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ADCP DEPLOYMENT LENGTH GUIDELINES

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A	2018-10-25	Issued for review	AB	AT
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Executive Summary

Dynamic Systems Analysis Ltd. (DSA) has performed an initial qualitative assessment of wind and wave exposure for 38 aquaculture sites in Nova Scotia. Wind exposure assessments were performed to provide guidance on the preferred locations for extended ADCP deployments. Wave exposure assessments were performed to provide guidance on which aquaculture sites would require an advanced wave propagation modeling to determine the maximum storm waves for an engineering analysis of the farm.

It was determined that sites in Chedabucto Bay, Jordan Bay, Lobster Bay, and St. Mary's Bay would all benefit from three-month ADCP deployments. At least one month of ADCP data must be collected at each individual site, as the tidal component and local effects from bathymetry and nearby headlands will cause current data to differ between sites.

All sites exposed to open ocean would require a wave propagation analysis. Sites located in the central region, Liverpool Bay, mouth of Shelburne Harbour, Pubnico region, Grand Passage, and St Mary's Bay all require wave propagation analysis.

It should be noted that this analysis uses a simplistic approach to determining wave and wind exposure, and should not be used in place of more robust methods. The approach taken was chosen to provide effective guidance without performing an extensive analysis which may yield small differences with the simplistic approach. A more complete analysis of wave exposure around the province should be completed to complement this analysis. Additionally, further investigation into the methodology of using three-month ADCP data for statistical analysis of the random component of current independent of the tidal component must be completed. This investigation would inform the validity of using ADCP data from nearby sites for determination of the random component.

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1 Introduction

1.1 Overview

Nova Scotia Department of Fisheries and Aquaculture (DFA) is aiming to deploy multiple ADCPs at aquaculture sites across Nova Scotia. Certain aquaculture mooring standards require an ADCP deployment duration of at least one month (such as Norwegian Standard NS9415) [1], while other standards require ADCP deployment durations of at least three months (such as Marine Scotland Technical Standard for Scottish Finfish Aquaculture) [2]. Due to ADCP availability, three-month deployments at all sites is not currently feasible, thus it must be determined which aquaculture sites in Nova Scotia can benefit most from a three-month ADCP deployment, and which sites may not be required to do so.

DSA has performed a qualitative assessment of wind and wave exposure for 38 aquaculture sites in Nova Scotia. Wind exposure assessments were performed to provide guidance on the preferred locations for extended ADCP deployments. Wave exposure assessments were performed to provide guidance on which aquaculture sites would require an advanced wave propagation model to determine the maximum storm waves for an engineering analysis of the farm.

The wind exposure assessment was performed using a wind exposure map for Nova Scotia published by the Nova Scotia Department of Natural Resources. Wave exposure calculations were performed by using maps to determine the maximum fetch and angle of open ocean exposure for each aquaculture site.

Each aquaculture site was given a qualitative value for wave exposure and wind exposure. Sites that ranked ‘very high’ for both wind and waves were recommended to longer term (3-month) ADCP deployments.

1.2 Objectives

- Determine qualitative wind exposure level for 38 aquaculture sites in Nova Scotia
- Determine qualitative wave exposure level for 38 aquaculture sites in Nova Scotia
- Provide guidance on preferred locations for longer term (3-month) ADCP deployments
- Provide guidance on which aquaculture sites would require wave propagation modelling (such as with STWave or SWAN) to determine maximum wave heights for an engineering analysis

1.3 Abbreviations and acronyms

DSA	Dynamic Systems Analysis Ltd.
DFA	Nova Scotia Department of Fisheries and Aquaculture
ADCP	Acoustic doppler current profiler

2 Methodology

2.1 Wind exposure level

The wind exposure level was determined using the *Digital Wind Exposure Map for Nova Scotia* [3]. The map was developed as part of a forest research report and uses several wind data sources around the province to

determine the average annual maximum wind speeds across Nova Scotia. Each aquaculture site assessed was co-located on the wind exposure map to determine the wind exposure level. Wind exposure levels are provided using the same scale as the exposure map, which is a rating from very low, to very high (5 possible ratings). The digital wind exposure map for Nova Scotia is shown in Figure 1.

