



Sustainability assessment in water planning: a case study in the Billings reservoir basin

Avaliação de sustentabilidade no planejamento da água: um estudo de caso na bacia hidrográfica do reservatório Billings

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ABSTRACT: Basins of interest for public water supply can be defined as Water Source Protection and Recovery Areas (APRM, in the Portuguese acronym) in São Paulo state, Brazil. These areas must have specific instruments for environmental management, such as the Development and Environmental Protection Plan (PDPA, Portuguese acronym), which must diagnose problems and propose actions to protect, recover, and preserve springs and must be included in basin plans. The Billings Reservoir Basin was defined as an APRM in 2009; its first PDPA was published in 2010, and the second in 2017. The role of these plans is underexplored in the scientific literature, and sustainability assessment is an interesting approach to subsidize discussions about the scope of these plans. In this paper, we present a sustainability assessment of the PDPA-Billings, identifying strengths and weaknesses in the context of one of the municipalities of Billings Basin - São Bernardo do Campo (SP). As a method, a case study was developed, with literature and document review and interviews, guided by a set of eight sustainability assessment criteria. The result was a table containing 51 questions on 24 themes. One of the relevant positive results is the identification of the PDPA as a central instrument for sectorial integration, especially between water and land use planning. As potential issues for improvement, we indicate the possibility of better exploring the multiple uses of water, deepening the theme of water security from the climate change perspective, and an opportunity for PDPA to contribute with regional development strategies, seeking to influence and support decisions about water in the future of the regional economy. The evidence also indicates low control and deficient implementation of the proposed actions, so it would be essential to review the governance arrangements.

Keywords: environmental management; environmental planning; water management; multicriteria analysis; public management.

RESUMO: Bacias hidrográficas de interesse para o abastecimento público de água podem ser definidas como Área de Proteção e Recuperação de Mananciais (APRM) no estado de São Paulo. Tais áreas devem possuir instrumentos de gestão ambiental específicos, como o Plano de Desenvolvimento e Proteção Ambiental (PDPA) que deve diagnosticar problemas e propor ações visando proteger, recuperar e preservar mananciais, e deve ser inserido em planos de bacia hidrográfica. A Bacia Hidrográfica do Reservatório Billings foi definida como APRM em 2009, teve seu primeiro PDPA publicado em 2010, e o segundo, em 2017. O papel desses planos é um tema pouco explorado na literatura científica, e, para esta análise, a avaliação de sustentabilidade é uma abordagem interessante para subsidiar discussões sobre o escopo e alcance deles. Neste artigo, apresentamos uma avaliação de sustentabilidade do PDPA-Billings, com identificação de pontos fortes e fragilidades para o contexto do município de São Bernardo do Campo (SP). Como método, foi desenvolvido um estudo de caso, reunindo revisão bibliográfica, documental e entrevistas, orientado por um conjunto de oito critérios de avaliação de sustentabilidade. Obteve-se como resultado um quadro contendo 51 questões de 24 temáticas. Um dos resultados positivos relevantes foi a identificação do PDPA como um instrumento central para a integração entre os planejamentos de recursos hídricos e de uso de solo. Como potenciais pontos para aprimoramento, indicamos a possibilidade de explorar melhor o tema dos usos múltiplos da água, a necessidade de aprofundamento no tema da segurança hídrica considerando impactos das mudanças climáticas e identificamos uma oportunidade do PDPA contribuir com estratégias de desenvolvimento regional, buscando influenciar e apoiar decisões sobre a água no futuro da economia. As evidências também indicaram a existência de um cenário de baixo controle e implementação deficitária das ações propostas no plano, demandando a revisão dos arranjos de governança.

Palavras-chave: gestão ambiental; planejamento ambiental; gestão da água; análise multicritério; gestão pública.

1. Introduction

The São Paulo Metropolitan Region (RMSP, *Região Metropolitana de São Paulo*), the main economic center of Brazil, covers approximately 70% of the area of the Alto Tietê River Basin, which concentrates about 21 million inhabitants and eight areas of interest for public supply (FABHAT, 2021; CBH-AT, 2021b). Currently, the critical state of degradation of the RMSP water bodies and changes in the rainfall regime, combined with the high water demand, have resulted in increasingly severe supply crises. The responses to such crises have consisted of transposition works from other river basins outside the RMSP, with little progress in strategic management (Jacobi *et al.*, 2015).

The largest reservoir in the RMSP in terms of volume is the Billings Reservoir (1.2 billion cubic

meters), which is part of the municipalities of São Paulo, Santo André, Diadema, Rio Grande da Serra, Ribeirão Pires, and São Bernardo do Campo (SBC) (São Paulo, 2010a). Currently, this source supplies about 1.5 million people; however, if it were not in a severe state of degradation, it could serve about 4.5 million people (Whately *et al.*, 2008; CPLA/SMA, 2010).

The municipality of São Bernardo do Campo has about 52% of the territory within the Billings basin. Beyond the use for water supply, in São Bernardo it is also possible to identify multiple uses of the water body, as for subsistence fishing (such as in the Z-17 colony "*Orlando Feliciano*"), sport fishing, the practice of nautical sports, tourism, and primary contact recreation (as occurs in *Prainha do Riacho Grande*) (CPLA/SMA, 2010; Marques & Tommasi, 2018).

The São Paulo State has a law that aims to protect and recover water source basins (State Law No. 9,866/1997) through the definition of a Water Source Protection and Recovery Areas (APRMs, in the Portuguese abbreviation for *Áreas de Proteção e Recuperação dos Mananciais*) in basins that are or could be used for public supply. The APRMs must have specific laws that define, among other attributions, a set of environmental quality goals and planning and management instruments, including the Development and Environmental Protection Plan (PDPA, *Plano de Desenvolvimento e Proteção Ambiental*), responsible for proposing programs and actions to achieve the established goals. Despite the focus on water supply, the law provides that the other multiple uses of water in these areas must be ensured if they are compatible with water supply.

