Revista Brasileira de Recursos Hídricos
Brazilian Journal of Water Resources
Versão On-line ISSN 2318-0331
RBRH, Porto Alegre, v. 29, e36, 2024
Technical Note

https://doi.org/10.1590/2318-0331.292420240052

Flow measurements with ADCP on the Guaíba River, during the highest water level recorded in history - May 2024 (floods in the State of Rio Grande do Sul, Brazil)

Medições de vazão com ADCP no Rio Guaíba, durante o maior nível d'água registrado na história - maio de 2024 (cheias no Estado do Rio Grande do Sul, Brasil)

Mauro Michelena Andrade[1], Márcio Piazera[1], Ruan da Luz[1], José Carlos Rodrigues Nunes[2], Fernando Scottá[2] & Tatiana Silva[2]

[1]Universidade do Vale do Itajaí, Itajaí, SC, Brasil
[2]Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil
E-mails: michelena@univali.br (MMA), marciopiazera@univali.br (MP), luz.ruan@univali.br (RL), jose.nunes@ufrgs.br (JCRN), fernandoscotta.sema@gmail.com (FS), tatiana.silva@ufrgs.br (TS)

Received: June 10, 2024 - Revised: July 30, 2024 - Accepted: August 16, 2024

ABSTRACT

This Technical Note aims to present data from in-situ measurements conducted with Acoustic Doppler Current Profiler (ADCP) under the highest level recorded in the Guaíba River. Flow measurements carried out on May 5th and 6th, with water levels of 5.27 and 5.25 m, resulted in average values of 30,180 and 29,852 m^3/s, respectively. The profiles with the river flow are presented, as well as the water level readings at the Usina do Gasômetro gauges. These data can be accessed on a open platform, can contributes to the understanding of the Guaíba's hydrodynamics and the flooding at Patos Lagoon and can provide valuable information for modeling maximum flow scenarios in these systems.

Keywords: Flooding; ADCP; High water level; Guaíba river flow.

RESUMO

Esta Nota Técnica tem como objetivo apresentar dados de medições de campo realizadas com um Perfilador Acústico de Correntes por Doppler (ADCP, sigla em inglês) durante o nível d'água mais alto registrado no Rio Guaíba. As medições de vazão realizadas nos dias 5 e 6 de maio, com níveis d'água de 5,27 e 5,25 m, resultaram em valores médios de 30.180 e 29.852 m^3/s, respectivamente. São apresentados os perfis com a vazão do rio, bem como as leituras de nível d'água dos sensores da Usina do Gasômetro. Esses dados, que podem ser acessados em uma plataforma aberta, tem potencial para contribuir no entendimento da hidrodinâmica do Guaíba e das inundações na Lagoa dos Patos e podem fornecer informações valiosas para a modelagem de cenários de vazão máxima nesses sistemas.

Palavras-chave: Enchente; ADCP; Maior nível d'água; Vazão do rio Guaíba.

INTRODUCTION

The field measurements of the liquid discharge in rivers under a different flow scenario, including drought and floods conditions, are of paramount importance for the planning and management of water resources (Nihei & Kimizu, 2008). In addition, limitations such as lack of metadata and restrict data access policies existed (Do et al., 2018), in-situ measurements of velocity and discharge result in high costs and significant acquisition challenges during high-flow and flood conditions (Mirauda et al., 2011). In these conditions, different materials such as tree trunks and bushes, etc., are transported in the water (Becchi & Tazioli, 1987) and may pose risks to vessel safety and operators (Mirauda et al., 2011).

The Guaíba River receives water flow from nine sub-basins spread across the central and northeastern regions of the Rio Grande do Sul (RS) state, Brazil, forming the Guaíba Hydrographic Region (GHR), encompassing 252 municipalities (Schuster et al., 2021). This region covers an area of approximately 85,000 km^2, representing around 31% of the total area of RS (Rio Grande do Sul, 2021).

Floods in these basins and in the Guaíba River have already been recorded, with special emphasis on the 1941 event, which reached a level of 4.76 meters on the Cais Mauá gauge. This event caused flooding in several areas of downtown Porto Alegre. As, in this 1941 event, there were no flow measurements on the Guaíba River, a study (Silveira, 2020) made a hydrological estimated a flow of 27,433 m3/s, for the peak of the flood. This same author calculated a rating curve for maximum flow events for the Guaíba River.

