MRE INFRASTRUCTURE ASSESSMENT UPDATE

BAY OF FUNDY

OERA

Final Report

Prepared by:

Mairead Atcheson
Cruz Atcheson Consulting Engineers

George Gibberd
Cruz Atcheson Consulting Engineers

Vincent Cliquet
INNOSEA

Antoine Henry
INNOSEA

Steve De Belie
Allswater

BY:	S. DE BELIE
CHECKED	R.CRUTCHER
APPROVED:	S. DE BELIE
DATE:	08/23/2016
REVISION:	1
PROJECT#:	16030
DOC #:	16030-100-R-001

1111 Bedford Highway
Halifax, NS
Canada, B4A 1B9
Tel:+1-902-444-7447
Fax +1-902-444-7449

Suite 201, 123 Clyde Ave
Mt. Pearl, NL
Canada, A1N 4R9
Tel:+1-709-747-9100
Fax +1-709-747-2778

www.allswater.com

Internal Ref: FT-009, May 2016

Revision Table

Rev #	Date	Change Description	By:	Checked By:	Approved by:
0	06/30/2016	Initial Release	S. De Belie	R. Crutcher	S. De Belie
1	08/23/2016	Final Release	S. De Belie	R. Crutcher	S. De Belie

EXECUTIVE SUMMARY:

Allswater in collaboration with Cruz Atcheson and INNOSEA, have been engaged by OERA to produce an update of the 2011 study "Marine Renewable Energy Infrastructure Assessment" [1].

Since the 2011 study, new developers have been awarded projects in the Bay of Fundy and different technologies introduced. In addition, the global tidal industry has been, and still is, changing rapidly with new developers emerging who might feasibly come to the area in the future.

A shortlist of tidal technology developers was surveyed to determine the latest projected infrastructure requirements. Ports in Digby, Hantsport, Parrsboro and Saint John were canvassed for up-to-date information regarding current infrastructure. Additionally, West Bay was investigated to determine the feasibility of a "greenfield" development in the area. The following European ports were also reviewed as a benchmark for comparison with Nova Scotia: Hatston Pier (EMEC, Scotland), Nigg Energy Park (Scotland), Cherbourg (France) and Brest (France).

The gap analysis of the collected data revealed:

- Infrastructure requirements have not changed significantly since the original 2011 study.
- A wet port was identified as a requirement by the majority of developers for installation and most currently anticipated operations & maintenance (O&M) activities. Digby and Saint John offer wet ports in the area.
- Digby's proposed port expansion, and the port of Saint John meet the majority of the respondents' current requirements.
- The case for using a dry port for operations and maintenance has not been sufficiently considered due to the lack of detailed O&M plans, and may come down to a trade-off between close proximity to the deployment site (with associated lower costs and risk) versus the limited availability of a dry port and available facilities.
- At present, evolving and undefined O&M plans make it difficult to determine port requirements and the viability of developing a new facility at West Bay, or upgrading Parrsboro or Hantsport facilities.
- Considering only availability during the tidal cycle and proximity to the Minas passage, West Bay near Ottawa House and Partridge Island would be a beneficial dry port. A cost-benefit analysis should be developed to determine the feasibility of using a dry port in West Bay, Hantsport or Parrsboro, that considers the costs of upgrading or greenfield development.
- There are a number of global and local uncertainties associated with the tidal energy industry, which in turn affects the timing and nature of infrastructure needs.

Based on the analysis, the following recommendations are offered:

- As the current short term installation requirements can be accommodated by the infrastructure already in place, and given the lack of precision of developers' O&M requirements, along with considerable uncertainties on the development timeline, it is recommended to defer investment in costly infrastructure improvements and/or greenfield construction until such time as the critical uncertainties are resolved.
- If it is later confirmed that an expansion of wet port facilities is required in Nova Scotia, the Port of Digby offers the best opportunity to meet the needs for the industry. This can be achieved by developing the proposed greenfield site.
- Perform a detailed assessment of infrastructure demands before investment is made as the current survey shows a large range of values.
- Conduct a future review of developer infrastructure demands relating to O&M, to facilitate a trade-off analysis of the three dry port options near Minas Passage. Generally, it is recommended to engage further with identified developers and installation contractors in order to fully account for their potential adaptability to the Bay of Fundy's unique characteristics as part of detailed port upgrade studies.
- Investigate the feasibility of a shared-usage submersible barge or drydock for use in the transport and possible installation of tidal devices.
- Investigate the feasibility of a smaller, shared-usage beach–lander vessel to support O&M and ancillary operations from dry ports.
- Search for synergies with other industries – although major multi-use opportunities like those experienced in Europe are unlikely in the Bay of Fundy, any multi-use opportunity will contribute to justification for infrastructure investment.

DEFINITIONS

BRTP – Black Rock Tidal Power

COMFIT – Community Feed-In Tariff

DOF – Degrees of Freedom

DP2 – Dynamic Positioning Class 2

EMEC - European Marine Energy Centre

FORCE - Fundy Ocean Research Center for Energy

FTI – Fundy Tidal Inc

LAT – Lowest Astronomical Tide

LOA – Length Over All

MRE – Marine Renewable Energy

NB – New Brunswick

NS – Nova Scotia

O&M – Operations and Maintenance

OEM – Original Equipment Manufacturer

OERA – Offshore Energy Research Association

ROV – Remotely Operated Vehicles

ROM – Rough Order of Magnitude

SPMT - Self-Propelled Modular Transporter

TEC – Tidal energy converter

TABLE OF CONTENTS

1 INTRODUCTION

Allswater in collaboration with Cruz Atcheson and INNOSEA, have been engaged by OERA to produce an update of the 2011 study "Marine Renewable Energy Infrastructure Assessment". This report outlines the methodology utilized, the data collected, the GAP analysis performed and conclusions and recommendations resulting from the analysis.

1.1 OVERVIEW OF THE STUDY

The Nova Scotia Department of Energy desires to fully understand the existing and projected needs of the tidal industry in Nova Scotia, and requires updated information on the capability of regional port options and manufacturing infrastructure required, in order to assess if the region is capable of servicing the industry's needs as it heads towards commercialisation.

In 2011 a study entitled "Marine Renewable Energy Infrastructure Assessment" was prepared. The study reviewed the anticipated requirements of developers and provided a benchmark of the regional ports and infrastructure [1]. This study reviews the previous 2011 study, and provides an updated assessment of the changes in the demands of tidal energy developers, and the infrastructure available to meet these needs. Figure 1 illustrates the methodology conducted to update the marine renewable energy (MRE) infrastructure assessment for Nova Scotia.

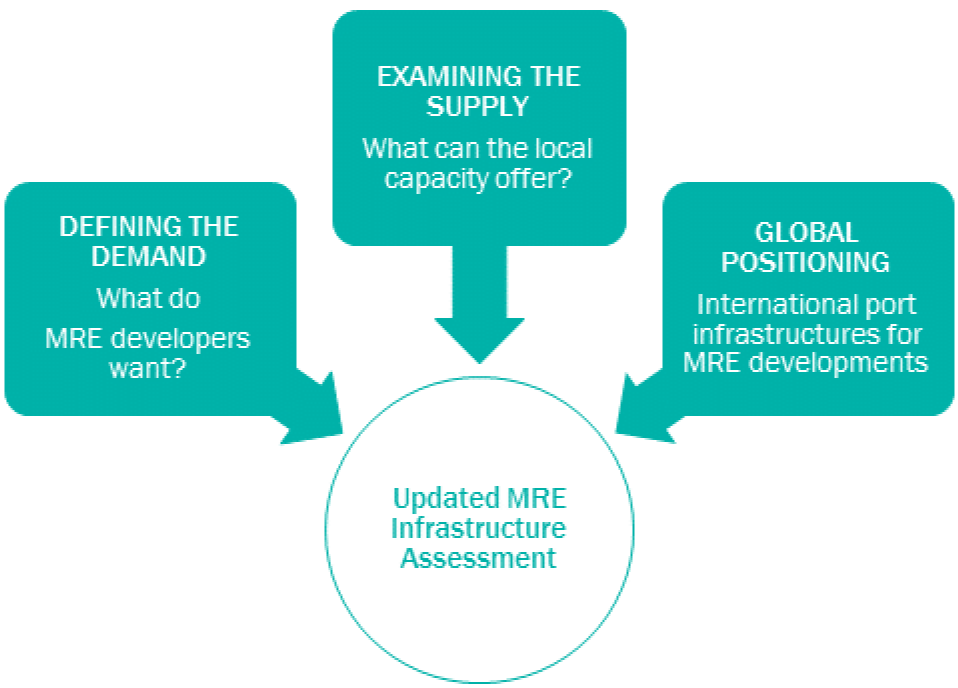


FIGURE 1 - UPDATED MRE INFRASTRUCTURE ASSESSMENT APPROACH

Defining the demand: What do tidal developers want?

Since the 2011 study [1], new developers have been awarded projects in the Bay of Fundy and some exploit different technologies than those contemplated at the time. In addition, the global tidal industry has been, and still is, changing rapidly with new developers emerging who might feasibly come to the area in the future (both to the Fundy Ocean Research Center for Energy (FORCE) facility, Minas Passage and elsewhere along the bay).

In the light of these developments, Section 0 reviews the global tidal industry to establish the infrastructure needs of those developers who might feasibly come to Nova Scotia, now and in the future. A shortlist of tidal technology developers was drawn up following a desktop study comprising:

- The identification of potential tidal development sites in Nova Scotia and the characteristics of these sites.
- A review of tidal technology characteristics to assess their suitability for the Nova Scotia site conditions.

The shortlisted companies were sent an online questionnaire, structured to secure information on projected infrastructure requirements. The data gathered aimed to be as comprehensive as possible, to allow an assessment of the projected infrastructure requirements, including meeting tidal technology developer requirements for:

- Manufacture & Assembly
- Storage and Load-out
- Installation
- O&M servicing

The information obtained from the online survey and port assessment was subsequently used to inform the infrastructure assessment gap analysis presented in Section 0.

Examining the supply: what can the local capacity offer?

Four candidate ports were identified by the client to consider and appraise the key port requirements presented in Section 0. The ports selected were Parrsboro, Hantsport, Digby, in Nova Scotia, and Saint John, New Brunswick. Additionally, the area of West Bay, near Parrsboro was identified as a potential area for new infrastructure, given its close proximity to the Minas Passage. A port questionnaire was developed (see Appendix B) and sent to the port authorities to obtain detailed information on their facilities.

A set of requirements for each candidate port was established based on both the operational and wider industry requirements. The criteria to be considered for the port assessment included:

- Distance to sites
- Available quayside specification
- Sea access: any access restriction based on water depth, locks, width that constraint vessel access based on its dimensions
- Storage areas and access specifications

- Tidal restrictions
- Dry docks availability
- Cranes specification
- Development plans
- Experience in offshore works
- Competition with other ports users

The results of the port assessment are given in Section 3.

Global positioning: International port infrastructures for tidal developments

Four European ports were selected to benchmark existing facilities with Nova Scotia Port infrastructure. The ports were selected based on their past and planned implications in tidal projects. The studied ports are presented in Section 4 and include:

- Hatston Pier (EMEC, Scotland)
- Nigg Energy Park (Scotland)
- Cherbourg (France)
- Brest (France)

A review of each port was completed which focused on the facility's role in tidal projects, and applications relevant to Nova Scotia ports were considered.

Gap analysis

Once the infrastructure demands of the tidal developers were established, and the available local infrastructure was identified, this information was compared in a gap analysis. Recommendations are given on the best way to tackle any gap through further port development.

Additionally, the following topics are discussed:

- Identify the limitations, if any, of servicing from a dry port
- Discuss whether greenfield construction is an option
- Discuss West Bay's viability for building infrastructure
- Discuss the possibility of dividing service capabilities among several ports

1.2 LIMITATIONS OF THE STUDY

The following points contribute to the limitations of this study.

1.2.1 DATA SOURCES

Overall, the data presented in this study comes from the following sources:

- Developers' needs are based on their answers to the developers' survey
- Local ports assessments are based on their answers to the port survey

- International ports reviews are based on publicly available data.

Data collected from developers and local ports have been reviewed as part of this study. Data credibility has been checked in a high level, and where possible, data which were outside the expected range were clarified with their respective owners (e.g. if a port would state a load bearing capacity significantly higher than industry standards). However, it was not asked to provide any evidence for the data provided, and no responsibility is taken here for its accuracy.

The intent of the developer survey was to collect the projected infrastructure requirements for tidal energy developers. A shortlisting exercise was completed to identify a representative set of developers to survey. A response rate of approximately 70% was achieved with detailed responses received from the majority of respondents, especially large tidal developers (see Section 2.3.2 and 2.3.3). The survey captures the demands from a wide variety of tidal device types (e.g. single turbine bottom mounted devices, multi-turbine platforms, moored floating platforms) which are considered to represent the current trends of the industry. Information provided by survey respondents was self-declared and answers were provided anonymously.

Both local and international ports data presented here aim to offer an overview of infrastructure availability and to identify areas of potential improvement. Nevertheless, such information is not intended to be used for any design or project decision purpose.

Data interpretation

Please also note that the developers' requirements survey results should be carefully interpreted. While it was asked to state single figures to represent their "requirements", each developer actually has a range of acceptable parameters, ranging from "absolutely necessary" to "preferable". For instance, a load bearing capacity of 10T/m² is commonly expressed by developers. This can be interpreted as a "preferable" value, as a load bearing capacity of 5T/m² shouldn't prevent project feasibility, as long as appropriate load spreader is used – bringing extra cost onto the developer.

This highlights that each developer has a level of flexibility which allows him to tailor some of the installation strategy to available infrastructures. This flexibility is not necessarily reflected within the survey results. As a consequence, these should be read as trends and indications of the market requirements rather than detailed specific assessments.

Overall, this document doesn't intend to be a substitution for the developers' own port assessment. It is indeed not possible to reach the same level of focus and detail when assessing port suitability for a large variety of devices in contrast with a single specific device.

1.2.2 CONCLUSIONS OF THE STUDY

Eventually, the purpose of this document is to investigate port infrastructure availability compared to the industry needs, and to suggest the best options in terms of upgrades. The scope of this study allows reaching a level of detail to identify gaps and opportunities, and to shortlist the preferred ones to be studied in further detail. However, it does not perform a detailed assessment of shortlisted options, which would require analysing their respective cost and benefits in a more quantitative way.

As a consequence, it is suggested that any upgrade investment decision should rely on a dedicated study aiming at comparing pros and cons of shortlisted options, including cost analysis, and impact on other industries. The current study provides an insight on the parameters that will support decisions; nevertheless a detailed quantification of all these parameters is beyond its scope.

2 DEFINING THE DEMAND

The first work package of this project has reviewed the global tidal industry to establish the infrastructure needs of developers who might feasibly come to Nova Scotia, in 2016 and in the medium term (i.e. next 10 years). A desktop study was carried out to identify a shortlist of tidal energy converter (TEC) technology developers. The shortlisted developers were invited to participate in an online survey to secure information regarding their projected infrastructure requirements.

2.1 SHORTLISTING TIDAL DEVELOPERS FOR NOVA SCOTIA

Since 2011, significant work has been completed by the Province of Nova Scotia to develop and deliver a strategy to support the growth of the tidal industry. The following key reports provide an overview of tidal energy resource and recent activities in Nova Scotia:

- In May 2012, Nova Scotia's Marine Renewable Energy Strategy [2] was released, outlining plans to address provincial research, development and regulatory priorities to support the growth of the tidal energy industry.
- An update of the Strategic Environmental Assessment (SEA) (Tidal Energy: Strategic Environmental Assessment Update for the Bay of Fundy [3]) for tidal energy-based projects in the Bay of Fundy was completed in 2014. This report provides a detailed account of how the tidal energy industry in Nova Scotia evolved since the original SEA was published in 2008.
- Some of the most recent industry progress and updates are presented in the Marine Renewables Canada Annual Report 2015 [4] and the country report for Canada presented in the IEA-OES Annual Report 2015 [5].

As a first step, a review of the 2012 Nova Scotia Department of Energy Marine Renewable Energy Strategy [2] and the 2014 Tidal Energy: Strategic Environmental Assessment Update for the Bay of Fundy [3] was conducted to identify the characteristics of potential tidal development sites in Nova Scotia (Section 2.1.1). This information was used to compare with the technology characteristics of the tidal devices to assess their suitability for the Nova Scotia site conditions (Section 2.1.2).

2.1.1 POTENTIAL TIDAL DEVELOPMENT SITES IN NOVA SCOTIA

The vertical tidal range of the Bay of Fundy can be over 16m in the Minas Basin [6], representing some of the highest tides in the world and an energetic tidal resource. Figure 2 illustrates sites in Nova Scotia of interest to tidal developers and provides an estimate of the potential installed capacity presented in [6]. The installed capacity represents the anticipated maximum power generation capacity of a turbine array (e.g. number of turbines in the array multiplied by the rated capacity of each device).

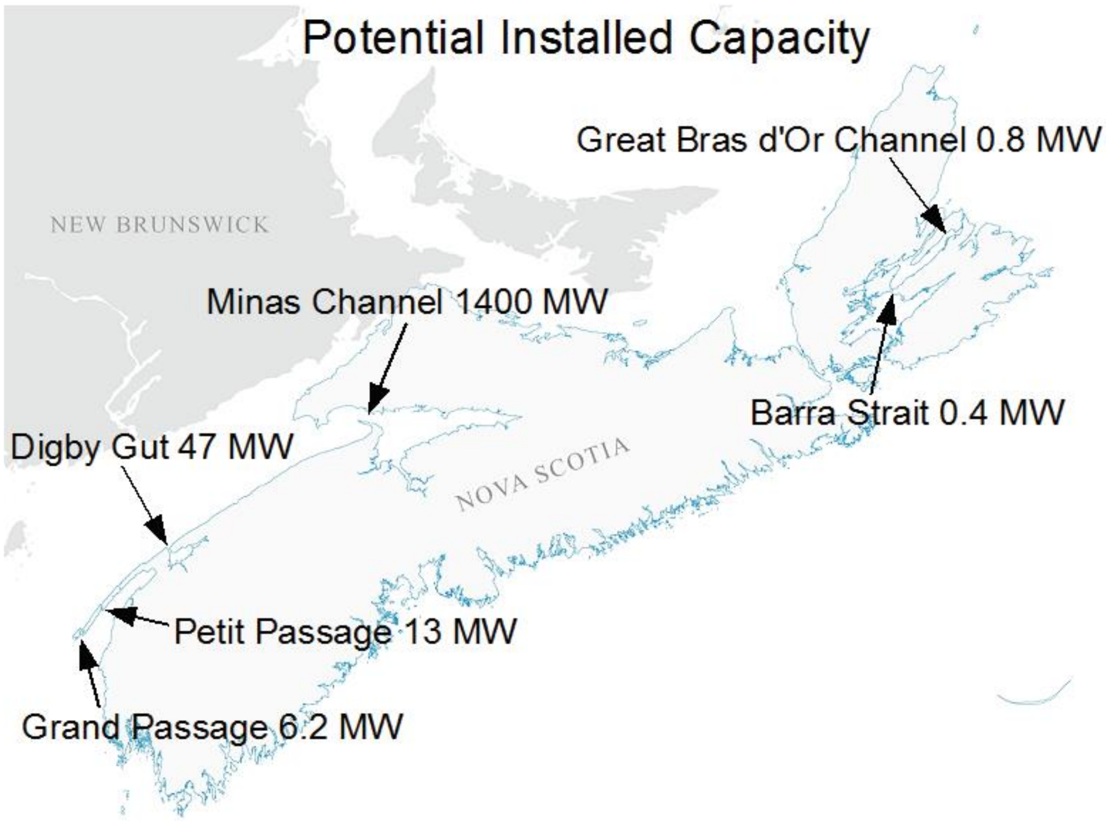


FIGURE 2 - POTENTIAL INSTALLED TIDAL ENERGY CAPACITY (SOURCE: [6])

An overview of the characteristics of the tidal development sites identified in Figure 2 (e.g. peak flow, appropriate water depths and channel widths) is presented in the following sub-sections.

2.1.1.1 MINAS CHANNEL

The Minas Channel represents the site with the largest energy resource in the Bay of Fundy, with a potential installed capacity of 1400MW [6]. Minas Channel connects Minas Basin to the Bay of Fundy, it is 50km in length and varies in width from 20km in the outer channel to 5km in Minas Passage [6]. Canada's research centre for tidal demonstration, FORCE is situated in the Minas Passage. The test facility consists of five berths located 1-3km from shore in water depths ranging from 30-60m. The seafloor consists of scoured, exposed bedrock in shallower water, and bouldery sand and gravel in deeper water [3]. Four subsea power cables were installed at the site in autumn 2014 to connect installed tidal turbines to land-based infrastructures. The four cables have a total capacity of 64MW.

The FORCE site is located near Black Rock, approximately 10km southwest of Parrsboro. In December 2014, four developers with projects at FORCE received Feed-in Tariff (FIT) approvals (totalling 17.5MW) to be developed at FORCE [7]. This allows the developers to enter into a 15-year power purchase agreement with Nova Scotia Power. The current berth holders at FORCE are listed below [7] - [8]:

1. Minas Tidal Limited Partnership (MTLP, Minas Tidal) (4MW): This is a partnership between International Marine Energy Inc. and Tocardo Tidal Power. Minas Tidal plan to deploy four Tocardo semi-submersible platforms, outfitted with four 250kW T2 bi-directional rotors. It is planned to begin the first platform deployment in 2017.
2. Atlantis Operations Canada in partnership with DP Energy (4.5MW): The technology proposed to be deployed is Atlantis's 1.5 MW AR-1500 turbine.
3. Cape Sharp Tidal Venture (4MW): This is a joint venture between OpenHydro (a DCNS company) and Emera. The current proposed deployment plans are a 4MW demonstration array, which will be the first phase of a commercial-scale project. Progress has been made on the Cape Shape Tidal development following the installation of the subsea connector cable, launch of the Scotia Tide deployment barge in Pictou for deployment operations, and completion of the first turbine, currently awaiting installation.
4. Black Rock Tidal Power (5MW): The current proposed technology to be deployed is the TRITON platform developed by TidalStream, which supports 40 lightweight horizontal axis SCHOTTEL STG turbines for the production of 2.5MW.

In 2015, FORCE began feasibility and impact studies, approvals, permitting and electrical design work to expand their onshore electrical infrastructure to accommodate up to 30MW[1] allowing small turbine arrays to connect to the electricity grid [5].

In December 2015, the Nova Scotia Government announced an agreement with the Irish-based renewable power development company DP Energy to install a 4.5MW stream tidal energy project at a 5th berth (Berth E) at the FORCE test site [9]. DP Energy has plans to install three 1.5 MW Andritz Hydro turbines [5].

2.1.1.2 Digby Gut, Petit Passage, and Grand Passage

Three sites have been identified in the Digby area with the tidal resource sufficient to support small scale commercial arrays: Digby Gut (47MW installed capacity), Petit Passage (13MW installed capacity) and Grand Passage (6.2MW installed capacity) [6].

Fundy Tidal Inc. (FTI) has received approvals under the Nova Scotia Community Feed-in Tariff (COMFIT) for the development of projects in Digby County at Digby Gut (1.95MW), Petit Passage (500kW) and Grand Passage (500kW). These approvals are for the development of small-scale tidal devices (up to 500kW) with a connection to the distribution grid. Tidal technologies are currently

[1] Personal communication with FORCE, July 2016.

being considered for installation at the FTI sites; the primary technologies under consideration by FTI are from Nautricity[2] and Tocardo[3].

A brief description of the primary site characteristics for each site is presented in Table 1.

TABLE 1 – PRIMARY SITE CHARACTERISTICS FOR DIGBY GUT, PETIT PASSAGE AND GRAND PASSAGE (USING INFORMATION FROM [10])

Digby Gut	Located between Annapolis Basin, the Annapolis River and the Bear River to the Bay of Fundy. Digby Gut is located approximately 50km northeast of Petit Passage. The numerically predicted maximum mean speed is approximately 1.4m/s and the overall maximum current velocity is approximately 3.9m/s. Digby Gut is approximately 4.25km long (measuring from Point Prim to the southern tip near the Ferry Terminal) and 0.8km wide at its narrowest point and approximately 1.6km at its widest.
Petit Passage	Located between Long Island and Digby Neck (located approximately 20km northeast of Grand Passage). The numerically predicted maximum mean speed is approximately 2.6m/s and the overall maximum current velocity is approximately 5.9m/s. Petit Passage is approximately 3.4km long (measuring from Boar head to French Beach Point) and 0.4km wide at its narrowest point and approximately 0.8km at its widest.
Grand Passage	Located between Brier Island and Long Island. The numerically predicted maximum mean speed is approximately 2m/s and the overall maximum current velocity is approximately 4.3m/s. Grand Passage is approximately 4.25km long (measuring from North Point to Dartmouth Point) and is approximately 0.75km wide at its narrowest point and approximately 1.75km at its widest.

Figure 3 and Figure 4 illustrates the depth at low water and mean speed, respectively, for the Grand Passage, Petit Passage and Digby Gut sites.

---

[2] FTI and Nautricity Ltd. have signed a Memorandum of Understanding (MoU) to develop a 500kW tidal project in Petit Passage. http://www.renewableenergyworld.com/articles/2014/06/nautricity-fundy-tidal-teaming-up-for-nova-scotia-ocean-energy-project.html, accessed 27/07/16.

[3] FTI and Tribute Resources Inc. have formed the Digby Gut Limited Partnership for the Digby Gut Tidal Power Project which will work with Tocardo International BV. http://www.tributeresources.com/fundy-tidal-inc-and-tribute-resources-inc-form-partnership-for-digby-gut-tidal-power-project/, accessed 27/07/16.

