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Tidal Energy Resource Characterization in Alberni Inlet, B.C.

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NONTECHNICAL SUMMARY

Renewable energy is an important resource for today's society to help offset the effects of burning non-renewable fuels. These types of renewable energy range from harnessing the energy of wind to elaborate systems of solar panels. Tidal energy is a relatively new idea in renewable energy's for coastal communities. Tides ebb and flood each day and transport a vast amount of water but the movement can be quite slow in the open ocean. To harness the power of the changing tides one must pick a site where the energy is focused into a very small area. Admiralty Inlet, located between Puget Sound and the Straits of Juan de Fuca, is the iconic site of study due to its constrictive effect, making the water move much more quickly than normal during tidal exchanges. But is this the only option in the Pacific Northwest? Alberni Inlet, located on Vancouver Island, B.C., is a fjord similar in structure to Puget Sound and may be a site suitable for tidal energy extraction. This study attempts to determine how suitable Alberni Inlet is for investing in tidal energy and to quantify its resource. Using the Acoustic Doppler Current Profiler (ADCP) aboard the R/V Thompson I was able to determine the amount of kinetic energy in the Alberni Inlet system. Results indicate that Alberni Inlet's extractable tidal energy is extremely low in comparison to similar tidal energy sites such as Admiralty Inlet.

ABSTRACT

As a global trend is developing in shifting from non-renewable to renewable energy use, interesting new methods of extracting energy from unlikely places have developed. Tidal energy extraction, a new process for generating renewable energy, relies on harnessing the energy associated with the changing tides. A typical tidal cycle has a significant amount of energy, but it's spread out over a large area. In order to extract any considerable amount of energy, one must find a region that focuses it into a very small area. Glacially scoured fjords of the Pacific Northwest are well known for focusing the tides energy. These fjords focus tidal energy by constricting the flow of water. Based on the conservation of energy this increases the velocity of the water through the constriction and makes them an ideal site for tidal energy extraction. Sproat Narrows, a very narrow and shallow constriction in Alberni Inlet, is a fjord system on Vancouver Island, B.C. That appears to be similar in structure to the high energy system that occurs in the Puget Sound's Admiralty Inlet. Though having similar structure to Admiralty Inlet, Sproat Narrows represents an obvious exception as the fjord is far less suitable for tidal energy extraction than expected. This indicates that there must be other processes that dissipate the energy associated with this fjord's water. Assessing the energetics of these fjord systems is then crucial in developing the tools to accurately predict other potential sites for tidal energy extraction.

INTRODUCTION

Renewable and alternative energy has become a focus of study in the world today. Reliance on our rapidly decreasing supply of fossil fuels has shifted the energy paradigm toward finding efficient, renewable sources of energy. An up–and-coming idea in this field of research is extracting energy from changes in tides (Stacey, 2005). As tides rise and lower each day, seawater forcibly flows in and out of sounds, inlets, fjords, and other geographical features around the world (Johnson, 2011). Like water flowing through a small pipe, these features produce high water velocities where constrictions in the "pipe" are smallest. As water flows faster, its associated kinetic energy increases proportionally. The energy from these high velocity water parcels can be extracted much in the same way a wind turbine extracts energy from passing wind. While designs for tidal energy turbines vary greatly, the underlying principle remains the same (Liu and Bose, 2012). Water flowing past turbine blades produces torque on the rotor to which they are attached. The force from the turbine blades spins a generator inside the turbine housing which converts the kinetic energy of the current into electricity.

As with wind turbines, the location of tidal energy extractors is critical to obtaining the maximum amount of energy over time. Admiralty Inlet is a well documented and highly researched area in the Puget Sound and is a promising site for tidal energy extraction. This site features a shallow sill, which constricts water flow, and is the opening for which all the water in the Puget Sound passes through. With so much water passing through a small area, the kinetic energy is focused considerably. There have been attempts to quantify this resource in the fjords of Puget Sound and it has been found that water velocity can reach upwards of 5 m/s. This type of high energy estuarine fjord exchange is the epitome of an ideal site for energy extraction (Kawase, 2010). Fortunately, sites that have very similar geographic features occur often in the glacially scoured Pacific Northwest.