More recently, smaller-scale floods occurred in 2015, 2016, and 2023, resulting in the displacement of people and causing considerable material damage. In the 2016 event, there were flow measurements with Acoustic Doppler Current Profiler (ADCP) at Ponta da Cadeia, in the Guaíba River. The values recorded were 14,270 m^3/s at a water level of 2.5 m (Scottá et al., 2020). In this same study, a comparison was presented between measurements carried out with ADCP, with data recorded by National Water Agency (ANA), in the tributary rivers of the Guaíba River. The calculated correlation was considered strong by the authors. In this same study, the authors made a relationship between the flow data measured on the Guaíba River, with the water level data recorded at the nearest gauge (Cais Mauá). The correlation was described as weak and the possible causes were the large surface area of the Guaíba River and the influence of level fluctuations in Patos Lagoon, located in the outflow of the Guaíba River.

However, on April 27th, 2024, a hydrological event of great proportions began, with heavy and persistent rains in the GHR, affecting 476 counties, displacing more than 570,000 people, and causing a hundred deaths in the state of RS (Rio Grande do Sul, 2024b). This extreme event is being considered the largest climatic tragedy in the history of Rio Grande do Sul. The accumulated rainfall in the river basin reached 652 mm, on May 5, 2024, the day of the highest water level recorded in the Guaíba River. The rainfall resulted from a combination of extreme weather patterns and climate change. The event was triggered by a confluence of factors, including intense rainfall driven by a weakening El Niño, which steered cold fronts towards the region and heightened atmospheric instability (Alcântara et al., 2024). The values of accumulated rainfall in the hydrographic basin and water level in the Guaíba river are considered higher than those recorded in the historic flood of 1941 (Alcântara et al., 2024; Collischonn et al., 2024), causing the largest flooding ever recorded in the metropolitan region of Porto Alegre. In the following days, persistent flooding occurred in cities located in the southern portion of the Patos Lagoon, especially affecting the counties of São Lourenço do Sul, Pelotas, and Rio Grande.

With the aim of measuring the discharge flow, a multi-institutional team with a history in this type of measurement on the Guaíba River (Andrade et al., 2017; Scottá et al., 2020) conducted campaigns to obtain data using an ADCP at the Ponta da Cadeia, in Porto Alegre, RS, between May 5th and 6th, 2024.

DESCRIPTION

Between May 5th and 6th, 2024, field data collection campaigns were conducted to measure the flow of the Guaíba River at a cross-section near the Gasometer Plant, in the municipality of Porto Alegre/RS (Figure 1). This is considered the narrowest cross-section of the Guaíba River, with approximately 850 meters in width. The first campaign was conducted on May 5th, with 4 consecutive crossings between 5:45 PM and 6:50 PM. The second campaign was conducted on May 6th, with 6 consecutive crossings between 9:30 AM and 11:15 AM. During the first campaign, the observed level at the Gasometer Plant's water level station was 5.27 meters, and during the second, it was 5.25 meters (Figure 2).

The measurements were carried out using a Acoustic Doppler Current Profiler (ADCP), SONTEK brand, model ADP®/1 MHz (Figure 3) with Bottom Tracking capability. A Garmin GPS, model 78S, with an external antenna attached above the ADCP, was connected to the system for measurements. The instrument was configured to record data in the water column, from surface to bottom, in 20 cells of 1 meter each, every 20 seconds. Criteria for obtaining quality data suggested by the manufacturer (SonTek, 2000), and by water resource regulatory agencies such as the National Water Agency (ANA), Geological Survey of Brazil (CPRM), and United States Geological Survey (USGS), were adopted in the field. For example, compass calibration procedures, navigation care during crossings, and a minimum of 4 consecutive crossings were implemented in the field.

In the laboratory, the data were processed using the RiverSurveyor® software to adjust the distances from the margins of each crossing and to choose the reference frame. In this case, GPS was chosen because in the field, the occurrence of moving bed was observed, which causes an underestimation of the values measured with the Bottom Tracking function (Mueller & Wagner, 2006).

On May 5th, 2024, the average liquid flow from the 4 crossings was 30,180 m^3/s. The area and width average of the section were 10,421 m^2 and 927 m, respectively (Table 1). The maximum flow recorded during one of the crossings was 31,349 m^3/s (Figure 4). The average current velocity in the section, considering all measurements, was 293 cm/s. Meanwhile, the maximum and minimum velocities were 418 and 22 cm/s (Table 1).

