APPENDIX 5A

SIGMA GEOPHYSICS REPORT: CROSSHOLE SURVEY, FEBRUARY 2006

GROS CACOUNA LNG TERMINAL

Shear wave velocity measurements

Presented to

Journeaux, Bédard and Assoc. Inc

1625, Newman Crescent, suite 200
Dorval, QC H9P 2R6

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GÉOPHYSIQUE SIGMA INC.

1400, rue Marie-Victorin, bureau 200
Saint-Bruno, QC J3V 6B9
Telephone :(450) 441-4600
Fax :(450) 441-3703

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1. INTRODUCTION

In January 2006, **JOURNEAUX, BÉDARD AND ASSOCIATES INC.** retained the services of **SIGMA GEOPHYSICS INC.** to carry out a resistivity survey and a shear wave cross-hole survey as part of the geotechnical investigation of the **CACOUNA ENERGY** proposed LNG terminal at Gros Cacouna, Québec.

The resistivity survey methodology and results are discussed in a report submitted earlier.

The present report deals with the shear wave measurements carried out in early March.

2. GENERALITIES

2.1. WORK SCHEDULE

The shear wave survey initially scheduled to be carried out concurrently with the resistivity survey had to be postponed due to technical difficulties encountered with the logging equipment at the site. The shear wave measurements were executed on March, 1st 2006, during a second trip to the site. A preliminary analysis of the results was transmitted on March, 8th and the present report was submitted on March, 16th, 2006.

2.2. LOCATION OF THE SITE

The site lies within the limits of the Gros Cacouna Harbour on the south shore of the Saint-Lawrence River, near Gros Cacouna, QC, which is located at approximately 300 km east of Quebec City.

2.3. GENERAL SITE CONDITIONS AND DOWNTIME

Not withstanding the numerous safety procedures, the access to the site was easy. A road built for the drilling crew allowed us to bring the equipment to the boreholes location with a 4x4 pickup truck.

The weather was fair, although very cold and windy. Due to this cold weather, a thick plug of ice had formed at the top of the borehole and had to be thawed in order to lower the probes and shear wave hammer in the holes.

Some equipment failures were probably caused by the cold weather (water seals may have frozen and failed, crack developed in the high pressure conduit of the hammer locking mechanism). Others were caused by the failure of the trigger device, which had to be replaced.

2.4. PERSONNEL

The measurements were carried out at the site by Jean-Jacques Sincennes, senior engineering geophysicist, and Jonathan Simard, technical assistant. The data analysis and report were executed by Jean-Jacques Sincennes, P.Eng. Sr geophysicist.

3. METHODOLOGY

3.1. STANDARD SURVEY METHOD

The survey was carried out according to the ASTM Standard **D4428/D 4428M**.[1]

Some minor modifications were made to the standard procedure since most of the measurements were carried out in the rock mass. These modifications were made in order to disturb the rock mass as little as possible. The most significant modifications to the standard

[1] ASTM Standard D4428/D 4428M, «Standard Test Method for Crosshole Seismic Testing», revised 2000

was to avoid using plastic pipes in the holes because we were afraid that the cement grout which would have been used to fasten the plastic pipe to the rock mass may have filled existing cracks and therefore modify the elastic properties of the rock mass.

3.2. TEST PROCEDURE

To carry out the seismic cross-hole measurements, three boreholes - **BH-5**, **BH-6** and **BH-7** - were drilled at every **7,5 m** along a straight line. The shear wave signal was generated at known elevation in borehole **BH-7** using a shear wave hammer. The signal was then picked up by triaxial geophones locked in borehole **BH-6** and borehole **BH-5** at the same elevation as the shear wave hammer. Multiple up going and down going hammer hits were produced in order to enhance the S wave pulse and to suppress the P wave pulse. A third triaxial station was installed at the surface near borehole **BH-7** to gather up-hole data. Figure 1, illustrates the set up used to carry out the measurements which were taken at every **50 cm** along the hole. The signal from the three triaxial sensors was recorded using a Geometric Strataview R24 seismograph.

