

ADVANCEMENTS IN ENVIRONMENTAL TECHNOLOGIES FOR TIDAL ENERGY DEVELOPMENT : PUBLIC REPORT

Lead Proponent: Offshore Energy Research Association of Nova Scotia (OERA)

Location: Halifax, Nova Scotia

Natural Resources Canada (Energy Innovation Program) Contribution: \$1.0 M

Total Project Costs: \$2.5 M

Project Period: April 2017 to March 2019

PROJECT BACKGROUND

Canada and, notably, Nova Scotia have been investing in tidal energy for more than a decade. Developing tidal power demands time, significant investment and technological innovation. Pursuing these will contribute to reducing uncertainties, investment risks and, most critically to reducing overall costs. Canada continues to make important contributions in tidal technology innovation, keeping us at the forefront of developing a reliable and predictable source of renewable energy.

This project supported research into innovative technologies and techniques to advance the tidal energy sector and was comprised of five unique research initiatives with focus areas in environmental monitoring, marine operations and cost reduction technologies. The project funding period ran from April 2017 to March 2019. However, actual project work extended into FY 2019-20, with all research completed by March 31 2020. Between April 1 2019 and March 31 2020, project work was supported by in-kind contributions from the Province of Nova Scotia, the Government of Canada (CFI, Mitacs, and DFO), three Atlantic universities (Dalhousie, University of New Brunswick, and Acadia), and industry partners (Luna Ocean, FORCE, and VEMCO). Project costs from April 2017 through to end of March 2020, amounted to \$3.25 million. All research activities were conducted in Nova Scotia, with field work undertaken in high-flow channels in the Bay of Fundy. Research activities included computer modeling and simulations, controlled laboratory testing, technology deployment sea trials, data collection, data processing and analyses, and software development.

The five research initiatives were as follows:

- 1. Fish Finders project:** Integrating hydro-acoustic approaches to predict fish interactions with in-stream tidal turbines.
Proponent: Fundy Ocean Research Centre for Energy (FORCE), Dr. Dan Hasselman.



- 2. Fish Tagging project:** Quantifying fish-turbine interactions using VEMCO's new high residency acoustic tagging technology.
Proponent: Acadia University, Dr. Mike Stokesbury.



- 3. Cabling/Mooring project:** Reducing mooring and cable costs through assessment of corrosion, wear and fatigue in turbulent tidal flows. Proponent: DSA, Mr. Dean Steinke.



- 4. Turbulence project:** Reducing the costs of tidal energy through a comprehensive characterization of turbulence in the Bay of Fundy. Proponent: Acadia University, Dr. Richard Karsten



- 5. ROV project:** Developing Enhance Marine Operations (DEMO) suitable to High Flow Tidal Environments. Proponent: Nova Scotia Community College, Dr. Etienne Mfoumou.



The respective research teams featured a diverse range of expertise and backgrounds including oceanography, engineering, physics, mathematics and biological sciences. The complement of talent was drawn from Nova Scotia, New Brunswick and British Columbia, and for some of the projects engaged experts from countries including Australia, the USA and Austria. Further, more than 25 Highly Qualified Personnel (HQPs)/students were actively engaged on the project. They collectively contributed to the delivery of successful results as well as expanding tidal energy R&D capacity available in Canada.

SUMMARY RESULTS

The project has made critical technological advancements, facilitating in the growth and development of tidal energy in Canada. Through simulations, testing and validation activities, new techniques, methodologies and software have been introduced with important implications to both government regulators and tidal developers. Further, these advances have the potential for new market opportunities in the global tidal energy supply chain.

Results highlights are:

1. **Fish Finders:** Collected data sets have enabled follow-on research to automate complex and expensive post-processing of echosounder data, reducing the time required to report fish/turbine interactions to regulators from months to weeks.
2. **Fish Tagging:** Performance gains for the VEMCO High Residency (HR) fish tracking technology for use by the sector to better understand how migratory fishes encounter and possibly avoid or interact with operating tidal devices.
3. **Cabling/Moorings:** Improved software and methods how to measure fatigue, wear, and corrosion to better predict how marine turbulence impacts on cablings and moorings. The models developed will ensure adequate designs, leading to improved performance, long-term component life and overall cost savings.
4. **Turbulence:** New software that generates complete spatial maps of tidal channel flow characteristics. The flow maps, now available at much lower costs than ever before, can be used by tidal developers to optimize turbine design and array deployment that are critical to assessing project economic viability.
5. **ROVs:** Established baseline (thruster performance) capabilities of the Cougar XT and Falcon Seaeye ROVs as a critical first step toward ruggedizing and optimizing ROV performance to operate safely and efficiently in high-flow tidal energy sites.

