854

Granimar Quarries Ltd. – 1-613-387-2419

Hunts Transport Ltd. – 1-800-563-1010

International Granite Corporation – Verrick Hillier – 709-256-4620

Johnsons Construction Ltd. – 709-686-2005

LIDC, Nain – Fred Hall – 709-896-8505

Marine Contractors – 709-686-2015

**Department of Works, Services & Transportation:**

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Gary Gosse – 709-729-5483

**Department of Mines and Energy:**

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William Oldford, Mineral Lands Division, NL Dept. Mines & Energy, 709-292-4503.

**Fisheries and Oceans: Small Craft Harbours:**

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West Coast Area Director – 709-637-4317

Jim Cheeseman – 709-637-4324

***National Research Council (NRC):***

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***New Brunswick Department of Public Works:***



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Ed Coy, Senior Project Manager, - 506-851-6040

**Ontario Ministry of Northern Development and Mines:**

Myra Grow, Industrial Mineral Geologist, Mines and Minerals Division, - 705-670-5828

[www.mndm.gov.ca/mndm/mines/mg/dimstone/alphprod\\_e.asp](http://www.mndm.gov.ca/mndm/mines/mg/dimstone/alphprod_e.asp)

**Prince Edward Island Department of Public Works:**

Terry Gee, Deputy Project Manager, - 902-566-7527

**Transport Canada:**

Don Lester, Regional Director, - 709-772-5154

Wayne Hamilton, - 709-772-2101

Jim Cochrane, - Stephenville, - 709-643-5626

[www.tc.gc.ca](http://www.tc.gc.ca)

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**United States Army Corps of Engineers**

Yuri Yatsevitch, USACE New England District, - 978-318-8387, [yuri.yatsevitch@nae02.usac.army.mil](mailto:yuri.yatsevitch@nae02.usac.army.mil)

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John Winmill, USACE, - 978-318-8691, [john.i.winmill@usace.army.mil](mailto:john.i.winmill@usace.army.mil)

**General Information Sites**

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Aggregate Industries UK, [www.aggregate-uk.com](http://www.aggregate-uk.com)

Belmont Rose Granite, Corporation, [www.proud.com/belmontrose](http://www.proud.com/belmontrose)

Birkendale Granite Quarry Limited, [www.birkendale.com](http://www.birkendale.com)

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Great Lakes Commission, [www.glc.org](http://www.glc.org)

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Lake Rip Rap, Incorporated, [www.lakeriprap.com](http://www.lakeriprap.com)

Ministry of Northern Development and Mines, Ontario, [www.mndm.gov.on.ca](http://www.mndm.gov.on.ca)

Northland Incorporated, [www.enorthland.net](http://www.enorthland.net)

North Norfolk District Council, North Norfolk Coastal Environment, [www.northnorfolk.org](http://www.northnorfolk.org)

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