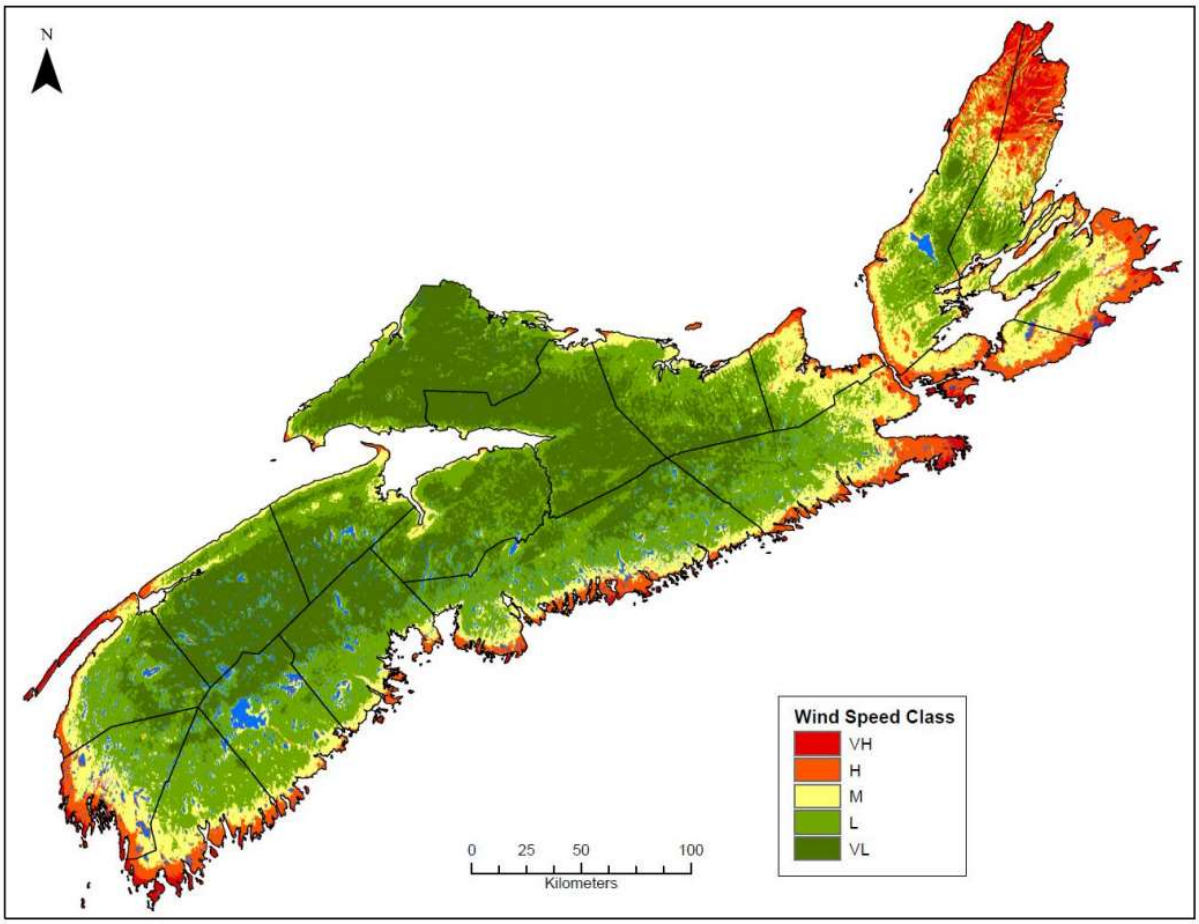

Figure 1 - Digital wind exposure map for Nova Scotia used for wind exposure level [3].

2.2 Wave exposure level

The wave exposure level was determined using the Google Earth software to determine the maximum fetch distance for each aquaculture site. All fetch lengths larger than 25km were assumed to be open ocean. For sites that are exposed to open ocean, the angle of exposure was calculated.

A qualitative wave exposure value was determined based on the angle of exposure to open ocean. For sites without open ocean exposure, the value was determined based on the maximum fetch. The criteria for each wave exposure rating is presented in Table 1.

Table 1 - Criteria for wave exposure rating

Rating:	Criteria:
Very low	Maximum fetch < 5km, no open ocean exposure
Low	Maximum fetch < 10km, no open ocean exposure
Medium	Maximum fetch > 10km, open ocean exposure < 10 degrees
High	Maximum fetch > 25km, open ocean exposure < 35 degrees
Very high	Maximum fetch > 25km, open ocean exposure > 35 degrees

It should be noted that this is a simplistic approach to determining wave exposure and should not be confused with more robust methods. These approaches were chosen to provide approximate guidance without performing an extensive analysis. A more complete analysis of wave exposure around the province should be completed to complement this analysis.