One such site that is similar in characteristics to Puget Sound is Alberni Inlet. Alberni Inlet is a fjord on the western coast of Vancouver Island B.C. Alberni Inlet is thought to offer a quality site to investigate the potential of tidal energy extraction. Specifically, Sproat Narrows is a shallow sill in the middle of Alberni Inlet that would be ideal to quantify this tidal resource (Figure 1). Sproat Narrows is appropriately named, as it is the shallowest of the sills in the inlet, a mere 20 meters deep, as well as the narrowest at only 500 meters wide. Previous studies indicate that this constriction may be energetic enough to generate adequate sustained energy over each tidal cycle (Stronach, 1993). The goal of this research is twofold; to investigate how tidal energy varies during tidal exchanges over the most constrictive sill in Alberni Inlet, and to determine factors that are important to the generation of tidal energy in this type of system.

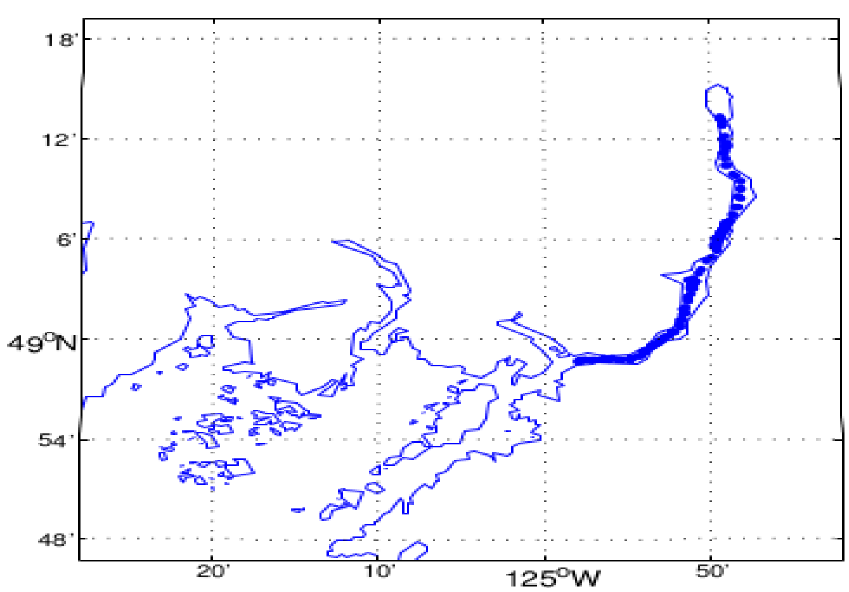

Figure 1. A map depicting the study site in on Vancouver Island B.C. Barkley Sound being the lower portion of the map and Alberni Inlet being the narrow inlet containing the cruise track. The blue dots represent binned and averaged ADCP profiles along the cruise track.

METHODS

The main method of data collection for this project involves using an Acoustic Doppler Current Profiler (ADCP) to measure the velocity of the water in a given area. ADCPs function based on a principle known as the Doppler Effect. Acoustic pulses or "pings" are emitted from the device from at least three different angles. The pings are then reflected off of particulate matter in the water, creating less energetic reflected waves. The depth at which velocity is measured is calculated based on the elapsed time between when the ADCP produces a ping and when it receives the reflected wave. The velocity is measured by examining the shift in frequency of the reflected pulse compared to the original ping. By knowing both how the Doppler Effect changes frequency and the depth at which each reflected pulse is obtained, the ADCP can measure velocity as a profile through the water column. There is a tradeoff however, between the velocity profile resolution and the maximum depth at which measurements can be obtained, which are affected by higher or lower frequency ADCP systems (RD Instruments, 1996).

