



Importance of river basin monitoring and hydrological data availability for the integrated management of water resources

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Abstract

Environmental conservation is essential for environmental and social maintenance, along with practices aimed at sustainable development that can address the integrated administration of natural resources. Therefore, this work aims to evaluate the possibility of implementing the Integrated Water Resources Management (IWRM) program, based on hydrological data made available at the National Water Resources Information System (NWRIS) under the responsibility of the Brazilian National Water Agency (Agência Nacional de Águas). As such, this study presents the conditions for hydrometric monitoring of the Sinos River watershed, located in the state of Rio Grande do Sul, Brazil, and discusses the importance of making hydrological data available to the IWRM. Based on information made available in the NWRIS, a survey was carried out on the historical series of pluviometric, fluvimetric and water quality stations installed in the basin to verify whether, based on the hydrometric monitoring carried out, it is possible to implement the IWRM. Based on the existing data, it was observed that the implementation and maintenance of the IWRM system is compromised. It appears that there are several entities that monitor water resources in the basin, however, when made available, the data observed by such entities are stored in each institution's specific websites or are not made available at all, which makes it difficult for users to acquire the data. In addition, there is a need to expand and implement an automatic and telemetric monitoring network in the basin.

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INTRODUCTION

Lack of planning for natural resources usage, especially water resources, often due to the illusion of abundant availability, generates a cycle of negative consequences. It results in economic, social and environmental losses, which consequently causes decline in development and social well-being. Schewe et al. (2014) points out that, due to the economic and population growth expected for the next decades, the demand for water resources tends to grow and intensify the problems related to them, both in already suffering regions and in those highly probable to suffer from scarcity events in the near future. One way to try to adequately get around this possibility is to manage those resources and the environment as a whole, through the Integrated Water Resources Management (IWRM) (SHRUBSOLE et al., 2017; VEALE; COOKE, 2017; LEIDEL et al., 2012; WMO, 2009; BISWAS, 2004).

The paper published by the Global Water Partnership (GWP) in 2000, states that IWRM must promote the development and management of water, land and related resources, to maximize economic and social well-being on an equitable basis without compromising the sustainability of vital ecosystems (GWP, 2000). Benham et al. (2011) state that watershed management can be a continuous, geographically defined, integrated, collaborative process of creating and implementing plans, programs and projects, developed to sustain and improve the basins and their functioning ecosystems.

Therefore, for an adequate management plan to be successful, continuous and accurate monitoring (spatial and temporal), as well as data evaluation, is essential in all phases. The World Meteorological Organization (WMO) published the Guide to Hydrological Practices, Vol. 1, in 2009, in which the entity emphasizes that, without systematic monitoring, followed by evaluation, the opportunity to learn from experience is reduced, as well as the opportunity to make adjustments in the light of new information, knowledge and experience. According to the GWP (2000), the assessment of water resources conditions must address surface and groundwater occurrence in a space-time dynamic, in order to give a preliminary appraisal of water requirements for the development project being considered.

As such, it is this article's objective to assess whether it is possible to implement the IWRM, based on hydrological data made available at the National Water Resources Information System

(NWRIS) data are from Agência Nacional de Águas (ANA), the federal agency responsible for the implementation of Brazilian water resources management; and to propose sites for monitoring stations installation. For the Sinos River basin case study, rainfall, fluviometric and water quality monitoring stations were used. The stations were all located at the Sinos River watershed, in the state of Rio Grande do Sul, Brazil.

WATER RESOURCES MANAGEMENT

River Basin Committees (RBC)

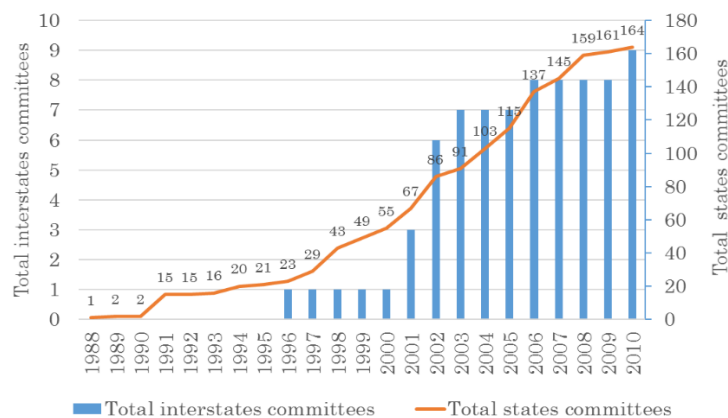
The developed country to first concentrate efforts on water pollution occurred at the beginning of the 20th century in the Ruhr River basin, located in Germany, when the Ruhr Basin Water Association was created in 1913. At that time, it was established in an assembly that all its associates (companies, industries, commerce, municipalities and community) would follow the water use policy, including paying for water use and pollution (RIBEIRO, 2006). Another experience worth noting was that of France, whose management policy has served as a model for several countries in the world, including Brazil. This model is one of the precursors in applying fees for water usage, combined with participatory and integrated watershed management. Lanna (1997) comments that, among the various regulations introduced in the French management water resources is Act 1245/64, which defined the watershed as a basic management unit. To implement participatory management, collegiate bodies were defined, which had the power to manage and approve programs. These bodies were denominated River Basin Committees (RBC).