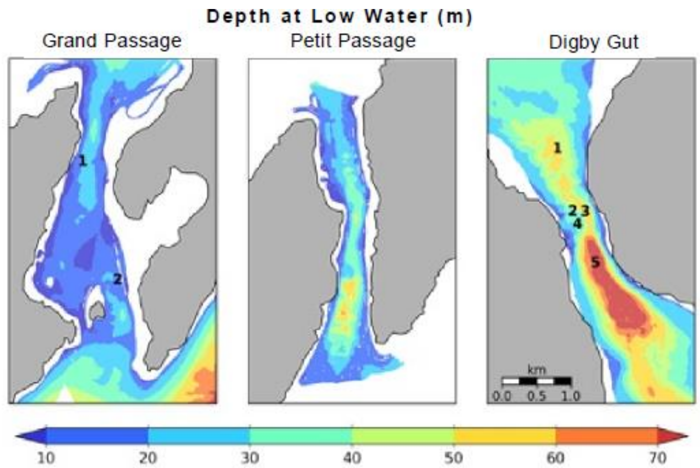


FIGURE 3 - DEPTH AT LOW WATER (M) AT GRAND PASSAGE, PETIT PASSAGE AND DIGBY GUT (SOURCE: [3])

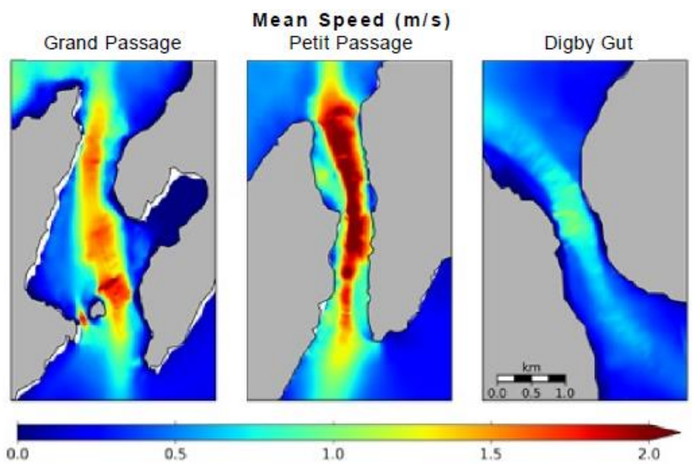


FIGURE 4 -MEAN SPEED (M/S) AT GRAND PASSAGE, PETIT PASSAGE AND DIGBY GUT (PRESENTED IN [3]; SOURCE [11])

The Southwest Nova Scotia Tidal Energy Resource Assessment [12] assessed the tidal resource in Southwest Nova Scotia in the counties of Shelburne, Yarmouth and Digby Counties. The initial reconnaissance results highlight the potential for small-scale tidal energy developments at sites along the Southwest coast of Nova Scotia [13]. Table 2 lists a summary of the maximum flow speeds measured at the nine reconnaissance sites.

TABLE 2 - SUMMARY OF MAXIMUM FLOW SPEEDS MEASURED AT RECONNAISSANCE SITES (DATA SOURCE: [13])

Site	V_{max} (m/s)
The Gap	4.16
Passages West of Big Tusket Island	3.00
Indian Sluice	4.09
The Sluice	3.21
The Tittle	2.43
Cat Island Bridge	3.30
Pubnico Harbour	1.61
Port Clyde Bridge	3.04
Port L'Hebert	1.26

2.1.1.3 GREAT BRAS D'OR CHANNEL AND BARRA STRAIT

Mc Millan et al. [14] present the results from the Cape Breton Resource Assessment in a report submitted to the Offshore Energy Research Association of Nova Scotia. The report presents a summary of flow measurements at three locations in Cape Breton: two in the Great Bras d'Or Channel (Carey Point and Seal Island Bridge) and one in the Barra Strait (near Iona) (see Figure 5 and Table 3).

FIGURE 5 - LOCATION OF ADCP MEASUREMENTS IN CAPE BRETON (SOURCE: [14])

TABLE 3 - BRIEF DESCRIPTION OF THE CHARACTERISTICS FOR MEASUREMENT SITES IN CAPE BRETON (USING INFORMATION FROM [14])

Carey Point	This site had the most energetic flow with horizontal currents reaching 2.8m/s and a mean water depth of 21.5m.
Seal Island Bridge	The maximum current speed at Seal Island Bridge was 1.9m/s and the mean depth was 15.1m. The seabed at this site consisted of coarse sediment over a mixture of bedrock outcrop medium-sized rocks and coarse gravel.
Barra Strait	The maximum current speed at Barra Strait was 1.1m/s and the mean depth was 21m. The seabed at the site was level, consisting of medium sized gravel.

2.1.1.4 SUMMARY OF POTENTIAL DEVELOPMENT SITES IN NOVA SCOTIA

As described in [6] and summarised in the following paragraph, the tidal resource varies across Nova Scotia. Some of the tidal passages connect tidal basins to the Bay of Fundy (e.g. Minas Channel and Digby Neck) and have a large amount of extractable power, whilst other passages lie between two large bodies of water (i.e. Petit Passage and Grand Passage) and may have a smaller amount of extractable power. The speed of the current in each passage also affects the choice of technology to efficiently exploit the resource.

In summary, two distinct project scales were identified for tidal energy developments in [3]:

- Large scale projects to be deployed in high current, deep water environments. These projects are typically >10MW, are located 1-10km offshore and generate electricity for sale.
- Smaller scale projects which are more suited to lower current speeds and may be deployed in shallower water close to the shore. These smaller scale projects will export power to the distribution grid and are typically less than 5MW (but maybe less than 1MW).

In Nova Scotia, it is suggested that the differences between the two tidal project scales are represented by the large scale test site in the Minas Passage (i.e. FORCE), which ultimately aims to transmit power, and the small scale projects proposed for locations near Digby and the Bras d'Or Lakes, which aim to distribute power to the local communities [3].

Tidal technologies suited to the two tidal project scales may be categorised as:

- Large tidal technologies - defined as a single device with a rated capacity of greater than 500kW. These tidal technologies would be suited for installation in the Minas Passage.
- Small tidal technologies - defined as a single device with a rated capacity of up to 500kW. These technologies would be suited for installation at locations near Digby and the Bras d'Or Lakes.

This categorisation of large and small tidal technologies corresponds to the presentation of the tidal technology base cases described in the 2011 Marine Renewable Energy Infrastructure Assessment [1].

Overall, the desktop study findings indicate that sites in Nova Scotia are suitable for a wide variety of tidal technology types and scales. Therefore, no specific tidal technology type or scale has been excluded from the shortlisting exercise presented in Section 2.1.2. However, it should be noted that a detailed assessment (beyond the scope of this report) of each passage should be conducted to determine the most appropriate tidal technology to be installed at each site.

2.1.2 TIDAL INDUSTRY REVIEW: TEC SHORTLIST

The global tidal industry has continued to evolve since the 2011 Marine Renewable Energy Infrastructure Assessment [1] was carried out. In [1], it was anticipated that the installation of commercial turbine arrays (in the range of 10MW) would begin in the UK in the following two years. However, these planned projects have yet to be completed. Tidal developers continue to test their technologies at the European Marine Energy Centre (EMEC) in Orkney, Scotland, and as of June 2016, tidal technology berth holders included (further information on the individual developer's activities is presented in Table 4):

- GE Renewable Energy (formerly Alstom)
- Andritz Hydro Hammerfest
- Atlantis Resources Corporation
- Bluewater Energy Services
- Nautricity
- OpenHydro
- Scotrenewables Tidal Power
- Sustainable Marine Energy (SME)
- Tocardo

Elsewhere, the Perpetuus Tidal Energy Centre (PTEC) in the Isle of Wight (UK) received approval in 2016. PTEC offers a fully consented tidal site available for a range of tidal technologies to deploy arrays. It is anticipated that the construction of the project will commence in 2017.

A number of tidal demonstration arrays are also under development or planned for the coming years, including:

- The MeyGen project located in the Pentland Firth, Scotland. As a precursor to the full development, MeyGen intends to deploy a demonstration array (Phase 1A) of 4 turbines (Atlantis Resources and Andritz Hydro Hammerfest technologies) in the Inner Sound. In 2015, the construction of the MeyGen Phase 1A (6MW) tidal array began. This is the first phase of a planned 398MW project.

- Cape Sharp Tidal (joint venture between OpenHydro and Emera) plans to deploy a fully grid-connected 4MW array at the FORCE site in the Bay of Fundy. Two OpenHydro 2MW tidal turbines plan to be deployed during the summer of 2016. The turbines will be transported from the Pictou Shipyard manufacturing site on the Scotia Tide barge to the FORCE test site.
- The Shetland Tidal Array in Scotland will be composed of five 100kW Nova Innovation M-100 tidal turbines. The first of the five planned tidal turbines was deployed in 2016.
- EDF's Paimpol-Bréhat tidal array composed of four OpenHydro turbines. The second tidal turbine in the array was deployed at the site off the coast of Brittany in May 2016.
- The Normandie Hydro project with DCNS (parent company of OpenHydro) and EDF Energies which plans to install an array of seven 2MW OpenHydro tidal turbines. The turbines will be installed in Raz Blanchard, off the French coast of Normandy, and are scheduled to be grid connected by 2018.
- GE Renewable Energy (formerly Alstom) has also been selected to supply four Oceade 18 (1.4MW) tidal turbines to ENGIE's tidal energy pilot project in Raz Blanchard.
- Black Rock Tidal Power, a subsidiary of Schottel Hydro, plans to deploy two 2.5MW, TRITON S40 platforms at the FORCE site, each with 40 turbines. The first platform is scheduled for installation in 2017.

Further information on arrays planned by the tidal technology developers is presented in Table 4.

2.1.2.1 Tidal Technologies

Similar to information presented in [1], it remains somewhat uncertain how tidal technologies will evolve in the coming years. A range of turbine types and base structures are under development, and a clear convergence to a specific technology type has yet to occur. Presently, there are a large number of TEC concepts at different stages of development. Horizontal axis tidal turbines (HATTs) may be the most common of all tidal technologies under development, but other technology types (e.g. vertical axis turbines, cross flow or other novel disruptive technologies) are also being actively pursued by developers. A description of the principal tidal technology types can be found in [15].

In [1], the tidal technology base cases considered for large tidal (i.e. >0.5MW) included gravity base and pin/pile foundations. Since this period, large tidal floating platforms with multiple turbines are also being actively pursued by developers. These floating units may be attached to the seabed using a flexible tether, a rigid mooring or through a midwater buoy that rises and falls with the tide.

Based on the consortium's experience a shortlist of TEC technology developers who are, or might potentially be, interested in deploying in Nova Scotia in the short to medium term (i.e. a 10-year horizon) was drawn up to identify participants for the online survey. Factors taken into consideration during the shortlisting exercise include:

- the inclusion of technologies with planned deployments in Nova Scotia;

- the technology characteristics of the tidal devices under development, a variety of technology types were incorporated;
- an assessment of the development and testing programme to date, including e.g. tank and field testing, operational history;
- a qualitative appraisal of the developers' funding status, considering e.g. and strategic partnerships with Original Equipment Manufacturers (OEMs), utilities or independent project developers.

Table 4 presents the shortlist of tidal technology developers selected to participate in the online survey. For completeness, a brief overview of the key technology features, demonstration / test programme activities and future developments are presented for each technology.

It should be noted that the information for each technology has been compiled from publicly available sources including the developer websites and news items. An effort was made to present recent demonstration and test programme activities for each technology, along with information currently available regarding future developments and strategic partnerships. Interested readers are referred to the individual technology developer's websites for further information on each technology.

TABLE 4 - SHORTLIST OF TIDAL TECHNOLOGY DEVELOPERS

Company	Large/small tidal	Technology description	Demonstration and test programme	Development activities and strategic partnerships
Allswater/XTIDAL	Small tidal	The XIP tidal platform is a twin-hulled floating turbine platform for 1-3 horizontal axis turbines, up to 450kW total.	The development of the device is currently at the detailed design phase.	The next step in the development of the technology is small scale prototype testing.
Andritz Hydro Hammerfest	Large tidal	The Andritz Hydro Hammerfest tidal turbine is a three bladed bottom mounted horizontal axis tidal turbine (HATT) device. The device substructure can be kept in position by gravity, pins or piling (depending on the site characteristics). Designed to generate power from currents with a speed of 1m/s or more.	In December 2011, Andritz Hydro Hammerfest successfully deployed its 1MW (HS1000) tidal device at EMEC in Scotland. The device was subsequently grid connected in February 2012 and retrieved in 2015.	Andritz Hydro Hammerfest is part of the Andriz Hydro GmbH group, a supplier of electro-mechanical equipment and services to the hydropower industry. Andritz Hydro Hammerfest is a supplier of turbines to the MeyGen Phase 1A tidal energy project in the Pentland Firth.
Atlantis Resources Ltd.	Large tidal	Atlantis's AR series turbine is a three bladed bottom mounted HATT device. The Atlantis AR series turbines include: AR1000 – a 1MW fixed pitch configuration AR1500 – a 1.5MW turbine system with pitching blades and full nacelle yaw rotation capability. The AR turbines have a patented stab system that enables rapid retrieval of the turbine, without having to recover the foundation structure.	Demonstration of their 1MW, AR1000 tidal energy device in EMEC in 2011 and subsequent PTO testing at the Nautilus facility in Narec in Blyth in the UK. In 2014, Atlantis teamed up with Lockheed Martin Corporation to complete the design of its 1.5MW AR1500 turbine.	Atlantis are developing numerous site globally, including: - At FORCE in Canada with project partners Lockheed Martin and Irving Shipbuilding - The MeyGen project in the Pentland Firth, UK - Atlantis has a strategic agreement with Dongfang Electric Machinery Co. Ltd. in China - Atlantis has been working with Gujarat Power Corporation Ltd to complete the concept design and consent for a 200MW project in the Gulf of Kutch in India Atlantis are supplier of turbines (AR1500) to the MeyGen Phase 1A project.
Black Rock Tidal Power and TidalStream Ltd., subsidiaries of SCHOTTEL HYDRO	Large tidal	The Triton S40 is a semi-submerged floating platform which supports multiple SCHOTTEL HYDRO turbines. The large platform connects to a gravity based foundation using a 3DOF subsea hinge with a slip ring unit and locking device.	The individual SCHOTTEL turbines have been tested in Ireland, with further tests planned at EMEC. A model scale of the Triton platform has been tank tested.	The first full-scale demonstration of a Triton 2.5MW platform is under development by Black Rock Tidal Power Inc. at FORCE. It is planned to deploy two 2.5MW installations in 2017 and 2018.

Company	Large/small tidal	Technology description	Demonstration and test programme	Development activities and strategic partnerships
Bluewater Energy Services BV	N/A	Developer of BlueTEC demonstrator unit; a floating support structure for tidal turbines. The project is turbine agnostic and Bluewater plan to collaborate with TEC developers to utilise their floating structure.	Bluewater secured a berth at EMEC in July 2011 for full-scale demonstration. The first BlueTEC Modular was installed in the summer of 2015 off the island of Texel and is connected to the Dutch electricity grid. In early 2016, the platform was commissioned with a larger T2 tidal turbine from Tocardo Tidal Turbines.	The core business of Bluewater is to design, engineer, construct, install and deliver Floating Production, Storage and Offloading (FPSO) systems, Floating Storage and Offloading (FSO) systems and Single Point Mooring (SPM) systems. The BlueTEC demonstration project at EMEC is supported by the EU LIFE+ program and plans to deploy a full-scale demonstration unit.
Flumill	Large tidal	System based on helix turbines hinged to the seabed moving back and forth with the tide.	Flumill's device was demonstrated at EMEC's nursery site in 2011/2012.	Flumill's next step is to deploy a full scale pilot in Rystraumen near Tromsoe in Norway.
GE Renewable Energy (formerly Alstom)	Large tidal	The Oceade 18 tidal turbine platform is a 1.4MW three bladed bottom mounted HATT device. The turbine system can rotate to face the oncoming flow and has variable pitch blades. The device's buoyant subsea hub allows rapid installation using small vessels.	Earlier generation of GE's tidal turbine have been demonstrated at EMEC in Scotland. In 2010, a 500kW device was deployed and in 2013 a 1MW device was installed at the site. A statement of feasibility was issued by DNV GL for the Oceade 18 device in 2015.	In 2014, GE was chosen to equip ENGIE's tidal pilot farm at raz Blanchard (France) with four Oceade 18 1.4MW devices. The construction is planned to begin in 2017.
Instream Energy Systems Corp.	Small tidal	Surface mounted vertical-axis hydrokinetic turbine.	Previous deployment projects include: Duncan Dam, BC (4 turbines rated at 25KW) and Roza Canal, Washington (1 x 25kW turbine)	Instream received EU Eureka Label and Canadian Government funding from the National Research Council for its Marine Floating Platform Design Project. Instream continues to work with BAE systems and is presently developing its next generation turbine. Instream have also received approval for a project at SEENEOH Bordeaux in France.
Minesto	Small and large tidal There are four different sizes of Deep Green devices (rated between 120 - 850kW).	The Deep Green device resembles an underwater kite with a wing and a turbine. It moves swiftly in an 8-shaped trajectory in the current. The Deep Green device can produce electricity at sites with velocities between 1.2-2.5m/s and at depths between 60-120m.	To date five Deep Green prototypes have been built and tested. A ¼ scale prototype was deployed in 2013 in Strangford Lough, Northern Ireland, and is currently undergoing extensive sea trials.	In May 2015, Minesto secured a €13m investment from the European Regional Development Fund through the Welsh Government for the commercial rollout of Deep Green in Holyhead Deep, Anglesey, Wales. Minesto plans to begin the installation of a 10MW array at the Holyhead Deep site in 2017. The first step will be the commissioning of the first Deep Green power plant (rated at 0.5MW) in summer 2017.

Company	Large/small tidal	Technology description	Demonstration and test programme	Development activities and strategic partnerships
Nautricity	Small tidal	Nautricity's CoRMaT device comprises a neutrally buoyant cylindrical nacelle with a contra-rotating turbine, suitable for deployment in water depths of 8 to 500m. CoRMaT uses two closely spaced dissimilar rotors, moving in opposite directions. The device is moored to the seabed.	CoRMaT has successfully completed its proof of concept testing and sea trials at a commercial scale have been conducted at one of EMEC's non grid-connected berths in the Sound of Shapinsay.	Nautricity Ltd. and Argyll Tidal Ltd. are developing a site off The Mull of Kintyre, in the West of Scotland. Plans are underway to deploy a single unit demonstration device at the site. Nautricity Ltd. and Fundy Tidal Inc. have signed a Memorandum of Understanding (MoU) to develop a 500kW tidal project in Petit Passage.
New Energy Corporation Inc.	Small tidal	New Energy's EnCurrent™ and EnviroGen™ Systems use a proprietary hydrofoil design which implements a vertical axis turbine. New Energy offer four power unit products ranging from a rated capacity of 4kW to 250kW.	New Energy has completed many demonstration projects of various scale to date. In 2011, New Energy commissioned its first project outside of North America with a 50kW pilot plant in Northern India. The project was for DLZ Power Private Ltd.	New Energy are involved in the following projects: - A 5kW system was installed in Ringmo, Nepal. - Two 5kW EnviroGen™ power generation systems were installed on the Thanlyin River in Myanmar. - Contracted to install a 25kW EnviroGen device to provide power to the Sagkeeng First Nation community in Manitoba, Canada. - Project plans to install a two 250kW power generation units in Canoe Pass, Canada.
Nova Innovation	Small tidal	The Nova M100 is a two bladed, bottom mounted HATT. The Nova M100 is targeted to shallow-water tidal and river deployment.	Demonstrated the 30kW Nova 30 device (grid connected) in Shetland (Scotland) in 2014.	Nova Innovation secured a Crown Estate lease to install five 100kW Nova 100 devices as part of the Shetland Tidal Array in the Bluemull Sound. The first Nova M100 turbine in the Shetland array project was deployed in early 2016.
Oceanflow Energy	Large tidal	Semi-submerged, floating, tethered tidal energy capture device with a HATT.	Previous deployment projects include: 1:10th scale Evopod device tested in Strangford Narrows, Northern Ireland. A 1:4th scale Evopod device has completed one year of testing at Sanda Sound in Scotland.	The 1:4th scale Evopod device was recovered in September 2015 and is being prepared for redeployment at Sanda Sound.

Company	Large/small tidal	Technology description	Demonstration and test programme	Development activities and strategic partnerships
Ocean Renewable Power Company (ORPC)	Small and large tidal	The ORPC Turbine Generator Unit (TGU) is a cross flow turbine with a modular design. The modules can be configured differently depending if a single unit or a multiple device array is required. ORPC's ocean power systems can be secured to the seabed using a fixed bottom support frame or buoyant tension mooring system. The TidGen® TGU is scalable from 0.15-0.6MW.	ORPC have built a number of demonstration units. The company currently has projects in Alaska and Maine.	In the coming years, ORPC looks to expand the Maine Tidal Energy project up to 5MWs in alignment with the terms of their 20-year power purchase agreement approved by the Maine PUC. ORPC also has a subsidiary in Ireland, ORPC Ireland Ltd.
OpenHydro a DCNS company	Large tidal	OpenHydro are developing a seabed mounted Open-Centre Turbine. The turbine has four key components: a horizontal axis rotor, a direct-drive permanent magnet generator, a hydrodynamic duct and a subsea gravity base support structure.	OpenHydro were the first company to install a tidal turbine at EMEC in 2006. OpenHydro have continued to use this platform to test its turbines. OpenHydro have completed multiple demonstration projects, including: - Installation of a 1MW commercial tidal turbine in the Bay of Fundy in 2009. - Installation of a 16m turbine in Paimpol-Bréhat, France in 2011/2012 and again in 2013/2014. Second 16m turbine installed in May 2016.	OpenHydro has a project portfolio spanning the USA, Canada, France, Ireland, Scotland and the Channel Islands with utility partners including Emera, EDF, Bord Gáis, SnoPUD and SSE renewables. Cape Sharp Tidal Venture is a joint venture between OpenHydro (a DCNS company) and Emera. Cape Sharp Tidal aims to deploy a grid-connected 4MW array in the Bay of Fundy (at the FORCE).
Sabella	Large tidal	Bottom mounted gravity based tidal device. Bi-directional turbine which can be installed in marine or estuarine environments. Sabella offers a range of machines with varying turbine diameters (including the D10, D12, D15)	First tests of the Sabella device took place during 2008-2009 in Southern Brittany with Sabella D03. The Sabella device was the first grid-connected marine current turbine in France. Full scale tests of the D10 1MW device were carried out in 2015 in Ushant.	Works is underway to develop a tidal energy farm in Fromveur Passage (France), in collaboration with the French renewable energy company Akuo Energy.
Scotrenewables Tidal Power	Large tidal	The SR2000 2MW tidal energy generator has two HATTs mounted just under the sea surface on a floating hull platform. The device has a flexible mooring system and can be installed in any water depth of 25m+, with a range of anchoring systems to suit most seabed types.	In 2011, the SR250 prototype was deployed at EMEC in Orkney and completed a 2.5-year test programme. In 2016, the SR2000 2MW turbine was launched at the Harland & Wolff Shipyard in Belfast. It underwent preliminary tow trial in Belfast Lough before being towed to EMEC and grid connected.	In 2016, a Horizon2020 grant of €10m was granted to the Scotrenewables FloTEC project. The FloTEC project aims to advance the SR2000 technology with the development of a mark 2 turbine. The SR2000-M2 prototype will be installed alongside the SR2000-M1 at EMEC's tidal test site at the Fall of Warness in Orkney, forming a 4MW floating tidal array.

Company	Large/small tidal	Technology description	Demonstration and test programme	Development activities and strategic partnerships
Sustainable Marine Energy (SME)	N/A	SME develops the tidal platform PLAT-O, a buoyant platform that is taut moored to the seabed using an anchoring solution.	A PLAT-O unit fitted with two SCHOTTEL HYDRO turbines was demonstrated off the south coast of England in 2015.	In 2015, SME signed a long term testing contract with the EMEC. SME plans to deploy five PLAT-O systems in an array over the next two years. The PLAT-O system hosts SCHOTTEL SIT turbines. The installed power output of the array will be 1MW and will be grid connected.
Tidal Energy Ltd. (TEL)	Large tidal	TEL's DeltaStream technology is composed of a triangular steel base frame and gravity based foundation. The platform supports three independent HATT on a tower at the apexes of the triangular main base.	In 2016, TEL deployed their DeltaStream device in Ramsey Sound, Wales.	Following a 12-month trial of the DeltaStream device in Ramsey Sound, TEL and Eco2 plan to install a commercial array (10MW) consisting of up to nine Deltastream machines off St. David's Head in Pembrokeshire, Wales.
Tocardo	Small/Large tidal	Tocardo are the producer of a range of tidal (T-series) and free-flow water (R-series) turbines. The Tocardo turbines consist of a permanent magnet direct drive generator and a patented bi-directional reversible rotor blades design.	Tocardo's technology has been demonstrated during the Den Oever project, which took place at a site in the north of The Netherlands in 2005. In 2008, a T100 was deployed at the site and is still in operation. Tocardo's T2 (200kW) turbines (5) were deployed in the Netherlands at the Eastern Scheldt storm surge barrier (Deltaworks). A Tocardo turbine (T2) has also been deployed on Bluewater's BlueTEC floating platform for the Texel Tidal Project in the Netherlands.	Tocardo has signed up to demonstrate a 20-year pre-commercial array at EMEC. Tocardo plans to install eight T2 turbines across two Tocardo systems at EMEC's grid-connected tidal test site at the Fall of Warness, off Eday, Orkney. Installation is scheduled to begin in 2017. Under the Minas Tidal Limited Partnership, it is planned to deploy four Tocardo semi-submersible platforms at FORCE. Tocardo are also working with the Digby Gut Tidal Power Project in Nova Scotia.
Verdant Power	Small tidal	Three bladed bottom mounted turbine designed to generate power from the currents of tides, rivers and manmade channels.	Demonstrated during the Roosevelt Island Tidal Energy (RITE) Project in the East River in the New York Harbour. In 2006 – 2009, six full-scale KHPS (Gen 4) tidal turbines were deployed and grid connected during the RITE project.	Verdant Power has partnered with Belleville Duggan Renewables Ltd. to develop commercial tidal energy projects at sites in Ireland and the UK under the joint venture Verdant Isles Ltd.
Water Wall Turbine Inc. (WWT)	Large tidal	Anchored floating structure with a large radial blade, bi-directional tidal turbine that rotates at a slow speed.	Test trials have been conducted at scales of 1:100, 1:75, 1:25, 1:10 and 1:6.	Water Wall Turbine Dent Island Tidal Power Generation Project: demonstration of a 500kW tidal energy power plant. A WWT self-floating power plant with WWT microgrid and energy storage will be installed at Dent Island, off the west coast of British Columbia.

2.2 DEVELOPERS SURVEY

The shortlisted developers were sent an online questionnaire, structured to secure information on the projected infrastructure requirements to install and operate their tidal technology. An overview of the survey sent to developers is presented in Appendix A.

The data gathered aimed to be as comprehensive as possible, to allow an assessment of the projected infrastructure requirements, including meeting TEC developer requirements for:

- Manufacture & Assembly
- Storage and Load-out
- Installation
- O&M servicing

Other factors which were also considered included:

- Projected long-term manufacturing infrastructure needs/requirements, including the relative importance of proximity to deployment site.
- The relative importance of proximity of port infrastructure to services and suppliers.
- Site area required including: quayside area for storage and loading out of large components, and adjacent areas for covered workshops, assembly and O&M facilities.
- Water depths alongside quays needed to accommodate the anticipated vessels for survey, installation, O&M, and general support workboats.
- Maximum weight and size of components, and how they are to be launched and recovered in the ports, e.g. slipways, SPMTs, mobile cranes and other lifting equipment.

In order to assess the infrastructure requirements, this study first considered the nature of the developers' likely marine operations for installation and O&M, and some of the factors that influence them, including:

- The sequence of operations required for each activity.
- The limiting metocean conditions for each task.
- Limitations on climate conditions, icing, protection from the elements.
- The proposed number, type and size of vessels proposed, their operational capacity (e.g. station-keeping ability), and transit speeds etc.
- Plans for port usage, multiple users or multi-sector.