BENEFITS TO CANADA

Technology advancements achieved through this project are important to the overall development of the tidal energy sector both here in Canada and globally. New software, techniques and methods tested and developed here have created opportunities for Canada to build its supply chain capacity to support the sector and reach new markets. The success of this research also contributes to building Canada's brand as a world leader in tidal energy expertise and experience. The concentration of talent found here increasingly helps to attract interest and investment from around the world to test and demonstrate tidal power devices in Canadian waters. This project has invested in both tidal technology innovation and expertise that will collectively help Canada remain a leader in bringing this clean and reliable source of renewable energy to market.

NEXT STEPS

More research is necessary to further refine the environmental technologies, methodologies and approaches to facilitate full utility and use by the tidal sector. The scope of new research for the respective projects is wide-ranging, including activities such as additional sea trials, collection and processing of new data sets, algorithm refinements, validation testing and new computer modeling simulations. Continued research investment in tidal technologies' development will keep that momentum going in building made-in-Canada technology solutions and know-how and move us closer to tidal energy commercialization over the next two decades.

KNOWLEDGE DISSEMINATION

Over the two-year project period, the researchers engaged with audiences locally, nationally and internationally to promote the research and progress, results, and importantly the implications of the research to advancing tidal energy development. The researchers presented at numerous forums around the globe, including Norway, France, Scotland, Austria, Italy, the USA, Singapore, as well as scores of events across Canada. Project information was delivered through conference presentations, workshops, symposia, webinars, courses, and roundtable participation to a range of audiences attended by subject matter experts, conference delegates, academia, and regulators. Furthermore, several papers were published. Of note, the Turbulence project produced five publications, including acceptance in esteemed journals such as the Journal of Atmospheric Ocean Technology and the Journal of Ocean Engineering.

Following, is summary information on each of the five initiatives, featuring a brief description of the project, methodologies, results and key achievements.

Project 1 “Fish Finders” - Integrating hydro-acoustic approaches to predict fish interactions with instream tidal turbines

Proponent: Fundy Ocean Research Centre for Energy (FORCE), Halifax, NS

Project Lead: Dr. Dan Hasselman; Lead Report Author: Dr. Haley Viehman, Echoview, Australia

Project Start: October 2017

Project Completion: December 2019

Brief Description and Methodology:

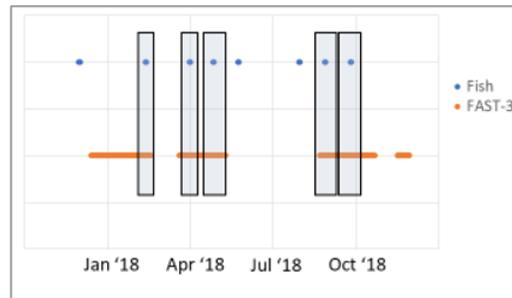
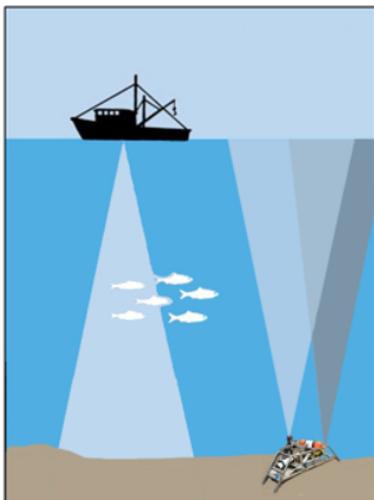
This project utilized hydro-acoustic data collected during five 24-hr mobile surveys and three long-term stationary deployments of a bottom-mounted echosounder at the FORCE test site (December 2017 – November 2019) to evaluate the scientific and operational utility of individual and integrated hydroacoustic survey methods.

Mobile surveys were conducted across a series of standardized transects of the FORCE test site from a vessel using a downward facing, pole-mounted Simrad EK80 WBAT echosounder with a 7° circular split-beam transducer (i.e., 120 kHz in narrowband continuous wave (CW) mode). Stationary surveys included the deployment of an upward-facing Simrad EK80 Wideband Autonomous Transceiver (WBAT) with a circular beam transducer (i.e., half-power beam angle of 7°; 120 kHz in narrowband CW mode), and a Nortek Signature 500 ADCP mounted on a Fundy Advanced Sonar Technology autonomous subsea platform (i.e., FAST-3) that was deployed at the FORCE test site. Data processing was conducted using

Echoview® software (version 10.0; Myriax, Hobart, Australia) and consisted of calibration, noise removal (i.e., minimum volume backscatter: -70 dB re 1 m² m⁻³), data partitioning and echo integration.

