Tideway
Offshore Contractors

LOWER CHURCHILL PROJECT

ROCK BERM CONCEPT DEVELOPMENT

STUDY REPORT

Project Name	:	Lower Churchill Project
Project Location	:	Strait of Belle Isle, Newfoundland
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Company	:	Nalcor Energy
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Review and Approval Record of the Present Document

Action	Name	Function	Signature	Date
Approved by	P. Scheers	Engineering Specialist		05-02-2011
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1.0 Introduction

The Lower Churchill Project is generally referred to as the Labrador – Island transmission Link and comprises a 1100km High Voltage Direct Current (HVDC) link from Gull Island in the central region of Labrador to Newfoundland's Avalon Peninsula.

Nalcor Energy is in the process of concept development to feed a feasibility study on the seabed installation of HVDC power cables across the Strait of Belle Isle.

A rock berm, as a method of protection, is being reviewed for the subsea cables.

Nalcor Energy has has awarded to Tideway a study to review the constructability of a berm in the Strait of Belle Isle and to provide a preliminary berm design and cost estimate.

This document contains the study report for the rock berm concept development.

The calculations in this technical note are carried out in accordance with the Tideway standard methodology for rock stability calculations and aim to provide rock sizes that ensure a stable and permanent protection.

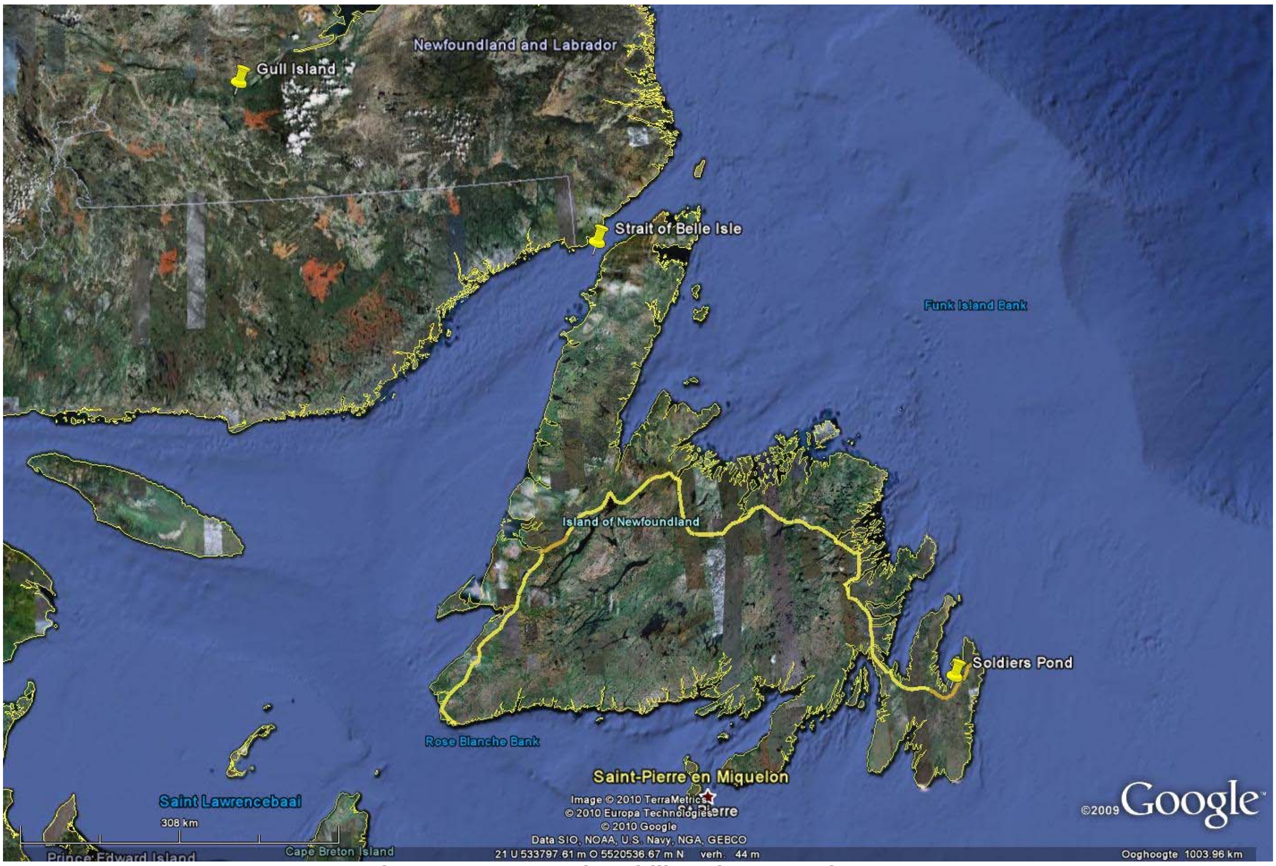

Figure 1-1 Lower Churchill Project Location

2.0 Basis of Design

This section presents a summary of the available data relevant to rock berm concept development.

2.1 Cable Route and Bathymetrical Data

The seabed profile of the Lower Churchill Cable route is presented in Figure 2-1. The water depth along the cable route varies between 0m at the shore landing locations at Labrador and Newfoundland and a maximum water depth of approximately 130 at the deepest location.

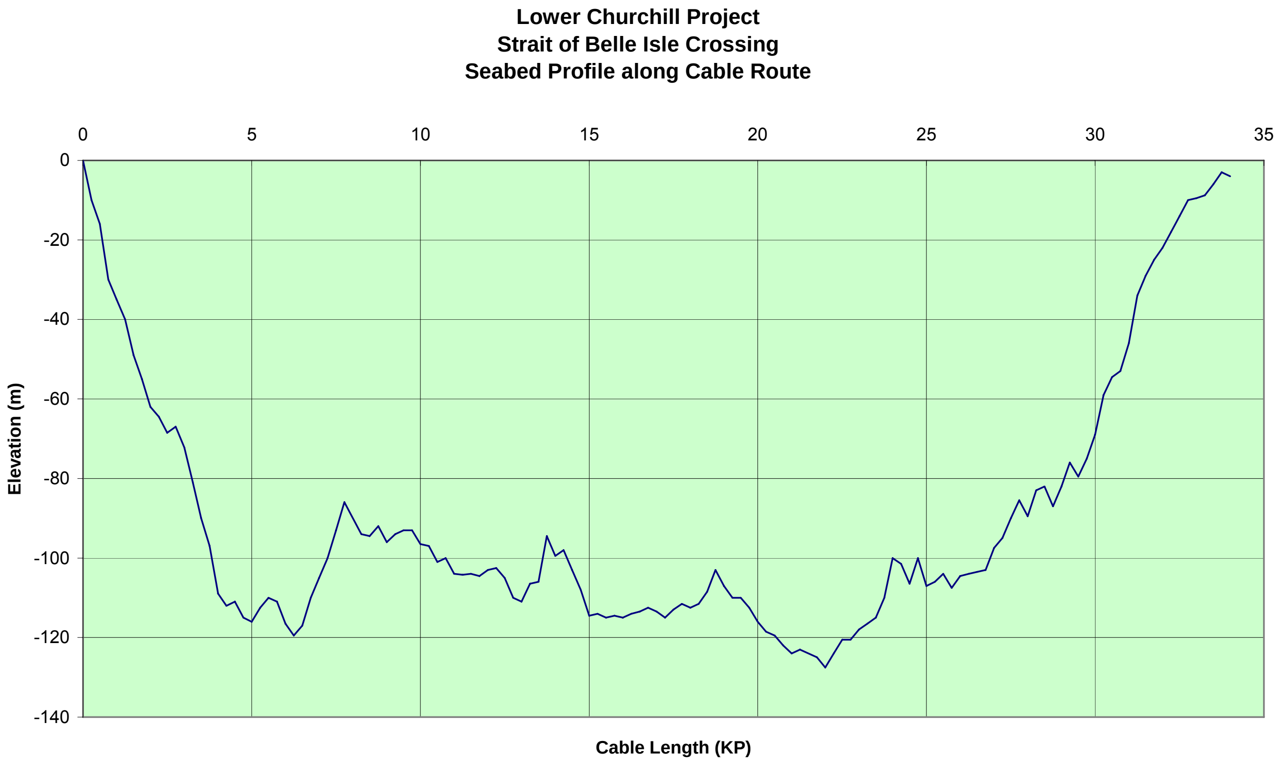

Figure 2-1 Seabed Profile along Cable Route

2.2 Wave Data

Limited wave data has been made available as part of the RFP documentation. Directional statistics have been calculated for four nodal locations in the project area based on hindcast data [Ref. 1]. This has resulted in a range of yearly statistical data providing a frequency of occurrence of the significant wave height. Based on this data the maximum expected wave height with a return period of approximately 1 year is in the order of 5 to 7m. It has been assumed that each node covers 25% of the route. Reference is made to Table 2-1, which presents an overview of the wave characteristics to be used.