2.3 Site selection for longer ADCP deployment

Justification for three-month ADCP deployment periods is outlined in the Scottish technical standard [2]. The primary reason for a three-month deployment is to ensure that enough independent samples are gathered to ensure a good statistical fit of the collected data to established extreme value analysis distributions, such as the Weibull distribution. In general, it can be statistically shown that collection of ADCP data over a three-month period provides a substantial increase in probability of capturing extreme peaks over a one-month deployment, thus providing a significant increase in accuracy of the predicted 10 and 50-year return periods for current. Measurement durations in excess of three months is shown to provided diminishing returns for statistical accuracy, therefore is likely not required [2].

In cases where enough data is collected, using a statistical distribution to determine extreme current maxima is a more accurate approach than alternative scaling methods. The Norwegian Standard states that one month of ADCP data must be gathered and then the maximum current speed collected must be increased by a factor of 1.85 to determine the theoretical 50 year return period maximum current [1]. This method has much higher risk and may result in farm over-design if a large storm were to occur during the ADCP deployment as there is no accounting for the quality of the data captured.

The Scottish Technical Standard discusses two components to the currents captured by ADCP deployments: A tidal component, and a random component. The tidal component is recurring and predictable using tidal modelling methods and tidal heights collected at nearby harbours. The random component can be dependant on many factors; however, these currents can be mainly attributed to wind-driven surface currents. For this analysis, the tidal component was ignored as it is predictable and therefore not as important when determining which sites should have longer ADCP deployments.

In certain regions of Nova Scotia where farms are exposed to high winds, variations in surface current may be somewhat correlated to surface wind speeds, which are known to be highly variable. Longer ADCP deployments are preferred to ensure enough samples are gathered to fit the data to a statistical distribution. This will ensure the highest level of accuracy for sites that are the most sensitive to wind-driven currents.

Wind-driven surface current equations found in literature state that the wind-driven surface current is a function of the wind speed, and independent of other factors such as fetch [4]. Therefore, only the wind exposure level, gathered from the wind exposure map was used to determine which sites should collect three months of ADCP data.

2.4 Site selection for required wave propagation model

For an engineering analysis to be performed on an aquaculture site, the maximum 10 and 50-year wave height and period must be determined. For sites in Nova Scotia that are exposed to open ocean, this can be determined using a wave propagation analysis. This analysis uses hindcast data from the nearest MSC50 hindcast data point to determine the maximum 10 and 50-year wave height and period for each environmental heading at the location of the MSC50 data point, approximately 10km offshore. Software such as STWave or SWAN is then used to model the propagation of the wave towards shore, passing through the aquaculture site.

All sites that are exposed to open ocean require a wave propagation analysis, therefore any site with a wave exposure value of medium, high, or very high, would require a wave propagation analysis to be performed as part of a site engineering analysis.

3 Aquaculture sites

3.1 Bras d'Or / Chedabucto bay region

All sites in Nyanza Bay, Denas Pond, St. Peters Inlet, and Whycocomagh Bay are quite sheltered with no exposure to the open ocean and either high or low wind exposure. These sites would only require a one-month ADCP deployment and do not need a wave propagation analysis. The sites in the St. of Canso South and Arichat Harbour are both sheltered well from wave exposure but are both exposed to very high wind speeds. Both sites would benefit greatly from a three-month ADCP deployment. The locations of each site is shown in Figure 2 and the results of the analysis for each site is presented in Table 2.

Table 2 - Results of analysis for Bras d'Or and Chedabucto bay region.

Site #:	Wind Exposure:	Wave Exposure:	Recommended ADCP Deployment length:	Propagation analysis required?
0745	Low	Low	1 month	No
0193	Low	Very low	1 month	No
0814	Low	Very low	1 month	No
0600	Low	Very low	1 month	No
0845	Low	Very low	1 month	No
0778	High	Very low	1 month	No
0994	High	Very low	1 month	No
0716	Very high	Very low	3 months	No
0826	Very high	Medium	3 months	No

Figure 2 - Map showing site locations for Bras d'Or and Chedabucto Bay region.