After processing, data were partitioned into bins, echo integrated, and exported for analyses. Analyses of mean volume backscatter (i.e., SV – a rough index of fish density) or the area backscattering coefficient (i.e., sa – the summation of backscatter values over a given layer in the water column; a complementary index of fish density) was conducted using the R statistical programming language (v3.6.2; R Core Team 2019). Analyses of mean SV was used to assess spatial and temporal trends in water column backscatter, whereas analyses of sa was used to assess the vertical distribution of backscatter through the water column. Spatial and temporal autocorrelation in the hydroacoustic data sets was assessed to determine the distance and time frame over which information from point measurements may be considered representative.

Integration of Datasets



- Spring: 2 months
- Fall: 2 months
- Winter: 1 month

Left: Schematic of mobile (downward facing) and stationary (upward facing) survey methodologies. Research conducted to study the integration of hydro-acoustic data sets with goal to optimize technologies' for use in predicting fish interactions with tidal turbines.

Photo courtesy of Fundy Ocean Research Centre for Energy (FORCE)

Results and Key Achievements:

This project provided the first in-situ assessment of the relative performance of mobile (downward-facing) and stationary (upward-facing) echosounders for monitoring fish in high-flow environments. This project demonstrated the influence of high-flow environments on the ability of current hydroacoustic technologies to monitor interactions between fish and tidal energy turbines.

Specifically, the primary achievements for this project include a deeper understanding of how dynamic forces in high flow environments (e.g., flow and bathymetry, turbulence and entrained air in the water column) combine to influence the efficacy of standard, commercially available, off-the-shelf hydroacoustic technologies for monitoring fish in areas where tidal power development are sought. This is crucial for understanding the limitations of current monitoring technologies and for quantifying the risk of tidal power development to marine animals. This project also highlighted the importance of 24-hr collection of monitoring data to capture the variability of fish density present during different tidal phases and the influence of diel migration on fish distribution.

The achievements of this project benefit project stakeholders and Canada by broadening our understanding of how to effectively monitor the potential environmental impacts of tidal energy turbines in dynamic marine environments. This helps to ensure the continued responsible development of the marine renewable energy sector in Canada by advancing our understanding of the risk posed to marine life. Moreover, this project helps advance monitoring capabilities and protocols, and assists in quantifying risks for the regulatory community.

The knowledge gained includes a deeper understanding of how to effectively monitor for interactions between tidal energy turbines and marine animals. This in turn has implications for future monitoring efforts and protocols, data analyses and reporting procedures.



Above: FAST 3 Platform being lifted from the recovery vessel to the Parrsboro wharf

Photo courtesy of Fundy Ocean Research Centre for Energy (FORCE)



Above: FORCE FAST-3 platform, used for the deployment of the hydro-acoustic technology to conduct the stationary data collection surveys.

Photo courtesy of Fundy Ocean Research Centre for Energy (FORCE)

Project 2 “Fish Tagging” - Quantifying fish-turbine interactions using VEMCO’s new high residency acoustic tagging technology

Proponent: Acadia University, Wolfville NS

Project Lead: Dr. Michael Stokesbury

Project Start: October 2017

Project Completion: December 2019

Brief Description and Methodology:

To initiate this project, members of the Coastal Ecology Lab at Acadia University, and Fisheries and Oceans Canada, captured Atlantic salmon smolts and Alewife from the Gaspereau River, Striped Bass from the Stewiacke River and Atlantic Sturgeon from Minas Basin. Vemco acoustic tags were surgically implanted in the fish, then released. When these fish passed by moored receivers that were deployed (in collaboration with FORCE and the Ocean Tracking Network), the tag’s acoustic transmissions were logged on to the receivers. Then, periodically, researchers downloaded the receivers. Data included unique identification numbers for fishes so they can be matched to metadata, time stamps, and the known receiver locations. Four or 5 receivers, depending on the time, were deployed at or close to the FORCE test site. These receivers provided information on fishes whose movements overlapped with areas scheduled for turbine deployment and operations. Several studies were done to determine tag signal range, as it is dependent on current speed.



Above: Acadia University students attending the ‘Advanced Surgical Techniques for Fish’ Training Course at UPEI. March 2019.

Photo courtesy of Acadia University



Above: Surgical implant of Vemco HR acoustic tag in Atlantic Salmon kelt - that will provide information on survival and migration corridors near tidal demonstration site, Bay of Fundy.