The Billings Reservoir Basin was established as an APRM through its Specific Law (State Law No. 13,579/2009) and, as a result, goals for phosphorus load and vegetation cover targets were defined, as well as land use and occupation guidelines, including urban parameters, for the entire basin. In 2010, the first version of the PDPA-Billings was made available and approved by the Billings-Tamanduateí Subcommittee (SCBH-BT), responsible for the management of this basin. In 2017, an update of the plan was presented.

Among the tools aimed at improving environmental planning processes, sustainability assessment as proposed by Gibson (2006a,b) is an analytical approach that can help strengthen decision-making by guiding a strategic mapping of sustainability issues and integrating policies and plans within a defined context. In this way, sustainability assessment can represent the achievement of better outcomes that balance regional development with the conservation of the Billings Reservoir basin,

thereby strengthening the multiple uses of the water in the reservoir.

Thus, this research aims to apply this sustainability assessment approach in the PDPA-Billings context, identifying key sustainability issues and the plan's strengths and weaknesses. The municipality of São Bernardo do Campo is the focus of the analysis.

Next, we present a section dedicated to the review of fundamental theoretical contents, such as the sustainability assessment process and a brief history of planning in the APRM-Billings. In the following section, we detail the methodology of the evaluative case study applied to the PDPA-Billings, including the interviews conducted and the construction of the evaluation framework. In the results section, the table containing the questions and answers of the PDPA-Billings evaluation is presented, highlighting three points for discussion. Finally, the concluding section summarizes the main ideas that emerged from the sustainability assessment.

2. Sustainability assessment and the Billings reservoir – theoretical foundations

This section comprises the theoretical foundation of the article in two subsections. In the first, we present the sustainability assessment approach as proposed by Gibson (2006a), and in the second, we explore the historical context of planning in the study area.

2.1. Sustainability assessment

Among the typologies of planning, environmental planning is based on integrating environ-

mental and social components, establishing relationships, and proposing interdisciplinary actions that explore the potential of an area while respecting environmental limits (Santos, 2004). In general, environmental planning should consider long-term goals, with the aims of maintaining natural processes and guaranteeing the right to opportunities for future generations; for this, it should focus on actions that promote the best use of resources, seeking a broad understanding of the impacts generated in the different scales and minimizing conflicts (Santos, 2004; Gibson, 2006b; Alvim *et al.*, 2015).

This discussion gives rise to a framework associated with the definition of sustainability as an integrating concept, capable of connecting human activities to the environment. Such a framework has emerged in our contemporary scenario – characterized by the increasingly aggressive and unsustainable exploitation of natural resources – and aims to provide new ways of living that would have a reduced impact on the planet (Gibson, 2006b). It is common to find definitions of sustainability that address the interactions between the three pillars – environmental, social, and economic. This definition is easy to understand for different stakeholders, but it can be seen as limiting for planning exercises.

For Gibson (2006a), the three-pillar approach is not well-suited for addressing the sustainability challenges that do not fit well into any of these pillars. Changes in land use and occupation, as well as problems of environmental justice and governance, would be relevant examples in this regard, as they include questions about how decisions are made and who wins and who loses. Criticism of the limitations of the three-pillar model is reinforced by other authors (Hacking & Guthrie, 2008; Purvis *et al.*, 2019); the Sustainable Development Goals (SDGs) of the 2030 Agenda articulated by the United

Nations (UN), adopted 17 themes as guidelines for action, extrapolating the idea of the Tripple Bottom Line (UNDP, 2016).

To overcome the limitations of the tripod model, Gibson (2006a) states that it is necessary to advance solutions capable of exploiting the interconnections between different themes and offering alternatives that solve multiple problems simultaneously. The author emphasizes that we need solutions that bring multiple contributions, which are mutually reinforcing and generate positive change in practice.

Considering this issue, Gibson (2006a) gathered guidelines and principles that a sustainability assessment should contain, summarizing them in a set of eight comprehensive and complementary criteria, presented in Table 1. The author recommends that such criteria, considered key sustainability issues, should be specified and complemented according to the context of the analysis. This set of criteria can assist the development and evaluation of policies, plans, programs, or projects by exploring themes in an integrated way that are not always considered in three pillar approaches. The latter usually do not include the interfaces between these three themes or other transversal themes (such as land use, for example), limiting the potential of sustainability research (Gibson, 2006a; Duarte *et al.*, 2013).

This set of criteria proposed by Gibson (2006a) has already been applied to various sectors, especially the energy sector, as in the case of sugarcane ethanol in Duarte *et al.* (2013) and biodiesel in Gaudreau and Gibson (2010). For water resources, the publications of Wiek *et al.* (2016) addressed water nanotechnology and communities, and Bega *et al.* (2021) the evaluation of sanitation indicators in water plans.

TABLE 1 – Summary of the sustainability criteria proposed by Gibson.

