

CEFOW – PENGUIN ARRAY

Project Information Summary

July 2018

Document History

Revision	Date	Description	Originated by	Reviewed by	Approved by
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1 Introduction

1.1 Project background

The most advanced wave power demonstrations today have showed the feasibility of power generation with single device deployments and MW-scale performance within various testing periods over several years. The next step beyond this is to deploy multiple wave energy converters at MW-scale with improved power generation capability, to demonstrate that they are able to survive rough sea conditions over a period of a number of years.

Fortum and Wello have collaborated under a European Commission Horizon 2020 project, Clean Energy From Ocean Waves (CEFOW) project which aims to deploy an array of three wave energy converters (WECs) at the European Marine Energy Centre (EMEC).

The wave energy converter technology ('Penguin') that has been selected for the project has already been tested and proven in real conditions at EMEC. There are three WECs to be installed at EMEC's wave test site, Billia Croo, under this project. The first WEC was installed under Wello's current marine licence in February 2017, and grid connected at the end of March 2017. It is proposed that two further WECs will be installed onsite as scheduled below:

- Penguin 2, deployment between September 2018
- Penguin 3, deployment between March-August 2019

According to the current schedule the testing period will continue until end of May 2020, however, to allow some redundancy in the programme the marine licence application will be until 1st March 2021. At the end of the testing period decommissioning will commence.

Although the CEFOW project has several consortium partners¹, Fortum Energy Ltd will be the marine licence holder associated with this application and will be responsible for discharging consent conditions.

1.2 Company background

1.2.1 Fortum Energy Ltd (Subsidiary of multinational Fortum Corporation)

The project is led by multinational energy utility, Fortum Corporation, which has a headquarter in Espoo, Finland. Today, Fortum is the most active energy utility company in wave power sector having ongoing wave power projects in Sweden (Seabased technology), Portugal and France (AW-Energy's Waveroller technology).

In 2014, Fortum's sales totalled EUR 4.1 billion and comparable operating profit was EUR 1.1 billion. Fortum employs approximately 8,200 people and its shares are traded on the NASDAQ OMX Helsinki.

Fortum's purpose is to create energy that improves life for present and future generations. Catering to the versatile needs of our customers, Fortum generates, distributes and sells electricity and heat, and offers related expert services. Among Fortum customers, Fortum has been recognised as one of the most well-known brands in Scandinavia, which is today Fortum's biggest market area. Fortum's operations focus on the Nordic and Baltic countries, Russia, Poland and the UK.

Alongside emissions-free hydro, nuclear power, combined heat and power production, Fortum is developing the use of biofuels and developing solar, wind and wave energy opportunities -

¹ Project Consortium consisting of Fortum (utility), Wello (technology), Green Marine (marine operator), Universities of Plymouth, Exeter and Uppsala (environmental research), EMEC (test facilities).

these all are part of the future energy system. Wave power is one of the Fortum's R&D focus areas, with significant growth expected in the near future.

1.2.2 Wello Oy

Founded in 2008, Wello Oy is a Finnish company dedicated to the development of wave energy converters. Having worked on a number of wave energy concepts since 1976, the unique Penguin model was selected in 2008 for further progression.

2 Technology background

2.1 Description of the WEC

The 2160-tonne Penguin device is around 30 meters long, nine meters in height and has a draft of around seven meters. Only two meters are visible above the water surface.

The Penguin device has unique simple and durable design which is able to convert wave movement into power, with no moving parts outside the hull. The power generation is based on converting the movement of the waves to rotational kinetic movement inside the device by using the asymmetric shape of the hull. As the Penguin is based on continuous rotational movement the forces and the thus the wear of the component is reduced, and the power takeout is increased. The asymmetric shape of the Penguin's hull has been optimised for maximum power generation and operates optimally in water depths of 50m or more, which makes it very attractive considering the site development worldwide, as there is no need to restrict to near-shore sites.

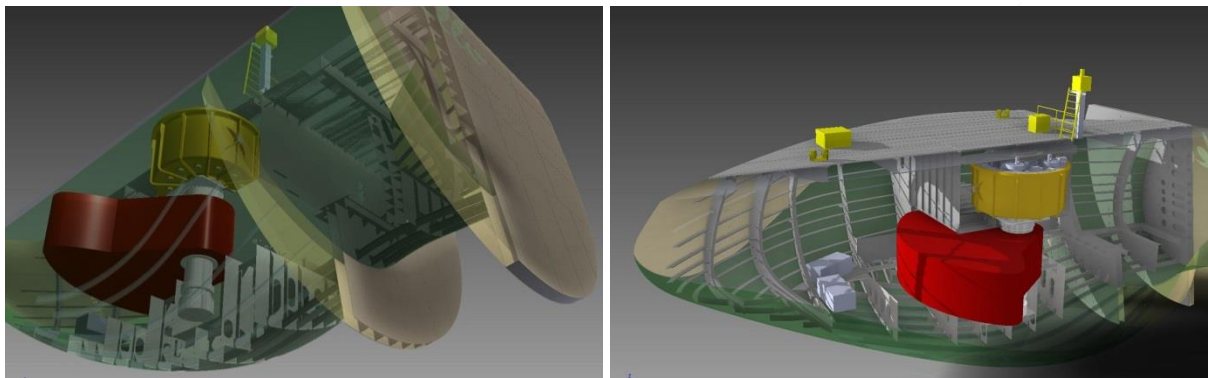


Figure 2-1: Operating principle of Penguin: rotating mass (red component) connected with generator

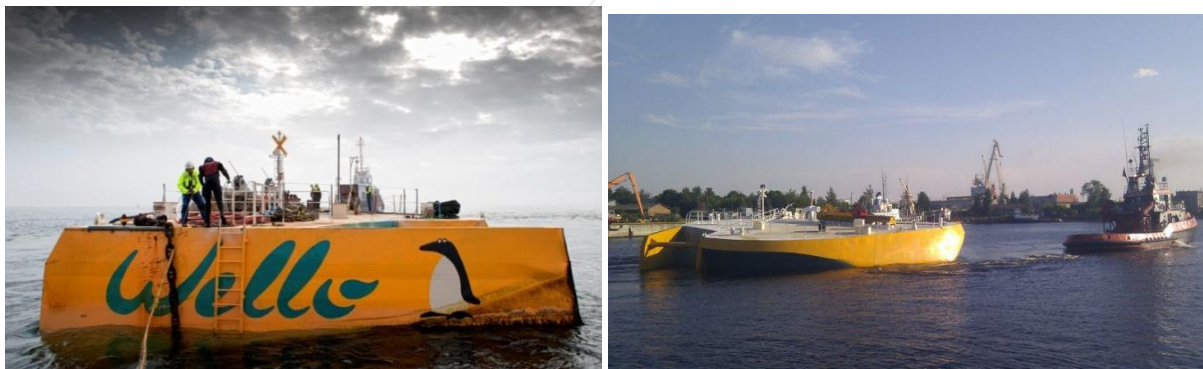


Figure 2-2: Wello's current Penguin (1220+ tons, length: 30m, width: 15m, depth: 7m)

One existing Penguin (Figure 2-2) was deployed in 2017, with two other Penguins to be deployed in summer 2018 and 2019. These devices will have the same working principle (all the moving parts are inside the hull) but will aim for increased power production rate and lower investment cost due to improved hull shape, see Figure 2-3.

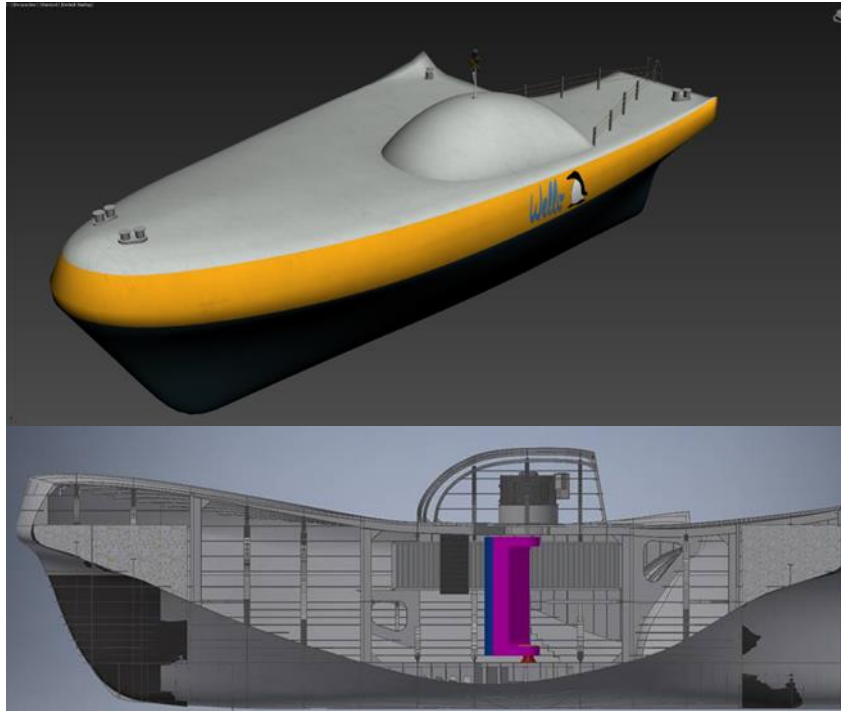


Figure 2-3: Sketch of WEC 2 with new advanced shape

2.2 How it works

Wello's patented key invention is to convert wave movement to gyration. The asymmetrical shape of the Penguin is used to capture the energy from the waves from all directions. The roll of the device spins the rotator inside the device, directly capturing the energy in the waves. Power is led from the rotator to generator using the same shaft eliminating conversion losses.

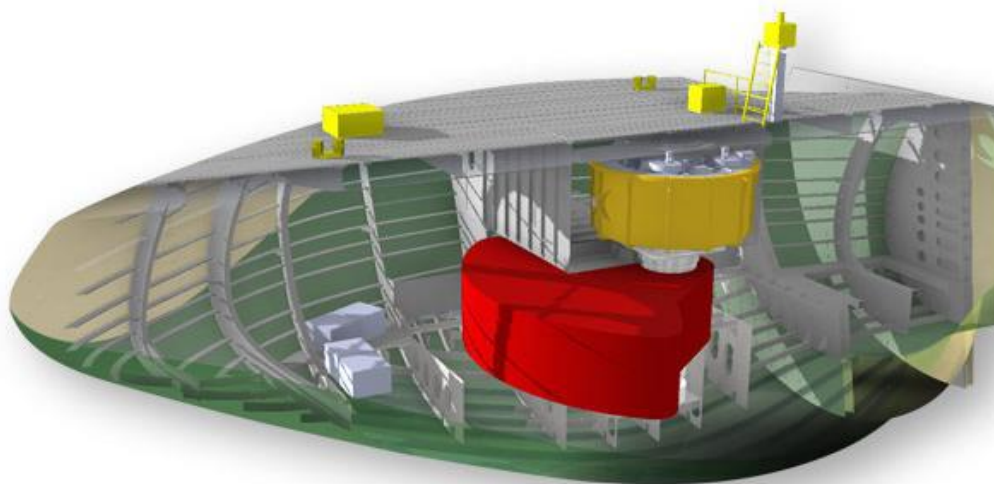


Figure 2-4: Schematic of the Penguin WEC – Mark 1

2.3 Electrical cabling and hub

To allow additional WEC devices to be installed at Berth 5 the export cable will be split using a 4-way smart hub as shown below

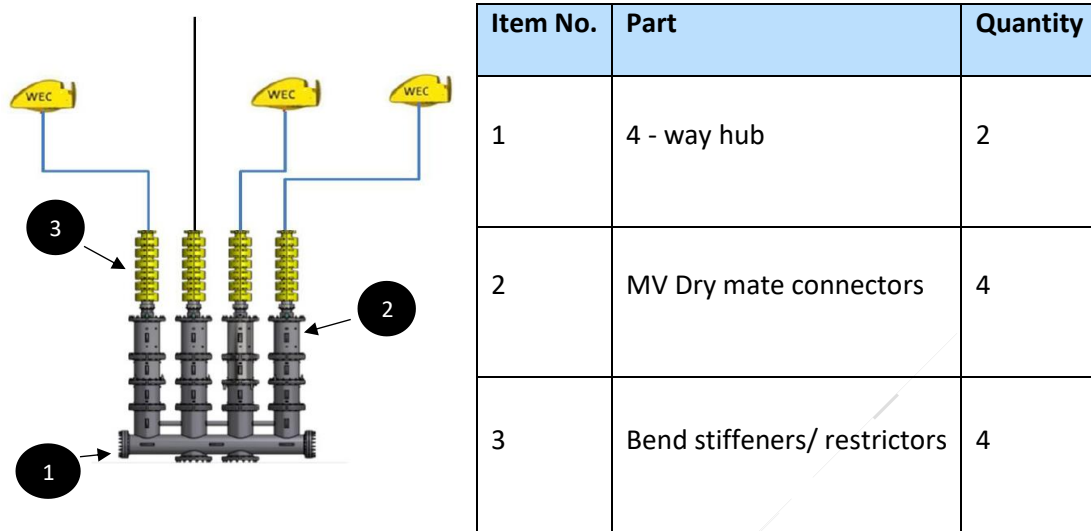


Figure 2-5: Schematic of 3 WEC connections

The smart hub is a ground-breaking utilisation of subsea switchgear, giving the opportunity to isolate a faulty WEC and thus preventing one device from causing an earthing fault over the whole array. Such a solution offers significant availability increases and also cost savings in being subsea.

Built utilising maintenance-free industry standard components which offer a high level of operational safety and reliability the Smart Hub is based on vacuum load break switches.

