

APPENDIX B
GEOTECHNICAL REPORT

**GEOTECHNICAL FACTUAL REPORT
SARS SITE, TWILLINGATE, NEWFOUNDLAND**

(FFC File: 3116)

Prepared by:

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Submitted to:

**Public Works and Government Services Canada
Public Services and Procurement Canada
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	PROVINCE OF NEWFOUNDLAND PERMIT HOLDER CLASS "A" This Permit Allows FRACFLOW CONSULTANTS INC.
To practice Professional Engineering in Newfoundland and Labrador. Permit No. as issued by APEGN <u>D0169</u> which is valid for the year <u>2018</u> .	

January 2018



Preface

Public Works and Government Services Canada (PWGSC) retained Fracflow Consultants Inc. to undertake a marine geotechnical site investigation for a proposed SARS site at Twillingate, Newfoundland. This investigation was conducted according to the stipulations outlined in the current Standing Offer Contract (No. EA003-160505/001/PWD) between PWGSC and Fracflow Consultants Inc.

The proposed scope of work for the Twillingate SARS project consisted of drilling six (6) boreholes from a barge. The field work for this investigation was conducted between December 6 and 18, 2017, and the revised scope of work included drilling five (5) boreholes at the five (5) locations requested by PWGSC with split-spoon sampling and Standard Penetration Tests (SPTs) every 1.5 m using a NW/NQ diamond drilling string. In addition, 15 Dynamic Cone Penetration Tests (DCPTs) were also conducted at the 15 locations requested by PWGSC. Environmental samples were collected at six (6) locations, consisting of a surface grab sample, a composite large split spoon sample from 0.1 to 1.0 m of depth and a composite sample from 1.0 to 2.0 of depth where the overburden was sufficiently thick at each location. A visual inspection of the subsurface soil conditions encountered, based on the split-spoon samples that were recovered during the field program, was used to describe the soil conditions at the site. The depths for the five (5) boreholes ranged from -5.04 m LNT to -6.43 m LNT. Refusal to the DCPTs ranged from -1.56 m to -8.26 m for the locations that were investigated. Bedrock was proven in three (3) of the five (5) boreholes by coring up to 3 m into rock at each location or until it was obvious that bedrock was being cored. The bedrock type(s) encountered in these boreholes has been identified and is described in the logs attached to this report.

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1.0 INTRODUCTION

Public Works and Government Services Canada (PWGSC) retained Fracflow Consultants Inc. to undertake a marine geotechnical site investigation at a proposed SARS site in Twillingate, Newfoundland. This investigation was conducted according to the stipulations outlined in the current Standing Offer Contract (No. E0224-03R031/001/PWD) between PWGSC and Fracflow Consultants Inc.

The proposed scope of work for the Twillingate SARS project consisted of drilling six (6) boreholes from a barge. The field work for this investigation was conducted between December 6 and 18, 2017, and the revised scope of work included drilling five (5) boreholes at the five (5) locations requested by PWGSC with split-spoon sampling and Standard Penetration Tests (SPTs) every 1.5 m using a NW/NQ diamond drilling string. In addition, 15 Dynamic Cone Penetration Tests (DCPTs) were also conducted at the 15 locations requested by PWGSC. Environmental samples were collected at six (6) locations, consisting of a surface grab sample, a composite large split spoon sample from 0.1 to 1.0 m of depth and a composite sample from 1.0 to 2.0 of depth where the overburden was sufficiently thick at each location. A visual inspection of the subsurface soil conditions encountered, based on the split-spoon samples that were recovered during the field program, was used to describe the soil conditions at the site. The depths for the five (5) boreholes ranged from -5.04 m LNT to -6.43 m LNT. Refusal to the DCPTs ranged from -1.56 m to -8.26 m for the locations that were investigated. Bedrock was proven in three (3) of the five (5) boreholes by coring up to 3 m into rock at each location or until it was obvious that bedrock was being cored or the required depth was reached. The bedrock encountered in these boreholes was an altered volcanic rock and is described in the logs attached to this report. A summary of the field work that was conducted is provided in **Table 1.1**, **Table 1.2** and **Table 1.3**.

This report contains a factual presentation and full disclosure of all findings of the subsurface investigation. The following sections provide: (1) a description of the site and the general

geology of the area; (2) a summary of the investigative procedures used; and (3) a detailed description of the subsurface soil conditions. Comments are also provided related to dredging depths and dredging issues. Appended to this report is a site plan showing the borehole locations, the detailed geotechnical logs for each borehole and the grain size analysis reports.

Table 1.1 Summary of Geotechnical Investigations at Twillingate, Newfoundland.

Borehole (BH)	Overburden Drilled (m)	Bedrock Drilled (m)	Total Depth Drilled (m)	Total Depth Below LNT (m)	Split-spoon Samples Attempted	Split-spoon Samples Tested
BH1	3.46	2.99	6.45	6.99	3	2
BH2	4.32	0.00	4.32	5.2	4	2
BH3	4.85	0.00	4.85	5.44	4	2 + 1*
BH4	3.15	0.99	4.14	5.90	0	1*
BH5	--	--	--	--	--	1*
BH6	1.79	1.13	2.93	5.04	0	1*
Totals	17.57	5.11	22.69	--	11	10

* The remaining samples from the marine sediment samples were analyzed for the grain size analysis.

Table 1.2 Summary of Dynamic Cone Penetration Test, Twillingate, Newfoundland.

DCPT #	DCPT depth below seabed (m)	Water Depth below LNT (m)	Total depth below LNT (m)	Comments
BH4PC	3.26	1.59	4.85	Refusal at -4.85 m LNT
BH5PC	4.85	1.58	6.43	Refusal at -6.43 m LNT
BH6PC	1.94	2.11	4.06	Refusal at -4.06 m LNT
PC1	1.26	0.3	1.56	Refusal at -1.56 m LNT
PC2	3.76	1.7	5.46	Refusal at -5.46 m LNT
PC3	3.09	0.73	3.82	Refusal at -3.82 m LNT
PC4	6.29	0.83	7.12	Refusal at -7.12 m LNT
PC5	7.64	0.62	8.26	Refusal at -8.26 m LNT
PC6	3.56	1.08	4.64	Refusal at -4.64 m LNT
PC7	3.53	1.3	4.83	Refusal at -4.83 m LNT
PC78	3.39	1.89	5.28	Refusal at -5.28 m LNT
PC9	2.38	1.8	4.18	Refusal at -4.18 m LNT
PC10	4.05	1.98	6.03	Refusal at -6.03 m LNT
PC11	2.12	1.92	4.04	Refusal at -4.04 m LNT
PC12	1.68	1.9	3.58	Refusal at -3.58 m LNT

Table 1.3 Summary of sampling depths for the marine sediment samples.

Sample ID	Sampling Date	Sample Type	Sampling Depth (m below sea bed)
3116-BH1-MS1-0z	December 8, 2017	Soil	Harbour bottom
3116-BH1-MS2-0.3-1z	December 9, 2017	Soil	0.50 - 1.10
3116-BH2-MS1-0z	December 12, 2017	Soil	Harbour bottom
3116-BH2-MS2-0.3-1z	December 11, 2017	Soil	0.35 - 0.85
3116-BH2-MS3-1-2z	December 11, 2017	Soil	0.80 - 1.34
3116-BH3-MS1-0z	December 12, 2017	Soil	Harbour bottom
3116-BH3-MS2-0.3-1z	December 12, 2017	Soil	0.40 - 1.00
3116-BH3-MS3-1-2z	December 12, 2017	Soil	0.95 - 1.15
3116-BH4-MS1-0z	December 16, 2017	Soil	Harbour bottom
3116-BH4-MS2-0.3-1z	December 17, 2017	Soil	0.25 - 0.75
3116-BH5-MS1-0z	December 17, 2017	Soil	Harbour bottom
3116-BH5-MS2-0.3-1z	December 17, 2017	Soil	0.30 - 0.85
3116-BH6-MS1-0z	December 16, 2017	Soil	Harbour bottom
3116-BH6-MS2-0.3-1z	December 17, 2017	Soil	0.20 - 0.63

2.0 SITE DESCRIPTION AND GENERAL GEOLOGY

The community of Twillingate is located on the north east coast of Newfoundland in Notre Dame Bay. It is located approximately 90 kilometres northeast of Gander. Overburden in the area of Twillingate is characterized as, “Thin glacial till and/or bedrock” (Hydrology, 1980). The overburden encountered in the boreholes consisted mainly of soft organic/silty material, poorly sorted sands and silty sands with minor gravel, gravel with boulders. Bedrock units in the area are composed of “Submarine mafic, intermediate and felsic rocks, including mafic volcanic rock of ophiolite complexes, mafic rock dominant in the northern Dunnage zone” (Knight 1990).

3.0 INVESTIGATIVE PROCEDURES

At the Twillingate site, five (5) boreholes were drilled at five (5) locations and DCPTs were driven at 15 locations, and environmental samples were collected at six (6) locations using a Mobile B-47 drill rig drilling from a barge. The borehole, DCPT and environmental sample locations are shown on the site plan in **Appendix A**.

Overburden material was drilled using ‘NW’ (OD 88.9 mm, ID 76.2 mm) flush joint casing. Soil samples were collected using a 51 mm OD, 610 mm long, split-spoon sampler. In conjunction with this split-spoon soil sampling, Standard Penetration Tests (SPT) were performed to estimate relative soil densities. The standard procedure is to drive each SPT, the split-spoon, into the ground using a 63.5 kg weight falling a distance of 760 mm. The number of blows is recorded for each 150 mm the split-spoon is advanced. After the first 150 mm advance, a N-value is calculated as the sum of the blow counts required to drive the spoon an additional 300 mm (i.e., the sum of the second and third set of blow counts). The calculated N-value is a direct reflection of the relative density of the soil strata as defined in the Canadian Foundation Engineering Manual (CGS, 1992).

In addition to borehole sampling, 15 Dynamic Cone Penetration Tests (DCPTs) were performed. During the driving of the pen cone, the cone was driven into the ground using a 63.5 kg weight falling a distance of 760 mm and the number of blow counts recorded for each 150 mm the cone advanced. The cone was driven into the soil until practical refusal occurred (50 blows per 150 mm or equivalent). In some cases. Once the drill string had reached the required depth, a DCPT was driven out through the bottom of the casing to determine how deep the overburden extended below the drilled depth.

Rock was drilled using an ‘NQ’ (OD 69.9 mm, ID 60.3 mm) diamond drill string, cored up to 3 m depth into rock to prove bedrock, where required.

Both the soil samples and rock core are logged and labelled in the field immediately after collection. Soil samples are stored in moisture proof containers and rock cores are stored in wooden core boxes in the field. All soil and rock samples are returned to Fracflow's office where any soil samples collected during the investigation are tested. Soil testing in the laboratory consists of standard mechanical sieve analyses, hydrometer tests and water contents that are performed according to ASTM standards. If clays are encountered and recovered, additional tests are performed to characterize the clay material. The soil and rock core samples are stored by Fracflow for a two-year period.

4.0 SUBSURFACE CONDITIONS AND CHARACTERIZATION

Subsurface characterization is based on the field data collected from the five (5) vertical boreholes drilled in conjunction with the Standard Penetration Test data and the 15 Dynamic Cone Penetration Test. A description of the soil profiles is provided below using both terminologies defined in the Unified Soil Classification System (USCS) and in the Canadian Foundation Engineering Manual (CGS, 1992). Detailed logs of the geological conditions at each borehole location are provided in **Appendix B**. **Appendix C** contains the grain size analysis information for each soil sample tested.

4.1 Soil Description

Overburden in the area of Twillingate is characterized as, “Thin glacial till and/or bedrock” (Hydrology, 1980). The overburden encountered in the boreholes consisted mainly of an upper layer of soft organic material with poorly sorted sand and silty sand, followed by gravels with some boulders.

Refusal was encountered in several of the boreholes during the standard penetration test at the Twillingate site or the required depth was reached before refusal. The boreholes and the depths of final refusal or depth in overburden without refusal are: Boreholes 1, 2, 3, 4, and 5 with depths of -4.0 m LNT, -5.2 m LNT, -5.44 m LNT, -4.91 m LNT, and - 3.91 m LNT, respectively.

The summary of depths for each DCPT are provided in **Table 1.2**. It is important to note that the DCPT data indicate a measurable thickness of soft material in BH5PC, PC2, PC4, PC5, PC6, PC7 PC8 and PC10.

Detailed information for each borehole and DCPT is contained in **Appendix B** and the sieve analysis data are provided in **Appendix C**.

4.2 Bedrock Description

Bedrock was encountered in three (3) of the five (5) boreholes. Bedrock was proven after SPT refusal by coring up to 3.0 m in to bedrock or to a depth that was sufficient to confirm bedrock had been encountered.

The core samples had high sample recoveries but low RQDs indicating that the upper bedrock is highly fractured. Detailed bedrock information is provided in the borehole logs in **Appendix B**.

Bedrock units in the area are composed of “Submarine mafic, intermediate and felsic rocks, including mafic volcanic rock of ophiolite complexes, mafic rock dominant in the northern Dunnage zone” (Knight, 1990). The bedrock encountered in Boreholes 1, 4, and 6, is similar in that it is composed of fractured to highly fractured, highly altered fine grained volcanic bedrock.

4.3 Dredging Issues

The depth to bedrock and the depth of DCPT refusal at the five (5) borehole locations show that in those locations overburden can be dredge to approximately 3.5 to 4.0 m below LNT. The depth to refusal for each DCPT, except for DCPT:PC1, ranged from approximately 3.5 m to 8 m below LNT. It is expected that DCPT:PC1 met refusal at about 1.5 m below LNT on a boulder since DCPT:PC2 did not meet refusal until a depth of approximately 5.4 m LNT was reached. Several of the overburden samples have a high percentage of fine sand to silt, and suspended material should be expected during dredging. However, most of the samples contain a large percentage of sand and gravel that should be sufficient to permit placement as fill if the

placement area is first inspected by a geotechnical engineer and any soft material excavated. Berms around the placement area is recommended. Care should be taken to place the excavated material in even layers to avoid creating areas with low bearing capacity if a wharf is constructed over the fill.

5.0 REFERENCES

Canadian Geotechnical Society (CGS, 1992), *Canadian Foundation Engineering Manual, 3rd Edition*, Technical Committee on Foundations, 512 p.

Hydrology Consultants Limited (Hydrology, 1980), *Hydrogeology of The Notre Dame Bay Area*, Department of Environment Water Resources Division, St. John's Newfoundland.

