Technical Report

University of Manitoba

Flow measurement on Assiniboine River at The Forks for hydrokinetic turbine deployment purposes

Samuel d'Auteuil
Jody Soviak
Amir Birjandi
Eric Bibeau

Prepared for Forks North Portage Corporation

CHTTC
Canadian Hydrokinetic Turbine Test Centre
75A Chancellors Circle
Winnipeg, Manitoba, R3T 5V6
Canada

Abstract

Flow measurement results on the Assiniboine River in vicinity of the Forks are presented. Measurements are conducted on Friday, May 15, 2015, using a mobile measurement platform equipped with an acoustic Doppler velocimeter and Humminbird sonar. The main goal of this project is to investigate the possibility of deploying a hydrokinetic turbine to generate electricity. The flow velocity is measured at 9 points, starting from the Main Street Bridge all the way down to the Forks walkway bridge. Results show the high potential of the Assiniboine River at the Forks for hydrokinetic turbine deployment.

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1 Introduction

The Forks is one of Winnipeg's most beloved places, at the junction of the Assiniboine and Red rivers. Framed by the banks of the two rivers, The Forks is Winnipeg's number one tourist destination with more than four million visitors annually. Winter, spring, summer or fall, The Forks is a must for a stunning array of dining experiences, incomparable shopping, a constantly changing slate of entertainment and events, and many unique attractions that encompass the site's natural, historic and man-made features.

The proximity of the Forks Market and restaurants to the Assiniboine River provides this opportunity to harvest the kinetic energy of the Assiniboine flow and convert it to electricity. The generated electricity can be used to offset part of the Forks Market electricity consumption. At the first stage, a fusibility study has to be conducted to evaluate the hydrokinetic potential near the Forks. Then, a 5-kW floating unit, provided by New Energy, will be installed on the River and will demonstrate the hydrokinetic energy potential of the River by energizing a charging station for cellphones and laptops. Personnel from the Canadian Hydrokinetic Turbine Test Centre (CHTTC) performed the resource assessment required for this project. Figure 1 shows the New Energy turbine design to be installed at the Forks.

2 Measurement locations

Measurements are conducted at 9 points, located on the satellite image. Flow characteristics are measured on each side of three bridge piers, as well as two measurements on both sides of

Figure 1: Vertical New Energy turbine being deployed and tested at the CHTTC on the Winnipeg River at Seven Sisters

Figure 2: Potential turbine deployment locations assessed for resource by CHTTC personnel. These location names are the IDs referenced later in this report.

the column in front of the Forks, and one measurement downstream the CN bridge. Figure 2 shows each of the locations measured.

3 Test equipment

The measurement device employed is an Acoustic Doppler Velocimeter (ADV). The model used is the Nortek Vector ADV. The device is attached to a boat via a two-pole system that allowed fast and simple deployment and retrieval of the device. The poles are designed to withstand the high velocities expected in the Winnipeg River. The ADV is connected to a laptop computer which runs the software that controls and records data from the ADV. Figure 3 depicts the experimental set up used in the experiment. Depth and GPS locations indicated by Humminbird 898c sonar and GPS system. A list of waypoints are created for measured locations.

4 Results

In total, 10 ADV measurements are taken at 9 locations. The location IDs are correspond to the locations shown in Figure 2 One location is measured twice, to test if the platform angle greatly affected the readings, for location IDs F-4 and F-4-2. In addition to the ADV data, the water depth at each location was recorded, along with the GPS coordinates corresponding to the measurement point. The ADV data was collected as a package and