Node	KP start	KP End	1-year RP Significant Wave Height in m
18070	0	8.5	7
18071	8.5	17	6.5
18072	17	25.5	6
18073	25.5	34	5.5

Table 2-1 Hindcast Wave Data

The criteria for the rock design are normally based on the 50 year or 100 year return period condition. Therefore some additional data has been obtained from the commercial website www.waveclimate.com operated by BMT ARGOSS.

Exceedance data has been obtained through extreme value analysis for the area indicated in Figure 2-2 below. The results are presented in Table 2-2.

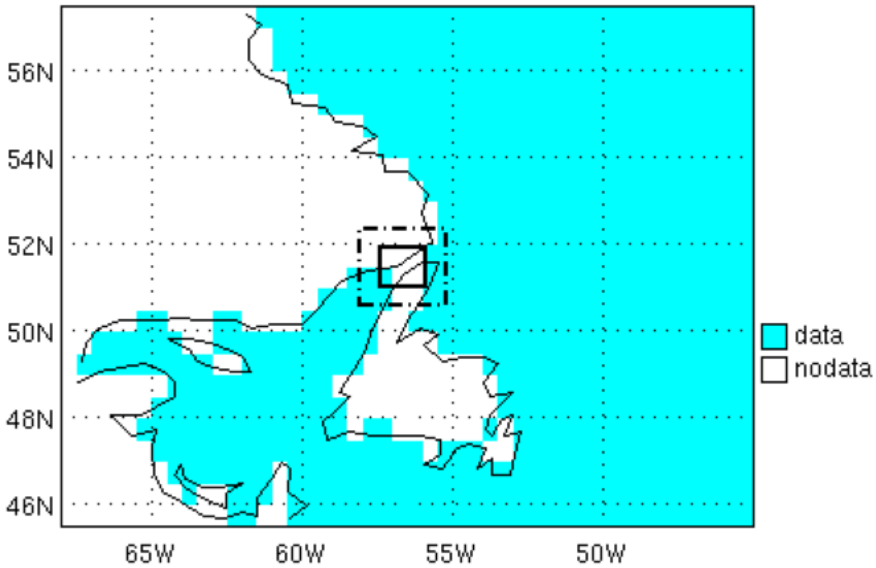

Figure 2-2 Waveclimate Data Area

Fractile wave height (m) versus return period of 3 hour exceedance			
return period	**wave height**	**lower limit**	**upper limit**
month	5.1	4.9	5.2
1 yr	6.5	6.3	6.7
2	6.9	6.7	7.1
5	7.4	7.1	7.6
10	7.7	7.5	8.0
25	8.2	7.9	8.5
50	8.5	8.2	8.8
100	8.9	8.5	9.2
1000	9.9	9.5	10.3

Table 2-2 Wave Exceedance Data

Based on the above it can be seen that the wave height with a return period of 1 year, lies within the range indicated by Ref. 1. The ratio between the 100 year return period and 1 year return period is approximately 1.37. This ratio can be applied to determine 100 year return period wave height for the other wave areas also.

Table 2-3 presents an overview of the 100 year RP wave data to be used in the calculations.

Node	KP start	KP End	100-year RP Significant Wave Height in m
18070	0	8.5	9.6
18071	8.5	17	8.9
18072	17	25.5	8.2
18073	25.5	34	7.5

Table 2-3 100 year RP Wave Data

2.3 Current Data

Based on Ref. 2, the following maximum current data applies in the Strait of Belle Isle. It can be seen that the maximum expected current velocities are given at three depth levels: Near-surface, Mid-depth and Near-bottom.

In accordance with Ref. 2, Table 2-4 shows the depth range of the various depth levels.

Depth Level	Min. Water Depth, m	Max Water Depth, m
Near-surface	0	25
Mid-depth	40	55
Near-bottom	15m off seabed	

Table 2-4 Definition of Depth Levels

Table 2-5 presents the maximum expected currents for each depth level. It has been assumed that the presented current speeds are average currents.

Maximum Expected Current Speed [ms^{-1}] per Season and Depth				
$\Delta U = \pm 0.8\ ms^{-1}$	WINTER	SPRING	SUMMER	FALL
Near Surface	3.3	3.6	4.2	4.3
Mid-Depth	3.5	3.6	4.0	3.5
Near Bottom	3.3	3.3	2.8	3.0

Table 2-5 Estimated Maximum Current Speeds

2.4 Wind Data

Based on Ref. 5 the following annual wind data has been taken into account:

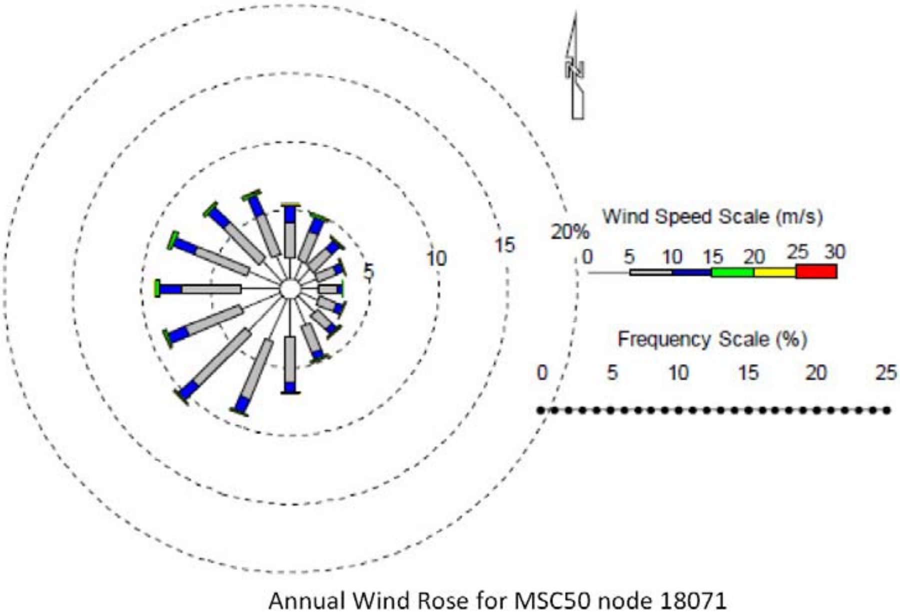

Figure 2-3 - Annual Wind Rose

3.0 Stability of the Rock Berm Armour Layer

3.1 Theory

The method herein described is based on the principle that the bottom shear stress due to the steady current, τ_c, and due to the wave induced current, τ_w, can be combined to a total bottom shear stress, τ_{cw}, (see also Reference 2) as follows:

$$\tau_{cw} = \tau_c + \frac{1}{2}\tau_w \quad \text{with :}$$

$$\tau_c = \rho_w\left(\frac{\sqrt{g}}{C}U\right)^2$$

$$\tau_w = \rho_w\left(\frac{\sqrt{f_w}}{\sqrt{2}}V\right)^2$$

The total bottom stress can be expressed as a function of the Shields parameter, ψ:

$$\Psi = \frac{\tau_{cw}}{(\rho_s - \rho_w) * g * D_{50}}$$

This can be re-arranged to:

$$\Psi_{cal} = \frac{\left(\frac{\sqrt{g}}{C}U\right)^2 + 0.5\left(\frac{\sqrt{f_w}}{\sqrt{2}}V\right)^2}{\Delta * g * D_{50}}$$

Ψ_{cal}, is denominates as the Stability Parameter. This parameter has to be equal or less than the critical parameter,Ψ_{cr}.