Criterion	Description
Socio-ecological system integrity	Build human-ecological relations to establish and maintain the long-term integrity of socio-biophysical systems and protect the irreplaceable life support functions upon which human, as well as ecological wellbeing, depends.
Livelihood sufficiency and opportunity	Ensure that everyone and every community has enough for a decent life and that everyone has opportunities to seek improvements in ways that do not compromise future generations' possibilities for sufficiency and opportunity.
Intragenerational equity	Ensure that sufficiency and effective choices for all are pursued in ways that reduce dangerous gaps in sufficiency and opportunity (and health, security, social recognition, political influence, etc.) between the rich and the poor.
Intergenerational equity	Favor presents options and actions that are most likely to preserve or enhance the opportunities and capabilities of future generations to live sustainably.
Resource maintenance and efficiency	Provide a larger base for ensuring sustainable livelihoods for all while reducing threats to the long-term integrity of socio-ecological systems by reducing extractive damage, avoiding waste and cutting overall material and energy use per unit of benefit.
Socio-environmental civility and democratic governance	Build the capacity, motivation and habitual inclination of individuals, communities and other collective decision-making bodies to apply sustainability requirements through more open and better informed deliberations, greater attention to fostering reciprocal awareness and collective responsibility, and more integrated use of administrative, market, customary and personal decision-making practices.
Prudence, precaution, and adaptation	Respect uncertainty, avoid even poorly understood risks of serious or irreversible damage to the foundations for sustainability, plan to learn, design for surprise, and manage for adaptation.
Immediate and long-term integration	Apply all principles of sustainability at once, seeking mutually supportive benefits and multiple gains.

SOURCE: Gibson *et al.* (2005).

Gibson (2006a) states that planning and evaluations conducted without integrating relevant themes from the beginning of these processes tend not to treat sustainability as an integrating concept since they do not explore the interconnections and

interdependencies between themes. Sustainability assessment, as explained above, can be employed in planning and evaluation processes to guide the selection of themes and interrelationships that are important for the scope definition in these processes,

as well as to support the proposition of actions to be taken to achieve better results for sustainability (Wiek *et al.*, 2016).

In this sense, sustainability-oriented planning should focus on the issues that are relevant to the context in the most integrated way possible and, at the same time, avoid trade-offs¹ and seek multiple gains in all selected sustainability themes, including stakeholders in the elaboration of proposals, in the decision and implementation of measures (Gibson, 2006a; Gaudreau & Gibson, 2010; Wiek *et al.*, 2016). For this purpose, an in-depth understanding of the regional and planning context is essential in sustainability-oriented planning. This theme is explored in the next section for the context of the case study presented in this article.

2.2. Brief history of planning at APRM-Billings

The Billings Reservoir was dammed in 1927 to feed the Henry Borden Hydroelectric Power Plant through the construction of the Pedreira Dam on the course of the Jurubatuba River, transposing water to the Rio das Pedras Reservoir, built the previous year. Between 1939 and 1940, the Pedreira and Traição Pumping Stations were built to improve energy production by increasing water flow so these stations started the reversal of the water direction of Pinheiros and Tietê Rivers; the responsibility for this project was the *Light Company – The São Paulo Tramway, Light and Power Company, Limited* (Carmo & Tagnin, 2001; CPLA/SMA, 2010). Although

this construction was planned for the generation of electricity, the reservoir was also used for public supply in 1958 through the Rio Grande River, a tributary (Risso *et al.*, 2018).

The Water Source Protection Laws in force in the 1970s (State Law No. 898/1975 and State Law No. 1,172/1976) were not able to protect water sources in the face of the population growth that occurred between the 1960s and 1970s due to industrial expansion and rural exodus (Carmo & Tagnin, 2001; Duarte & Malheiros, 2012). The laws for the protection of water sources established many restrictions on the use of these areas; this kept the *formal* real estate market away, and the illegal occupation of these areas was the most viable alternative for the low-income population that found itself without housing options. Thus, irregular settlements were established in the area (Maricato, 2003), causing the degradation of these environments due to the discharge of untreated sewage and solid waste directly into water bodies (Duarte & Malheiros, 2012).

The transposition of the Pinheiros and Tietê rivers' water, along with the discharge of solid waste and untreated effluent from irregular settlements into the reservoir, has compromised the quality of the reservoir's water and affected its potential use for supply (Whately *et al.*, 2008; CPLA/SMA, 2010). To ensure the continuity of the use for public water supply, a new dam (Anchieta Dam) was built in 1980 to isolate the Braço do Rio Grande, where water quality was considered adequate. However, it was only after pressure from the population and

¹ *Trade-off* is a term used to define a situation in which there is a conflict of choice; when a path is chosen, it is assumed that there will be associated losses (Mattos *et al.*, 2011).

the environmental movement that the transposition was reduced in 1992, limited only to flood control in the São Paulo city (Carmo & Tagnin, 2001; CPLA/SMA, 2010; Risso *et al.*, 2018).

Aiming to replace the previous laws in the State of São Paulo, a new legal norm for water source areas was enacted (State Law No. 9,866/97), defining that basins of interest for water supply could be defined as APRMs in specific laws. The APRMs must have a deliberative and consultative collegiate organization responsible for their management, along with the technical body (in this case, the Alto Tietê River Basin Agency Foundation – FABHAT, *Fundação Agência da Bacia Hidrográfica do Alto Tietê*), and with the public administration body (the Billings-Tamanduateí Subcommittee, composed of the State of São Paulo, municipalities and civil society representatives).

Basins of regional interest must also have their own PDPA as one of the main planning and management instruments. The content of the PDPA is outlined in Article 31 of the same law and should address guidelines for sectoral policies and activities compatible with the preservation of the water source; proposals to update guidelines, environmental standards, and a new framework for environmental recovery areas (ARA, *Áreas de Recuperação Ambiental*); goals for the achievement of environmental quality, programs, projects and actions; integrated monitoring, environmental education, control and inspection and, investment programs (São Paulo, 1997).

Due to its large extension and the differences in land use and occupation on its riparian area,

the Billings basin was divided in its Specific Law into five different environmental compartments (Figure 1), namely: *Corpo Central I and II, Taquacetuba-Bororé, Capivari-Pedra Branca* and *Rio Grande-Rio Pequeno*. Each compartment has specific environmental quality goals and only the last (Rio Grande-Rio Pequeno) is used for public water supply. In addition, they all flow through the municipality of São Bernardo do Campo, which was chosen as the focus of this sustainability assessment (CPLA/SMA, 2010).