According to Porto and Porto (2008), in Brazil, the first records of river basin committees were made based on the complex and eminent sanitary demands of the Alto Tietê and Cubatão basins, in the state of São Paulo. In 1978, the Special Committee for Integrated Studies of Hydrographic Basins was created and, subsequently, the Paraíba do Sul, São Francisco and Ribeira de Iguape basins executive committees were created as well. Since then, several decentralized management initiatives have appeared, such as the Santa Maria/Jacu Intermunicipal Consortium, in the state of Espírito Santo, and the Piracicaba, Capivari and Jundiá consortia, also in the state of São Paulo. In 1988, as a result of community initiative, and

with the support of the State Government of Rio Grande do Sul, the Sinos and Gravataí Basin Committees emerged, both affluents of the Guaíba Lake, which is considered the first Brazilian experience of instituting a basin

committee based on the French model (ANA, 2011). Figure 1 shows the growing number of state and interstate river basin committees implemented in the national context.

Figure 1 - Number of river basin committees created in Brazil from 1988 to 2010.



Source: Adapted from ANA (2011).

Correlating geographic, demographic, socioeconomic and sanitation variables versus Brazilian states that have RBCs, Feil et al. (2017) concluded that the existence of river basin committees is related to population size, which promotes greater pressure as it increases in number. The existence of river basin committees is also due to several factors, such as economic growth, the number of conflicts arising from multiple uses, sewage collection and the level of environmental quality degradation.

Santos et al. (2015), Dourojeanni (2002) and Lanna (1996) point out that a basin committee is a state entity, with normative, deliberative and consultative characteristics, imbued with decision-making powers in situations where many individual and collective interests coexist. With the basin committees listed, they must act as a representative body for the various water users, both public and private, acting in their interest. According to Senra and Nascimento (2017), within the IWRM, a broader range of stakeholders from water-related sectors should be considered, not only the traditional “water professionals”, which favors a more holistic view.

According to the National Policy on Water Resource (NPWR), the RBC is an essential body for the implementation, maintenance and development of a policy articulated between different municipal, state and national management levels. Therefore, the RBC aims at managing water resources in a territorial unit called the watershed. The watershed, according to the NPWR, is the basic unit for the planning and

management of water resources. Watanabe et al. (2014) affirms that the decision-making on water resources management in the watershed must be well evaluated, since once the changes are processed, returning to the previous state is much more difficult due to losses and gains resulted from subsequent environmental and social processes. The authors also state that the group components responsible for the decision-making process must include government, business, society and financial institutions representatives. Korfmacher (2001) warns that the main threats to management credibility with different users are groups that are at a disadvantage in relation to others, non-representativeness, power struggles, among others. To that end, Rauber and Cruz (2013) address that, to enact water management, integrated river basin management should be used, with a focus on the multiple uses and the shared responsibility for quantity and quality.

Importance of hydrometric monitoring

The premise for a successful IWRM implementation and maintenance is to know the quantity and quality of water available in the basin in question. Therefore, hydrological monitoring is of paramount importance for determining the water balance and knowledge of the various processes interrelations and aggregations. These processes comprise the various forms the water enters the basin, such as precipitation, snow and hail, through evaporation and evapotranspiration, infiltration, percolation,

storage of water in the soil, subsurface formation and surface runoff. Added to these there is also flow generation, through erosion caused by transit and sediment deposition, and by organic and inorganic substances transports, until its effluvium at the basin's outfall.

The WMO (2008) guide states that hydrological data collection's ultimate goal, whether it is precipitation and discharge measurements, water level records, groundwater monitoring or water quality sampling, is to provide a set of indicators with sufficient quality to be used in the decision-making process of all water resource management aspects, in the wide range of operational applications, as well as in research.

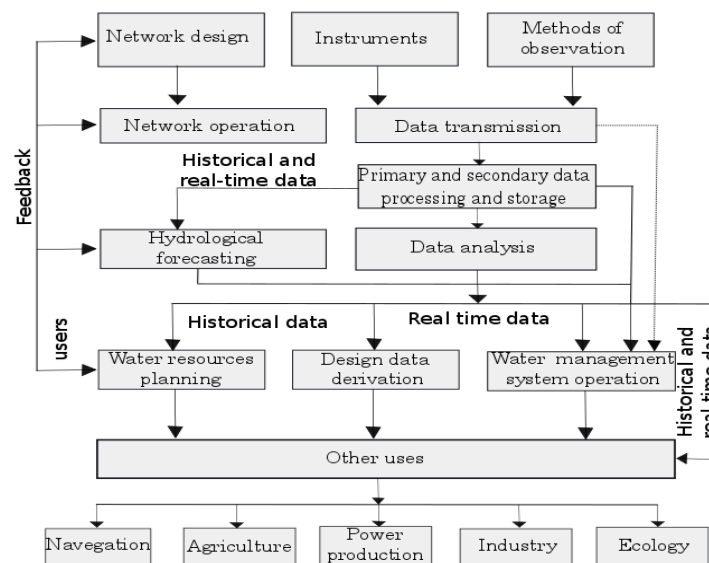
Field monitoring is an arduous and expensive task, since measurement equipment implementation and field teams capable of carrying out hydrometric monitoring training requires investment. Despite the difficulties, Stahli et al. (2011) argue that a long historical series of precipitation and flow is essential to determine correct conclusions about the

watershed's behavior and tendencies due to climate changes and land use. Thus proving the importance of constant monitoring and equipment implementation that performs data measurement continuously and in a time interval that is able to accurately measure the hydrometeorological phenomena.

As this data set has great intrinsic value, hydrological data monitoring is, therefore, an important work in itself. As such, to maximize the results of the investments placed for its acquisition and the possibility of being effectively used it must be carried out effectively.