3.2 Central region

Both sites in Ship Harbour are exposed to high winds and have a small open ocean exposure angle. These sites would benefit from a three-month ADCP deployment, however, a one-month ADCP deployment is acceptable. Both sites would require a wave propagation analysis to determine the maximum wave heights. The locations of each site is shown in Figure 3 and the results of the analysis for each site is presented in Table 3.

Table 3 - Results of analysis for central region.

Site #:	Wind Exposure:	Wave Exposure:	Recommended ADCP Deployment length:	Propagation analysis required?
0833	High	Medium	1 month	Yes
0772	High	High	1 month	Yes

Figure 3 - Map showing site locations for central region.

3.3 South shore

The Aspotogan and Mahone Bay sites are well sheltered from waves and in a region of high and low wind exposure respectively, therefore only a 1-month ADCP deployment is required and no wave propagation model is required. The site in Liverpool bay is very exposed to waves and would thus require a wave propagation analysis. This site has a medium wind exposure and therefore requires only a 1-month ADCP deployment. The site in Port Mouton is well sheltered from waves and in a region of high wind exposure, requiring a 1-month ADCP deployment and no wave propagation analysis. The locations of each site are shown in Figure 4 and the results of the analysis for each site is presented in Table 4.

Table 4 - Results of analysis for south shore.

Site #:	Wind Exposure:	Wave Exposure:	Recommended ADCP Deployment length:	Propagation analysis required?
1006	High	Very low	1 month	No
0074	Low	Very low	1 month	No
1205	Medium	Very High	1 month	Yes
0835	High	Low	1 month	No

