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**Programme Area:** Marine

**Project:** TEC Phase 2

**Title:** Black & Veatch - Addressing the Uncertainties in Application of Hydrodynamic Loads for Industrial Tidal Stream Technology Support Structure Design

**Context:**

Phase two of the ETI Tidal Energy Converter (TEC) project will see two Atlantis owned 1.5MW commercial tidal energy turbines installed on an innovative foundation structure designed and built as part of the project. This will take place at the MeyGen site in Scotland and increase the number of turbines at the site from four to six, increasing the rated capacity of the tidal array from 6MW to 9MW (enough to power 4,500 local homes). Atlantis are developing a patent-pending innovative and cost effective multi-turbine foundation design as a result of the work they undertook in the first phase of the project - a total system lifecycle cost of energy methodology to identify tidal energy system technologies capable of significantly reducing the cost of energy being deployed at array scale.

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# BUILDING A WORLD OF DIFFERENCE

8<sup>th</sup> September 2015

## ADDRESSING THE UNCERTAINTIES IN APPLICATION OF HYDRODYNAMIC LOADS FOR INDUSTRIAL TIDAL STREAM TECHNOLOGY SUPPORT STRUCTURE DESIGN

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Building a world of difference.®

# AGENDA

**About Us**

**ETI TEC Project**

**Design Process**

**Hydrodynamic Model Testing**

**Summary**

# ABOUT US



# BLACK & VEATCH - MARINE ENERGY - OVERVIEW

- c. 100 marine energy projects over 10 years, c. 20 marine energy staff
- Wave, since 1991, 10 devices in detail, 15 briefly
- Tidal Current since 1986, 15 devices in detail, many briefly
- Tidal Barrage, since 1975, most UK sites + others



*Reproduced with permission from Marine Current Turbines Ltd*



*Reproduced with permission from Pelamis Wave Power*

# BLACK & VEATCH - MARINE ENERGY - OVERVIEW

## Services:

- Strategic Planning
- Policy Development
- Resource Analysis
- Feasibility Studies
- Project Development
- Permitting/consenting
- Performance Assessment
- Cost / Cost of Energy Assessment
- Technical Review
- Technology Design / Development
- Project Design
- Project Management
- Programme Management

Diverse projects  
worldwide (UK,  
USA, Asia-Pacific)

Black & Veatch Project Experience  
by Service Offering



# ETI TEC PROJECT

# ENERGY TECHNOLOGIES INSTITUTE (ETI) TIDAL ENERGY CONVERTER (TEC) PROJECT



**BLACK & VEATCH**

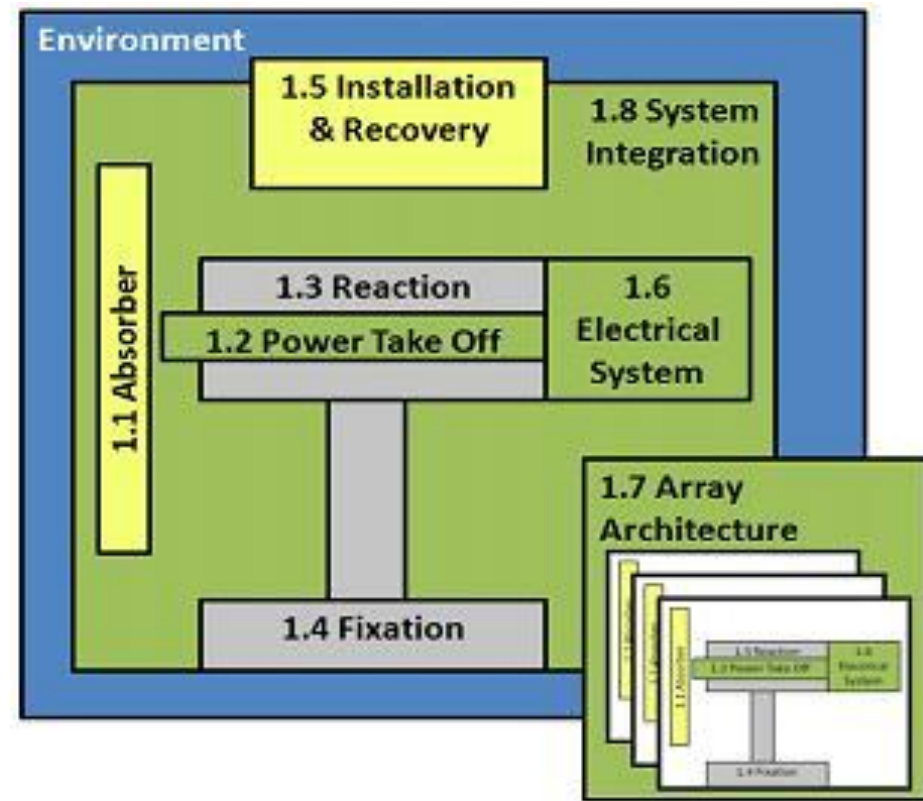


## Traditional Approach

A single innovation scaled up to array.