Data management can be approached from two complementary points of view: one aiming at preservation and degradation control, making it accessible, disseminating data sets that have been collected, and another aiming at increasing its value to users, which includes data consistency and fault filling, to generate calculated data (e.g. evaporation or liquid discharge), or to aggregate (e.g. average discharge) (WMO, 2008). Figure 2 presents a procedural organization chart to be adopted for hydrological data's implementation, operation and availability.

Figure 2 - Organization chart for data implementation, operation, storage, transmission and availability from a hydrological monitoring network.



Source: WMO (2009).

Automatic measuring equipment

Since the 1980s, with information technology and telecommunications expansion, hydrological information can be acquired in real time, improving data measurement. These improvements happened due to measurement equipment automation. Among the variables monitored, precipitation and river level could be

measured in a more discerning way, consequently allowing for more accurate knowledge of the hydrological phenomena.

Currently, tipping containers is the most used automatic pluviograph. In this equipment, the water collected by a cylinder with a capture area of 400 cm² is directed to a set of two containers articulated by a central axis. A seesaw effect is then set off as each container is filled and

emptied and the device records the number of movements and how many movements are executed. Each container has 0.25 mm in volume. This equipment's advantage is that it has a data logger capable of storing data for a finite time. The storage capacity is directly linked to data acquisition, in which the log storage capacity will be shorter if time intervals between recordings are also shorter. Generally, the measurement interval occurs according to the degree of detail required, due to the basin's concentration time and the intervals between technical team's visits to the equipment. The equipment set consists of the pluviograph itself, a data logger, a power battery and a solar panel. Detailed information on automatic equipment and indirect measurement methods such as weather radars and remote sensing can be found at the WMO (2017) guide. Automatic equipment has, among other advantages, the possibility of more accurately measuring the intensity, duration and precipitation timeframes.

For river level measurement, there are several measurement principles, ranging from float sensors, ultrasonic sensors and water column pressure sensors, the latter being the most used. This type of sensor measures the water column over it, as level oscillations are recorded at predetermined times. With the exception of the level sensor, the other components are the same as the pluviometric system. Detailed information about the different types of sensors can be found at the WMO (2010) guide. Both rainfall and river level data can be transmitted remotely, if they are equipped with specific transmitting equipment (modem). Remote data transmission, a telemetric station, is essential for a river basin preventive planning, as they can have a warning system implemented to prevent natural disasters, such as landslides and floods, according to Reis et al. (2016). In Brazil, according to the Critical Events Alert System - SACE, 16 river basins have hydrological alert systems in operation. In addition to this potential, automated monitoring provides other benefits, such as improving data quality through data gathering at all stations in the network within shorter intervals and at the same time.

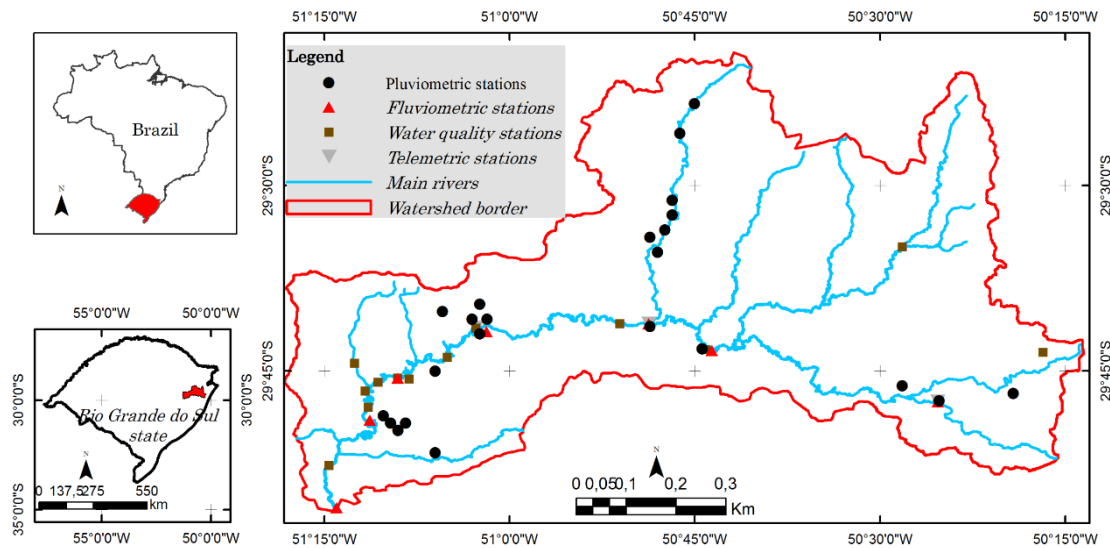
Consequently, a holistic view of the basin's hydrological conditions is provided. Accurate data, when used as hydrological models' feed sources, can enhance the model's representativeness.

CASE STUDY: SINOS RIVER BASIN

The Sinos River watershed is located in the Northeastern portion of the state of Rio Grande do Sul. It has an area of approximately 3,746.68 km², covering 32 municipalities, and has an estimated population of 1,350,000 inhabitants (Figure 3). The main rivers that drain the basin are the Rolante River, the Ilha River, the Paranhana River and the Sinos River. The latter has its source in the municipality of Caraá and its mouth in the Jacuí Delta. Due to its socioeconomic development level, the basin presents several problems related to water resources and the environment. These are due to the demand for water usage, such as consumption, industry and irrigation, which is often greater than the availability. Its tributaries and its main river receive large amounts of untreated industrial and domestic waste, in addition to being contaminated by pesticides (PETRY et al., 2016; BENVENUTI et al., 2015).