- The hub contains 3 import connection and 1 export connection.
- The dynamic cable from the WEC devices can be quickly and easily connected to the import connections of the hub via the use of a dry mate connection.
- A dry mate connection enables an effective and low-cost connection procedure.
- Using a 4-way hub then allows multiple WEC devices to be installed exporting power through just the one cable.

A GA of the smart hub is given in Figure 2-6. The hub is approx. 3m wide by 3m long by 1.2m tall. The hub is estimated to weigh 4000kg in air and weigh 1700kg in sea water.

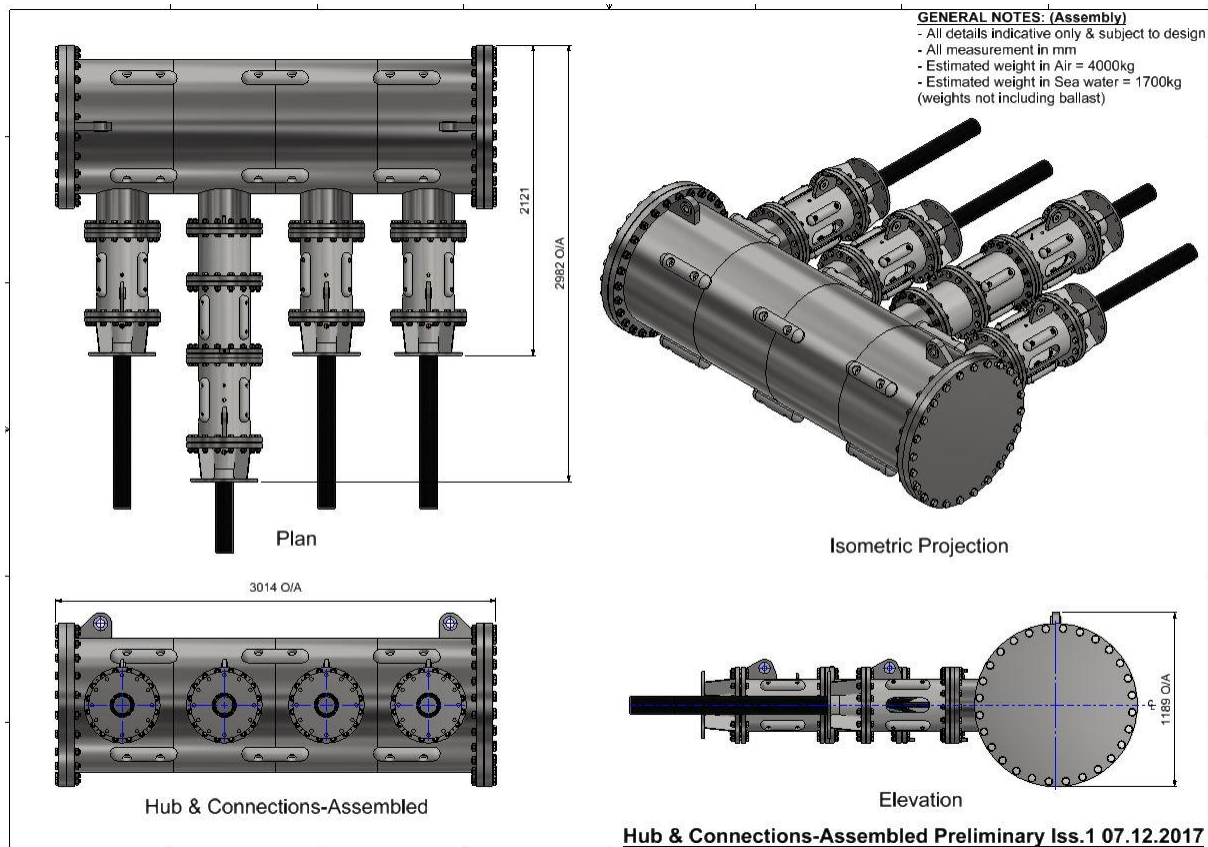


Figure 2-6 - Smart Hub GA

2.4 Mooring system

The mooring design is a 6-legged catenary system where buoys are used to provide compliance in the shallow water-depths. The mooring system has been designed with ease of installation as a main design parameter. The mooring system is designed so all phases can be executed in short weather windows or safely be aborted due to unexpected poor weather conditions.

Each WEC will be anchored with either embedment anchors or gravity base anchors, no drilling into the seabed will be needed. The different anchoring options are presented as:

- Drag Embedment Anchors
 - 3te MK4 Bruce anchors
- Gravity anchor
 - 150Te of second hand chain formed into a chain clumps
 - 175t of high density concrete clumps as with the first WEC
 - 3 times 250Te and 3 times 175t steel weight which have recently been proposed to the project for rental from Green Marine

Each mooring leg is built up of different sizes of chain and a subsurface buoy that has a marker buoy above the surface. The design parameter of the chain is weight / meter to create the right shape of catenary. Additional safety factors have been built into the design of the mooring legs. Each mooring leg contains of anchor, seabed chain and catenary chain up to buoy and another catenary chain from buoy to WEC.

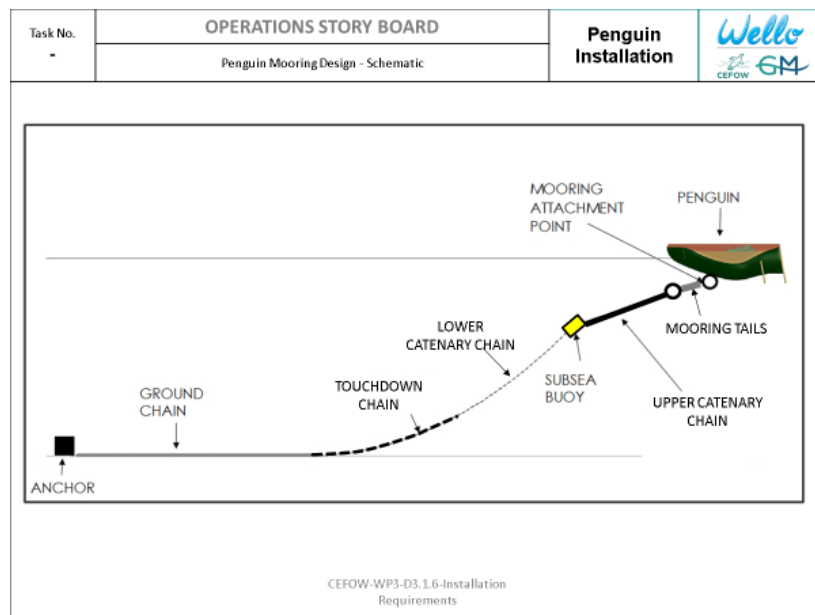


Figure 2-7: Breakdown of mooring legs

The mooring spread for WEC 1 has an approximate diameter of 800m, for WECs 2 & 3 the diameter is reduced to 500m due to the use of embedment anchors. Each device will be anchored with an approximate heading of 245 degrees. The heading will be fixed. The mooring spread is designed so that the WEC will have a maximum excursion in all direction of approximately 25 meters in severe conditions.

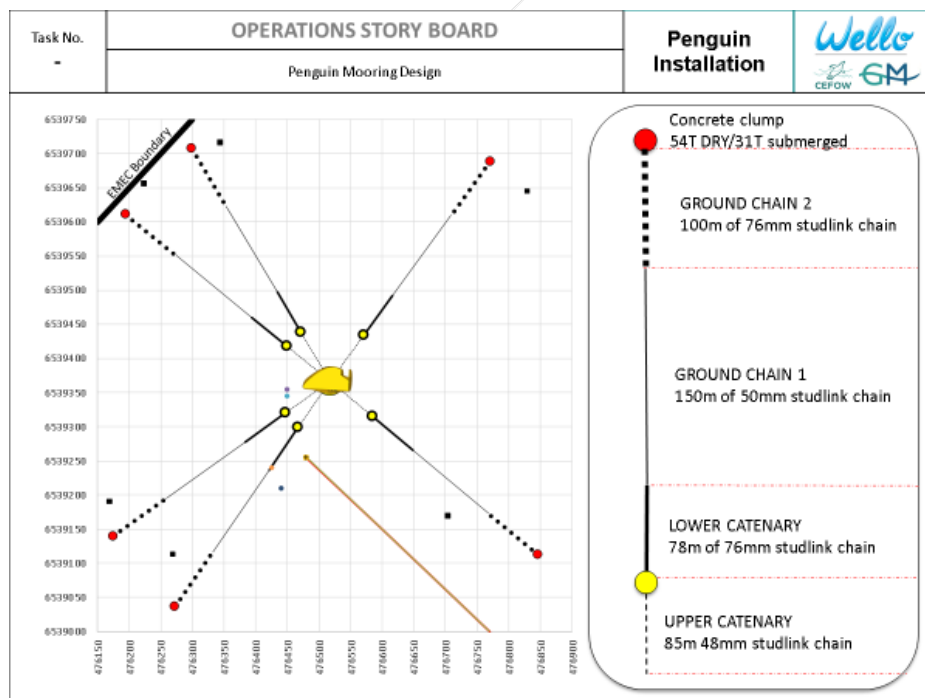


Figure 2-8: Schematic of mooring system

A schematic displaying the dimensions of the Bruce MK4 drag embedment anchor is given in Figure 2-9 with Table 2-1 giving the corresponding figures. The anchor is expected to embed to 1.5 time the fluke height (dimension B in Figure 2-9) and take 5 or 6 fluke lengths (dimension A in Figure 2-9) to embed. So for the 3Te MK4 Bruce anchors, which have been proposed for

the project, are expected to embed 3.6m below the sea bed and are expected to be dragged 20m before reaching their UHC (ultimate holding capacity).

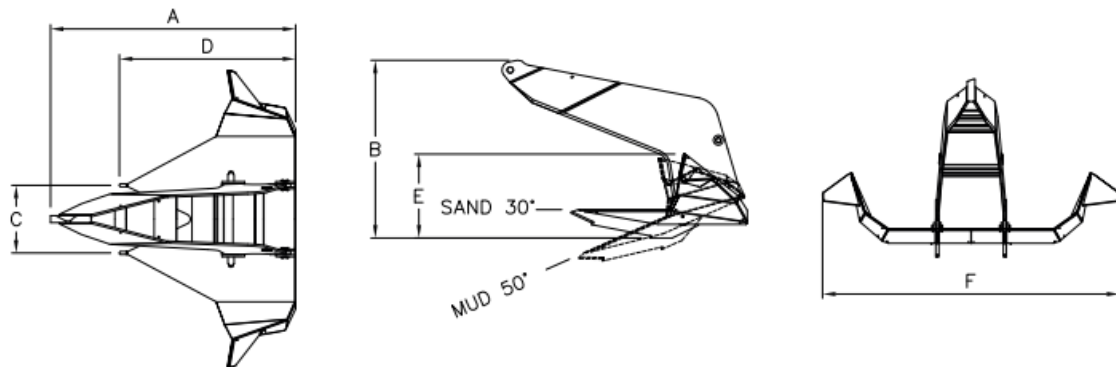


Figure 2-9 - Bruce MK4 anchor Dimensions

Example Sizes	Nominal Dimensions (in mm)					
Weight (kg)	A	B	C	D	E	F
500	1812	1312	499	1303	619	2196
1500	2540	1881	700	1880	883	3100
3000	3381	2447	932	2431	1155	4097

Table 2-1: Bruce MK4 anchor dimensions

Should drag embedment anchors not be feasible for the project, gravity anchors are proposed. The preferred gravity anchors would be chain clumps built from second hand chain as illustrated in Figure 2-10.



Figure 2-10 - Example Chain Clump built from second hand chain

2.5 Materials used

General terms of use:

- Any materials used in this project will be recovered at the end of the testing period.
- No materials will be extracted from the seabed during this deployment.
- No toxic or hazardous materials are used in this project.
- Paint coatings will be suitable for use in the marine environment and no antifouling is used on hulls or mooring components.
- Fuels or lubricants will all be contained appropriately to protect against accidental leaching.

During marine operations including installation, maintenance and decommissioning it may be necessary to temporarily deploy a vessel anchoring system. Each anchor is anticipated to be 40 tonnes and maximum of 8 anchors will be deposited at any one time. This will allow two vessels to moor at the deployment site at any one time.

2.5.1 WEC 1

This is an envelop approach and all values are given as an upper bound.

Component	Materials	Weight or Volume
Clump weight anchors (x6)	Concrete	188m ³
Subsurface buoys (x6)	Steel	10t (each) (total 60 tonne)
Chain	Steel	1800m (total 201 tonne)
Abandonment wire	Steel	5.2t
Hull	Steel	410t
Rotator	Steel and concrete	20t steel, 40t concrete (17m ³)
Ballast	Concrete	631m ³
Generator	Steel, copper, resin	60t (steel frame) 2t (copper windings) 100kg (resin coating)
Cooling water piping	Plastic	200kg (<1m ³)
Transformers	Iron, aluminium, steel	5t (iron) 500kg (aluminium and steel combined)
Frequency converter	Steel, aluminium, copper, plastic	510kg
UPS	Steel and lead	200kg
Switch gears LV/HV	Steel, copper, aluminium, plastic	570kg
Tubing	Steel	300kg
Lubricant	Grease/oil	20kg/1000l
Coolant	Fresh water - glycol mixture	150 l
Paint (marine standard)		160kg
Electrical converter	Steel	200kg
Cable buoyancy	Plastic	1.5m ³
Electric cables	Copper, PVC plastic	2 t (roughly 180m)
Bending restrictor	Polyester/rubber	20kg
Unused - Steel roll plates	Steel	2 x 77t 1 x 105t (total 259t)
Unused - Clump weights (x6)	Concrete	(14t each) 60m ³ in total

Table 2-2: WEC1 - Summary of Equipment deployed (seabed and floating)

2.5.2 WEC 2

Each mooring leg will either be anchored by a 3t drag embedment anchor (holding capacity of up 100 to 160t) or via a gravity anchor (either 150t chain clump, or 175t of high density concrete, or 3x250T 3x175T steel weights as recently proposed by Green Marine). Both anchoring solutions have been included in the deposits listed in the marine licence application form.