## TEC Project Approach

A holistic approach is required to realise step change in cost of energy.

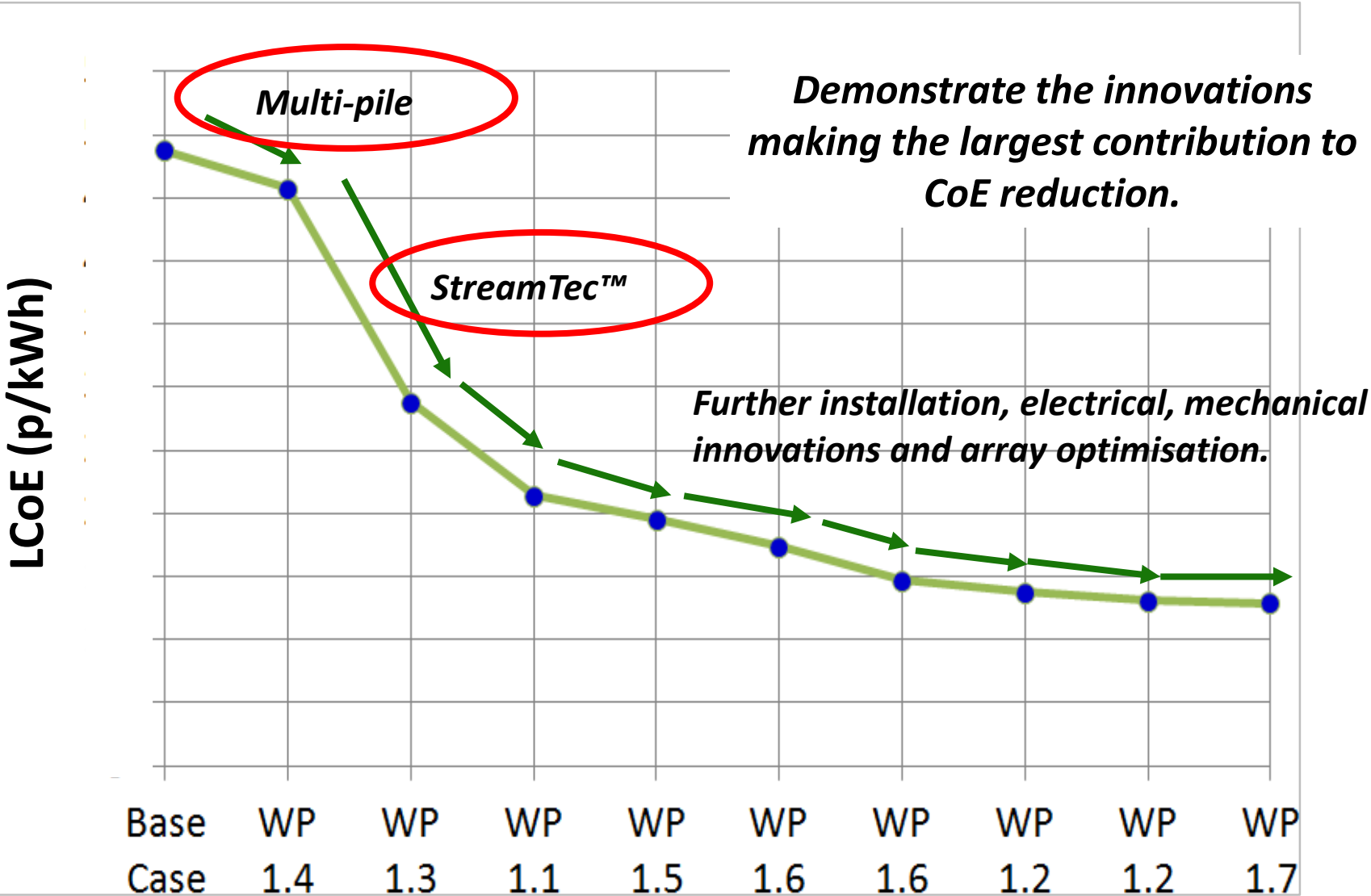


**Phase 1a considered over 1400 unique combinations!**



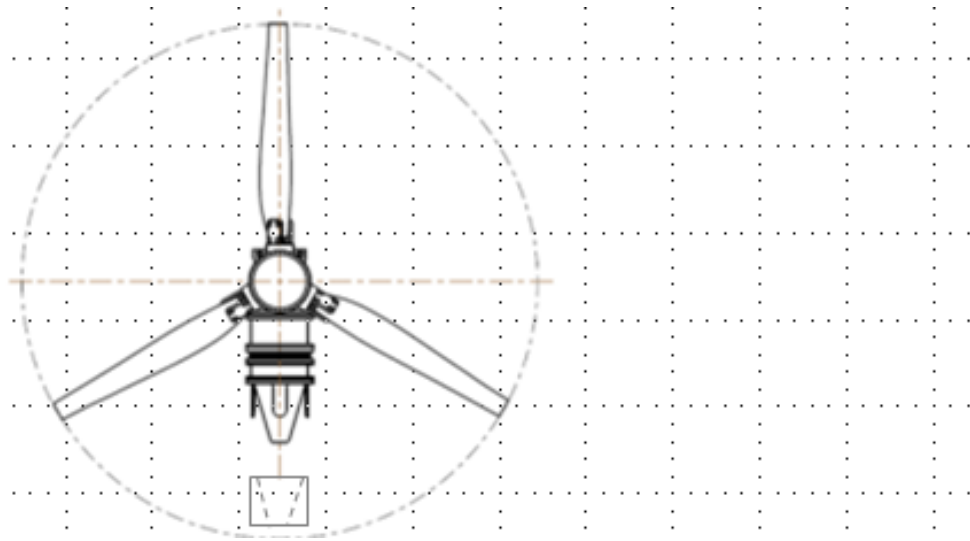