On May 6th, 2024, was conducted the second campaign for measuring liquid flow. Six consecutive crossings were made from bank to bank between 09:37 AM and 11:15 AM. The average liquid flow was 29,852 m^3/s, with a maximum of 32,507 m^3/s (Figure 5). The area and width average of the section were 11,606 m^2 and 1,012 m, respectively (Table 2). The average current velocity in the section, considering all measurements, was 272 cm/s. The maximum and minimum velocities were 408 and 7 cm/s (Table 2).

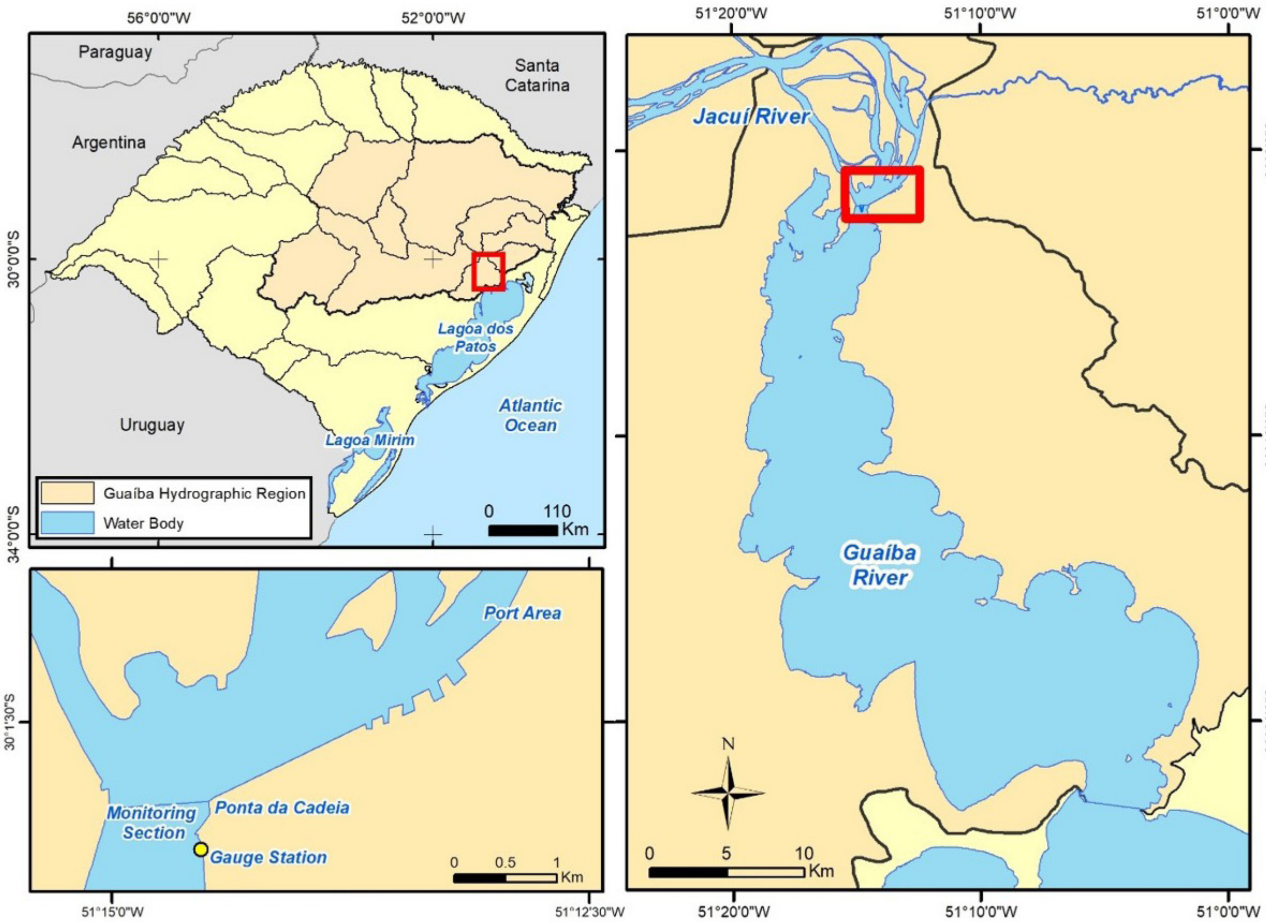

Figure 1. Flow monitoring section on the Guaíba River, at Ponta da Cadeia, near the Gasometer Plant, city of Porto Alegre/RS.