Photo courtesy of Acadia University

Results and Key Achievements:

For this study, the overlap of four migratory fishes was quantified: Alewife which is a commercial species; Atlantic Sturgeon designated as “Threatened” by COSEWIC; Striped Bass designated as “Endangered” by COSEWIC; and Atlantic Salmon listed as “Endangered” by the SARA. Through this study, there is greater understanding on the spatial and temporal interaction between these fishes and the FORCE test site. Further, great progress has been made toward determining whether the new Vemco HR technology can be used to track tagged fishes in 3 dimensions as they approach and interact with operating tidal devices. Answering the question of migratory fishes overlap and possible avoidance or interaction with operating HK devices is central to reducing the uncertainty regarding the negative environmental effects associated with operation of HK devices. Further, the results contribute to informing cost-benefit analyses that must be conducted by regulators and the general public in determining investments in tidal power, as an industry that holds great promise for the reduction of greenhouse gases.

The benefits to Canada and stakeholders of this project are clear. All Canadians have a vested interest in healthy ecosystems, safeguarding biodiversity through the protection of species of concern and protecting commercially valuable fish. Also, reducing uncertainty regarding an industry that holds great promise for reducing the production of greenhouse gases is critical for Canadians. More specific benefits have been achieved regarding the testing and proof of concept for new Canadian manufactured Vemco HR technology used in macro-tidal high current speed environments. Conducting on-going research, linked to regulators, and traditional knowledge holders such as fishers helps disseminate and clarify information on research results regarding fish turbine interactions. Through dissemination of results by researchers and graduate students both the value of the Canadian Ocean Tracking Network (OTN) and the efforts being made to quantify turbine effects by all levels of government are brought to the forefront both nationally and internationally.

Gains in technology include testing and proof of concept of Vemco HR technology. Also, as part of this project, Acadia University researcher Dr. Brian Sanderson, has determined a way to gain information on Vemco tagged fish, using icListen hydrophones. These results are preliminary but hold promise for gaining information on fishes tagged with acoustic tags of any frequency,

from Canadian manufactured broad band hydrophones commonly deployed on HK devices globally. Knowledge products also include acoustic tag analysis models produced by graduate students in the Coastal Ecology Lab at Acadia, that can be used in other areas to determine spatial and temporal interactions of tagged fishes with HK devices.



Above: Honours student Sarah Mitchell, holding a juvenile Atlantic Sturgeon captured via an otter trawl in the Southern Bight, Minas Basin. This Sturgeon was later tagged with a High Residency acoustic tag and released back into Minas Basin. Location- Trawl in the Southern Bight of Minas Basin, July 2018.

Photo courtesy of Anna Murphy

Project 3 “Cabling/Moorings” - Reducing mooring and cable costs through assessment of corrosion, wear & fatigue in turbulent tidal flows

Proponent: Dynamic Systems Analysis (DSA), Halifax, Nova Scotia and Victoria, British Columbia

Project Lead: Mr. Dean Steinke and Mr. AJ Barron

Project Start: October 2017

Project Completion: January 2019

Brief Description and Methodology:

The impacts of wear, corrosion, fatigue, and VIV (vortex induced vibration) on moorings and cables used for tidal energy applications is not yet well understood. Tidal environments contain turbulence, strongly directional currents, and large tidal elevation changes. Floating tidal platforms are moored in highly dynamic environments, and the unsteady hydrodynamic loading on the turbines and the structure is transmitted to its moorings and cables. Accurately predicting the lifetime of cables and moorings requires simulating platform motions and hydrodynamic loads, as well as hydrodynamic loading on the cables.

Vortex induced vibration (VIV), or vortex induced motion (VIM) will occur on bodies in flow when asymmetrical vortex shedding occurs, resulting in an oscillating lift force which can cause movement. Additionally, turbulence at a range of frequencies is present in tidal channels, resulting in varying drag loading.

Firstly, to better understand the role of turbulence on mooring loads, a numerical model, previously created by DSA of the ecoSpray tidal energy test platform, was augmented by adding synthetic turbulence input into ProteusDS using data from NREL's TurbSim. The synthetic turbulence model was generated using the turbulence spectra recorded by an ADCP stationed near the platform. The mooring line loads from the numerical model were compared with load cells deployed on the ecoSpray platform.

The comparison demonstrated that oscillating and stochastic loads caused by turbulence acting on floating platforms is significant and should be accounted for in numerical models of tidal platform's mooring systems which are routinely used for mooring system design. The comparison also demonstrates that if the turbulence spectra is known, then a synthetic turbulence model developed using the TurbSim and ProteusDS software packages can be used to accurately predict loads and motions.

Second, the project looked at the role of VIM on floating platforms motions, as these motions would affect mooring and cable loads. Computational fluid dynamic (CFD) software uses the Navier – Stokes equations combined with finite element discretization to solve complex fluid flow in either steady state or transient simulations. A CFD analysis was performed for the ecoSpray platform to determine whether CFD could predict VIM occurring on a floating platform. It was determined that no regular vortex shedding pattern could be seen in the simulation. This agrees with previous results that significant VIM is not occurring on the ecoSpray platform, as all the measured loads can be accounted for in the synthetic turbulence model.

