XXVI SIMPÓSIO BRASILEIRO DE RECURSOS HIDRÍCOS

RELATIVIZED TIME OF FLASH FLOODS

Franciele Maria Vanelli[1]; Willian Richard De Souza Cidral[2] & Leonardo Romero Monteiro[3]

Abstract: In disasters triggered by natural hazards, both physical and social aspects are interwoven, and their interactions over time and space play a relevant role in determining the impacts of the disaster. Flash floods are a subset of floods, and they are one of the most destructive disasters in the world. Although the time of flash flood development can be based on the physical characteristics of the natural phenomena, the subjective terms express the perception of risk in the definitions. This means that time related to flash flood development influences the disaster response from society, as well as society's perception can influence the flash flood definition. Both physical and social aspects should be considered in flash flood dynamics, aiming to reduce flash flood risks and their disaster impacts. We invite the reader to reflect on the role of time in flash flood analysis. For this, a bibliography review was conducted to support the development of this exploratory research based on discussions.

Resumo: Em desastres desencadeados por perigos naturais, aspectos físicos e sociais estão relacionados, e suas interações ao longo do tempo e do espaço desempenham um papel relevante na determinação dos impactos do desastre. As enxurradas constituem um subconjunto das inundações e estão entre os desastres mais destrutivos do mundo. Embora o tempo de desenvolvimento dessas inundações possa ser definido com base nas características físicas do fenômeno natural, os termos subjetivos utilizados nas suas definições expressam a percepção de risco de desastre. Isso significa que o tempo relacionado ao desenvolvimento de enxurradas influencia a resposta da sociedade ao desastre, ao mesmo tempo em que a percepção social também pode influenciar a definição dessas inundações. Assim, tanto os aspectos físicos quanto os sociais devem ser considerados na dinâmica das enxurradas, com o objetivo de reduzir os riscos e os impactos associados a esses desastres. Convidamos o leitor a refletir sobre o papel do tempo na análise das enxurradas. Para isso, foi realizada uma revisão bibliográfica para embasar o desenvolvimento desta pesquisa exploratória com base em discussões.

Key-Words – Disaster; Socio-hydrology.

INTRODUCTION

In disasters triggered by natural hazards, both physical and social aspects are interwoven, and their interactions over time and space play a relevant role in determining the impacts of the disaster (Vanelli *et al*. 2020; Vanelli *et al*. 2022; World Bank and United Nations 2010). Natural hazards can be intensified by anthropogenic origin, but they are always controlled by natural processes (Vilímek and Spilková, 2009), as well as natural hazards only result in disasters in the presence of humans or their activities (UNDRR 2020). Among natural disasters related to hazards, floods were the most

1) Pós-Doutoranda do Programa de Pós-Graduação em Engenharia Civil do Centro de Ciências Tecnológicas (CCT) – Universidade do Estado de Santa Catarina (UDESC) – francielevanelli@gmail.com
2) Graduando do Curso de Graduação em Engenharia Civil do CCT/UDESC
3) Professor do Departamento de Engenharia Civil do CCT/UDESC

frequent between 2009 and 2018 (CRED 2020). Flash floods are a subset of floods and they are one of the most destructive disasters in the world (WMO, 2020).

However, there is still no consensus on the formal and clear scientific definition of flash floods, and the main characteristics, such as rapid rise and high energy, do not have quantitative limits established to differentiate them from a gradual flood (Silva and Monteiro 2020). Among the characteristics of river dynamics during a flash flood, the rise in water level stands out due to its worrisome threat to life, which is justified by the short response time to decision-making (Archer and Fowler 2021). Several definitions cite the time interval between the time of occurrence of the causative event and the time of occurrence of the flash flood. Some of them indicate a time interval only based on empiricism (Kobiyama and Goerl 2007), for instance, the Bureau of Meteorology (2022), NSW (2012), and WMO (1994) indicated 6 hours as the limit to differentiate flash floods from other gradual floods. While others applied subjective expressions such as "short period of time" (Foody *et al.* 2004; Norbiato *et al.* 2008), "sudden discharge" (Castillo-Effen *et al.* 2004), "the response time of the drainage basin is short" (Pham *et al.* 2020), among others studies.