For this study, the mounted 75 kHz ADCP on the R/V Thomas G. Thompson provided the basis for conducting current velocity surveys along Alberni Inlet and over its sills. Current surveys were performed over a complete tidal cycle at the narrows, including maximum and minimum tidal exchanges. For each tidal cycle, the ship moved back and forth over the sill to collect data depicting mostly temporal variability in current velocity. To accurately assess the tidal energy available over a given area, kinetic energy must be averaged over the entire tidal cycle. If tidal energy is to be a viable alternative energy, it would be necessary to have sustained energy production. Current measurements were conducted from January 28th to 29th and were spent specifically mapping velocity over the narrows. A minimum of two tidal cycles worth of data were necessary to obtain a rough idea of energy density in the area.

Data from the ADCP was processed in real time using UHDAS (University of Hawaii Data Acquisition Systems), an open source ADCP visualization and processing software maintained by the University of Hawaii. This software incrementally builds a data set of averaged and edited current velocities for each ADCP ping. Once an averaged and edited velocity data set has been compiled, the equation $Ke=\left(\frac{1}{2}\right)\rho u_{obs}^2$ is then used to determine the average kinetic energy over the tidal cycle in question (where Ke is kinetic energy, ρ is the average density of water, and u_{obs} is the corrected observed velocity). This provided an estimate of tidal energy during two tidal cycles over the Sproat Narrows sill and spatial variability of energy throughout the inlet. However, because the data is not orientated in relation to the channel, the data had to be rotated to depict along channel and across channel velocities. The reasoning behind this is that for this system we are assuming that the across channel flow is usually dissipated, and does not contribute to the general scheme of flow in the inlet. From here, one can use the relationship of kinetic energy and velocity to determine the tidal energy density throughout Alberni Inlet.

RESULTS

Using the 75KHz ADCP system aboard the R/V Thompson enough data was collected to provide a decent time series of water movement over the Sproat Narrows sill and throughout Alberni Inlet. However, this frequency of ADCP system has a few limitations in shallow water. The high amplitude pulses create considerable noise just below the sensor and about 10m off the bottom. This limits the depth range of the velocity profile for a given point on the cruise track. These portions of the data have been omitted due to the considerable amount of noise. In addition to this, direct measurements from over the shallowest and most energetic section of Sproat Narrows were not possible as this region was too shallow for ADCP survey. As the sill is a shallow 20m, the ADCP has insufficient range to capture measurements directly over the sill. Therefore velocity over the sill was inferred by performing sweeps over the sill and determining the velocity on a small spatial scale on either side of the sill.

Despite the loss of data in the water column, the data set provided enough coverage to determine the general patterns in velocity over the sill. The general profile of velocity in Alberni is that of very slow moving water. Throughout the entire survey in the Inlet velocities did not exceed velocities greater than 50 cm s^-1(Figure 2). The maximum velocity over the sill peaked during each tidal periods maximum transition as one would expect for tidally driven currents. However this does not agree with the significantly reduced velocity that is observed in the region. Comparing the floods with ebbs did not add clarity to the situation either. When averaged the maximum mean ebb and flood velocities are basically comparable. While the site is fairly homogenous in energy density over a tidal cycle, it does not make up for the fact that the energies are quite lower than expected.

Being proportional to velocity, the energy density of Alberni Inlet is similarly as small. The energy profile exhibits homogeneously low densities throughout the water column (Figure 3). Maximums in tidal energy are highest during maximum exchanges between tides. Even then, energy densities reached a maximum of 60 joules per unit volume, which over a sustained period, is not a significant amount of energy.