Table 1. Details of flow measurements in the cross-section of the Guaíba River on May 5th.

Transect	Initial time	Final time	Distance (m)	Area (m²)	Discharge (m³.s⁻¹)	Maximum Velocity (cm.s)	Minimum Velocity (cm.s)	Average Velocity (cm.s)
1	17:46	17:55	924	10.766	31.307	418	22	289
2	17:56	18:12	902	10.187	31.349	418	64	316
3	18:13	18:23	930	10.528	27.870	356	56	267
4	18:30	18:50	954	10.203	30.195	403	113	300
Average	-	-	**927**	**10.421**	**30.180**	-	-	293

Table 2. Details of flow measurements in the cross-section of the Guaíba River on May 06th.

Transect	Initial time	Final time	Distance (m)	Area (m²)	Discharge (m³.s⁻¹)	Maximum Velocity (cm.s)	Minimum Velocity (cm.s)	Average Velocity (cm.s)
1	09:37	09:45	1.011	11.789	28.676	378	61	261
2	09:46	10:13	1.007	11.498	30.010	385	34	269
3	10:14	10:25	991	11.545	27.687	408	63	235
4	10:25	10:45	1.006	11.482	31.112	384	70	299
5	10:49	10:57	1.042	11.805	29.122	380	7	262
6	10:57	11:15	1	11.516	32.507	379	10	306
Average	-	-	**1.012**	**11.606**	**29.852**	-	-	**272**

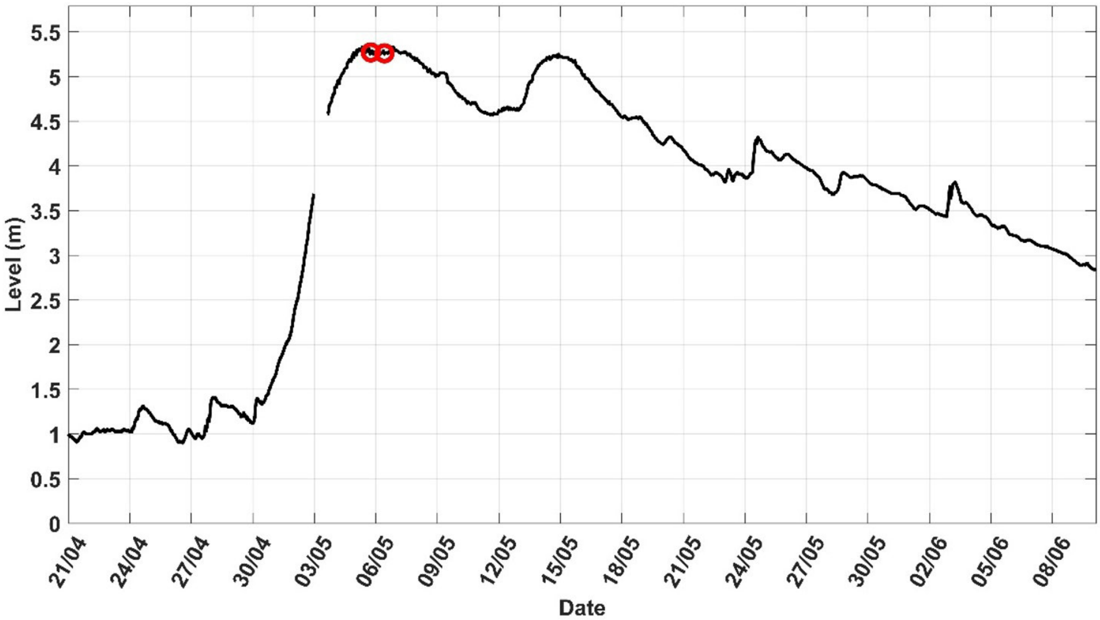

Figure 2. Water level of Guaiba River registered at Gauging station Usina do Gasômetro. Fonte: SEMA-RS (Rio Grande do Sul, 2024a).

Figure 3. ADCP and GPS antenna attached to a board during the liquid flow measurement campaigns in a cross-section of the Guaíba River, in Porto Alegre/RS.