The developers surveyed were asked to define their vessel requirements, but were not specifically canvassed on the details of the marine operations, in order to optimise the length of the survey. The first three of the above points were therefore assessed on the basis of the consortium's in-house knowledge and installation experience, with the aim of confirming the range of vessels required, and hence supporting the port requirements in terms of wharf length, crane type and capacity, quayside facilities and, critically, the minimum water depth.

In terms of protection for the elements, covered space may be required for turbine assembly and for O&M, but fabrication of steel and concrete foundations and final device assembly can be carried out in the open on a quayside, and indeed would have to be so for the large devices. In the survey developers were asked to specify their site area requirements for storage, staging and at the quayside for load-out to ascertain the demand for space.

It is understood that parts of the Bay of Fundy can see sea ice which can sometimes damage wharf and jetty structures; however, withstanding this damage is a generic design issue for these facilities and no additional design requirements are imposed by the proposed tidal developer operations. Otherwise, quayside exposure to the elements is little different from the situation at the EMEC harbour facilities, for example those at Kirkwall, Stromness and Lyness, albeit snow and ice may be more common.

Other metocean conditions (wave, wind, fog, temperature) will have an impact on marine operations, however the Bay of Fundy is relatively sheltered (compared for example with the exposed East Coast) and these do not impose any special additional infrastructure requirements.

2.3 KEY RESULTS: WHAT DO TIDAL TECHNOLOGY DEVELOPERS WANT?

A TEC technology developer survey was conducted between the 24th of May and 13th of June 2016. Leading technology developers from across the globe were invited to complete the survey (see Table 4). The survey was composed of twenty-five carefully selected questions to assess the main infrastructure needs of tidal developers. Personalised e-mail invitations were sent directly to key contacts from each developer, and the surveys were completed electronically via an online survey tool.

Survey responses and feedback were received from 15 developers, which equates to approximately 70% of the developers surveyed.

This section provides an overview of the data gathered from the survey. The information obtained is used to determine the projected infrastructure requirements for tidal energy developers in the gap analysis presented in Section 5.

2.3.1 OVERVIEW OF TIDAL TECHNOLOGIES AND CURRENT STATUS

2.3.1.1 TECHNOLOGY STATUS

The TEC technologies associated with the survey respondents are at various stages of development (see Figure 6). The majority of respondents have completed small scale (i.e. model tests) and full size (i.e. prototype) installations, with others at a commercial generation stage. One developer is planning prototype testing as the next step of their technology development programme.

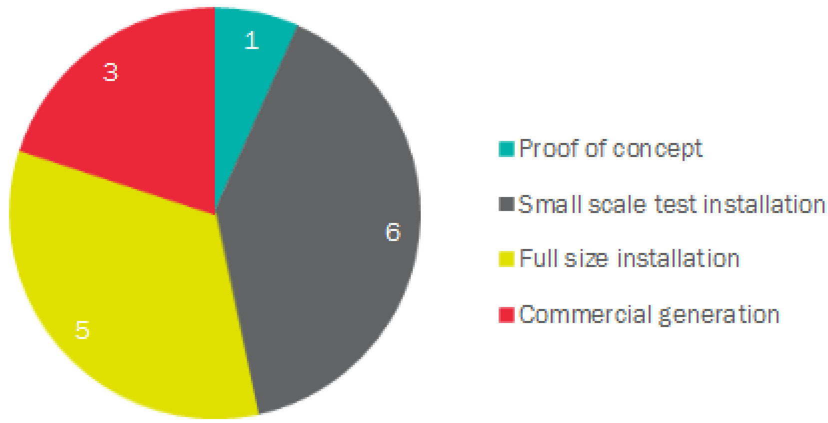


FIGURE 6 - CURRENT STAGE OF DEVELOPMENT OF TIDAL TECHNOLOGIES

The majority of developers who responded to the survey (i.e. 14 out of 15 respondents) have conducted deployments in tidal environments. These include tests at the European Marine Energy Centre (EMEC), as well as sites in a variety of locations globally including Canada, the UK, France, the Netherlands and America. Five of these deployments were grid connected and at least three of the devices deployed were rated at a capacity of 1MW.

Developers were asked to provide information on any current or future tidal development plans in Nova Scotia. The majority of respondents (i.e. 11 respondents) did not have any current or future tidal development activities planned in Nova Scotia, but all would consider opportunities in Nova Scotia within the next 10 years. Other respondents are currently developing projects at FORCE and COMFIT approved sites in Digby County.

Future plans specified by survey respondents for tidal projects in Nova Scotia include expanding to multiple turbine installations and potential community scale demonstration projects. The project locations in Digby County may be developed up to 1.99 MW each (under the Marine Renewable Electricity Act). Expansion of these locations is directly contingent on overcoming grid restraints and a suitable market mechanism being available to purchase the power.

2.3.1.2 TIDAL TECHNOLOGY TYPES

In the survey, developers were asked to describe their tidal technology which could be installed in Nova Scotia in the short term (i.e. next 5 years).

The tidal technology types under development by developers who provided feedback to the survey are illustrated in Figure 7 and can be summarised as follows:

- 10 horizontal axis tidal turbines
- 1 vertical axis tidal turbine
- 1 cross-flow turbine
- 3 'other' technology types

The three 'other' technology types included a novel turbine system and turbine independent platforms.

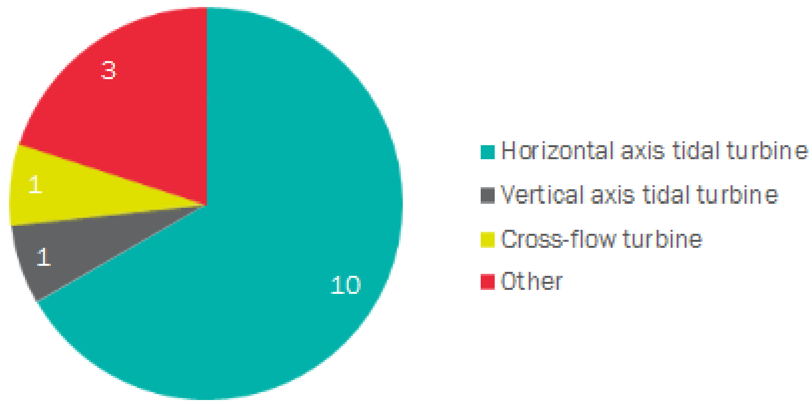


FIGURE 7 - TIDAL TECHNOLOGY TYPES

The device foundation types related to the survey respondents are summarised in Figure 8 and can be described as follows:

- 7 bottom mounted – gravity base foundations
- 0 bottom mounted – piled foundations
- 3 moored – catenary mooring arrangements
- 1 moored – mid-water mooring arrangement
- 4 'other' types of foundations or platform

The following comments were included to describe the four 'other' TEC foundation types specified by survey respondents:

1) gravity based or piled foundations could be used;
2) the developer's current device uses catenary moorings with drag anchors, but in the Bay of Fundy they would investigate using piles;
3) the turbine is mounted on a floating power plant;
4) one of the respondent's technologies could implement a fixed bottom support frame or a buoyant tension mooring system.

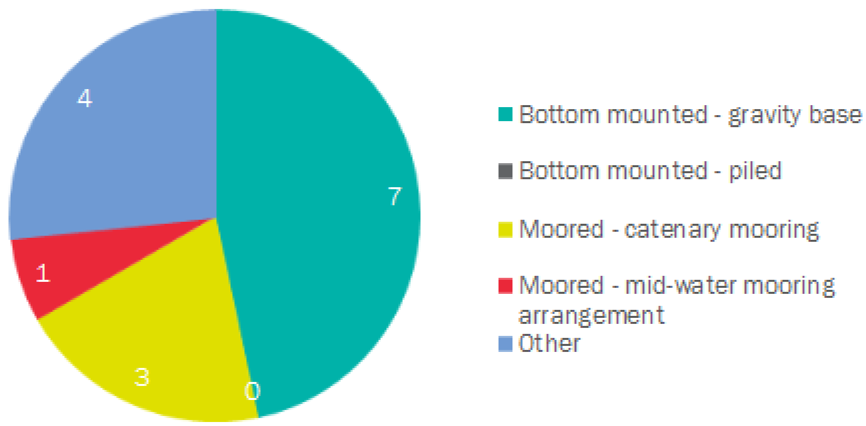


FIGURE 8 - DEVICE FOUNDATION TYPES

Developers were asked to specify the generating capacity of their device. From the responses received, 9 respondents are developing a technology with a generating capacity of >500kW, whilst the other 6 respondents are developing a device with a generating capacity of up to 500kW (small tidal).

The infrastructure needs for developers may vary according to the size and scale of the tidal development. Therefore, the survey responses received have been compiled into large and small tidal developments based on the generating capacity of the device. The data provided by large tidal survey respondents (i.e. device generating capacity of >500kW) is presented in Section 2.3.2. The survey results provided by small tidal technology developers (i.e. device generating capacity up to 500kW) is summarised in Section 2.3.3.

2.3.2 Large Tidal Technologies (>500kW)

The survey responses for tidal technologies with a generating capacity of >500kW have been analysed and are presented in the following section.

2.3.2.1 Size and Weight of Devices and Foundations

The majority of survey respondents under this category are developing horizontal axis turbine technologies (i.e. 7 out of 9 respondents). The range of turbine diameter sizes quoted varied between 4 – 21m, with one survey respondent quoting a range of diameter sizes. The turbine diameter range quoted by the majority of survey respondents was between 10 – 18m. Figure 9 illustrates a breakdown of the survey responses.

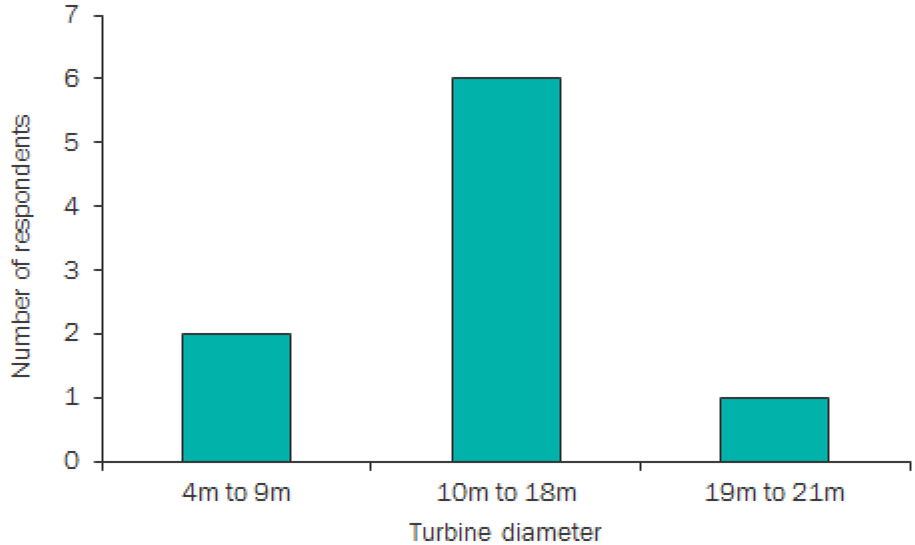


FIGURE 9 - TURBINE DIAMETER RANGE FOR LARGE TIDAL TECHNOLOGIES (>500KW RATED CAPACITY)

Most of the tidal devices under development by respondents have a gravity base foundation, with the remaining devices implementing a catenary mooring system. The dimensions of the foundations and platforms vary between systems. An overview of the range of technology dimensions and weights quoted by respondents is provided in Table 5.

TABLE 5 - SUMMARY OF LARGE TIDAL TECHNOLOGY DIMENSIONS AND WEIGHTS

Turbine diameter range:	4 – 21m; majority of respondents 10 – 18m
Number of turbines per device:	Single turbine – 4 survey respondents Multiple turbines – 5 survey respondents
Foundation / platform width:	10 – 80m; majority of respondents 10 – 24m
Foundation platform height:	6.3 – 66m; majority of respondents 10 – 14m
Dry weight of the nacelle:	Single turbine technologies: 100 – 300t Multiple turbine technologies: 1.5 – 75t
Maximum dry weight of the platform/foundation:	Single turbine technologies (Gravity based): 160 – 700t Multiple turbine technologies (Gravity based): 50 – 4400t Floating platforms: 220 – 500t

2.3.2.2 Projected infrastructure requirements

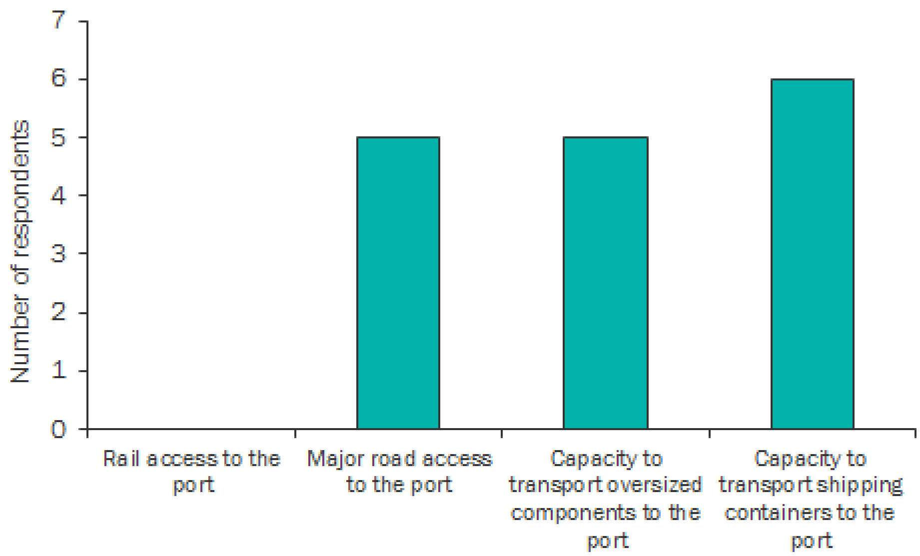
The following tables summarise the key findings related to the infrastructure requirements for large tidal technology developments (i.e. >500kW unit rating), including:

- Manufacturing requirements (Table 6)
- Assembly requirements (Table 7)
- Installation requirements (
- Table 8)
- Operation and maintenance (O&M) requirements (Table 9)

TABLE 6 - MANUFACTURING REQUIREMENTS

Turbine fabrication	4/8 survey respondents would be interested in fabricating their turbine in Nova Scotia. The requirements specified by those who would like to fabricate their turbine in Nova Scotia include: • Fabrication hall with an overhead crane of 10-15t and basic utilities (water, heat, etc.). Parts would be shipped to the facility in containers. • Machine shop. • Around 4000m^2 of working area, water depth at quayside minimum of 14m. • Shipyard, marine operations support facilities and shore side infrastructure.
Platform / foundation fabrication	All survey respondents stated that they would be interested in fabricating their foundation/platform in Nova Scotia. The fabrication requirements specified by respondents include: • The following facilities: a mechanical workshop, steel pipe works, steel and concrete fabrication facilities. • A large foundry able to manufacture equipment of up to 15m long. • Ship-building area with fabrication facilities, work site area and port space. The fabrication of one respondent's device requires a suitable area with appropriate bearing capacity, hold-back winch and proximity to deployment site. • Around 4000m^2 of working area, water depth at quayside minimum of 14m. • A dry dock with a minimum depth over sill of 5m and gate width of 25m.

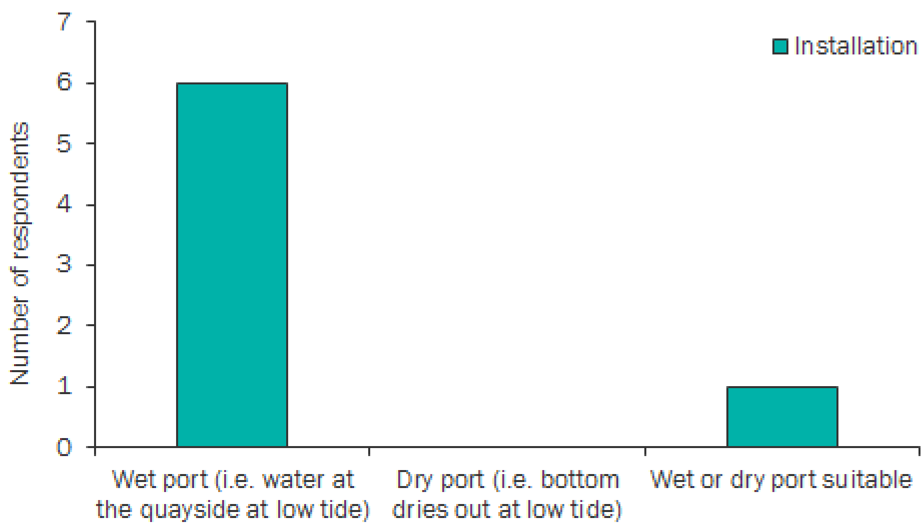
TABLE 7 - ASSEMBLY REQUIREMENTS

Transport	Developers were asked to specify the transport requirements for their operations (with the option of selecting all necessary transport requirements, i.e. more than one answer). The survey responses received are summarised below: • 5/8 respondents require major road access to the port. • 5/8 respondents require the capacity to transport oversized components to the port. • 6/8 respondents require the capacity to transport shipping containers to the port. • No respondents specified rail access to the port as a requirement.  Other transport requirements specified by respondents included: • Access for marine operations, cement trucks and work vehicles and access by boats.
Storage	**Storage facilities off site** Area required: 100 – 2500m^2 Load bearing capacity of storage area: 2.5t/m^2 – 10t/m^2 **Staging area (adjacent to the port)** Area required: 250 – 6300m^2 Note: the maximum staging area specified (i.e. 6300m^2) is a combined requirement for an area of 1800m^2 and 4500m^2.

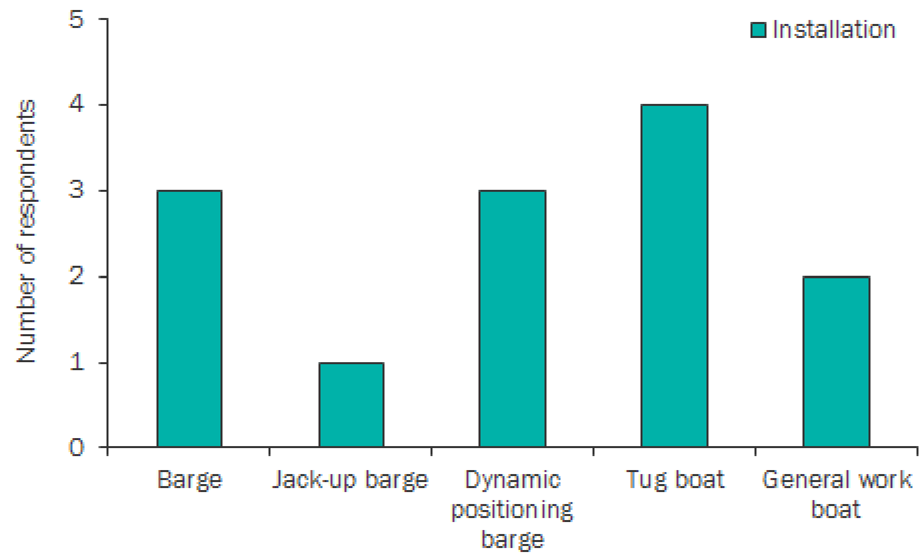
	Quayside area for storage Area required: 500 – 4000m^2 Some survey respondents did not have information on storage requirements currently available. **Quayside area for load-out of large components** Area required: 2500 – 5000m^2 Load bearing capacity of quayside: 2.5 – 10t/m^2 Some survey respondents did not require quayside area for the load-out of large components and others did not have this information currently available.
Launch and recovery	The following launch and recovery options were provided for developers to select from: • Slipway • Self-propelled modular transporter (SPMT) • Mobile crane • Heavy lift crane • Quayside crane The responses obtained are summarised below: • The majority of developers specified that at least one crane type is required. • Some developers stated than more one option for the launch and recovery operations would be suitable. • The option of using a SPMT was selected by developers with a gravity base foundation and turbine diameters ranging between 16 - 18m. • A lay down space adjacent to slipway, as well as alongside the dock is required to deploy one of the respondent's platforms. Lifting airbags and an area with appropriate ground conditions (e.g. slope and composition) and a hold back winch is also required. • A dry dock was specified as a requirement by one respondent.
Crane lifting capacities	Mobile crane: 200 – 300t Heavy lift crane (on-board a vessel): 300 – 800t <u>Quayside crane:</u> Bottom mounted technologies: 200 – 300t

	Floating platform technology: 10t

TABLE 8 - INSTALLATION REQUIREMENTS

Impact on ports	• A wet port was selected as a requirement by the majority of developers for installation activities. • A minimum water depth of 8m at the lowest astronomical tide (LAT) was specified as a requirement by one respondent. The survey responses are summarised in the following graph. 
Vessels	Developers were asked to specify the vessel requirements for their installation operations. The survey responses received are summarised in the following graph.

<table>
<tr>
<td></td>
<td>



Other requirements specified by survey respondents include:

Other vessels specified include a purpose built barge which is used to meet the respondent's heavy lift capacity requirement.
A 20t bollard pull multicat with a winch of 40t capacity and crane of 10t nominal capacity.
Tugs with a bollard pull of 55 - 80t capability.
Remotely operated vehicles (ROVs) may be required.

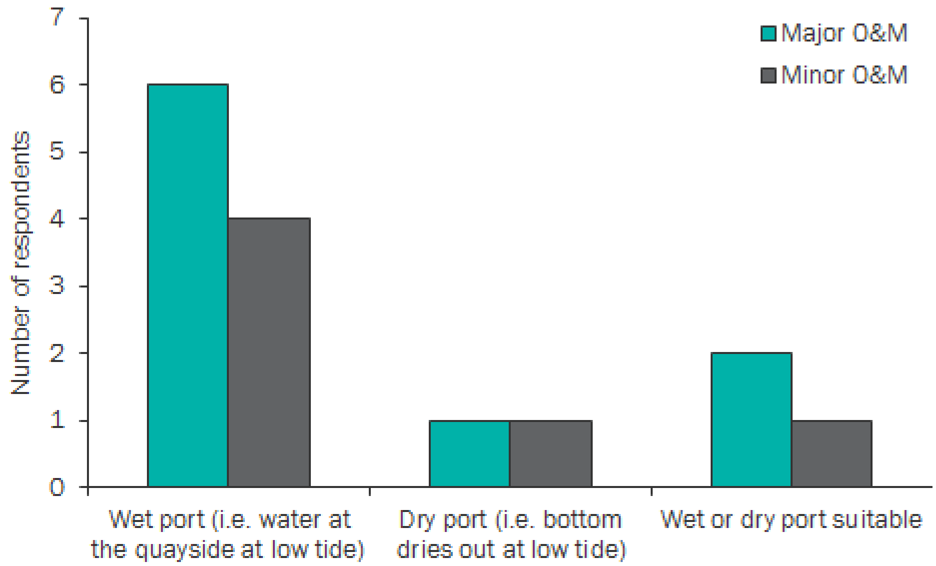
</td>
</tr>
</table>

TABLE 9 - O&M REQUIREMENTS

<table>
<tr>
<td>Impact on ports</td>
<td>

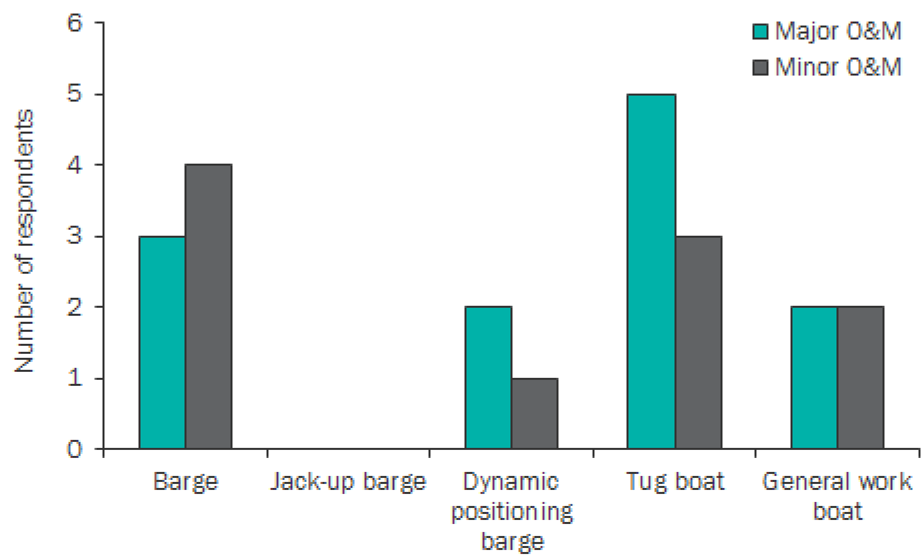
A wet port was selected as a requirement by the majority of developers for O&M activities.
A minimum water depth of 8m at the lowest astronomical tide (LAT) was specified as a requirement by one respondent.
One respondent specified the need for both a wet and dry port for major O&M activities (presumably for different O&M activities).
Some respondents did not provide a response for their port requirements for minor O&M.

The survey responses are summarised in the following graph.
</td>
</tr>
</table>

	 Other comments from survey respondents include: • One respondent specified that a location for dry docking every 10 years as well as a workshop for maintenance is required.
Importance of the proximity to the port	One survey respondent stated that the proximity of the port to the deployment site was a decisive factor in the deployment of their foundation structure. From the remaining survey respondents, 3/7 respondents stated that the proximity of the port to the deployment site is important. The developers who selected this option are all at the commercial generation stage. Other respondents (i.e. 4/7) said that the proximity to the port is desirable. One respondent stated that it would be possible to safely tow the devices long distances but this adds to the installation cost and can impact the economics.

Vessels

Developers were asked to specify the vessel requirements for their O&M operations (with the option of selecting all vessels types required). The survey responses received are summarised in the following graph.



Other requirements specified by survey respondents include:

- Other vessels specified include a purpose built barge which is used to meet the respondent's heavy lift capacity requirement.
- A 20t bollard pull multicat with a winch of 40t capacity and crane of 10t nominal capacity.
- Tugs with a bollard pull of 55 - 80t capability.
- Remotely operated vehicles (ROVs).
- An additional consideration would be an operations specific catamaran vessel.

Frequency of O&M activities

The frequency of O&M activities varied between developers. The range of survey responses received are summarised below:

- Device inspections (single turbine): 0 to 10/year
- Device inspections (multiple turbines): 3/year to bi-weekly in operation mode
- Minor maintenance events: 5/year to once every 5 years
- Major maintenance events: Every year, every 5 years or every 10 years

2.3.3 SMALL TIDAL TECHNOLOGIES (UP TO 500KW)

The survey responses for tidal technologies with a generating capacity of up to 500kW (i.e. 6 of the 15 respondents) have been analysed and are presented in this section.