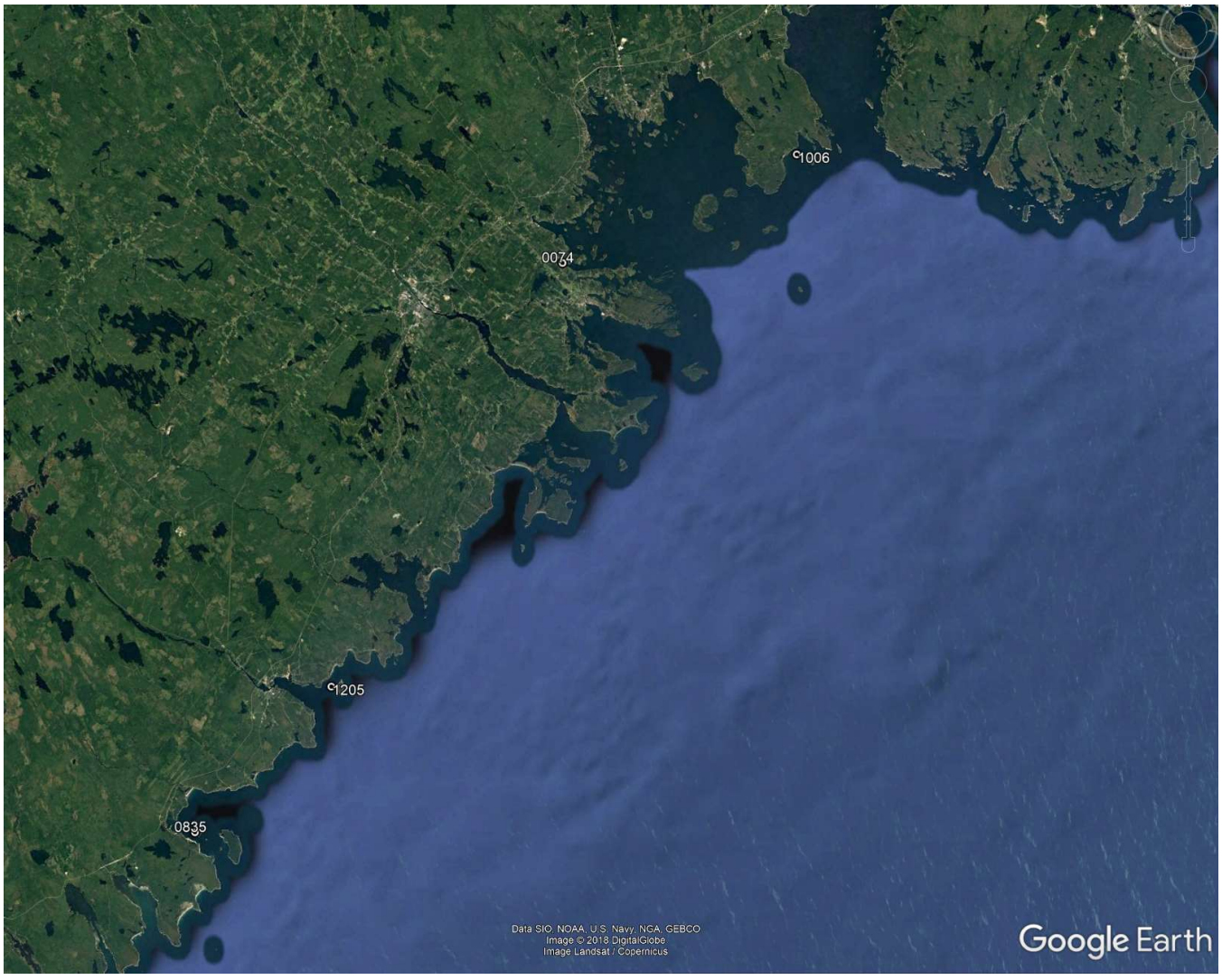

Figure 4 - Map showing site locations for south shore region.

3.4 Shelburne region

The sites in Jordan Bay and at the mouth of Shelburne Harbour are very exposed to waves and exposed to high winds. These sites would benefit from a 3-month ADCP deployment due to their general exposure and would require a wave propagation analysis. The sites in Shelburne Harbour closer to Shelbourne are well sheltered and have medium wind exposure. These sites only require a 1-month ADCP deployment and do not require a wave propagation analysis. The locations of each site are shown in Figure 5, and the results of the analysis for each site is presented in Table 5.

Table 5 - Results of analysis for Shelburne region.

Site #:	Wind Exposure:	Wave Exposure:	Recommended ADCP Deployment length:	Propagation analysis required?
1358	High	Very High	3 months	Yes
1359	High	Very High	3 months	Yes
1345	High	Very high	3 months	Yes
0983	Medium	Low	1 month	No
1192	Medium	Low	1 month	No
0602	Medium	Low	1 month	No

Figure 5 - Map showing site locations for Shelburne region.

3.5 Pubnico region

All sites in the Pubnico region have a very high wind exposure, except for the site in Pubnico Harbour, which has a high wind exposure. All sites with a very high wind exposure would benefit from a 3-month ADCP deployment. All sites have a medium, high, or very high wave exposure and are all exposed to open ocean waves. Therefore, all sites would require a wave propagation analysis. The locations of each site is shown in Figure 6, and the results of the analysis for each site is presented in Table 6.

Table 6 - Results of analysis for the Pubnico region.

Site #:	Wind Exposure:	Wave Exposure:	Recommended ADCP Deployment length:	Propagation analysis required?
1029	Very high	High	3 months	Yes
1181	Very high	Very high	3 months	Yes
0967	Very high	Very high	3 months	Yes
0955	High	High	1 month	Yes
0770	Very high	Very high	3 months	Yes
0900	Very high	Medium	3 months	Yes
0899	Very high	High	3 months	Yes
0912	Very high	Medium	3 months	Yes
1021	Very high	High	3 months	Yes

Figure 6 - Map showing site locations for Pubnico region.

3.6 Bay of Fundy

The sites located in Grand Passage or St. Mary's Bay have a very high wind exposure and would benefit from a three-month ADCP deployment. All sites except the southern site in Grand Passage would require a wave propagation analysis. The sites located in Annapolis Basin have a high wind exposure and only require a one-month ADCP deployment. None of these sites are exposed to open ocean and therefore do not require wave

propagation analyses. The locations of each site is shown in Figure 7, and the results of the analysis for each site is presented in Table 7.

Site #:	Wind Exposure:	Wave Exposure:	Recommended ADCP Deployment length:	Propagation analysis required?
0742	Very high	Very low	3 months	No
0829	Very high	High	3 months	Yes
1353	Very high	Very high	3 months	Yes
1354	Very high	Very high	3 months	Yes
1012	Very high	High	3 months	Yes
1039	High	Medium	1 month	No
1041	High	Medium	1 month	No
1040	High	Medium	1 month	No

Table 7 - Results of analysis for the Bay of Fundy region.