This upper limit of the Stability Parameter, Ψ_{cr}, is according to Shields, equal to:

$$\Psi_{cr} = 0.055$$

This value is valid for a flat surface.

It is self-explanatory, that it is easier for a current to lift a stone from a steep slope than from a shallow slope or a flat seabed. To take this effect into account, a correction factor, p, is applied to the Shields Parameter to implement the effect of the side slopes of a rock protection:

$$\Psi_{cr} = p*0.055$$

with: $p = \cos\alpha(1 - \tan\alpha/\tan\phi)$.
α = angle of the side slope
ϕ = angle of internal friction of the rock material.

When the rock needs to be absolutely stable and no movement is allowed at all a lower range value of 0.03 can be adopted in order to ensure a conservative approach.

The dumped rock is usually crushed rock from a quarry. The angle of internal friction,ϕ, ranges from 39 to 45 degrees for loose to dense, angular well-graded materials (see, for instance, Lambe and Whitman: "Soil Mechanics, Reference 3).
A value of 40 degrees for the crushed rock can safely be used.

This means that for instance, for 1:3 side slopes:

α = 18.4 degrees
p = 0.573

and Ψ_{cr} = 0.0343.

Furthermore:

g = 9.81 m/sec^2
C = Chézy coefficient, which is:

$$C = 18*\log(12D_w/k)$$

D_w = water depth
k = skin roughness, for which 2*D_{50} can be taken
D_{50} = 50% value of sieve curve
U = steady current component (averaged over the depth)
f_w = friction coefficient, which is:

$$f_w = \exp(-5.997+5.213*(y/k)^{-0.194})$$

V = wave induced velocity (at 1 m above the seabed)
y = amplitude of water particle movement (= T/2π*V)
Δ = $(\rho_g - \rho_w)/\rho_w$
ρ_s = density of backfill = 2650 kg/m^3
ρ_w = density of seawater = 1025 kg/m^3.

There are no Submarine Codes or Guidelines which specify which design criterion should be taken into account to assess the stability of stones on the seabed. They only state that the dumped mound has to be stable and fulfill its function.
The CERC 'Shore Protection Manual' (Ref. 4) states that the design of flexible structures like structures built with rock can be based on the significant wave height. Constant loading with this wave height has the same effect as the spectrum of waves, which the significant wave represents.

3.2 Calculations

Calculations of rock stability have been carried out for the following conditions:

- According to the SoW, water depths in the range of 40m to 110m are to be assesses. However, based on the seabed profile, a water depths in the range of 20m to approx. 130m will be assessed.
- Analysis is based on the significant wave weight, as discussed in Section 3.1.
- Depth averaged current velocity will be used as basis for calculations.

Based on the conditions above and the various environmental data available, the rock sizes have been determined for the following cases:

<table>
<tr><th>Case</th><th>KP Start</th><th>KP End</th><th>Min. WD m</th><th>Max. WD m</th><th>Wave Data Nodal Point</th><th>Current Data Depth Zone</th><th>Hs 100yr RP m</th><th>Max. Current m/s</th></tr>
<tr><td>1</td><td>0.0</td><td>1.3</td><td>0.0</td><td>40.0</td><td rowspan="3">N18070</td><td>Near-surface</td><td rowspan="3">9.6</td><td>4.2</td></tr>
<tr><td>2</td><td>1.3</td><td>2.0</td><td>40.0</td><td>62.0</td><td>Mid-depth</td><td>4</td></tr>
<tr><td>3</td><td>2.0</td><td>8.5</td><td>62.0</td><td>120.0</td><td rowspan="4">Near-bottom</td><td rowspan="4">3.3</td></tr>
<tr><td>4</td><td>8.5</td><td>17.0</td><td>92.0</td><td>115.0</td><td>N18071</td><td>8.9</td></tr>
<tr><td>5</td><td>17.0</td><td>25.5</td><td>100.0</td><td>127.5</td><td>N18072</td><td>8.2</td></tr>
<tr><td>6</td><td>25.5</td><td>30.0</td><td>69.0</td><td>107.5</td><td rowspan="3">N18073</td><td rowspan="3">7.5</td></tr>
<tr><td>7</td><td>30.0</td><td>31.0</td><td>46.0</td><td>69.0</td><td>Mid-depth</td><td>4</td></tr>
<tr><td>8</td><td>31.0</td><td>34.0</td><td>0.0</td><td>46.0</td><td>Near-surface</td><td>4.2</td></tr>
</table>

Table 3-1 Load Cases

3.3 Results

The calculation results are presented in Table 3-2. Cases that are considered feasible based on installation by fall pipe (max. stone size of 400mm) are highlighted in green.

Based on the results shown below, it can be concluded that rockdumping of the Lower Churchill cable is considered feasible along the majority of the route.

Case	KP Start	KP End	Min. WD m	Hs 100yr RP m	Max. Current m/s	1:3	1:4	1:5
1	0	1.3	20.0	9.6	4.2	677.0	423.0	340.0
			25.0			428.0	286.0	235.0
			30.0			307.0	213.0	178.0
			40.0			192.0	140.0	119.0
2	1.3	2.0	40.0		4	174.0	127.0	108.0
			50.0			126.0	94.0	81.0
			60.0			99.0	76.0	66.0
3	2.0	8.5	62.0		3.3	62.0	48.0	42.0
4	8.5	17.0	92.0	8.9		40.0	32.0	28.0
5	17.0	25.5	100.0	8.2		37.0	30.0	26.0
6	25.5	30.0	69.0	7.5		49.0	38.0	33.0
7	30.0	31.0	46.0		4	116.0	87.0	76.0
8	31.0	34.0	40.0		4.2	152	113	97
			30.0			218.0	157.0	134.0
			20.0			399.0	270.0	223.0

Table 3-2 Minimum Stone Sizes (D50) for various conditions

The shallowest parts of Section 1,say, less than 25m water depth, require large rock gradings that can not be installed using the standard fall pipe methodology, as the maximum rock size through the fall pipe is approximately 400mm. It should be noted that alternative rock placements could be utilized, such as side stone dumping etc. In the area between 25m and 40m water depth, a 4 – 16 inch grading could be applied with varying side slopes.

In Section 2 various rock berm solutions can be applied. Larger berms with shallow side slopes (1:4 and 1:5) enable the use of a typical 2 – 8 inch grading. Alternatively, steeper side slopes can be applied resulting in smaller berms in case a larger grading of 4-16 inch is used.

In Sections 3 through 6, the minimum d50 is approximately 60mm, with an associated rock grading of 1 - 5 inch.

In Section 7, 4 – 16 inch or 2 – 8 inch can be applied with 1:3 or 1:4 side slopes, respectively.

In the shallow nearshore section approaching the shore of Newfoundland, Section 8, a 4 – 16 inch rock grading is required in order to maintain a stable rock berm, although it should be noted that a smaller grading of 2 – 8 inch could be applied in the deeper sections in case 1:5 side slopes are specified.

The minimum grading requirements can de summarized as presented in Table 3-3.

Case	KP Start	KP End	Min. WD m	Hs 100yr RP m	Max. Current m/s	1:3	1:4	1:5
1	0	1.3	20.0	9.6	4.2			
			25.0					4 - 16
			30.0				4 - 16	4 - 16
			40.0			4 - 16	4 - 12	4 - 10
2	1.3	2.0	40.0		4	4 - 16	2 - 10	2 - 8
			50.0			2 - 10	2 - 8	2 - 8
			60.0			2 - 8	2 - 8	2 - 8
3	2.0	8.5	62.0		3.3	1 - 5	1 – 5	
4	8.5	17.0	92.0	8.9		1 - 5	1 – 3	
5	17.0	25.5	100.0	8.2		1 - 5	1 – 3	
6	25.5	30.0	69.0	7.5		1 - 5	1 – 5	
7	30.0	31.0	46.0		4	2 - 10	2 - 8	2 - 8
8	31.0	34.0	40.0		4.2	4 - 14	2 - 10	2 - 8
			30.0			4 - 16	4 - 14	2 - 12
			20.0					4 - 16

Table 3-3 Minimum Grading Requirement

It should be noted that any grading larger than 1 – 5 inch material, normally requires a filter layer

3.4 Berm Design

Typical cross-sectional berm profiles are required for two scenarios:

1) Three cables located close together with a nominal spacing of 3m.
2) Cables spaced apart so that individual berms do not interact.