Third, the project was primarily focused on developing an field experiment to determine whether VIV would occur on a cable suspended in a tidal channel, and if it did, whether that VIV could be predicted using traditional predictive methods based on theoretically derived equations or using modal analysis software (Shear7). The experiment was setup to represent a scaled version of a power umbilical deployed by Scotrenewables at EMEC (Orkney Scotland). DSA developed a streamlined buoy that allowed for a low scope in the mooring and would maintain a specific required tension that was likely to contain modes expected at full scale. DSA used accelerometers attached to the mooring line and a load cell to measure vibration in the mooring. The experiment was deployed for several weeks in the Minas Passage in Nova Scotia in November 2018. The data collected showed that VIV did occur in the tidal channel environment.

To better assess corrosion effects in tidal passages, an assessment of codes and standards regarding corrosion on mooring lines was conducted. All offshore mooring standards considered in this review provide the same methodology to design for mooring line corrosion. The standards state that the diameter of the chain (or wire rope) must be increased based on a given corrosion rate. Other sources on corrosion were reviewed, from these studies, it can be concluded that the baseline rates of corrosion

provided in the offshore standards are not applicable to these regions and baseline corrosion data must be established for this region. Once a baseline corrosion study has been completed, the rates of corrosion can then be factored into the design of moorings to ensure that the mooring maintains required strength over its lifespan.

The materials of each component in the experiment were measured to provide a baseline of corrosion data for the Minas Passage. However, due to the timeline of the project and experiment, the components were only deployed for 28 days. This is not a long enough time period to develop a baseline for corrosion rates.

The experiment provided qualitative results that demonstrated that painted surfaces were quick to lose paint and begin corroding immediately, whereas hot dipped galvanized surfaces were successful at slowing the corrosion process. The experiment demonstrated that zinc-plated cotter pins, which typically come with mooring shackles, will corrode very quickly and should not be used for deployments greater than one (1) month in the Minas Passage. The cotter pins recovered from the experiment were heavily corroded.



Above: 27 day mooring trial completed near Black Rock Minas Passage Bay of Fundy; retrieval of mooring 7 December 2018

Photo courtesy of DSA

Results and Key Achievements:

The results indicated that the turbulence present at high frequencies (>1Hz) is not powerful enough to interfere with VIV or prevent its occurrence. The experiment also demonstrated that both the theoretically derived equations and the modal analysis software could predict the primary frequency of oscillation reasonably well, but neither could predict the exact modes that would occur. The experiment also demonstrated the effectiveness of accelerometer data loggers in measuring the frequency of cable vibrations.

Another key project achievement was the significant advancement of the state-of-the-art mooring and cable load assessment - as evidenced by:

- Development and validation of dynamic simulation using synthetic turbulence model: TRL 5 (technology development) → TRL 6 (technology demonstration)
- CFD analysis to predict VIM on tidal energy platforms: TRL 1 (basic principles) → TRL 2 (application formulated).
- Procedure and expertise to predict VIV occurrence: TRL 2 (technology concept formulated) → TRL 5 (Laboratory testing of system)
- Procedure and equipment to measure VIV: TRL 2 (technology concept formulated) → TRL 5 (Laboratory testing of system)
- Site and cable specific VIV testing: TRL 2 (technology concept formulated) → TRL 5 (Laboratory testing of system)
- Corrosion guidelines for industry: TRL 1 (basic principles) → TRL 2 (application formulated)



Above: Field experiment and testing of SHiFT buoy deployed in Minas Passage near FORCE site.

Photo courtesy of DSA

Project 4 “Turbulence” - Reducing the costs of tidal energy through a comprehensive characterization of turbulence in the Bay of Fundy.

Proponent: Acadia University, Wolfville, Nova Scotia

Project Lead: Dr. Richard Karsten

Project Start: October 2017

Project Completion: March 2020

Brief Description and Methodology:

Turbulence is a significant issue at every site under consideration for instream tidal energy development. As strong tidal flow passes over the rough sea bottom and past variations in the coastline, eddies and random fluctuations in tidal currents develop, generically known as turbulence. This turbulent flow in turn creates fluctuating forces on tidal turbine blades and support structures, degrading turbine performance and shortening turbine lifespan. For these reasons, properly characterizing turbulence is a critical step to designing durable devices and accelerating the pace of technology development. Furthermore, improving and validating numerical models of turbulence and turbine operation in turbulent flow is necessary to better predict device operation in such conditions and ultimately, is a critical element to considering the financial viability of developing a tidal energy project.