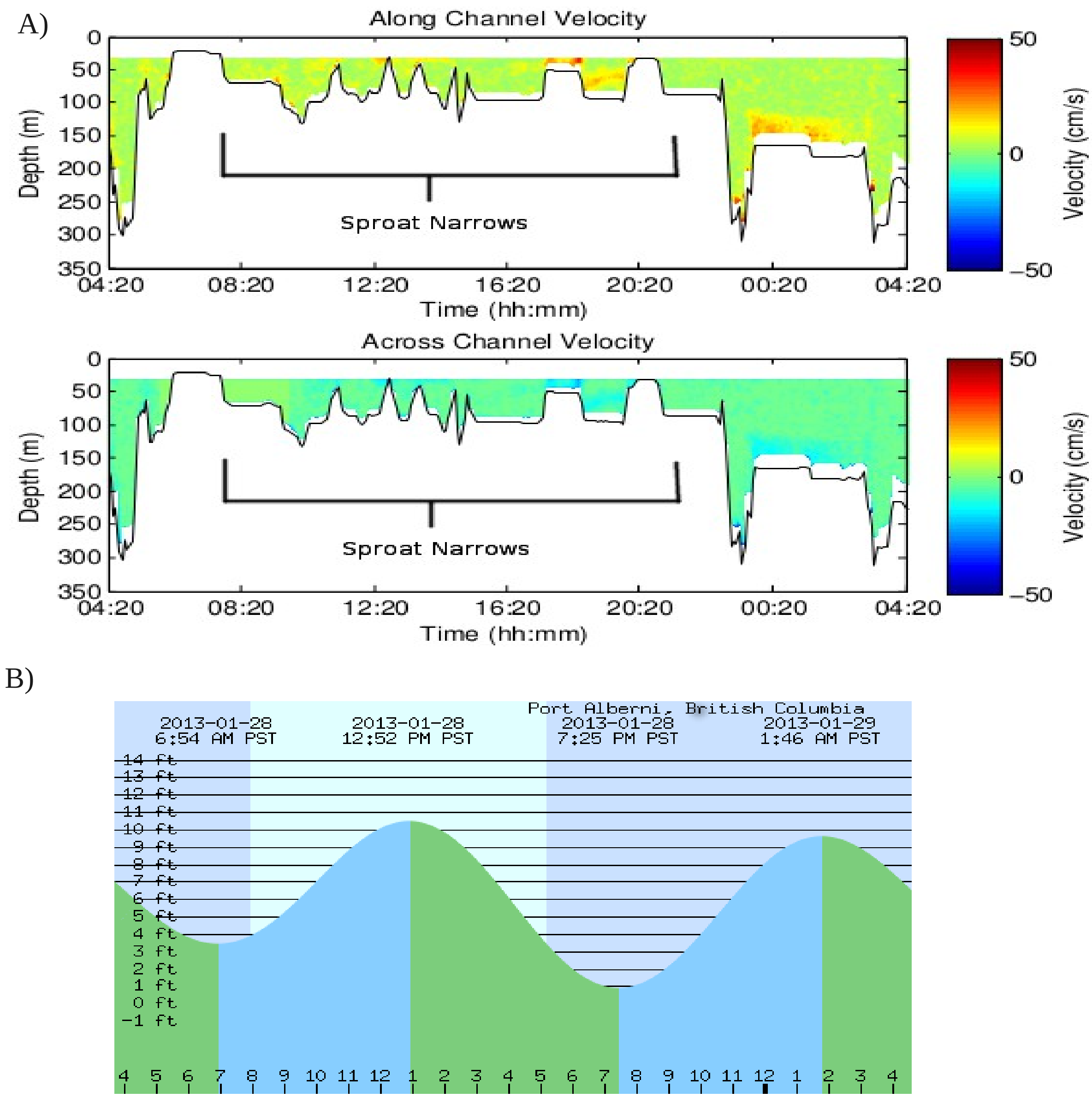

Figure 2. A) Two contour plots depicting the velocity for the along channel and across channel throughout the Alberni Inlet cruise track. The time period where specific sampling of Sproat Narrows is indicated by the brackets. The black line represents the bathymetry profile. The color contours indicate water velocity, ranging from -50 to 50 cm s^-1, positive being out of the Inlet. B) Over-laid is a plot of tidal height from Port Alberni, this is used to compare changes in tidal height to changes in water velocity over time.