Reference is made to Appendix A, which contains General Arrangement Drawings of both Scenario 1 and Scenario 2.

It should be noted that the cable diameter is assumed to be 0.2m.

3.4.1 Scenario 1

Typical cross sectional profiles for a single and double layer system are presented in Figure 3-1 and Figure 3-2. A typical cover for a single layer system is approximately 0.5m. In a two layer system, a 0.3m cover is typically maintained for the filter material. The layer thickness of the armour material is typically 0.6m, as the size of the armour material will be larger than in a single layer system.

The overall (design) width of the profile is approximately 12.6m and 15.8m for a single layer and double layer system, respectively.

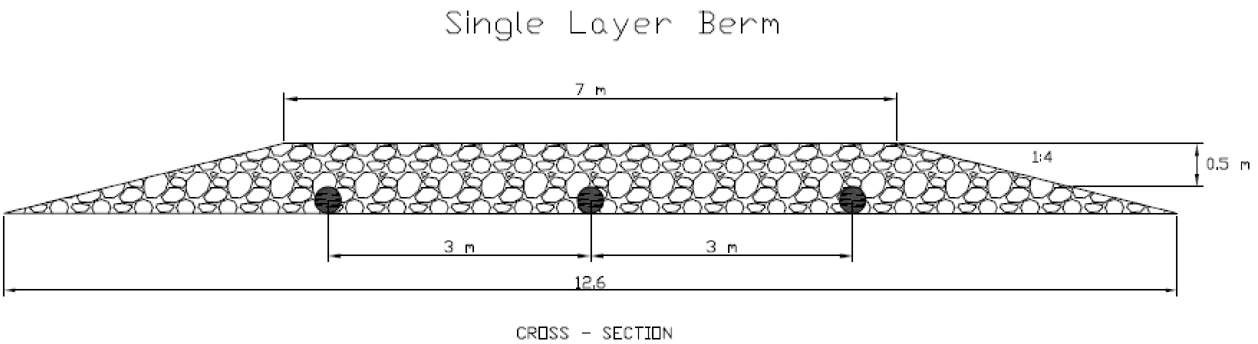

Figure 3-1 Scenarion 1 - Single Layer System

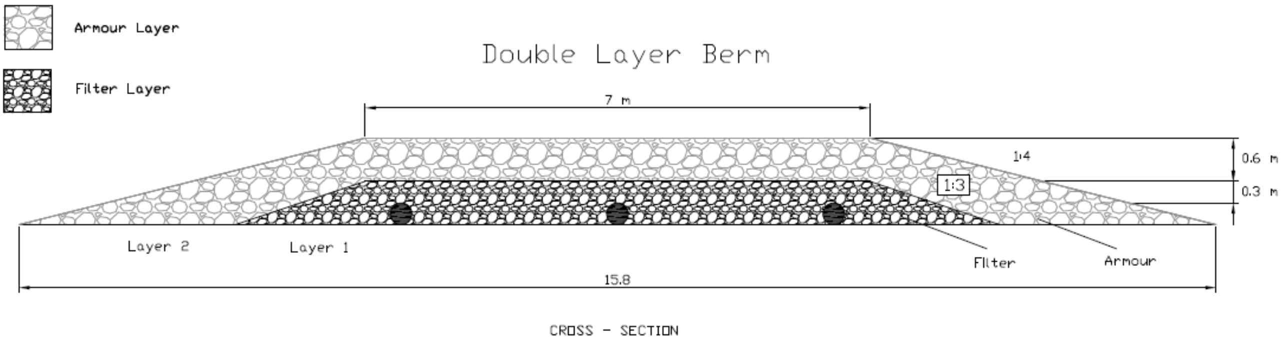

Figure 3-2 Scenarion 1 - Double Layer System

3.4.2 Scenario 2

Typical cross sectional profiles for a single and double layer system are presented in Figure 3-3 and Figure 3-4. Similarly to Scenario 1, a typical cover for a single layer system is approximately 0.5m. In a two layer system, a 0.3m cover is typically maintained for the filter material. The layer thickness of the armour material is typically 0.6m, as the size of the armour material will be larger than in a single layer system.

The overall (design) width of the profile is approximately 29.8m and 39.4m for a single layer and double layer system, respectively.

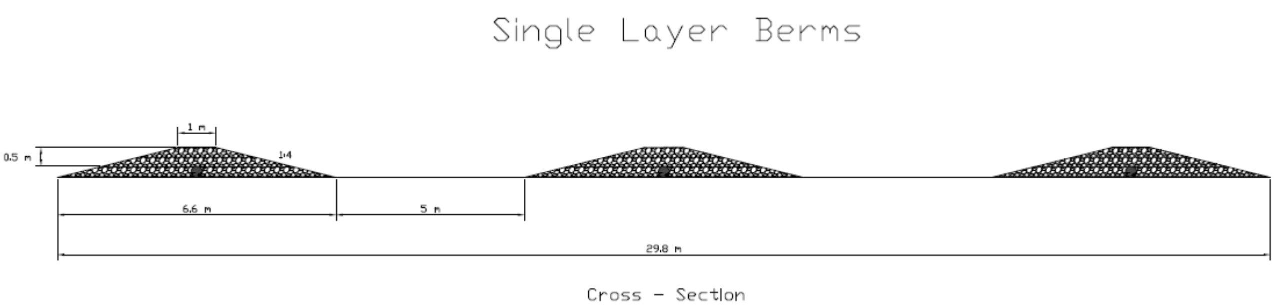

Figure 3-3 Scenarion 2 - Single Layer System

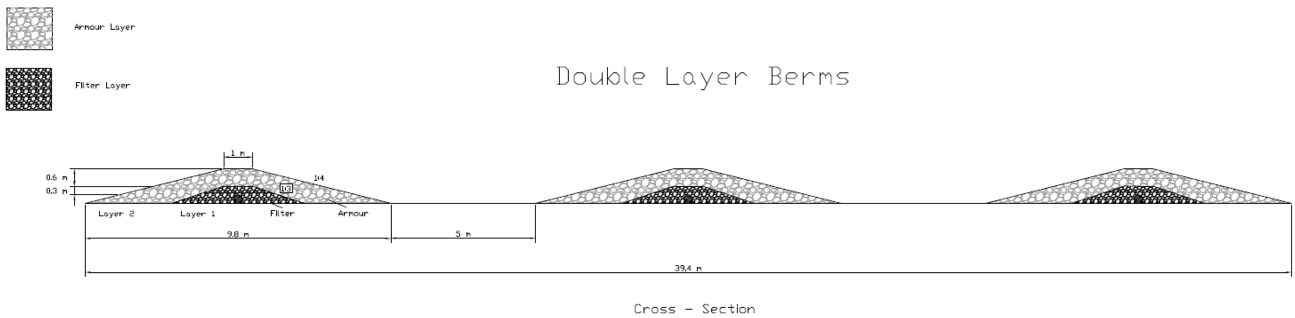

Figure 3-4 Scenarion 2 - Double Layer System

3.5 Impact Assessment

When an object falls down in water, it will soon reach a constant equilibrium velocity, V, which is the balance between the gravity force and the drag force. In formulae:

$$F_G = F_D$$

in which:

$$F_G = \frac{1}{6}\pi D^3 (\rho_g - \rho_w) g$$

$$F_D = \frac{1}{2}\rho_w \frac{\pi D^2}{4} C_D V^2$$

with D : diameter of falling object
ρ_g : density of rock
ρ_w : density of seawater
g : 9.81 m/sec^2
C_D : drag coefficient

For ideal spheres the drag coefficient is equal to 0.4, but for crushed rock a shape factor may be introduced which gives a drag coefficient of 1.0.