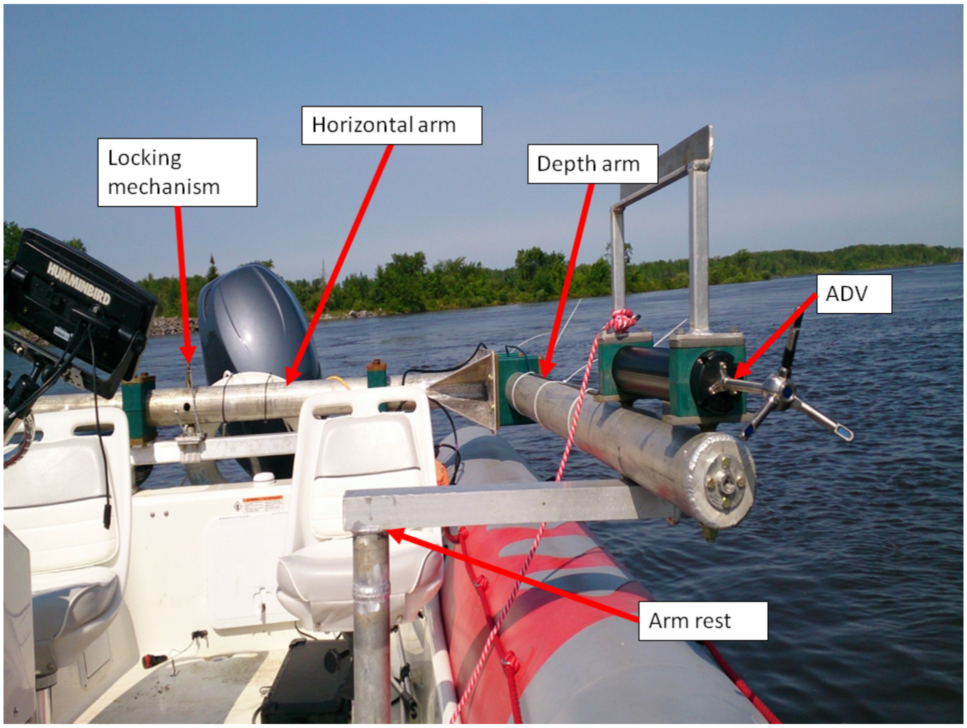

Figure 3: Measurement equipment used for determining velocities in Assiniboine River at the Forks.

put through a Matlab code generated by the research group, which is publicly available at www.chttc.ca.

The outputs of the code include information the mean streamwise velocity at each measurement point, as well as the correlation and Signal-to-Noise Ratio (SNR) for the data point, as well as the magnitude of the velocity. Additionally, the code allows for the user to select which window of the data they require after showing the user what the raw data looks like, so that the user can manually remove any low-quality sections of data. Finally, the code then despikes the data by using a hybrid algorithm written by Birjandi *et al.* [1]. After despiking, the flow statistics are calculated and the user can choose to display several graphs, such as the raw streamwise velocity with time, the distribution of the streamwise velocity as compared with a normal distribution, the de-spiked data and a rose plot showing the directionality of the flow, among others. Examples of the graphs created by the code can be seen in Figure 4, Figure 5, Figure 6, and Figure 7 respectively. For ease of reading, not all of the figures will be shown in this report, but the full results data set can be obtained by contacting any of the above listed authors. The numerical results of the code can be seen in Table 1.

As can be seen in Table 1, the maximum mean streamwise velocity was found to be approximately 2.6 m/s at location F-3. The maximum velocity magnitude was found to be approximately 2.8 m/s, at the same location. This is value was larger than other locations on this river and is adequate for the placement of a hydrokinetic turbine. Other locations, such as F-2, F-6 and F-7, have large velocities as well, and may also be suitable for the

Table 1: Mean velocity results from the ADV and Humminbird sonar and GPS system

Location ID	U [m/s]	Magnitude of Velocity [m/s]	ADV Correlation [%]	ADV SNR	Duration [s]	% Spikes Removed	Depth [m]	GPS
F-1	1.326	1.090	94.63	48.98	203.391	5.92	6.0	N 49 53 140 W 97 07 919
F-2	2.508	2.573	94.21	47.78	154.194	23.89	2.8	N 49 53 152 W 97 07 919
F-3	2.665	2.759	95.51	48.12	160.735	12.65	5.3	N 49 53 156 W 97 07 925
F-4	1.868	1.946	90.45	49.65	155.186	10.13	2.6	N 49 53 143 W 97 07 906
F-4-2	1.563	1.976	90.99	48.82	158.441	2.07	2.6	N 49 53 143 W 97 07 906
F-5	1.588	1.729	85.69	49.08	198.338	19.26	3.0	N 49 53 156 W 97 07 835
F-6	2.400	2.504	95.55	49.00	121.954	8.90	3.2	N 49 53 161 W 97 07 874
F-7	2.231	2.302	96.14	49.12	153.822	5.70	5.5	N 49 53 147 W 97 07 746
F-8	1.420	1.531	94.32	49.77	154.194	3.16	2.6	N 49 53 132 W 97 07 754
F-9	1.266	1.278	94.77	48.64	150.009	3.51	1.9	N 49 53 165 W 97 07 839

operation of a hydrokinetic turbine. Due to platform motion during measurement, the data for locations F-1 and F-5 have been compensated for this motion using the inertial motion unit contained within the ADV. However, even with motion compensation, location F-5 retains high turbulence. It is suspected that the motion compensation code is not completely removing all motion due to the amount of motion in the data set. Location F-6 contains platform motion in the beginning of the recording, so this portion of the recording is left out of the calculations.