The amount of information provided by small tidal technology respondents is significantly more incomplete to that presented by large tidal technology developers. This may be influenced by the current development stage of the technologies and the lack of currently available information on projected infrastructure requirements.

2.3.3.1 SIZE AND WEIGHT OF DEVICES AND FOUNDATIONS

The majority of survey respondents in this category are also developing horizontal axis turbine technologies. An overview of the range of technology dimensions and weights quoted by respondents is provided in Table 10.

TABLE 10 - SUMMARY OF SMALL TIDAL TECHNOLOGY DIMENSIONS AND WEIGHTS

Turbine diameter range:	4 – 14m
Number of turbines per device:	1 turbine – 3 respondents Multiple turbines – 3 respondents
Foundation / platform dimensions:	Length: 14 – 17m Width: 9 – 14m Height: 2.5 – 9m
Dry weight of the nacelle:	1 – 28t (site dependent)
Maximum dry weight of the platform/foundation:	Gravity base foundations: 100 – 300t (site dependent) Floating platforms: 30 – 40t

2.3.3.2 PROJECTED INFRASTRUCTURE REQUIREMENTS

The following tables present information on the projected infrastructure requirements for small tidal technologies (i.e. up to 500kW rated capacity), including:

- Manufacturing requirements (
-
-
- Table 11)
- Assembly requirements (Table 12)
- Installation and operation and maintenance (O&M) requirements (Table 13)

TABLE 11 - MANUFACTURING REQUIREMENTS

Turbine fabrication	2/4 survey respondents would be interested in fabricating their turbine in Nova Scotia. The requirements specified by those who would like to fabricate their turbine in Nova Scotia include: • Steel fabrication, cable fabrication, composite manufacturing and electrical machine manufacturing. • Transport; quayside assembly; quayside lifting; deployment vessels. One respondent also had the following comment: • Some of the precision engineering systems already come from a Nova Scotia based supply chain.
Platform / foundation fabrication	All survey respondents stated that they would be interested in fabricating their foundation/platform in Nova Scotia. The fabrication requirements specified by respondents include: • Steel, cable and concrete fabrication facilities and electrical and assembly skills. • Transport; quayside assembly; quayside lifting; deployment vessels.

TABLE 12 - ASSEMBLY REQUIREMENTS

Transport	Developers were asked to specify the transport requirements for their operations. The survey responses received are summarised below. • Major road access and the capacity to transport shipping containers to the port (from Halifax). • Platforms are designed to breakdown into modules for transportation by flatbed truck or shipping container. • Locally available resources normally suffice.
Storage	**Storage facility offsite** Area required: 400m^2 Load bearing capacity of storage area: up to 10t/m^2 **Staging area (adjacent to the port):** 200 – 1600m^2 **Quayside area for storage**

Launch and recovery	Area required: 100 – 400m² Load bearing capacity of quayside: up to 10t/m² [4] **Quayside area for load-out of large components:** 150 – 1600m² Many small tidal developers did not provide a response to this question; one respondent stated that the answer to this question very much depends on the scale and timing of the project. The following launch and recovery options were specified by survey respondents: • Slipway • Mobile crane • Quayside crane Other requirements specified by survey respondents include: • One respondent specified that two options could be used to launch their device: A mobile crane for assembly, and to launch from pier-side, or assembly could also occur on a slipway, and launched from the slipway. • A vessel crane may suffice depending on the port and the vessel.
Crane lifting capacities	Mobile crane: 20 – 100t Quayside crane: 20 – 200t

TABLE 13- INSTALLATION AND O&M REQUIREMENTS

Wet versus dry ports	Many small tidal developers did not provide a response to this question. One respondent specified that a wet port is required for installation and major O&M activities, and a dry port is required for minor O&M activities. Another respondent specified that a wet or dry port would be suitable for installation, major and minor O&M.
Importance of the proximity to the port	Many small tidal developers did not provide a response to this question. Two respondents specified that the proximity to the port is desirable. One survey respondent stated that tow-out is relatively easy for the floating platform. Open ocean towing in rough weather should be avoided. Its modular design and small size should allow assembly and launching relatively close to installation sites

[4] Minimum load bearing capacity requirements should be confirmed with small tidal developers as there was uncertainty in some values provided.

Vessels	Many small tidal developers did not provide a response to this question. One respondent specified that a general workboat is required for installation, minor and major O&M. Another respondent specified that a tug boat and general work boat are required for installation and for major and minor O&M a general work boat is needed. The installation of the respondent's device consists of deploying a mooring spread with a workboat/tug, launching and tow-out of the device with a large workboat/small tug and cable laying to shore with a work boat.
Frequency of O&M activities	Many small tidal developers did not provide a response to this question. One respondent specified the following O&M activities: • Device inspections: 2/year • Minor maintenance: 1/year • Major maintenance: Once every four years Another respondent specified the following O&M activities: • Device inspections: 2-4/year at the installation site – workboat access • Minor maintenance: 1-2/year at the installation site – workboat access • Major maintenance: Turbine replacement for major repairs, either on site (workboat access) or haul into port and quayside turbine replacement.

2.3.4 SUMMARY OF KEY INFRASTRUCTURE REQUIREMENTS

A summary of the key developer requirements for large and small tidal technologies identified from the survey are presented in Table 14. The requirements identified are linked with the infrastructure available in the gap analysis presented in Section 5.

TABLE 14 - SUMMARY OF KEY INFRASTRUCTURE REQUIREMENTS

Large tidal technologies
 	
(>500kW rated capacity)
	• All survey respondents stated that they would be interested in fabricating their foundations or platforms in Nova Scotia.
	• The upper limit of the storage and quayside areas specified by respondents is listed below:
	  ○ Storage facility offsite: 2500m^2
	  ○ Staging area (adjacent to the port): 6300m^2
	  ○ Quayside area for storage: 4000m^2
	  ○ Quayside area for load-out of large components: 5000m^2
	• The maximum load bearing capacity requirements are:
	  ○ Storage area: 10t/m^2
	  ○ Quayside: 10t/m^2
	• Cranes are required by the majority of developers during the fabrication or launch

	and recovery stage. The maximum crane lifting capacity requirements are: o Mobile crane: 300t o Heavy lift crane (on-board a vessel): 800t o Quayside crane: 300t • A wet port was selected as a requirement by the majority of developers (6 out of 7 respondents) for installation activities. • A wet port was also selected as a requirement for major O&M activities (6 out of 8 respondents) and minor O&M activities (4 out of 6 respondents). • The proximity of the port to the deployment site has greater importance to commercial generation scale projects. • The frequency of O&M activities varied considerable between device types. • Most respondents did not specify additional port requirements (e.g. minimum depth). Only two respondents specified a minimum depth requirement; one developer requires a depth of more than 8m at LAT at a port and another specified a minimum water depth of 14m at the quayside. See Section 2.4.4 for further discussion on water depth based on vessel requirements.
Small tidal technologies (up to 500kW rated capacity)	• All survey respondents stated that they would be interested in fabricating their foundation/platform in Nova Scotia. • The upper limit of the storage and quayside areas specified by respondents is listed below: o Storage facility offsite: $400m^2$ o Staging area (adjacent to the port): $1600m^2$ o Quayside area for storage: $400m^2$ o Quayside area for load-out of large components: $1600m^2$ • The maximum load bearing capacity requirements are: o Storage area: $10t/m^2$ o Quayside: $10t/m^2$ • Mobile or quayside cranes are required by the majority of developers during the fabrication or launch and recovery stage. The maximum crane lifting capacity requirements are: o Mobile crane: 100t o Quayside crane: 200t • A limited amount of information was provided for installation and O&M activities for small tidal developments. The requirements specified include a wet port for installation and major O&M, and a dry port for minor O&M activities by one respondent. Another respondent specified that a wet or dry port would be suitable for installation, major and minor O&M. • No respondents specified additional port requirements (e.g. minimum depth). See Section 2.4.4 for further discussion on water depth based on vessel requirements.

Developers were asked to provide information on their tidal technology which could be installed in Nova Scotia in the short term (i.e. next five years). Some of the survey respondents also said that they would anticipate some major changes in their infrastructure needs in the medium term (i.e. 10-year horizon). Some changes highlighted by developers include:

- The need for a fabrication facility closer to the deployment site.
- The size of the infrastructure will increase if size of the project is high (hundreds of turbines).
- One survey respondent stated that a specialized vessel designed for the tidal industry would be beneficial for the continued development of the industry.

2.4 Summary of the Key Findings

The survey captured a wide range of information from different tidal developers (15 respondents; 9 large tidal and 6 small tidal developers), which can be used to assess current trends and any changes in tidal technology developer needs from the 2011 study [1]. This section summarises the key findings that define the developer's needs. The main high-level conclusions of the study are first presented, followed by a more detailed discussion of specific issues, including:

- How changes in the global tidal industry and proposed future projects in the Bay of Fundy impact the findings from the 2011 study.
- The limitations, if any, related to servicing devices out of a dry port.
- An evaluation of proximity requirements for O&M versus manufacturing requirements.

2.4.1 High Level Conclusions

- The tidal stream industry has been slower to develop than anticipated; many of the leading technologies are still in their infancy, and it is only now that the first tidal array (MeyGen's Inner Sound project) is being constructed in the UK.
- Whilst it seems that globally a reasonable amount of capital investment is still available for prototype demonstration, funding for early arrays is less accessible. This is due to a combination of the technologies being not yet fully proven, high early stage capital and O&M costs and uncertainties in market support measures.
- That said, however, there are still over 100 known tidal technology developers worldwide, and a significant number of these (22) were shortlisted in this study as being technically and financially credible.
- All fifteen developers who provided data for the survey indicated either firm plans to deploy in Nova Scotia, or a willingness to come to Nova Scotia within the next ten years. Although many have not yet carried out detailed appraisals (resource, metocean, geotechnical, grid etc.), the site conditions, local infrastructure and market support are seen as viable – nobody has stated there are insurmountable obstacles to developing in the Bay of Fundy area.

- Whilst there are no devices currently in the water at FORCE, several projects are at an advanced stage of development.
- On the basis of the survey, it is therefore considered that there are still good prospects for harnessing the resource in Nova Scotia, but it is likely to be on a slightly longer time scale than originally anticipated.
- The requirements survey covers a wide variety of tidal device types, including a multi-turbine platform, single turbine bottom mounted devices (both with gravity and piled foundations), and moored catenary platforms. Each technology type has different plans for installation and O&M, and these have been assessed in terms of the port infrastructure and vessel needs.
- In terms of appraising the development status of each technology it was difficult to assess this on the basis of information received; many developers were not in a position to provide the information requested owing to their early stage of development and inevitable uncertainties about future plans. This was especially true for the emerging smaller devices. A qualitative assessment has been provided, however, in Table 4 based on public domain data and the consortium's knowledge.
- History demonstrates how difficult it is to predict the course of an industry at such an early stage. Since the 2011 study [1], there have been several significant changes in the tidal industry, including (not exhaustively):
    - Some developers (e.g. Voith) have ceased development.
    - Marine Current Turbines Ltd., which was formerly in consortium with Minas Pulp & Power for a project at FORCE, has been sold by Siemens to Atlantis Holdings. It is understood that Atlantis intended to continue with development of MCT's technology, however it is not known whether the SeaGen-S and SeaGen-U platforms are currently being actively developed.
    - The period since 2011 has seen the progression of a range of moored floating platforms such as Schottel's Triton, XTIDAL's XIP and SME's PLAT-O tidal platform, as well as novel devices such as Flumill's gravity based device and some small propeller and cross-flow turbines.
- With the possible exception of Schottel's Triton technology (see below), these changes do not significantly alter the infrastructure requirements; the lifting requirements for turbine nacelles, foundations and anchors are enveloped by the existing requirements for the larger gravity base and tripod technologies, and the O&M requirements can be serviced from the same range of ports.
- Since 2011, the Triton platform has been introduced and is currently part of the Black Rock Tidal Power project at FORCE. The gravity base and associated turbine supports are large structures, and their fabrication, assembly and load-out may require specialist engineering and port facilities. For the FORCE project, the developer is understood to be adapting the design and marine operations to work within the constraints of existing local resources, in

particular the lack of locally-based heavy lift vessels, which are prohibitively expensive to mobilize from Europe.

- Future changes in the industry are inevitable, but cannot be reliably predicted; on the basis of the last five years' progress, however, it can reasonably be concluded that most generic types of device have now been identified, and that major changes to developers' infrastructure requirements relating to installation in the short to medium term are unlikely. The O&M infrastructure requirements of developers is less clearly defined from the survey, with a large variation in the responses received on the anticipated frequency of O&M activities planned for different device types. The uncertainty associated with developer O&M requirements is considered to be more inherent to the advancement of the industry than incomplete survey information.
- The quayside lifting requirements in terms of fixed and mobile cranes and SPMTs have not changed since the 2011 study. A maximum lift weight of approximately 300t represents the envelope. In the short to medium term, crane hire is considered likely to be the optimum route, until the pattern of port usage is better established for the industry, and the main infrastructure issue is therefore to ensure that quayside loading capacities at selected ports are adequate for the maximum weight of lift required.
- Four developers identified either a requirement (or a feasible option) to use a slipway for deployment or O&M. Such a facility could have shared use with local commercial fleets and leisure craft, and could readily be integrated adjacent to a wharf facility, for example at the proposed Digby development.
- Use of a dry dock is under consideration by only one developer as a possible option, to overcome the port limitations local to FORCE and Minas Passage. Dry docks are expensive to build and operate, however, and the size and specification are not clear. If bespoke to a single developer, it is also not clear whether it could be operated as a shared facility. It is suggested that further consideration of dry docks is parked, unless and until there is a firm need.
- Only two developers specified a minimum quayside water depth requirement; one was for 8m @ LAT, and the other was a minimum depth of 14m. See Section 2.4.4 for a detailed discussion on water depth based on the vessel utilised by tidal developers and their standard water depth requirements.
- Proximity to site was identified as an important or desirable parameter for installation and O&M. It is considered likely that for light and medium maintenance on early projects at FORCE, developers will take advantage of the local existing dry ports, and will adapt their design and maintenance strategies to accommodate any infrastructure limitations. Some minor upgrades may be needed to do this, however these would be technology- and port-specific and therefore likely to be funded by the developers themselves.
- The majority of survey respondents (7 out of 9) specified a wet port as a requirement for installation. The use of a dry port for deployment is potentially problematic for installation activities except for possibly the smallest devices.

- Currently anticipated major O&M requirements include a wet port, which was selected by the majority (7 of 10) of respondents. With respect to minor O&M activities, half of the respondents indicated a preference for a wet port while half preferred a dry port.
  The use of a dry port is considered technically feasible for O&M subject to (i) a more detailed assessment of the tidal access times, and (ii) provision of a "bottoming-out" bed. The extent to which developers have considered O&M from a dry port is not clear from the survey data.
  If O&M is conducted from distant wet ports, there are potential issues with transit times, the need for on-board accommodation, increased fuel and crew costs, increased weather window susceptibilities etc. Essentially the costs and risks increase with distance.
- Road access was identified as a significant requirement by many developers, but none stated they required rail access. Five developers required the ability to transport over-sized items to the port, and seven developers required container transport to the port.
  In this context, it is noted that Halifax has both an international container port and road and rail access to Canada and hence the US network, and is respectively 230 km from Digby and 80km from Hantsport by road on good roads. Whilst Halifax is a long way from Minas Passage and the Bay of Fundy by sea, it is therefore feasible to consider developing port infrastructure at Digby making use of the road link to access the fabrication and engineering facilities in the Halifax region, and import specialist equipment via containers or form manufacturing sites elsewhere in North America.

- The infrastructure required for subsea cabling was not addressed in this study, for a number of reasons:
  - Cables will be shipped in from Europe or the US, and will arrive on storage reels or in tanks on dedicated cable vessels; this does not impose any specific new infrastructure requirements.
  - The cables at FORCE were installed using locally available barge spreads and engineering resource, and this is expected to be the case for most of the early arrays. Again, this does not call for new infrastructure.
  - The methods and subsea infrastructure for connecting multiple devices together and back to shore are still under development; there are many possibilities and no real convergence as yet; it is likely however, that existing infrastructure will be adequate.

  It is possible that future large developments may require above-surface offshore platforms, potentially posing a need for gravity or piled foundations and surface-breaking piles. This is too far in the future, however, to be able to comment meaningfully at this stage on the infrastructure requirement of such an approach.

- Overall, therefore, it is fair to conclude that although there have been some changes to the main industry players, with some exits and some new market entrants, and an increase in development activity in regard to the smaller devices, the infrastructure requirements have not changed significantly since the originally 2011 study [1].

Some of the main points are considered in more detail in the following sections.

2.4.2 THE GLOBAL TIDAL INDUSTRY AND IMPLICATIONS FOR FUTURE DEVELOPMENT IN NOVA SCOTIA

Overall the tidal industry has developed much more slowly than originally anticipated. The cost of tidal energy has remained high, which has made raising capital for early demonstrators and commercial arrays increasingly difficult. Established developers' plans have frequently had to change as a result, and several have in fact ceased trading; whilst, on the other hand, new technologies are still emerging, however the companies behind them are inexperienced and the technologies unproven.

The main uncertainties within the UK and European tidal industry are:

1. All the potentially 'ready' technologies are still at a relatively early stage of development, even those that have had MW-scale prototypes operating at sea for some years. Many are unproven at commercial scale, and no arrays have yet been operated;
2. Some developers have ceased activity, whilst other new technologies are still emerging. It is possible that none of the currently perceived 'industry leading' devices will ultimately be successful, and that one or more of the novel disruptive technologies that are currently under early stage development will emerge. The evidence of the last fifteen years has been that early movers are not necessarily the most likely to succeed;
3. The costs of tidal energy are still high, and cost of energy studies have shown that all technologies require significant levels of funding support (capital and revenue) in order for installations to be commercially viable. In the UK and Europe, the uncertain level of long-term market support available makes it difficult to raise capital for demonstrators or early commercial arrays;
4. In the UK, several of the power utilities and major OEMs that were previously supporting marine energy developments have closed down their marine departments to focus on offshore wind, or reduced them to a 'watching brief' status;
5. Several of the major OEMs that once owned or held a stake in a tidal developer have either pulled out of the industry or are showing signs of pulling out (Rolls Royce, Siemens, ABB and Voith Hydro).

The above summary aims to raise awareness of the realities and the uncertainties that developers face in trying to commercialise a technology in harsh remote environments, within the context of a competitive energy market. This study has identified those developers (twenty-two in number) which appear to be technically and financially credible, both now and for the near future, and the results suggest a positive conclusion for developments in Nova Scotia. However, the above uncertainties apply equally to Nova Scotia as they do to Europe; future change is inevitable, and could see either an explosion of activity if a major project developer or utility adopts a proven technology, or a collapse of the tidal stream industry if it fails to meet the required cost point compared with other sources of renewables and non-renewable energy.

2.4.3 Developer Technical & Financial Strength

For understandable reasons of confidentiality, it was not possible to question developers directly for information about their funding status. Table 4, however, identifies the information provided on projects and strategic partnerships with OEMs, utilities or independent project developers, supplemented with information from public domain sources. Twenty-one of the shortlisted developers have demonstrated the capability to design, build, install and test a prototype at a reasonable scale (50kW to 1.5MW) in a representative ocean environment.

2.4.4 The importance of water depth

Water depth is a key criterion since it determines the maximum draft of vessels that can access a port, and in the case of a dry port, it determines the amount of time each day when vessels of a certain draft can access the port.

It is useful to distinguish port requirements for installation from those for O&M. Installation ports generally require a larger water depth than O&M, because the vessels are larger, although this is not always the case and it depends on the maintenance strategy and the anticipated frequency of major overhauls. For example, if unplanned failures between major overhauls occur at sea, the O&M port may only have to accommodate small shallow draft vessels for the transport of personnel and light equipment; this could feasibly be carried out at dry ports subject to appropriate seabed conditions and vessel designs. If, however, O&M requires large pieces of equipment to be transported back to shore and lifted out of the water (complete nacelles for example), then the O&M port is likely to have similar vessel and water depth requirements as for installation. This may be the case for major overhauls, when the complete turbine and possibly part of the support structure and foundations need to be recovered.

It should be noted that some developers are suggesting that it would be useful to construct a bespoke DP installation and O&M barge/workboat for the region. Light/medium maintenance could be carried out on the deck on this vessel, avoiding the need to recover items to shore, and it could act as a crane and towage vessel for major overhaul recovery. This option is unlikely to be commercially justifiable in the short to medium term, but may be worth considering for larger arrays in the longer term.

Considering installation operations first, large scale devices are likely to deploy the foundations or mooring anchors first, followed by subsequent placement of the turbine/support structures, and finally complete hook-up of the cabling. This is the case for all types of foundation - seabed-mounted gravity bases, piled foundations, and moored floating foundations. Many of the smaller devices may be fully assembled onto their foundations on the quayside and deployed as complete units.

Most device foundations will be fabricated onshore, at or close to a suitable load-out quayside. Turbines and major components are likely to be imported by road or sea, and also assembled in a quayside facility. Small turbines may be delivered as complete nacelles, for fitting in to foundation frames.

The main types of operation required for load-out and transport to site are discussed below. These are technology-specific, however there is a general difference between large and small TECs in terms of reduced crane requirements and reduced quayside space required. There is one exception, however, which is a floating moored device that uses a heavy gravity clump anchor; this cylindrical structure will need to be fabricated on the quayside and represents a 300t lifting requirement. This is for deployment only and in service the buoyant nacelle, which is <30t, will be recovered to shore for maintenance.

The typical load-out operations proposed by the developers include:

- Lifting the foundation/mooring anchors onto the deck of the main installation vessel, which could be a DP construction vessel, heavy life crane barge, jack-up barge or flat barge, for transport to site.
- Vessel and barge cranes will be used where possible to self-load, otherwise a mobile crane will be needed.
- For piled foundations, the drilling and grouting spreads will have been pre-mobilised onto the vessel at the vessel mobilisation quay (which may be elsewhere depending on where the vessel is chartered).
- Alternatively, the foundations can be launched into the water on a slipway on a powered trolley or cradle of some kind, or using a fixed restraining winch.
- Float-out of the foundation and towage to site by tugs is being considered by some developers. This requires lifting into the water (by crane or on a slipway) and placing it on the sea bed, followed by floating it with airbags or some other form of buoyancy/de-ballasting system.

As a rough guide, the vessels typically available and used for tidal operations, and their limitations, are as follows:

- Class DP2 Offshore Construction Vessel (CSV) – these vessels are typically 90m-160m LOA (Length Over All), 20-26m beam and with a draft generally in the range 6m-8m; vessels towards the lower end of the range will be adequate for the currently proposed tidal developments. Vessels fitted with Voith-Schneider propulsion systems have historically proven better station-keeping and stability in tidal currents than vessels fitted with tunnel thrusters or Azipods, however they have a slightly higher draft. They can hold to within a 1-2m working circle (depending on the combination of tide, wind and wave) if the vessel is positioned predominantly head-on to the current; most vessels will hold against 7kt with a 20kt beam-on wind.

- Anchor handling tugs (AHTS), offshore supply vessels (OSV) and platforms are generally smaller than CSVs and have smaller drafts, but have similar DP and station-keeping capabilities.
- Jack-up barges are typically between 70m and 170m long and up to 40m beam. They can stand in 40m water (largest ones up to 70m) and with appropriate qualification can stand in current of 7kt. The jacking process is weather limited, especially at the point of leg touchdown onto hard rocky seabeds, and may be limited to 1.5kt current max. However, once jacked up, the vessels are much less sensitive to weather and can (subject to a vessel and site-specific assessment) withstand 8kt currents and waves of several meter significant wave height (H_s).

One developer is proposing to use a jack-up barge for installation. Jack-ups have the advantage that they provide a fixed platform from which to conduct seabed installation works, and avoid the reliance on DP vessels with the attendant risk of run-offs. In terms of the port requirements for jack-ups, clear access and suitable seabed jacking conditions are the main issues that may be different from accommodating DPs. The vessels generally transit and float into harbour with legs up to minimise draft, so any overhead lines or obstructions must be assessed. In harbour the key thing is to ensure the vessel can jack up close enough to the quayside to reach over and self-load equipment onto the deck using its crane. The foot loading can be considerable and can interact adversely with the integrity of the piling of the quayside itself, and a site-specific jacking assessment is therefore needed. In addition, underwater materials close to the quayside and any other obstructions to jacking should be avoided.

There are many possibilities and each technology developer is preparing their own detailed marine operations plans. Looking at wet ports within 150km sea distance of FORCE, a minimum (low tide) water depth of 9m is available at the wet ports considered in this study; Saint John (NB) (see Section 3.1.4) and Digby (see Section 3.1.1).

It is considered that a depth of 9m @ LAT envelopes the minimum water depth requirement of tidal developers[5]. This depth would enable access by all the main types and sizes of vessel likely to be required for both deployment and O&M - DP construction vessels, anchor handlers, heavy lift crane barges, jack-up barges, flat barges, tugs and support vessels. It therefore represents a good starting point when considering a gap analysis for port infrastructure in Nova Scotia.

Industry feedback from a stakeholder in the tidal sector in Nova Scotia specified a required quayside water depth range between 8.5 - 9.1m based on previous experience of tidal device deployments.

[5] A minimum water depth of 14m was specified as a requirement by one survey respondent, however this is considered to be an outlier to the envelope and is not considered as a requirement by the majority of tidal developers.

This requirement is captured in the minimum water depth envelope (i.e. 9m @ LAT) considered for tidal developers and adopted in the gap analysis presented in Section 5.

2.4.5 LIMITATIONS OF OPERATING OUT OF "DRY" PORTS

The 2011 study [1] identifies that there are no wet ports within 50km of FORCE. In deciding whether to use a wet or a dry port for O&M for developments at FORCE, it comes down to a commercial balance between:

- the port facilities that are available - the further away from FORCE/Minas Passage, the greater the available draft and the better the wharf space are likely to be, and the lower the costs of any infrastructure upgrades for a developer;
- the distance to site - which determines the costs of O&M, the larger the distance the greater the costs and operational risks.