The data used in this work were obtained from the ANA website in the Hydrological Information System (HidroWeb) section. This website is part of the National Water Resources Information System (NWRIS), in which access to the database regarding information collected by the National Hydrometeorological Network (NHN) is made available. To verify the available data (precipitation, elevation, flow and water quality), a survey was carried out verifying the pluviometric, fluviometric and water quality stations located in the respective basin, as shown in Figure 3. It should be noted that only the stations that presented their condition as "in operation" were considered for the IWRM analysis. The access period to the respective website was from August 2017 to March 2018.

Figure 3 - Sinos River basin location and pluviometric, fluviometric and water quality stations spatialization in the basin.



Source: the Authors (2017).

Rainfall Monitoring

Precipitation data, collected continuously and without fail, are essential for determining rainfall’s spatial and temporal behavior. Kaiser and Porto (2005) comment that, traditionally, rain is measured in pluviometric stations, but it can also be measured indirectly by remote sensing, through satellites and weather radars.

The data related to rainfall monitoring in the Sinos River basin, made available on the ANA website, are collected directly, with conventional and automatic rain gauges. Of the 23 stations shown in Figure 3, only four have data available for download, (Table 1). The Canela and Campo Bom stations are disabled. Thus, only the Taquara Montante and the Sapucaia do Sul stations have available data and are in operation.

Table 1 – Sinos River basin’s basic data for pluviometric stations located in municipalities in the state of Rio Grande do Sul, Brazil.

Code	Name	City	Responsible body	Latitude (S)	Longitude (O)	Historical series
2950009	Canela	Canela	CEEE	29°48'00"	50°48'00"	01/05/41 - 31/12/78
2950068	Taquara Montante	Taquara	ANA	29°43'15"	50°44'06"	01/10/09 - 01/01/18
2951028	Sapucaia do Sul	Sapucaia do Sul	ANA	29°49'12"	51°09'40"	01/01/64 - 01/01/18
2951069	Campo Bom	Campo Bom	INMET	29°41'00"	51°02'00"	01/01/85 - 31/12/98

Source: the Authors (2018).

Fluviometric Monitoring

The stations’ fluviometric monitoring includes river level - elevation (m), liquid discharge - Q (m³/s), solid discharge - Qs (ton/day), measuring section transversal profile survey (m) and water quality parameters - WQ measurements. These parameters are correlated with each other, but not all of them are measured every time. The river level variation monitoring over time can be

carried out conventionally with linimetric rules or automatically through sensors (linigraphic). The flow can be determined directly with measurements made in the field, and indirectly through the key curve equation, or else, through synthetic time series (DETZEL et al., 2013) and satellite images, which is called remote sensing. Sichangi et al. (2016) and Birkinshaw et al. (2014) report that several researchers have used remote sensing for determining flows, mainly in large

basins, successfully. According to the WMO (2010) guide, flow records are the basic data used as reliable sources to know the river's temporal space variability. The data obtained from continuous monitoring are extremely useful, as these records may serve as an aid for scientific studies and to plan engineering projects, defining priority uses and actions for environmental conservation. The quota and flow data available at <http://www.NWRIS.gov.br/hidroweb>, referring to stations located in the Sinos River

basin, come from direct and indirect measurements obtained by the key curve equation. Table 2 shows the stations that make up the basin's monitoring. The Campo Bom (83377800), São Leopoldo (87382000) and Taquara Montante (87374000) stations alone monitor all the parameters presented out of all the stations listed, while only three stations transmit their data via telemetry and three present data available for download at the aforementioned website.

Table 2 – Sinos River basin's fluviometric stations in operation located in municipalities in the state of Rio Grande do Sul, Brazil.

Station Code	87318000	87380000	87376000	87393000	87382000	87385000	87374000
Station Name	Arroio Caraá	Campo Bom	Foz do Paranhana	Foz do rio dos Sinos 59	São Leopoldo	Siderurgica Riograndense	Taquara Montante
Responsible body	SEMA-RS	ANA	SEMA-RS	DMAE	ANA	DEPRC	ANA
City	Caraá	Campo Bom	Taquara	Canoas	São Leopoldo	Sapucaia do Sul	Taquara
Last update	08/04/2016	05/07/2017	08/04/2016	25/04/2006	05/07/2017	25/04/2006	05/07/2017
Active	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Average quotas	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Average flow	Yes	Yes	No	No	Yes	No	Yes
Sediments	No	Yes	No	No	Yes	No	Yes
Water quality	No	Yes	No	No	Yes	No	Yes
Telemetric	Yes	Yes	Yes	No	No	No	No
Latitude (S)	29° 47' 24"	29° 41' 24"	29° 41' 24"	29° 55' 48"	29° 45' 36"	29° 49' 12"	29° 43' 12"
Longitude (O)	50° 25' 12"	51° 03' 00"	50° 48' 36"	51° 13' 48"	51° 09' 00"	51° 10' 48"	50° 44' 24"
Historical series	Not available for download	01/11/1939 - 01/01/2018	Not available for download	Not available for download	01/07/1973 - 01/10/2017	Not available for download	01/08/1996 - 01/01/2018

Source: the Authors (2018).

Water Quality Monitoring

With society's advancement, the demand for water resources increased considerably and, as a result, monitoring had to follow this evolution. Besides the quantitative part, water availability is also intrinsically linked to water quality, since water source pollution can make different types of uses unfeasible (WWAP, 2017). In this sense, water quality monitoring aims at verifying whether its physical-chemical conditions are adequate for the intended use. The WMO (2013) guide presents a series of actions provided

directly by water quality monitoring, useful to define usage potential and to make decisions regarding the IWRM. Regarding monitoring in the Sinos River basin, Table 3 presents stations that perform it as well as monitoring parameters and the number of measurements for each parameter.