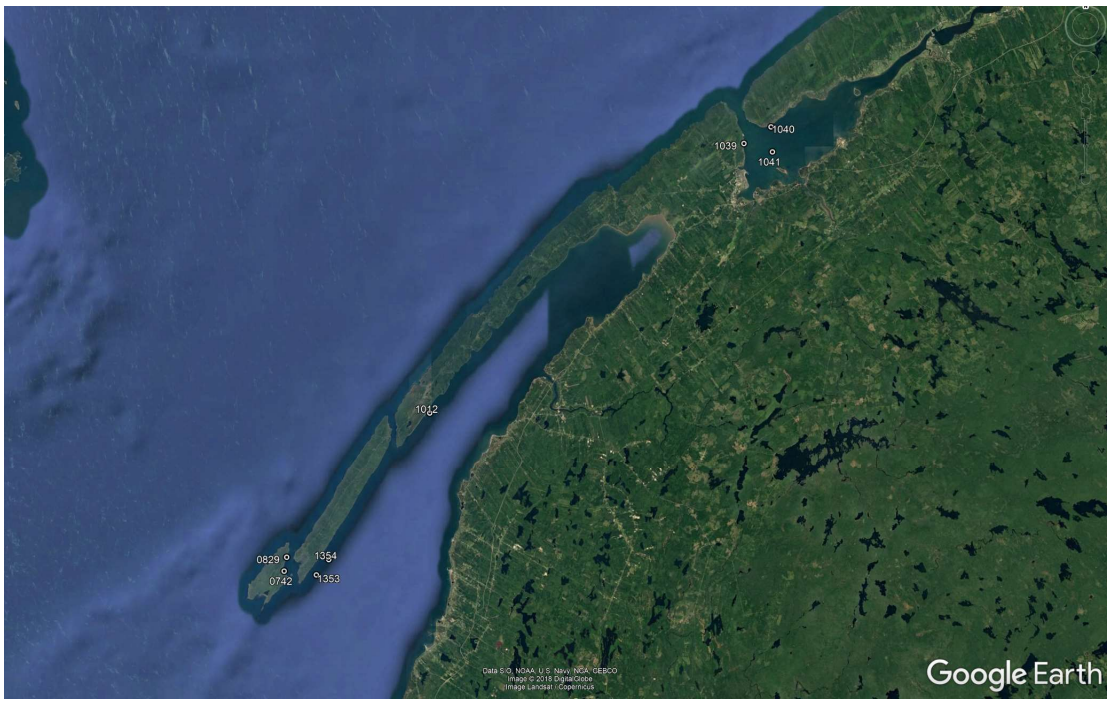

Figure 7 - Map showing site locations for Bay of Fundy region.

4 Conclusions

A qualitative assessment of wind and wave exposure for 38 aquaculture sites in Nova Scotia was performed. Wind exposure assessments were performed to provide guidance on the preferred locations for extended ADCP deployments. Wave exposure assessments were performed to provide guidance on which aquaculture sites

would require a wave propagation analysis to determine the maximum storm waves for an engineering analysis of the farm.

It was determined that sites in Chedabucto Bay, Jordan Bay, Lobster Bay, and St. Mary's Bay would all benefit from three-month ADCP deployments. At least one month of ADCP data must be collected at each individual site, as the tidal component and local effects from bathymetry and nearby headlands will cause current data to differ between sites.

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It should be noted this report uses a simplistic approach to determining wave and wind exposure, and should not be used in place of with more robust methods. These approaches were chosen to provide effective guidance without performing an extensive analysis. A more complete analysis of wave exposure around the province should be completed to complement this analysis. Additionally, further investigation into the methodology of using three-month ADCP data for statistical analysis of the random component of current independent of the tidal component must be completed. This investigation would inform the validity of using ADCP data from nearby sites for determination of the random component.

5 References

[1] Norwegian Standard, *NS 9415E:2009 Marine fish farms: Requirements for site survey, risk analyses, design, dimensioning, production, installation and operation,* Lysaker: Standards Norway, 2009.

[2] Marine Scotland, *A Technical Standard for Scottish Finfish Aquaculture,* Ministerial Group for Sustainable Aquaculture's Scottish Technical Standard Steering Group, 2015.

[3] Nova Scotia Department of Natural Resources, "Digital Wind Exposure Map for Nova Scotia," 2017.

[4] J. Bye, *Wind-Driven Circulation in Unstratified Lakes,* Scripps Institutions of Oceanography, 1965.