In terms of transit costs of vessel, equipment spreads, crew, and fuel etc. it is probably reasonable to assume they are proportional to transit distance. However, the following factors also need to be taken into account:

(i) the greater the transit distance, the longer the time a vessel is likely to have to spend punching against the tide, the slower will be the transit and the greater the fuel burn;

(ii) longer transits are more weather-sensitive, so overall availability is likely to be reduced, and on-board accommodation may be required to allow crew changeovers. For example, the transit time to and from a port located 100km away from site could be five hours if steaming at 12kt (time is very dependent on the type of boat - a multicat might only steam at 8kt max economic speed); this leaves virtually no time on site to do work within a 12hr shift and get back to port, so larger vessels with on-board accommodation will be needed - and hence higher day rates. Operationally, it is then necessary to plan for a min. 24hr good weather window, with an emergency abort plan etc., and generally the larger the weather window required the less often it arises, depending on the site metocean characteristics;

(iii) a port within 20km can clearly avoid these problems, but of course a dry port requires a "bottoming-out" bed and the use of vessels designed to bottom-out. An important factor is the degree of dryness of the port - in other words, how many hours of wet operation and access at what draft is available over an average each day. The detailed requirements will all depend on the maintenance regime of the specific developer. If all light and medium maintenance is carried out offshore, then (subject to the range of times needed for each of the maintenance operations) a shallow draft workboat that can put to sea and get back throughout the "wet" period, carrying technicians only may be acceptable; but if maintenance requires a device to be towed back to shore, or equipment needs to be brought back on a barge, then a dry port may not be feasible. If it takes a long time to recover the device offshore, a dry port may never offer a sufficient access window.

In summary, the survey results indicate that developers are not currently proposing to use dry ports extensively for O&M. However, the extent to which developers have considered O&M (and installation) from a dry port is not clear from the survey data. As discussed in Section 1.2, it is recognised that each developer is likely to have a level of flexibility which may allow them to tailor their deployment and recovery strategies to the available infrastructure.

It is considered that those developers who carry out most light and medium maintenance offshore may prefer to adapt their operations to a local dry port. Conducting O&M activities out of a dry port closer to the deployment site offers the advantage of the greatly reduced costs and risks during sea transit. However, if maintenance requires bringing larger equipment into harbour or onshore, then developers may have no option but to use a wet port further away. Many developers have not yet defined their O&M strategies to a level where they can make this decision, so it remains an open issue.

In some cases, innovative solutions may be implemented to extent the capacity of dry ports and open up new possibilities to support developer activities. Some examples of innovative solutions already under consideration in Nova Scotia include the use of marine railways or slipways that make use of the high tidal range to aid in deployment and recovery, and the successful cable laying performed at the FORCE site, using local marine resources.

2.4.6 PROXIMITY REQUIREMENTS FOR MANUFACTURING

Several developers expressed a requirement for shipyard, fabrication and heavy manufacturing facilities. Ideally these would be at the deployment port to minimise transport and handling of heavy components, however it is not reasonable to propose establishing major new facilities unless and until the industry has moved into very large scale deployments.

Saint John, Halifax and Pictou (where two of the FORCE projects have or are planning to manufacture foundations) already have major engineering facilities, and Halifax and Saint John have access by road, rail and sea to imports of specialist components from elsewhere. In the short and medium term, therefore, it is expected that manufacturing will be carried out at the nearest suitable facility, selected by developers on a case-by-case commercial basis, and that components or assembled nacelles will be transported by road or sea to the assembly/deployment quayside. This puts Digby in a good position for development as a deployment and O&M port, since it has easy road access to Halifax, and also Ro-Ro ferry access to Saint John for trucking in components.

3 PORT ASSESSMENT

3.1 PORT SURVEY

The client requested the following ports be examined, to update the findings of the 2011 report: Digby, Hantsport, Parrsboro in Nova Scotia, and Saint John NB. Additionally, the West Bay area in Minas Passage was examined to assess the viability of creating infrastructure in this area.

FIGURE 10 – PORT ASSESSMENT LOCATIONS

A port assessment survey was developed and sent to contacts at the ports for completion (found in Appendix B). Follow-on inquiries via email and phone provided additional information for each port.

The following sections provide a brief summary of each port. Section 1.1 provides a compilation table of the collected data.

3.1.1 Digby

FIGURE 11 – FISHERMAN'S WHARF IN DIGBY (IMAGE EXTRACTED FROM HTTP://WWW.PORTOFDIGBY.CA/IMAGES/DIGBY_TIDAL_WEB.PDF)

FIGURE 12 – ARIAL VIEW OF FISHERMAN'S WHARF IN DIGBY (IMAGE EXTRACTED FROM GOOGLE MAPS, JUNE 20, 2016)

The Port of Digby consists of a combined Marginal/spur wharf with two ells, and 11 floating docks. It is used primarily by the local fishery, with a high usage of its docks. At low tide the port is wet, with a quayside depth of 9m. Tidal variation is 9.1m.

The port is accessed by sea from the Bay of Fundy via the Digby Gut, where currents can reach up to 5 kts during tide run. The distance to Minas Passage by sea is 115km.

The port is accessed by land via 100-series highway (within 5km). Distance to the Halifax metropolitan area is approximately 230km. A ferry offers service to/from Saint John NB, for passenger car and commercial truck traffic. A nearby airport provides access for small commuter aircraft.

The Municipality of the District of Digby commissioned a study in 2012 [16] that investigated the potential of tidal energy development in the Bay of Fundy, its potential economic impact, and offered recommendations for port infrastructure development in the area. The study investigated three areas for a green-field development: immediately north of the existing fisherman's wharf (site 1 in Figure 13), a location along Shore Road near the public look-off (site 2), and a third location immediately north of the existing ferry terminal facility (site 3).

FIGURE 13 - PROPOSED LOCATIONS FOR DIGBY DEVELOPMENT (IMAGE EXTRACTED FROM [16] WITH PERMISSION)

3.1.2 HANTSPORT

FIGURE 14- ARIAL VIEW OF HANTSPORT WHAARF AND GYPSUM FACILITY (IMAGE EXTRACTED FROM GOOGLE EARTH, JUNE 20, 2016)

Hantsport is located approximately 75 km northwest from Halifax, on the Avon River. The main wharf is privately owned and previously used for pulp and paper operations. It consists of a marginal wharf, with adjacent warehouse facilities. There are 3 acres available within 1km for storage. The wharf is infrequently used, and would require evaluation of suitability for future use.

Access to the Bay of Fundy is via the Avon River, and is approximately 40km by sea to the Minas Passage. At low tide, the wharf is dry. At high tide, the water level can be as high as the wharf deck, offering up to 9.4m draft alongside.

Access to 100-series highway is within 1 km, with rail access within 1km.

To the north of the wharf is a gypsum loading facility, which has been inactive since 2011, consisting of pile piers for docking. Loading chutes lead to the gypsum plant facility. There is no wharf deck at this facility.

In 2011, a preliminary investigation looked at a launch ramp concept to the north of the dock. Using either a trolley on rails, or self-propelled modular transporters, (SPMTs), the concept would use the rise and fall of the tide to advantage for the launch and retrieval of large devices and platforms.

3.1.3 PARRSBORO

FIGURE 15 - ARIAL IMAGE OF THE PARRSBORO PORT (IMAGE EXTRACTED FROM GOOGLE MAPS, JUNE 20, 2016)

Parrsboro is located along the northern shore of the Minas Basin. It is approximately 185km from Halifax, and 90 km from Truro. The wharf is approximately 12km by sea from the Minas Passage.

Primarily used by fishers, barges and pleasure craft the wharf consists of a stem and ell configuration. The main ell is 119.5m long and 16.5m wide. The ell has a vessel bed of 85m x 16m wide on the north end, and 15m x 9m on the south end. The access channel and wharf are dry at low tide, and offer up to 6.1m draft at high tide, with a tidal range in the area of up to 14.2m during spring tides. Anchorage depths of 11m exist outside the harbour entrance. An adjacent slipway allows launching of fishing vessels and pleasure craft.

There are 2-3 acres available nearby (within 100m) available for development, owned by Parrsboro & area Harbour Commission. The remaining property nearby is privately owned. Some storage is available on the pier, as well in the nearby parking lot.

Main access into town is via secondary highway 2 (which is subject to spring weight restrictions). Access to 100 series highway is approximately 80km away.

The Parrsboro facility was used as a local base during the cable laying operations for the FORCE tidal energy test berths in Minas Passage.

There are plans for wharf repairs, to be completed by the end of 2016.

3.1.4 SAINT JOHN NB

FIGURE 16 – PORT OF SAINT JOHN FACILITIES (IMAGE PROVIDED BY PORT OF SAINT JOHN)

The Port of Saint John is located along the northern shore of the Bay of Fundy. A major shipping port for the eastern seaboard of North America, it consists of numerous wharfs used for cargo handling, including a container terminal.

A wet port, Saint John offers at least 10m of draft at low tide, and has a tidal range of approximately 7.4m. The port is approximately 110km to Minas Passage by sea.

Saint John is located very close to main Highway 2 (subject to spring weight restrictions), and has direct rail access. A ferry runs daily to Digby NS, providing car and truck transport. An international airport is located in Moncton, 150km away, and a regional airport is 20km away.

The various facilities offer both wharf-side storage and close-by storage capacity.

The Rodney container terminal is slated for upgrade work, beginning in the fall of 2016, with expected completion in 2023. Details of the upgrade are found in Appendix C.

3.1.5 WEST BAY

West Bay is located along the northern shore of the Minas Passage. The area was suggested as a possible location for a green field development. Figure 17 shows West Bay and the surrounding area. Figure 18 shows a relief map of the area.

A visit was made to the area, including West Bay, Partridge Island to the east, and to the west of the FORCE visitor center location. The observations below are based on personal observation, web information, maps and charts, and discussion with a long-time area resident [17].

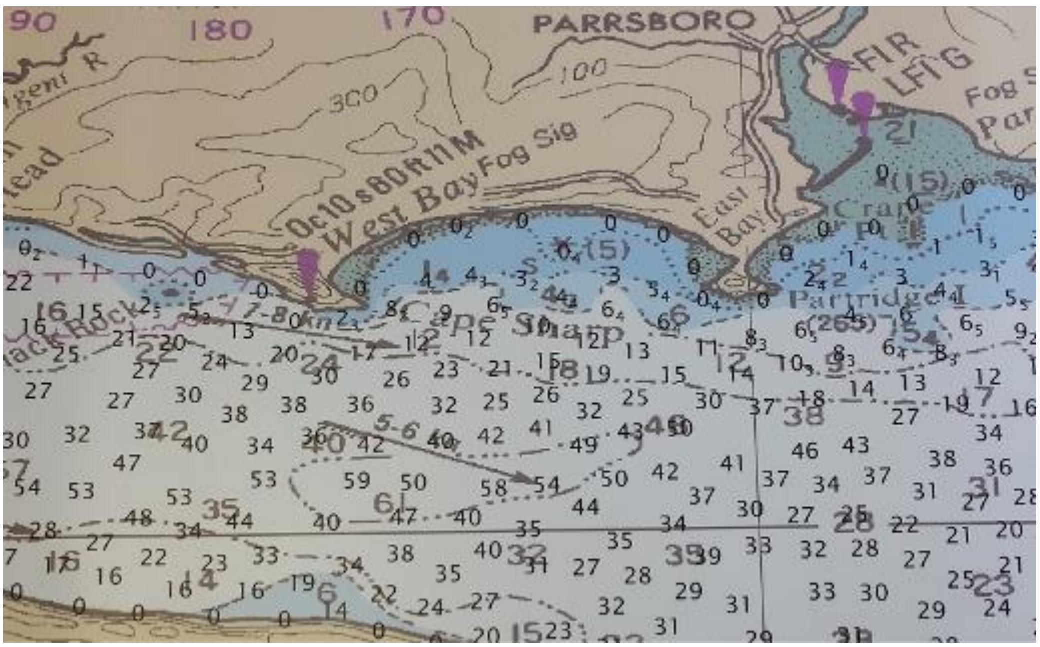


FIGURE 17 – MINAS PASSAGE (DEPTHS IN FATHOMS)

FIGURE 18 – RELIEF MAP OF WEST BAY AREA (EXTRACTED FROM 21H/08, NOVA SCOTIA TOPOGRAPHIC DATABASE)

FIGURE 19 – LOCATION EAST OF FORCE VISITOR CENTER (EXTRACTED FROM GOOGLE EARTH JUNE 24, 2016)

Figure 19 shows a location just to the east of the FORCE site, where there is water up to the shoreline at low tide. Shown is a 300m length to represent a wharf. At low tide the end of a 300m wharf might provide a minimum water depth of 9m (see Section 2.4.4), however, it is an exposed point, with 7-8kt current during tide run, and subject to prevailing surf. Tide range in the area is 12-14m. The topography map shows steep shoreline at this location, indicating steep road access.

FIGURE 20 – WEST BAY (EXTRACTED FROM GOOGLE EARTH JUNE 24, 2016)

Figure 20 shows the West bay shoreline, with a 300m wharf. This site is sheltered, and may offer 4-8m at low tide at the end of the wharf. The shoreline is sloping with no nearby flat land. The local land is privately owned. Road access is currently by narrow dirt driveways; road construction for access from West Bay Road would be required. West Bay is an active lobster fishing area.

FIGURE 21 – EAST BAY (EXTRACTED FROM GOOGLE EARTH JUNE 24, 2016)

Figure 21 shows a 300m wharf in East Bay, just west of Partridge Island. The water depth is similar to West Bay. The topography offers flatter land. Road access would require road construction out to the West Bay Road. East Bay is exposed to prevailing surf. There is a fishing weir located in this area.

FIGURE 22 – PARTRIDGE ISLAND BEACH AND OTTAWA HOUSE (EXTRACTED FROM GOOGLE EARTH JUNE 28, 2016)

Figure 22 shows a 300m wharf located near the Ottawa House Museum to the east of Partridge Island. The beach is dry at low tide. The wharf location shown is at the approximate site of a previous wharf. The end of the wharf may see 2m at low tide and tide range is 12-14m. Because of the low water depth at low tide, this location is considered a dry port, in the context that 24 hour access is available for medium to large vessels. Partridge Island offers shelter from prevailing conditions.

Access to the West Bay road is close by, however there is an incline and a proper access road would be required. Access to the beach area would require upgrading the existing narrow dirt road, and possible re-routing to reduce grade. The property is owned by the Department of Natural Resources and the Town of Parrsboro.

In summary, should the West Bay area be considered for a new infrastructure, the Ottawa House-Partridge Island Beach area would offer the best alternative, considering access to existing roads, shelter, likely availability of land, and minimal disturbance of existing fishery.

3.2 PORT SURVEY RESULTS SUMMARY

TABLE 15 – PORT SURVEY RESULTS SUMMARY

ALLSWATER

Allswater
1111 Bedford Highway
Halifax, NS B4A 1B9
902-444-7447
www.allswater.com

MRE Infrstructure Assessment Update - Port Questionnaire
Updated June 28, 2016

	Parrsboro Wharf (The Parrsboro wharf is owned and operated by the Parrsboro & Area Harbour Commission)	Digby	Hantsport (Minas Basin)	West Bay	Saint John NB - Rodney Container Terminal	Saint John NB - Navy Island	Saint John NB - Lower Cove	Saint John NB - Long Wharf - Light Industrial Use Only	Lot X - Saint John NB
Location									
Distance from Minas passage	The Parrsboro wharf is located just inside the Minas Basin *(12km)*	*135 km*	40 KM +/-	5-10 km	60 Nautical Miles- **See Appendix D**	60 Nautical Miles- **See Appendix D**	60 Nautical Miles- **See Appendix D**	60 Nautical Miles- **See Appendix D**	60 Nautical Miles- **See appendix D**
Maximum Vessel Dimensions									
Draft at quayside (all tidal conditions)	low tide: dry -high tide: 20ft (6.09m)	low tide: 9m - high tide:	low tide: dry - high tide: 30 ft		Low Tide: 12.2 M High Tide: 19.6 M	Low Tide: 10.4 M- High Tide: 17.8 M	Low Tide: 10.4 M- High Tide: 18.1 M	Low Tide: 10.7 M- High Tide: 18 M	N/A
Draft along channel approach (all tidal conditions)	low tide: dry - high tide: 30ft (9.14m) Off Parrsboro lighthouse, there is good anchorage in depths of 11m outside the harbor entrance		low tide: dry - high tide:		Low Tide: 8.4 M High Tide: 15.8 M	Low Tide: 8.4 M- High Tide: 15.8 M	Low Tide: 8.4 M- High Tide: 15.8 M	Low Tide: 8.4 M- High Tide: 15.8 M	N/A
Length Overall	A large vessel	91m			300 M +	300 M +	224 M	285 M	N/A
Beam	Same as above	Any size			45 M +	37 M	35 M	36 M	N/A
Displacement	Each vessel has different tonnage	Any size					45,000 approximately		N/A
Height Clearance	Unlimited	No restriction			Unrestricted	Unrestricted	unrestricted	None	N/A
Tidal Variation	38 ft - 45 ft (Tidal range at Parrsboro is 11.3 to 12.5 m during neap tides and 12.7 to 14.2 m during spring tides)	30 ft *(9.1m)*	42		Approx. 7.4 M	Approximately 7.4 M	7.4 M	Approximately 7.4 M	N/A
Historic of maintenance dredging	R.J. MacIsaac Construction Ltd.	No history of dredging	No		Annually when required	Annually when required	Annually when required	Annually when required	N/A
Berth & Quay details									
Wharf type	**Ell**: (on Pilings: 119.5m x 16.5m wide, *area = 1971m^2*) **Stem**(on Rock: 47m x 10m wide, *area = 470m^2*) A vessel bed measuring 100m is located along the west side of the ell wharf; The north section of the bed measures 85m long and 16m wide; the south side of the vessel bed is 15m long and 9m in width	Marginal, spur, spur ext., 2 ells, 11 floating docks	Marginal	No existing wharf	Concrete Pile / Deck	Concrete crib construction , ro-ro capabilities	concrete crib construction	Concrete crib construction	N/A
Berth Length / width (ft)	(396 / 65)The facility has the capacity for berthing along the majority of each side of the stem wharf and along the entire length of each side of ell and at the end of the ell.	1230/45 *(375m / 13.7m)*	449 ft / 62 ft *(137m / 18.9m)*		Slip Berth 291 M/ 45 M marginal 369 M/ 45 M	1ab: 378 M, 2b: 190 M, 2ab: 312 M	224 M	285 M	N/A
Possibility to jack up	no	Yes			Yes	Yes	Yes	Yes	N/A
Quayside Working Area and Loading capacity	Wharf dimensions for working area; Truck Loading CL625; Truck to be centred in approach (stem) end; UDL Loading - 70kN per sq. Meter (*7.1 te/m^2*) - Track cranes or excavators to stay 1.5 meters from wharf edge	Small cranes possible			37 M , 250lbs per ft2 (*1.2 t/m^2*) *Area: Slip = 10,767 m^2, Marginal = 13,653 m^2*	78 M / 1000lbs per ft2 (*4.88 t/m^2*) *Area: 1ab = 29,484 m^2, 2b = 14,820 m^2, 2ab = 24,336 m^2*	unrestricted	1000lbs per ft2 (*4.88 t/m^2*), *Area = 28,500 m^2 min*	N/A
Lifting equipment – Crane details	PAHC has 1 Derrick/Winch: 2 Private Derricks/Winches	Upon demand *(brought in)*	none		2 container cranes- 45 ton capacity each. 150 offsite cranes available with lift capacities ranging from 8 ton - 500 tons	150 offsite cranes available with lift capacities ranging from 8 ton - 500 tons	150 offsite cranes available with lift capacities ranging from 8 ton - 500 tons	150 offsite cranes available with lift capacities ranging from 8 ton - 500 tons	150 offsite cranes available with lift capacities ranging from 8 ton - 500 tons
Nature and condition of existing slipway facilities	Slipway facilities for fishing vessels, pleasure crafts	N/A	N/A						N/A
Storage Possibility									
Size of available storage	P&AHC has 2 -3 acres that can be developed, the rest is private land nearby	Industrial Park options available and vacant buildings in close proximity	3 acres	none existing	Total terminal size is 37.5 acres however storage area is located adjacent at Navy Island or Lot X- **See Appendix D**	Shed A:152,500 ft2/ Shed B: 177,378 ft 2/ Shed C: 118,600 ft2/ Shed D: 119,705 ft2/ Mod-Fab: 24,000 ft2	Open Area: 18 acres	19.6 acres	5 + acres
Load capacity of storage area		70 tons	None (limited by SWL of wharf)			1000 lbs per ft2 *(4.88 t/m^2)*	1000 lbs per ft2 *(4.88 t/m^2)*	1000 lbs per ft2 *(4.88 t/m^2)*	Unrestricted
Distance between storage area and quayside	100 meters	Industrial Park options available and vacant buildings in close proximity	500 m +/-		Min: 369 Ms/ Max: 1100 Ms - See Appendix D	78 M		N/A	N/A
Access restrictions to storage area	none	None	enclosed by fence		Secure area- 24 hour security - Note: Navy Island has a different terminal operator.	Fulltime security	Security required during operational periods	Security required during operational time	N/A
What kind of equipment is usually used for transport	P&AHC does not own transport equipment, usually owned pr	Flatbed trucks	Highway tractor		Ottawa trailer	Trailer units as well as mobile crane as indicated above	See note on lifting equipment	Note crane details	Note crane details
What lifting equipment is available	Private winch on wharf	Cranes in the area when needed	no heavy lifting capacities on site		Forklifts and top lifter , mobile cranes	Forklifts		Note crane details	Note crane details
Port Usage									
Other Port Users (Conflicting usage?)	Fishing vessels, pleasure crafts and barge	fishery	several times per year		Under lease arrangement with Logistec Stevedoring until December 2016 . Terminal operator thereafter is DP World.	Terminal is leased by Logistec Stevedoring until 2020	Common user terminal	Common user facility	Common user terminal
Passage Plan for channel access (priority users?)	Fishermen	Work undertaken with Port Authority to coordinate			Harbour Master and/or pilots will set priorities when needed	Pilots and/or harbour Master will set priorities when needed	Pilots and/or harbour Master will set priorities when needed	Pilots and/or harbour Master will set priorities when needed	N/A
Berth Occupancy Levels	low (3-4 Fishing Vessels, 3 Pleasure Crafts and Barge)	high	low		Weekly service by 2 lines		Minimal	Minimal	N/A
Berthing slots	10 Slots plus Barge	Currently for fishing fleet							N/A
Weather restrictions	Open Harbour	No			Pilot boat goes off station / Container cranes limited to 45 knots	Pilot boat goes off station	Pilot boat goes off station	Pilot boat goes off station	N/A
Shelter Availability	None	Yes	Large warehouse adjacent wharf			Yes	Arrangements can be made to provide	No	N/A
Port Access									
Additional navigation restrictions (bridge, locks, ect)	none	No	N/A		Unrestricted	None	None	None	N/A
Rail Access	none	No	yes - 1km		Direct	Direct	None available on terminal , nearest siding available adjacent to facility	No	No
Road Access	Yes, with Spring Road Restrictions	Yes 100 series highway and Digby - St. John Ferry Services/ Yarmouth -Portland Ferry Service	yes - 1km	local road access via Whitehall and West Bay roads. 2-lane, paved and graded unpaved	Direct - Spring weight restrictions applicable	Direct - Spring weight restrictions applicable	Direct - Spring weight restrictions applicable	Direct - Spring weight restrictions applicable	Direct - Spring weight restrictions applicable
Constraints for oversize transportable loads from road (rail if applicable)?	Not at this time	None	Truck route from Hwy capable of large loads	local roads could be an issue - Use access to FORCE as a guide	Harbour Bridge if traveling east	Harbour Bridge if traveling east	None	Harbour bridge if traveling west	Harbour Bridge if heading east
Port Services and other infrastructures									
Operating/access hours (365/24/7?)	Yes, 365/24/7	Yes	Can be arranged 24/7/365		365/24/7 if needed	365/24/7 when needed	365/24/7 when needed	365/24/7 when needed	365/24/7 when needed
Experience in similar works (offshore)	Yes: i.e. R.J. MacIsaac Construction (Barge) laid cable for FORCE	Yes			**See Appendix D**	**Appendix D**	**See Appendix D**	**See Appendix D**	**See Appendix D**
Port Authority	Not Authority: Parrsboro & Area Harbour Commission	Yes		n/a	Saint John Port Authority	Saint John Port Authority	Saint John Port Authority	Saint John Port Authority	Saint John Port Authority
Pilot/Mooring/Towage Services	Croydon Wood: Harbour Pilot	Available if needed	No		Pilot- Atlantic Pilotage Authority & Towage- Atlantic Towing	Pilot- Atlantic Pilotage Authority & Towage- Atlantic Towing	Pilot- Atlantic Pilotage Authority & Towage- Atlantic Towing	Pilot- Atlantic Pilotage Authority & Towage- Atlantic Towing	N/A
Office Space	none	Yes	near by (not adjacent)		Yes, not available on terminal site	Yes, located in Shed A and C	Options available onsite/ temporary	Can be made available onsite- Temporary	Temporary if required
Warehousing/Workshops	none	warehouse 20 km	Large warehouse adjacent wharf		Not on terminal property, available adjacent at Navy Island. **See Appendix B**	See Storage	None	N/A	None
High Value Secure Storage	none	As required	fenced in area		No	Can be customized to facilitate	None	No	None
Covered/Open Storage	Open Storage on Wharf and in parking area	As needed	both		Open Storage	34 Acres open storage	18 Acres Open	Open area 19.6 acres	5 + Acres Open storage
Development									
Land options available for development	P&AHC 2-3 acres for development. Plus Possible Private development	**Industrial Park options available and vacant buildings in close proximity**	**yes**	Numerous properties for sale near FORCE	Port to begin modernization of Rodney Container Terminal Fall 2016 . For additional detail please S**ee Appendix D**	DP World will assume terminal lease in 2020 at the conclusion of the Logistec Stevedoring lease	Land available for long term lease. No existing development plans	Long term lease available	Long term lease available
Existing development plans	3 Proposal Options from Eagle Beach Contractors Limited for repairs to wharf	Industrial Park Strategic Plan	no			At the conclusion of Rodney container terminal modernization berth 3ab will no longer be available	None	N/A	N/A
Timescale for Availability of new capabilities (if applicable)	End of 2016	Ready for commercial deployment by 2021			2016- 2023	2023	Immediate availability for lease development	Lease availability immediate	Available immediately
Electrical service to the facility/port and local grid capacity	Yes, 120/240	Yes 3 phase to Conway Substation	would be available		12.5 KV power as the main entrance to the port	7.2 KV down 600/347 volt 400 amp x 2 (400 amp service fo	600/347 volt 400 amp	12.5 KV down to 600/347 volt 400 amp	Fed from the maintance shop 30 amp 600 volt (this is for light pole and camera only)

4 BENCHMARK: EUROPEAN PORTS EXPERIENCE

A sample of 4 European Ports were selected to benchmark existing facilities with Nova Scotia Port infrastructure. The studied ports are:

- Hatston Pier (EMEC, Scotland)
- Nigg Energy Park (Scotland)
- Cherbourg (France)
- Brest (France)

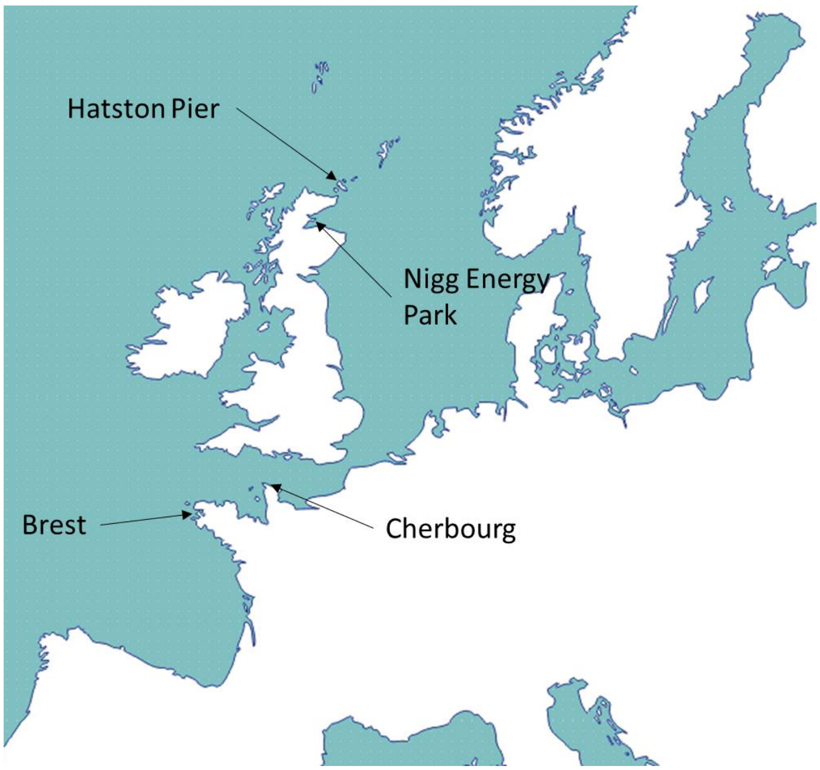


FIGURE 23 - MAP OF PORT LOCATIONS

The ports were selected based on their past and planned implications in tidal projects. The aim is not to present an exhaustive representation of existing projects, but a few examples on how European Ports have supported the tidal industry and the trends in infrastructure upgrades.