Of the stations presented, it is worth noting that the Novo Hamburgo (87380015) and the São Leopoldo (87382000) stations have a greater number of parameters and measured data, but they still have a small historical series. The São Leopoldo station (87382000) presents a

discrepancy between the numbers of measurements for each parameter, which indicates that the water quality monitoring is not continuous. And at the Novo Hamburgo station (87380015), no liquid discharge measurement is recorded. Consequently, it is impossible to determine the polluting load, and thus impossible to determine the medium's effective contamination.

The Campo Bom (87380000) and the Taquara Montante (87374000) stations monitor only the water parameters and measure

temperature, pH, turbidity, electrical conductivity and dissolved oxygen by sampling. The parameters are measured, usually, when the station measures liquid discharge.

The Campo Bom (87377800), Caraá (87318500), Parobé (87376800), Portão (87382020), São Leopoldo (87380030), São Leopoldo (87381800), São Leopoldo (87382010) and Sapucaia do Sul (87382025) stations presented only two measurements, from 2016 to 2017. Hence, they are not shown in Table 3.

Table 3 – Sinos River basin's water quality parameters measured in the stations located in municipalities in the state of Rio Grande do Sul, Brazil.

Station Code	87380000	87380015	87382000	87374000
Station Name	Campo Bom	Novo Hamburgo	São Leopoldo	Taquara Montante
Responsible	ANA	FEPAM	ANA	ANA
Historic series	11/02/2000 - 23/01/2018	01/01/2001 - 17/04/2017	12/07/1976 - 24/01/2018	09/02/2002 - 16/11/2017
Air temperature	54	-	59	45
Sample temperature	54	36	88	47
pH	55	36	84	47
Turbidity	30	36	47	34
Electrical conductivity	50	-	81	45
DQO	-	-	15	-
DBO	-	36	10	-
OD	49	36	71	44
Total Solids	-	36	1	-
Total Suspended Solids	-	-	15	-
Total Dissolved Solids	-	-	1	-
Chlorides	-	-	1	-
Total Phosphate	-	36	3	-
Total Nitrogen	-	36	1	-
Ammoniacal Nitrogen	-	36	14	-
Nitrates	-	36	14	-
Nitrides	-	36	15	-
Fecal Coliforms	-	36	15	-
Total Alkalinity	-	-	14	-
Total Orthophosphate	-	-	14	-
Organic Nitrogen	-	36	-	-
Net Discharge	73	-	42	46
Solid Discharge	73	-	1	35
Total Phosphorus	-	36	-	-
Total Nitrogen	-	36	-	-

Source: the Authors (2017).

Assessing the current situation in the Sinos River basin

There are 23 pluviometric stations, seven fluviometric stations and 12 water quality stations along the basin. However, as shown in Tables 1, 2 and 3, it appears that there are only two pluviometric stations, three fluviometric

stations and four water quality stations operating effectively and with available data (Figure 4). The fluviometric and pluviometric monitoring stations are in the basin's middle and lower part. No station has data available in the basin's highest part or in the Sinos River tributaries. This concentration in the downstream locations causes a space-time gap in water resources' qualitative

and quantitative knowledge. Therefore, it is difficult, for example, to study water balance as well as geographical locations of organic and inorganic contamination points.

Regarding pluviometric stations, of the 23 stations listed in Figure 3, only the Sapucaia do Sul (02951028) and the Taquara Montante (02950068) stations are in operation and with downloadable data (Table 1). These stations, however, are in the basin's middle and lower part. As a result, precipitation events that occur at the basin's headwaters are not generating available data.

Concerning the fluviometric stations, of the seven monitored stations, only the Campo Bom (87380000), the São Leopoldo (87382000) and the Taquara Montante (87374000) stations present quota and flow data, with a historical series (daily) of 78 years, 44 years and 22 years, respectively.

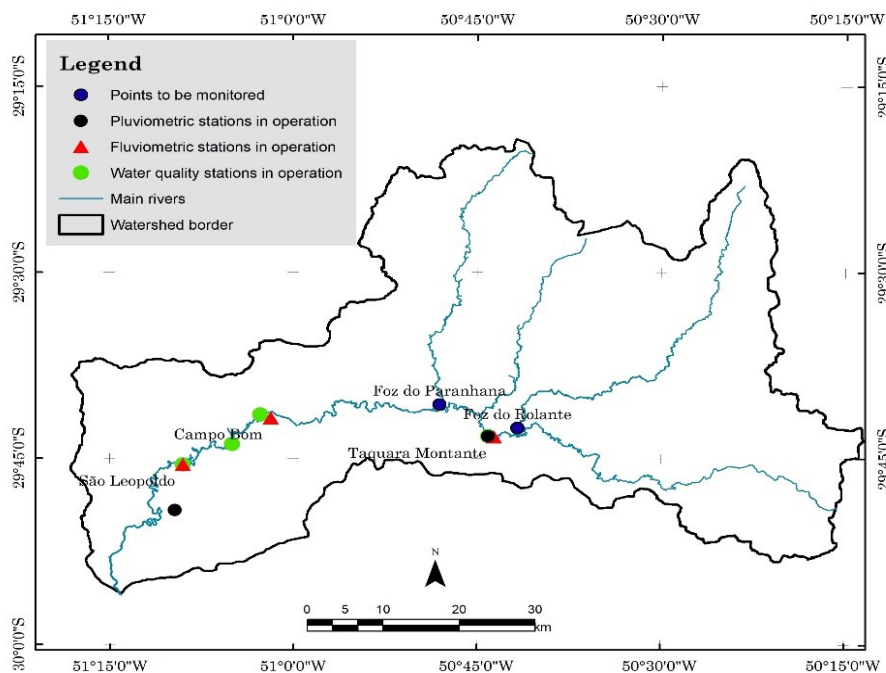
As for the water quality stations, of the 12 stations listed on the NWRIS website, only four stations have relatively continuous monitoring, which is an insufficient number in a basin with so many environmental problems.