Knight et al. (Knight 1990), *Geology of the Island of Newfoundland*, Map 90-01, from published and unpublished sources, Newfoundland Department of Mines, Mineral Development Division

APPENDIX A

Borehole and DCPT Location Map

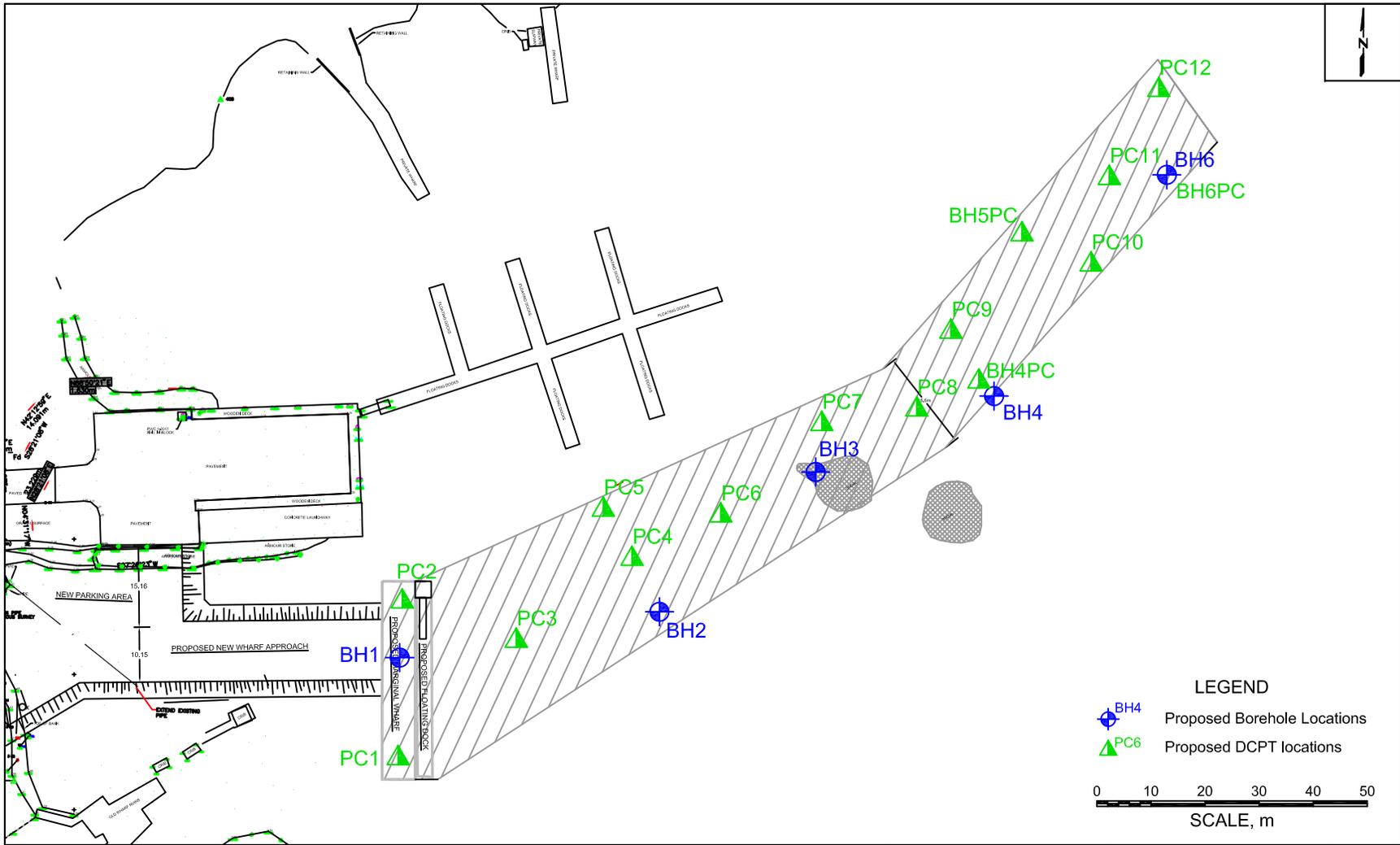


Figure 1 Locations of the boreholes and DCPTs.

Project No. 3116	Document Reference FFC-NL-3116-001	
Location Twillingate, NL	Date January 2018	

APPENDIX B
Borehole and DCPT Logs

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of Borehole: BH1

Project No: 3116
 Date: December 8 - 9, 2017

SUBSURFACE PROFILE				SAMPLE					Standard Penetration Test "N" Value per 300 mm
Depth below LNT	Symbol	Geologic Description	Elevation (m)	Sample Type	Sample No.	"N" Value	Recovery (%)	RQD (%)	
0		0 m LNT	0						
1		Harbour bottom (-0.54 m LNT)	-0.54						
2		Split-spoon sank 0.32 m into soft sediments under own weight	-0.86						
3		SPT: 2 / 1 / 2 / 4 CFEM: Silty/Clayey Sand, trace Gravel	-1.47	SS	1	3	50		
4		Gravel	-1.86	OB	--		18	0	
5		SPT: 52 for 0.11 m (Refusal) CFEM: Gravel and Sand, trace Silt/Clay		SS	2	52	44		
6		Gravel and boulders		OB	--		21	0	
7			-3.36						
8		Gravel and boulders	-3.71	OB	--		51	0	
9		SPT: 52 for 0.03 m (Refusal) SS3; "N" Value = 52; Recovery = 50%	-4	OB	--		58	0	
10		Rock chips		RC	--		100	0	
11		Gravel		RC	--		100	25	
12				RC	--		99	0	
13				RC	--		100	0	
14		Bedrock: Altered volcanic rock		RC	--		100	0	
15				RC	--		99	0	
16				RC	--		100	0	
17				RC	--		100	0	
18				RC	--		100	0	
19				RC	--		100	0	
20				RC	--		100	0	
21				RC	--		100	0	
22				RC	--		100	0	
23			-6.99						



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Drilling Method: NW Casing / NQ Coring

Driller: Formation Drilling Ltd.

Datum: Geodetic

Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of Borehole: BH2

Project No: 3116
 Date: December 11, 2017

SUBSURFACE PROFILE				SAMPLE					Standard Penetration Test "N" Value per 300 mm
Depth below LNT	Symbol	Geologic Description	Elevation (m)	Sample Type	Sample No.	"N" Value	Recovery (%)	RQD (%)	
0		0 m LNT	0						
1		Harbour bottom (-0.88 m LNT)	-0.88						
2		Split-spoon sank 0.24 m into soft sediments under own weight	-1.11						
3		SPT: 1 / 7 / 3 / 4 CFEM: Sand, some Silt/Clay, trace Gravel	-1.72	SS	1	10	18		
4		SPT: 4 / 4 / 10 / 15 CFEM: Gravelly Sand, some Silt/Clay	-2.33	SS	2	14	17		
5		Gravel	-3.14	OB	--		21	0	
6		SPT: 14 / 8 / 11 / 21 Grey, very fine sand with rock fragments	-3.74	SS	3	19	14		
7		Gravel	-3.98	OB	--		23	0	
8		Gravel	-4.59	OB	--		8	0	
9		SPT: 10 / 18 / 16 / 9 Gravel	-5.2	SS	4	34	17		
10		End of Borehole							



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Drilling Method: NW Casing / NQ Coring

Driller: Formation Drilling Ltd.

Datum: Geodetic

Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of Borehole: BH3

Project No: 3116
 Date: December 12, 2017

SUBSURFACE PROFILE				SAMPLE					Standard Penetration Test "N" Value per 300 mm
Depth below LNT	Symbol	Geologic Description	Elevation (m)	Sample Type	Sample No.	"N" Value	Recovery (%)	RQD (%)	
0		0 m LNT	0						20 40 60 80
1		Harbour bottom (-0.59 m LNT)	-0.59						
2		Split-spoon sank 0.35 m into soft sediments under own weight	-0.94						
3		SPT: 1 / 2 / 10 / 3 Black, organic material	-1.54	SS	1	12	19		
4		No Recovery	-1.92	OB	--		0	0	
5		SPT: 3 / 7 / 17 / 20 CFEM: Sand, some Gravel, some Silt/Clay	-2.53	SS	2	24	42		
6		No Recovery	-3.34	OB	--		0	0	
7		SPT: 15 / 14 / 13 / 16 CFEM: Gravelly Sand, trace Silt/Clay	-3.95	SS	3	27	46		
8		Gravel and boulders	-4.83	OB	--		19	0	
9		SPT: 15 / 17 / 5 / 5 Gravel with rock fragments	-5.44	SS	4	22	8		
10		End of Borehole							



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Drilling Method: NW Casing / NQ Coring

Driller: Formation Drilling Ltd.

Datum: Geodetic

Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of Borehole: BH4

Project No: 3116
 Date: December 16, 2017

SUBSURFACE PROFILE				SAMPLE					Standard Penetration Test "N" Value per 300 mm			
Depth below LNT	Symbol	Geologic Description	Elevation (m)	Sample Type	Sample No.	"N" Value	Recovery (%)	RQD (%)	20	40	60	80
0		0 m LNT	0									
1												
2												
3												
4												
5		Harbour bottom (-1.76 m LNT)	-1.76									
6												
7												
8		Drilling after DCPT. See 'Log of DCPT: BH4PC' for details. No recovery		OB	--		0	0				
9												
10												
11			-3.45									
12												
13												
14		Gravel and boulders		OB	--		28	0				
15												
16			-4.91									
17		Broken bedrock: Altered volcanic rock	-5.15	BC	--		100	0				
17				RC	--		94	83				
17		DCPT: 51 for 0.05 m (Refusal)		PC	1	51						
18				RC	--		89	64				
19		Bedrock: Altered volcanic rock		RC	--		100	54				
20			-5.9									
21		End of Borehole										
22												
23												



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Drilling Method: NW Casing / NQ Coring

Driller: Formation Drilling Ltd.

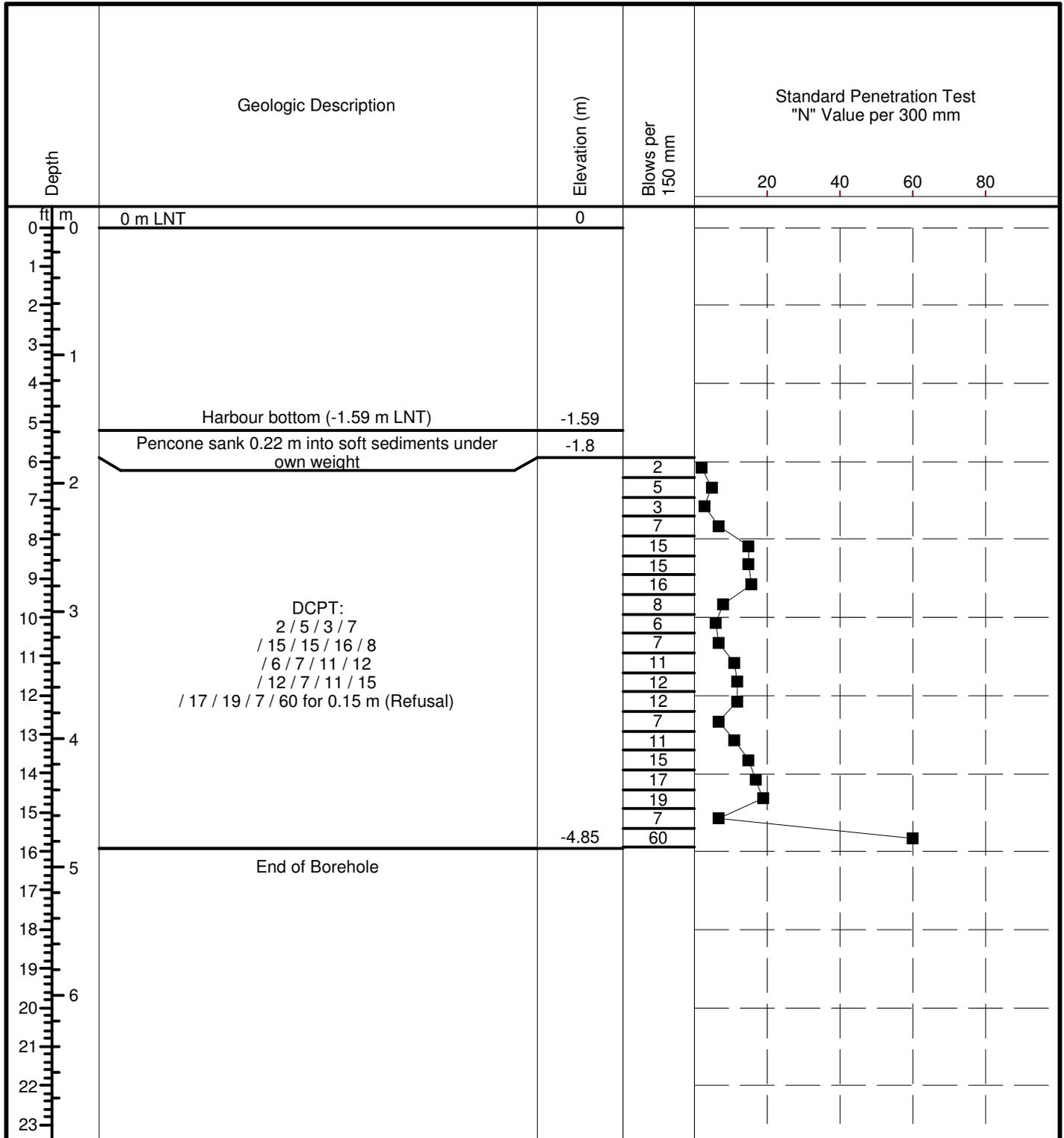
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Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: BH4PC

Project No: 3116
 Date: December 16 - 17, 2017



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Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

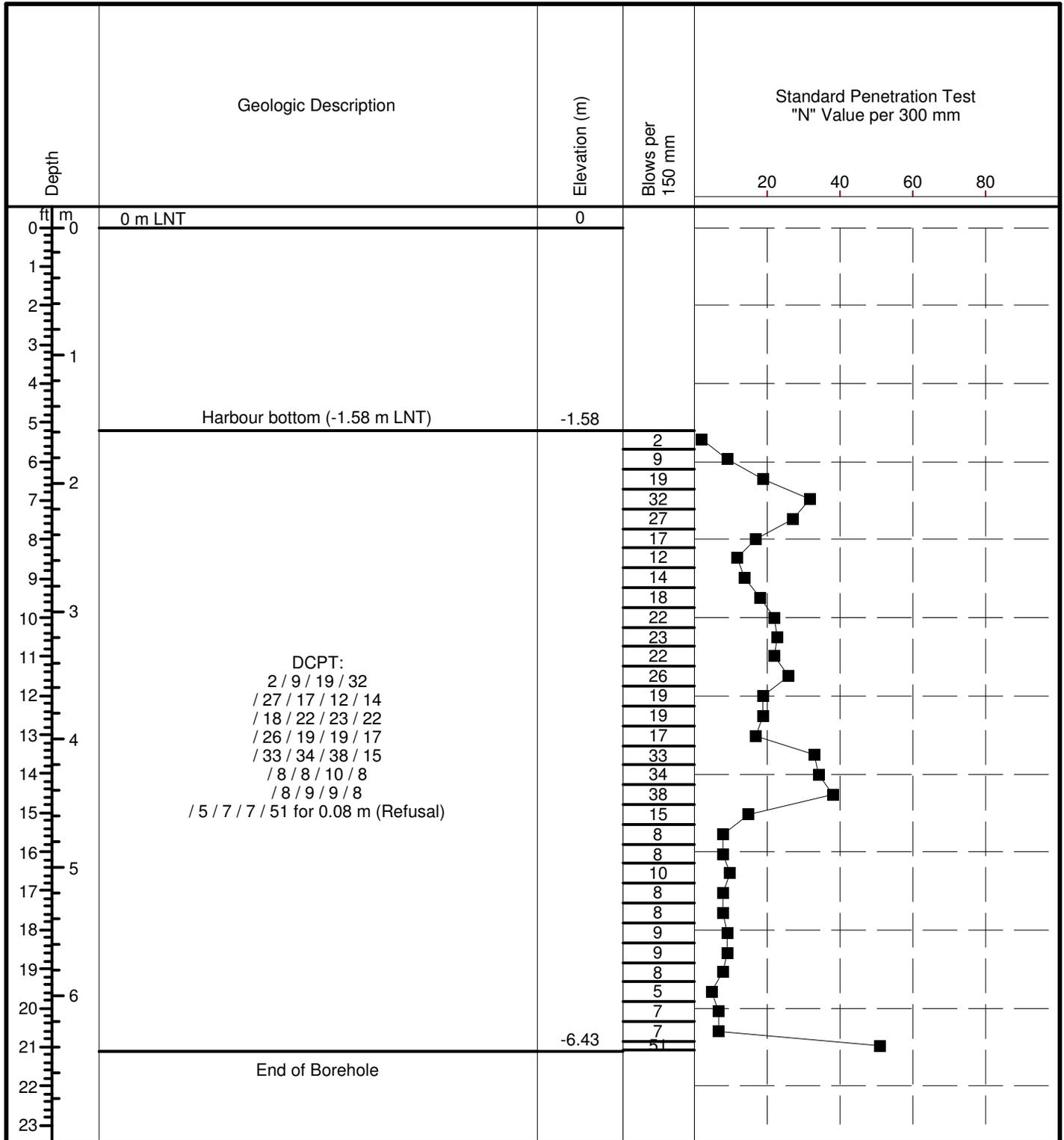
Driller: Formation Drilling Ltd.

Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: BH5PC

Project No: 3116
 Date: December 17, 2017



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Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

Driller: Formation Drilling Ltd.

Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of Borehole: BH6

Project No: 3116
 Date: December 16, 2017

SUBSURFACE PROFILE				SAMPLE					Standard Penetration Test "N" Value per 300 mm			
Depth below LNT	Symbol	Geologic Description	Elevation (m)	Sample Type	Sample No.	"N" Value	Recovery (%)	RQD (%)	20	40	60	80
0		0 m LNT	0									
1												
2												
3												
4												
5												
6		Harbour bottom (-2.11 m LNT)	-2.11									
7												
8		Drilling after DCPT. See 'Log of DCPT: BH6PC' for details. No recovery		OB	--		0	0				
9												
10			-3.33									
11												
12		Gravel and rock fragments		OB	--		62	0				
13			-3.91									
14				RC	--		100	0				
15				RC	--		100	34				
16		Bedrock: Altered volcanic rock		RC	--		92	31				
17			-5.04	RC	--		99	66				
18		End of Borehole										
19												
20												
21												
22												
23												



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Drilling Method: NW Casing / NQ Coring

Driller: Formation Drilling Ltd.

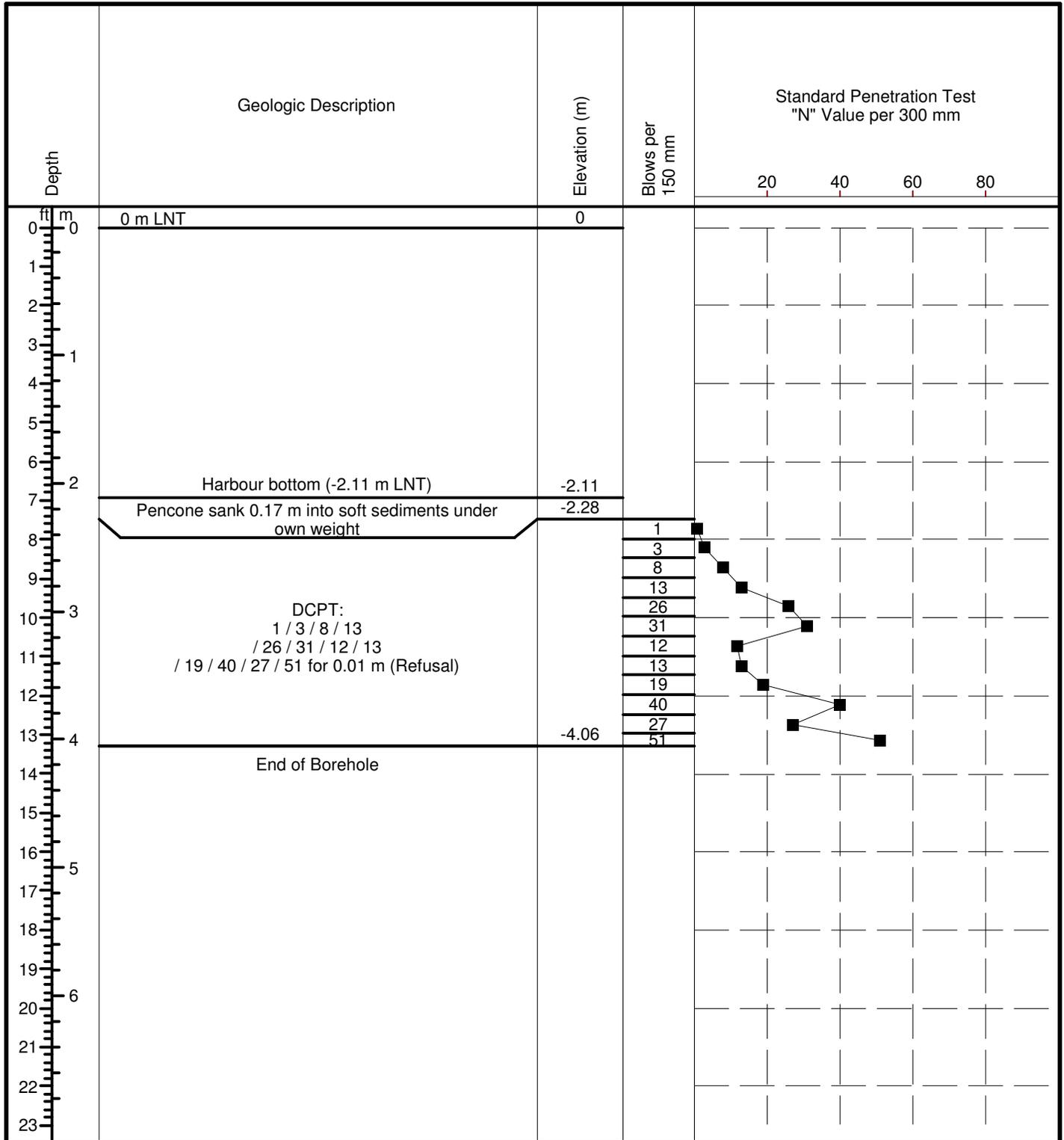
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Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: BH6PC

Project No: 3116
 Date: December 16, 2017



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Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

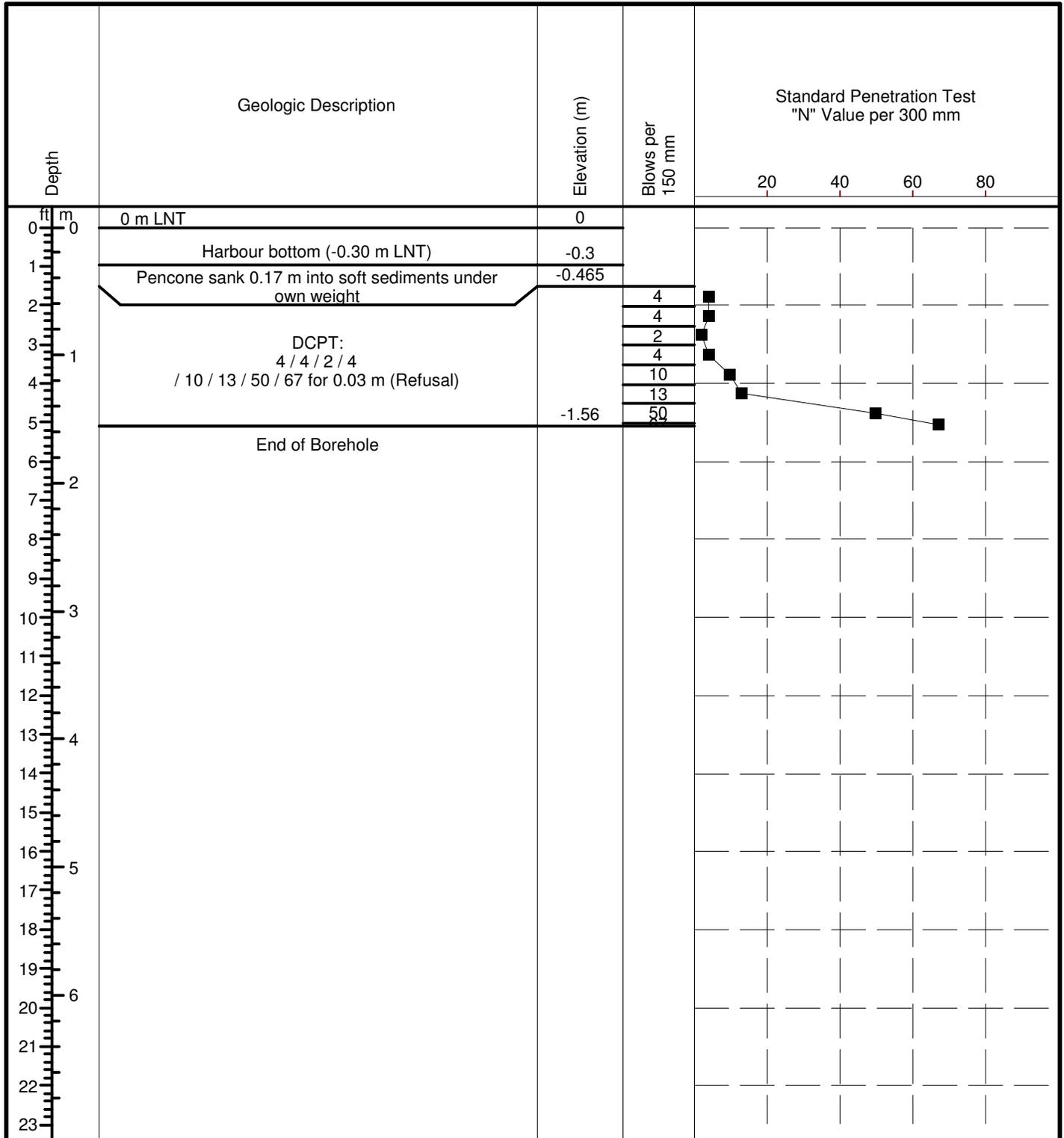
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Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC1

Project No: 3116
 Date: December 9, 2017



Fracflow Consultants Inc.
 154 Major's Path
 St. John's, NL A1A 5A1
 Phone: (709) 739-7270
 Fax: (709) 753-5101

Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

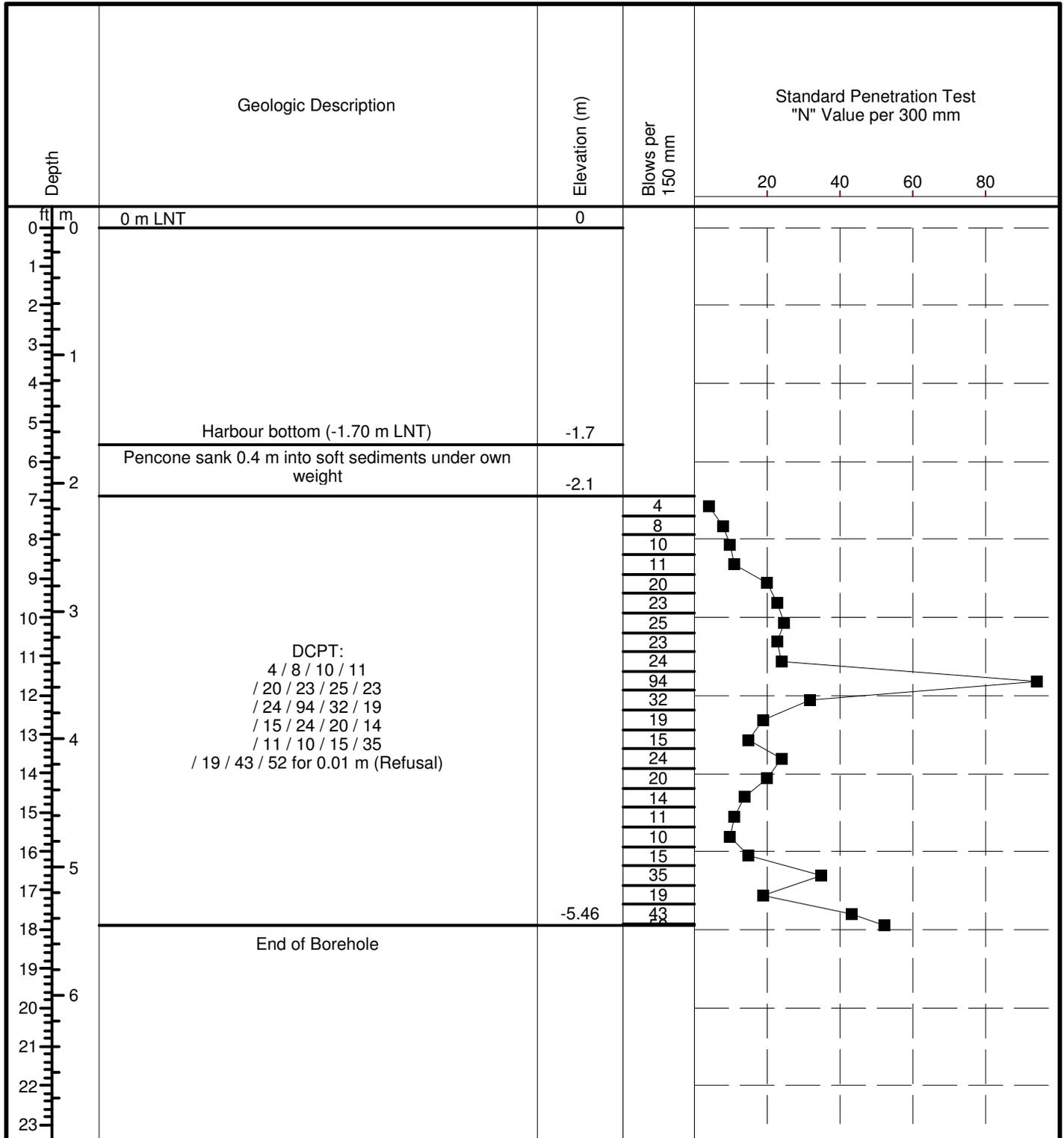
Driller: Formation Drilling Ltd.

Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC2

Project No: 3116
 Date: December 9, 2017



Fracflow Consultants Inc.
 154 Major's Path
 St. John's, NL A1A 5A1
 Phone: (709) 739-7270
 Fax: (709) 753-5101

Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

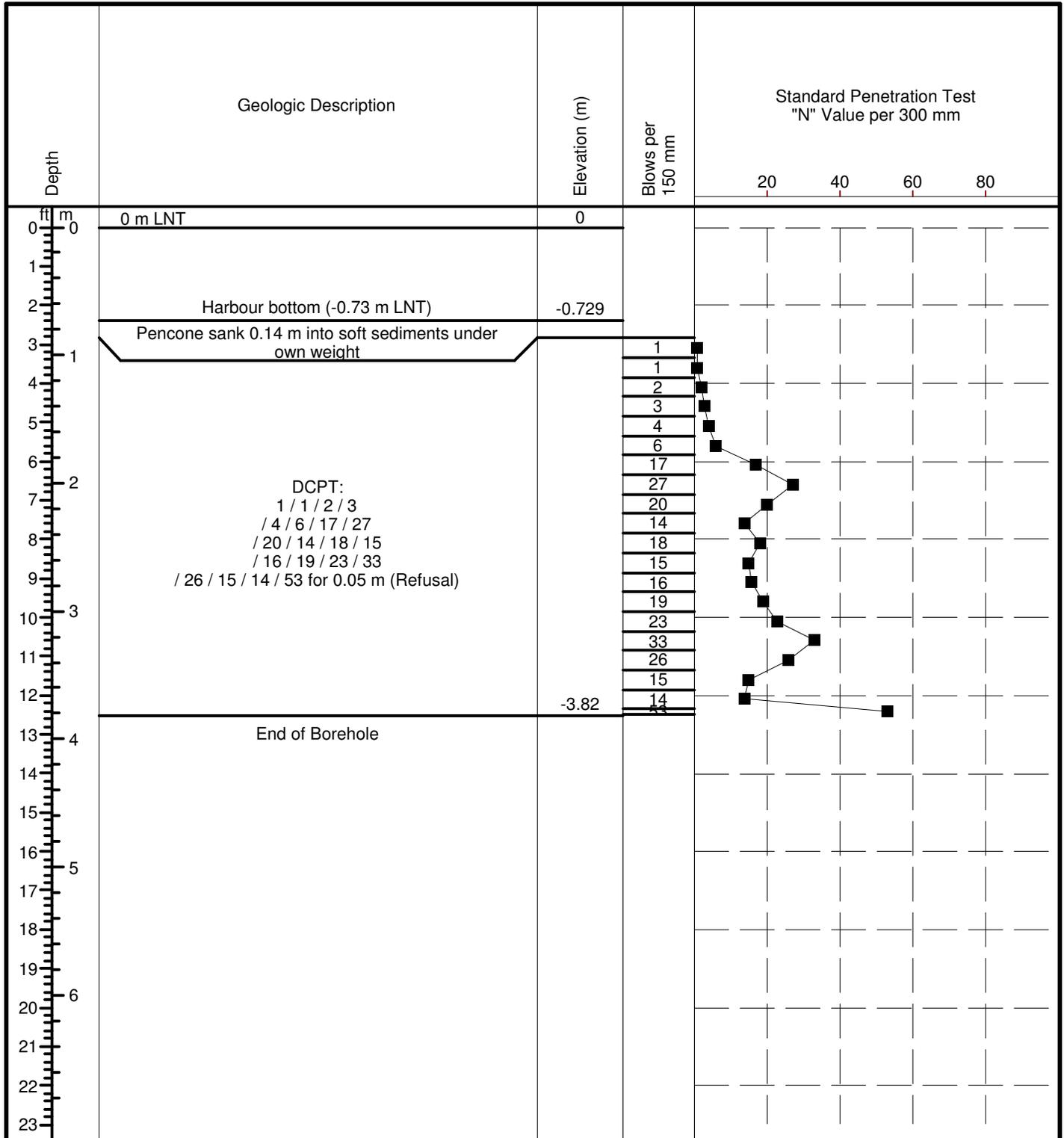
Driller: Formation Drilling Ltd.

Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC3

Project No: 3116
 Date: December 17, 2017



Fracflow Consultants Inc.
 154 Major's Path
 St. John's, NL A1A 5A1
 Phone: (709) 739-7270
 Fax: (709) 753-5101

Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

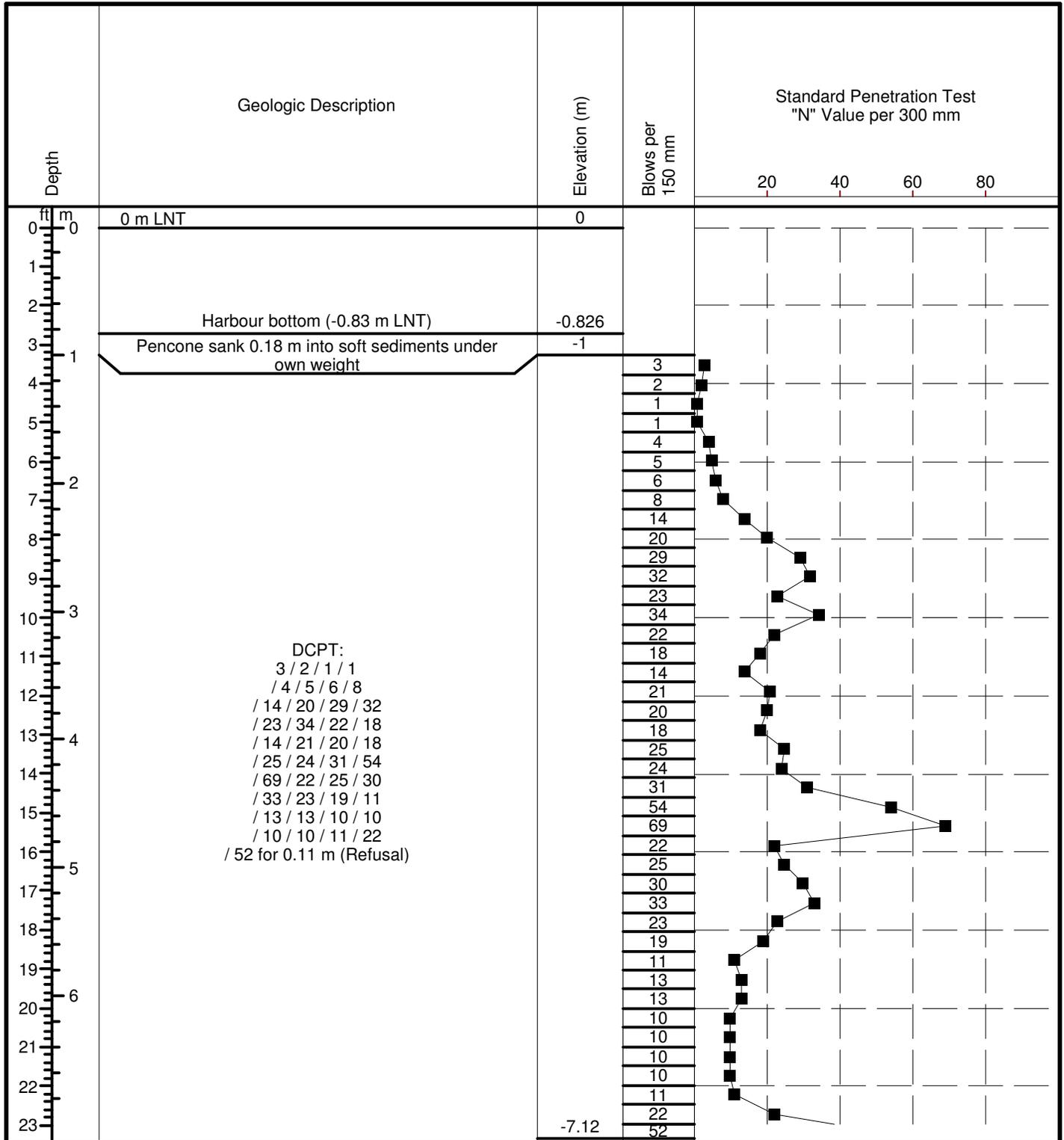
Driller: Formation Drilling Ltd.

Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC4

Project No: 3116
 Date: December 11, 2017



Fracflow Consultants Inc.
 154 Major's Path
 St. John's, NL A1A 5A1
 Phone: (709) 739-7270
 Fax: (709) 753-5101

Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

Driller: Formation Drilling Ltd.

Sheet: 1 of 2

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC4

Project No: 3116
 Date: December 11, 2017

Depth	Geologic Description	Elevation (m)	Blows per 150 mm	Standard Penetration Test "N" Value per 300 mm				
				20	40	60	80	
23	End of Borehole		52					
24								
25								
26			8					
27								
28								
29			9					
30								
31								
32								
33			10					
34								
35								
36			11					
37								
38								
39			12					
40								
41								
42								
43	13							
44								
45								
46	14							



Fracflow Consultants Inc.
 154 Major's Path
 St. John's, NL A1A 5A1
 Phone: (709) 739-7270
 Fax: (709) 753-5101

Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

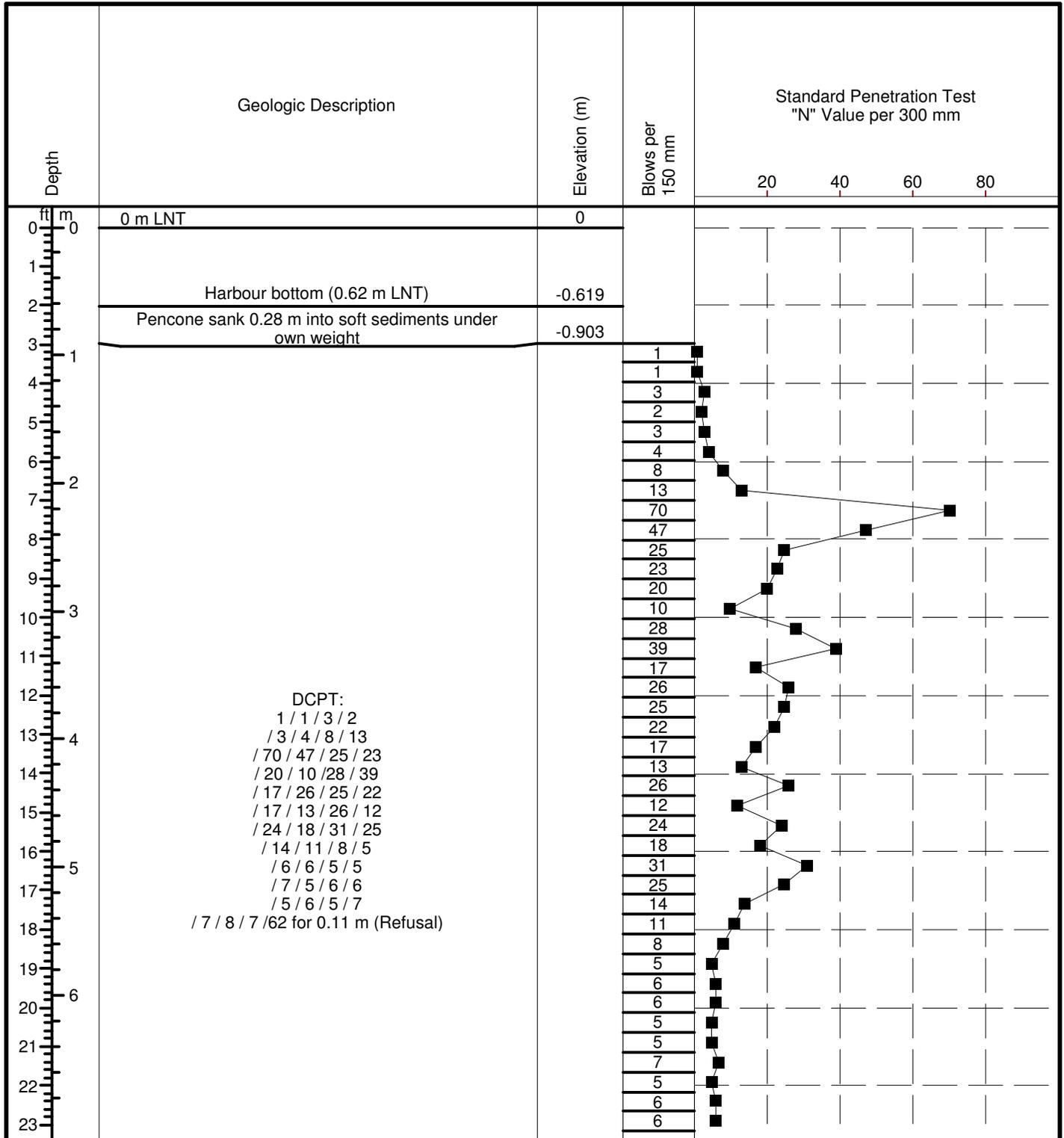
Driller: Formation Drilling Ltd.

Sheet: 2 of 2

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC5

Project No: 3116
 Date: December 11, 2017



Fracflow Consultants Inc.
 154 Major's Path
 St. John's, NL A1A 5A1
 Phone: (709) 739-7270
 Fax: (709) 753-5101

Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

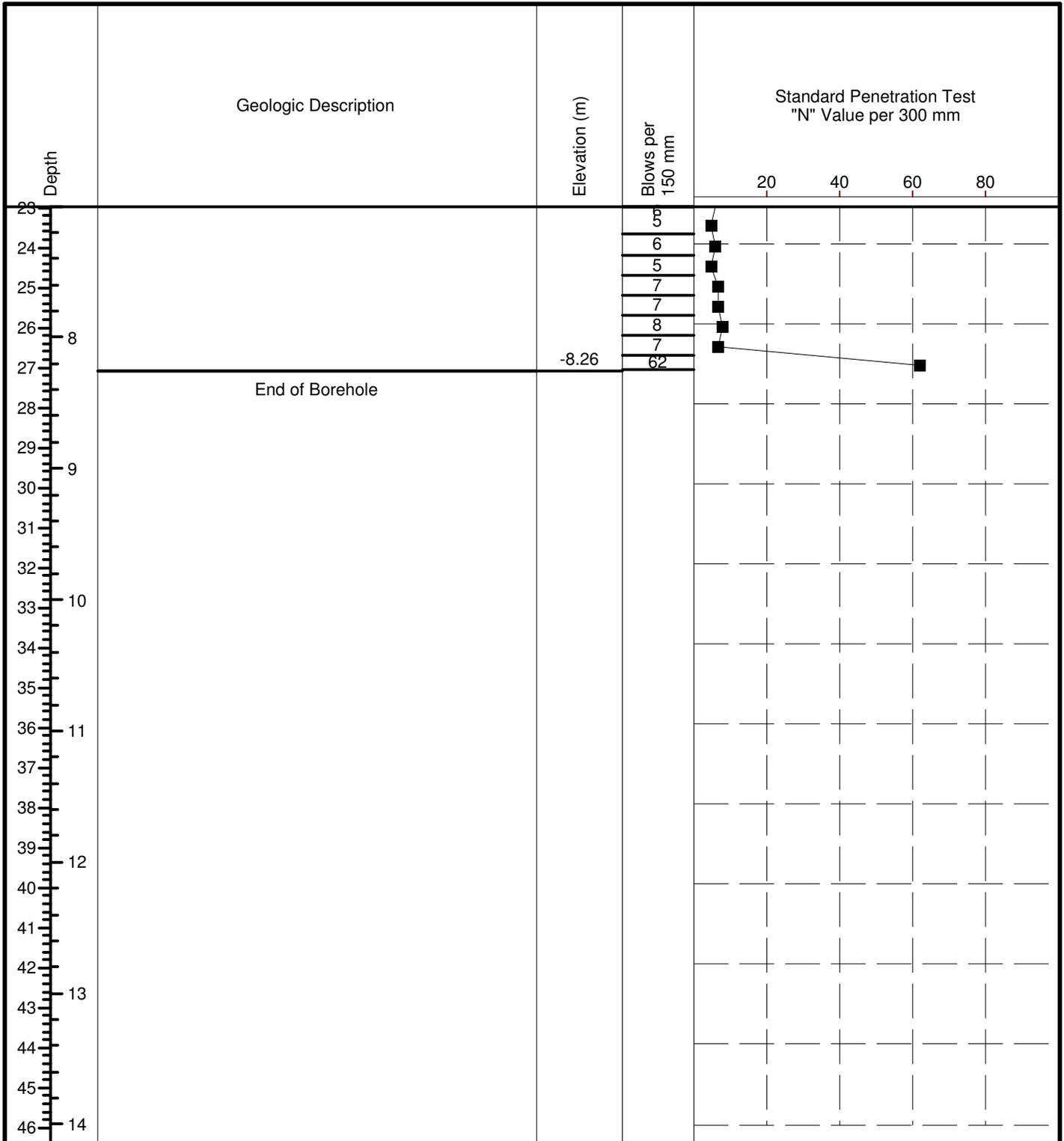
Driller: Formation Drilling Ltd.