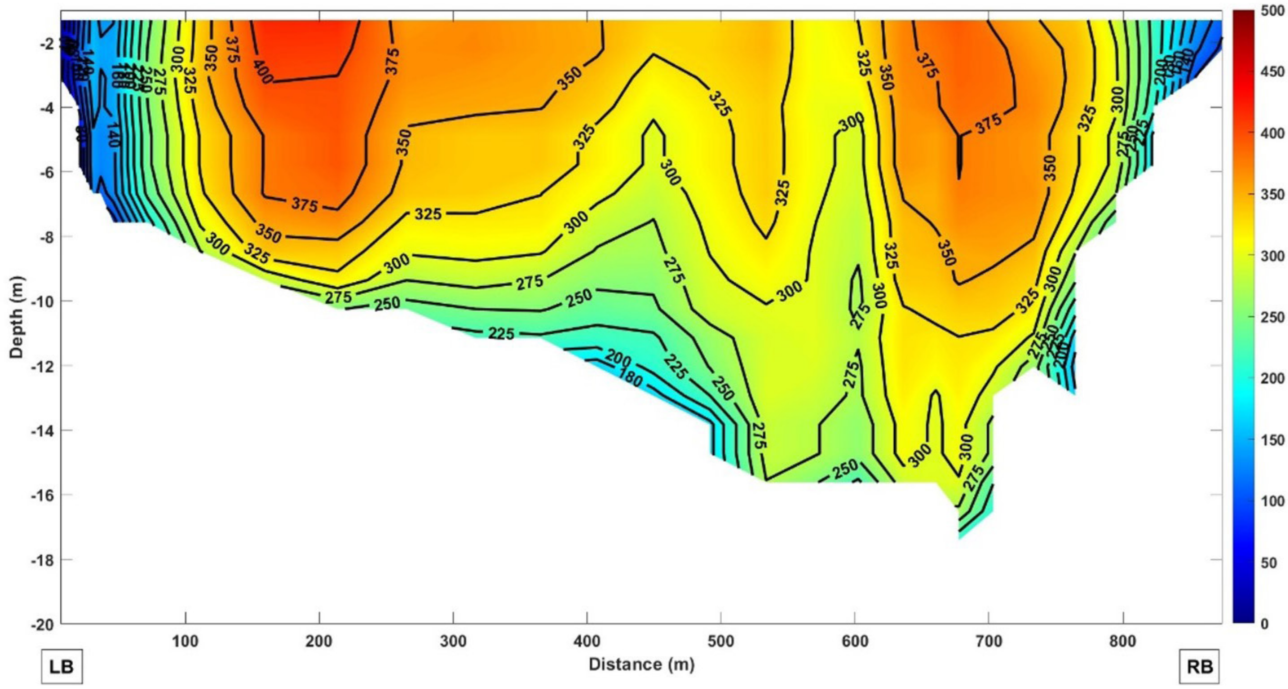

Figure 4. Cross-sectional velocity profile of transect 2 at 17:56, May 5th.