A)

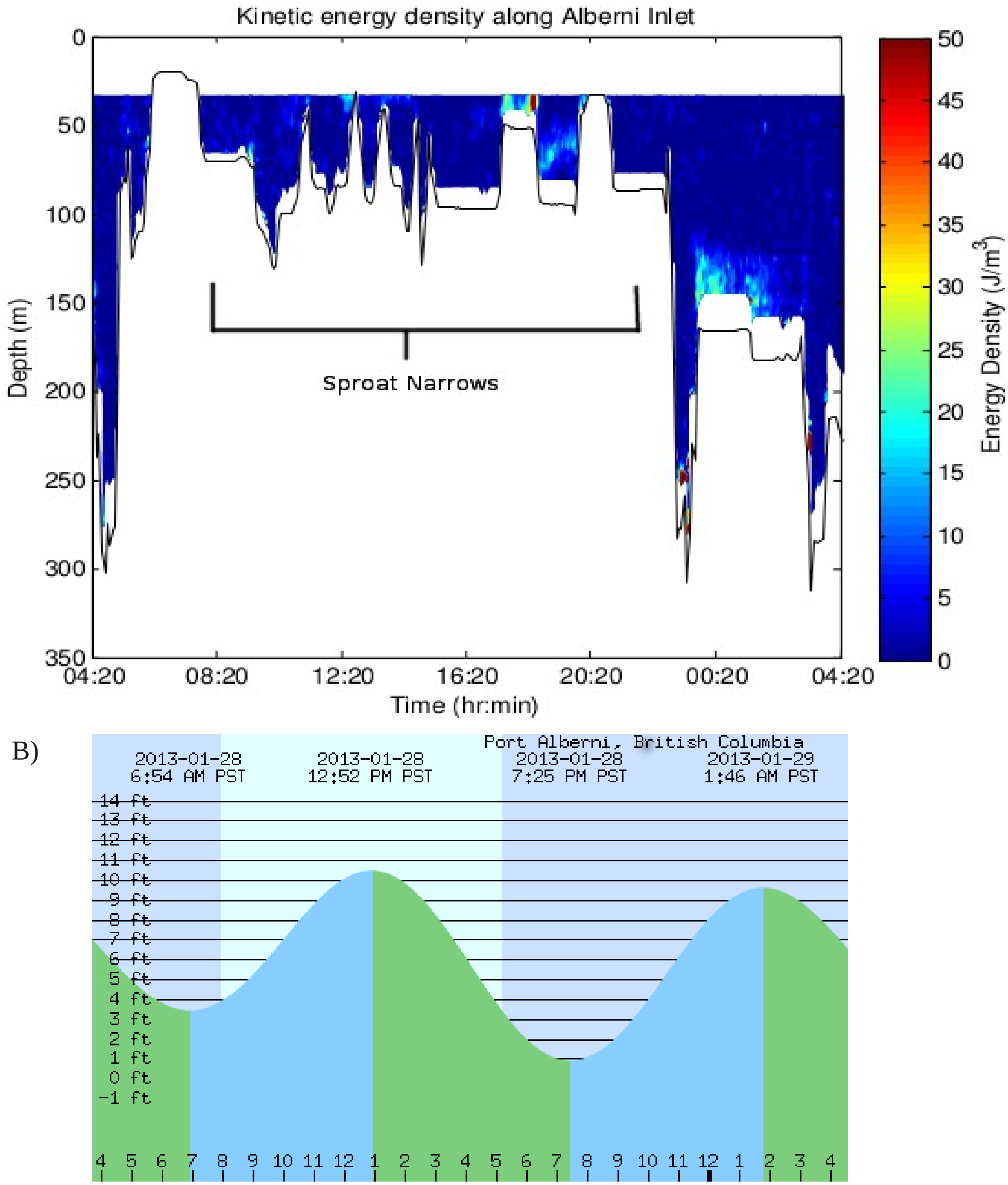

Figure 3. A) Contour plot depicting kinetic energy density in Joules per unit volume throughout the cruise track along Alberni Inlet. The specific section over Sproat Narrows is marked by the bracketed section. The black line indicates the bathymetry profile. Contours indicate kinetic energy density on a scale of 50 joules per meter cubed.