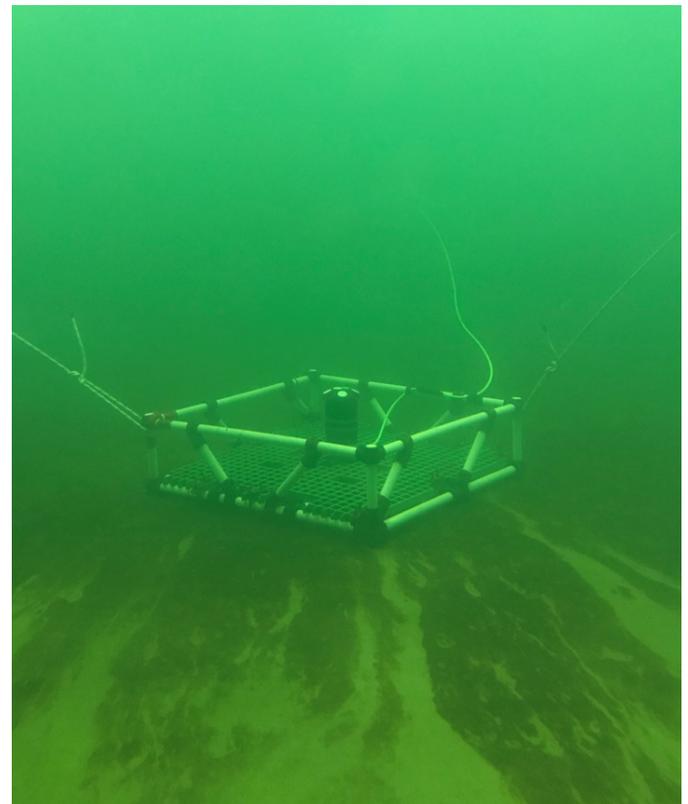
This project addresses the issue of turbulence in Minas Passage. First, using an innovative suite of mobile measurement devices, the spatial variation of turbulence in Minas Passage was characterized, including the turbulence in turbine wakes. Second, a high-resolution numerical model of the FORCE region in Minas Passage simulated the generation and dissipation of turbulence, resulting in a spatial map of turbulence in the region. Furthermore, numerical models of turbines were embedded in these simulations to determine the effect of turbulence on turbine performance and turbine wakes.

Finally, a regional numerical model, which includes tidal forcing, local weather effects and accurate turbulent parameterizations has been created for use in ocean forecasting of the Minas Passage, suitable for both short term planning of marine operations and long-term project assessments. All numerical models have been validated against field measurements to ensure the models accurately capture the spatial and temporal variations of the flow. The project end result is a complete mapping of the turbulence characteristics in Minas Passage that will allow for the development of tidal energy projects at reduced cost.



Left: Drifter sea trials to measure and map turbulence. Grand Passage, NS.

Photo courtesy of Acadia University



Above: Lab Tank testing of the Signature 1000 (5 beam) Acoustic Doppler Current Profiler (ADCP). At the Dalhousie University Aquatron facility. January 2019

Photo courtesy of Dalhousie University'

Results and Key Achievements:

First-time measurements of the turbulent wake behind a turbine mounted on a floating platform using ADCP drifters in a high-flow tidal channel:

The project has completed its most important milestone: the measurement of a turbine wake using drifting ADCPs. The measurements took place in Grand Passage, Bay of Fundy, around the SME Plat-I floating turbine platform. The process was validated measuring turbulence with the floating ADCP's. This validation step was completed sequentially, that is, with the turbines not operating, followed at a later time with the turbines operational.

Development of a turbulence-resolving numerical model of an in-situ tidal turbine: The research team has developed an innovative, computational fluid dynamics (CFD) to simulate the tidal flow through Grand Passage for flood and ebb conditions, both on coarse and fine grids. Monitoring points have been added to allow for the validation of the simulations through comparison to field measurements and to understand the effects of the turbine's operation on the turbulence level in the flow. A turbine has successfully been embedded into the coarse grid as a proof of concept step.

Development of a software package to predict spatial variation of tidal flow: Working with Luna Ocean, the researchers have developed a phase-learning, tidal-prediction software package (LunaTide) that significantly improves the ability to predict flow in high-energy tidal channels. The software innovatively combines tide gauge observations, with short-duration field measurements (i.e. drifters, drifting ADCPs, intermittent radar), to produce accurate predictions of the tidal flow. Most importantly, it can predict the spatial variation of the flow in regions of high turbulence (i.e. in the wake of an island) where standard methods have failed. The software can also incorporate data from our regional tidal-circulation model, producing accurate predictions of flow conditions through all the Bay of Fundy tidal passages.