Therefore, empirical quantitative values and subjective terms related to time are used to define flash floods and differentiate them from gradual floods. Although the time of flash flood development can be based on the physical characteristics of natural phenomena, subjective terms express the perception of risk in the definitions. This means that time related to flash flood development influences the disaster response from society, as well as society's perception can influence the flash flood definition. Both physical and social aspects should be considered in flash flood dynamics, aiming to reduce flash flood risks and their disaster impacts. From a socio-hydrological perspective, we invite the reader to reflect on the role of time in flash flood analysis. For this, a bibliography review was conducted to support the development of this exploratory research based on discussions.

TIME CONCEPTS FROM PHYSICAL ASPECTS OF FLASH FLOODS

The time of physical aspects can be related to hydrological variables such as the hydrograph lag time, the recession limb, and the watershed concentration time. Nonetheless, watershed concentration time has uncertainties, because it can be estimated from different valid approximations, obtaining very different results (de Almeida et al., 2014, Queiroz and Alves, 2020). The hydrograph lag time and recession limb time help to define how long the flash flood will last, which is expected to be shorter than a gradual flood. Depending on the region, the quantification of these times will be defined on a case-by-case basis (Kaiser et al., 2020).

In this context, Saharia *et al.* (2017) proposed a new variable called "flashiness", ϕ, as a measure of flood severity based on the event development time concerning the rising rate of the hydrograph and watershed area, as

$$\phi_{ij} = \frac{Q_{ij}^{(p)} - Q_{ij}^{(a)}}{A_i T_{ij}} \tag{1}$$

where $Q_{ij}^{(p)}$ is the peak discharge, $Q_{ij}^{(a)}$ is the action stage discharge (similar to bankfull stage), A_i is the basin area, T_{ij} is the flooding rise time, i is a given gauge, and j is a given event. The authors have tested this variable in the United States of America and evaluated how flash flood severity varies throughout the country. This expression is only based on physical aspects of flash floods when higher values correspond to a more flashiness floods, i.e., a physical perspective strongly related to flash flood time. Under the same discharge and rise time conditions, a smaller watershed will exhibit a more sudden flood than a larger one. Similarly, if a watershed has a shorter rise time than another, while all other conditions remain the same, it will also experience a flashier flood.

Considering the importance of time in physical aspects of flash floods, a particular type of phenomenon draws attention because it presents clearly physical time characteristics due to its behavior: a higher rate of water level rise compared to common flash floods, causing, from a hydrological perspective, an almost instantaneous rise in the hydrograph (Archer *et al.* 2024, Collischonn and Kobiyama 2019b, Viggiani 2022). This rate of rise is associated with a translational visible wave in the water that can travel kilometers downstream (Archer *et al.* 2024). Phenomena with these characteristics have been given various names found in historical documents, such as *roll-wave* (Cornish 1907) and in studies such as head of water (cabeça d'água in Portuguese translation) (Collischonn and Kobiyama 2019a), *surge waves* (Viggiani 2022), and *walls of water* (Archer and Fowler 2021), indicating an undefined nomenclature in the scientific literature. In this study, the term Abrupt Wave Fronts (AWF) suggested by Archer *et al*. (2024) and Collischonn and Kobiyama (2019b) will be adopted.

Through the British chronology, Archer and Fowler (2021) identified 289 AWFs out of 8,000 flash floods reported between 1700 and 2020 in Great Britain, the applied criteria was the rapidity of onset. Additionally, Archer *et al*. (2024) examined hydrographs of the events with the five highest rates of water level rise classified for each station in the 18 Pennine (North England) catchments for the period between 1980 and 2014. They differentiated 122 AWFs from common flash floods through the peaks-over-a-threshold obtained from the 15-minute level acquisition interval records. These events exhibited nearly instantaneous water level rises compared to common flash floods, forming hydrographs with almost vertical ascents and rapid recessions.