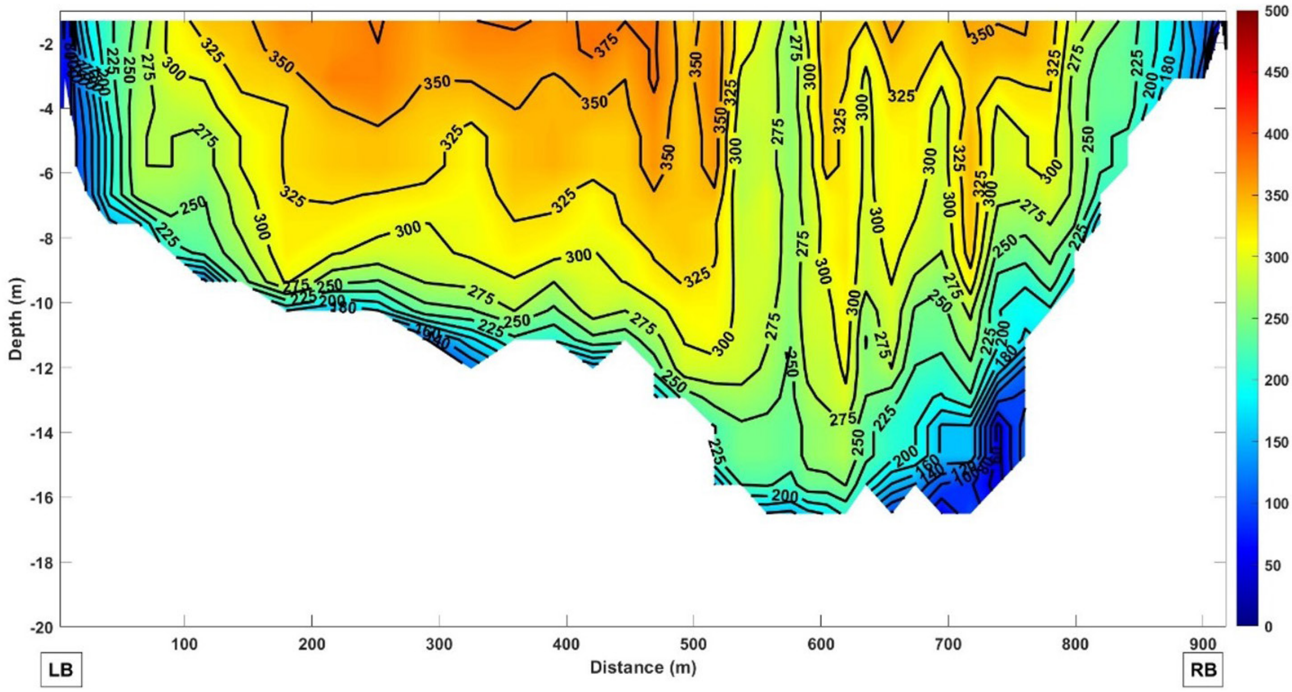

Figure 5. Cross-sectional velocity profile of transect 2 at 10:57, May 6th.

CONCLUSION

This technical note presents the basic data and results of flow measurements conducted on the Guaíba River on May 5th and 6th, 2024, during the highest water level recorded in recent history.

The results and data will contribute to understand the hydrodynamic processes that occurred during the flood. They can also be used to calibrate and validate numerical/hydrological models with the aim of predicting and mitigating future extreme events.

The raw data recorded during the two campaigns are available in a public repository and can be accessed at Andrade et al. (2024).

Finally, it is worth noting that the measured flow values may be underestimated since measurements were not taken in flooded areas, such as the region of Pintada Island. Therefore, the measured values should be considered as minimum values.

ACKNOWLEDGEMENTS

The authors thank the Portos-RS through the Port Environmental Management Program, Project 2.20.2126 (423), Agreement No. 1117/2021, executed by the Federal University of Rio Grande do Sul, for the financial support during this research. We would like to thank Professor Dr. Elírio Toldo Junior and CECO/UFRGS for their logistical support. We also thank Luiza Weimer for translating the manuscript into English.

REFERENCES

Alcântara, E., Mantovani, J., Baião, C., Pampuch, L., Curtarelli, M., Guimarães, Y., Londe, L. R., Ribeiro, J. V., Massi, K., Marengo, J., Nobre, C., Assireu, A., Bortolozo, C., Simões, S. J. C., Tomasella, J., Moraes, O., & Park, E. (2024). *Unprecedented flooding in Porto Alegre Metropolitan Region (Southern Brazil) in may 2024: causes, risks, and impacts.* Rochester, NY: SSRN.

Andrade, M. M., Piazera, A., Luz, R. A., & Scottá, F. C. (2024). *Liquid discharge from Guaíba river, Southern Brazil.* Charlottesville, VA: Center for Open Science. http://doi.org/10.17605/OSF.IO/JAXTM.

Andrade, M. M., Scottá, F. C., Toldo Junior, E. E., Weschenfelder, J., & Nunes, J. C. (2017). Hidrodinâmica do Rio Guaíba: resultados preliminares. In *Anais do XXII Simpósio Brasileiro de Recursos Hídricos.* Florianópolis: Associação Brasileira de Recursos Hídricos.

Becchi, I., & Tazioli, G. S. (1987). On the river processes methodological approach: experience with the River Musone, Italy. Isotope techniques in water resources development. In *Proceedings of IAEA Symposium* (pp. 683-696). Vienna: IAEA.