All four selected ports have supported tidal projects in the past, and have a number of tidal projects planned. The two Scottish and two French ports are close to some of the greatest tidal energy resources identified worldwide.

Some of these ports have already undergone infrastructure upgrades to answer the industry demand, while some significant investments are still being made on other ports. However, it is to be noted that the tidal industry is usually not the single user of these facilities, and it benefits from local synergy with other Offshore Renewable expanding industries, especially in France, or other previously established activities. This context may not be fully applicable to Nova Scotia. However, the example of the Hatston Pier in EMEC demonstrates how investments for port upgrades and addition of facilities can rely on tidal industry as its main industrial user, together with passenger transportation activities.

The presentation here will mainly focus on the ports' role in tidal projects, providing high level background information. Please note that a full port characteristics comparison is included in Section 4.5.

Further comments on the feedback on the European Ports upgrades are included in Section 6.1.

4.1 Hatston Pier (EMEC, Scotland)

4.1.1 Port Infrastructure

The Hatston Pier is located in Northern Scotland near Kirkwall in the Orkney Islands. It is Orkney's largest commercial pier and Scotland's longest deep-water commercial berth.

The harbour is frequently used for the deployment of tidal energy devices because of its proximity to the test sites: it is located 19km from the EMEC tidal full scale test site and 7km from the reduced scale test site.

The pier was originally built in 2002 as a multi-purpose facility. The Orkney Islands Council, owner of the port, later invested £8 million along with additional £3.2 million provided by the European Regional Development Fund mainly to support the tidal energy sector. The upgrade was completed in 2013 and consisted of a 160-meter extension of the main quay and the addition of a 1000t crane [18]. As a result, the longest berth is now 385 meters long with a depth of 10.5 meters. In total there are 884 meters of quay side and 10 hectares of storage area available for any purpose (tidal energy projects, commercial transportation, ferries, cruise ships) [19] and [20].

This port may represent the most comparable situation with Nova Scotia ports within this benchmark, both regarding the size of the original pier and the level of investment considered. The primary objective of the upgrade was also focused on the tidal energy market with no synergy with offshore wind industry requirements, in contrast to the other ports studied. However the upgrade also benefits other users within commercial transportation, ferry and cruising economy.

FIGURE 24 - HATSTON PIER UPGRADED (SOURCE: ORKNEY.GOV.UK)

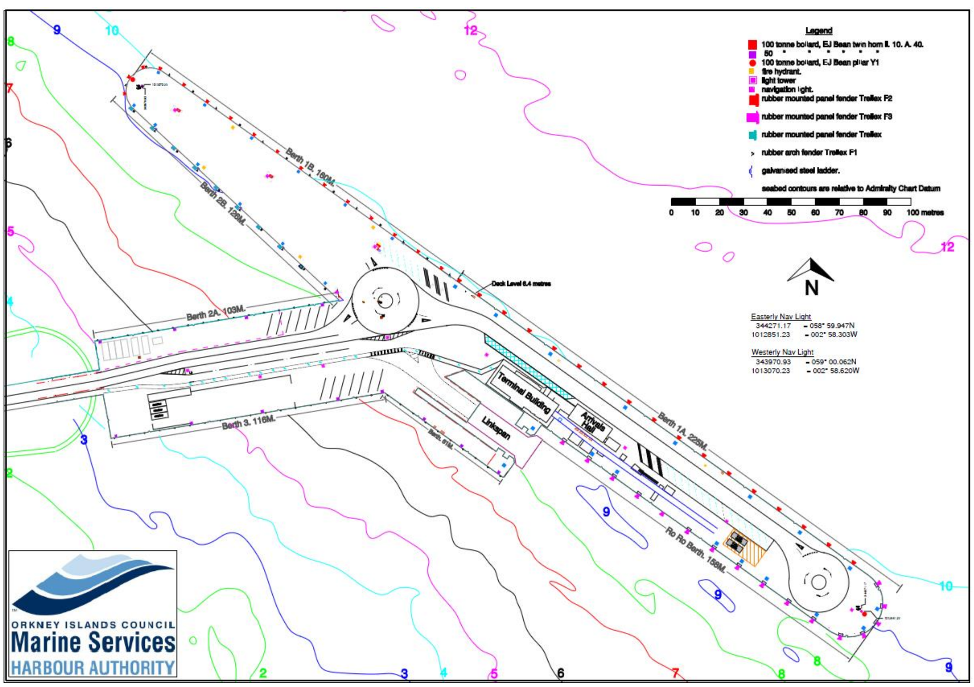


FIGURE 25 - HATSTON PIER – CONFIGURATION (SOURCE: ORKNEY ISLANDS COUNCIL)

4.1.2 TIDAL PROJECTS

The pier has already been used by a number of technology developers which include [21]:

- **OpenHydro** for its 250kW twin piled research platform installed in 2006. The pier was used to load the turbine on the OpenHydro barge and then tow it to the test site (Fall of Warness).

- **Alstom Hydro** tested its 500kW turbine at EMEC from 2010.
- **Scotrenewables Tidal Power** used the pier for its SR250 250kW floating tidal turbine from 2011 and onwards.
- **Andritz Hydo Hammerfest** deployed a full scale 1 MW pre-commercial tidal turbine at the Fall of Warness from the Hatston pier in 2011.
- **Voith Hydro** installed its 1 megawatt (MW) tidal turbine at EMEC's tidal test site in 2013. The pier was used for the turbine storage and loading.

The activity increased after the 2013 upgrade with for example 5 distinct developers (Alstom Hydro, ANDRITZ Hydro Hammerfest, OpenHydro, Scotrenewables Tidal Power Ltd, and Voith Hydro) using the quay during the first half of the year 2013 and up to 4 devices at quay simultaneously.

At the time this report is being written (June 2016), the pier is used by Scotrenewables to host the new SR2000 turbines before deployment along with the SR250 from 2011 [22]. Sustainable Marine Energy's PLAT-O is also stored at the pier and undergoes preliminary tests before its future deployment at the Fall of Warness site [23].

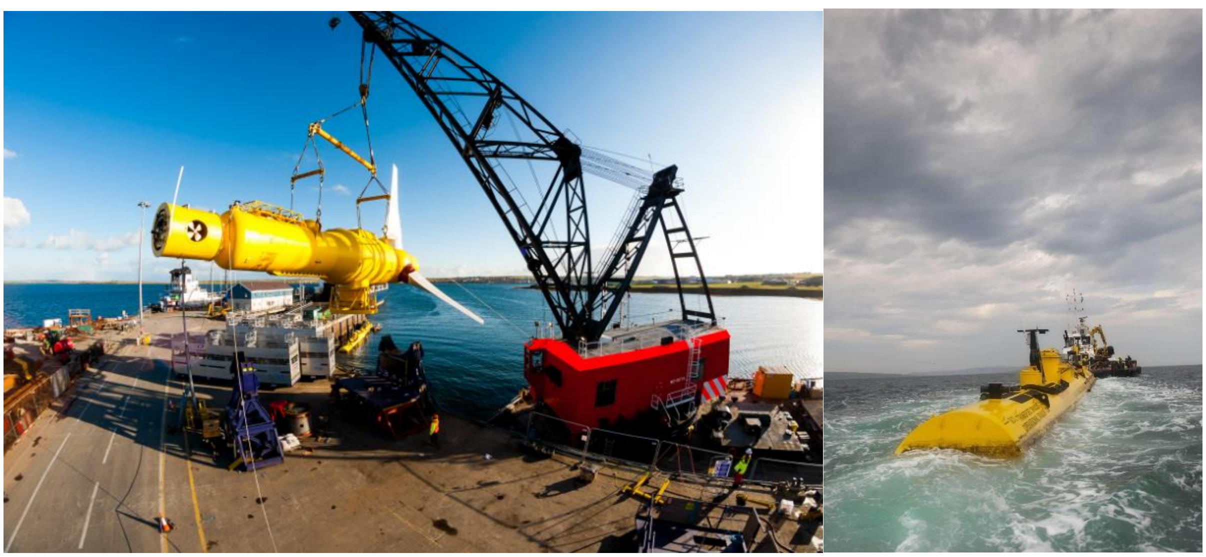


FIGURE 26 - ALSTOM HYDRO TURBINE LOADING (LEFT) / SCOTRENEWABLES TURBINE TOWING (RIGHT) AT EMEC TEST SITE (SOURCE: EMEC.ORG.UK).

4.2 NIGG ENERGY PARK

4.2.1 PORT INFRASTRUCTURE

Nigg Energy Park is a construction yard located in the Moray Firth Cluster, Northern Scotland, nearby Inverness. Due to its location, the main activities undertaken concern the Oil & Gas and MRE industries. It is owned by Global Energy Group, which invested £45M in 2011 to upgrade the facilities and extend the quayside to attract more offshore projects [24].

Its main features are summarized hereafter:

- Allowable vessel dimensions: 320m
- 900m of heavy load bearing deep water quayside (depth up to 12m Lowest Astronomical Tide – LAT)
- Entrance channel depth: 15.5m excluding tidal range
- Dry dock facilities (LOA: 305m B: 121.9m)
- 33.2Ha Construction yard, including 3.6Ha covered area.
- Crane capacity up to 1350t, Mobile cranes up to 750t

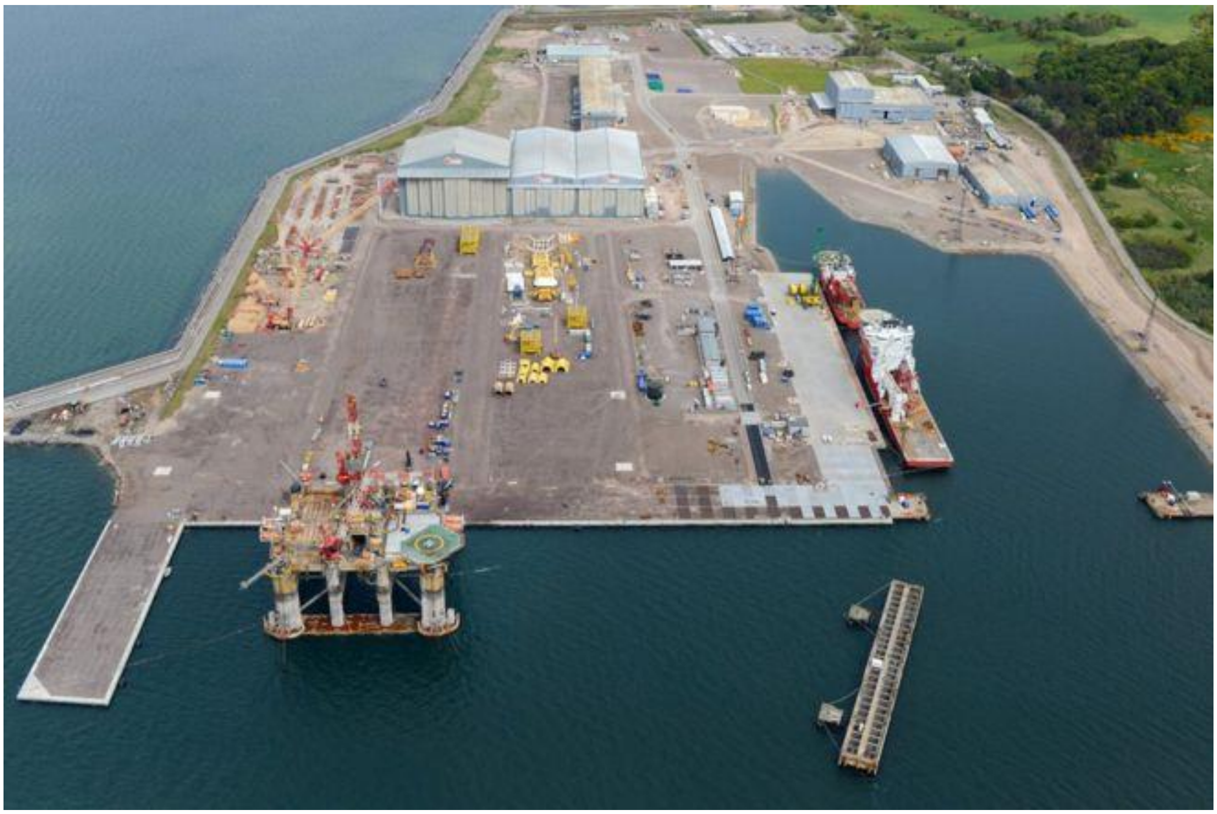


FIGURE 27 - NIGG ENERGY PARK. THE RIGHT BASIN IS THE DRY DOCK (SOURCE: DEREK GORDON PHOTOGRAPHY)

4.2.2 *Tidal Projects*

Atlantis is currently manufacturing and assembling AR1500 turbines in their leased facility at Nigg Energy Park. The company expects to install four 1.5MW devices in the Inner Sound of the Pentland Firth by the end of 2016 as part of the MeyGen project.

The company eventually plans to install up to 269 turbines within this project.

The yard was also recently selected to support Siemens turbines assembly for the Beatrice Project, a 588MW Offshore Wind Farm in Scotland [24].

FIGURE 28 - ATLANTIS AR1500 FABRICATION IN NIGG FACILITY (SOURCE: ATLANTIS)

4.3 CHERBOURG (FRANCE)

4.3.1 PORT INFRASTRUCTURE

The Port of Cherbourg is located in the North West of France, in the Channel Sea and is owned and operated by Ports Normands Associés (PNA) which is an alliance between the Port of Cherbourg and Caen-Ouistreham. It is one of France's major port facilities, both for passengers and goods transport. The Port of Cherbourg has also a history of Oil & Gas project and naval base which allows for an existing supply chain.

Cherbourg is involved in the Marine Renewables industry through Offshore Wind and Tidal Energy. It is located 30km from the Alderney Race, with major tidal resource and a number of projects in the pipelines. Its location also allows Cherbourg to be positioned to supply services for a number of offshore wind farms located in France and the UK.

The Port of Cherbourg has identified these industries as an axis of development and is undertaking a 160M€ investment to develop its infrastructure according to the industry requirements [32]. It is to be noted that the investment decision was made in 2011, when very little visibility was available regarding the potential of the tidal energy market. French offshore wind tenders were just launched. These investments aim at the following [26]:

- Increase the Laydown area to 100Ha (as shown in red on Figure 31)
- Increase berth load capacity up to 15t/m²
- Increase quayside length
- Increase the water depth at quayside (allowable draft for construction vessels up to 14m)

It is noted that this level of investment and development is not directly transposable to the Nova Scotia Ports assessed. However, it provides a benchmark of what is currently being done in the industry in terms of infrastructure upgrade. It is also to be noted that these investments are motivated by the perspective of attracting both tidal and offshore wind projects. The tidal market alone is unlikely to have attracted the same level of investment given its current limits, which also limits the comparison with the context in Nova Scotia.

FIGURE 29 - PORT OF CHERBOURG – CURRENT VIEW (SOURCE: PORTS NORMANDS ASSOCIÉS)

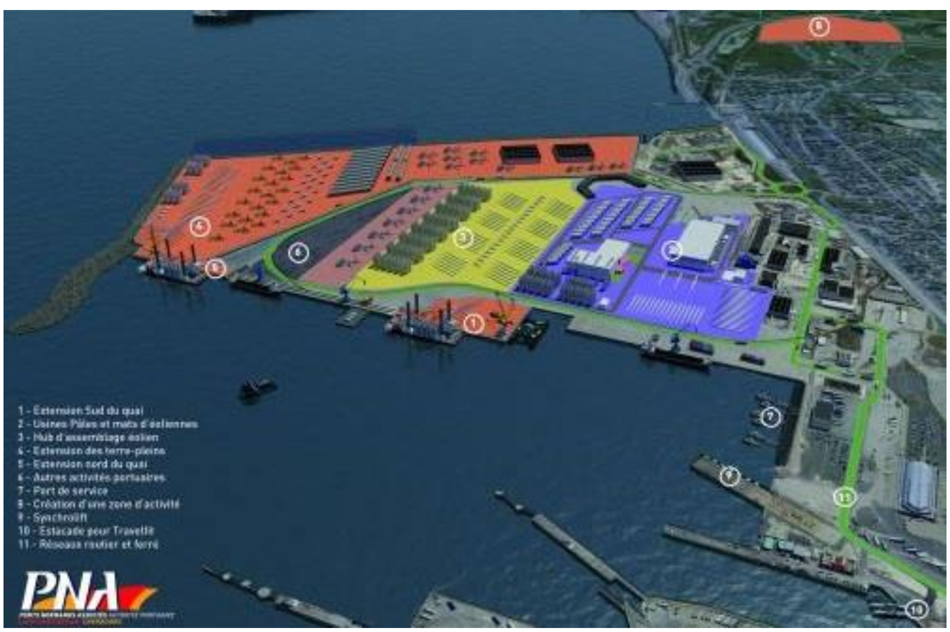


FIGURE 30 - CHERBOURG PORT PLANNED INFRASTRUCTURE UPGRADE (SOURCE: PORTS NORMANDS ASSOCIES)

FIGURE 31 - CHERBOURG PORT LAND DEVELOPMENT (SOURCE: PORTS NORMANDS ASSOCIÉS)

4.3.2 *Tidal Projects*

Tidal projects using or planning to use the Port of Cherbourg are referenced hereafter. Please note that there are also a number of planned projects in offshore wind (e.g. GE blades and tower plant).

OpenHydro

OpenHydro has reserved Port Space in Cherbourg, as part of its plan to build an assembly facility for future Raz Blanchard farm. It will use a 25ha land adjacent to the Quai des Flamands [27].

CMN/Hydroquest

Constructions Maritimes de Normandie (CMN), a Cherbourg based construction yard, has acquired shares in the Hydroquest technology. It is planned to deploy a 1.3MW demonstrator in Paimpol Bréhat, from Cherbourg. [28]

HyTide

Voith's 1MW HyTide turbine was assembled in 2013 in CMN's facilities in Cherbourg. It was launched for a short time test within the port, before being shipped to EMEC for the test campaign. The launch was performed from CMN quayside, using a mobile crane. [29]

FIGURE 32 - VOITH TURBINE ASSEMBLY AND LAUNCH IN CHERBOURG (SOURCE: ENERGIEDELAMER.EU (LEFT), AFP (RIGHT))

4.4 BREST (FRANCE)

4.4.1 PORT INFRASTRUCTURE

The Port of Brest is located at the most Western tip of France, between the Channel Sea and the Bay of Biscay. It is hosting a number of activities, including Oil & Gas, trade, military navy and sailing. It is located nearby a number of tidal sites:

- 50 km from Ushant (Sabella)
- 200 km from Paimpol-Bréhat (OpenHydro)
- 360 km from Alderney Race (OpenHydro, GE)

Like Cherbourg Port, Brest has identified the Marine Renewable Energy Industry as a major axis of development given its location and existing supply chain for Offshore works. The port undertaking a two-step 220 M€ investment (170 M€ and 50 M€) [33] to accommodate these activities through the creation of an MRE Terminal. Investments are divided into 3 phases, with the final one due in 2020.

Once the works are completed, the Port will feature [30]:

- 3 quaysides 100 to 210m long, with 4-15t/m² load capacity
- 40Ha available land for MRE suitable for heavy loads (4t/m², 1% inclination)
- A handling platform of 1.3 ha with 15t/m² load capacity
- Specific facilities for loading/unloading large, heavy-duty components
- Suitable marshalling connections and transport access

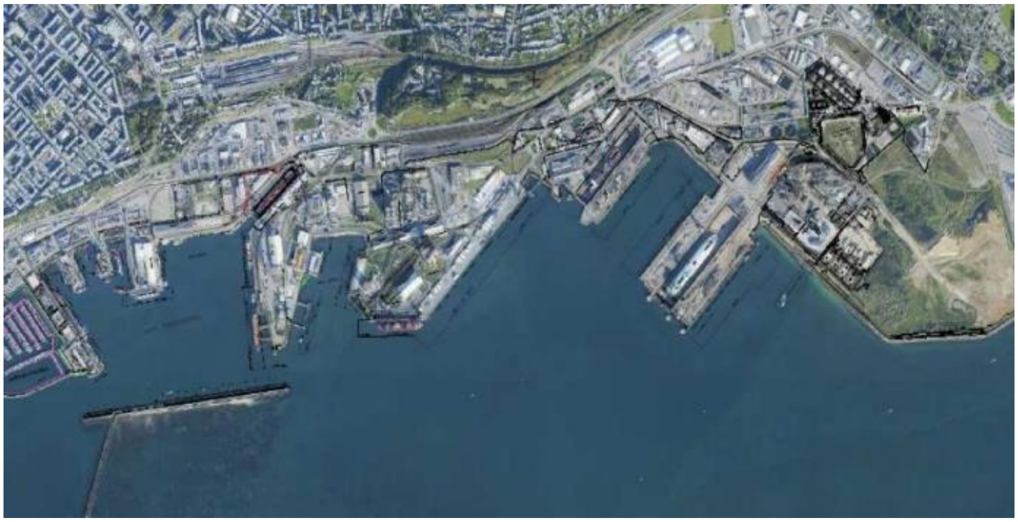


FIGURE 33 - BREST PORT AERIAL VIEW (SOURCE: REGION BRETAGNE)

FIGURE 34 - BREST MRE TERMINAL WORKS (SOURCE: INVEST-IN-BRETAGNE.ORG)

FIGURE 35 - BREST FUTURE MRE TERMINAL PLAN (SOURCE: INVEST-IN-BRETAGNE.ORG)

4.4.2 Tidal Projects

Two tidal projects were already deployed from Brest Port. Please note that these were deployed from the commercial port, since the new MRE Terminal was not available at the time of deployment.

Sabella (Ushant)

Sabella's D10 turbine was assembled in Brest Commercial Port. The turbine was secured on its foundation using a mobile crane, before being offloaded on the Palembang, a dual crane vessel which was used for transport to site and installation.

The key parameters that allowed a successful usage of the ports were:

- The availability of the quayside
- Road access allowing for components delivery

- Quayside bearing capacity
- Unrestricted vessel access (the operation lasted a few days, including waiting for the appropriate weather window)
- Possibility to mobilise a mobile crane

FIGURE 36 - BULBS ROAD DELIVERY AND WORKS ON THE NACELLE IN BREST (SOURCE: SABELLA-D10.BZH)

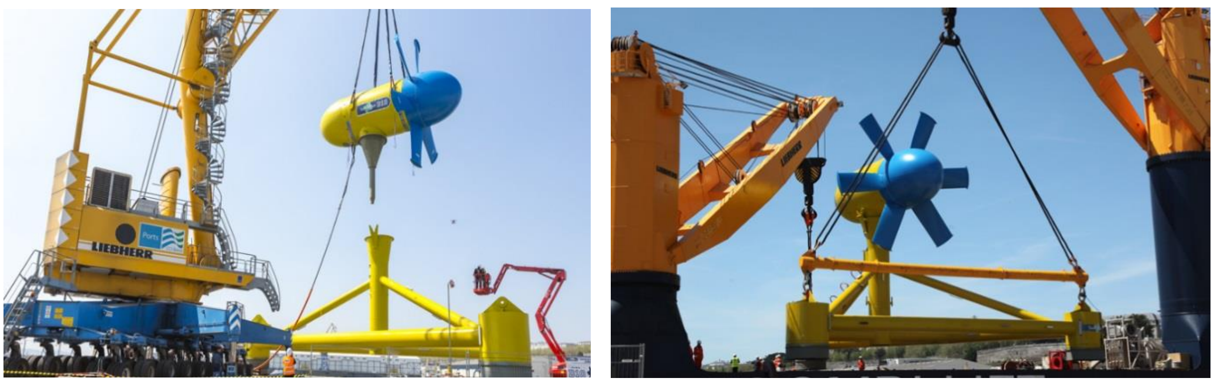


FIGURE 37 - TURBINE-FOUNDATION ASSEMBLING AND OFFLOADING (SOURCE: SABELLA-D10.BZH)

OpenHydro (Paimpol-Bréhat)

DCNS has assembled two OpenHydro turbines from the commercial Port of Brest. The first one is already deployed, using a purpose built barge. SPMTs and Mobile cranes were used to handle the 900T and 16m diameter turbine from the quayside to the barge.