As reported by Hjalmarson (1984), on July 26, 1981, a *"killer flood"* struck a group of 150 bathers, resulting in 8 fatalities on a sunny day in the Tanque Verde Creek stream at Tucson, AZ (USA), whose catchment contribution area is 100 km². In this event, a flash flood with AWF characteristics was reported to have suddenly hit the area, causing a water level rise of 0.6 m in 15 seconds and 1.2 m in just 1 minute. The author noted that in terms of height and discharge, this event is not among the largest in this basin. According to Archer *et al*. (2024), it is possible that many AWFs recorded in the Pennine region had very similar rise rates, but the 15-minute measurements may often capture the event already in its recession phase, and a higher frequency acquisition is required to record appropriately this kind of event. An AWF was also recorded in the Luthern River (CH) after intense rainfall at the headwaters, which caused the discharge at the gauge station, just under 30 km downstream, to increase 50 times in 30 minutes (Collischonn and Oliveira 2023). The hydrograph showed the typical behavior of an AWF, with an abrupt peak and an immediate recession, and the wavefront was filmed at four points along the river.

Collischonn and Kobiyama (2019b) state that for an AWF to remain stable and propagate downstream, as in the examples above, the flood wave velocity must be greater than the speeds at which disturbances propagate downstream. In other words, the AWF kinematic celerity (C) must be greater than the sum of the flow velocity (v) and the surface wave celerity in the river ($\sqrt{g.y}$) ahead of the AWF (*i.e.* $C > v + \sqrt{g.y}$), tending to dissipate into surface waves when reaching deeper and less steep regions (Henderson 1966). The appearance of the AWF wave front is related to the difference in celerity of kinematic waves in the same flow (Viggiani 2022). Confirming the necessity of a fast flow to develop the AWF, Archer *et al*. (2024) analyzed the mean catchment slope by Drainage Path Slope (DPSBAR) and confirmed that AWFs originate predominantly in small, very steep, upland catchments.

The formation of AWFs induced solely by rainfall in natural channels is still highly debated. Based on AWF simulations performed on catchments in southern Italy, Viggiani (2022) concluded AWFs can be caused by intense rainfall in catchments with morphology that creates an abrupt lateral inflow in steep channels. However, among engineers and hydrologists, it is common to associate these events with the breaking of ephemeral blockages upstream, such as dam or levee breaks. Complementing the idea of the existence of an AWF induced solely by rainfall, Archer *et al*. (2024) present that the occurrence of two simultaneous AWFs of more than 1 meter at downstream gauge stations on the River Wear and Tees provides conclusive evidence that AWF flood events do not require upstream blockage. It highlights the necessity of more studies to understand the physics of this phenomenon development.

TIME CONCEPTS FROM SOCIAL ASPECTS OF FLASH FLOODS

Fast-developing hazards, such as flash floods, represent a challenge for Disaster Risk Management, due to their rapidly developing which leave short time for institutions and population to take actions to reduce the risks and the impacts. The cycle of Disaster Risk Management consists of three interlinked steps: pre-event (mitigation, prevention, and preparedness), event (warning and response), and post-event (recondition, recovery, and reconstruction) (Vanelli and Kobiyama 2021). In the pre-event step, we usually develop medium- and long-term measures that consist of reducing community exposure to hazard and vulnerability, some examples are engineering techniques, land-use planning, contingency planning, hazard and risk mapping, and evacuation training, among others. This step contributes to increasing the knowledge and capacities to deal with disaster, underpinning early warning systems and disaster response. In this sense, strengthening individuals, communities, and government preparedness can shape the risk perception, due to each actor knowing and being able to act in the face of a disaster (self-protection), reducing disaster impacts, such as loss of lives and material damage (Sene 2013).