For the most part, the monitored data (precipitation, elevation, flow and water quality) do not present a robust historical series.

Therefore, it is not possible to draw reliable conclusions on the basin's trophic state behavior over time and space.

Because the Paranhana River and the Rolante River are the Sinos River main tributaries and because of these sub-basins, they present small and medium-sized cities around their rivers. As a suggestion, fluviometric stations should be installed, for measuring levels, flow, water quality and telemetry at the respective rivers' mouths, as shown in Figure 4. The pluviometric stations shown in Figure 3 monitor rainfall in the basin's middle and upper parts. However, the data collected are not available on the NWRIS website. For water quality monitoring, it is recommended to reactivate the monitoring points, mainly in the basin's middle and upper parts, as well as implement parameters that diagnose the watercourse trophic state. A viable and economical way to operate the network and make data available is the communication between the various entities operating the system. In addition, it is essential to implement and maintain a telemetric hydrological network in the Sinos River basin for more consistent monitoring, providing robust information for adequate integrated water resources management.

Figure 4 - Monitoring stations scattered along the Sinos River basin that are actually in operation and with data available for download at <<http://www.snirh.gov.br/hidroweb>>.



Source: the Authors (2017).

FINAL CONSIDERATIONS

It is expensive to register and collect hydrological data (WMO, 2014), but its availability is of great value to society. Therefore, monitoring continuity, new stations implantation and enough parameter collection would provide a better understanding of the water resources space-time dynamics in the watershed. Consequently, subsidies for the best way to implement an IWRM system could be made available. In addition, continuous monitoring provides an understanding of possible long-term changes, such as consumptive uses of water, climate change or land use and occupation, which may occur in the watershed, causing hydrological series to become stationary. Senra and Nascimento (2017) state that the lack of knowledge on these changes affects water infrastructure planning and operation to serve multiple uses, such as power generation, navigation, irrigation, water supply, flood control, among others.

This study has shown that there are several entities that monitor water resources in the Sinos River basin, however, when made available, the data observed by such entities are stored on each institution's specific websites or are not made available to the general public at all, which makes data acquisition difficult for users. It is evident that hydrological monitoring in the Sinos River basin is precarious, due to little or even lack of hydrological information. Consequently, it is difficult to implement an IWRM system. As such, a single platform is recommended, in this case Hidroweb, linked to the ANA, which has the potential to be a storage source that can guarantee hydrological data availability. It is recommended to maintain the monitoring stations in the Sinos River basin as well as implement new monitoring stations, preferably in the tributaries to the main river. Studies carried out in the basin, in their recommendations, show that monitoring must be continuous and distributed in such a way that it contemplates its various sub-basins (NASCIMENTO et al., 2015; ALVES et al., 2018).

Determination and data collection are of great value for understanding the quantitative and qualitative conditions of the various watercourses that make up the Sinos River basin. This data availability after its due treatment (consistency) will bring great benefits to the community, making it possible to study the basin's trophic conditions and provide the necessary tools to create action plans for environmental conservation and sustainable development. Therefore, for an IWRM system in

the Sinos River watershed effective implementation, from the hydrometric monitoring perspective, the maintenance of the stations in operation, along with their data being made available, as well as implementing new stations are indispensable actions for the success of such an undertaking. In this sense, financial resources should be made available by funding sources and research support is essential, as well as the effectiveness of the National Policy on Water Resources.

REFERENCES

- ALVES, D. D.; RIEGEL, R. P.; QUEVEDO, D. M. de, OSÓRIO, D. M. M.; COSTA, G. M. da; NASCIMENTO, C. A. do, TELÖKEN, F.; Seasonal assessment and apportionment of surface water pollution using multivariate statistical methods: Sinos River, southern Brazil. **Environmental Monitoring and Assessment**, v. 190, n. 384, p. 13, 2018. Available at: <https://doi.org/10.1007/s10661-018-6759-3>
- ANA - Agência Nacional de Águas (Brasil); O Comitê de Bacia Hidrográfica: o que é e o que faz? – **Cadernos de capacitação em Recursos Hídricos**, v.1, Brasília: 64 p. 2011. Available at: <http://arquivos.ana.gov.br/institucional/sge/CEDOC/Catalogo/2012/CadernosDeCapacitacao1.pdf>. Accessed in: 04/10/2017.
- BENHAM, B. L.; YAGOW, G.; CHAUBEY, I.; DOUGLAS-MANKIN, K. R.; Advances in Watershed Management: Modeling, Monitoring, and Assessment. **American Society of Agricultural and Biological Engineers**, v. 54, n. 6, p. 2167-2170, 2011. Available at: <http://dx.doi.org/10.13031/2013.40915>
- BENVENUTI, T.; KIELING-RUBIO, M. A.; KLAUCK, C. R.; RODRIGUES, M. A. S.; Evaluation of water quality at the source of streams of the Sinos River Basin, southern Brazil. **Brazilian Journal of Biology**, v. 15, n. 2, p. 98–104, 2015. Available at: <http://dx.doi.org/10.1590/1519-6984.1513>
- BIRKINSHAW, S. J.; MOORE, P.; KILSBY, C. G.; O'DONNELL, G. M.; HARDY, A. J.; BERRY, P. A. M.; Daily discharge estimation at ungauged river sites using remote sensing. **Hydrological Processes**, v.28, p. 1043-1054, 2014. Available at: <http://dx.doi.org/10.1002/hyp.9647>
- BISWAS, A. K.; Integrated Water Resources Management: A Reassessment - A Water Forum Contribution. **International Water Resources Association**. Water International,