FIGURE 38 - OPENHYDRO TURBINE AND PURPOSE BUILT BARGE (SOURCE: DCNS)

4.5 SUMMARY TABLE

TABLE 16 - SUMMARY TABLE OF EUROPEAN PORTS ([19], [20], [24], [26], [30], [31])

	Hatston Pier - EMEC	Nigg Energy Park	Brest	Cherbourg
Location				
Distance from site	7 km to reduced scale test site, 19 km from full scale test site	130 km from Pentland Firth / Inner Sound	50 km Ushant (Sabella), 200 km Paimpol-Bréhat (OpenHydro)	30km from Raz Blanchard (Alderney Race)
Maximum Vessel Dimensions				
Draft at quayside (all tidal conditions)	10,5 m	up to 12 m LAT	11 m	up to 14,5 m
Draft along channel approach (all tidal conditions)	15,5 m	15,1 m	7-9 m	12,5 m
Length Overall	longest quay 385 m	320 m maximum	max 210m (175,140,100)	max length 680 m
Beam	unlimited	not disclosed	not disclosed	unlimited
Displacement	unlimited	unlimited	not disclosed	unlimited
Height Clearance	unlimited	unlimited	none	unlimited
Tidal Variation	4 m	not disclosed	not disclosed	not disclosed
Historic of maintenance dredging	non necessary	not disclosed	on-going	not disclosed
Berth & Quay details				
Berth Length / width (ft)	385 max 884m total	900 m of quayside	max 210 / 40 m	680m/100m
Possibility to jack up	yes	yes	yes	yes
Quayside Working Area and Loading capacity	125 tons / m² [31]	Up to 20 tons/m²	up to 15T/m²	15 tons/m²
Lifting equipment – Crane details	1000 tons new crane 2013	up to 1200 tons	2 000 tons+	not disclosed
Nature and condition of existing slipway facilities	good	not disclosed	not disclosed	not available
Storage Possibility				
Size of available storage	10 hectares	construction yard 33 ha	15 hectares, +11 in 2017, + 14 in 2020	additional 39 ha from 2016, 100ha total
Load capacity of storage area	not disclosed	not disclosed	4t/m²	not disclosed
Distance between storage area and quayside	500m	not disclosed	approx. 100m	none
Port Usage				
Other Port Users (Conflicting usage?)	shared with ferries and cruise ships	Oil & Gas, plans and investments to avoid conflict	specialized zone MRE	specialized zone MRE
Berthing slots	6 (depending on vessels size)	3	3	depending on vessels dimensions
Weather restrictions	not disclosed	no	no	No

Port Access				
Additional navigation restrictions (bridge, locks, etc)	none	none	none	none
Rail Access	no	no	no	yes
Constraints for oversize transportable loads from road (rail if applicable)?	Designed for MRE	Designed for Oil & Gas	Designed for MRE	Designed for MRE
Port Services and other infrastructures				
Operating/access hours (365/24/7?)	365/24/7	not disclosed	365/24/7	365/24/7
Experience in similar works (offshore)	yes – tidal and wave	yes - Oil & Gas – planned for offshore wind and tidal	Yes – tidal, oil&gas – planned offshore wind	Yes – Oil & Gas - tidal
Port Authority	Orkney harbours (public, regional port)	Global Energy Group (private company)	Port of Brest (public, regional port)	Ports Normands Associés (public, regional port)
Pilot/Mooring/Towage Services	yes	not disclosed	yes	yes
Warehousing/Workshops	possibility to develop	yes, possibility to develop	yes	yes
High Value Secure Storage	not disclosed	not disclosed	yes	not disclosed
Covered/Open Storage	both	both + 36 ha covered fabrication	both	both, new 17 ha zone
Development				
Land options available for development	10 hectares made available in 2013	development ongoing for MRE	developing adjacent land	developing adjacent land
Existing development plans	2013 - extension of previous 225m berth to 385m	on going	undergoing development	undergoing development
Timescale for Availability of new capabilities (if applicable)	N/A	utilisation started by Atlantis	gradually commissioning until 2020	on-going / commissioning in 2017

5 Gap analysis

Upon reviewing the results of the developer's requirements survey, and the port infrastructure survey, a GAP analysis was performed. The following sections outline the discussion points. A summary is provided in Table 17, located in Section 5.2

5.1 Discussion

5.1.1 Limitations of a Dry port

Section 2.4.5 discusses the limitations of operating out of dry ports. In summary, most large scale installation operations are not suitable for dry ports. Based on the survey results, developers are not currently proposing to use dry ports extensively for O&M. However, with respect to minor O&M activities, half of the respondents indicated a preference for a wet port while half preferred a dry port.

For O&M operations that can use dry ports, the decision to do so is essentially one of economics – do the savings and reduced risk offered by the short transit to the Minas Passage outweigh the limitations of operating from a dry port. Given the undefined nature of developers' O&M strategies, the results of this trade-off are difficult to ascertain, and it remains an open issue.

5.1.2 West Bay Option

The option to build new infrastructure in West Bay has been considered as part of this study and is discussed in Section 3.1.5. The site along the Partridge Island beach and near the Ottawa House museum would provide a good location for port facilities, with the understanding that water depth may still limit operations. The discussion considered 300m piers; longer piers would reach deeper water. For O&M operations, and small scale installations, the limited use may be acceptable, however a longer pier providing access to the deeper water required to support large scale installation would be expensive; the trade-off is one of cost against usability.

Limitations of the West Bay option include the need to update existing roadways and construct access roads, suitable for the expected truck traffic. Additionally, laydown and storage area will likely need to be incorporated into any pier constructed, as there is little level ground in the area. The West Bay option is a green-field project; this is a positive because any infrastructure put in can match the set requirements. It is also a negative as new-build cost is likely greater than modifying existing facilities.

5.1.3 Ports in close proximity to Minas Passage

Hantsport, Parrsboro and West Bay offer the advantage of proximity to Minas passage, with the disadvantage of the limitations of dry ports, namely accessibility, in both timing and capacity. To choose between the three options, considerations include:

1. Cost of construction/upgrading – West Bay is identified as a green-field option, with costs associated with wharf building, access roads and site storage preparation. The advantage of new facilities is a longer lifespan, and the ability to build to meet requirements.

   Parrsboro's is an active facility, with repairs scheduled for this year. However it is aging and lifespan would need to factor into the analysis.

   Hantsport's facility has been inactive for a number of years. Repairs and upgrades will likely be needed to bring the facility up to working capacity.

2. Proximity to Minas Passage by sea – West bay is the closest at 5-10km, Parrsboro next at 12km, with Hantsport at 40km.

3. Port availability due to water depth – with both Hantsport and Parrsboro dry at low tide, and the West Bay option near Ottawa House/Partridge Island beach, almost dry at low tide, the consideration becomes one of relative availability. The West Bay option will offer the longest time-access to the facility. Additionally, with a longer pier at this location, availability can be increased, albeit at a higher cost.

There is no clear advantage of one dry-port facility over the next, as the trade-off is one of cost vs. proximity vs availability. However, the West Bay site offers the best perspectives in terms of water depth availability and proximity.

As the dry port option may be more attractive to smaller tidal projects (<500kW) for both O&M and installation, consideration should be made as to the potential location of these developments. Smaller projects are investigating locations outside of Minas Passage, including Digby Gut, Petite passage and Grand Passage. In these instances, the advantage of close proximity to Minas Passage is not applicable.

5.1.4 LOCAL INDUSTRY FEEDBACK

Local industry involved in previous tidal energy efforts in the Bay of Fundy were contacted to provide an opportunity to offer feedback regarding infrastructure for tidal energy developments in the Bay of Fundy.

From the feedback came the suggestion of procuring or building a large submersible barge/floating dry dock to provide safe/efficient sea transport of tidal equipment/devices, which are too big for road transport, from fabricators and builders in Nova Scotia to the Bay of Fundy where existing resources could perform installation work. This barge would be made available for all developers to use. Cost is dependent on capabilities, and the ownership and operation responsibilities would need to be worked out.

Safe sea transit would greatly diminish the risk of transporting tidal devices to the installation site. Locally available equipment would eliminate the costs associated with mobilizing such equipment from Europe.

Additional feedback relating to previous operations at the FORCE site emphasizes the necessity for nearby shore access, for reasons relating to safety, and timely personnel transfers. Because the nearby dry ports in Parrsboro, Hantsport and Halls Harbour are not always accessible, being able to land on a beach or slipway is advantageous. Delayed crew changes due to a low tide can be inconvenient and costly. Additionally, access to a vessel capable of beach landing, and carrying smaller cargo, as well as personnel, and would be an advantage.

Feedback also emphasized the successful deployment of the subsea cables and monitoring at the FORCE Site, utilizing local resources, and mobilizing from Parrsboro, the result of working around the tides, and developing creative solutions to get the jobs done.

A main theme of tidal energy development is the proportion of cost associated with device installation, primarily with the high day rates for heavy lift vessels. This is further increased by the mobilization costs for Nova Scotia projects, as these vessels don't exist in this region. The current downturn in oil and gas projects has reduced the costs and increased the availability of such vessels; however any upturn on the oil market will negate that advantage.

5.1.5 WET PORTS

The developer survey indicates the requirement of a wet port (over dry ports) for installation activities, with the majority of survey respondents (7 out of 9 respondents) specifying a wet port requirement.

Similarly, for currently anticipated major O&M requirements, a wet port was selected by the majority (7 of 10) of respondents. With respect to minor O&M activities, half of the respondents indicated a preference for a wet port while half preferred a dry port.

The two ports that offer a wet port capability are Digby (both existing and proposed facilities) and Saint John. The GAP analysis summary table in Section 5.2 shows that the port of Saint John meets the majority of the developer requirements right now.

The existing facilities in Digby meet some of the requirements, most notably wet port, water depth required, and nearby storage space. Included in the table is a proposed option for Digby as part of their development plans, which is outlined in Section 5.1.6. This option will further address the developer requirements specified by survey respondents.

5.1.6 DIGBY DEVELOPMENT PLANS

Digby's port characteristics present a correlation with the requirements stated by the technology developers who responded to the online survey. Some limitations can however be outlined regarding the existing facilities including:

- limited berth availability due to intensive fishery activity and number of adequate berth slots.

- limited storage area and quayside space for storage and operations of large projects (lower than 4000m² requested by some developers).
- only small existing slipways close to the port.

Considering the existing facilities, the port of Digby could therefore be suitable for small projects provided that the load bearing capacity offered is sufficient for the considered projects.

Greenfield construction is possible near the port of Digby to build an additional wharf and facilities in order to meet the majority of technology developer needs specified by survey respondents. The Digby port authority has plans for this kind of development as communicated during the information gathering process. A 2012 report [16] commissioned by the Municipality of the District of Digby outlines three options for a wharf, shown in Figure 39. An evaluation of the three proposed sites indicates a preference for Site 2, mainly based on the deep water available (9m), available land at a moderate cost, and good road access. Site 3, located north of the present Bay Ferries terminal, while having deep water, is exposed to higher currents, and is surrounded by steep, privately owned land that is costly to acquire. Recent dialogue with the municipality indicated that option 2 is being pursued. Early stage efforts are underway, although a completion date is not set at this time.

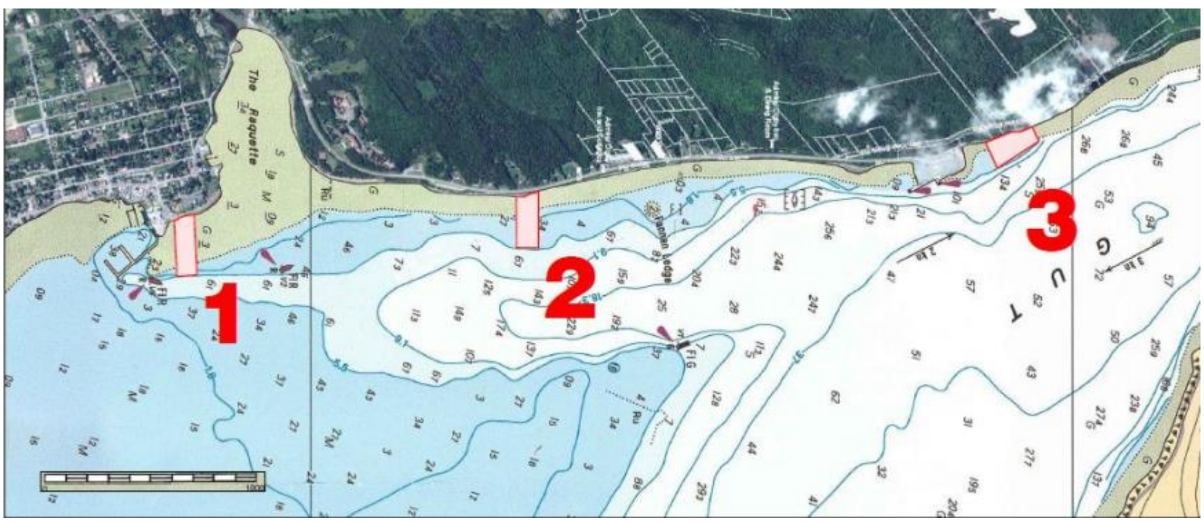


FIGURE 39 - PROPOSED LOCATIONS FOR DIGBY DEVELOPMENT (IMAGE EXTRACTED FROM [16] WITH PERMISSION)

Option 2 is located along Shore Road, 3km north of the existing fisherman's wharf. This location provides the required road access, and water depth suitable for the majority of the developers. The proposed construction shown in Figure 40 offers the required storage and quayside areas. Figure 40 shows the support base concept, Figure 41 shows the concept at the Shore Road location and Figure 42 shows an image of the concept support base. From the 2012 report, the cost estimate for this support base is $27 million.

The Municipality should also consider constructing a slipway adjacent the pier, taking advantage of any efficiencies of constructing this at the same time as the pier. While smaller slipways exist in the area, a larger slipway may serve the community as well as tidal energy development efforts.

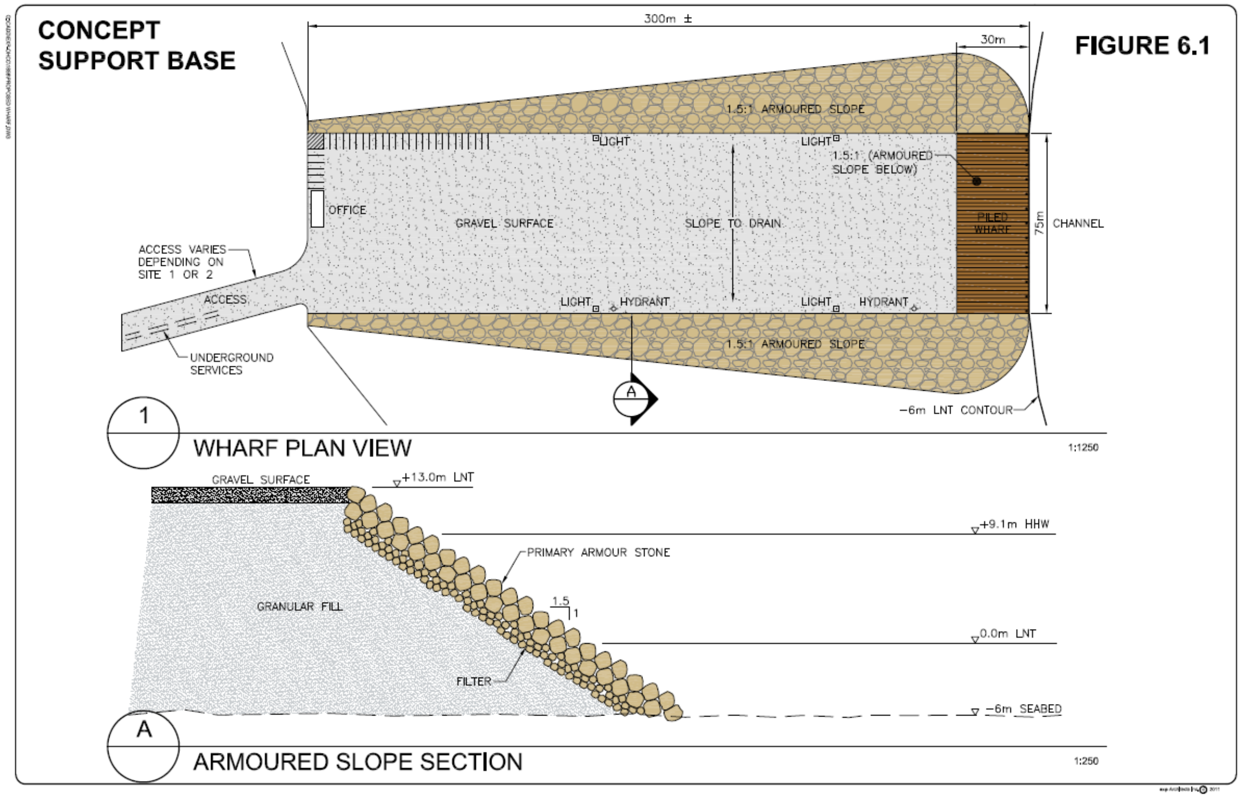


FIGURE 40 – CONCEPT SUPPORT BASE (EXTRACTED FROM [16] WITH PERMISSION)

FIGURE 41 – PROPOSED SUPPORT BASE IN DIGBY (EXTRACTED FROM [16] WITH PERMISSION)

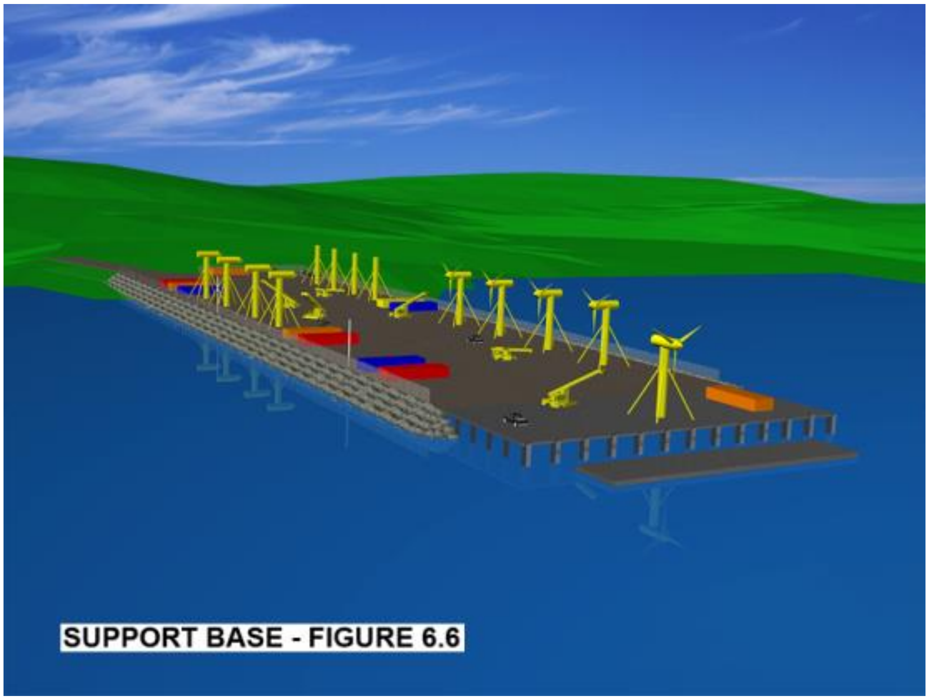


FIGURE 42– PROPOSED SUPPORT BASE IN DIGBY (EXTRACTED FROM [16] WITH PERMISSION)

As a conclusion, when considering the potential for infrastructure development within Nova Scotia the proposed development outlined above provides sufficient capabilities to support the tidal energy industry. It is therefore recommended to engage further with the Port of Digby and technology developers to investigate in more detail the potential port upgrades to meet the developers' needs.

5.1.7 STAGED APPROACH TO INFRASTRUCTURE DEVELOPMENT

Currently BRTP and OpenHydro are producing and planning to deploy turbine systems in the Bay of Fundy, in 2016-17, with Minas Energy recently announcing plans for deployment later in 2017. BRTP and OpenHydro are utilizing currently available resources, constructing their turbine platforms in Pictou and transporting to the Bay of Fundy.

Aside from these projects, the timeline for build-out of the FORCE test site, and subsequent development within Minas Passage and other areas in the Bay of Fundy is not defined. Many factors will contribute to the future development timeline, including:

1. The world energy market – with the current low cost of oil, and slowing rate of increase in energy demand, newer alternative energy sources such as tidal are less economically viable due to high costs.
2. Availability of capital in uncertain world and regional economies – combined with the reduced economic viability, capital is becoming scarcer for tidal development projects.

A staged, or incremental approach to infrastructure development could be an attractive alternative to a full on effort to meet all developer requirements with one large greenfield development. The requirement for a large amount of on- or near-site storage and load-out space could be reduced for developments occurring one at a time. The proposed green-field development at Digby could be staged to include the full (75m x 30m) pier with the sufficient water depth and minimal storage. The proposed installation offers 20,250m^2, plus 2250 m^2 at quayside; however the largest area requirements are for 5000m^2 for quayside loadout. If the required 6300m^2 for staging is located offsite for the first installations, perhaps the initial construction could be reduced, with a subsequent stage to support multiple on-site tidal installations occurring once developer demand is solidified.

5.1.8 Combination of several ports

Going into larger tidal energy projects, it is likely that manufacturing, assembly, and O&M are to be carried from different locations.

While manufacturing has not been fully addressed as part of this scope of work, Section 2.4.6 provides some elements. The European experience in offshore wind has shown that manufacturing infrastructures investments need significant committed projects before going through (typically, Alstom/GE new built plants rely on 1500MW of wind projects in France). The same level of confirmed project pipelines is not foreseen in the short term in the tidal industry, hence it is more reasonable to assume that the tidal industry around Nova Scotia will rely on existing facilities for manufacturing.

Identified ports have indeed been reviewed as to be used as assembly and/or O&M base. These three activities can be accommodated from the same location, or from different ones if the distance factor becomes important.

It is to be noted that the suitability criteria defining the assembly base are more stringent than the ones defining the O&M base, hence any port suitable for assembly is also suitable for O&M.

The following parameters are taken into account when choosing where to locate deployment and O&M activities:

- Failure rates of components (accidental O&M)
- Size of the project (number of turbines)
- O&M strategy (performed offshore or at port)
- Frequency of planned O&M
- Distance of the various bases to site
- Weather Down Time on site and along the route (caused by current, waves, wind, visibility), and more specifically tidal impact

While these parameters are project/technology specific, certain trends can be anticipated.

On small projects with 1-2 devices, it is more likely to see the O&M activities at the same location as the installation activities; as spare parts for Maintenance can be collected and stored at the same facilities used for deployment. Nevertheless, the larger the project, the most likely to have multiple bases, as the distance criteria is multiplied by the number of turbines.

In the Nova Scotia context, it can be anticipated that manufacturing will be undertaken from Saint John, Halifax or Pictou. In Nova Scotia, Digby is the most credible candidate as an assembly port as developed in Sections 3.1.1 and 5.1.6. However, its distance (135km) to site may push developers to seek a closer port as an O&M base if the industry progresses towards large tidal farms. There would then be a market to support the development of the West Bay area, as it is the closest (less than 10km) to the resource and given its advantages detailed in 3.1.5 and 5.1.2. Other dry ports may be used, pending developer's capacity to tailor their strategy to existing facilities.

Globally, the respective benefit of upgrading Digby vs West Bay is going to be a trade-off between:

- Cost: While both the proposed Digby wharf and West Bay are green-field developments, Digby has the advantage of a nearby industrial park, and a suitable access road. West Bay is expected to be more expensive.
- Distance: West Bay is closer to Minas Passage project sites than Digby.
- Benefits to other users: not quantified as part of this study, but both sites development would benefit other users (recreational navigation in West Bay; potentially fishermen or ferry in Digby).
- The evolution of the developers' needs, who may be able to adapt to the specific conditions found in the Bay of Fundy and conceive innovative solutions e.g. taking advantage of the high tidal variation and the specificities of a dry port.

5.1.9 MULTI-USE

European ports studied in Section 4 have been used by multiple industries, including oil and gas, and offshore wind, in addition to servicing the requirements of the tidal energy industry. This multi-use capability greatly enhances the justification for the large expenditures required for port infrastructure.

Of the ports assessed in Section 3, the multi-use opportunities beyond the tidal industry are limited. Oil and gas support in Nova Scotia is primarily based out of Halifax. Offshore wind development hasn't occurred yet in Nova Scotia, although there was a recent announcement of a planned development off of Yarmouth [34]. Approximately 130km by sea from Digby, this development might use a facility in Digby, if the existing nearby ports in Yarmouth and Shelbourne do not have sufficient capabilities. However, as no firm plans have been announced, this is speculation.

A launch ramp in West Bay could provide greater accessibility (because of the deeper water) than the existing slipway in Parrsboro, which could attract usage from local fisherman and recreational boaters, as well as government agencies performing monitoring and research in the area.

Other industries in the Bay of Fundy include fishing, aquaculture and tourism, all of which could utilize upgraded or new dock facilities. Recreational boating can also benefit from dock and slipway access. However, existing facilities are meeting current needs.

Perhaps a new facility in Digby could attract cruise ships visitation, as cruise ships visit Saint John regularly. A larger facility may also offer more opportunity for cargo shipments.

While some multi-use may be possible, there are no major multi-use opportunities at present for the ports in the Bay of Fundy.

5.2 SUMMARY TABLE: SUPPLY VS DEMAND

Table 17 plots the key developer infrastructure requirements summarized in Table 14 against the ports surveyed. The values used in the gap analysis (for the most part) are based on the upper limits of the requirements specified by survey respondents.

TABLE 17 – GAP ANALYSIS SUMMARY

GAP Analysis Updated July 29, 2016	Digby existing	Digby proposed	Hantsport	Parrsboro	West Bay	Saint John, Rodney	Saint John Navy Island	Saint John Lower Cove	Saint John Long Wharf	Saint John Lot X	Comments
Large scale >500 kW											
Fabrication of Platforms and foundations in NS	✔	✔	✔	✔	✔						Assumes off-site fabrication, delivery access by road or sea
Storage											
Offsite - 2500m^2	✔	✔	✔	✔	X	✔	✔	✔	✔	✔	
staging area adjacent to port - 6300m^2	?	✔	✔	✔	X	✔	✔	✔	✔	✔	
Quayside storage - 4000m^2	X[1]	✔	X	X	X	✔	✔	✔	✔	✔	[1]Adjacent buildings, size unknown
Quayside load-out - 5000m^2	✔	✔	X	X	X	✔	✔	✔	✔	✔	
Load bearing requirements											
storage - 10t/m^2	?	✔	?	X	X	X[1]	X	X	X	X	[1]Planned upgrades increase capacity to 9.8 t/m^2
quayside - 10 t/m^2	?	✔	?	X	X	X[1]	X	X	X	X	[1]Planned upgrades increase capacity to 9.8 t/m^2
Cranes											
mobile crane - 300t	✔[1]	✔[1]	✔[1]	✔[1]	✔[1]	✔[1]	✔[1]	✔[1]	✔[1]	✔[1]	[1]Available offsite, subject to dock capacity
Quayside crane - 300t	X	X	X	X	X	X	X	X	X	X	Refers to fixed cranes. Mobile cranes available offsite, subject to dock capacity
Wet port	✔	✔	X	X	X	✔	✔	✔	✔	✔	
Depth at low tide - 9m	✔	✔	X	X	X	✔	✔	✔	✔	✔	
Port proximity to Minas Passage FORCE location	4	4	3	2	1	4	4	4	4	4	rank, closest=1
Small scale <500 kW											
Fabrication of Platforms and foundations in NS	✔	✔	✔	✔	✔						Assumes off-site fabrication, delivery access by road or sea
Storage											
Offsite - 400m^2	✔	✔	✔	✔	X	✔	✔	✔	✔	✔	
staging area adjacent to port - 1600m^2	?	✔	✔	✔	X	✔	✔	✔	✔	✔	
Quayside storage - 400m^2	✔[1]	✔	✔	X	X	✔	✔	✔	✔	✔	[1] adjacent buildings
Quayside load-out - 1600m^2	✔	✔	✔	✔	X	✔	✔	✔	✔	✔	
Load bearing requirements											
storage - 10t/m^2	?	✔	?	X	X	X[1]	X	X	X	X	[1]Planned upgrades increase capacity to 9.8 t/m^2
quayside - 10 t/m^2	?	✔	?	X	X	X[1]	X	X	X	X	[1]Planned upgrades increase capacity to 9.8 t/m^2
Cranes											
mobile crane - 100t	✔[1]	✔[1]	✔[1]	✔[1]	✔[1]	✔[1]	✔[1]	✔[1]	✔[1]	✔[1]	[1]Available offsite, subject to dock capacity
Quayside crane - 200t	X	X	X	X	X	X	X	X	X	X	Refers to fixed cranes. Mobile cranes available offsite, subject to dock capacity
Wet port for installation, major O&M	✔	✔	X	X	X	✔	✔	✔	✔	✔	
Dry port OK for minor O&M	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	

Note: the summary table indicates that load bearing requirements are not met. The developer requirements range from $2.5 t/m^2$ up to $10 t/m^2$. The available capacities provided by the ports range up to $7.1 t/m^2$. Quayside loads will require proper investigation to ensure specific load bearing capacities are not exceeded.