The event step involves warning and response, and it is directly related to time for population react. The fast-developing of flash floods results in a social short-term response. Monitoring and forecasting can indicate the imminence of hazards, and the warning system should enable the population and governments to take timely, effective, and appropriate action to reduce disaster risks and impacts before hazardous events develop (United Nations – UN 2016). However, flash floods can take from minutes to hours to develop and sometimes in areas where it is not necessarily raining, hampering the warning and response during the event. Self-protection, i.e., protecting themselves, and their family and neighbors during hydrological extreme events can be fundamental for saving lives because the more prepared society is, the less surprised it will be by the event. Community involvement is relevant to the success of a warning system, because the population needs to receive warning and subsequently take appropriate actions to protect themselves. Examples involving self-help, unofficial or informal approaches, such as residents watching river levels and contacting others, are often shown to play a valuable role (Sene 2013).

Finally, post-event time is dependent on society preparedness, as well as, societal and institutional response to the disaster. The post-event times required need to be estimated on a case-by-case concerning personal characteristics and environmental conditions, such as time of day or night, season (winter, spring, summer, autumn), and experience of flooding (Sene 2013). Besides this, financial support by external organizations can be essential to effective reconstruction.

To open a wider discussion, according to Neal (2013), social time drives many collective actions and activities, and it is based on necessity (for example, people eat when they become hungry) and objective measures of time that define specific period (*e.g.* clocks, schedules, …) that take on social meaning to define markers, special meanings for specific activities or institutionalize rituals among and within societies, organizations, and others. In this context, social time influences how we perceive events, what we do within a specific period, and how we perceive the pace of time (Neal 2013). Besides this, disasters can be understood as disruptions of social time because they modify routine activities.

The issues discussed up to this point are, in a way, related to human relativization (whether of time or damage), which can shape the perception of natural events, thus influencing the categorization and classification of these phenomena. Knowledge is linked to how society is organized, with social order being a product of human activity in the environment in which it has established itself. The knowledge that guides human actions affects the way reality is seen, interpreted, and experienced.