Sheet: 1 of 2

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC5

Project No: 3116
 Date: December 11, 2017



Fracflow Consultants Inc.
 154 Major's Path
 St. John's, NL A1A 5A1
 Phone: (709) 739-7270
 Fax: (709) 753-5101

Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

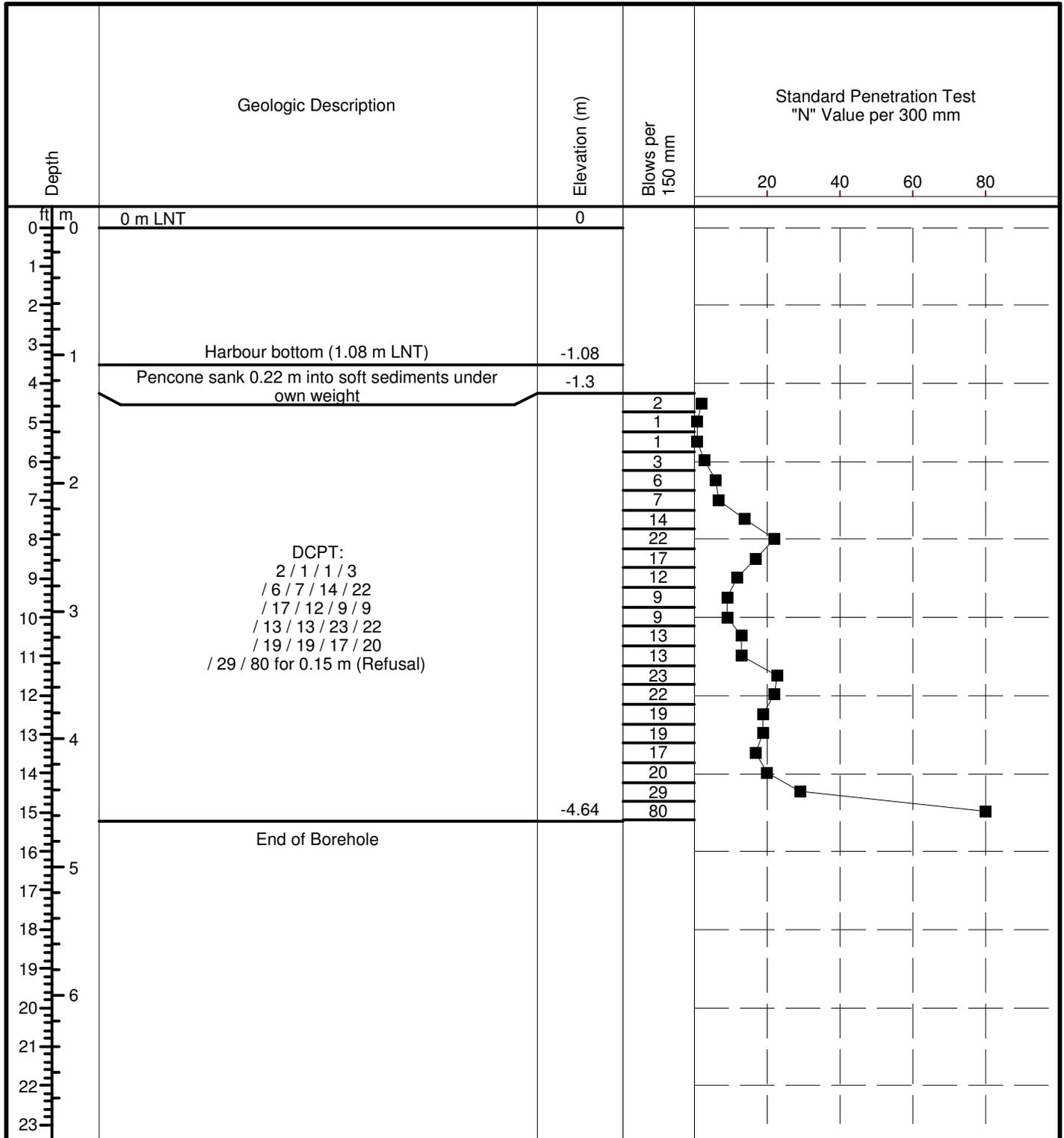
Driller: Formation Drilling Ltd.

Sheet: 2 of 2

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC6

Project No: 3116
 Date: December 12, 2017



Fracflow Consultants Inc.
 154 Major's Path
 St. John's, NL A1A 5A1
 Phone: (709) 739-7270
 Fax: (709) 753-5101

Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

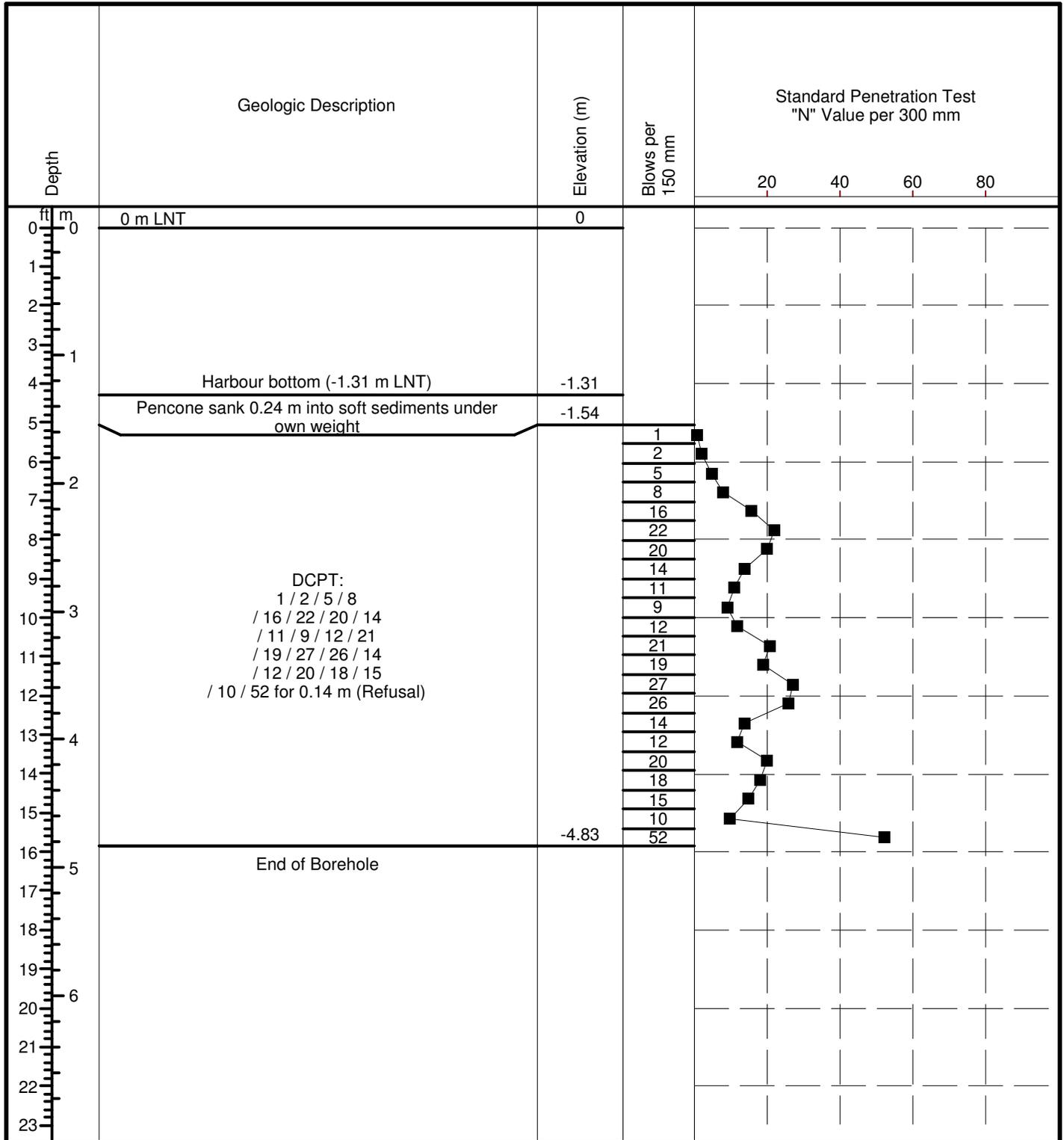
Driller: Formation Drilling Ltd.

Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC7

Project No: 3116
 Date: December 12, 2017



Fracflow Consultants Inc.
 154 Major's Path
 St. John's, NL A1A 5A1
 Phone: (709) 739-7270
 Fax: (709) 753-5101

Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

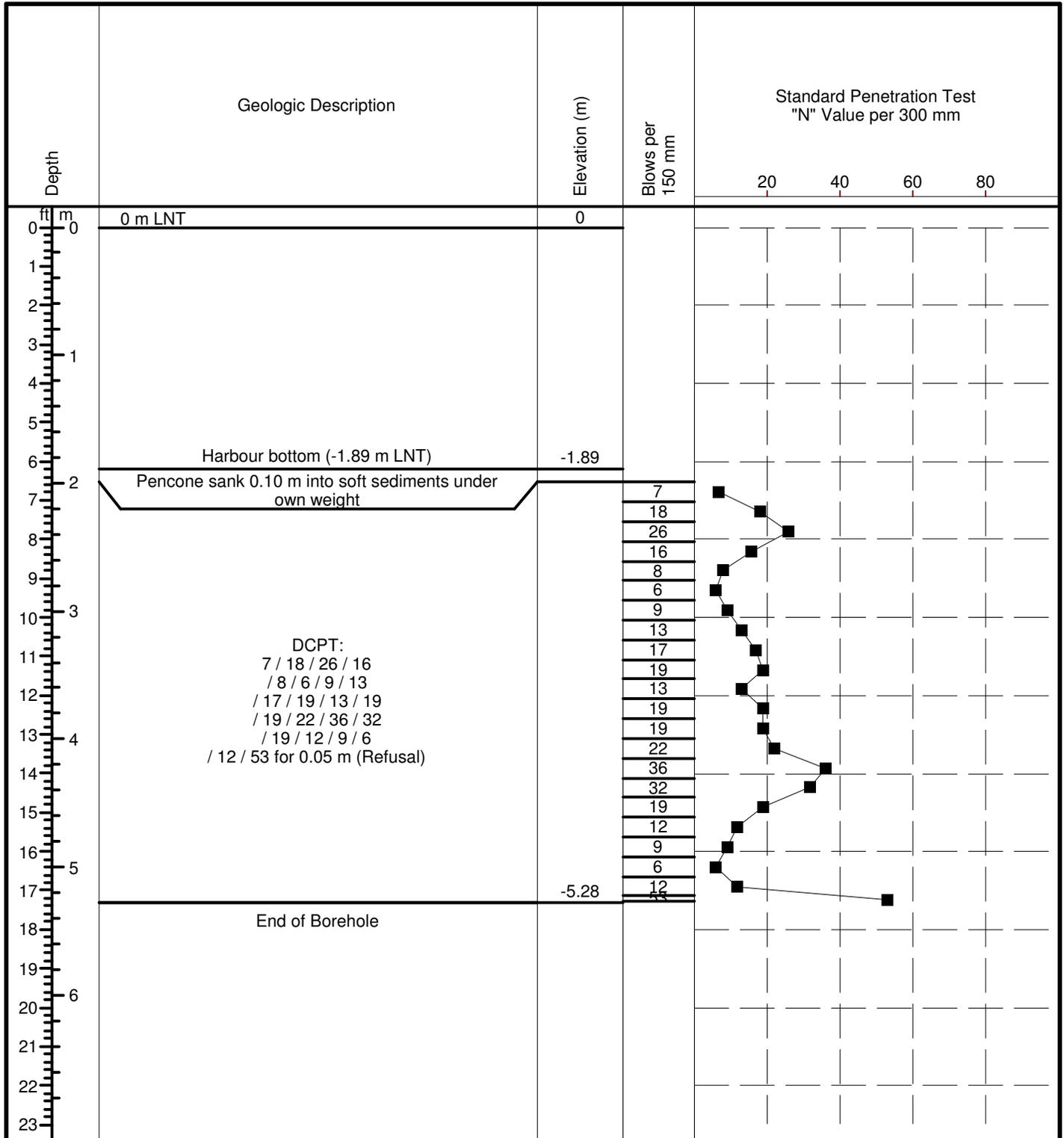
Driller: Formation Drilling Ltd.

Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC8

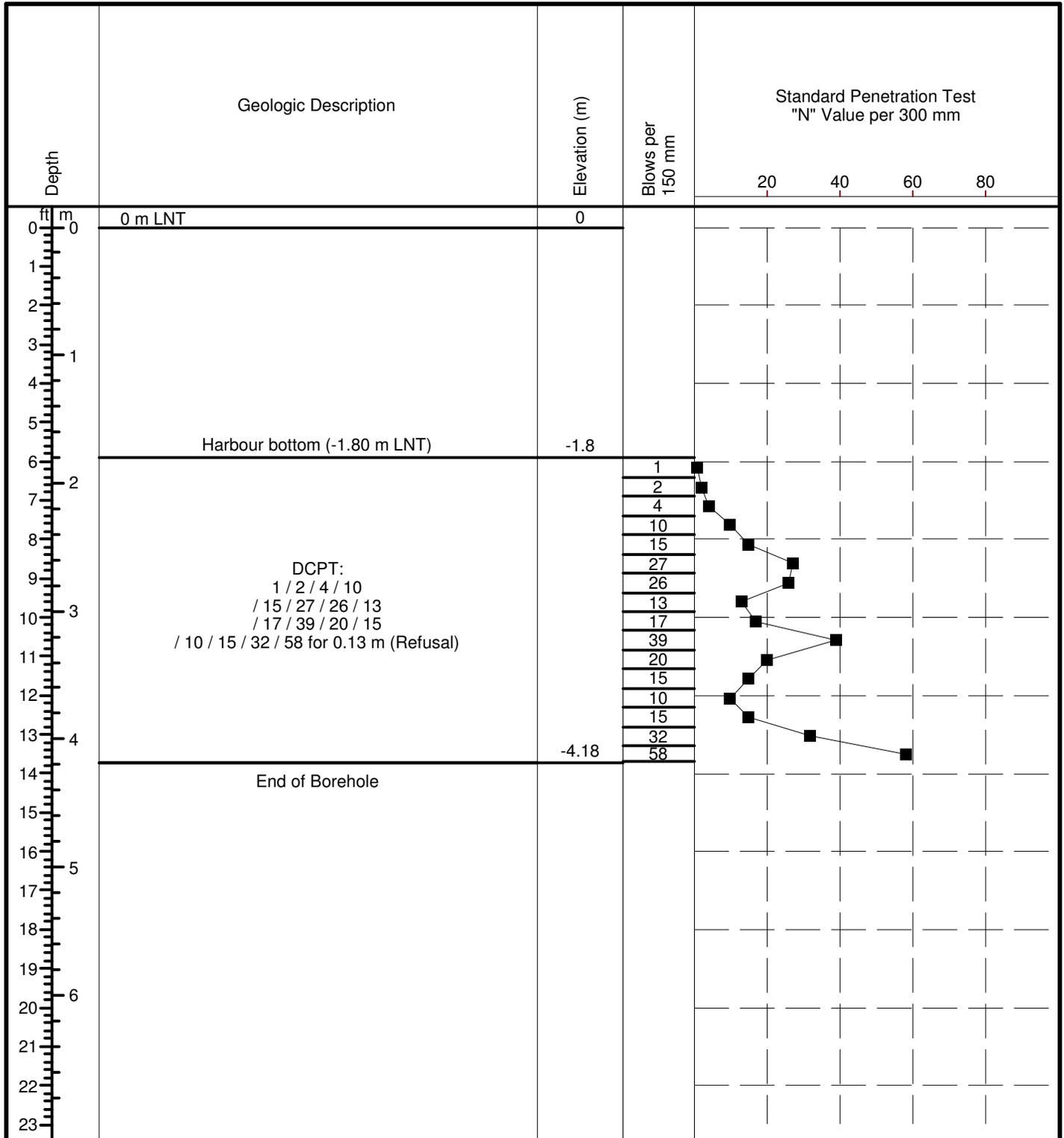
Project No: 3116
 Date: December 17, 2017



Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC9

Project No: 3116
 Date: December 17, 2017



Fracflow Consultants Inc.
 154 Major's Path
 St. John's, NL A1A 5A1
 Phone: (709) 739-7270
 Fax: (709) 753-5101

Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

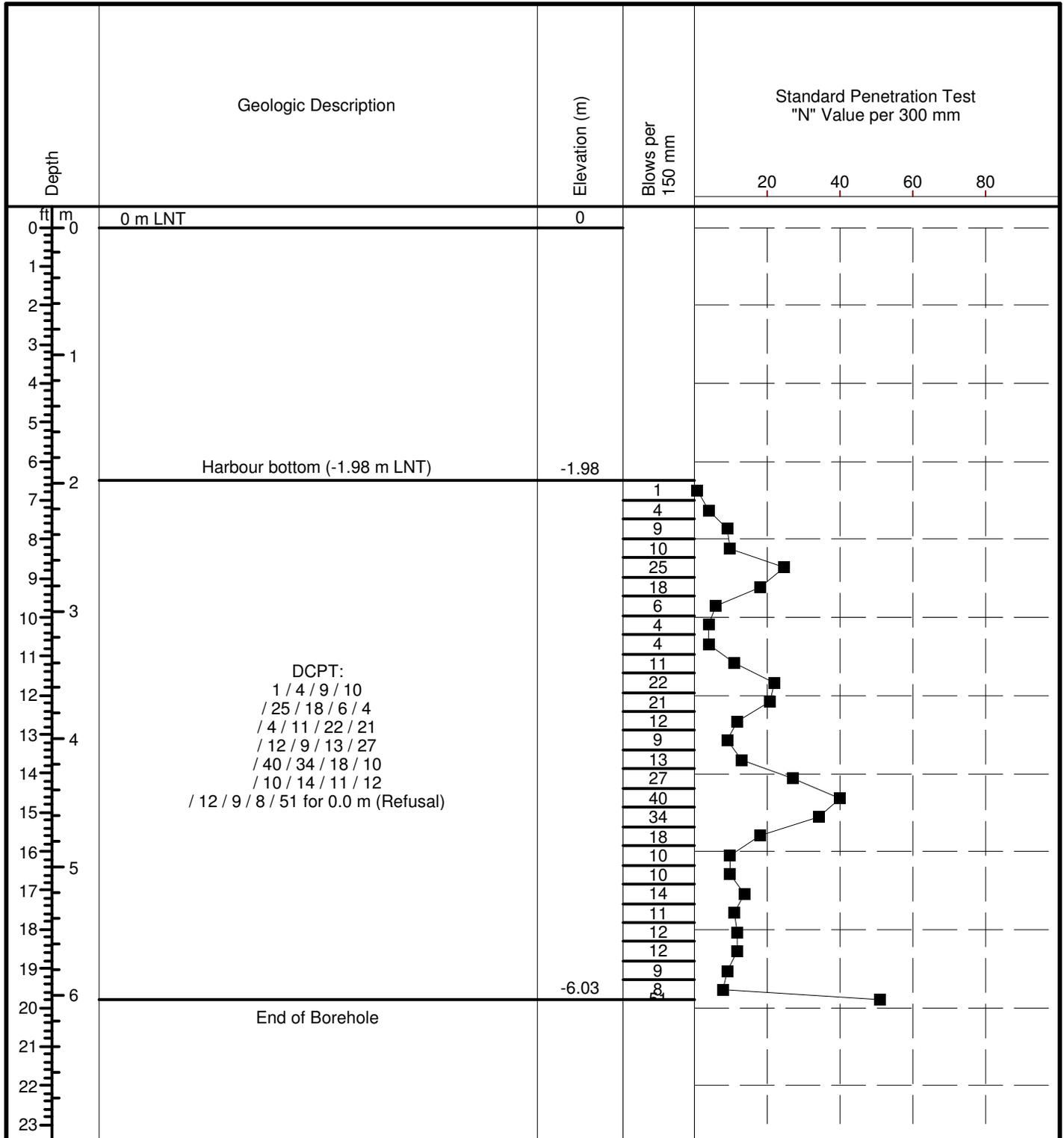
Driller: Formation Drilling Ltd.

Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC10

Project No: 3116
 Date: December 12, 2017



Fracflow Consultants Inc.
 154 Major's Path
 St. John's, NL A1A 5A1
 Phone: (709) 739-7270
 Fax: (709) 753-5101

Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

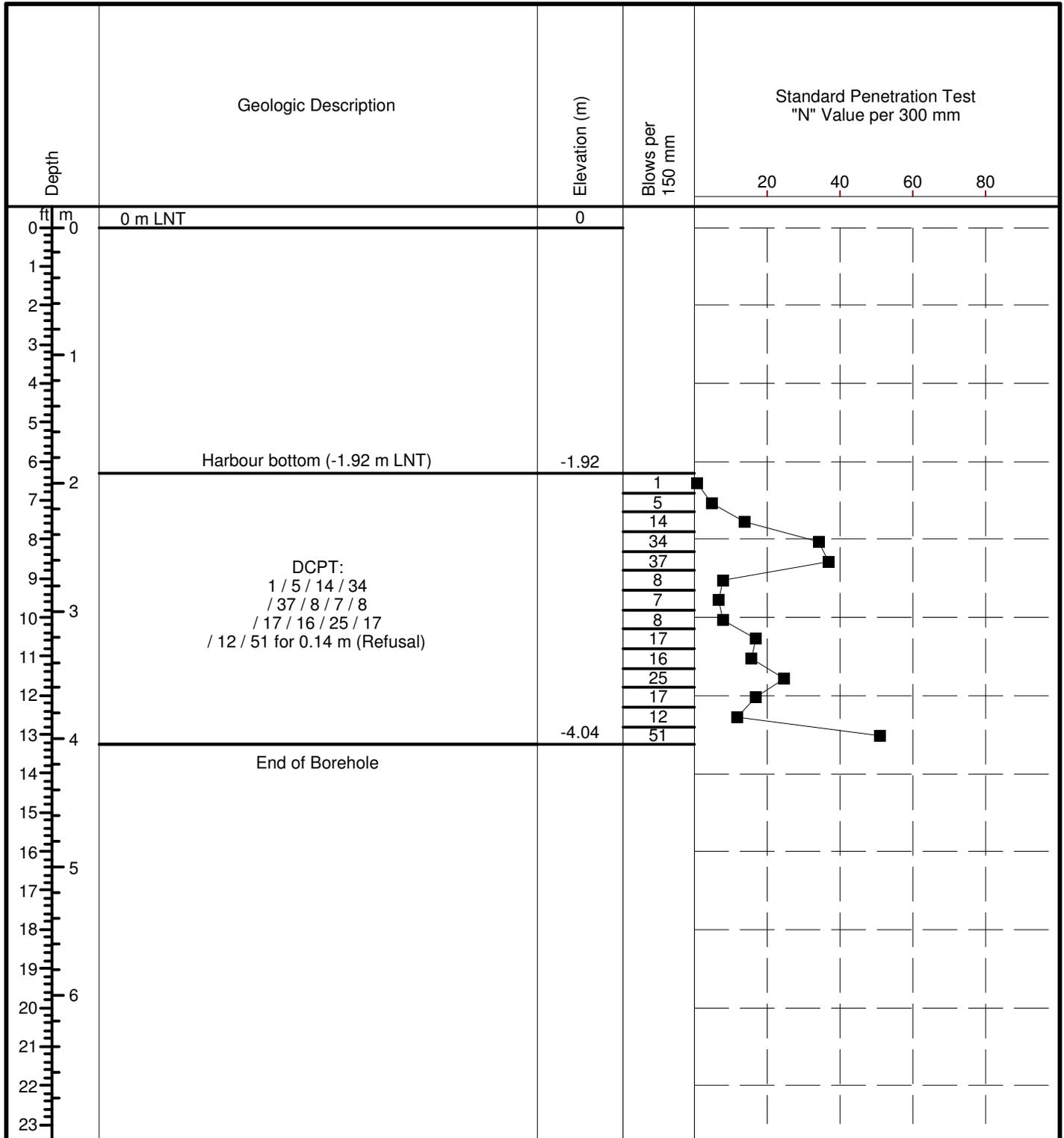
Driller: Formation Drilling Ltd.

Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC11

Project No: 3116
 Date: December 17, 2017



Fracflow Consultants Inc.
 154 Major's Path
 St. John's, NL A1A 5A1
 Phone: (709) 739-7270
 Fax: (709) 753-5101

Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

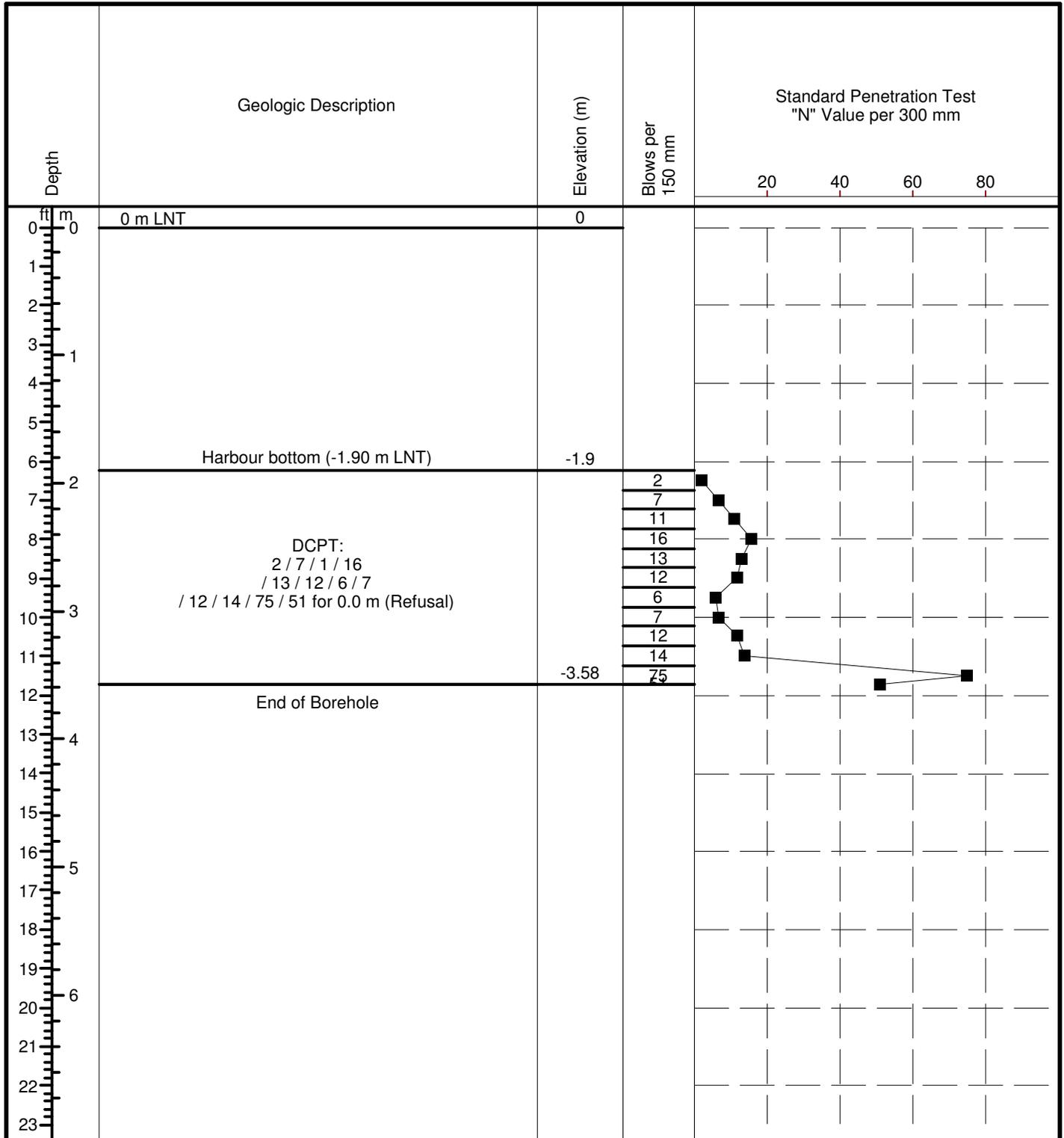
Driller: Formation Drilling Ltd.

Sheet: 1 of 1

Project: Marine Geotechnical Investigation
 Client: Public Works Government Services Canada
 Location: Twillingate, NL

Log of DCPT: PC12

Project No: 3116
 Date: December 17, 2017



Fracflow Consultants Inc.
 154 Major's Path
 St. John's, NL A1A 5A1
 Phone: (709) 739-7270
 Fax: (709) 753-5101

Drilling Method: Dynamic Cone Penetration Test

Datum: Geodetic

Driller: Formation Drilling Ltd.

Sheet: 1 of 1

APPENDIX C
Grain Size Analysis

GRAIN SIZE ANALYSIS

Project : 3116 - Twillingate, NL

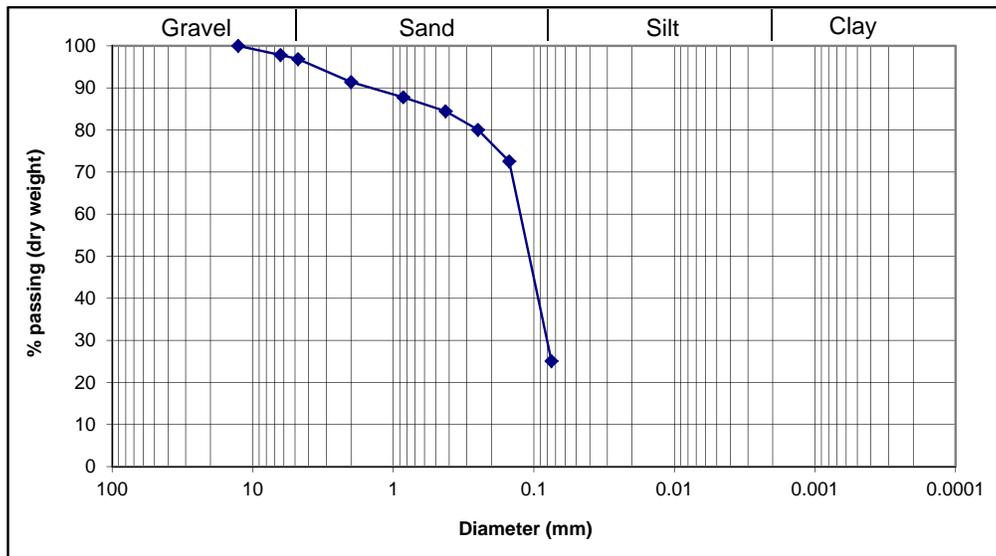
Sample No. : BH1-SS1

Depth below LNT : 0.86 m - 1.47 m

Sieve Analysis

Dry weight of sample (g) = 204.65

Sieve	Opening (mm)	Retained (g)	% Retained	Cumulative % Ret	% Passing
2	50.8	--	--		
1	25.4	--	--		
1/2"	12.7	0.00	0.00	0.00	100.00
1/4"	6.35	4.43	2.16	2.16	97.84
4	4.76	1.99	0.97	3.14	96.86
10	2.00	11.18	5.46	8.60	91.40
20	0.85	7.42	3.63	12.23	87.77
40	0.425	6.76	3.30	15.53	84.47
60	0.25	9.03	4.41	19.94	80.06
100	0.15	15.34	7.50	27.44	72.56
200	0.075	97.17	47.48	74.92	25.08
pan	---	51.33	25.08	100.00	---
		204.65			



$D_{10} = \text{NA}$

$D_{30} = 0.08$

$D_{60} = 0.125$

$C_u = \text{NA}$

$C_c = \text{NA}$

USCS: SM (Silty sand) or SC (Clayey sand) or SC-SM (Silty, clayey sand)