- v. 29, n. 2, p. 248–256, 2004. Available at: <https://doi.org/10.1080/02508060408691775>
- DETZEL, D. H. M.; BESSA, M. R.; MINE, M. R. M.; Amostragem de Séries Sintéticas Hidrológicas. **Revista Brasileira de Recursos Hídricos**, v. 18, n. 4, p. 173-184, 2013. Available at: <http://dx.doi.org/10.21168/rbrh.v18n4.p173-184>
- DOUROJEANNI, A.; JOURAVLEV, A.; CHÁVEZ, G. Gestión del agua a nivel de cuencas: teoría y práctica. Santiago de Chile: CEPAL, **Serie recursos naturales e infraestructura**, v. 47, 83 p., 2002. Available at: http://repositorio.cepal.org/bitstream/handle/11362/6407/1/S028593_es.pdf Accessed in: 13/10/2017.
- FEIL, A. A.; STRASBURG, V. J.; SPILKI, F. R.; Variáveis intervenientes na existência de comitês de bacias hidrográficas no Brasil. **Revista Ambiente & Água**, v. 12 n. 2, p. 340-351, 2017. Available at: <http://dx.doi.org/10.4136/ambi-agua.1828>
- GLOBAL WATER PARTNERSHIP (GWP) – Technical Advisory Committee. **Integrated water resources management**. TAC Background Paper, nº 4, Stockholm, Sweden, 71p., 2000. Available at: <https://www.gwp.org/globalassets/global/toolbox/publications/background-papers/04-integrated-water-resources-management-2000-english.pdf> Accessed in: 12/09/2017.
- HEINKE, J.; et al. Multimodel assessment of water scarcity under climate change. Proceedings of the National Academy of Sciences, **PNAS**, v. 111, n. 9, p.3245–3250, 2014. Available at: <http://dx.doi.org/10.1073/pnas.1222460110>
- KAISER, I. M.; PORTO, R. de M. Campos de Precipitação Parte I: Fundamentos Teóricos e Estudos Preliminares. **Revista Brasileira de Recursos Hídricos**, v. 10, n.4, p. 99-111, 2005. Available at: <http://dx.doi.org/10.21168/rbrh.v10n4.p99-111>
- KORFMACHER, K. S. The politics of participation in watershed modeling. **Environmental Management**, v. 27, n. 2, p. 161–176, 2001. Available at: <http://dx.doi.org/10.1007/s002670010141>
- LANNA, A. E. L. Introdução à gestão ambiental e à análise econômica do ambiente. Porto Alegre: **Instituto de Pesquisas Hidráulicas** da UFRGS, 1996.
- LANNA, A. E. L.; Modelos de gerenciamento das águas, a água em revista. Porto Alegre: **CPRM**, 1997.
- LEIDEL, M.; NIEMANN, S.; HAGEMANN, N.; Capacity development as a key factor for integrated water resources management (IWRM): improving water management in the Western Bug River Basin, Ukraine. **Environmental Earth Science**, v. 65, p. 1415-1426, 2012. Available at: <http://dx.doi.org/10.1007/s12665-011-1223-5>
- NASCIMENTO, C. A.; STAGGEMEIER, R.; BIANCHI, E.; RODRIGUES, M. T.; FABRES, R.; SOLIMAN, M. C.; BORTOLUZZI, M. LUZ, R. B.; HEIZELMANN, L. S.; SANTOS, E. L.; FLECK, J. D.; SPILKI, F. R.; Monitoring of metals, organics compounds and coliforms in water catchment points from the Sinos River basin. **Brazilian Journal Biological**, v. 75, n.2, p. 50-56, 2015. Available at: <http://dx.doi.org/10.1590/1519-6984.1613>
- PETRY, C. T.; COSTA, G. M. da; BENVENUTI, T.; RODRIGUES, M. A. S.; DROSTE, A.; Avaliação integrada da qualidade química e da genotoxicidade da água do arroyo Luiz Rau, no trecho inferior da bacia do Rio dos Sinos, no Sul do Brasil. **Ambiente & Água**, v.11, n.4, p 867-877, 2016. Available at: <http://dx.doi.org/10.4136/ambi-agua.1779>
- PORTO, M. F. A.; PORTO, R. L L.; Gestão de bacias hidrográficas, **Estudos Avançados**, n. 22, v. 63, p. 43 – 60, 2008. Available at: <http://dx.doi.org/10.1590/S0103-40142008000200004>
- RAUBER, D.; CRUZ, J. C.; Gestão de Recursos Hídricos: uma abordagem sobre os comitês de bacia hidrográfica. **Revista Paranaense de Desenvolvimento**, v. 34, n. 125, p. 123-140, 2013. Available at: <http://www.ipardes.pr.gov.br/ojs/index.php/revistaparanaense/article/download/640/867>
- REIS, J. B. C. dos; PONS, N. A. D.; LOPES, E. S. S. Monitoramento e alerta de inundação no município de Itajubá (MG) por regressão polinomial. **Geociências**, v. 35, n. 1, p.134-148, 2016. Available at: <http://www.ppegeo.igc.usp.br/index.php/GEOSP/article/view/9002/8267>
- RIBEIRO, C. B. A importância dos comitês de bacia na gestão dos recursos hídricos. Dissertação de Mestrado em Geografia, área de concentração **Gestão Ambiental e Territorial**. Brasília – DF, 114 p., 2006. Available at: <http://repositorio.unb.br/handle/10482/5754> Acesso em 10/09/2017>
- SANTOS, L. C. D.; NHAMPOSSA, J. A.; COSTA, C. C.; GOMES, L. J. Atuação do Comitê da Bacia Hidrográfica do Rio Sergipe na denúncia e encaminhamento de conflitos socioambientais. **REGA**, v. 12, n. 2, p. 35-45, 2015. Available at: <http://dx.doi.org/10.21168/rega.v12n2.p35-45>
- SISTEMA NACIONAL DE INFORMAÇÕES