Additionally, since the ADV records the instantaneous velocities in all three directions, turbulence statistics can be calculated. Table 2 shows the turbulence intensity and Turbulent Kinetic Energy (TKE) at each measurement location. The TKE is calculated by the following equation:

$$TKE = 0.5 \times (\overline{u^2} + \overline{v^2} + \overline{w^2})$$

Where u, v and w respectively are the streamwise, spanwise and vertical fluctuating velocity components. The turbulence intensity is then calculated using the following formula, where $|U|$ is the magnitude of the velocity vector:

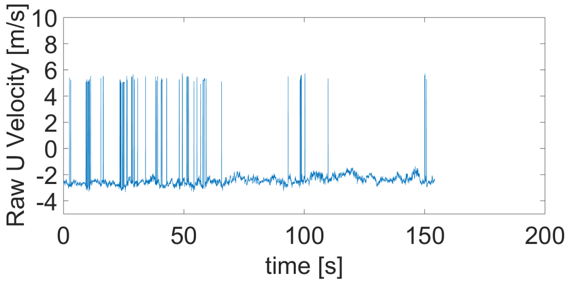

Figure 4: Raw streamwise velocity as collected by the ADV at location F-2

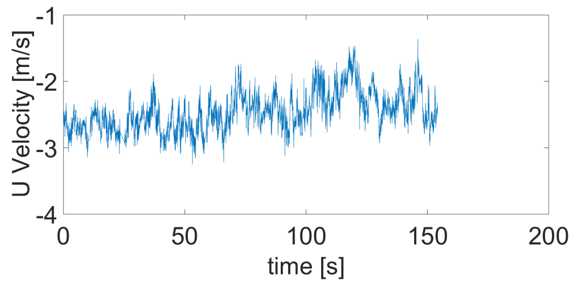

Figure 5: Streamwise velocity data despiked using a hybrid method [1] at location F-2

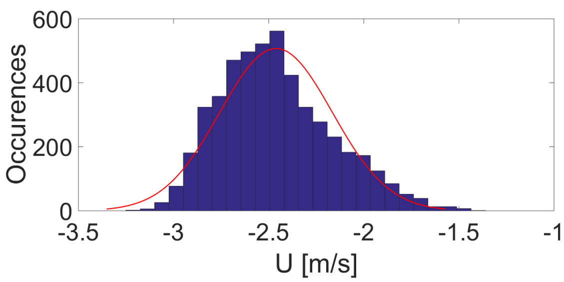

Figure 6: Streamwise velocity distribution compared to a normal distribution for the data at location F-2

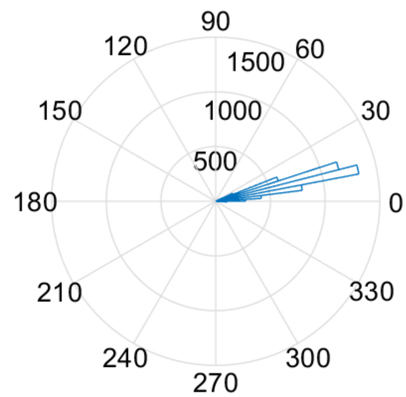

Figure 7: Angular distribution of velocity for measurements taken at location F-2

$$TI = 100 \times (\frac{\sqrt{\frac{2}{3} \times TKE}}{|U|})$$

The results from Table 2 indicate that this reach of the assiniboine river is highly turbulent. The most turbulent location had turbulence intensity of over 30%, which is large in comparison to the rest of the locations. This turbulence intensity is likely inflated due to platform motion causing the ADV to record turbulence in the measurement volume, even after motion compensation. This suggests that improvements need to be made to the motion compensation code to handle cases with excessive motion. It is worth noting that the location with the highest mean streamwise velocity and mean velocity magnitude had the lowest turbulence intensity of all of the locations. In fact, the other locations with the highest mean velocity also had some of the lowest turbulence intensities found in the data set.