Thus, the PDPA is an important object of research, given its relevance as a planning and management instrument for the protection of water source basins through its guidelines and programs, and can be even more advanced in terms of sustainability and for ensuring the best possible scenario of environmental quality for the basin and quality of life for the population of the region (CAU/SMA, 2017).

3. Methodology

The evaluation of the PDPA-Billings was developed based on Yin's (2015) proposal for an evaluative case study. It included documental and bibliographic reviews and semi-structured interviews with stakeholders involved in the management of the basin or experts in water resources. To structure the sustainability assessment, the criteria of Gibson (2006a), presented in Table 1, were adopted, wherein questions and answers were developed in an iterative manner based on the results of the documentary and bibliographic reviews, and interviews.

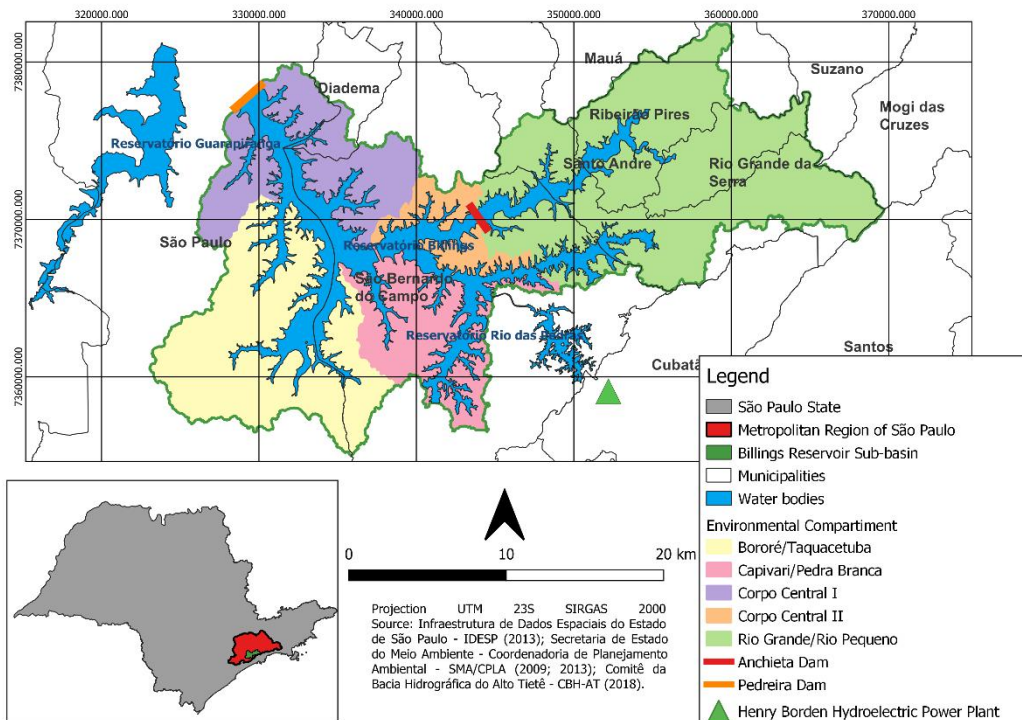


FIGURE 1 – Environmental Compartments of APRM-Billings.

SOURCE: elaborated by the authors.

Data collection through documentary research focused on the PDPA itself, but other related municipal plans, available on the SBC municipality website² were also used to complete the evaluation, such as the Municipal Master Plan, the Municipal Integrated Solid Waste Management Plan (PM-GIRS, *Plano Municipal de Gestão Integrada de Resíduos Sólidos*), the Local Social Interest Housing Plan (PLHIS, *Plano Local de Habitação de Interesse Social*) and comprehensive plans for the entire ABC Paulista area, such as the Climate Change Action Plan. In addition, the minutes of meetings of

the Billings-Tamanduateí subcommittee, available on the website³ of the Alto Tietê Basin Committee (CBH-AT, *Comitê de Bacia Hidrográfica do Alto Tietê*), were also consulted. The bibliographical research contributed to the characterization of the context in which the APRM-Billings is inserted, as well as its entire construction history and current use, and included searches in databases, such as Google Scholar and the CAPES Periodicals Portal.

Since the research had the collaboration of professionals involved with the management of the basin in some way, the project was submitted

² Secretariat of the Environment Portal (SBC) – Plans: <<https://www.saobernardo.sp.gov.br/web/sma/simiqua/relatorios-e-planos/planos>>.

³ Meetings Memoirs (Billings-Tamanduateí Subcommittee): <<https://comiteat.sp.gov.br/subcomites/billings-tamanduatei/memorias/>>.

to and approved by the Research Ethics Committee (CEP, *Comitê de Ética em Pesquisa*) of the *Universidade Federal de São Paulo* (Brazilian Certificate of Presentation for Ethical Consideration, CAAE: 31770720.0.0000.5505). The questions asked in the interviews ranged from the plan's content to actions of the municipalities or the Billings-Tamanduateí Subcommittee (Table 2). A total of five interviews were carried out, with questions adapted to the profile of each interviewee: two water quality specialists, a Billings-Tamanduateí subcommittee member, a former secretary of the municipality of SBC, and a representative of the consultancy responsible for the elaboration of the PDPA.

The search for the interviewees was based on the membership lists of the Billings-Tamanduateí Subcommittee and on the attendance lists of the PDPA drafting meetings available in the document itself, choosing, in principle, at least one representative from each of the relevant actors in the process of drafting and managing the PDPA, either from the PDPA itself or from the basin region, and from the municipality of São Bernardo do Campo. Contacts were made by e-mail, and interviews were conducted remotely with those who agreed to participate, according to procedures approved by the CEP. The interviews brought new points to be addressed in the evaluation process, as well as insights into the actions implemented in the Plan and the overall context in which it is inserted, as well as the strengths, weaknesses, and limitations of the PDPA. In order to evaluate the PDPA-Billings, the questions formulated reflect the themes of each evaluation criterion for the specific context of the PDPA-Billings. In cases where data from the PDPA and other documents analyzed (e.g. data on the percentage of municipal sewage collection and

treatment) conflicted, the final choice was to follow the pattern adopted in the PDPA-Billings since this was the central object of the research.