Connection to the Eco-II project:

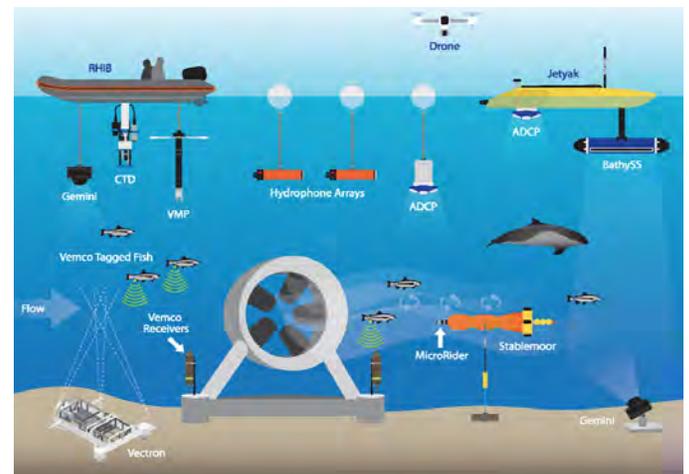
The SME Plat-I was deployed at the site first characterized as part of the Project Lead's EcoII project, near the location where the ecoSpray observational platform was deployed (2016). The combination 2016 research and this project work – i.e. multi-beam mapping of bathymetry, extensive velocity measurements use of ADCPs, characterization of the turbulence, development and validation of both a tidal circulation model and a turbulence-resolving model – contributed to attracting SME to deploy PLAT-I in Grand Passage and made the subsequent successes in the field campaigns and simulations possible. The 5-beam ADCP data collected in Grand Passage under Eco-II has been used to validate the velocity profiles and turbulence statistics predicted by CFD models. Finally, the EcoII data

set was a critical component in developing the LunaTide software package used for this project.

Benefits to Canada

With its extensive coastal regions and many tidal sites, Canada can be a leader in the development of other marine renewable energy, in particular tidal energy. Nova Scotia's Bay of Fundy has recently become the focus of testing, development, and commercialization of in-stream tidal turbines. Various companies, both Canadian and European are deploying their devices at sites in the locations throughout the bay. The companies come to Nova Scotia for many reasons but a key one is that the tidal sites have been extremely well studied and characterized by the regional scientific experts through projects like this one. This project's work to characterize turbulence at a tidal site, and the ability to measure the wake properties of the turbine attract such companies to do their testing and development in Canada.

Furthermore, these companies are developing the next generation of tidal turbines that can be deployed at many more sites around the globe including Canada's remote, northern coastal regions. The development of economic and efficient site characterization methods (using drifting ADCPs, LunaTide, etc.) will allow Canada's remote communities to develop and benefit from renewable marine energy. It will also be used in the development of tidal energy in the developing world with opportunities in Central and South America, the Philippines, and Indonesia, that require expertise that Canada can provide.



Above: Schematic of flow and turbulence observation system featuring the Jetyak with its ADCP; the ADCP drifters; the RHIB with VMP and CTD (conductivity temperature depth) profiler; the drone; and the FAST platform with the Vectron. The shore-based X-band radar is not shown. The Stablemoor/ MicroRider, hydrophone arrays, and fish-monitoring gear are not part of the present project.

Photo courtesy of Acadia University

Project 5 “ROV” - Developing (ROV) Enhanced Marine Operations (DEMO) suitable to High Flow Tidal Environments

Proponent: Nova Scotia Community College (NSCC) - Ivany Campus. Dartmouth, NS

Project Lead: Dr. Etienne Mfoumou

Project Start: October 2017

Project Completion: November 2019

Brief Description and Methodology:

The project comprised three research components: to establish baseline capabilities of a specific ROV; to develop modeling capabilities for the ROV model; and software development to assess motions and loads on the ROV configurations.

The first phase was to establish baseline capabilities of the Cougar XT-1420 ROV. The research team successfully conducted a technical pre-assessment of the Cougar ROV capabilities through computer simulation of ROV thrusters' performance analysis. To generate the results, a 3-D CAD model as well as a mesh of the ROV were developed. These capabilities were established with consideration of the current marine renewable sites in the Digby and Minas Passage areas. NSCC has assessed the technical feasibility of deploying an ROV in selected sites, based on Dominion Diving's (a Dartmouth based marine service company) marine assets and expertise to conduct testing in the Bay of Fundy and to develop the technology upgrade required to successfully complete the DEMO research program.

The second phase has contributed to the development of modeling capabilities that apply the outcomes from phase one toward developing a set of tools that will help reduce the risks associated with ROV operations in high flow tidal environments. The capabilities being developed can also be used to assess optimization requirements to existing marine assets. This has built on expertise developed by the Heuristic and Evolutionary Algorithms Laboratory of the School of Informatics, Communications and Media of the University of Applied Sciences in Upper Austria (NSCC project partner).