This is an envelope approach and all values are given as an upper bound.

Component	Material	Weight or Volume
EITHER Embedment anchors (x6)	Steel	3t Weight each, 18t Total – capacity 100-160t (each)
OR Gravity Anchors	Steel	150t/leg 900t total of second hand chain OR 175t/leg 1050t total of high density concrete per leg OR 3x250T & 3x175T steel weights
Subsurface buoys (x6)	Steel	10t (each) (total 60 tonne)
Chain	Steel	1680m (total 180 tonne)
Hull	Steel	320t
Rotator	Steel	160t
Ballast	Concrete	1633t
Generator	Steel, copper, resin	37t (steel frame) 2t (copper windings) 100kg (resin coating)
Cooling water piping	Plastic	200kg (<1m ³)
Transformers	Iron, aluminium, steel	5t (iron) 500kg (aluminium and steel combined)
Frequency converter	Steel, aluminium, copper, plastic	510kg
UPS	Steel and lead	200kg
Switch gears LV/HV	Steel, copper, aluminium, plastic	570kg
Tubing	Steel	300kg
Lubricant	Grease/oil	20kg/1000l
Coolant	Fresh water - glycol mixture	150 l
Paint (marine standard)		160kg
Electrical converter	Steel	200kg
Cable buoyancy	Plastic	1.5m ³
Electric cables	Copper, PVC plastic	2 t (180m)
Bending restrictor	Polyester/rubber	20kg

Table 2-3: WEC2 - Summary of Equipment to be deployed (seabed and floating)

2.5.3 Electrical hub

Component	Material	Weight or Volume
Electrical smart hub	Steel, copper, aluminium, plastic	4000kg (air) 1700kg (sea water)

Table 2-4: Electrical hub - Summary of Equipment to be deployed (seabed)

2.5.4 WEC 3

Each mooring legs will either be anchored by a 3t drag embedment anchor (holding capacity of up 100 to 160t) or via a gravity anchor (either 150t chain clump, or 175t of high density concrete, or 3x250T 3x175T steel weights as recently propose by Green Marine).

This is an envelope approach and all values are given as an upper bound.

Component	Material	Weight or Volume
EITHER Embedment anchors (x6)	Steel	3t Weight each, 18t Total – capacity 100-160t (each)
OR Gravity Anchors	Steel	150t/leg 900t total of second hand chain OR 175t/leg 1050t total of high density concrete per leg OR 3x250T & 3x175T steel weights
Subsurface buoys (x6)	Steel	10t (each) (total 60 tonne)
Chain	Steel	1680m (total 180 tonne)
Hull	Steel	320t
Rotator	Steel	160t
Ballast	Concrete	1633t
Generator	Steel, copper, resin	37t (steel frame) 2t (copper windings) 100kg (resin coating)
Cooling water piping	Plastic	200kg (<1m ³)
Transformers	Iron, aluminium, steel	5t (iron) 500kg (aluminium and steel combined)
Frequency converter	Steel, aluminium, copper, plastic	510kg
UPS	Steel and lead	200kg
Switch gears LV/HV	Steel, copper, aluminium, plastic	570kg
Tubing	Steel	300kg
Lubricant	Grease/oil	20kg/1000l
Coolant	Fresh water - glycol mixture	150 l
Paint (marine standard)		160kg
Electrical converter	Steel	200kg
Cable buoyancy	Plastic	1.5m ³
Electric cables	Copper, PVC plastic	2 t (180m)
Bending restrictor	Polyester/rubber	20kg

Table 2-5: WEC3- Summary of Equipment to be deployed (seabed and floating)

3 Location

The CEFOW array will be installed at test berth 5 at the European Marine Energy Centre's wave test site, Billia Croo. EMEC is an existing grid-connected test site located off the west coast of Orkney.

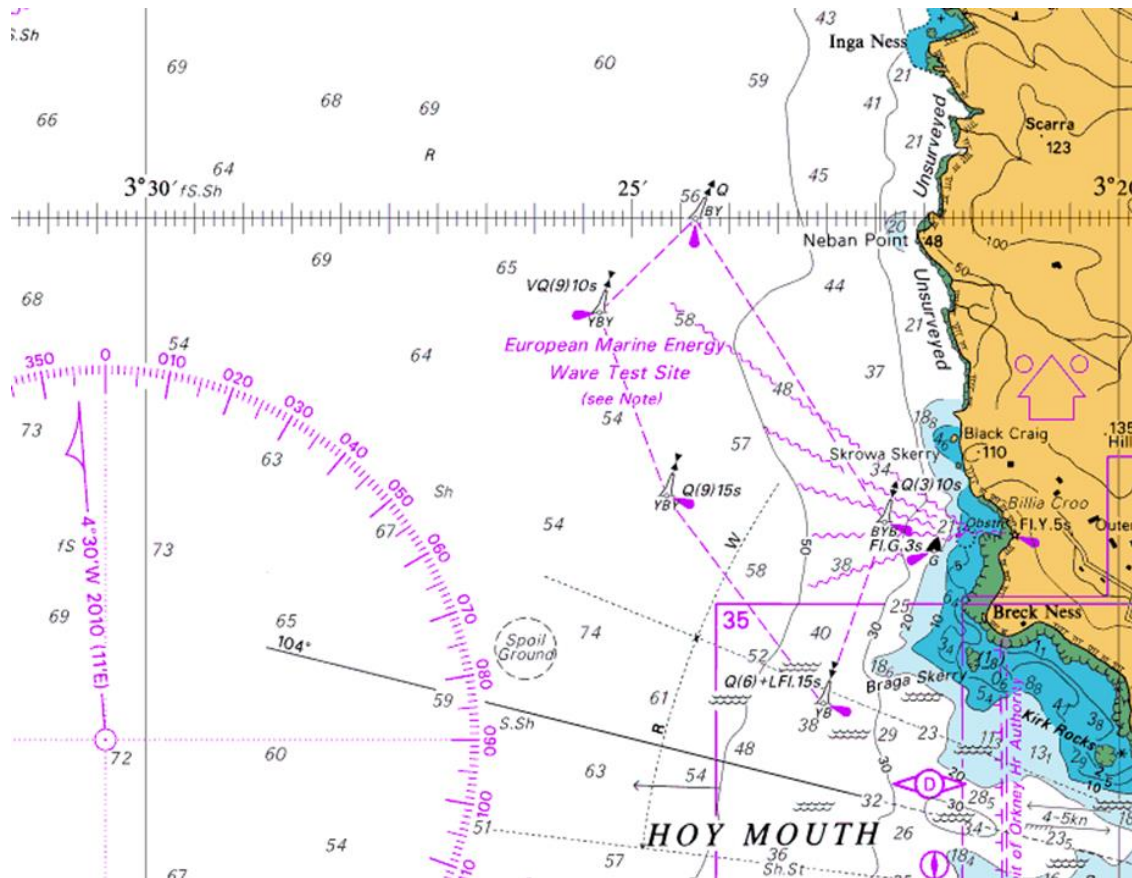


Figure 3-1: Part of Admiralty Chart 2249 showing Billia Croo test site

A global view of the position of the devices along with the licence boundary is given in Figure 3-2.

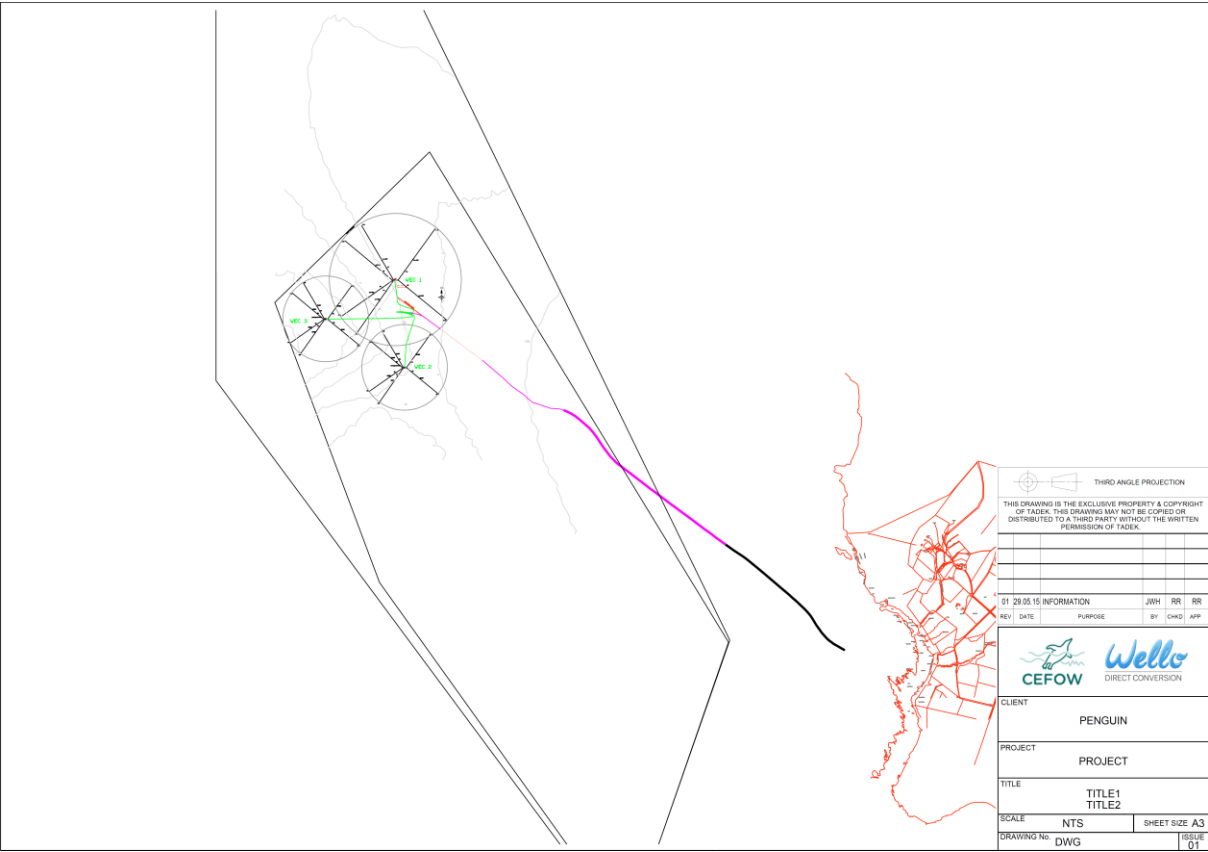
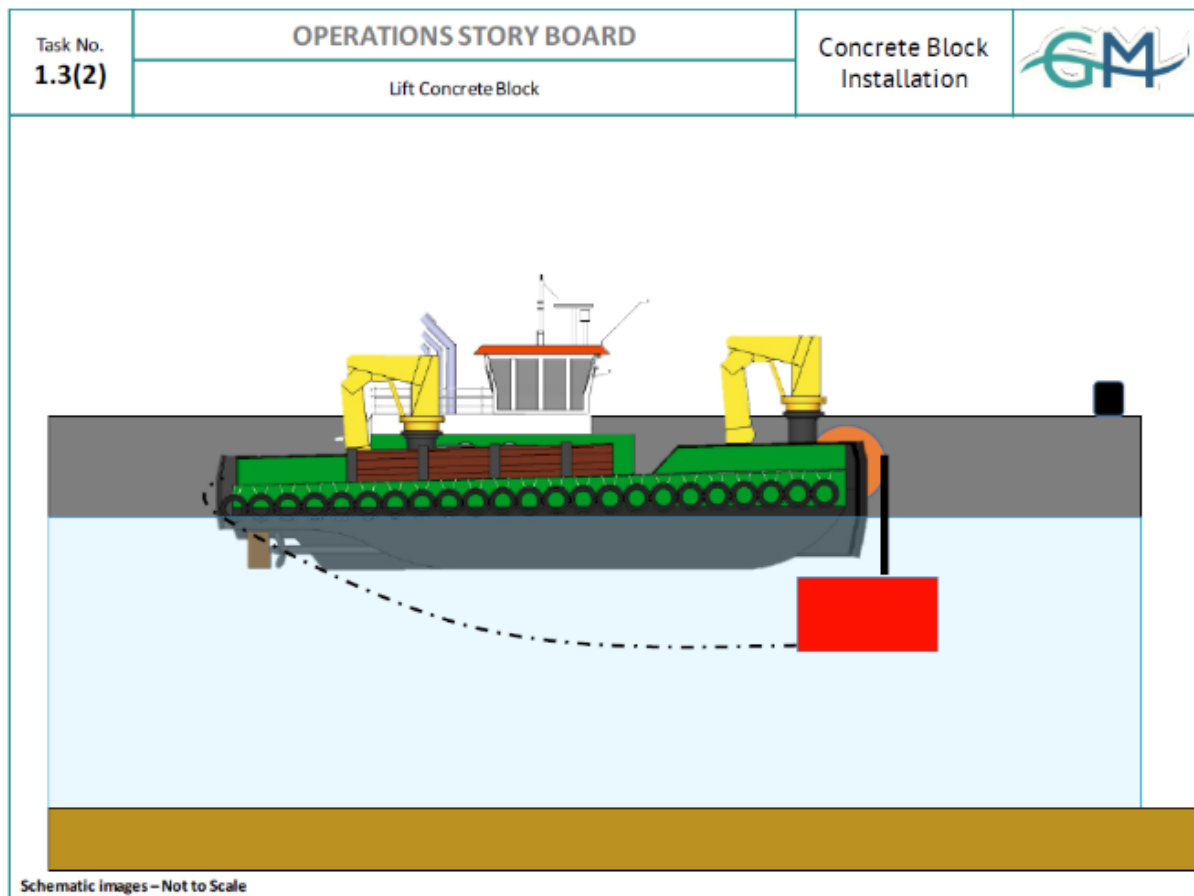