From the analysis of the evaluation framework developed (Box 1), it was possible to select key issues for discussion in this paper, which are explored below.

4. Results and discussion

4.1. Description of the content of the PDPA-Billings

Prepared in 2017 by the *Companhia Brasileira de Projetos e Empreendimentos* (COBRAPE), the PDPA-Billings contains the following sections in its 213 pages (Figure 2):

- (1) Introduction, which provides a summary of the contents of the plan;
- (2) Basin characterization, which includes a brief history of the Billings Basin, and a diagnosis of land use and occupation, territorial planning, socioeconomics and demography, urban expansion vectors, sanitary infrastructure, protected areas, and water quality;
- (3) Scenario modeling, based on a model for correlating land use and water quality (called MQUAL, *Modelo de Correlação Uso do Solo e Qualidade da Água*), to describe future phosphorus load scenarios in the short, medium and long term, depending on the intervention measures implemented in the basin;
- (4) General assessment of the current state of the basin;

TABLE 2 – Main points discussed in the interviews conducted by interviewee's profile.

Id	Interviewee	Key Points Discussed
E1	Water Quality Specialist	Water quality indices (IAP and EIT) ⁴ and their fragilities; Importance of the instrument for population charging leaders; Effects of climate change not addressed in plans; Government priorities.
E2	Billings-Tamanduateí Subcommittee Member	Specific Law elaboration; Monitoring the load of phosphorus and other compounds; Number of monitoring points; Vegetation cover; Billings-Tamanduateí Subcommittee; Enterprises causing impacts; Climate change; Water stored volume; Water multiple uses in the reservoir.
E3	Water Quality Specialist	Phosphorus loads; Weaknesses and advantages of different quality indices (IAP and EIT); Presence of cyanobacteria and cyanotoxins; Pinheiros River transposition and Billings degradation.
E4	Former Environment Secretary of São Bernardo do Campo	Historical perspective on basin protection policies in São Paulo; Presence of landfills in the municipality and its remediation; the Ecological Neighborhoods Program; Integration between sectors; Participation of municipalities in the elaboration of the PDPA; Billings-Tamanduateí Subcommittee; Vegetation Cover; Water multiple uses in the reservoir.
E5	Representative of the consultancy responsible for the preparation of the PDPA-Billings	Importance of the PDPA as a planning tool; choice of MQUAL as a model and its importance; Ability to integrate between sectors; Difficulties encountered in implementing plans; Relevance of the industrial effluent discharge in the RMSP; Consideration of water multiple uses; the Southern section of the Rodoanel impacts; Governance approach.

SOURCE: prepared by the author (2021).

(5) General and sectoral guidelines, by sector and also by environmental compartment;

(6) Programs, plans, and projects, 6 are programs, 7 subprograms, and 42 actions;

(7) Investment program and sources of funding;

(8) Indicators, both those used for the diagnosis, through the Driving Force, Pressure, State, Impact and Response (DPSIR) matrix and the management indicators of the programs;

(9) Final considerations;

(10) Bibliography and

(11) Annexes (SSRH, 2017).

4.2. PDPA-Billings Sustainability Assessment

The case study resulted in a table containing fifty-one questions (Box 1) reflecting the sustainability criteria grouped into different categories and answered based on the documents examined, focusing on the PDPA content itself, and complemented by the interviews conducted.

⁴ IAP and IET, Raw Water Quality Index for Public Supply Purposes and Trophic State Index, respectively (in Portuguese, *Índice de Qualidade das Águas Brutas para Fins de Abastecimento Público* and *Índice de Estado Trófico*), are indices currently calculated by the state environmental agency (Cetesb) through the parameters measured at the monitoring points, indicating the presence of toxic substances and other substances that can affect the organoleptic characteristics of the water, for the former; and nutrient enrichment, for the latter (CETESB, 2020).