Collischonn, W., Ruhoff, A., Cabeleira Filho, R., Paiva, R., Fan, F., & Possa, T. (2024). *Chuva da cheia de 2024 foi mais volumosa e intensa que a da cheia de 1941 na bacia hidrográfica do Guaíba.* Porto Alegre: UFRGS. Retrieved in 2024, June 6, from https://www.ufrgs.br/iph/wp-content/uploads/2024/06/Comparacao-2024-e-1941-final.pdf

Do, H. X., Gudmundsson, L., Leonard, M., & Westra, S. (2018). The Global Streamflow Indices and Metadata Archive (GSIM) – Part 1: the production of a daily streamflow archive and metadata. *Earth System Science Data*, *10*(2), 765-785. http://doi.org/10.5194/essd-10-765-2018.

Mirauda, D., Greco, M., & Moscarelli, P. (2011). Practical methods for water discharge measurements in fluvial sections. *WIT Transactions on Ecology and the Environment*, *146*, 355-367. http://doi.org/10.2495/RM110301.

Mueller, D. S., & Wagner, C. R. (2006). *Application of the loop method for correcting acoustic Doppler current profiler discharge measurements biased by sediment transport* (U.S. Geological Survey Scientific Investigations Report, No. 2006-5079, 18 p.). Reston: United States Geological Survey. http://doi.org/10.3133/sir20065079.

Nihei, Y., & Kimizu, A. (2008). A new monitoring system for river discharge with horizontal acoustic Doppler current profiler measurements and river flow simulation. *Water Resources Research*, *44*(4), 1-15. http://doi.org/10.1029/2008WR006970.

Rio Grande do Sul. Governo do Estado. (2024b). *Boletins sobre o impacto das chuvas no RS*. Porto Alegre. Retrieved in 2024, June 6, from https://www.estado.rs.gov.br/boletins-sobre-o-impacto-das-chuvas-no-rs

Rio Grande do Sul. Secretaria de Meio Ambiente e Infraestrutura – SEMA. (2021). *Relatório anual sobre a situação dos recursos hídricos no Estado do Rio Grande do Sul* (329 p.). Porto Alegre: SEMA.

Rio Grande do Sul. Secretaria de Meio Ambiente e Infraestrutura – SEMA. (2024a). *Medições do nível do Guaíba – usina do gasômetro.* Porto Alegre: SEMA. Retrieved in 2024, June 6, from https://app.powerbi.com/view?r=eyJrIjoiYWNhZDg0MDgtNWI5Ni00NjU3LTgyNDctYjgyOTE5MDFiMWM0IiwidCI6IjE1ZGNkOTA5LThkYzAtNDBlOS1hMWU1LWNlY2IwNTNjZGQxYSJ9

Schuster, R., Scottá, F. C., & Paranhos, R. (2021). Inserção de municípios e bacias hidrográficas no estado do Rio Grande do Sul. *Boletim Geográfico do Rio Grande do Sul*, *36*, 138.

Scottá, F. C., Andrade, M. M., Weschenfelder, J., Toldo Junior, E. E., & Nunes, J. C. R. (2020). Descarga líquida e sólida em suspensão no Rio Guaíba, RS, Brasil. *Pesquisas em Geociências*, *47*(3), e094818. http://doi.org/10.22456/1807-9806.109983.

Silveira, A. L. L. (2020). Chuvas e vazões da grande enchente de 1941 em Porto Alegre/RS. *Boletim Geográfico do Rio Grande do Sul*, (35), 69-90.

SonTek. (2000). *SonTek ADP Acoustic Doppler Profiler technical documentation* (186 p.). San Diego: SonTek Inc.

Authors contributions

Mauro Michelena Andrade: Conceptualization (equal), formal analysis (equal), resources (equal), supervision (lead), writing – original draft (lead).

Márcio Piazera: Formal analysis (equal), investigation (equal), methodology (equal), writing – original draft (equal).

Ruan da Luz: Investigation (equal), methodology (equal).

José Carlos Rodrigues Nunes: Formal analysis (equal), methodology (equal), writing – review & editing (equal).

Fernando Scottá: conceptualization (equal), investigation (equal), project administration (equal), writing – review & editing (equal).

Tatiana Silva: Funding acquisition (equal), project administration (lead), resources (lead), writing – review & editing (equal).

Editor-in-Chief: Adilson Pinheiro

Associated Editor: Fernando Mainardi Fan