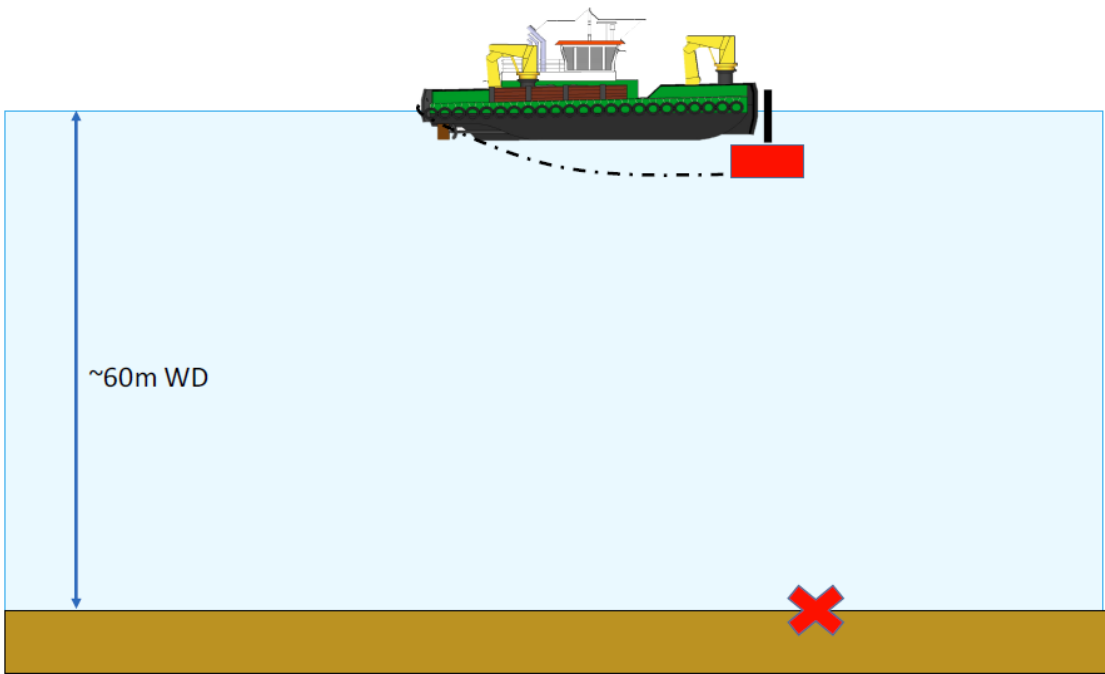
Figure 3-2 - WEC Positioning - Global View


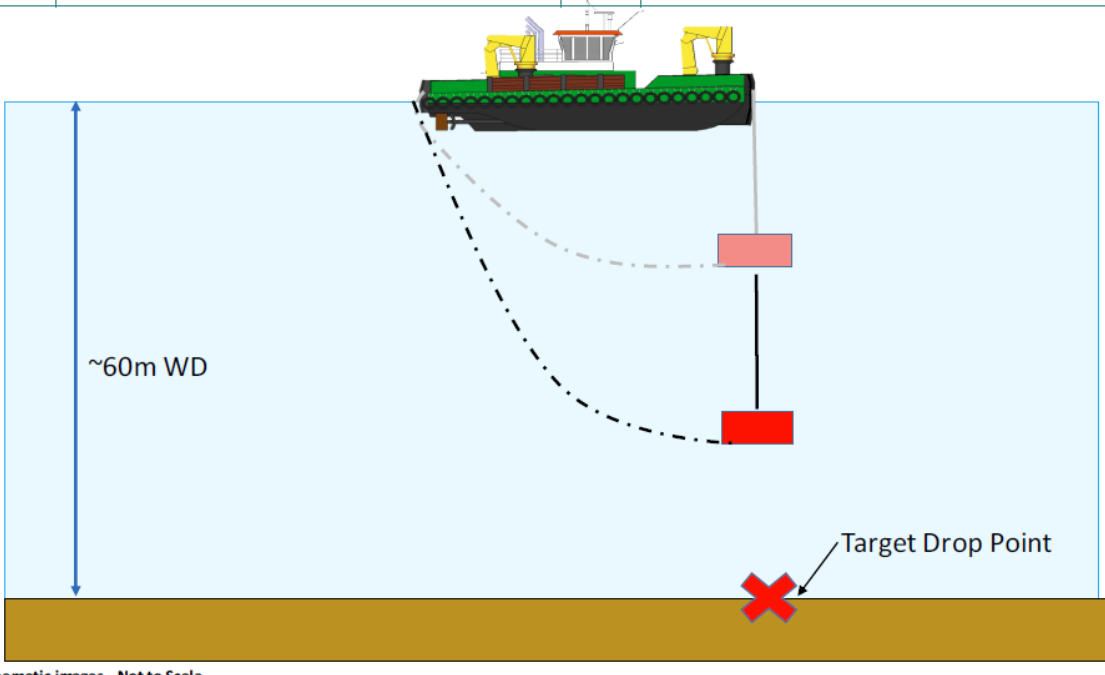
4 Installation method


4.1 Deployment of Anchors

The anchors will be installed using a multi-cat type vessel. The anchors will be lowered down at predefined locations. Each anchor will have a length of chain attached at the base and this will be laid down and buoyed off. The anchors will be pre-tensioned during the installation process. The ground chain will then be laid and buoyed off. Below are some images from the operational storyboard during the WEC 1 installation which remain relevant to the WEC 2 and 3 installations.

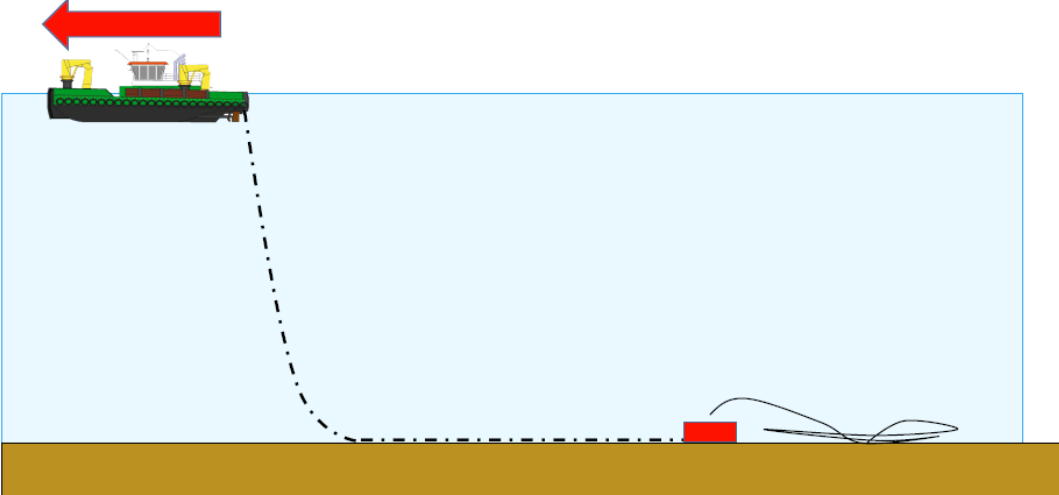


Task No. 2.1	OPERATIONS STORY BOARD		Concrete Block Installation	
	Arrive on Site, Connect remaining 50mm Chain to double shot of Chain Connected to Block			
1	Arrive on site. Vessel Master to choose vessel bearing (depending on weather) and hold position.		2	Deploy drop down camera. Aft starboard winch run through block on the forward crane.
				
Schematic images – Not to Scale				


Task No. 2.2	OPERATIONS STORY BOARD		Concrete Block Installation	
	Lower Concrete Block, Simultaneously pay out 50mm chain			
1	Aft towing winch and port tugger winch to be connected to 50mm chain. Chain will be yo-yo'd using the two winches.		2	Drop down camera used to monitor catenary shape of chain at the concrete block. Used as feedback to winch crew
				
Schematic images – Not to Scale				

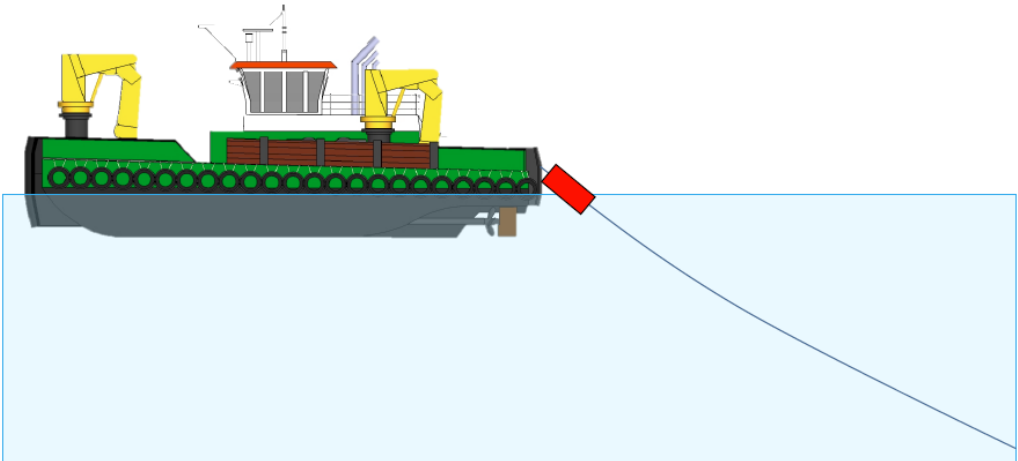
Task No. 3.2	OPERATIONS STORY BOARD		Concrete Block Installation	
	Pay Out Remaining Length of Chain			
1	Proceed along lay path. Vessel Master in communication with deck crew.		2	Deck Crew monitor chain departure angle. Minimum and maximum angles defined to ensure chain is laid correctly.

Direction of Travel




Schematic images – Not to Scale

Task No. 3.3	OPERATIONS STORY BOARD		Concrete Block Installation	
	Remove Twist from Chain			
1	When nearly all chain is paid out, hold tension on winch(1), place swivel between winch(2) and end link of 50mm chain.	2	Overboard the two winch wires and transfer load on to winch(2).	
3	Apply forward thrust (Green Isle to remain in lay corridor).	4	Build up to required Bollard pull, hold for 5 minutes for twist to remove from suspended chain.	
5	Move back to remove tension from line. Simultaneously recover swivel to main deck.		6	Remove swivel from 50mm chain.



Schematic images – Not to Scale

Task No. 3.4	OPERATIONS STORY BOARD		Concrete Block Installation	
	Lower on Dynema Riser and Buoy Off Chain			
1	70m of 50mm Dynema is pre-wound on to the anchor winch. Additional 20m polypropylene tail is joined to buoy end of dynema.	2	The end of 50mm is connected to the dynema riser using shackle.	
3	Continue laying anchor chain based on departure angle. (yo-yo on two winches).	4	Once polyprop tail goes slack (end of 50mm chain is on seabed), overboard buoy.	

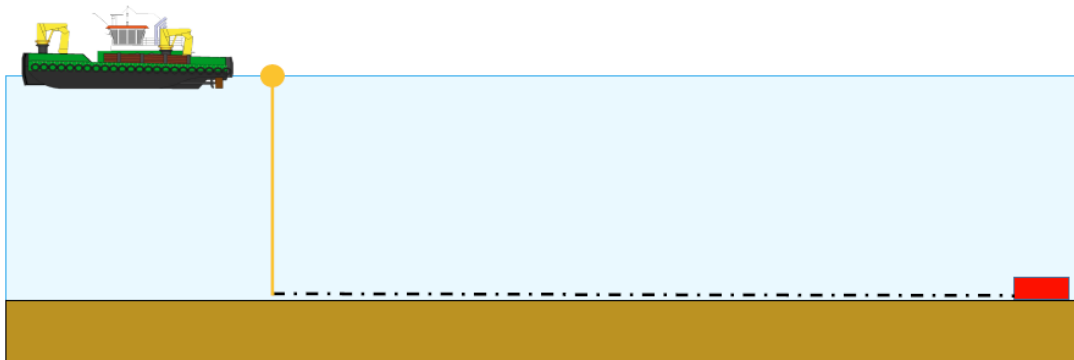


Figure 4-1: Deployment of Anchors




4.2 Penguin Installation


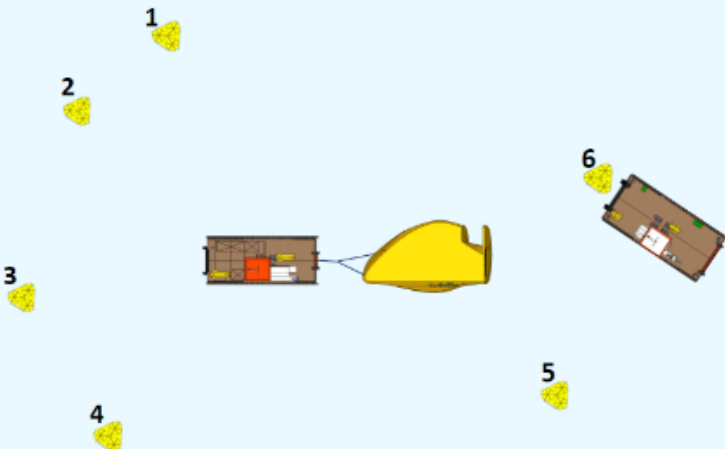
Following the installation of the ground chain, lower catenary and buoys, the Penguin will be towed to site and attached to the mooring spread.