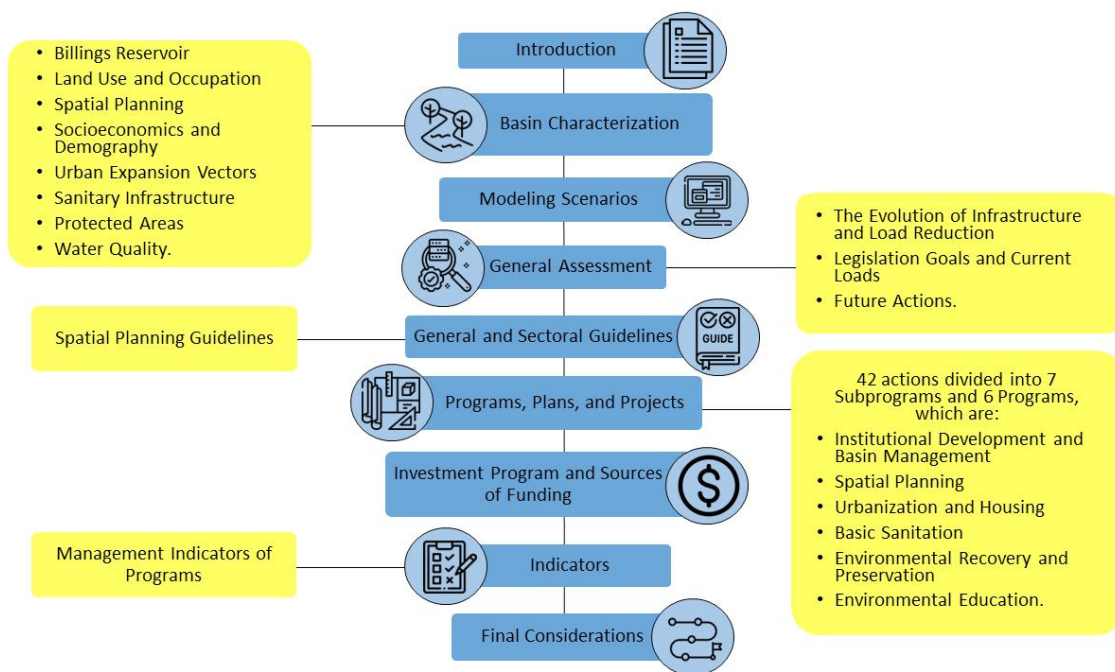


FIGURE 2 – Graphic scheme of the PDPA-Billings content.
SOURCE: adapted from SSRH (2017).

Box 1 presents, in general, a diagnosis of the central issues of sustainability of the APRM Billings raised in the context of this research. Through the application of the eight criteria, questions about the area were developed, and these were answered, beyond PDPA-Billings, by consulting the Master Plan of the municipality of São Bernardo do Campo,

the Alto Tietê Hydrographic Basin Plan (PBH-AT, *Plano de Bacia Hidrográfica do Alto Tietê*), other relevant planning instruments. In this way, the sustainability assessment explains several issues and allows the identification of the strengths and weaknesses of the planning in this basin.

BOX 1 – Summary table of the APRM-Billings sustainability assessment.

Criteria and Questions
Socio-ecological system integrity
<i>A1. Water quality</i>
A1a. How is APRM-Billings water quality considered?
Three different sets of data are gathered to indicate the reservoir water quality: the result of the monitoring of the works in the APRMs (Guarapiranga and Billings) together with modeling carried out where there is no monitoring, considering the sewage systems efficiency, both referring to the phosphorus load, in addition to the data obtained by the São Paulo State Environmental Company (CETESB, <i>Companhia Ambiental do Estado de São Paulo</i>), through the IAP and IET indices (SSRH-SP, 2017).

A1b. What are the instruments/programs related to water quality in APRM-Billings?

Among the proposed programs, there is the Basic Sanitation Program, which includes the drainage subprogram, and its actions, such as studying the economic viability of implementing treatment systems in polluted streams and rivers, riparian forest revitalization, and requirement of primary surface water treatment systems. Also, within the subprograms, the collection, export, and treatment of sewage, in a way, has a strong relationship with water quality, as it aims to reduce the volume of untreated domestic effluents that reaches the reservoir (SSRH-SP, 2017).

A1c. What are the proposed water quality targets?

The targets are based on the Billings Specific Law that defines the phosphorus load that each municipality must achieve, chosen because it is a key nutrient for the eutrophication of water bodies, a phenomenon commonly observed in reservoirs in urbanized environments due to the discharge of sewage into reservoirs. Its calculation uses MQUAL, which considers the land occupation of the area to define the corresponding loads for the different uses. The target for the entire basin is 281 kg/day and for SBC 60 kg/day (São Paulo, 2009; SSRH-SP, 2017).

A1d. Are the data on the collection and treatment of sewage presented, and is there evidence that this wastewater is discharged in accordance with appropriate parameters to ensure the integrity of aquatic ecosystems?

The data on collection and treatment are presented in two different ways, as a total percentage of the APRM and as a percentage of the municipalities portion that are included in the APRM. In the case of SBC, 64% is collected and 5% is treated/exported. There is no mention of the treatment efficiency adopted in the wastewater treatment plants (ETEs, *Estações de Tratamento de Esgoto*) or the characterization of these effluents (SABESP, 2016 *apud SSRH-SP, 2017*).

A1e. Does the PDPA deal specifically with the protection of spring discharge points separately to ensure the hydrological balance?

The PDPA considers Permanent Preservation Areas (APPs, *Áreas de Preservação Permanente*) in general, discussing the intense occupation in the northeast portion of the basin, not specifically addressing the springs. However, it does include an action aimed at restoring the APPs (SSRH-SP, 2017).

A1f. Is the PDPA linked to the municipal solid waste management plan?

According to the PDPA, SBC has a municipal solid waste management plan with a coverage rate of 96.6%, which meets the goal proposed in 2010 by the National Basic Sanitation Plan (PLANSAB, *Plano Nacional de Saneamento Básico*), with 11% of the waste destined for the Mauá Sanitary Landfill. The municipal solid waste management plan does not mention the PDPA but mention the provisions of the Billings Specific Law (São Bernardo do Campo, 2015; SNIS, 2016; CETESB, 2014 *apud SSRH-SP, 2017*; SSRH-SP, 2017).

A1g. Does the PDPA present studies on the rainfall regime of the region?

There are no detailed studies on rainfall patterns in the PDPA (SSRH-SP, 2017).

A1h. Does the PDPA consider potential sources of point/diffuse pollution, that may reach the reservoir without treatment, as well as the existence of environmental liabilities?

The loads generated by the untreated wastewater discharge and after treatment represent 96% of the total loads, therefore, the targets focus on these loads, and do not explain the existing environmental liabilities, which are all grouped as degradation events (SSRH-SP, 2017).

A1i. Does the PDPA consider separately the discharge of industrial wastewater in the municipality?

The PDPA only addresses domestic wastewater and does not consider the contributions that may come from industrial activities (SSRH-SP, 2017).

A2. Biodiversity**A2a. Does the PDPA identify deforestation in the basin? Are actions being taken to address this issue?**

Deforestation is addressed because of the increasing urbanization in the basin, which causes problems with water quality and biodiversity. Among the actions presented to avoid deforestation, there is the aforementioned action to restore APPs, the vegetated areas target, and the reduction of the edge effect goal (SSRH-SP, 2017).