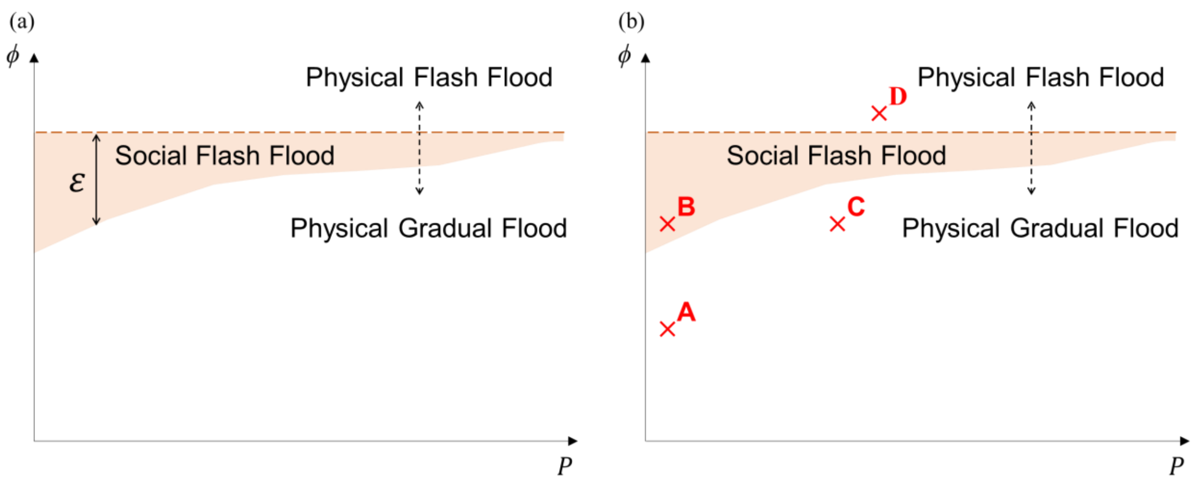
SOCIAL FLASH FLOODS

Floods occur in nature and compose hydrodynamic variations in a watercourse, being part of a fluvial dynamic. Therefore, the consideration that a flood is a flash flood can be based on the severity of its development, as proposed in the "flashiness" variable (Sahari *et al.* 2017). When such a phenomenon affects an established society and causes losses and/or fatalities based on the severity of how the flash flood occurs, it can be understood differently from the physical manner due to human interaction and the losses caused, based on community preparedness. Therefore, the characteristics of flash floods as a disaster are not necessarily the same as those of flash floods of natural causes. Many applied methodologies present a social point of view of flash floods, which does not necessarily fit the physical development of the phenomenon. Flash flood time evaluation is frequently attributed indirectly to heavy rainfall and morphological steepness. The time evaluation of a flash flood phenomenon itself is difficult to validate, because of the lack of information, due to the difficulty of registering them.

One of the main incentives for flash flood studies is its consequences in society, generally identified as a disaster. The metric used by the authorities to classify a runoff as a flash flood is the impact on the human/society, even if physically they may not represent such a sudden runoff, to be considered physically as a flash flood. Thus, there is a possible disconnect between a flash flood as a physical phenomenon and a flash flood as a social phenomenon because of its danger to society. That disconnection can be seen as a decoupling (ε) that depends on the preparedness of society (P) and the flood "flashiness" (ϕ), following as $\varepsilon = f(P, \phi)$. Let us consider that ϕ can represent the threshold to define if the phenomenon is a physical flash flood or not. When ϕ is small, even non-prepared societies can deal with the gradual flood and there is no decoupling ε, *i.e.,* there are no subjective assumptions of "flash". When ϕ has a considerable value, only a well-prepared society can deal with the flood and it is easily assumed subjectively as a flash flood, even if it is not a physical flash flood. Here we call it a "social flash flood" (Figure 1). We consider that ε is bigger for a society with low preparation.

Hence, a social flash flood is not necessarily a physical flash flood. We consider a flash flood as a Physical Flash Flood when it can be classified as a flash flood no matter what its severity as a disaster. Then, flash floods certainly can display purely physical behavior, as presented in the AWF discussion. However, suppose that the flood is a gradual flood, yet it can pose a great potential for destruction. In that case, local media and authorities can consider it a flash flood, as it can carry people, cars, and destroy houses, leading to the complications that a gradual flood can also entail. This fact is related to the difference in people's and society's response time and the time of flash flood onset.

Figure 1: Hypothetical relationship between flood "flashiness" and society preparedness for defining the phenomenon as a gradual flood, social flash flood, or a physical flash flood. a) Representation of decoupling variable; b) three different situations are highlighted, where A is a situation that independently of P it will be considered as a gradual flood, B is a situation that for unprepared societies a physical gradual flood is considered as flash flood by society (a social flash flood), C for the same flood intensity, a better prepared society considers the phenomenon as a gradual flood, and D is a representation of a physical flash flood, that is independent of society preparedness.



FINAL REMARKS

Based on this initial discussion, we hope to stimulate reflections about flash flood definitions. Here, we focused on the relativized time of flash floods, due to it can be a value based on physical characteristics or an expression based on perceptions by society. Not every flash flood called as such by the media and authorities necessarily has flash flood physical characteristics. Considering the negative impacts of floods on society, flash floods can be sociohydrological phenomena. It is important to highlight that the social part of a flash flood displays deeper complexity, as it is a runoff with high velocity that surprises people and has a capacity for destruction.

At certain moments, a runoff is defined by society as a flash flood, but it does not necessarily display such a sudden variation in the depth and velocity of the runoff to be defined as a physical flash flood. On the social scope, avoiding social flash flood occurrence depends on how prepared the population is to deal with this phenomenon. In a mutual interaction, improvements in Flash Flood Risk Management increase preparedness, a more prepared society copes better with extreme hydrological events, and a comprehensive understanding of the physical characteristics of flash floods is developed, which also strengthens risk management. Therefore, a better understanding of flash floods as natural disasters requires qualitative and quantitative methods concerning social and physical components in an integrative way.

ACKNOWLEDGEMENT

Os autores agradecem à Fundação de Amparo à Pesquisa e Inovação do Estado de Santa Catarina (FAPESC) e à Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) – Brasil pelo apoio financeiro concedido.