When the three equations are combined, the equilibrium velocity, V, can be established from:

$$V = \sqrt{\frac{4}{3}\frac{D}{C_D} g\Delta}$$

$$\Delta = \frac{\rho_g - \rho_w}{\rho_w}$$

Table 4 below gives some results for which the following values have been applied:
ρ_g : 2,650 kg/m^3
ρ_w : 1,025 kg/m^3
C_D : 1

The maximum impact is equal to the kinetic energy incl. added mass:

$$E = ½ (m+m_a)V^2$$

where: ma = $\rho_w . C_a . (1/6 . \pi . D^3)$ and C_a =1.

Diameter D (mm)	Mass m (kg)	Max. Fall Velocity, v, (m/s)	Kin. Energy, E, Nm or Joule
0	0.0	0.0	0.0
25	0.0	0.7	0.0
50	0.2	1.0	0.1
75	0.6	1.2	0.6
100	1.4	1.4	2.0
125	2.7	1.6	4.9
150	4.7	1.8	10.1
175	7.4	1.9	18.7
200	11.1	2.0	31.9
225	15.8	2.2	51.1
250	21.7	2.3	77.9
275	28.9	2.4	114.1
300	37.5	2.5	161.5
325	47.6	2.6	222.5
350	59.5	2.7	299.3
375	73.2	2.8	394.4
400	88.8	2.9	510.6

Table 3-4 Velocity and kinetic energy of rock dumped in water

The maximum rock size that will impact the cable directly, is the maximum stone size in the 1 – 5 inch grading, which is approximately 125mm. The maximum kinetic energy for a 1 – 5 inch rock grading is, thus, not more than 4.9 Joule.

Although such impact energy is expected to be well within allowable limits of a normally armoured cable, it is recommended that Company confirms the impact resistance capacity of the cable with the potential suppliers.

4.0 Fall Pipe Vessel Information

4.1 Vessel Capacity

For these type of rock placement operations we propose to use the following D.P. Fall Pipe Vessels:

- ‘Rollingstone” : loading capacity 11,500 tons
- “Seahorse” : loading capacity 18,500 tons
- “Flintstone” : loading capacity 20,000 tons.

Vessel leaflets are attached.

Figure 4-1 D.P. Fall Pipe Vessel “Seahorse”, entering St John’s Harbour

4.2 Vessel Travel Speed

Vessel travel speeds for both loaded and unloaded cases :

- “Rollingstone” / “Seahorse” : approx 12 Nm
- “Flintstone” : approx 16 Nm

4.3 Loaded Vessel Draught

- “Rollingstone” / “Seahorse” : approx 6,75 metres
- “Flintstone” : approx 7.80 meters

4.4 D.P. Capabilities

All vessels are fully certified Class II D.P. vessels, inclusive completed FMEA trials and can therefore operate, if necessary, within 500 metre zones of subsea structures and close to surface platforms/structures.

Figure 4-2 - Vessel next to platform

4.5 Fall Pipe Sizes

Vessels can be equipped with various fall pipe sizes, i.e. 0.50 m / 0.75 m and 1.00 m.
The maximum allowable rock sizes is approx 16 inch.

4.6 Unloading Rate / Rate of Rockdumping

Rate for placement of rock is depending on profile, length and height to be dumped, however unloading / dumping rates of 1,000 tons / hour can be achieved.

4.7 Loading Facilities Newfoundland

Various loading facilities have been reviewed such as:

[redacted]

[redacted]

4.8 Rock Supply and Loading

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5.0 Constructability Review

5.1 Workability in Bell Strait

5.1.1 Waves

The governing seastate for rock dumping operations is approximately 2.5 m significant wave height. Based on the statistical wave data for the governing location (worst wave data) of node 18070, results in a maximum workability of 96% and almost 99%, for maximum operational seastates of 2m and 2.5m Hs, respectively, as can be seen in Table 5-1 below.

Hs (m)		N	NE	E	SE	S	SW	W	NW	Total	Workability %
6.5	7	0	0	0	0	0	0.001	0	0	0.0	
6	6.5	0	0	0	0	0	0.002	0	0	0.0	
5.5	6	0	0	0	0	0	0.004	0	0	0.0	
5	5.5	0	0	0	0	0	0.007	0	0	0.0	
4.5	5	0	0	0	0	0	0.016	0	0	0.0	
4	4.5	0	0	0	0	0	0.053	0	0	0.1	
3.5	4	0	0	0.001	0	0	0.133	0.008	0	0.1	
3	3.5	0	0.002	0.005	0	0.001	0.281	0.032	0	0.3	
2.5	3	0	0.023	0.009	0.002	0.016	0.629	0.121	0.001	0.8	
2	2.5	0.027	0.121	0.053	0.033	0.075	1.544	0.414	0.027	2.3	**98.7**
1.5	2	0.133	0.418	0.298	0.148	0.194	3.261	1.264	0.226	5.9	**96.4**
1	1.5	0.629	1.361	0.817	0.444	0.381	5.72	2.609	1.308	13.3	**90.4**
0.5	1	1.6	2.695	2.153	0.716	0.898	9.112	4.366	1.409	22.9	**77.2**
0	0.5	5.174	5.114	5.798	2.973	4.174	16.691	8.07	6.209	54.2	**54.2**
Total		7.6	9.7	9.1	4.3	5.7	37.5	16.9	9.2	100	

Table 5-1 Workability based on yearly statistical wave data Node 18070

5.1.2 Wind & Currents

The workability with respect to station keeping capability is governed by the DP capability to maintain position under a certain combination of wind and current. This DP capability is typically demonstrated using the DP capability plots which show the maximum windspeed that can be withstood for a certain current velocity. Figure 5-2 and Figure 5-2 show the maximum windspeed for current levels of 1.5 and 3.0 knots for various directions. It can be seen that the maximum windspeed is over 100 knots for both cases, which is well over the typical maximum wind speed in Bell Strait, which is approximately 50 knots.

Note that the vessel during rockdumping operation will be able to adjust heading such that station keeping capabilities are maximum.

It can be concluded therefore, that there are no restrictions to the normally applied operating criteria wrt workability for rockdumping operations in the Strait of Belle Isle.