- SOBRE RECURSOS HÍDRICOS (SNIRH) Website available at: <http://www.snirh.gov.br/hidroweb>
- SCHEWE, J.; HEINKE, J.; GERDEN, D.; HADDELAND, I.; ARNELL, N. W.; CLARK, D. B.; DANKERS, R.; EISNER, S.; FEKETE, B. M.; CÓLON-GONZÁLEZ, F. J.; GOSLING, S. N.; MASAKI, Y.; PORTMANN, F. T.; SATOH, Y.; TANG, Q.; WADA, Y.; WISSER, D.; FRIELER, K.; WARSZAWSKI, L.; KABAT, P.; Multimodel assessment of water scarcity under climate change. *Proceedings of the National Academy of Sciences, PNAS*, v. 111, n. 9, p.3245–3250, 2014. <http://dx.doi.org/10.1073/pnas.1222460110>
- SENRA, J. B.; NASCIMENTO, N. O. Após 20 anos da lei das águas como anda a Gestão Integrada de Recursos Hídricos do Brasil, no âmbito das Políticas e Planos Nacionais setoriais? *REGA*, v. 14, n. 6, 18 p. 2017. Available at: <http://dx.doi:10.21168/reg.v.14e6>
- SICHANGI, A. W.; WANG, L.; YANG, K.; CHEN, D.; WANG, Z.; LI, X.; ZHOU, J.; LIU, W.; KURIA, D. Estimating continental river basin discharges using multiple remote sensing data sets. *Remote Sensing of Environment*. v. 179, p. 36–53, 2016. Available at: <http://dx.doi.org/10.1016/j.rse.2016.03.019>
- SHRUBSOLE, D.; WALTERS, D.; VEALE, B.; MITCHELL, B. Integrated Water Resources Management in Canada: the experience of watershed agencies. *International Journal of Water Resources Development*. v. 33, p. 349-359, 2017. Available at: <http://dx.doi.org/10.1080/07900627.2016.1244048>
- STAHLI, M.; BADOUX, A.; LUDWIG, A.; STEINER, K.; ZAPPA, M.; HEGG, C. One century of hydrological monitoring in two small catchments with different forest coverage. *Environmental Monitoring Assessment*, v. 174, p. 91-106. 2011. Available at: <http://dx.doi:10.1007/s10661-010-1757-0>
- VEALE, B.; COOKE, S. Implementing integrated water management: illustrations from the Grand River watershed. *International Journal of Water Resources Development*, v. 33, p. 375-392, 2017. Available at: <http://dx.doi.org/10.1080/07900627.2016.1217503>
- WATANABE, M. M.; MADRUGA, L. R. G.; YAMAGUCHI, C. K.; VIEIRA, A. C. P.; JENOVEVA-NETO, R. Decision Making and Social Learning: the Case of Watershed Committee of the State of Rio Grande do Sul, Brazil. *Water resources management*, v. 28, n. 11, p. 3815-3828, 2014. Available at: <http://dx.doi.org/10.1007/s11269-014-0711-2>
- WMO- WORLD METEOROLOGICAL ORGANIZATION; **Guide to hydrological Practices**, v.1, Hydrology – From Measurement to Hydrological Information, 296 p., 2008. Available at: http://www.whycos.org/chy/guide/168_Vol_I_en.pdf Accessed in: 01/05/2018.
- **Guide to Hydrological Practices**, v. 2, Sixth edition, Management of Water Resources and Application of Hydrological Practices. 302 p., 2009. Available at: http://www.whycos.org/chy/guide/168_Vol_II_en.pdf Accessed in: 01/05/2018.
- **Manual on Stream Gauging. Fieldwork**, v.1. Quality Management Framework. n. 1044. 254 p., 2010. Available at: http://www.wmo.int/pages/prog/hwrr/publications/stream_gauging/1044_Vol_I_en.pdf Accessed in: 01/05/2018.
- **Planning of Water-Quality Monitoring Systems. Technical Report Series**, n. 3, 128 p., 2013. Available at: http://www.wmo.int/pages/prog/hwrr/publications/Technical_report_series/TR-No3water_quality_monitoring_systems.pdf Accessed in: 01/05/2018.
- **Guidelines for Hydrological Data Rescue**, n 1146, 47 p., 2014. Available at: https://library.wmo.int/pmb_ged/wmo_1146_en.pdf Accessed in: 01/05/2018.
- **Guide to Meteorological Instruments and methods of Observations**. N.8, 1177p. 2017. Available at: https://library.wmo.int/doc_num.php?explnum_id=4147 Accessed in: 05/02/2020.
- WWAP - United Nations World Water Assessment Programme. **The United Nations World Water Development Report 2017**. Wastewater: The Untapped Resource. Paris, UNESCO, 198p., 2017. Available at: <http://unesdoc.unesco.org/images/0024/002471/247153e.pdf> Accessed in: 03/06/2018.



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