A2b. Does the PDPA include specific measures to achieve the vegetation cover goal of the Specific Law?

The PDPA has a measure that aims to achieve the vegetated area target and reduce the edge effect, prioritizing the compartments that did not meet the target, such as the Corpo Central I and Rio Grande/Rio Pequeno, in addition to the Corpo Central II and Taquacetuba/Bororé compartments, which have a larger urban area (SSRH-SP, 2017).

A2c. Do the vegetation cover targets included in the PDPA take into account the connectivity between vegetation fragments?

The vegetation cover targets proposed in the Specific Law, defined in percentage (%), and area (km²) and segmented by environmental compartment, do not consider the connectivity between vegetation fragments, but the document address this concern through the measure of maintaining the vegetated area target and reducing the edge effect, as vegetation areas are found in small, and isolated fragments (SSRH-SP, 2017).

Livelihood sufficiency and opportunity**B1. Individual livelihood****B1a. Is fishing considered as a profitable and subsistence activity considered in the PDPA?**

Given that artisanal fishing is an activity known in the APRM-Billings as a source of income for part of the population, it should be considered in this type of planning, but there is no mention of the activity in the PDPA (SSRH-SP, 2017).

B1b. Does the PDPA consider establishments moved by tourism?

The Riacho Grande beach, located in SBC, has establishments of great importance for local tourism, such as restaurants and shops. The PDPA provides for the creation of a sustainable tourism development plan that aims to enhance these activities in the APRM-Billings, generating income for the local population, but does not provide specifications for the existing areas (SSRH-SP, 2017).

B1c. How does the PDPA deal with agricultural activities that use reservoir water for irrigation?

Among the sectoral guidelines introduced in the PDPA, there is the promotion of agricultural activities that do not compromise the environmental quality of the APRM, in addition to the adoption of good practices in the use of natural resources, but there are no specifications for these activities (SSRH-SP, 2017).

B1d. Does the plan encourage the training of tourist guides in the region?

The plan includes the development of a Sustainable Tourism Development Plan, which includes the training of local professionals, as also mentioned in the Climate Change Action Plan (SSRH-SP, 2017; Consórcio, 2017).

B2. Leisure

B2a. Does the PDPA consider recreational activities in the APRM-Billings?

The plan does not provide data on the Bathing Index, which is a measure of water quality for activities such as swimming, calculated by the CETESB. The reservoir is classified as Class 1 and 2, depending on the compartment, but according to the PDPA, none of the monitoring points comply with the classification, making some types of activities inappropriate, such as those involving direct contact (SSRH-SP, 2017; ANA, 2021).

Intragenerational equity

C1. Water

C1a. Does the municipality provide water treatment and distribution to all individuals?

The PDPA presents data on SBC water supply at 94%, which is considered satisfactory. Areas considered rural and without regular sanitation infrastructure do not have access to treated water (IBGE, 2010; SEADE, 2013; SABESP, 2016 *apud* SSRH-SP, 2017).

C2. Residence

C2a. How is land regularization of subnormal settlements treated in the PDPA?

The regularisation of subnormal settlements connects dwellings to the public system of treated water and sewerage, thus improving the quality of life of these people compared to the previous scenario. In the PDPA, it is addressed as a possible solution to reduce the pollution generated in the basin (SSRH-SP, 2017).

C2b. Does the PDPA propose housing alternatives for families living in areas of geological risk within the basin?

Through the action of the Social Interest Recovery Program (PRIS, *Programa de Recuperação de Interesse Social*), the PDPA presents a measure for these families, which is the responsibility of the municipality, and includes the urbanization or relocation of the population (SSRH-SP, 2017). The municipality of SBC has a social housing plan, an instrument that aims to plan actions related to the housing sector, prioritizing the settlements with greater environmental risk. This plan, however, does not specifically mention the PDPA specifically, although it refers to the Billings Specific Law (São Bernardo do Campo, 2012).

C3. Socioeconomics

C3a. Does the PDPA take into account the socio-economic conditions of the population living in the basin?

The Plan presents the socio-economic data of the population through the São Paulo Social Vulnerability Index (IPVS, *Índice Paulista de Vulnerabilidade Social*), which shows that about 55% of the population is in a situation of medium to high vulnerability. In SBC, the percentage of the population living in the APRM that is in these conditions of vulnerability is 43.76%. In addition, the PDPA maps out the areas where the subnormal clusters are located (SSRH-SP, 2017).

Intergenerational equity

D1. Long-term Water Quality

D1a. Have phosphorus load targets been set with a view to long-term basin quality given population growth?

The MQUAL, the tool responsible for guiding the phosphorus load targets, take into account the land use and occupation and estimated population growth for the APRM, for the modeling to set targets for this growth (SSRH-SP, 2017).

D1b. Are there measures in place to ensure the protection of aquatic life in the PDPA?

The water quality index for the protection of aquatic life (IVA, *Índice de Qualidade das Águas para a Proteção da Vida Aquática*) is not taken into account in the PDPA and no actions are proposed in this respect, even though the reservoir classification classes (1 and 2) establish that this protection is necessary (CETESB, 2020).

D1c. Does the PDPA include measures to address the effects of climate change on water sources?

Given the recent water scarcity events faced in São Paulo, measures to address extreme events should be included in the planning, within the framework of water security, but the issue is not addressed in the PDPA (Jacobi *et al.*; 2015; SSRH-SP, 2017).

*D2. Vegetation Cover***D2a. Does the PDPA provide for the creation of new protected areas or the expansion of existing ones?**

One of the actions foreseen in the PDPA for environmental protection is the feasibility study for the creation of new Conservation Units (UCs, *Unidades de Conservação*), in addition to the preparation of the management plan for the existing natural parks and the creation of new ones, as a form of environmental compensation by the company *Desenvolvimento Rodoviário S/A* (DERSA). After the elaboration of the PDPA, a new park was created to conserve the riparian forest of the APRM, the *Parque Estadual Águas da Billings* (SSRH-SP, 2017; SIGAM/SIMA, 2021).