REFERENCES

ARCHER, D.; WATKISS, S.; WARREN, S.; LAMB, R.; FOWLER, H. J. (2024). *"Gauged and historical abrupt wave front floods ('walls of water') in Pennine rivers, northern England"*. Journal of Flood Risk Management, 17, e12989, pp. 1-16.

ARCHER, D.R.; FOWLER, H.J. (2021). *"A historical flash flood chronology for Britain"*. Journal of Flood Risk Management, 14 (e12721), pp. 1-13. Available in: <https://doi.org/10.1111/jfr3.12721>

BUREAU OF METEOROLOGY. (2022). *Australian water information dictionary*. Available in: http://www.bom.gov.au/water/awid/product-water-forecasts-flood-warning-services.shtml

CASTILLO-EFFEN, M.; QUINTELA, D.; JORDAN, R.; WESTHOFF, W.; MORENO, W. (2004). *"Wireless sensor networks for flash-flood alerting"* in Proceedings of the Fifth IEEE International Caracas Conference on Devices, Circuits and Systems, 2004., 1, pp. 142–146.

COLLISCHONN, W.; KOBIYAMA, M. (2019b). *"A hidrologia da cabeça d'água: formação de frente de onda abrupta"* in Proceedings XXIII Simpósio Brasileiro de Recursos Hídricos.

COLLISCHONN, W.; KOBIYAMA, M., (2019a). "*A hidrologia da cabeça d'água: ocorrências e observações no Brasil"* in Proceedings XXIII Simpósio Brasileiro de Recursos Hídricos.

COLLISCHONN, W.; OLIVEIRA, A. M. (2023). *"Descrição de um evento de cabeça d'água bem monitorado"* in Proceedings XXV Simpósio Brasileiro de Recursos Hídricos.

CRED - Centre for Research on the Epidemiology of Disasters. 2020. *Natural disasters 2019: Now is the time to not give up*. Available in: <https://www.preventionweb.net/publication/natural-disasters-2019-now-time-not-give>

DE ALMEIDA, I. K.; ALMEIDA, A. K.; ANACHE, J. A. A.; STEFFEN, J. L.; ALVES SOBRINHO, T. (2014). *"Estimation on time of concentration of overland flow in watersheds: A review*". Geociencias, 33(4), pp. 661–671.

FOODY, G.M.; GHONEIM, E.M.; ARNELL, N.W. (2004). *"Predicting locations sensitive to flash flooding in an arid environment"*. Journal of Hydrology, 292 (1–4), pp. 48–58.

HENDERSON, F.M. (1966). *Open channel flow*. Macmillan New York, 522p.

HJALMARSON, H. W. (1984). *"Flash flood in Tanque Verde Creek, Tucson, Arizona"*. Journal of Hydraulic Engineering, 110(12), pp. 1841–1852.

KAISER, M.; GÜNNEMANN, S.; DISSE, M. (2020). *"Providing guidance on efficient flash flood documentation: An application-based approach"*. Journal of Hydrology, 581, 124466.

KOBIYAMA, M.; GOERL, R. F. (2007). "*Quantitative method to distinguish flood and flash flood as disasters"*. SUISUI Hydrological Research Letters, 1, pp. 11–14.

KOBIYAMA, M.; GRISON, F.; LINO, J. F. L.; SILVA, R. V. (2006). *"Time of concentration in the UFSC campus catchment, Florianópolis-SC (Brazil), calculated with morfometric and hydrological methods"* in Proceedings VI Regional Conference on Geomorphology, Goiânia, GO. Brazilian Geomorphological Union.

NEAL, D. M. (2013). "*Social Time and Disaster*". International Journal of Mass Emergencies & Disasters, 31(2), pp. 247-270.

NORBIATO, D.; BORGA, M.; DEGLI ESPOSTI, S.; GAUME, E.; ANQUETIN, S. (2008). *"Flash flood warning based on rainfall thresholds and soil moisture conditions: An assessment for gauged and ungauged basins"*. Journal of Hydrology, 362(3–4), pp. 274–290.