In terms of how the flow rate on the day of measurement compares with flows at this time of year, Figure 8 shows the discharge rate of the Assiniboine River for 2015 using data obtained from the Water Office of Canada [2]. As one can see from this graph the flow rate at the

Table 2: Turbulence statistics calculated from ADV results

Location ID	Turbulence Intensity (%)	TKE (m^2/s^2)
F-1	15.94	0.1715
F-2	10.32	0.1058
F-3	5.60	0.0358
F-4	16.35	0.1519
F-4-2	15.15	0.1344
F-5	31.62	0.4485
F-6	6.59	0.0409
F-7	6.76	0.0341
F-8	12.06	0.0511
F-9	17.80	0.0775

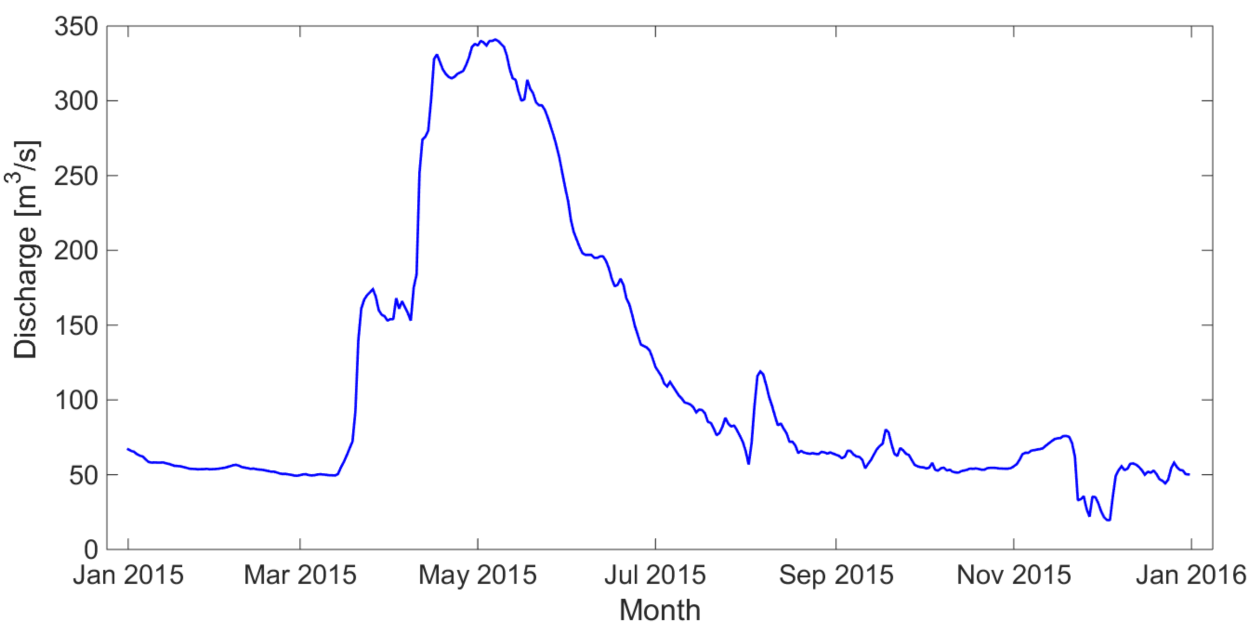

Figure 8: Discharge rate for the Assiniboine River at Headingley. Discharge data obtained from the Water Office of Canada [2]

measurement time is not above the norm of this river during summer time. The flow rate drops during the winter but it ramps up again after spring.

5 Conclusion

In conclusion, the research group has found several locations near The Forks to place a hydrokinetic turbine that would generate a satisfactory amount of energy. It was found that many locations were highly turbulent, but the locations with the highest velocity experienced the lowest amount of turbulence in the data set. Locations that were observed to have relatively high turbulence intensities are influenced by platform motion, and the data can be corrected using the inertial motion unit within the ADV. The measurements are taken during the high flow season of the year to assess the maximum power available for a demonstration.

References

[1] A. Birjandi, S. Kassam, and E. Bibeau, "Turbulence measurement with the acoustic doppler velocimeter (adv) in bubbly flow," in *AIAA Fluid Dynamics Conference*, vol. 39, 2009.

[2] Water Office of Canada. (2017) Historical hydrometric data. [Online]. Available: https://wateroffice.ec.gc.ca/report/historical_e.html?mode=Graph&type=h2oArc&stn=05MJ001&dataType=Daily&parameterType=Flow&year=2015&scale=normal