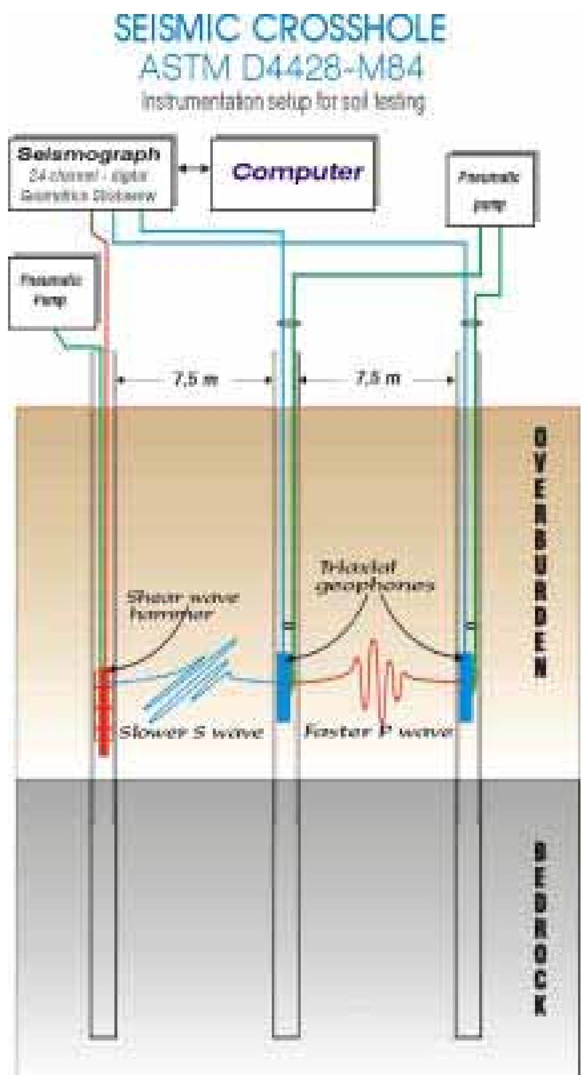

Figure 1 – Seismic crosshole setup

3.3. DATA PROCESSING

For each recording, the shear wave signal was identified and the travel time of the shear wave between borehole **BH-6** and borehole **BH-5** was noted. Then, the shear wave velocity was computed by dividing the distance between the boreholes by the travel time.

4. RESULTS

4.1. PRESENTATION OF THE RESULTS

The shear wave cross-hole results are listed in Table 1 of page 3. For each measurement, the depth (m), the altitude (m), the travel time of the shear wave (ms), the nominal distance (m) between the boreholes and the computed shear wave velocity are given. In addition, notes describing the probable causes of observed lower velocity zones are given.

The shear wave log shown on Figure 2 of page 4 illustrates the variation of shear wave velocity versus the altitude (blue). A red line that gives the probable minimum and maximum shear wave velocity considering the instrumental error depicts the anticipated margin of error.

4.2. ACCURACY OF THE RESULTS

The accuracy of the computed shear wave velocity depends on the accuracy of the time measurements, which is estimated to ±0,1 ms for this survey, on the accuracy of the distance between the triaxial geophones, which is expected to be less than ±0,25 m and on the site geology. For this site, the computed shear wave velocities are expected to be within ±10% of the actual shear velocity.

SIGMA GÉOPHYSIQUE SIGMA INC.