The third phase was supported by project partner, Dynamic Systems Analysis Ltd. (DSA), who provided dynamic analysis software and expertise to assess the motions and loads on the proposed ROV configurations. This research is supportive to reducing operational risks in planning a deployment in high flow tidal environments.

The results suggested conducting validation tests in a controlled environment. This validation step was taken with testing done using another model - the Falcon Seaeye ROV – and completed as part of this phase at Dalhousie's Aquatron facility in Halifax. A better understanding of the deployment limits was gained, leading to improvements in existing modeling capabilities.



Above: Jordan Kamga (left) a Mechanical Engineering coop student from Dalhousie University; and NSCC Research Assistant Shaza Abumousa developing solutions for manufacturing ROV parts using CNC machining and 3D-printing technology.

Photo courtesy of NSCC

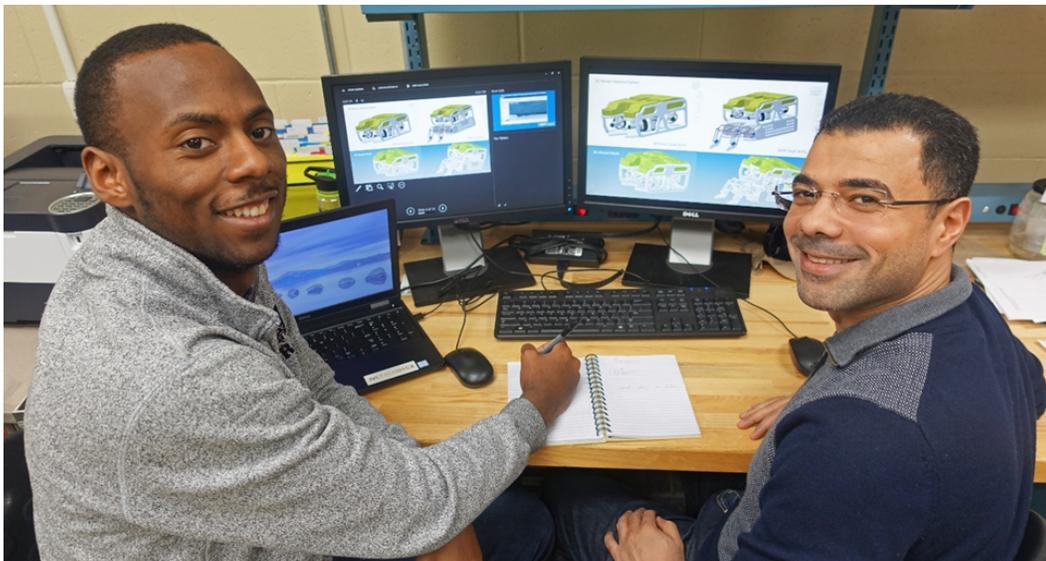
Results and Key Achievements:

- Baseline capabilities of the Cougar ROV established. The results add to the body of knowledge available on this ROV model.
- The baseline capabilities have been used to develop a method for applying a 'heuristic and evolutionary algorithm' approach to optimizing data processing in the DSA ProteusDS software.
- The project has demonstrated the feasibility of using ShipMo3D and NEMOH software for the determination of added mass at infinite frequency. This has benefit to other small-medium-enterprises (SMEs) in the sector, not able to afford expensive tools required to conduct their activities.
- The project has produced a simulation-based optimization method that uses Surrogate Modeling (SM), Machine Learning (ML), and Efficient Global Optimization (EGO), where these knowledge products have been shared with DSA for their use for further software developments.
- Testing the Falcon ROV at different configurations at the Aquatron Facility at Dalhousie University has led to the collection of new data sets of the Falcon reaction loads for use by others in the sector.
- The values are compared with the predictions obtained from ProteusDS modeling software. Good agreement was observed between the experiments and the model for the ROV with no skid, at flow rates up to 100% of one pump's full capacity (corresponding to ~0.6 m/s).
- The research is an important first step toward improving marine operations in the Bay of Fundy, by enabling a proper selection of intervention tasks and operational windows for ROV deployments. However, more research is required.



Above: NSCC Applied Research Team at the Aquatron facility at Dalhousie University for site assessment prior to deployment of the Cougar XT-1420 ROV for testing in a controlled environment.

Photo courtesy of NSCC



Left: Jordan Kamga (on the left) a Mechanical Engineering coop student from Dalhousie University discussing ROV simulation results with Dr. Mo Shamma from NSCC Applied Research.

Photo courtesy of NSCC