6 Conclusions & Recommendations

6.1 Conclusions

6.1.1 Conclusions on the Infrastructure Requirements

The analysis of infrastructure requirements presented in Section 2 indicates that:

- Although there have been changes to the main industry participants, with both exits and new market entrants, and an increase in development activity in regard to smaller devices, the infrastructure requirements have not changed significantly since the original 2011 study [1].
- All participating developers indicated either firm plans to deploy in Nova Scotia, or a willingness to come to Nova Scotia within the next ten years. Survey results suggested that there are good prospects for harnessing the tidal resource in Nova Scotia, but development is likely to be on a longer time scale than originally anticipated.
- For tidal device installation activities, a wet port was identified as a requirement by the majority (7 of 9) of developers who responded to the survey.
- Developer O&M requirements are less clearly defined from the survey, with a large variation regarding the anticipated frequency of O&M activities for different device types and limited information on actual O&M plans and activities. Currently anticipated *major O&M* requirements include a wet port, which was selected by the majority (7 of 10) of respondents. Half the survey respondents were in favor of using a dry port for *minor O&M* activities, with half (4 of 8) respondents specifying a wet port as a requirement for these activities.
- In deciding whether to use a wet or dry port for O&M activities, it may come down to a commercial balance between:
    - Accessibility to available facilities (road/rail service, vessel accessibility duration during the tidal cycle), as well as the equipment and dock capabilities for meeting the developer's needs.
    - The distance from a wet or dry port to the tidal site - which determines the cost of O&M: the greater the distance the greater the costs and operational risks.
- Several developers expressed a requirement for shipyard, fabrication and heavy manufacturing facilities. Ideally these would be at the deployment port to minimise transport and handling of heavy components. Saint John, Halifax and Pictou already have major engineering and production facilities, and Halifax and Saint John have access by road, rail and sea to import specialist components from elsewhere.
- In the short and medium term, it is expected that manufacturing will be carried out at the nearest suitable facility, selected by developers on a case-by-case commercial basis, and that components or assembled nacelles will be transported by road or sea to the assembly/deployment quayside. Given this, it would be a considerable risk to establish any

major new facilities unless and until the industry has moved into very large scale deployments.

6.1.2 CONCLUSIONS ON THE EUROPEAN PORTS FEEDBACK

The review of the European ports' experience indicates:

- Infrastructure upgrades currently supporting the tidal industry have been made possible because they also benefit other industries (offshore wind, oil & gas, and passenger transport). This multi-use allows cost sharing and reduces the risks associated with uncertainties in the developing tidal market.
- Synergies with other port and marine users can also facilitate tidal project acceptance, if it can be demonstrated that port upgrades benefit the broader local economy. This applies especially to established users who may perceive tidal projects as competitors both for port and marine usage. Infrastructure upgrades should incorporate mechanisms to identify and reduce potential conflicts between users.
- Offshore renewables construction and installation activities for ports are relatively short term (e.g. 2 to 3 years for a 500MW offshore wind farm). The European experience has shown that port owners tend to give priority to longer term activities such as bulk materials handling, which contributes to more steady revenues. In contrast, O&M activities for a multi-MW tidal farm are long term in nature, since tidal energy projects are typically designed for 20-25 years. Therefore, in the absence of multi-use opportunities, the long term tidal energy development plans must clarify O&M requirements, in order to economically justify the infrastructure investment decisions.

6.1.3 CONCLUSIONS OF THE GAP ANALYSIS

The GAP analysis offers the following (with reference to Table 17):

- The proposed development plans in Digby and in the Port of Saint John provide the wet port required for installation activities by most developers and for O&M by many developers. Up to now, the existing Digby port does not provide the necessary quayside space nor the staging area near the port. Neither port provides sufficient load bearing capacity on the quays nor sufficiently high load quayside cranes.
- Digby's proposed expansion, outlined in Section 5.1.6, will provide a facility meeting the majority of the requirements specified by respondents, especially a sufficient storage space on the quayside and load bearing capacity. As is currently the case, a sufficient high load mobile crane could be brought to site when needed.
- Saint John currently has facilities that meet the majority of developers' requirements specified by respondents. Rodney pier will ensure an almost sufficient load bearing capacity

after the planned upgrade. As in Digby, a mobile high load crane could palliate the absence of a sufficient quayside crane.

- Considering only availability during the tidal cycle and proximity to the Minas Passage, West Bay near Ottawa House and Partridge Island would be a beneficial dry port. A cost-benefit analysis should be developed to determine the feasibility of using a dry port in West Bay, Hantsport or Parrsboro, that considers the costs of upgrading or greenfield development.
- Industry feedback has suggested that a shared-usage floating drydock or submersible barge, which would allow for the safe transport of large tidal energy systems from manufacturing facilities outside of the Bay of Fundy, would be useful. A smaller shared-usage vessel with beach landing capability could be a valuable resource for offloading personnel and smaller equipment very close to Minas Passage, aiding in safety and cost effective operations during installations, and ongoing operations and maintenance.
- While some multi-use may be possible, there are no major multi-use opportunities at present for the ports in the Bay of Fundy.

6.1.4 Remaining uncertainties

There are a number of uncertainties, both locally and globally, that make it difficult to draw firm conclusions with respect to port infrastructure in Nova Scotia. These uncertainties result from the following (see also the limitations in trying to predict the industry evolution in Sections 2.4.1 and 2.4.2):

- Evolving and undefined O&M plans make it difficult to determine port requirements, which in turn prevent determination of the viability of a new facility at West Bay, or upgrading facilities in Parrsboro or Hantsport.
- Some developers may not be familiar with the use of dry ports, and so have not determined whether they can adapt their O&M operations to periodic dry conditions, nor have they determined whether a dry port in close proximity to a deployment site is a better option than a wet port farther away. To some extent, this may also affect installation strategies. This uncertainty in the usefulness of a dry port is a critical question that must be addressed when considering port investment options.
- There is ongoing uncertainty with respect to the timeline to large scale commercialization. Observed delays regarding the installation timeline are caused by technical issues, local acceptability and other global factors. An important development step is up scaling from small prototype validation projects to commercial scale arrays that would in turn justify important infrastructure investments.

- Factors affecting the economic viability of tidal projects, such as the evolution and expansion of the current FIT and COMFIT program, other energy projects underway for the province, and the currently depressed global oil price.
- Uncertainties in the global energy market, and the global economy in general, affecting MRE investments and developments.

6.2 Recommendations

6.2.1 Infrastructure upgrade decision

The investigation undertaken for this report reveals that many uncertainties remain, primarily the lack of clarity regarding O&M infrastructure needs, and the time frame in which commercial scale infrastructure will be needed. Given these uncertainties, it does not appear that upgrading existing ports or greenfield construction will be commercially viable over the short term.

Additionally, the uncertainties discussed currently prevent the determination of when infrastructure investment will be suitable.

The decision to move ahead with infrastructure investment is a separate analysis, and will depend on a detailed justification for the expenditure. Justification could include revenues through user fees, benefits to local and provincial economies, job creation, and the degree of usage by other industries.

At this time, it is recommended that as many of these uncertainties and risks as possible (as listed in 6.1.4) are addressed to ensure investment decisions are based on actual future tidal project infrastructure needs.

6.2.2 Infrastructure upgrade opportunities

Should the market bring sufficient economical evidence to justify investments, a number of promising opportunities have been identified to provide the infrastructure requested by the developers.

1. Given the current prospective needs expressed by developers during the survey, the Port of Digby has been identified as the best Nova Scotia infrastructure investment opportunity to support the tidal industry (see Sections 5.1.6 and 6.1.3). This is mainly due to its status as a wet port and its quayside water depth at low tide. If a decision is made to move ahead with infrastructure investment, it is recommended to support the Municipality of the District of Digby in assessing its greenfield development proposal as described in Section 5.

   Interaction with other port and marine users should be considered when designing the Digby upgrade. As an example, it is suggested to investigate including a slipway in the upgrades as it may allow the facilities to be used for a range of other activities.

2. The two dry ports investigated (Hantsport and Parrsboro) offer advantages of existing usable infrastructure (Parrsboro) and road/rail accessibility and proximity to fabrication resources in Halifax (Hantsport). As the requirements for O&M are still developing, and vary widely, the utilization of a dry port currently depends on individual project requirements for installation and O&M.
3. Should a dry port be considered as a viable option, the West Bay location provides the closest proximity to Minas Passage, and greatest accessibility (defined as amount of quayside or slipway access during the tidal cycle). It is recommended to investigate costs of the West Bay option as detailed in Section 3.1.5 (see also 5.1.2 and 5.1.3 for discussions), including road upgrades and storage sites. Indeed the rather steep bathymetry and its situation in sheltered waters next to the Minas Passage deployment site make it an interesting site, at least as an O&M base.

6.2.3 RECOMMENDED FURTHER INVESTIGATIONS

This section summarizes suggested investigations to follow-up this study and to be carried out ahead of performing infrastructure upgrades.

1. Any port upgrades should be designed on specifications derived from a detailed assessment of the market needs. Requested quay and lay down area dimensions, water depth, and bearing capacity should be assessed in further detail ahead of investment decisions. The current survey shows a large range of values – some requests are unlikely to be economically achievable but they may represent optimal values as opposed to absolute minimum requirements.
2. A detailed review of developer O&M plans should be undertaken sometime in the future, perhaps once Cape Sharp Tidal and BRTP systems are operational, to determine requirements for O&M that might be supported by a dry port. With this information, a revised analysis of the three dry port options within close proximity to Minas Passage can be performed. Generally, it is recommended to engage further with identified developers and installation contractors in order to fully account for their potential adaptability to the unique conditions within the Bay of Fundy as part of detailed port upgrade studies.
3. Investigate the feasibility of a suitable shared-usage submersible barge/drydock, or similar vessel for use in the transport and possibly the deployment of tidal devices (as discussed in Section 5.1.4). Include ROM costs and scenarios for ownership and operation of this equipment.
4. Investigate the feasibility of a smaller, shared-usage beach lander vessel that could be used for transporting personnel and small equipment to support O&M and ancillary operations, such instrumentation deployment.

5. Search for synergies with other industries – although major multi-use opportunities like those experienced in Europe are unlikely in the Bay of Fundy, any multi-use opportunity will contribute to justification for infrastructure investment.

7 REFERENCES

[1] Collective Wisdom Solutions (CWS), exp. Services Inc. and Maritime Tidal Energy Corporation (2011) Marine Renewable Energy Infrastructure Assessment prepared for Nova Scotia Department of Energy, August 2011.

[2] Nova Scotia Department of Energy (2012) Nova Scotia Marine Renewable Energy Strategy, Province of Nova Scotia, Canada, May 2012.

[3] AECOM Canada Ltd (2014) Tidal Energy: Strategic Environmental Assessment (SEA) Update for the Bay of Fundy, Offshore Energy Environmental Research Association (OERA), Halifax Canada, January 2014.

[4] Marine Renewables Canada (2015) Marine Renewable Canada, Annual Report 2015.

[5] Ocean Energy Systems (OES) (2015) Annual Report – Ocean Energy Systems 2015.

[6] Karsten, R. (2013) Measuring and Assessing the Tidal Resource. In MacDougall, S. and J. Colton (Eds). Community and Business Toolkit for Tidal Energy Development. Acadia Tidal Energy Institute Publication 2013-01. Pp. 25-37.

[7] Fundy Energy Research Network (FERN) (2016) Fundy Energy Research Network (FERN), Annual Newsletter, Issue 5, March 2016.

[8] Fundy Ocean Research Centre of Energy (FORCE) (2016) [online], http://fundyforce.ca/technology/, accessed 29/07/2016.

[9] DP Energy, Press Release – Nova Scotia Government welcomes DP Energy to the Fundy Ocean Research Centre for Energy (FORCE) (2016) [online] http://www.dpenergy.com/news/press-release-1st-december-2015-dp-energy-secures-go-ahead-for-4-5mw-tidal-energy-rights-in-canada/, accessed 14/06/2016.

[10] Trowse, G. (2011) Project Description, Outer Bay of Fundy Tidal Energy Project, Fundy Tidal Inc., August 2011.

[11] Karsten, R. (2012) Report to OEER/OETR for Tidal Energy Resource Assessment Map for Nova Scotia, Acadia Tidal Energy Institute, Department of Mathematics and Statistics, Acadia University, Revised November 9, 2012.

[12] Hay, A., Karsten, R., Trowse, G. et al. (2013) Southwest Nova Scotia Tidal Energy Resource Assessment – Final Report, 24 June 2013

[13] Trowse, G., Cheel, R. and Hay, A. (2013) Southwest Nova Scotia Tidal Energy Resource Assessment Volume 1: Tidal Energy Potential Reconnaissance, 24 June 2013.

[14] McMillan, J., Trowse, G., Schillinger, D. et al. (2012) Cape Breton Resource Assessment, Dalhousie University and Cape Breton University, 22 August 2012.

[15] Molloy, S., Taylor, J. (2013) Tidal Power Extraction Devices. In MacDougall, S. and J. Colton (Eds). Community and Business Toolkit for Tidal Energy Development. Acadia Tidal Energy Institute Publication 2013-01. Pp. 38-49.

[16] O'Halloran, D., Deveaux, M. (2012) Tidal Power Service Site Selection and Development Plan – Draft Report

[17] Telephone discussion with long-time area resident, June 24, 2016

[18] European Marine Energy Centre (EMEC) (2013) [online], http://www.emec.org.uk/blog-unprecedented-tidal-energy-activity-at-hatston-pier/.

[19] Orkney Harbours (2016) [online], http://www.orkneyharbours.com/port_infrastructure.asp

[20] Orkney Marine Renewables (2016) [online]
http://www.orkneymarinerenewables.com/infrastructure.asp#Hatston_Pier

[21] European Marine Energy Centre (EMEC) (2016) [online], http://www.emec.org.uk/about-us/our-tidal-clients

[22] European Marine Energy Centre (EMEC) blog (2016) [online], http://www.emec.org.uk/blog-sr2000-arrives-in-orkney

[23] European Marine Energy Centre (EMEC) blog (2016) [online], http://www.emec.org.uk/blog-sme-wet-test-plat-o-ahead-of-emec-deployment

[24] Global Energy Group: Nigg Energy Park Yard Specification report, 2012

[25] Atlantis Resources Limited (2016) [online], http://atlantisresourcesltd.com/projects/meygen-scotland.html

[26] Ports Normands Associés (2016) [online]

http://www.pna-emr.fr/rubrique/page.php?id_rubrique=17&id_article=6

[27] DCNS Group (2016) [online],

http://fr.dcnsgroup.com/news/futur-atelier-dassemblage-dhydroliennes-de-dcns-openhydro-a-cherbourg-feu-vert-pour-le-permis-de-construire/

[28] Hydroquest (2016) [online],

http://www.hydroquest.net/les-hydroliennes/hydroliennes-marines/

[29] RENews (2013) [online],

http://renews.biz/39962/voith-turbine-lands-at-cherbourg/

[30] Invest in Bretagne

http://www.invest-in-bretagne.org/-des-infrastructures-pour,363-.html

[31] Scottish Development International: Kirkwall Factsheet

[32] Ports Normands associés (2015) [online],

https://iut-stmalo.univ-rennes1.fr/sites/iut-stmalo.univ-rennes1.fr/files/images/ppt%20chauvet%20cherbourg.pdf

[33] Région Bretagne (2016) [online],

http://www.bretagne.bzh/jcms/prod_319902/fr/port-de-brest-cherche-entreprises-de-travaux-publics

[34] Beothuk unveils plan for $4b wind farm off Yarmouth, The Chronicle Herald, Dec 21, 2015. Accessed July 21, 2016. http://thechronicleherald.ca/business/1328766-beothuk-unveils-plan-for-4b-wind-farm-off-yarmouth

Appendix A OERA TIDAL DEVELOPER SURVEY

Please provide information on any current or future tidal development plans in Nova Scotia

1 Do you have any current tidal development activities in Nova Scotia?
☐ Yes – a berth in FORCE
☐ Yes – a smaller scale installation site
☐ No
☐ Other (please specify)

2 If applicable – please provide a brief description of your current tidal development activities in Nova Scotia (e.g. location, project size, etc.)

3 Do you have any future tidal development plans for Nova Scotia?
☐ Yes
☐ Not yet – but would consider opportunities in Nova Scotia within the next 10 years
☐ No

4 If applicable – please briefly describe your future tidal development plans in Nova Scotia

Please provide a description of your tidal technology which could be installed in Nova Scotia in the short term (i.e. next 5 years)

5 What is your technology type?
☐ Horizontal axis tidal turbine
☐ Vertical axis tidal turbines
☐ Cross-flow turbine
☐ Other (please specify)

6 What is your device foundation type?
☐ Bottom mounted – gravity base
☐ Bottom mounted – piled
☐ Moored – catenary mooring
☐ Moored – mid-water mooring arrangement
☐ Other (please specify)

7 What is the generating capacity of your device?
☐ Up to 500kW
☐ > 500kW

8 What is the current stage of development of your technology?
☐ Proof of concept
☐ Small scale test installation
☐ Full size installation
☐ Commercial generation
☐ Other (please specify)

9 Please provide a brief description of any previous deployments (e.g. location, size of device installed, etc.)

10 Please specify the weight and physical size of your device.

Turbine diameter [m]
Number of turbines per device
Max. dry/wet weight of the nacelle [tonne]
Max. dry/wet weight of the platform/foundation [tonne]
Foundation/platform dimensions (LxWxH) [m]

Please help us to identify your infrastructure needs

11 Would you be interested in fabricating your turbine in Nova Scotia?
☐ Yes
☐ No

12 If you answered 'Yes' to Q11 - please briefly describe your infrastructure requirements.

13 Would you be interested in fabricating your foundation or platform in Nova Scotia?
☐ Yes
☐ No

14 If you answered 'Yes' to Q13 - please briefly describe your infrastructure requirements.

15 What transport requirements do you require for your operations?
☐ Rail access to the port
☐ Major road access to the port
☐ Capacity to transport oversized components to the port
☐ Capacity to transport shipping containers to the port
☐ Other (please specify)

16 What is your desired site area for storage and load-out requirements?
Storage facility off site [m^2]:
Staging area (adjacent to the port) [m^2]:
Quayside area for storage [m^2]:
Quayside area for load-out of large components [m^2]:

17 Are there requirements on the load bearing capacity of the quayside or storage area?
Yes – Quayside [T/m^2]:
Yes – Storage area [T/m^2]:
No

18 What do you require to launch and recover your device in a port?
☐ Slipway
☐ Self-propelled modular transporter (SPMT)
☐ Mobile crane
☐ Heavy lift crane
☐ Quayside crane
Please specify any other equipment / infrastructure requirements here:

19 If cranes are required during the load-out, please specify the lift capacity required for each:
Mobile crane [tonne]
Heavy lift crane [tonne]
Quayside crane [tonne]

Please help us to identify your port and vessel needs

20 Which type of port do you require for device installation and O&M activities?

	Installation	Minor O&M activities	Major O&M activities
Wet port (i.e. water at the quayside at low tide)	☐	☐	☐
Dry port (i.e. bottom dries out at low tide)	☐	☐	☐
Wet or dry port suitable	☐	☐	☐

Please elaborate on any additional port requirements here:

21 If a dry port is suitable, please specify any additional requirements (e.g. level sea bed):

22 How critical is the proximity of the port to the installation site?
☐ 1 – Decisive factor
☐ 3 – Important
☐ 5 – Desirable

Please provide any additional comments on the importance of port proximity to your installation site here:

23 Which type of vessel(s) do you require for device installation and O&M activities?

	Installation	Minor O&M activities	Major O&M activities
Barge	☐	☐	☐
Jack-up barge	☐	☐	☐
Dynamic positioning barge	☐	☐	☐
Tug boat	☐	☐	☐
General work boat	☐	☐	☐

Please elaborate on any additional vessel requirements here (e.g. DP, bollard pull, heavy lift capacity, ROVs, etc.):

24 What is the anticipated frequency of your O&M activities per device?
Device inspections [per year]:
Minor maintenance events [per year]:
Major machine overhauls [per year]:

25 Do you anticipate any major changes in your infrastructure needs in the medium term (i.e. in a 10-year horizon)?

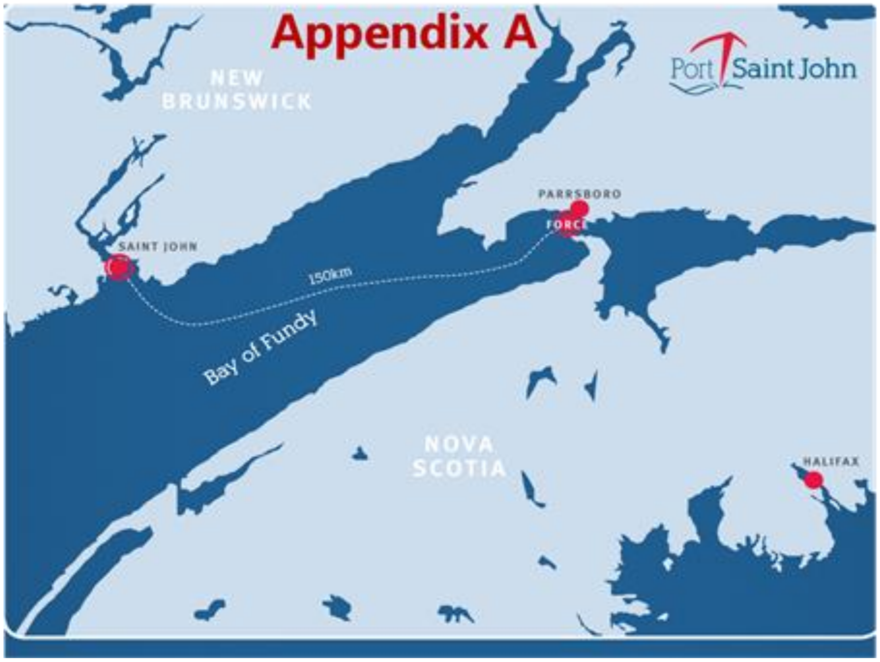
☐ No
☐ Yes – please provide a brief overview

Appendix B OERA PORT ASSESSMENT SURVEY

	Port Name
Location	
Distance from Minas passage	
Maximum Vessel Dimensions	
Draft at quayside (all tidal conditions)	
Draft along channel approach (all tidal conditions)	
Length Overall	
Beam	
Displacement	
Height Clearance	
Tidal Variation	
Historic of maintenance dredging	
Berth & Quay details	
Wharf type	
Berth Length / width (ft)	
Possibility to jack up	
Quayside Working Area and Loading capacity	
Lifting equipment – Crane details	
Nature and condition of existing slipway facilities	
Storage Possibility	
Size of available storage	
Load capacity of storage area	
Distance between storage area and quayside	
Access restrictions to storage area	
What kind of equipment is usually used for transport	
What lifting equipment is available	
Port Usage	
Other Port Users (Conflicting usage?)	
Passage Plan for channel access (priority users?)	
Berth Occupancy Levels	
Berthing slots	
Weather restrictions	
Shelter Availability	
Port Access	
Additional navigation restrictions (bridge, locks, ect)	

Rail Access	
Road Access	
Constraints for oversize transportable loads from road (rail if applicable)?	
Port Services and other infrastructures	
Operating/access hours (365/24/7?)	
Experience in similar works (offshore)	
Port Authority	
Pilot/Mooring/Towage Services	
Office Space	
Warehousing/Workshops	
High Value Secure Storage	
Covered/Open Storage	
Development	
Land options available for development	
Existing development plans	
Timescale for Availability of new capabilities (if applicable)	
Electrical service to the facility/port and local grid capacity	

Appendix C PORT OF SAINT JOHN ADDITIONAL INFORMATION




Appendix C
Cable Reel Handling
Port Saint John


Cable Reel Warehousing
Port Saint John


Port Saint John
Suction Anchors
Reel for LNG Facility
Windmill Blades
Windmill Base


Appendix D
Current Specifications
Current Main Channel Depth
8.4 m at chart datum (low tide)
16.9 m at high tide
Current Depth Alongside at Container Terminal
12.2 m at chart datum (low tide)
Current Berth Length at Rodney Face & Slip Piers
Rodney Face 435 m
Pier 2 315 m
Load-bearing Capacity of Rodney Terminal Pier Current
12 KPA (250 lbs/ft2)
Container Yard Handling Capacity per Annum
125,000 TEU*
Rail Handling Capability per Annum
75,000 TEU*
Truck Movement Capacity per Annum
50,000 TEU*
Container Handling Area of Terminal in Hectares
5.8 (14 acres)
Area Available for Breakbulk & Project Cargoes Pier 2 in Hectares
0.8 (2 acres)
Modernize Port Saint John
Project Completion
Main Channel Depth at Project Completion
10 m at chart datum (low tide)
18.5 m at high tide
Depth Alongside at Container Terminal at Project Completion
15.2 m at chart datum (low tide)
Berth Lengths at Rodney Face at Project Completion
Rodney Face 667 m
Pier 2 455 m
Load-bearing Capacity of Rodney Terminal Pier At Project Completion
96 KPA (2000 lbs/ft2)
Container Yard Handling Capacity per Annum
320,000 TEU*
(Further potential of 373,000 TEUs with removal of sheds C & D)
Rail Handling Capability per Annum
330,000 TEU*
Truck Movement Capacity per Annum
135,000 TEU*
Container Handling Area of Terminal in Hectares
10.1 (25 acres)
Area Available for Breakbulk & Project Cargoes At Completion of Project Pier 2 in Hectares
2.2 (5.5 acres)