This will be achieved in the following stages:

- Phase 1: Tow Penguin device from either Hatston Quay or Lyness Pier to the Billia Croo test site.
- Phase 2: Undertake micro-siting onsite and complete connection to buoys
- Phase 3: Connect to the midline
- Phase 4: Repeat Phase 2 and 3 for all mooring legs

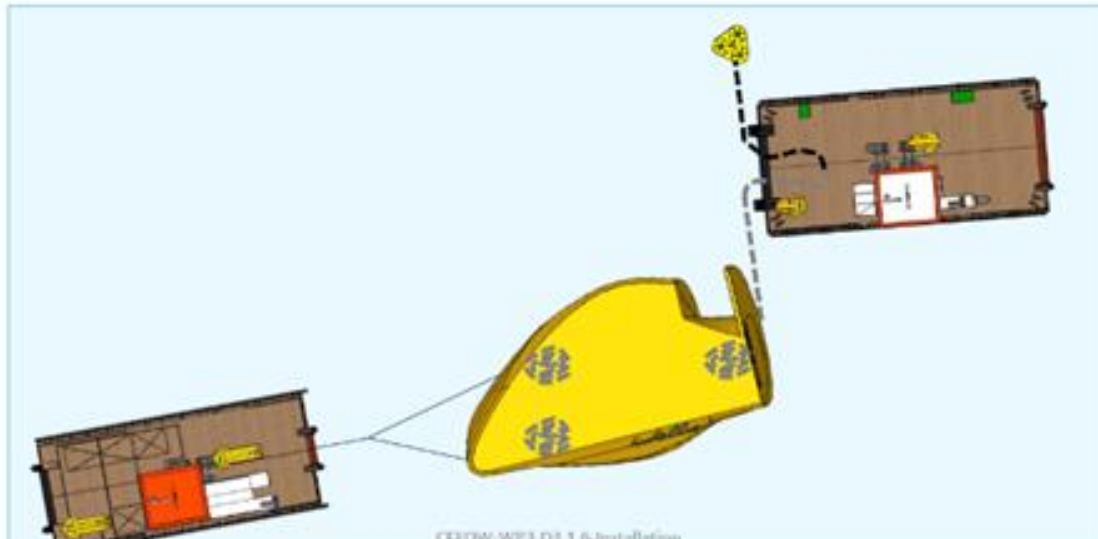
Below are images depicting the operational storyboard during the WEC 1 installation which remain relevant to the WEC 2 and 3 installations.

Task No. 1.1	OPERATIONS STORY BOARD		Penguin Installation	
	Penguin towed to site			
1	Penguin towed to site using Green Isle aft and second support vessel forward	3	The Green Isle disconnects tow bridle and moves free to retrieve first mooring chain	
2	Upon arrival at site the second support vessel remains positioned forward of the Penguin			
<div></div> <div></div> <p>CEFLOW-WP3-D3.1.6-Installation Requirements</p> <p>Schematic images – Not to Scale</p>				

Task No. 2.1	OPERATIONS STORY BOARD		Penguin Installation	
	First Mooring Chain Collected			
1	The Green Isle collects the first mooring chain starting at the Northern most mooring point (#1)	-	Exact order of mooring connect pending site conditions on the day	
2	The Penguin is held into tide flow by the support vessel			
<div></div> <p>CEFLOW-WP3-D3.1.6-Installation Requirements</p> <p>Schematic images – Not to Scale</p>				


Task No. 2.3	OPERATIONS STORY BOARD		Penguin Installation	  
	First Mooring Chain Overboarded			

1	After both mooring chains have been secured on deck the Green Isle settles at the connection point	3	The secondary vessel maintains penguin position throughout connection
2	The mooring chains are connected together and then overboarded	4	Mooring chains lowered and released using hydraulic shackle

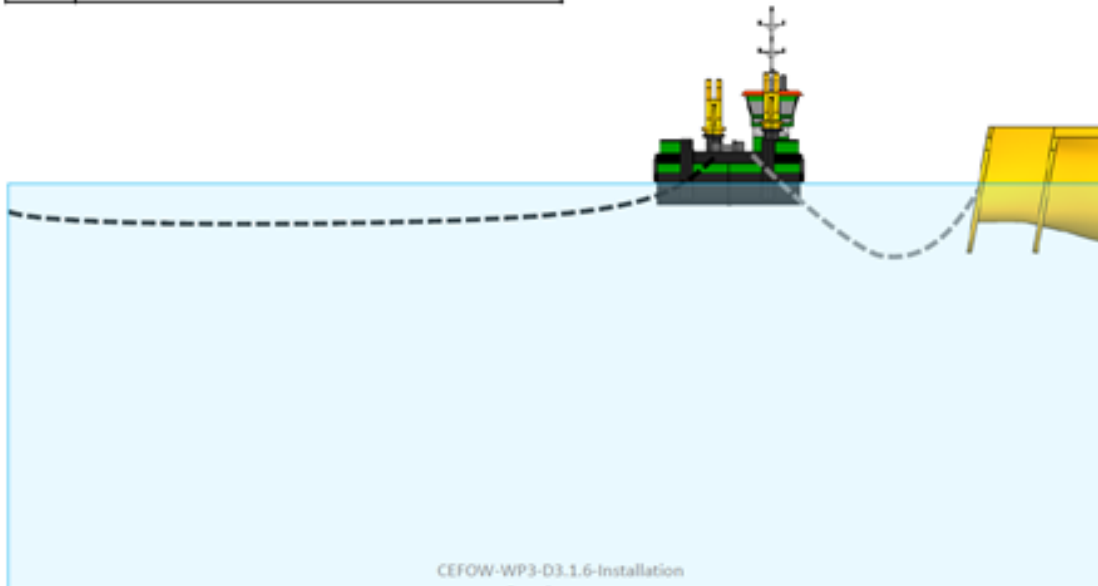


CEPOW-WP3 D3.1.6-Installation
Requirements

Schematic images – Not to scale

Task No. 2.2	OPERATIONS STORY BOARD		Penguin Installation	
	First Mooring Chain Connected			

1	After connecting the buoy mooring chain the Green Isle moves over to the penguin paying out the chain
2	Once at the Penguin the Green Isle retrieves the device mooring chain



CEFOW-WP3-D3.1.6-Installation Requirements

Schematic images – Not to Scale

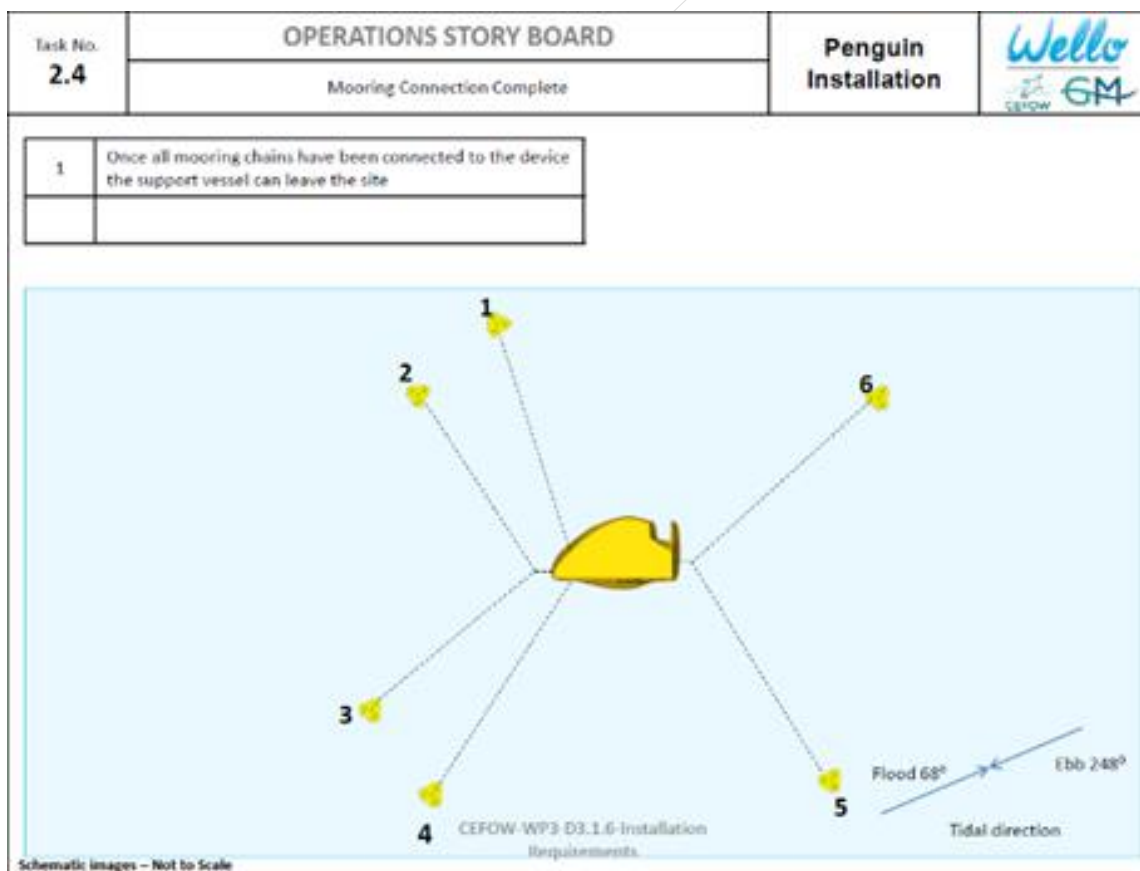
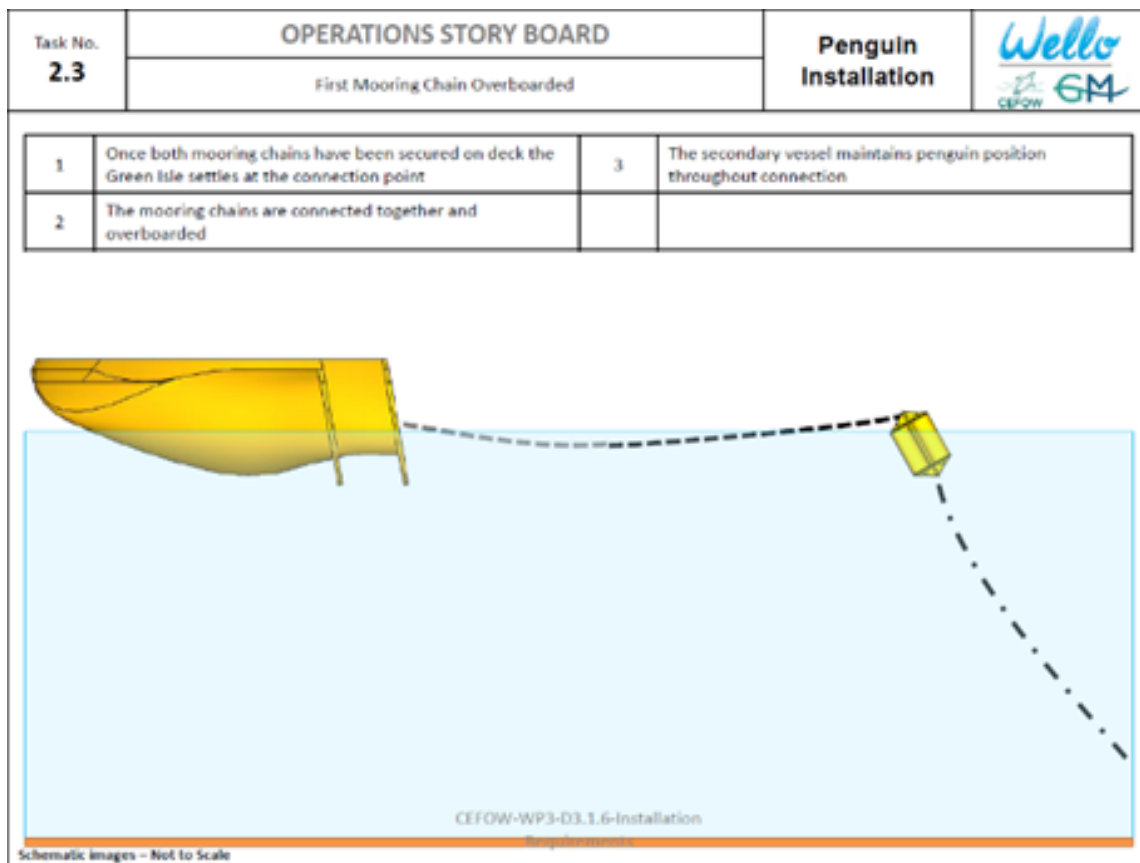
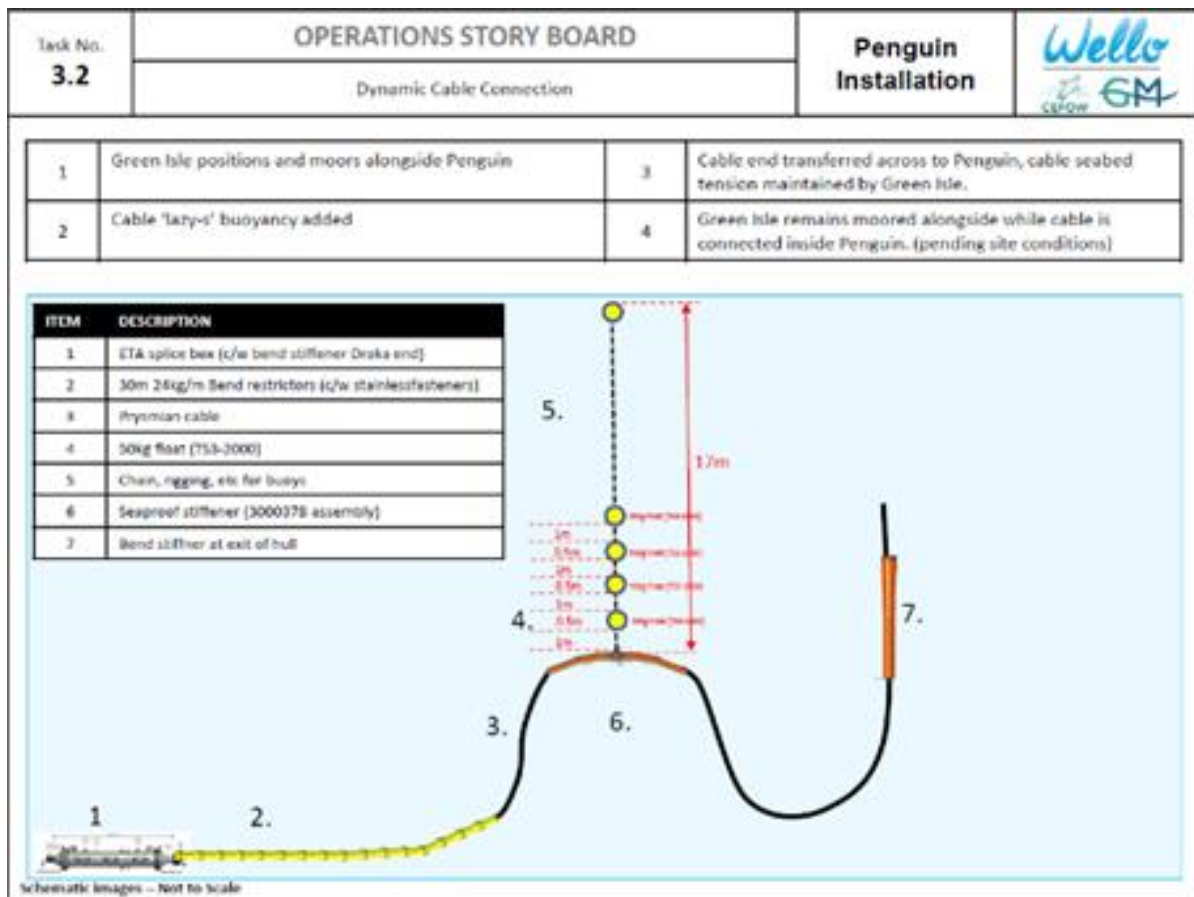