$R_{200} = 74.92$

$R_4 = 3.14$

$R_4/R_{200} = 0.04$

SF = 71.78

GF = 3.14

% Gravel = 3.14

% Sand = 71.78

% Silt & Clay = 25.08

% Clay = NA

CFEM: Silty/Clayey Sand, trace Gravel

Moisture Content (%): 70.74

GRAIN SIZE ANALYSIS

Project : 3116 - Twillingate, NL

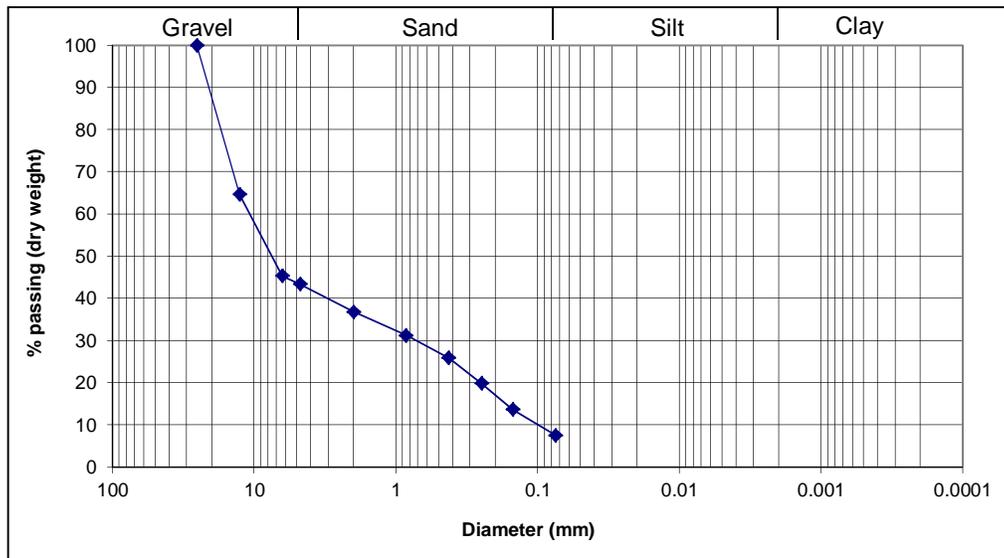
Sample No. : BH1-SS2

Depth below LNT : 1.86 m - 1.98 m

Sieve Analysis

Dry weight of sample (g) = 128.05

Sieve	Opening (mm)	Retained (g)	% Retained	Cumulative % Ret	% Passing
2	50.8	--	--		
1	25.4	0.00	0.00	0.00	100.00
1/2"	12.7	45.19	35.29	35.29	64.71
1/4"	6.35	24.72	19.30	54.60	45.40
4	4.76	2.52	1.97	56.56	43.44
10	2.00	8.42	6.58	63.14	36.86
20	0.85	7.05	5.51	68.65	31.35
40	0.425	6.91	5.40	74.04	25.96
60	0.25	7.76	6.06	80.10	19.90
100	0.15	7.90	6.17	86.27	13.73
200	0.075	7.87	6.15	92.42	7.58
pan	---	9.71	7.58	100.00	---
		128.05			



$$D_{10} = 0.098$$

$$D_{30} = 0.705$$

$$D_{60} = 10.75$$

$$Cu = 109.69$$

$$Cc = 0.47$$

USCS: GP-GM (Poorly graded gravel with silt and sand) or GP-GC (Poorly graded gravel with clay and sand)

$$R_{200} = 92.42$$

$$R_4 = 56.56$$

$$R_4/R_{200} = 0.61$$

$$SF = 35.85$$

$$GF = 56.56$$

$$\% \text{ Gravel} = 56.56$$

$$\% \text{ Sand} = 35.85$$

$$\% \text{ Silt \& Clay} = 7.58$$

$$\% \text{ Clay} = \text{NA}$$

CFEM: Gravel and Sand, trace Silt/Clay

Moisture Content (%): 19.75

GRAIN SIZE ANALYSIS

Project : 3116 - Twillingate, NL

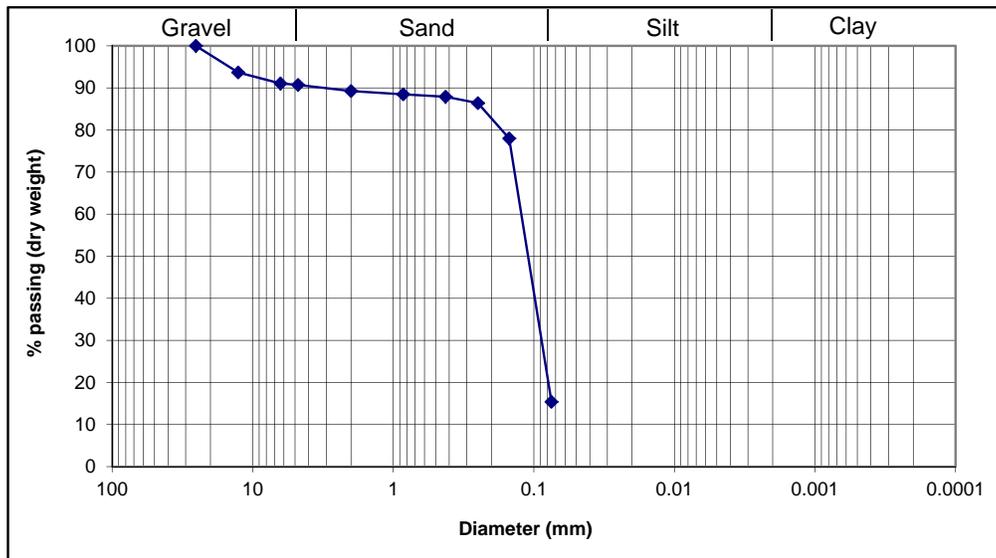
Sample No. : BH2-SS1

Depth below LNT : 1.11 m - 1.72 m

Sieve Analysis

Dry weight of sample (g) = 200.45

Sieve	Opening (mm)	Retained (g)	% Retained	Cumulative % Ret	% Passing
2	50.8	--	--		
1	25.4	0.00	0.00	0.00	100.00
1/2"	12.7	12.66	6.32	6.32	93.68
1/4"	6.35	5.26	2.62	8.94	91.06
4	4.76	0.67	0.33	9.27	90.73
10	2.00	2.94	1.47	10.74	89.26
20	0.85	1.55	0.77	11.51	88.49
40	0.425	1.14	0.57	12.08	87.92
60	0.25	3.05	1.52	13.60	86.40
100	0.15	16.82	8.39	22.00	78.00
200	0.075	125.48	62.60	84.59	15.41
pan	---	30.88	15.41	100.00	---
		200.45			



$D_{10} = \text{NA}$

$D_{30} = 0.088$

$D_{60} = 0.123$

$C_u = \text{NA}$

$C_c = \text{NA}$

USCS: SM (Silty sand) or SC (Clayey sand) or SC-SM (Silty, clayey sand)

$R_{200} = 84.59$

$R_4 = 9.27$

$R_4/R_{200} = 0.11$

SF = 75.32

GF = 9.27

% Gravel = 9.27

% Sand = 75.32

% Silt & Clay = 15.41

% Clay = NA

CFEM: Sand, some Silt/Clay, trace Gravel

Moisture Content (%): 51.15

GRAIN SIZE ANALYSIS

Project : 3116 - Twillingate, NL

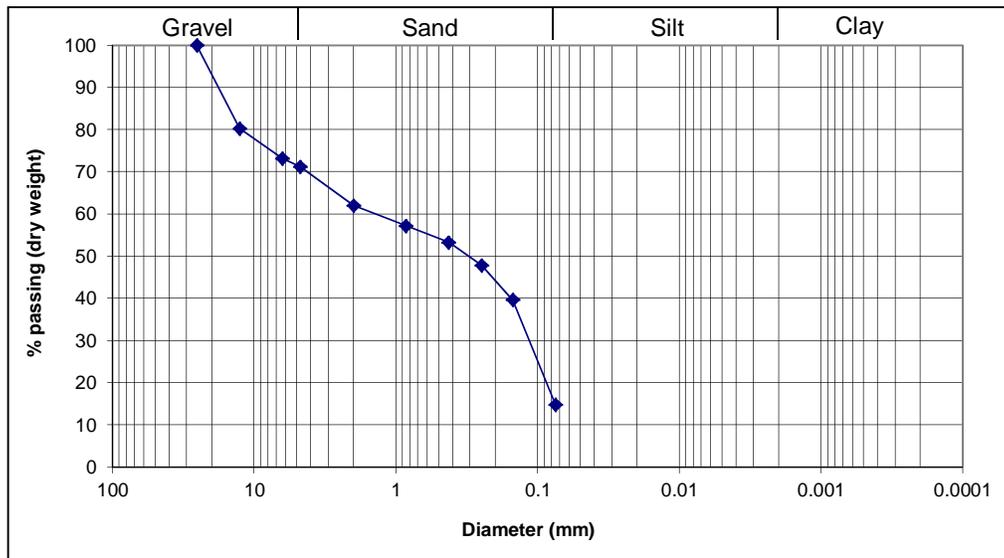
Sample No. : BH2-SS2

Depth below LNT : 1.72 m - 2.33 m

Sieve Analysis

Dry weight of sample (g) = 206.82

Sieve	Opening (mm)	Retained (g)	% Retained	Cumulative % Ret	% Passing
2	50.8	--	--		
1	25.4	0.00	0.00	0.00	100.00
1/2"	12.7	40.65	19.65	19.65	80.35
1/4"	6.35	14.76	7.14	26.79	73.21
4	4.76	4.05	1.96	28.75	71.25
10	2.00	19.11	9.24	37.99	62.01
20	0.85	9.91	4.79	42.78	57.22
40	0.425	8.03	3.88	46.66	53.34
60	0.25	11.32	5.47	52.14	47.86
100	0.15	16.93	8.19	60.32	39.68
200	0.075	51.25	24.78	85.10	14.90
pan	---	30.81	14.90	100.00	---
		206.82			



$D_{10} = \text{NA}$

$D_{30} = 0.114$

$D_{60} = 1.4$

$C_u = \text{NA}$

$C_c = \text{NA}$

USCS: SM (Silty sand with gravel) or SC (Clayey sand with gravel) or SC-SM (Silty, clayey sand with gravel)

$R_{200} = 85.10$

$R_4 = 28.75$

$R_4/R_{200} = 0.34$

SF = 56.35

GF = 28.75

% Gravel = 28.75

% Sand = 56.35

% Silt & Clay = 14.90

% Clay = NA

CFEM: Gravelly Sand, some Silt/Clay

Moisture Content (%): 35.59

GRAIN SIZE ANALYSIS

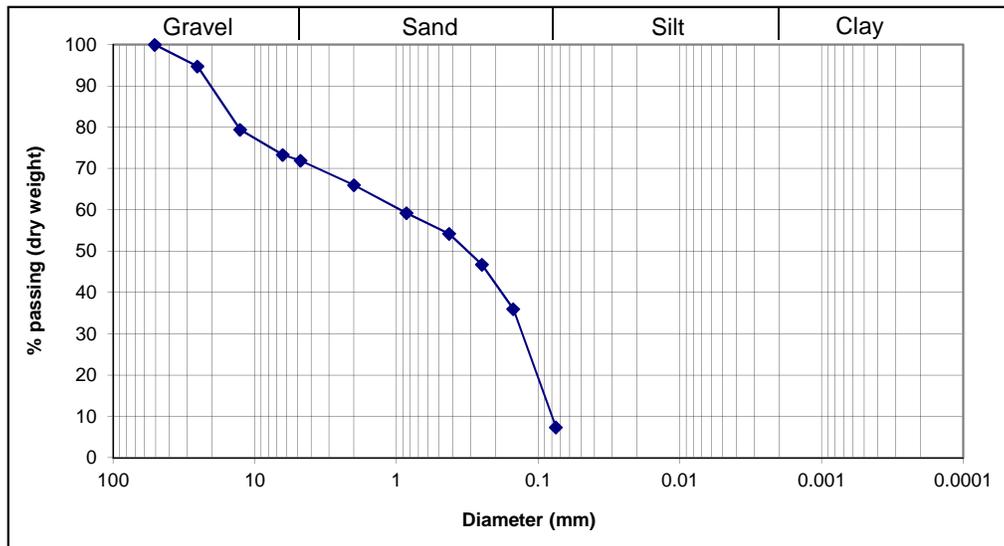
Project : 3116 - Twillingate, NL

Sample No. : BH3-MS2-0.3-1z
Depth below LNT: 0.40 m - 1.00 m

Sieve Analysis

Dry weight of sample (g) = 424.37

Sieve	Opening (mm)	Retained (g)	% Retained	Cumulative % Ret.	% Passing
2	50.8	0.00	0.00	0.00	100.00
1	25.4	22.25	5.24	5.24	94.76
1/2"	12.7	65.05	15.33	20.57	79.43
1/4"	6.35	25.80	6.08	26.65	73.35
4	4.76	6.01	1.42	28.07	71.93
10	2.00	25.10	5.91	33.98	66.02
20	0.85	28.91	6.81	40.79	59.21
40	0.425	21.16	4.99	45.78	54.22
60	0.25	31.61	7.45	53.23	46.77
100	0.15	45.76	10.78	64.01	35.99
200	0.075	121.56	28.64	92.66	7.34
pan	---	31.16	7.34	100.00	---
		424.37			



$D_{10} = 0.079$

$D_{30} = 0.13$

$D_{60} = 0.94$

$C_u = 11.90$

$C_c = 0.23$

USCS: SP-SM (Poorly graded sand with silt and gravel) or SP-SC (Poorly graded sand with clay and gravel)

$R_{200} = 92.66$

$R_4 = 28.07$

$R_4/R_{200} = 0.30$

SF = 64.59

GF = 28.07

% Gravel = 28.07

% Sand = 64.59

% Silt & Clay = 7.34

% Clay = NA

CFEM: Gravelly Sand, trace Silt/Clay

Moisture Content (%): 27.18

GRAIN SIZE ANALYSIS

Project : 3116 - Twillingate, NL

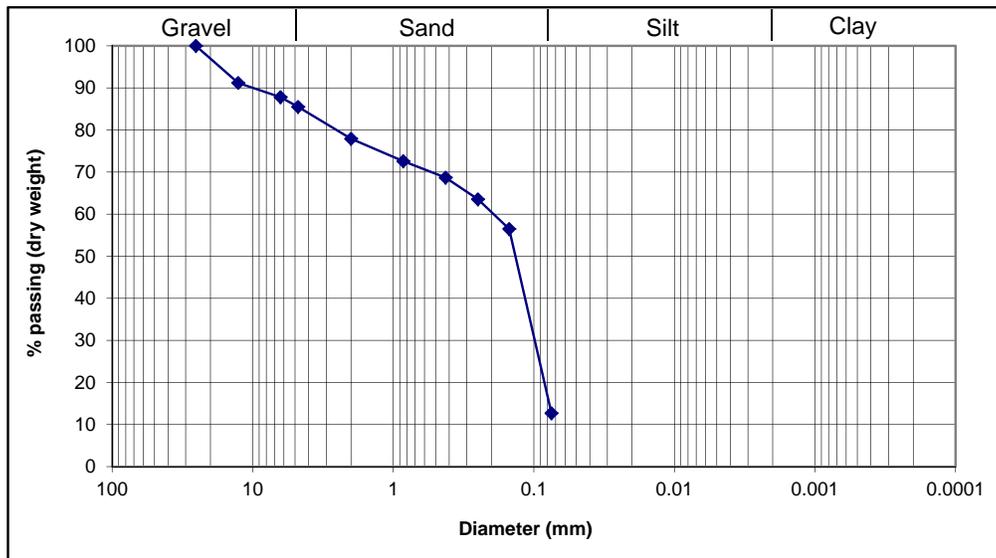
Sample No. : BH3-SS2

Depth below LNT : 1.93 m -2.53 m

Sieve Analysis

Dry weight of sample (g) = 200.50

Sieve	Opening (mm)	Retained (g)	% Retained	Cumulative % Ret	% Passing
2	50.8	--	--		
1	25.4	0.00	0.00	0.00	100.00
1/2"	12.7	17.67	8.81	8.81	91.19
1/4"	6.35	6.77	3.38	12.19	87.81
4	4.76	4.61	2.30	14.49	85.51
10	2.00	15.21	7.59	22.07	77.93
20	0.85	10.68	5.33	27.40	72.60
40	0.425	7.83	3.91	31.31	68.69
60	0.25	10.31	5.14	36.45	63.55
100	0.15	14.14	7.05	43.50	56.50
200	0.075	87.81	43.80	87.30	12.70
pan	---	25.47	12.70	100.00	---
		200.50			