# TEC PHASE 2



## TEC PHASE 2

Detail design, build and deploy the StreamTec™ structure.



**TO BE ANNOUNCED  
IN 2016**

# PHASE 2 TIMELINE & SCOPE

Date	WP
Sep 2014 - Dec 2015	Detailed Design and Testing
Jan 2016 – Sep 2016	StreamTec™ Fabrication
Oct 2016 – Jan 2017	StreamTec™ Installation

## B&V Scope

PM design phase

Author Basis of Design report

Lead detailed design of StreamTec™

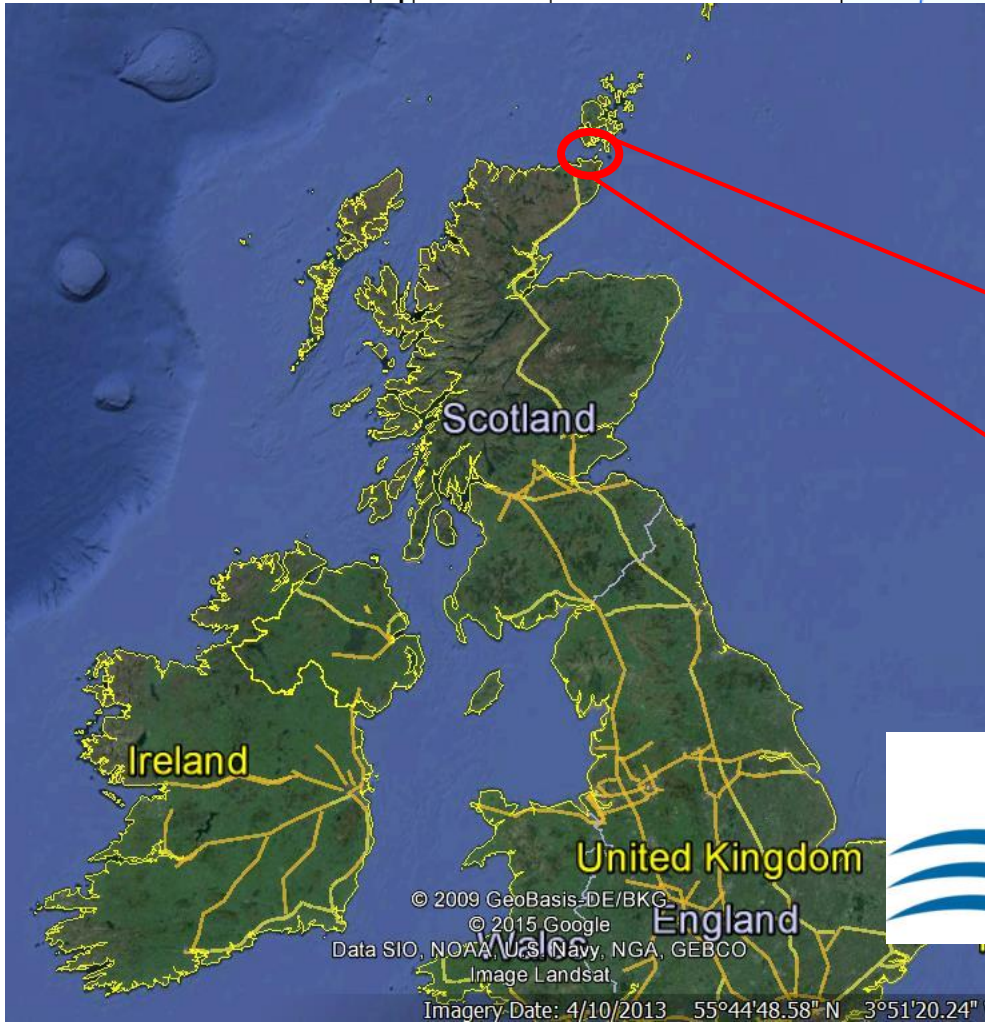
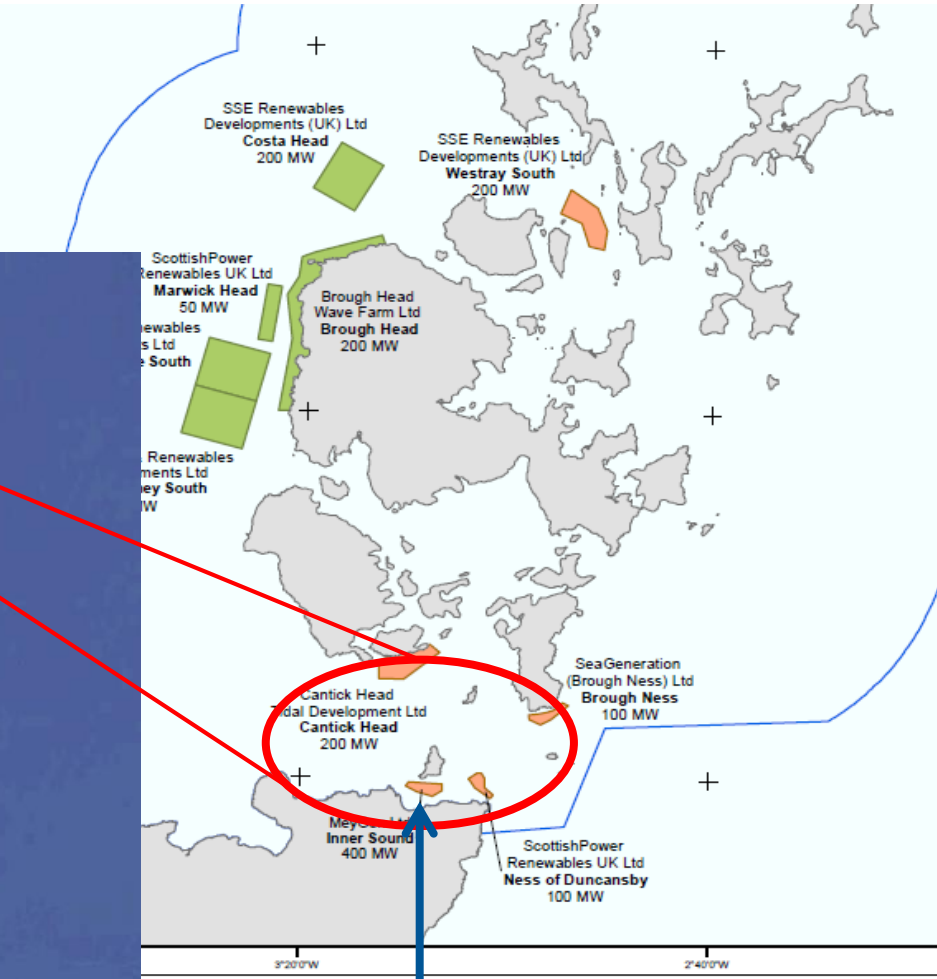
Lead interface with Certification body