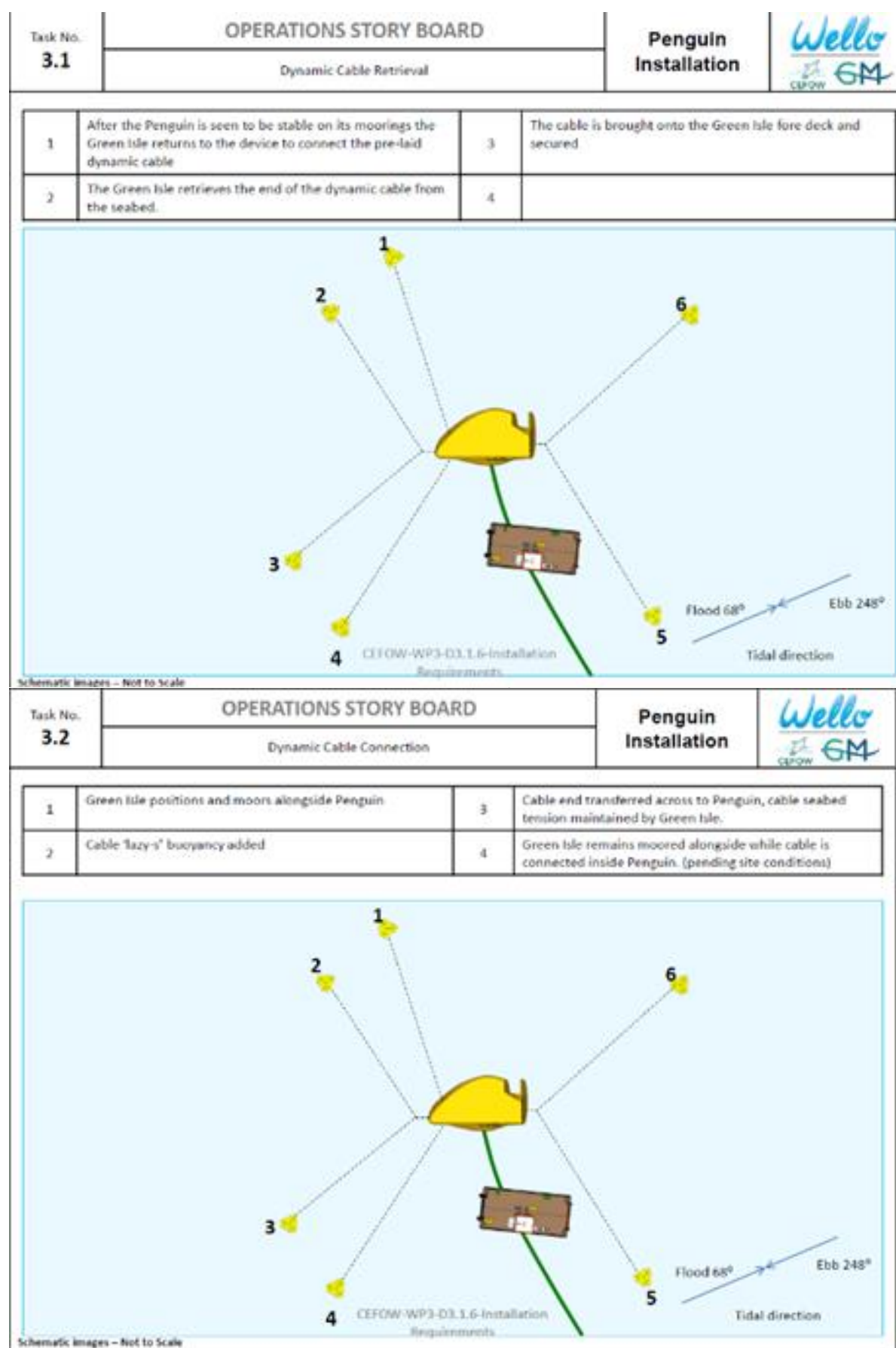
Figure 4-2: Storyboard depicting Penguin installation

4.3 Penguin Electrical Hookup

To achieve the electrical hook-up, an ROV must thread the recovery line to mini clump. The multicat will then lay and connect a 2-point mooring spread. The dynamic cable will be recovered and the abandonment cap cut-off. The buoyancy bend stiffener will be slid onto the electrical cable and reeled in.

Below are images from the operational storyboard during the WEC 1 installation which remain relevant to the WEC 2 and 3 installations.





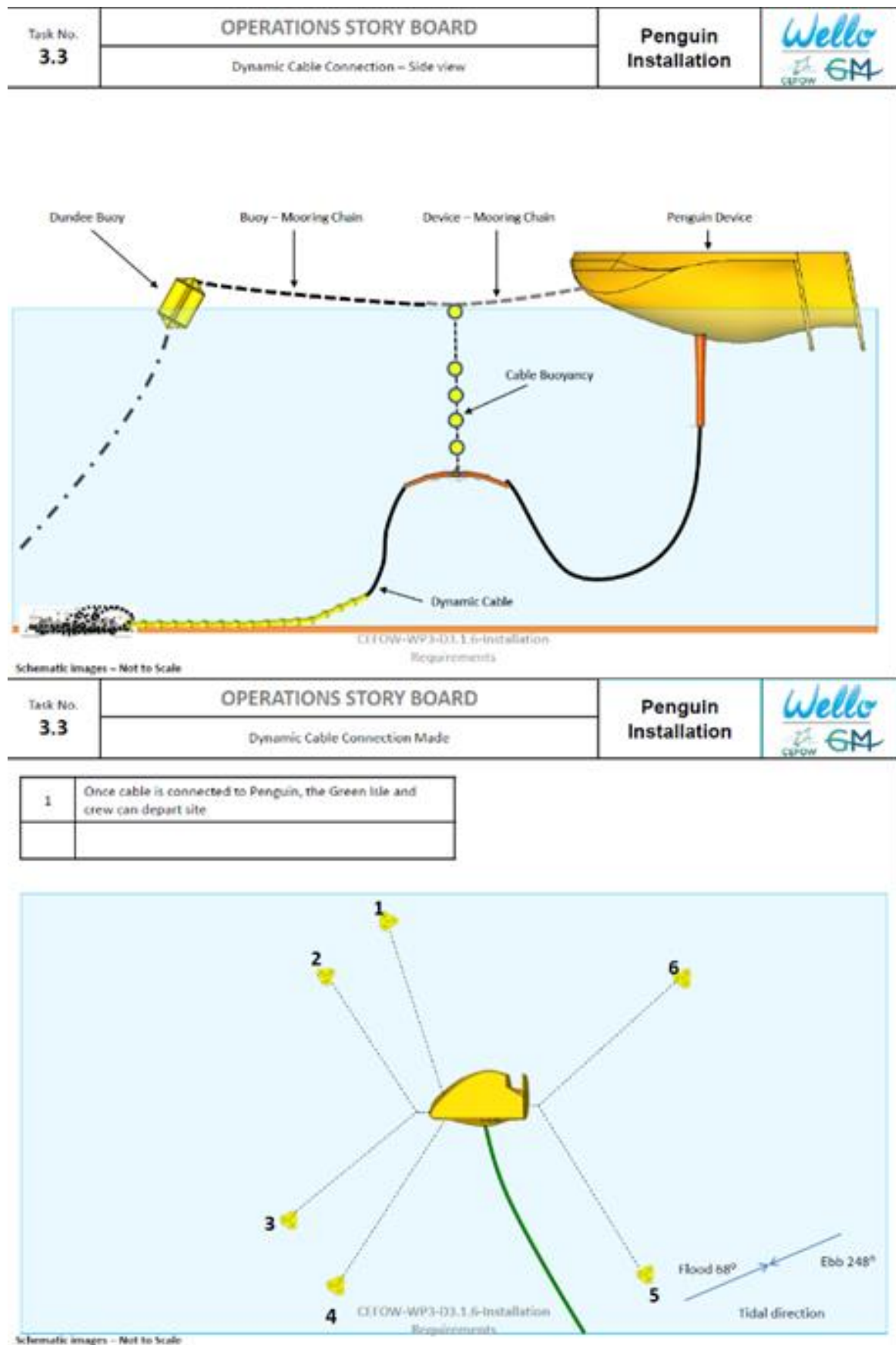


Figure 4-3: Electrical connection storyboard

4.4 Anticipated vessel traffic to site

Green Marine are a project partner in the CEOFW project. Table 4 outlines the vessels to be used during the construction phase. Appendix A provides further information regarding the vessel specification.

Vessel Name	Vessel Operator	Vessel Type
Green Isle	Green Marine	Damen Multicat 2712
Green Chief	Green Marine	Damen Stan Tug Workboat
Green Quest	Green Marine	Safe / Fast Crew Transfer Vessel
Aurora	Green Marine	Fast Operation RIB Safety

Table 4-1: Anticipated vessel traffic to site

4.4.1 Planned maintenance

The device has been designed so that regular maintenance is not required. However, it is anticipated that during testing, maintenance and inspection will be required approximately once a month. This will essentially involve using a RHIB or small workboat to transfer personnel onto the device where maintenance and inspection will be conducted within the hull. Maintenance will only be carried out in calm sea conditions (with a wave height less than ~1.5m Hs to ensure safe access to the device).

4.4.2 Unplanned maintenance

Should the device need to undergo major maintenance/repair, the device will be towed to quayside using a multicat vessel or a tug. Once ready for redeployment, the hook up methods will apply again. Local mariners and stakeholders will be informed prior to any device towing operations through the normal Notice to Mariners procedure.

4.5 Device monitoring systems

Anticipated maintenance and inspection frequency is planned to happen on average every second month. Critical monitoring information is stored at the Stromness office via the fibre optic link.

During those visits ROV can be used to check moorings and visual inspection can be done inside the devices. In addition, inspections will be done after every severe storm especially during the first years of the project.

5 Decommissioning / removal method

After completion of the testing period the system will be decommissioned in the reverse order to the installation process, this has been outlined in detail in the Decommissioning Plan. Decommissioning is expected to happen earliest in summer time (May-September) 2020, when the European Commission funded project will end.

6 Third Party Verification (TPV)

6.1 WEC 1

The third party verification of the moorings and device is detailed in:

TPV OP 212.001 Rev 1.0 30.04.2018

6.2 WEC 2

The TPV for WEC 2 is ongoing and will follow the scope described below.