$D_{10} = \text{NA}$

$D_{30} = 0.098$

$D_{60} = 0.195$

$C_u = \text{NA}$

$C_c = \text{NA}$

USCS: SM (Silty sand) or SC (Clayey sand) or SC-SM (Silty, clayey sand)

$R_{200} = 87.30$

$R_4 = 14.49$

$R_4/R_{200} = 0.17$

SF = 72.81

GF = 14.49

% Gravel = 14.49

% Sand = 72.81

% Silt & Clay = 12.70

% Clay = NA

CFEM: Sand, some Gravel, some Silt/Clay

Moisture Content (%): 44.36

GRAIN SIZE ANALYSIS

Project : 3116 - Twillingate, NL

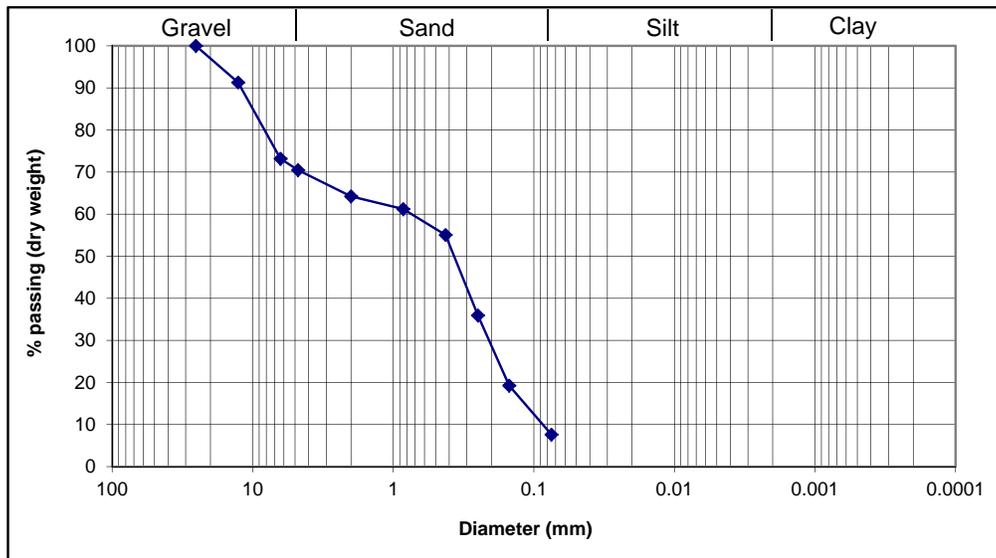
Sample No. : BH3-SS3

Depth below LNT : 3.34 m - 3.95 m

Sieve Analysis

Dry weight of sample (g) = 185.75

Sieve	Opening (mm)	Retained (g)	% Retained	Cumulative % Ret	% Passing
2	50.8	--	--		
1	25.4	0.00	0.00	0.00	100.00
1/2"	12.7	16.18	8.71	8.71	91.29
1/4"	6.35	33.63	18.10	26.82	73.18
4	4.76	5.04	2.71	29.53	70.47
10	2.00	11.58	6.23	35.76	64.24
20	0.85	5.60	3.01	38.78	61.22
40	0.425	11.45	6.16	44.94	55.06
60	0.25	35.51	19.12	64.06	35.94
100	0.15	30.98	16.68	80.74	19.26
200	0.075	21.64	11.65	92.39	7.61
pan	---	14.14	7.61	100.00	---
		185.75			



$$D_{10} = 0.086$$

$$D_{30} = 0.208$$

$$D_{60} = 0.74$$

$$Cu = 8.60$$

$$Cc = 0.68$$

USCS: SP-SM (Poorly graded sand with silt and gravel) or SP-SC (Poorly graded sand with clay and gravel)

$$R_{200} = 92.39$$

$$R_4 = 29.53$$

$$R_4/R_{200} = 0.32$$

$$SF = 62.86$$

$$GF = 29.53$$

$$\% \text{ Gravel} = 29.53$$

$$\% \text{ Sand} = 62.86$$

$$\% \text{ Silt \& Clay} = 7.61$$

$$\% \text{ Clay} = \text{NA}$$

CFEM: Gravelly Sand, trace Silt/Clay

Moisture Content (%): 18.45

GRAIN SIZE ANALYSIS

Project : 3116 - Twillingate, NL

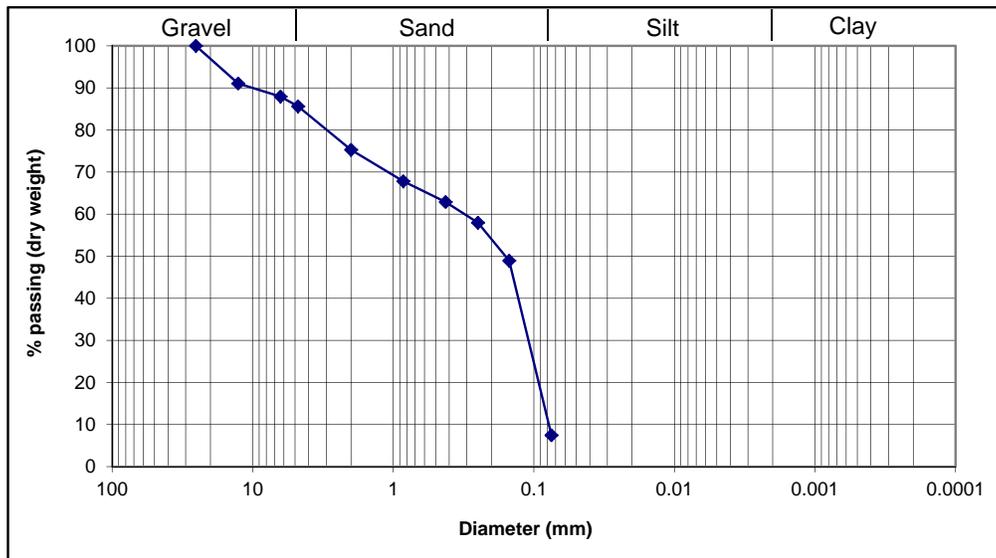
Sample No. : BH4-MS2-0.3-1z

Depth below LNT : 0.25 m - 0.75 m

Sieve Analysis

Dry weight of sample (g) = 288.31

Sieve	Opening (mm)	Retained (g)	% Retained	Cumulative % Ret	% Passing
2	50.8	--	--		
1	25.4	0.00	0.00	0.00	100.00
1/2"	12.7	25.80	8.95	8.95	91.05
1/4"	6.35	8.93	3.10	12.05	87.95
4	4.76	6.72	2.33	14.38	85.62
10	2.00	29.76	10.32	24.70	75.30
20	0.85	21.53	7.47	32.17	67.83
40	0.425	14.23	4.94	37.10	62.90
60	0.25	14.21	4.93	42.03	57.97
100	0.15	25.99	9.01	51.05	48.95
200	0.075	119.65	41.50	92.55	7.45
pan	---	21.49	7.45	100.00	---
		288.31			



$$D_{10} = 0.078$$

$$D_{30} = 0.109$$

$$D_{60} = 0.31$$

$$Cu = 3.97$$

$$Cc = 0.49$$

USCS: SP-SM (Poorly graded sand with silt) or SP-SC (Poorly graded sand with clay)

$$R_{200} = 92.55$$

$$R_4 = 14.38$$

$$R_4/R_{200} = 0.16$$

$$SF = 78.17$$

$$GF = 14.38$$

$$\% \text{ Gravel} = 14.38$$

$$\% \text{ Sand} = 78.17$$

$$\% \text{ Silt \& Clay} = 7.45$$

$$\% \text{ Clay} = \text{NA}$$

CFEM: Sand, some Gravel, trace Silt/Clay

Moisture Content (%): 24.17

GRAIN SIZE ANALYSIS

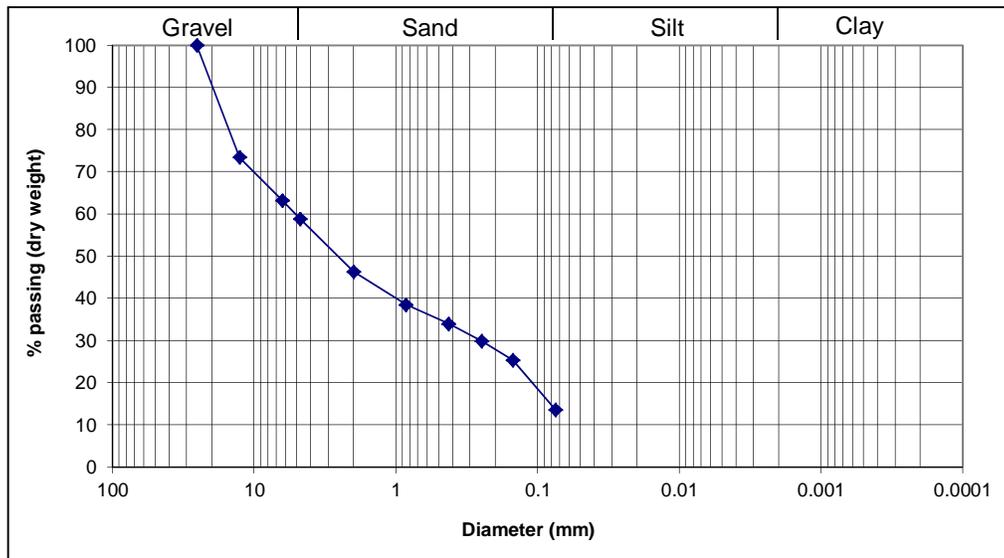
Project : 3116 - Twillingate, NL

Sample No. : BH5-MS2-0.3-1z
Depth below LNT : 0.30 m - 0.85 m

Sieve Analysis

Dry weight of sample (g) = 296.17

Sieve	Opening (mm)	Retained (g)	% Retained	Cumulative % Ret	% Passing
2	50.8	--	--		
1	25.4	0.00	0.00	0.00	100.00
1/2"	12.7	78.66	26.56	26.56	73.44
1/4"	6.35	30.15	10.18	36.74	63.26
4	4.76	12.83	4.33	41.07	58.93
10	2.00	37.04	12.51	53.58	46.42
20	0.85	23.42	7.91	61.48	38.52
40	0.425	13.50	4.56	66.04	33.96
60	0.25	11.90	4.02	70.06	29.94
100	0.15	13.25	4.47	74.53	25.47
200	0.075	34.92	11.79	86.33	13.67
pan	---	40.50	13.67	100.00	---
		296.17			



$D_{10} = \text{NA}$

$D_{30} = 0.25$

$D_{60} = 5.1$

$C_u = \text{NA}$

$C_c = \text{NA}$

USCS: SM (Silty sand with gravel) or SC (Clayey sand with gravel) or SC-SM (Silty, clayey sand with gravel)

$R_{200} = 86.33$

$R_4 = 41.07$

$R_4/R_{200} = 0.48$

SF = 45.25

GF = 41.07

% Gravel = 41.07

% Sand = 45.25

% Silt & Clay = 13.67

% Clay = NA

CFEM: Sand and Gravel, some Silt/Clay

Moisture Content (%): 13.57

GRAIN SIZE ANALYSIS

Project : 3116 - Twillingate, NL

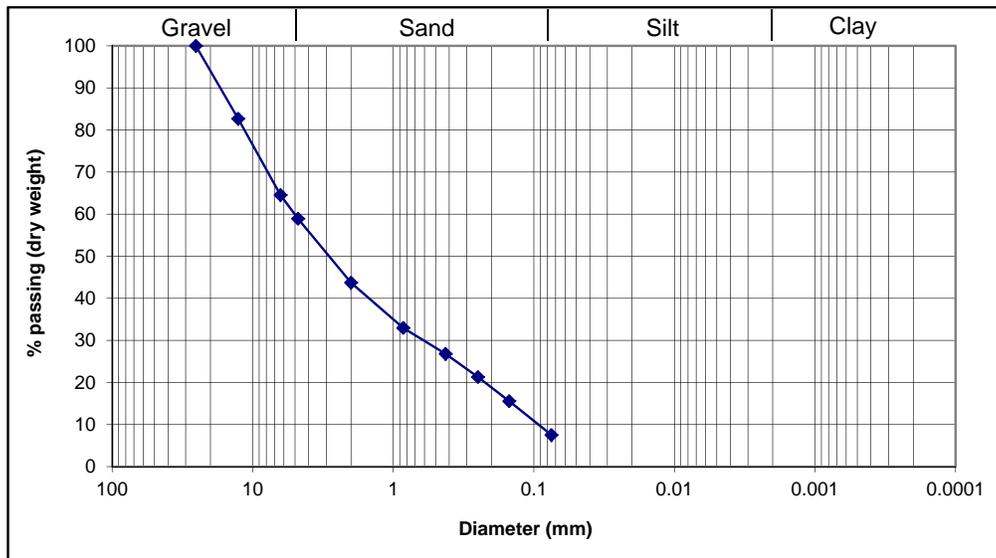
Sample No. : BH6-MS2-0.3-1z

Depth below LNT : 0.20 m - 0.63 m

Sieve Analysis

Dry weight of sample (g) = 220.59

Sieve	Opening (mm)	Retained (g)	% Retained	Cumulative % Ret	% Passing
2	50.8	--	--		
1	25.4	0.00	0.00	0.00	100.00
1/2"	12.7	38.18	17.31	17.31	82.69
1/4"	6.35	40.00	18.13	35.44	64.56
4	4.76	12.44	5.64	41.08	58.92
10	2.00	33.53	15.20	56.28	43.72
20	0.85	23.72	10.75	67.03	32.97
40	0.425	13.60	6.17	73.20	26.80
60	0.25	12.14	5.50	78.70	21.30
100	0.15	12.64	5.73	84.43	15.57
200	0.075	17.74	8.04	92.47	7.53
pan	---	16.60	7.53	100.00	---
		220.59			



$$D_{10} = 0.092$$

$$D_{30} = 0.605$$

$$D_{60} = 5$$

$$Cu = 54.35$$

$$Cc = 0.80$$

USCS: SP-SM (Poorly graded sand with silt and gravel) or SP-SC (Poorly graded sand with clay and gravel)

$$R_{200} = 92.47$$

$$R_4 = 41.08$$

$$R_4/R_{200} = 0.44$$

$$SF = 51.39$$

$$GF = 41.08$$

$$\% \text{ Gravel} = 41.08$$

$$\% \text{ Sand} = 51.39$$

$$\% \text{ Silt \& Clay} = 7.53$$

$$\% \text{ Clay} = \text{NA}$$

CFEM: Sand and Gravel, trace Silt/Clay

Moisture Content (%): 10.29