# TEC PHASE 2

Westray South	SSE Renewables Developments (UK) Limited
Brough Head	Aquamarine Power Limited & SSE Renewables Holdings (UK) Limited
Marwick Head	ScottishPower Renewables UK Limited
West Orkney Middle South	E.ON Climate & Renewables UK Limited
West Orkney South	E.ON Climate & Renewables UK Limited
Cantick Head	SSE Renewables Holdings (UK) Limited & OpenHydro Site Development Limited
Brough Ness	Marine Current Turbines Limited

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Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
Image Landsat

Imagery Date: 4/10/2013 55°44'48.58" N 3°51'20.24" W



# DESIGN PROCESS

# SCALE OF DESIGN TASK

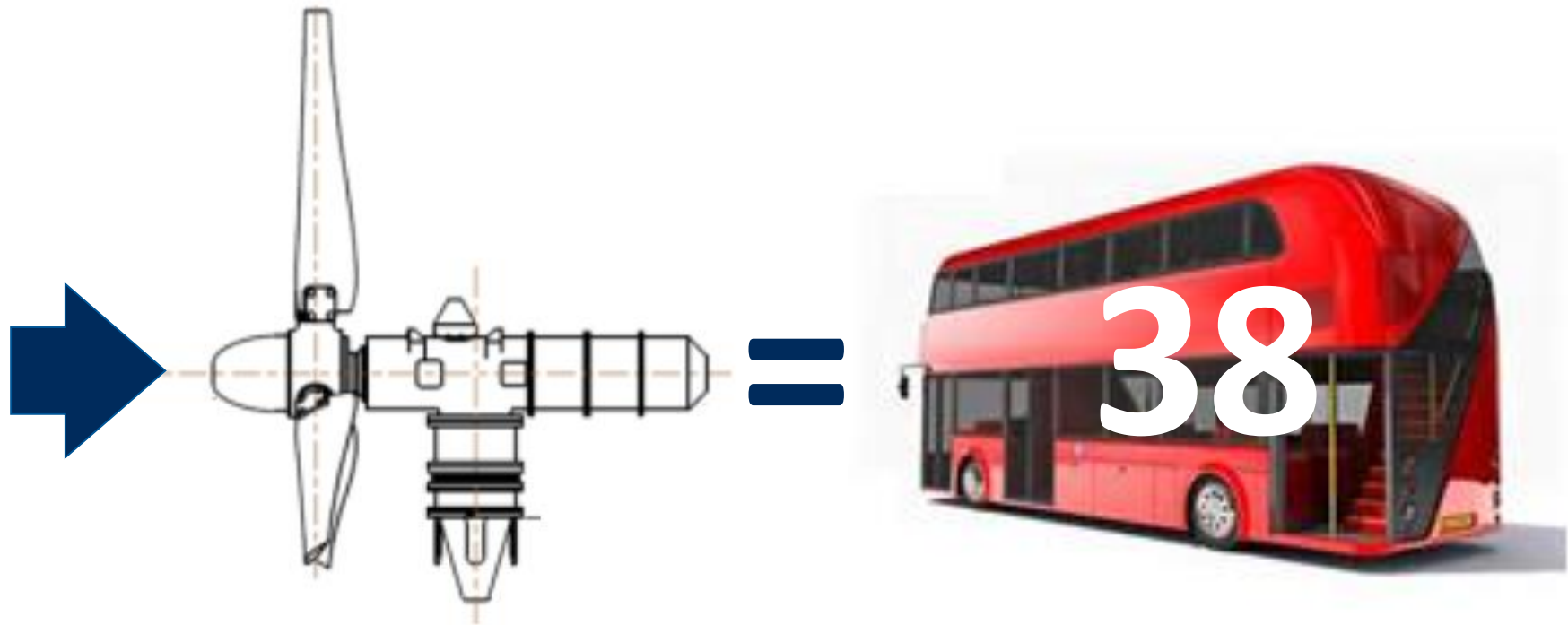


*Provided by Atlantis Resources Corporation.*

A storm in December at the western extent of MeyGen site.



# SCALE OF DESIGN TASK



Axial force from 20m diameter rotor turbine equivalent to weight of 38 London buses!

And the tide reverses...

And there is turbulence...

# SCALE OF DESIGN TASK

And the structure must be sufficiently light to be installed from a specialised dynamic positioning vessel.