There are two elements required for a thorough third-party verification of the CEFOW Wello Penguin mooring and device structure:

- Design Review
- Installation & Maintenance Review / Further Due Diligence

6.2.1 SCOPE 1: Design Review Proposal

The scope of work is to:

- Review the load cases
- Confirm design capability of components selected is sufficient for the load cases
- Confirm a low risk to EMEC infrastructure and other operations onsite during a single or multiple mooring line failure
- Confirm design has been performed to a specified code following industry practice
- Review the Wello mooring design analysis files
- Perform independent computer and hand calculation analysis
- Make comments on the design, components and analysis process

6.2.2 SCOPE 2: Installation & Maintenance Review / Further Due Diligence

This scope is the approval of the procurement and execution phase of the moorings. The scope has not been fully confirmed at this stage but is fundamentally:

- Review of component list from a practical perspective.
- Independent surveyor to perform an inspection of second hand components
- A review of the installation methodology
- A review of the inspection and maintenance philosophy

6.3 WEC 3

(TBC) As WEC 2.

7 Proposed Timescales

7.1 Programme of Works

Works at the berth will happen in three phases, as described below.

7.1.1 Phase 1: Penguin 1 deployment – already completed

Phase 1 has been completed between February-August 2017. Moorings were prepared and deployed at the Berth 5 in February 2017 for Penguin 1. After deployment of moorings, Penguin WEC 1 was towed onsite and connected to the moorings in February. Electrical connection via the dynamic cable (umbilical cable) was connected by splicing to EMEC static cable on March 2017.

7.1.2 Phase 2: Penguin 2, deployment between August - September 2018

Moorings will be prepared and deployed at the Berth 5 in August/September 2018 for Penguin WEC 2.

An electrical hub will be procured and deployed in September 2018, which will enable the grid connection for three Penguin WECs.

When the moorings have been successfully deployed, Penguin 2 will be towed to the site. The Penguin's umbilical cable will be connected directly to the Hub with a pre-deployed connector.

7.1.3 Phase 3: Penguin 3, deployment between March-August 2019

All the following deployments have been planned to be done between March-August 2019, dependent on the weather at the sea.

The moorings will be prepared and deployed at the Berth 5 in March-April 2019, for Penguin WEC3.

When the moorings have been successfully deployed, Penguin 3 will be towed to the site between May-August 2019. The Penguin's umbilical cable will be connected directly to the Hub with a connector.

7.1.4 Operation period 2017-2020

All three devices are planned to be operated continuously until summer 2020, depending on their technical performance.

7.1.5 Anticipated maintenance and inspection frequency

Anticipated maintenance and inspection frequency is planned to happen on average every second month. During those visits, ROV can be used to check moorings and visual inspections can be done inside the devices. In addition, inspections will be completed after severe storms, especially during the first years of the project.

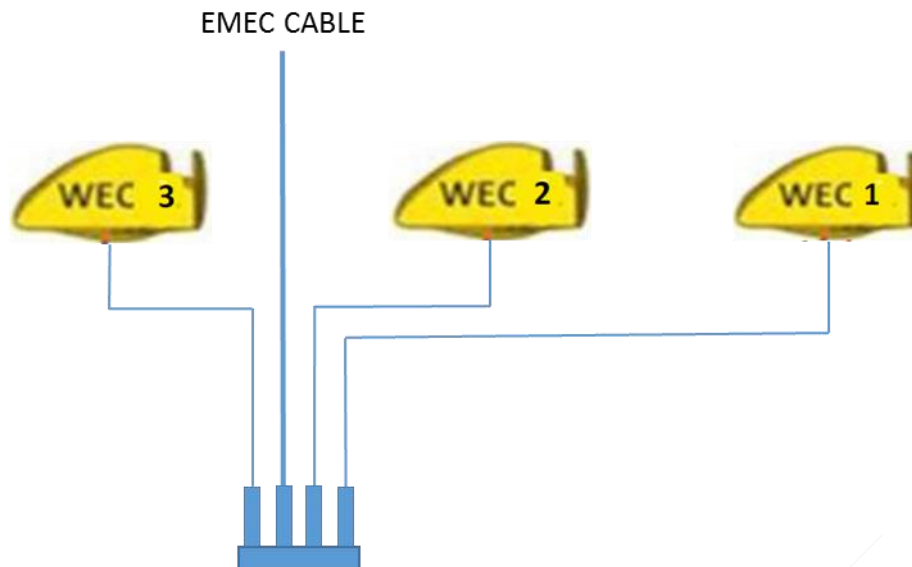


Figure 12. Array of WEC's connected electrically with EMEC static cable

7.1.6 Decommissioning

After completion of the testing period the system will be decommissioned in the reverse order to the installation process. Decommission is expected to happen earliest in summer time (May-September) 2020, when this European Commission funded project will end.

Fortum as a leaseholder will be responsible for decommissioning.

If possible, mooring components and static electric cables may remain in situ for future use as part of a larger planned array subject to future consent applications.

Appendix A: Vessel Spread



Specification Sheet

Green Isle – DAMEN MULTI CAT® 2712



GENERAL

YARD NUMBER	571674 / A15058 (Damen Shipyards Hardinxveld)
DELIVERY DATE	Approx. end April 2015
BASIC FUNCTIONS	Anchor handling, dredger service, supply, towing, hose handling and survey
CLASSIFICATION	Bureau Veritas I * Hull • MACH Tug Unrestricted navigation, • AUT-UMS
NAT. AUTHORITIES	MCA CAT 1 Workboat code
FLAG	United Kingdom
OWNER	Green Marine

DIMENSIONS (APPROX.)

LENGTH O.A.	27.70	m
BEAM O.A.	12.45	m
LENGTH LOAD LINE	23.90	m
DEPTH AT SIDES	3.90	m
DRAUGHT (98%CONDITION)	± 2.85	m
DISPLACEMENT LIGHT SHIP	405	ton(m)
GROSS TONNAGE	299	GT
BRITISH TONNAGE	178,8	BT

TANK CAPACITIES (APPROX.)

FUEL OIL	109.5	m ³
FRESH WATER	31.4	m ³
DIRTY OIL	1.5	m ³
SEWAGE	10.5	m ³
SLUDGE	1.3	m ³
HYDR OIL	2.2	m ³
LUB OIL	1.7	m ³
BILGE WATER	4.0	m ³
FW TANKS	51.8	m ³

PERFORMANCES (APPROX.)

BOLLARD PULL (AVERAGE)	33.0	ton(m)
SPEED	10.0	knots

PROPULSION SYSTEM

MAIN ENGINES	2x Cat C32 TTA ACERT
TOTAL POWER	1790 bkW at 1800 rpm
GEARBOXES	2x Reintjes WAF 572L 7,091 : 1
PROPULSION	2x fixed pitch propellers in Optima nozzles, 1900 mm
BOWTHRUSTER	Kalkman Beta 250H, 200pk / 184kW Hydraulic driven

AUXILIARY EQUIPMENT

GENERATOR SETS	2x Cat. C 04.4, 107 kVA each
HYDRAULIC POWER	Cat C12 TA, 339 kW 1800rpm
FUEL OIL SEPARATOR	Facet MV-11-AG

DECK LAY-OUT

ANCHOR	2x 300 kg Pool TW (HHP)
ANCHOR WINCH	1x Hydraulically driven, Kraaijeveld
DECK CRANES	1x HS Marine AKC290 LHE3 11,3T @ 16.5m
	1x HS Marine AKC185 HE4 6,44T @ 17,07m
ANCHOR HANDLING WINCH	1x single drum
CAPACITIES	100 ton@ 2,5m/min pulling force 1 st layer
	120 ton brake holding force 1 st layer
TOWING WINCH	1x single drum
CAPACITIES	50 ton@ 6.8m/min pulling force 1 st layer
	90 ton brake holding force 1 st layer
TOWING PINS FRONT	1x WK double pin type with chain stopper
TOWING PINS AFT	1x WK triple pin type in line
TUGGER WINCH	1x Dromec HPV 12000, 15T pull, SB aft
TUGGER WINCH	2x Northsea Winch CWS110, 11T pull, PS aft en SB front

ACCOMMODATION

Comfortable heated and air-conditioned accommodation for 7 persons in 5 cabins, galley, sanitary facilities, etc. Two double cabins and three single cabins.

NAUTICAL AND COMMUNICATION EQUIPMENT GMDSS AREA 3

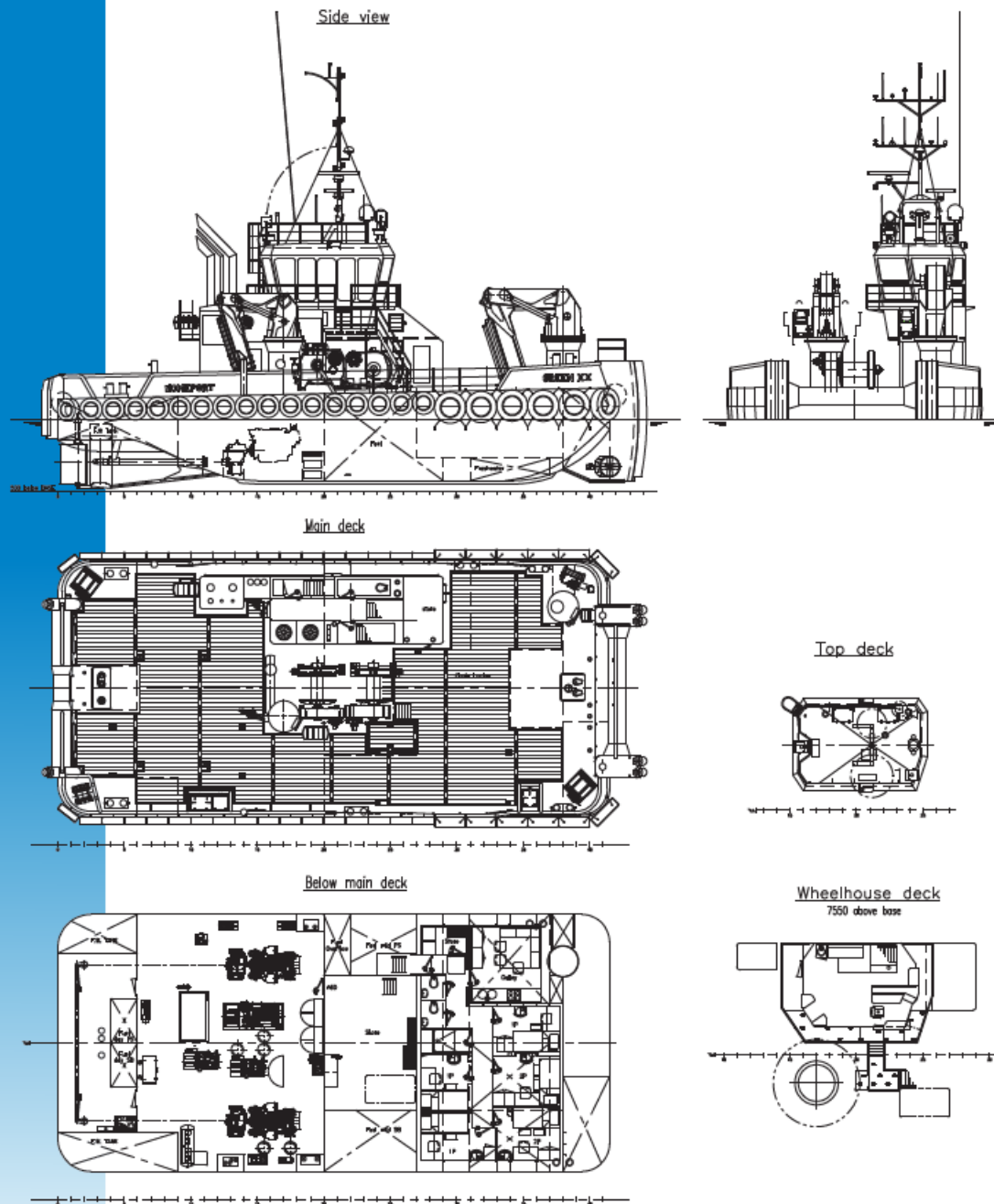
SEARCH LIGHTS	2x Pesch 2000 W
RADAR SYSTEM	1x Furuno, FAR 2117
RADAR SYSTEM	1x Furuno, FAR 8062
COMPASS	1x Cassens & Plat, Reflecta 1
GYRO COMPASS	1x Anshuetz, Standard 22
AUTOPILOT	1x Sea pilot 75
GPS	1x Furuno, GP-150 D
ECHOSOUNDER	1x Furuno, FE-700
SPEEDLOG	1x Furuno, DS-80
AIS	1x Furuno, FA-150
INTERCOM	Sigma-700
VHF	2x Sailor, RT6222, with DSC
HANDHELD VHF	3x TR-20
SSB	1x Furuno, FS-1570
INMARSAT - C	2x TT-3000E
NAVTEX	1x Furuno, NX-700
WATCH ALARM	1x Marble, 421
ENTERTAINMENT SYSTEM	1x Seatel ST 24
FLEET SYSTEM	1x Fleet broadband FBB150
WIND INDICATOR	1x Obsermet OMC 115
CHART PLOTTER	1x Transas NS 4000

Contact us:

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P: Green Marine (UK) Ltd, Euston House, Back Road, Stromness, Orkney, Scotland, KW16 3AJ
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Specification Sheet



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Specification Sheet

Green Chief – DAMEN Stan Tug 2608

Multi Purpose Tug / Workboat
Call sign - 2CRL5

Built 1980 | Rebuilt 2009
MMSI – 235.075.142



General

Type of vessel : Damen Stan tug 2608
Builder : Damen Shipyards – Yard No. 3113
Basic Functions : Anchor handling, dredger service
Towing, hose handling, survey
Ship assist, supply
Classification : Lloyds tug +100A1
: Unrestricted navigation
: Workboat Code Cat 1
: MCA approved
: 160 miles from shore