Cacouna LNG Terminal

Seismic cross-hole survey
Final results

Depth	Altitude	ΔT_S	ΔT_P	ΔD	V_S	V_P	ρ	G_D	ν	Notes
m	*m*	*ms*	*ms*	*m*	*m/s*	*m/s*	*g/cm³*	*GPa*	*unitless*	
0,0	3,5	-		7,5	-					**Surface of backfill**
1,0	2,5	8,30	2,80	7,5	904	2679	2,2	1,8	0,4358	**Frozen backfill**
2,0	1,5	5,70	1,98	7,5	1316	3788	2,6	4,5	0,4314	**Rockmass weakened by quarry blasting**
2,5	1,0	4,71	1,95	7,5	1592	3846	2,6	6,6	0,3966	
3,0	0,5	3,32	1,80	7,5	2259	4167	2,6	13,3	0,2918	
3,5	0,0	3,02	1,55	7,5	2483	4839	2,6	16,0	0,3212	
4,0	-0,5	3,00	1,55	7,5	2500	4839	2,6	16,3	0,3179	
4,5	-1,0	2,97	1,55	7,5	2525	4839	2,6	16,6	0,3128	
5,0	-1,5	2,80	1,50	7,5	2679	5000	2,6	18,7	0,2987	
5,5	-2,0	2,76	1,44	7,5	2717	5208	2,6	19,2	0,3130	
6,0	-2,5	2,65	1,39	7,5	2830	5396	2,6	20,8	0,3102	
6,5	-3,0	2,68	1,44	7,5	2799	5208	2,6	20,4	0,2971	
7,0	-3,5	2,70	1,40	7,5	2778	5357	2,6	20,1	0,3161	
7,5	-4,0	2,84	1,47	7,5	2641	5102	2,6	18,1	0,3170	
8,0	-4,5	2,89	1,50	7,5	2595	5000	2,6	17,5	0,3156	
8,5	-5,0	2,92	1,55	7,5	2568	4839	2,6	17,2	0,3038	
9,0	-5,5	2,91	1,55	7,5	2577	4839	2,6	17,3	0,3020	
9,5	-6,0	2,87	1,53	7,5	2613	4902	2,6	17,8	0,3015	
10,0	-6,5	2,80	1,53	7,5	2679	4902	2,6	18,7	0,2872	
10,5	-7,0	2,94	1,56	7,5	2551	4808	2,6	16,9	0,3041	
11,0	-7,5	3,10	1,70	7,5	2419	4412	2,6	15,2	0,2850	
11,5	-8,0	3,02	1,67	7,5	2483	4491	2,6	16,0	0,2798	
12,0	-8,5	2,80	1,53	7,5	2679	4902	2,6	18,7	0,2872	
12,5	-9,0	3,10	1,60	7,5	2419	4688	2,6	15,2	0,3184	
13,0	-9,5	4,05	2,08	7,5	1852	3606	2,6	8,9	0,3209	**Lower velocity zone probably associated to the conglomerate layer identified in BH-6.**
13,5	-10,0	4,25	2,21	7,5	1765	3394	2,6	8,1	0,3147	
14,0	-10,5	4,10	2,14	7,5	1829	3505	2,6	8,7	0,3128	
14,5	-11,0	3,40	1,79	7,5	2206	4190	2,6	12,7	0,3083	
15,0	-11,5	3,10	1,60	7,5	2419	4688	2,6	15,2	0,3184	
15,5	-12,0	3,40	1,76	7,5	2206	4261	2,6	12,7	0,3170	
16,0	-12,5	3,50	1,79	7,5	2143	4190	2,6	11,9	0,3229	