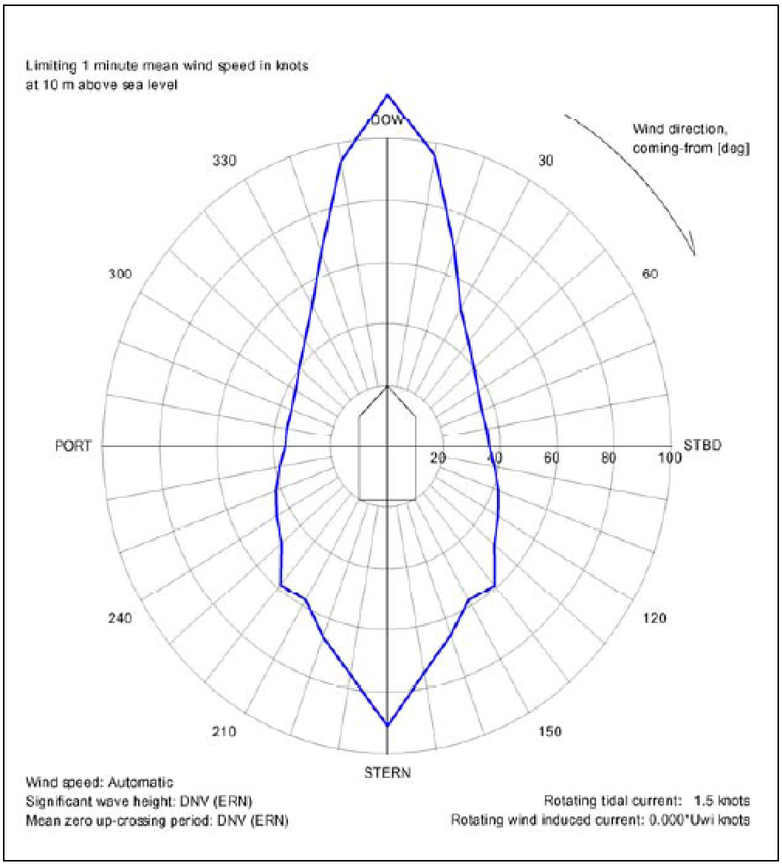


Figure 5-1 DP Capability Plot - 1.5 knots current

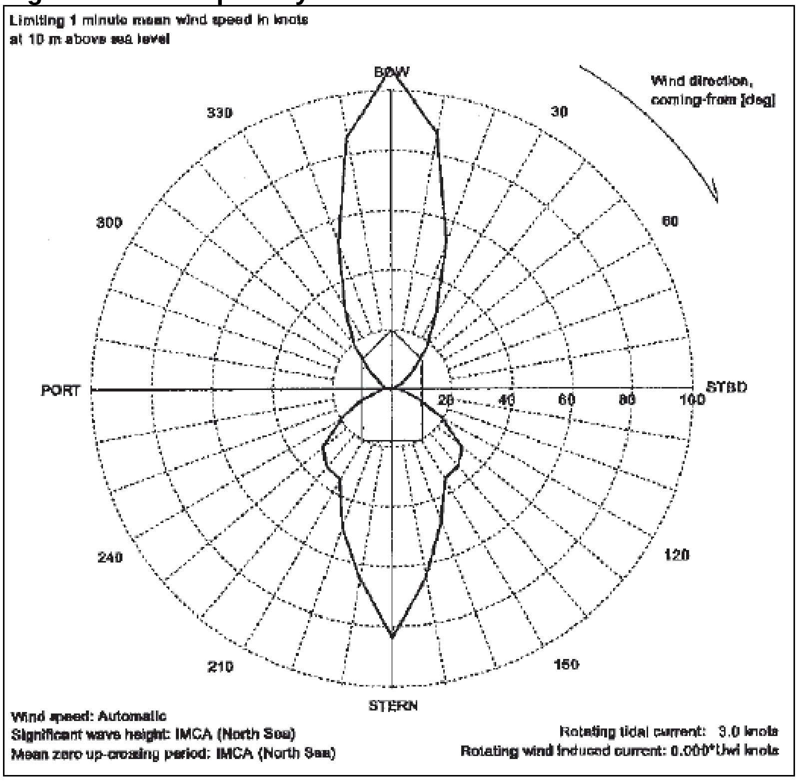


Figure 5-2 DP Capability Plot – 3.0 knots current

5.2 Accuracy of Placing a Rock Berm

The following accuracies can be taken into account relative to the installed pipeline/umbilical:

Horizontal accuracy	: +/- 0.50 metres
Vertical accuracy	: +/- 0.20 metres

5.3 Working Depth

The vessel draught in loaded conditions can be seen in Section 4.3. The minimum and the maximum working depths for rockdumping operations are governed by the fall pipe equipment. The minimum working depth is approximately 12m. The maximum working depth varies per vessel and is 1000m for Rollingstone and 2000m for Flintstone.

5.4 Rock Removal

Removal of rockdump is normally not required. If removal however is required, fi in case of a necessary cable repair, some techniques do exist to free the cable from the rock. The rock can be airlifted or alternatively removed using mass flow excavation techniques.

6.0 Method Statement

6.1 Preparations on Site

Upon arrival on site the operational systems, the integrity of the positioning systems and survey systems will be verified and checked and environmental conditions will be monitored.

- Quality Check Positioning Systems
- Check actual and expected environmental conditions (weather / tide /sea-state)
- Start up DP System
- DP Location trials
- Check SDU (Stone Dumping Unit)
- Deploy USBL transponder and perform CTD-dip
- Pre-dive Checks FPROV.

All systems such as gyro's, motion sensors, Multibeam Echo sounder, bathymetric unit and USBL system shall have been calibrated and the relevant calibration reports and certificates are available on board for Client review.

When the results of these checks are satisfactory the fall pipe will be launched. This will be done at a safe distance from any sub sea structures/features, typically minimal 1x the water depth.

Once the fall pipe is built up and the ROV launched the vessel will move in towards the working location.

When the vessel is in position the ROV will be positioned at working depth i.e. approx. 3 to 8 meters above the seabed.

In case the work shall be carried out in the vicinity of an offshore installation, a good communication between the offshore installation and the shall be established prior arrival on site.

6.2 Pre-dump Survey

Prior the start of any rock placement activities the pre-dump survey will be carried out. Pictures below illustrate a typical subsea field lay-out including ROV and pipelines.

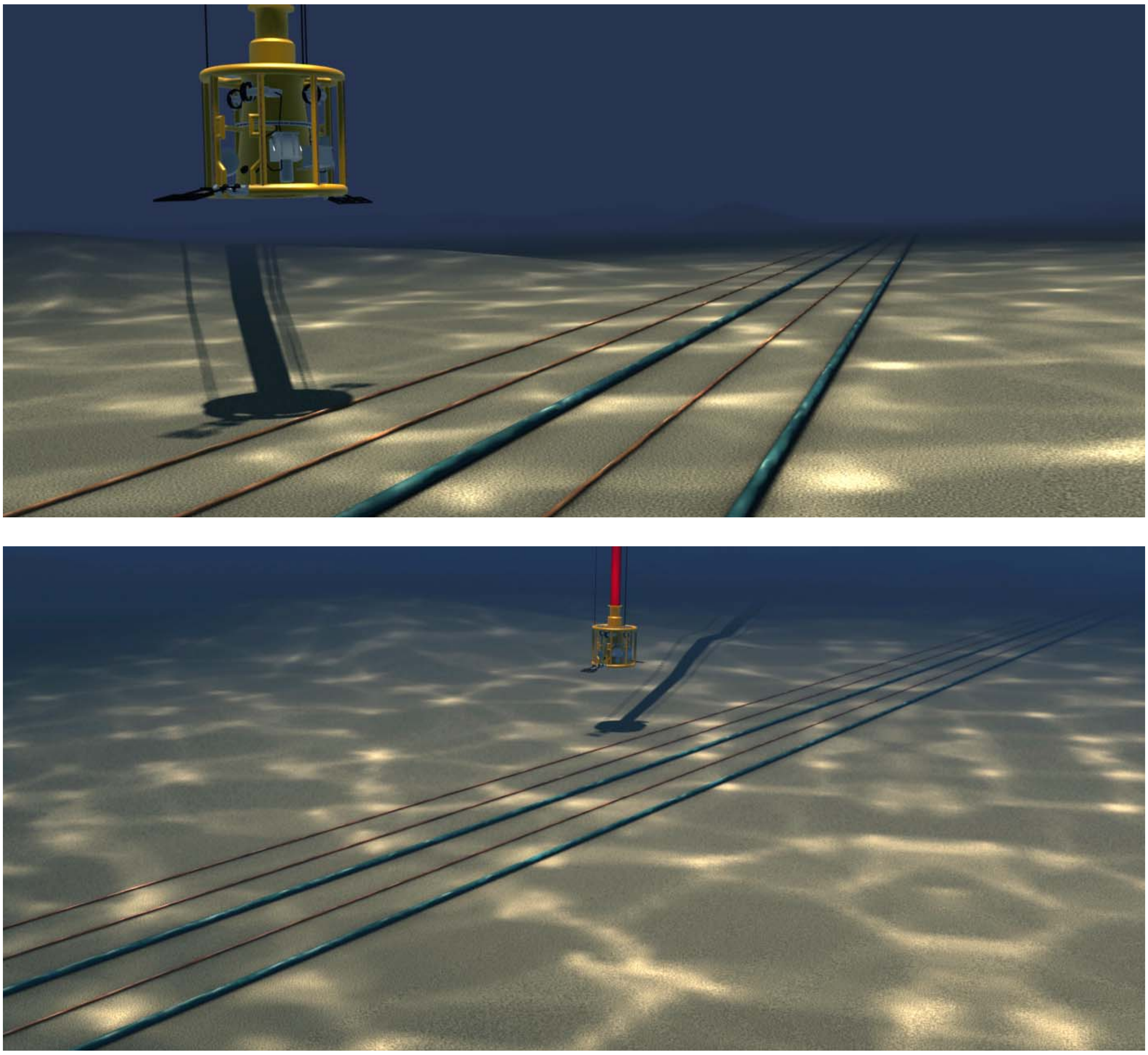


Figure 5-0-1 Execution of pre-survey prior to rockdumping operations.