Dimensions

Length o.a. : 26.00 m
Beam : 7.80 m
Depth at sides : 4.05 m
Draft : 3.00 m

Supply Tanks

Fuel oil : 82.60m³ – Transfer 12m³/hour
Fresh Water : 17.80m³

Performances

Bollard Pull : 26 tons
Speed : 12.4 knots

Propulsion System

Main Engines : 2 x Caterpillar type D399
Total power : 1678 bkW at 1250 Rpm
Gearboxes : 2 x Reintjes 3.95:1
Propulsion : 2 x fixed pitch propellers in nozzles
Rudders : 2 x steering rudders
: 4 x flanking rudders

Auxiliary Systems

Generator sets : 2 x Cummins 6BT 80kVa
Hydraulic Engine : Detroit DDA type 6-71N

Deck lay-out

Deck crane : BS3004 30t/m 15t@1.85m, 2.2t@12.44m
Towing winch : 35 ton pull, 90t brake, 700m x 44mm wire
Drum end : 2 ton
Tugger winch : 13 ton, 100m x 22mm wire
Capstan (Fwd) : 2 ton
Free deck space : 44.6m²
Tow hook : Mampaey 35ton
Stern roller : 1.9 m
Stern opening : 4.8 m
Push knee : At bow

Accommodation

Comfortable heated and air-conditioned accommodation
For 8 persons in 5 cabins, galley, sanitary facilities etc

Navigation & Communication

Radar system : 1 x Furuno FR-8252
: 1 x Furuno 1715
Compass : Observer Pilot II
Satellite Compass : Furuno SC-50
Echosounder : Furuno LS-4100
GPS : Furuno GP150
Chart plotter : Transas Navisailor
: Seiwa Oyster
Autopilot : Furuno NAVpilot-500
VHF : Icom IC-M422
: Icom IC-M411
: Icom IC-M302 (DSC)
VHF handheld : 2 x Icom GM1600 GMDSS compliant
: 2 x Icom M32 working sets
Navtex : Furuno NX-700A
AIS : Transas M-2 Class A
GSM cellphone, email & internet (coastal)

Additionally Fitted

Plough & stern A-frame for seabed levelling/dredging

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Specification Sheet

Green Quest – 18m MCA Cat 2

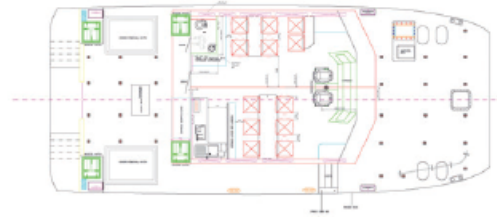
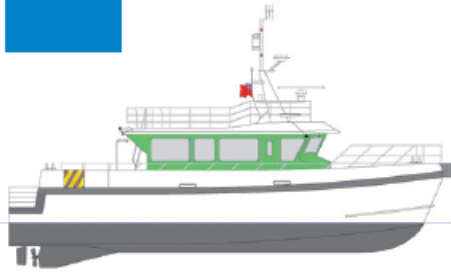


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Specification Sheet



Green Quest

18m MCA CAT 2 Wind Farm Support Vessel

PERFORMANCE

MAX SPEED	27 knots
SERVICE SPEED	22 knots

DIMENSIONS AND CAPACITIES

LENGTH O.A.	17.8 m
BEAM O.A.	6.4 m
DRAUGHT	1.5 m
CARGO DECK AREA FWD	24 m ²
CARGO DECK AREA AFT	14 m ²
CARGO LOAD FWD	2.5 tons
CARGO LOAD AFT	2.5 tons
MAX DECK LOAD	1.5 t/m ²
FUEL OIL	5 m ³
FRESH WATER	0.78 m ³
BLACK WATER	0.25 m ³

DECK LAYOUT

CRANE	Bonfiglioli, 470Kg@6.35m
MOUNTS	Multiple 5-Ton Lashing Points
FUEL TRANSFER	100 l/h 15m
PRESSURE WASHER	VEGA Psi 35-5000
FENDERING	Rubber D with Nipple

WELFARE

SEATS	KAB 500
DECK HOUSE	12 seats, wet gear room, galley and heads
CABINS	Cabins for 4
HEATING	Webasto Thermo 90ST
ENTERTAINMENT	LCD TV, DVD, Radio, Internet

SAFETY EQUIPMENT

SART	Tron SART 20
EPIRB	McMurdo Smartfind C1 406 MHz
LIFE RAFTS	2 x 8 persons
MOB	Waterlevel Platforms
SAR FINDER	TAIYO TD-L 1550
HANDHELD VHF	2 x ICOM M35
SEARCHLIGHT	Jabeco 135SL
ENGINE ROOM FIRE SYSTEM	Firepro Stat-X

MAIN ENGINES

MAKE	CAT
TYPE	2 x C18
MAX POWER	1746 bhp (1300kw)

GEARBOXES

MAKE	Twin Disc
MODEL	2 x MGX5145R

PROPULSION

TYPE	Fixed Pitch Prop
------	------------------

GENERATOR

ELECTRICAL SYSTEM	24v, 230v shore and generator
MAKE	Cummins Onan
TYPE	MDKBN (Spec A)
OUTPUT	11kw

ELECTRONICS

MAIN RADAR	Raymarine RD424HD 24" 4Kw Radome
SECOND RADAR	Raymarine RD418HD 18" 4Kw Radome
ECDIS	Raymarine C140W + Raymarine A70D Furuno NX300
NAVTEX	Raymarine Raystar 125
GPS	Raystar 125
SATELLITE COMPASS	Maretron DSM250
ANEMOMETER	Raymarine DSM300
ECHO SOUNDER	Raymarine ST6002
AUTO PILOT	Jotron TRT-2500
AIS	ICOM IC-M505 + ICOM M411
VHF	Eagle 30watts
HAILER	Raymarine CAM100, IM-ENC-02
CCTV	3G Wireless Hub
BROADBAND	

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The following vessels may additionally be used in the work scope to install and maintain the system:



MV Uskmoor



Specifications

General		Dimensions		Facilities	
Type of vessel	Workboat	Length	16m	Specious galley and day cabin	
Year built	1984	Beam	5.5m	Webasto diesel heating system	
Category	MCA Cat 2	Draught	1.5m		
	Up to 60 miles (from safe haven)	Gross tonnage	40.31gt	Generator	
Passengers	14			1 off 9 KVA Generator	
Flag state	UK	Deck Equipment		1no. 10m ³ Compressor	
Port of registry	Kirkwall	Hydraulic Stem Gantry certificated at 4 tonnes			
Official Number	705438	2 tonne Hydraulic Deck Winch		Propulsion System	
Call Sign	MDEF2	2no. 2 tone capstan winches		Main engines	2 x Doosan 200bhp
Basic Functions		Hiab Crane XS 1222-2 lifting 3800kg at 2.8m/1280kg at 8.2m		Propellers	Twin fixed in nozzles
Marine support vessel				Speed	9 knots
Dive support vessel					
Commuter					

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6 Crowness Road, Hatston Industrial Estate, Kirkwall, Orkney, KW15 1RG
T: +44 (0) 1856 874725 E: info@leaskmarine.com







MV C-FENNA



Specifications

General

Type of vessel Neptune Eurocarrier 2611
 Year built January 2013
 Category MCA Cat 1
 Up to 150miles (from safe haven)
 Passengers 12 (plus 3 crew)
 Flag state UK
 Port of registry Kirkwall
 Classification B.V.
 Official Number 922340
 IMO 9675963
 Call Sign MBAH3
 MMSI 232008023

Dimensions

Overall Length 26.48m
 LPP 23.65m
 Beam 11m
 Depth 3.5m
 Draught 2.61m
 Freeboard 847mm
 Free Deck Space 145m²
 Maximum Deck load 100te (60m²)
 Gross tonnage 160.78t
 Net Tonnage 76t

Tank Capabilities

Fuel Oil 106m³
 Fresh Water 43m³
 Lub Oil 5.7m³
 Hydraulic Oil 1.9m³
 Dirty oil 2m³
 Gearbox oil 1.9m³
 Bilge Water 8m³
 Ballast 34m³
 Sewage 4m³

Propulsion System

Main engines 2 x Cummins QSK38-M
 Total Output 2 x 1400 bhp at 1800 opm
 Gearboxes Reinjes WAF 364L 4.92:1
 Propulsion 2xF.P. Ø 1630mm

Bow Thruster

360° 280kw

Auxiliary Equipment

Generator Sets Caterpillar C9, 2 x 200kW, 250 kVA
 Fuel Oil Separator Westfalia 1740, L/H, OTC-3-02-137

Deck Equipment

Deck Cranes - FWD Heila HLRM 230-4SL, Fixed hook
 SWL 10.3te at 16.5m winch SWL
 - AFT Heila HLRM 140-3S, Fixed hook SWL
 10te at 12.17m winch SWL
 Winches - 1 x Anchor Handling Winch 100te
 - 1 x Towing Winch 50te
 - 4 x Tugger Winches 15te (Fwd Port, Fwd
 Stbd, Aft Port, Aft Stbd)

Towing Hook 1 x Mampaey 30te SWL
 Towing pins 2 x Hydraulic + wire catcher
 Anchor 2 x 265kgs
 Chain 110m x 17.5mm
 Anchor winch 1 x 17.5mm hydraulic heeling motor:
 140bar-60 ltr./min
 Bow roller 6m

Performance

Speed 10 knots
 Bollard Pull 35.6 ton

Accommodation

Heated and air-conditioned living spaces for 10 persons, consisting of 5 double crew cabins, a galley and mess and sanitary facilities.

Nautical Equipment

1 x X-band ATA Radar + ARPA, JRC type JMA-5212
 2 x VHF radio telephones THRANE & THRANE type SAILOR RT 6222
 1 x MF/HF radio telephone THRANE & THRANE type SAILOR 6300
 2 x INMARSAT-C satellite communication systems THRANE & THRANE type SAILOR 6110
 1 x Echosounder JRC type JFE-380/25
 1 x Universal AIS JRC type JHS-182
 1 x Auto Pilot ALPHASEAPILOT MFA
 1 x Navtex JRC type NCR-333
 1 x Satellite Compass JRC type JLR-21
 1 x Magnetic Compass CASSENS & PLATH
 1 x DGPS global positioning system JRC type JLR-7800
 1 x EPIRB, MCMURDO type E5
 1 x SART, MCMURDO type S4
 1 x Speed log JRC type JLN-205
 1 x GSM/UMTS system
 1 x Bridge Navigational watch alarm system ALPHATRON
 2 x portable VHF Radiotelephones GMDSS SAILOR type SP3520



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MV C-Odyssey



Specifications

General

Type of vessel	Multiworker Twenty6
Year built	2011
Category	MCA Cat 1 Up to 150 miles (from safe haven)
Passengers	12 plus crew
Flag state	UK
Port of registry	Kirkwall
MMSI No.	235088132
IMO No.	9636307
Call Sign	2ETW7
Official Number	917987

Dimensions

Length	26m
Beam	10.5m
Depth	3.5m
Draught	2.5m
Air draught – mast up	13.8m
Air draught – mast down	8.2m
Gross tonnage	150t
Free Deck Space	120m ²

Deck Equipment

Towing winch	60 t
Anchor handling (Combined lift)	60 t
Tugger winch	120 t
Towing hook	3 x 15 t
Capstan	SWL 25 t
Bow roller	5 t
Aft roller	5m SWL 120 t
	3m SWL 60 t
Deck carrying capacity	100 t
Deck crane	Hs 185t/m 5530kg @ 18.5m
Deck crane (aft)	Hs 60t/m 4630kg @ 10m

Hydraulics towing pins/stopper

Pins	
SWL	50 t
Design load	105 t
Hub	400 mm
Stopper	
SWL	75 t
Design load	150 t
Hub	400 mm

Tank Capabilities

Fuel/oil	100m ³
Black/grey water	9m ³
Fresh water	45m ³
Dirty oil	0.9m ³
Ballast water	88m ³

Accommodation

Cabins	2 off twin berth 2 off single berth
Large mess room	
Galley and laundry	

Generators

1 off 78 KVA
1 off 35 KVA
K.W. 1790

Propulsion System

Main engines	2 x caterpillar C32
Total power	2,400bhp at 1,800 rpm
Propulsion	2x fixed pitch propellers Nozzles 1,500mm

Performance

Bollard pull	27 t
Speed	10 knots

www.leaskmarine.com

6 Crowness Road, Hatston Industrial Estate, Kirkwall, Orkney, KW15 1RG

T: +44 (0) 1856 874725 E: info@leaskmarine.com





MV Explorer



Specifications

Ferryman FRM720 Workboat (RHIB)

Builder: Ferryman Boats RHIB

Built 2002

Classification: Mecal

Category: MCA cat 3 (Restricted): up to 20 miles from a safe haven

Speed: 25 knots maximum speed in calm water (with reduced speeds in weather up to force 5)

Commercial Purpose: Light Work Boat Duties

Maximum Number of Persons to be Carried: **6 Persons**

Length 7.4m

Beam 2.75m

Dry weight 420kgs

Engine: Volvo Penta KAD32P (125 kW)

Maximum H.P. 170HP

Maximum Load 450kgs (6 persons)

Equipment

Liferaft: 6 Person - Ocean Safety ISO9650, with Solas Pack B

Fixed VHF DSC

Portable VHF: ICOM IC MIEUROV

GPS: 2no. FURUNO NAVNET V

Radar: Incorporated in above

Sounder: Incorporated in above

Log: Incorporated in above

EPIRB: 6no. PLB's "Fast Find"

Compass: Plastimo (Magnetic)



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