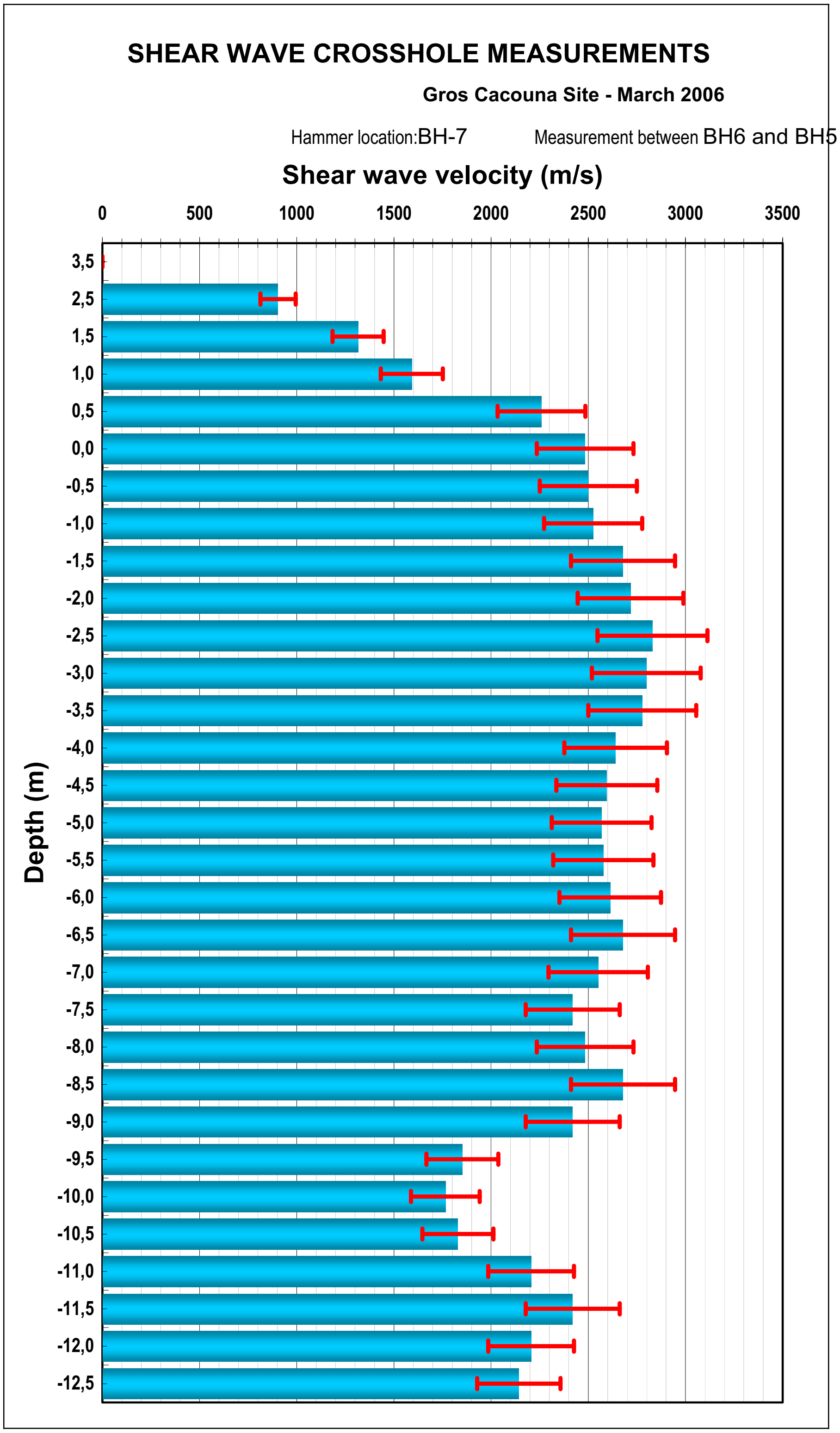

Figure 2 – Shear wave velocity log

4.3. Results analysis

The shear wave velocity measurements show that:

1. at or near the surface, the computed shear wave velocity is **904 m/s**. This velocity is consistent with the frozen back fill layer. It should by noted that the velocity in the upper layer will be much lower in the summer time due to the melting of the ice. Expected shear wave velocity for the thawed backfill could be as low as **200 m/s**.

2. below the frozen backfill layer the velocity gradually increases to above **2200 m/s** at approximately **2,7 m** below the surface. This transition zone probably consists of rock weakened by the blasting carried out during the construction of the harbour.

3. from **2,7 m** to **13 m** below the surface, the shear wave velocity varies from a low **2259 m/s** to a maximum of **2830 m/s** for an average shear wave velocity of **2590 m/s**. These shear wave velocities are consistent with the sandstone formation seen at the site. The lower limit probably reflects a higher fracture density.

4. from **13 m** to **14 m**, the average shear wave velocity decreases to **1815 m/s**. This lower velocity zone is probably related to micro-conglomerates and conglomerates observed in borehole **BH-6** and are not necessarily related to a higher fracture rate.

5. below **14 m**, the shear wave velocity increases to above **2240 m/s**.

5. CONCLUSION

The shear wave velocity measurements carried out on the Cacouna LNG terminal site show that the rock mass is generally of good quality.

The upper layer damaged by quarry blasting is somewhat weaker as shown by the lower shear wave velocities between **1300** and **1590 m/s**.

A weaker layer may exist between 13 and 14 m below the surface as revealed by the **1815 m/s** average shear wave velocity. However, this lower velocity zone may also be limited to an area located between borehole **BH-6** and **BH-7** and may not extend to whole area.

According to the measurements, the average shear wave velocity of the upper 15 m of the rock mass should be above **2400 m/s**.

This report was written by Jean-Jacques Sincennes, P.Eng.

Jean-Jacques Sincennes, ing