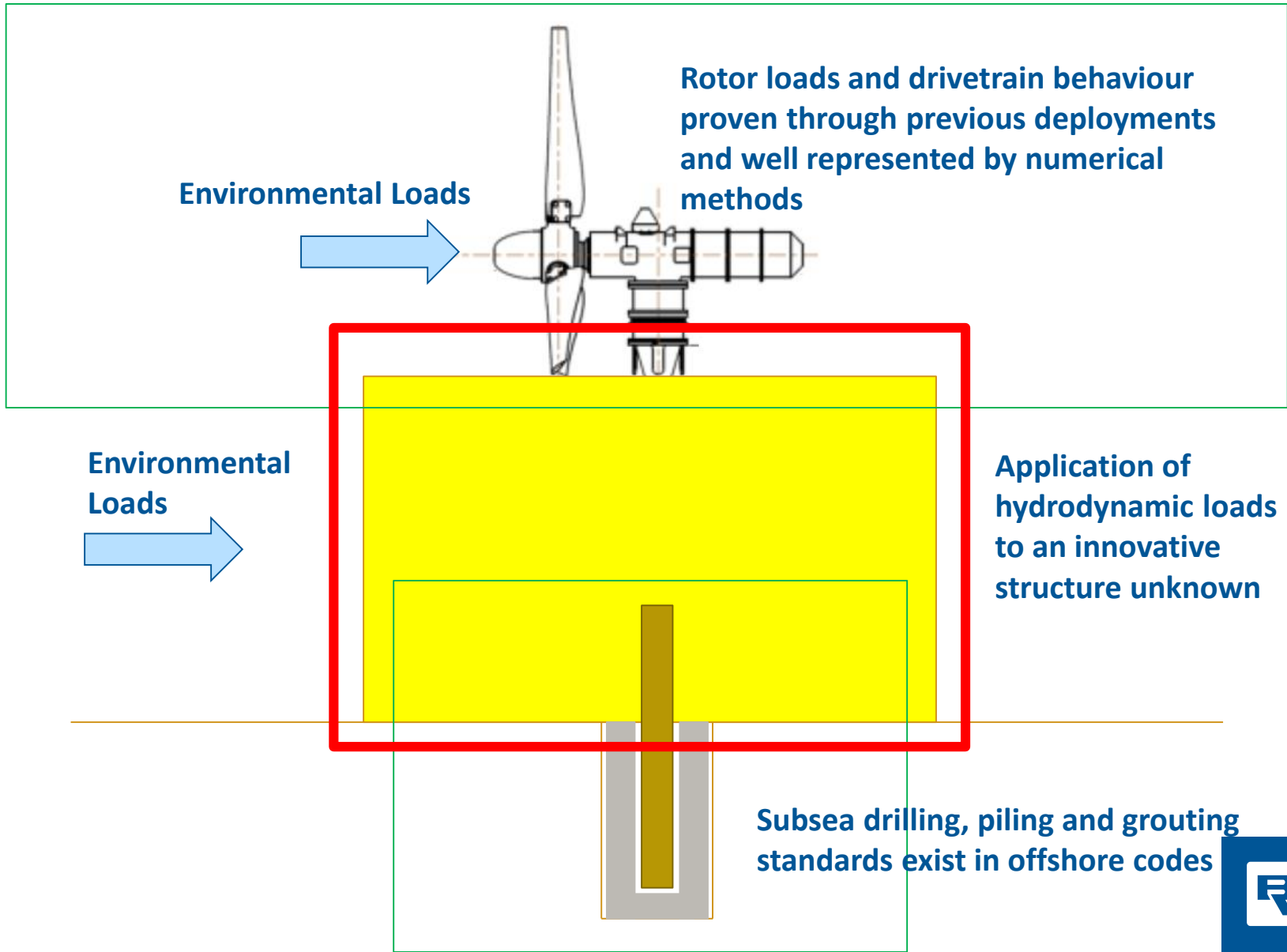


*Reproduced from Atlantis Resources Corporation*





# SOURCES OF UNCERTAINTY



# ADDRESSING UNCERTAINTIES FOR SUPPORT STRUCTURE DESIGN

- Requirements of design process for StreamTec™:
  - '000s design load cases (DLC) – identify governing DLCs
  - Likely to be fatigue driven (FLS) designs, therefore:
    - Operational conditions would drive design
    - Contribution of rotor loads is much higher than estimated hydrodynamic loads on support structure during governing operational conditions (FLS)
  - Simple, conservative method of applying hydrodynamic loads to support structure during assessment of DLCs
- Conclusion: ensure Morison's Equation (described in offshore codes) is sufficiently conservative in applying hydrodynamic loads to support structure



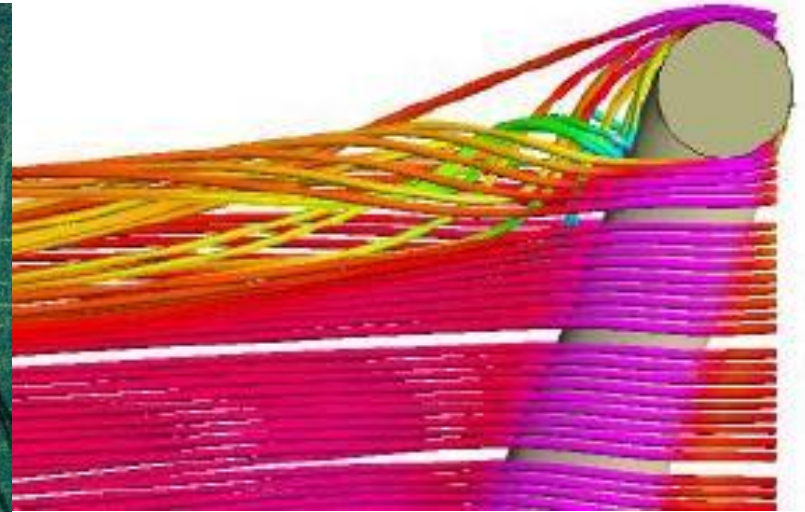
# DESIGN PROCESS PHILOSOPHY

- **The solution to a complex problem, composed of an array of smaller complex problems, does not necessarily need to be a complex one**
- **Acknowledging uncertainty and identifying the sensitivity of system costs to design parameters with larger uncertainty ranges can lead to a cost effective design process**
- **In this project, hydrodynamic loads on the support structure do not drive the design, but do contribute a small proportion of damage throughout the lifetime of the structure**
- **They cannot be neglected, but ensuring the method of applying this minor contribution of damage is conservative satisfies the holistic design process**