NWS - National Weather Service. (2012). *National Weather Service Glossary*. Available in: <http://w1.weather.gov/glossary/index.php>

PHAM, B.T.; PHONG, T.V.; NGUYEN, H.D.; QI, C.; AL-ANSARI, N.; AMINI, A.; HO, L.S.; TUYEN, T.T.; YEN, H.P.H.; LY, H.-B.; PRAKASH, I.; TIEN BUI, D. (2020). *"A Comparative Study of Kernel Logistic Regression, Radial Basis Function Classifier, Multinomial Naïve Bayes, and Logistic Model Tree for Flash Flood Susceptibility Mapping"*. Water, 12(1), pp. 239.

QUEIROZ, M. S. D.; ALVES, N. D. S. (2020). *"Aplicação de diferentes fórmulas de tempo de concentração para uma bacia hidrográfica urbana"*. Revista Tocantinense de Geografia, 9(18), pp. 219–231.

SAHARIA, M.; KIRSTETTER, P. E.; VERGARA, H.; GOURLEY, J. J.; HONG, Y.; GIROUD, M. (2017). *"Mapping flash flood severity in the United States"*. Journal of Hydrometeorology, 18(2), pp. 397-411

SENE, K. (2013). *Flash floods: Forecasting and warning*. Springer.

SILVA, F.A.R.E.; MONTEIRO, L.R. (2020). *"Revisão Conceitual de Enxurradas"* in Proceedings II Encontro Nacional de Desastres, 2020, Rio de Janeiro, 2020, p. 1-4.

UN - UNITED NATIONS. (2016). *Terminology on disaster risk reduction*. Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction. Geneva: UNDRR.

UNDRR - United Nations For Disaster Risk Reduction. (2020). *Human Cost of Disasters.* Geneva. Available in: <https://doi.org/10.18356/79b92774-en>.

VANELLI, F. M. KOBIYAMA, M. (2021). *"How can socio-hydrology contribute to natural disaster risk reduction?"* Hydrological Sciences Journal, 66(12), pp. 1758–1766.

VANELLI, F.M.; KOBIYAMA, M.; GONZÁLEZ-ÁVILA, I.; FUSINATO, E.; DE BRITO, M.M. (2022). *"An integrative approach for overcoming dichotomous thinking in natural hazards and disasters research", in Ensino de geografia e a redução do risco de desastres em espaços urbanos e rurais*. Org. por Magnori Júnior, L.; Magnori, M.G.M.; Cabral, M.; Torres, M.M.; Castro, C.E.; Londe, L.R.; Serrano-Notivoli, R.; Figueiredo, W.S.; Barbosa, H.A.; Prieto, J.I. Centro Paula Souza, São Paulo – SP, pp.697-719.

VANELLI, F.M.; KOBIYAMA, M.; MONTEIRO, L. R. (2020). *"Dicotomias associadas aos desastres"* in Proceedings II Encontro Nacional de Desastres, Rio de Janeiro, 2020, p. 1–4.

VIGGIANI, G. (2022). *“The elusive topic of rainfall-induced surge waves in rivers: Lessons from canyon accidents”*. International Journal of River Basin Management, 20(1), pp. 17-31.

VILÍMEK, V.; SPILKOVÁ, J. (2009). *“Natural hazards and risks: the view from the junction of natural and social sciences”*. Geografie,114 (4), pp. 332–349. Available in: <https://doi.org/10.37040/geografi e2009114040332>.

WMO – World Meteorological Organization. (1994). *Guide to hydrological practices*. WMO: Geneva; 735.

WMO – World Meteorological Organization. (2020). *Flash Flood Guidance System: response to one of the deadliest hazards*. Available in: <https://wmo.int/media/magazine-article/flash-flood-guidance-system-response-one-of-deadliest-hazards>

WORLD BANK; UNITED NATIONS. (2010). *Natural Hazards, UnNatural Disasters.* Washington DC.