6.3 Rock Placement Operations

The Superintendent will issue a dump schedule, which is based on the results of the survey data. This schedule will function as a guideline for all personnel involved in the rock placement operations and will show typical information such as: start and stop KP, amount of runs, quantity to be dumped, etc.

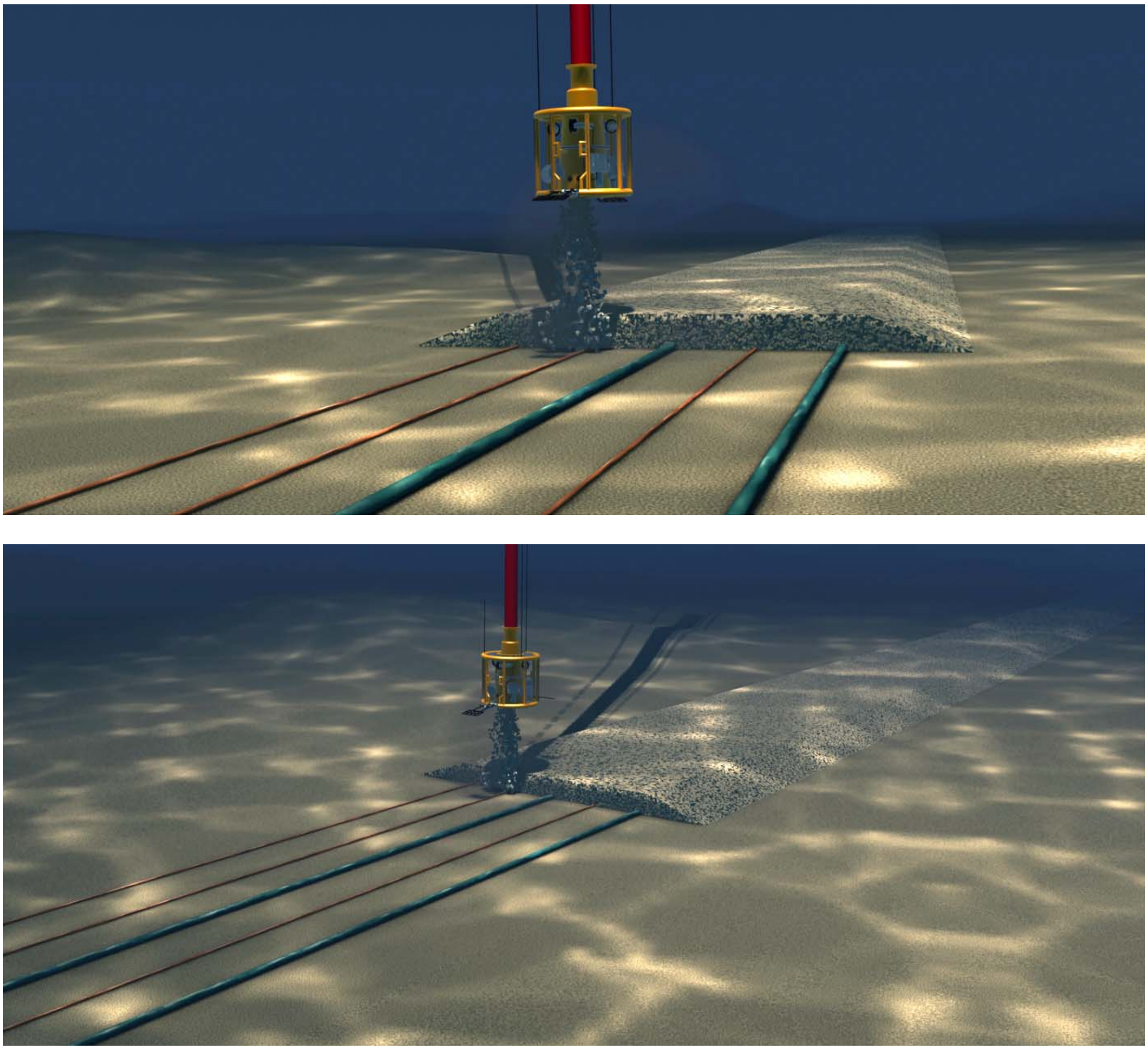


Figure 0-2 Rockdumping along flowlines/umbilicals.

The amount of rock placed per linear meter is a function of the rock flow rate and the vessel tracking speed. The rate can be controlled by adjusting the outflow of the central hopper feeder, whereas with the DP system the tracking speed can be adjusted. In this way the rock placed per linear meter can be controlled. Monitoring of dumped quantities is done by means of a Ramsey belt weigh system.

The MBE in combination with the Navigation Screen gives the ROV pilot information about the ROV position.

On the MBE (or mechanical profiler) cross profiles will be displayed, these can be compared (at regular intervals) with the theoretical profiles drawn in the pre survey. This allows the ROV pilot to monitor the progress and build-up of the rock material.

The thrusters on the FPROV allow positioning the Fall Pipe end precisely above the rock placement location. Larger movements in lateral direction to the sailed track the vessel's DP system will be used.

Intermediate surveys are carried out at regular intervals to monitor the progress and quality of the work.

6.4 Post-dump Survey

After execution of the rock placement operations, a post-survey will be executed and will be compared to the pre- and eventual intermediate surveys to establish the fulfillment of the specifications. The results are presented to the Company's Representative; data are interpreted establishing that requirements for the rock berm over the flowlines and umbilical have been met. After approval and acceptation the dumping system is recovered and vessel will be demobilized.

7.0 Cost Estimate

7.1 Basis of Estimate

- Lump Sum cost are based on rock dumping the complete cable route (34 km)
- Roundtrips of approximately [redacted] nautical miles between [redacted] Strait of belle Isle
- Cost estimate is based on the following rock sizes
  - Offshore Area (KP2 - KP30) – Single layer system of 1 – 5 inch material
  - Nearshore Areas – Double layer system of 4 - 16 inch armour material with 1 – 5 inch filter layer.
  - Based on cable diameter of 0.2m
- Cost are based on present rates
- Cost are in Euro's.

7.2 Mobilisation and Demobilisation

Cost for mobilisation and demobilisation are based on mobilization from Europe to Newfoundland and demobilization back to Europe. Estimated duration for both mob and demob is 1.5 week each.

Description	Unit	Amount [EURO]
Mobilisation & Demobilisation	LS	[redacted]

7.3 Rock Supply

Description	Unit	Amount [EURO]
Purchase rock (FOB), including loading and purchase rock, min. 1,000 ton	Per ton	[redacted]

7.4 Rock Placement

The cost for rock placement include:

- Loading
- Roundtrips
- System Setup
- Infield Transit
- Execution

Description	Unit	Amount [EURO]
Rock Placement	Per ton	[redacted]

7.5 Day Rates

Description	Unit	Amount [EURO]
Vessel day rate operational	Dayrate	
Vessel day rate standby at sea	Dayrate	
Vessel day rate standby in port	Dayrate	

7.6 Typical Cost Rockdump Along Entire Route

Description	Unit	Amount [EURO]
Mobilisation	LS	
Execution of the works option “3 in 1 berm” – 670,000 tonnes	LS	
Execution of the works option “3 separated berms” - 850,000 tonnes Total of 3 berms	LS	
Demobilisation	LS	

8.0 Conclusions

The following conclusions can be drawn:

- Protection of the cables crossing the Strait of Belle Isle using rockdump is considered feasible within the water depth range of 40 – 110m as per SoW.
- A single layer system of 1-5 inch grading suffices along the majority of the offshore section of the route from roughly 60m to the maximum water depth.
- A double layer system with armour grading of 4 – 16 inch material is recommended in the nearshore sections between 20 – roughly 60m water depth.
- The study has also reviewed requirements in (nearshore) areas where the water depth is less than 40m. For water depths less than approximately 20m, the required material gradings are in excess of 16 inch material, which can not be installed using fall pipe techniques.
- Maximum cost of complete coverage of the three cables by separate berms along the entire route is approximately [redacted] Euro.
- A single berm covering the various cables as per Scenario 1 would be more cost effective when compared to individual berms for each cable as per Scenario 2 ([redacted] Euro).