B) Over-laid is a plot of tidal height from Port Alberni, this is used to compare changes in tidal height to changes in energy density over time.

DISCUSSION

The results of this study indicate quite clearly that Alberni Inlet is not a site suitable for tidal energy extraction, but that does not mean it has not refined the tidal energy paradigm. The fact that Alberni Inlet was found to be unsuitable for tidal energy extraction has interesting implications on what criteria are used to evaluate a site for energy extraction potential.

The loss of data due to the range of the ADCP system is an important consideration when performing a study of this nature. This is important particularly because of the loss of the surface layer. In typical estuarine fjords river input creates a stratified freshwater layer that moves independently of the more dense seawater beneath it and can be as thin as a meter. Because of this range limitation, it was impossible to observe the interaction between the freshwater and saltwater layers, missing an important part of the estuarine circulation. This barotropic interaction between fresh and saltwater layers may be a considerable source of energy dissipation in the system, but was unable to be resolved (Deyoung, 1989).

Alberni Inlet proves to be an interesting exception to the ideal case of a sill restricted fjord , such as Puget Sound, being a potential site for tidal energy extraction. One would expect a small constriction such as Sproat Narrows to provide a sufficient constrictive effect to amplify tidal velocities by a great degree. This however, is not the case at all. Alberni Inlet exhibits extremely slow velocities, significantly slower than expected typical fjord system. Bernoulli's principle indicates there should be at least some factor of increase in water velocity over the sill, thus, there must be more processes at work in the inlet that effect the circulation of the water. These may include and are not be limited to; dissipation through turbulent eddies, fresh and salt water layer shearing, and mixing over the Inlet's many sills.

Comparing this to a study of circulation over Sproat Narrows it seems the sill itself is limiting the amount of water being transported each tidal cycle (Braund, 2013). Estuarine fjords, like those in the Pacific Northwest, have strong freshwater inputs that serve to stratify the water in the fjords. This has some unique implications for Alberni Inlet. The various sills throughout Alberni Inlet reduce the volume transport and greatly restrict movement of water to the upper portion of the sills. This stratification of dense seawater below the tops of the sills, an intermediate water layer above the sills, and a freshwater lens on top of the intermediate water impose a limit to the amount of water that can be transported through tidal forcing. This limiting of exchange to a small intermediate layer of water considerably reduces the volume being transported. In effect, this reduces the exchange to a significantly smaller amount of water and because less water is passing through the constriction, there is less energy to be focused. This extreme case of estuarine circulation clearly has a significant effect on the suitability of tidal energy extraction for the area.

This very simple exception to the ideal model of an energetic fjord proves a very important point; tidal energy is even more limited in scope than once thought. Alberni Inlet offers an excellent counter case to the limitations of fjords as potential sites of energy extraction. This study suggests that fjords are limited by the amount of water exchanged with each tidal cycle, which when limited by intense estuarine stratification, significantly reduces its potential as a renewable energy system. Therefore, preliminary methods needed to quantify the energy available for extraction must be more robust to include a more thorough survey of circulation as well. Specifically, a high resolution profile of water velocity will be helpful in determining smaller scale flow patterns. On top of this having a longer time series and sampling from different seasons will create a clearer picture as to how energy varies on a longer time-scale.

CONCLUSIONS

Alberni Inlet is not a suitable site for tidal energy extraction. While it may appear similar compared to Admiralty Inlet the circulation is much weaker. This study is an important step forward in identifying adequate sites for tidal energy. It seems that the circulation in Alberni Inlet is limited by the estuarine stratification, which separates different characteristic water masses. This limitation of circulation leads to very slow moving water throughout the basin, and proportionately low energy constrictive sills. These combined features prove to significantly alter the energetic effects of a constriction upon a tidally forced fjord.

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