# HYDRODYNAMIC MODEL TESTING

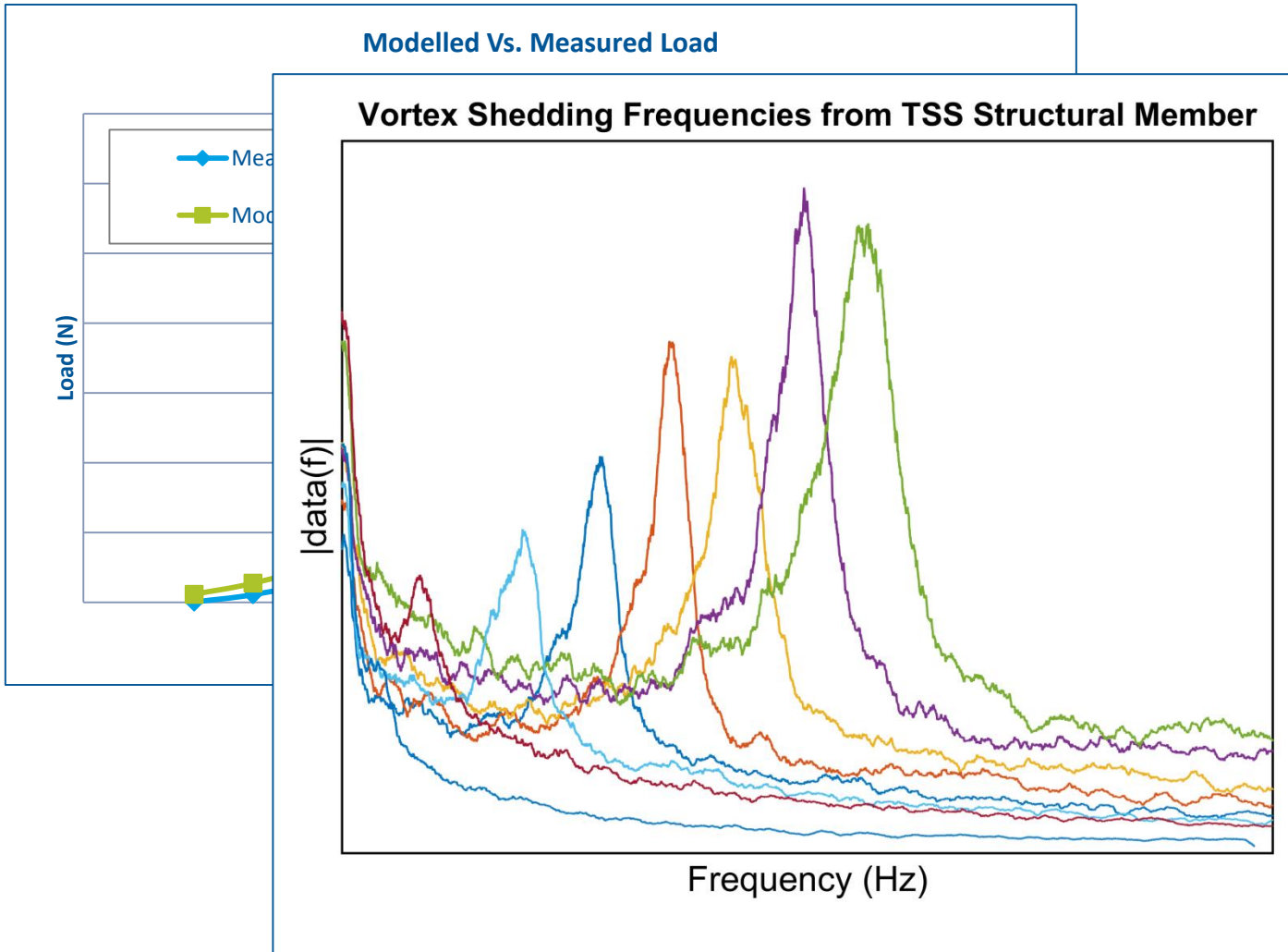
# COMPUTATIONAL FLUID DYNAMICS & LABORATORY TESTING



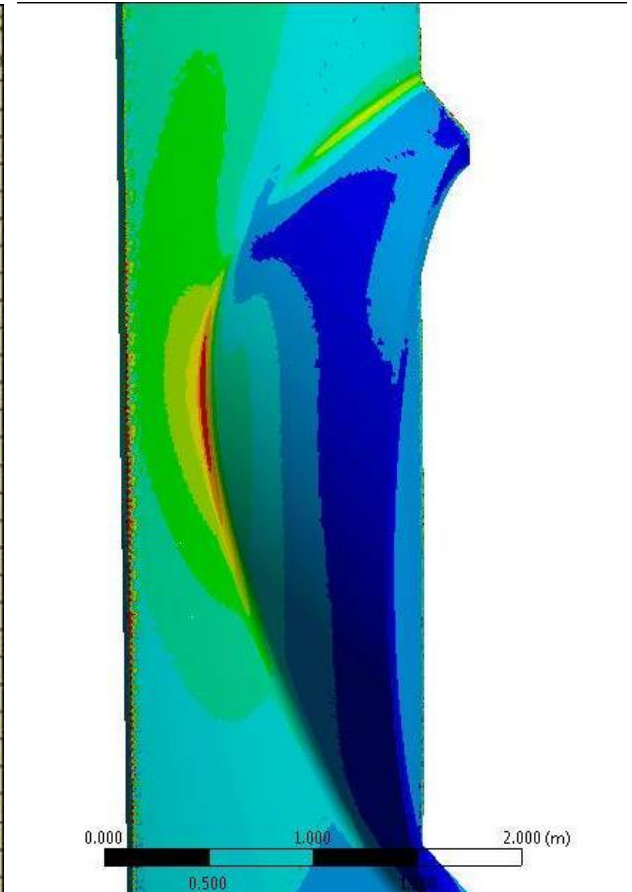
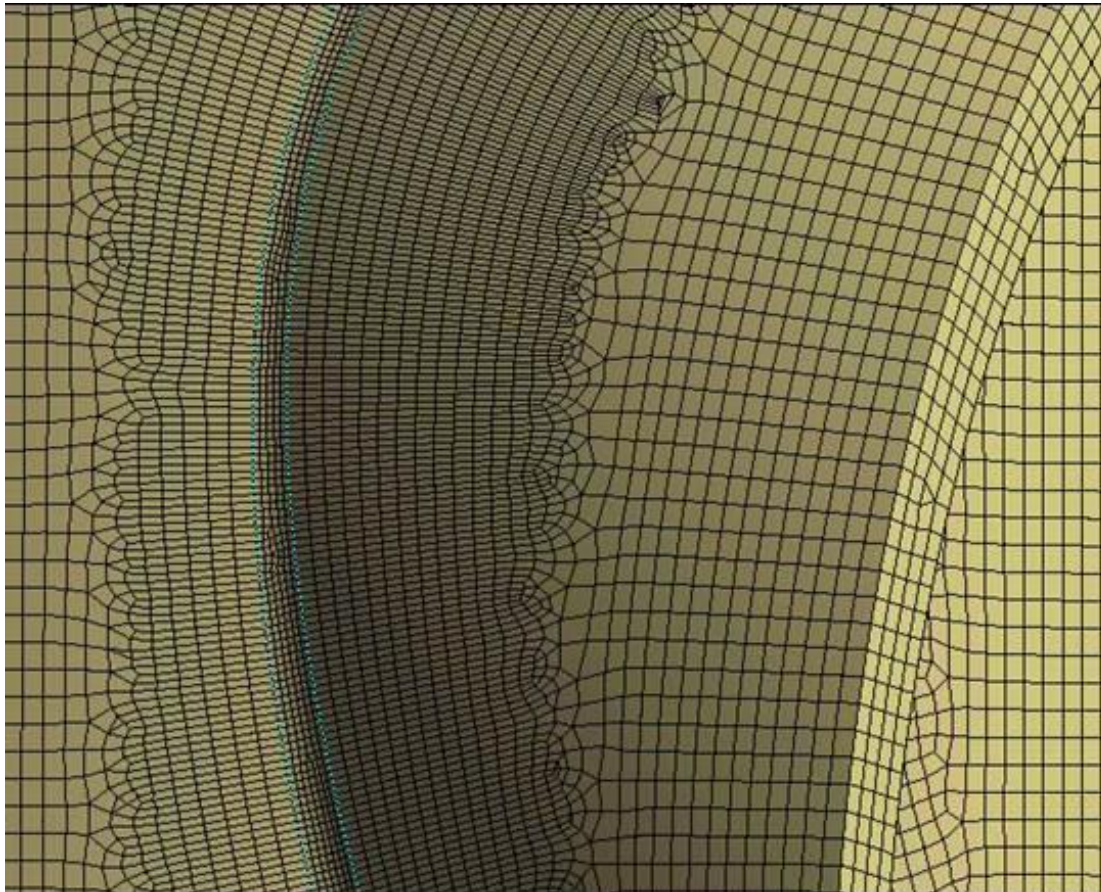
**Detailed understanding of hydrodynamics must be sought and CFD team in Redhill supported.**

# OUTPUTS OF LABORATORY TESTING

Modelled Vs. Measured Load



# STRUCTURAL DESIGN – FINITE ELEMENT ANALYSIS



**FEA facilitates the detailed design necessary to optimise the structure.**

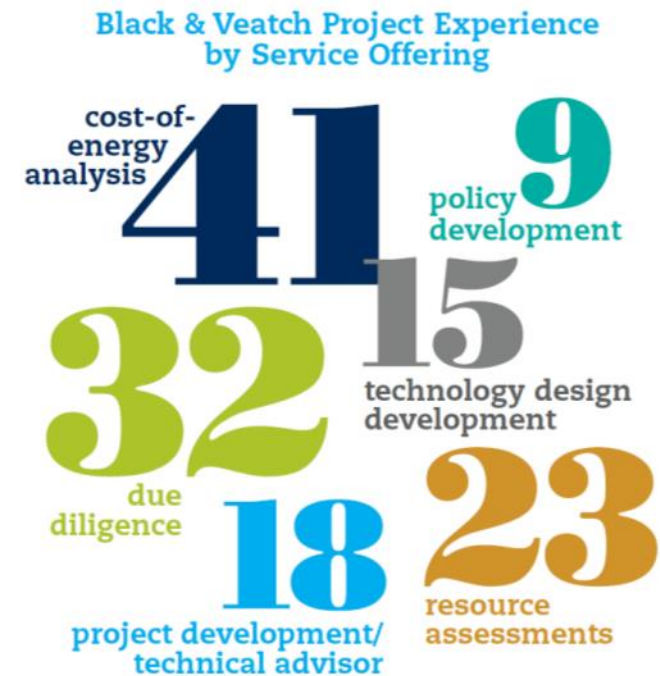
# SUMMARY





# SUMMARY

- B&V are currently finalising the detailed design of an innovative subsea support structure for the tidal energy industry – StreamTec™
- This concept has been borne out of industry experience and a holistic approach to optimising tidal stream technology
- The design process has been developed from a comprehensive understanding of the dependency of the economic feasibility of the concept on the various system components and their respective design drivers
- The solution to a complex problem, composed of an array of smaller complex problems, does not necessarily need to be a complex one!



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**Together**



**BLACK & VEATCH**