9.0 References

[Ref. 1] Strait of Belle Isle – Sea State Information
[Ref. 2] Summary of Ocean Current Statistics for the Cable Crossing at the Strait of Belle Isle
[Ref. 2] CIRIA C683, The Rock Manual, 2007
[Ref. 3] Lambe and Whitman: “Soil Mechanics , Wiley and Sons, 1979
Coastal Engineering Research Center: “Shore Protection Manual”
[Ref. 4] US Army Coastal Engineering Research Centre (CERC): “Shore Protection Planning and Design”
[Ref. 5] Scope of Work – Preliminary Rock Berm Design, Concept Development Stage, Strait of Belle Isle.

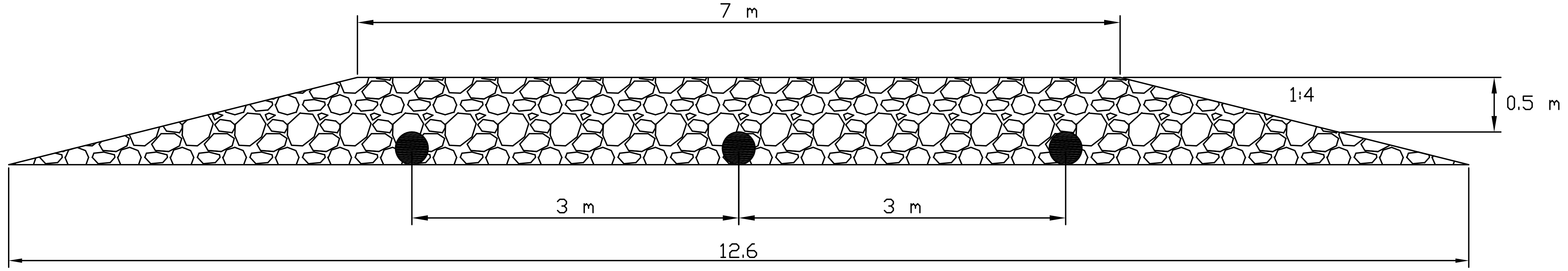
10.0 Appendices

Appendix A – General Arrangement Drawings Scenario 1 and 2

APPENDIX A

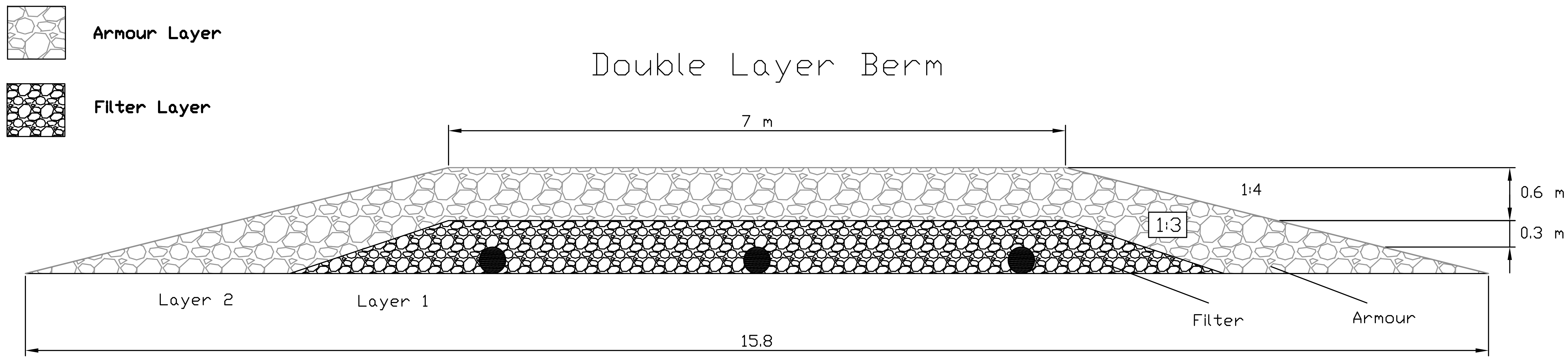
GENERAL ARRANGEMENT DRAWINGS SCENARIO 1 AND SCENARIO 2

Single Layer Berm



CROSS - SECTION

Double Layer Berm



CROSS - SECTION

Area		
	Single Layer	Double Layer
Layer 1	6.86 m²	4.25 m²
Layer 2		8.29 m²
Tot.	6.86 m²	12.54 m²

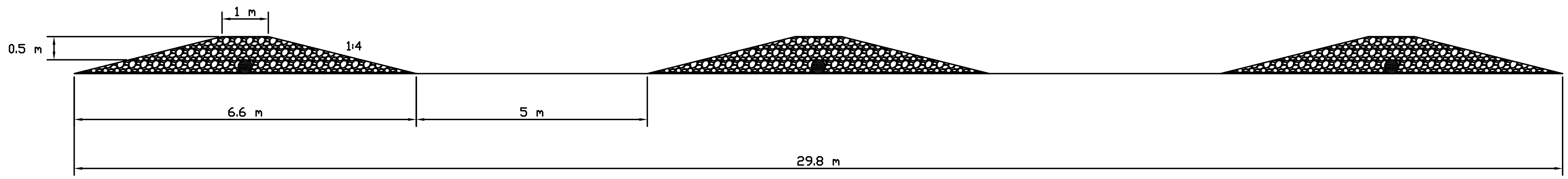
Company: nalcor energy LOWER CHURCHILL PROJECT		Client:		Contractor: Tideway Offshore Contractors	
-	GRM	30/11/2010	SCP	-	-
Rev.	Drawn	Date	Checked	Approved	Details

Project: LOWER CHURCHILL PROJECT

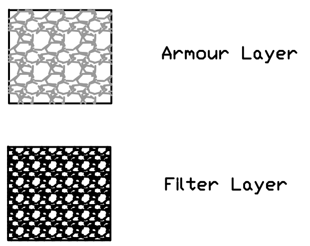
Drawing: ROCKBERM CONCEPT 2 DEVELOPMENT

Scale: ...-... | Drawing number: TW-XXX-XXX-XXX | Rev.: 0.0

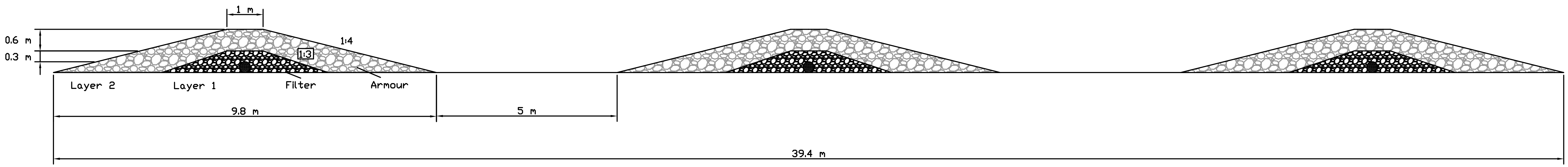
Single Layer Berms



Cross - Section



Double Layer Berms



Cross - Section

	Area	
	Single Layer	Double Layer
Layer 1 (3x)	7.98 m²	3.75 m²
Layer 2 (3x)		17.82 m²
Tot.	7.98 m²	21.57 m²

Company: nalcor energy LOWER CHURCHILL PROJECT	Client:	Contractor: Tideway Offshore Contractors			
-	GRM	30/11/2010	SCP	-	-
Rev.	Drawn	Date	Checked	Approved	Details
Project:	LOWER CHURCHILL PROJECT				
Drawing:	ROCKBERM CONCEPT 2 DEVELOPMENT				
Scale: ...-...	Drawing number: TW-XXX-XXX-XXX				Rev.: 0.0