Resources maintenance and efficiency*E1. Loss Reduction***E1a. Does the PDPA include proposals to reduce water distribution losses?**

There is no PDPA proposal for the reduction of losses, but it presents a state government program aimed at this reduction in the appendix (SSRH-SP, 2017).

*E2. Reuse***E2a. Does the PDPA present measures to promote the use of reused water?**

The RMSB has the *Aquapolo Ambiental Project*, which aims to distribute recycled water for industrial use, from the ETEs present in the region, such as ABC ETE, to where SBC exports part of the collected sewage. However, no measures are proposed to address the use of recycled water in the PDPA (SSRH-SP, 2017; SABESP, 2021).

E2b. Does the PDPA include measures for using rainwater?

Among the measures planned for use, those of the Drainage Subprogram stand out, which include the implementation of a rainwater reuse system to reduce the use of potable water for purposes such as cleaning (SSRH-SP, 2017).

E2c. Does the PDPA encourage the reuse of sludge from treatment plants?

Given the overload of sanitary landfills and the possibility of reusing sludge from water treatment plants, this is an interesting topic to explore, but there is no mention of this reuse in the PDPA (Consórcio, 2017).

*E3. Agriculture***E3a. Does the PDPA consider the sustainability of agricultural activities?**

The plan proposes the development of a Sustainable Agricultural Development, within the Environmental Recovery and Preservation Program, which aims to provide guidance and subsidies to small producers identified in the area and consumer markets (SSRH-SP, 2017).

E4. Solid Waste

E4a. Does the PDPA cover activities such as recycling?

The PDPA includes the recycling of waste as an action to reduce its undesirable disposal in landfills, both for urban solid urban waste and construction waste, to increase the life cycle of these wastes and to promote the activities of cooperatives and associations activities (SSRH-SP, 2017).

E5. Water Usage Charge

E5a. Does the plan consider charging for the use of water resources, a PNRH instrument?

Charging for the use of water is mentioned in the specific law and considered in the plan as a potential alternative source of funding for the implementation of PDPA. It is mentioned as part of the State Water Resources Fund (FEHIDRO, *Fundo Estadual de Recursos Hídricos*) (São Paulo, 2009; SSRH-SP, 2017).

Socio-environmental civility and democratic governance

F1. Civil Society Representation

F1a. Does the Subcommittee have members representing different sectors of civil society?

Civil society is represented in the committee by the Movement for the Defense of Life (MDV, *Movimento em Defesa da Vida*, the most active representative of all the participants), the *Universidade Federal do ABC* (UFA-BC), the Brazilian Association of Sanitary and Environmental Engineering (ABES, *Associação Brasileira de Engenharia Sanitária e Ambiental*), the Center for Industries of the State of São Paulo (CIESP – SBC, *Centro das Indústrias do Estado de São Paulo*) and the SIADES Institute (CBH-AT; 2021a).

F1b. Is the vulnerable population represented on the committee?

The SCBH-BT has representatives from the MDV as the body responsible for representing the vulnerable population (CBH-AT; 2021a).

F1c. Was civil society involved in the process of drafting the PDPA?

The minutes of the PDPA draft presentation meetings show that there were no representatives of civil society (CBH-AT; 2021c); however, the E2 pointed out that there was greater participation and engagement of organized civil society at the time of the drafting of the Billings Specific Law.

F1d. Is there evidence of civil society participation in monitoring the activities proposed by the PDPA?

In one of the meetings held by the river basin committee, a representative of civil society pointed out the lack of participation of civil society in various processes and the absence of entities that are also decisive in corroborating the management of the basin (CBH-AT; 2021c).

F1e. Are there any criticisms of the subcommittee's activities?

During the interviews (E2 and E4), it was pointed out that the subcommittee had been dismantled, that is was only for consultative purposes, without deliberative discussions and without counting on the participation of all the necessary members.

F2. Environmental Education

F2a. Does the plan present the interaction of the population with natural landscapes as an environmental education action?

As a guideline for environmental education that seeks to bring the population closer to natural landscapes, there is the use of elements of water resources (rivers, ETEs, water treatment plants – ETAs, *Estações de Tratamento de Água*, among others) as an educational tool but any specific measures are presented (SSRH-SP, 2017).

F2b. What plans involving environmental education are proposed in the PDPA?

For environmental education, it is proposed a signaling and identification plan and an environmental communication plan (SSRH-SP, 2017).

F2c. Does the municipality carry out activities aimed at environmental education in the APRM?

SBC has an Environmental Education Center (CEA, *Centro de Educação Ambiental*), provided for in the Municipal EA Policy, which aims to promote activities related to natural resources and their respective conservation. Among the activities carried out in the municipality are visits to a protected area, the Estoril Municipal Natural Park, which focuses on showing the importance of the basin to the population, and the Open Eco-School (*Ecoescola Aberta*), which promotes courses, seminars, and technical visits to bring citizens closer to environmental issues (São Bernardo do Campo, 2022).

Prudence, precaution, and adaptation*G1. Enforcement***G1a. Is there a proposal to create a system for the inspection risk areas in the PDPA?**

The plan mentions the action as part of the Urbanization and Housing Program and recommends elaboration/ updating municipal risk reduction plans, which include mapping the areas and their respective management (SSRH-SP, 2017).

G1b. Is there environmental enforcement to minimize urban expansion on the APRM in the municipality based on vectors?

All the vectors of expansion of the APRM are presented in PDPA, and out of the six, five have an influence on SBC and, for the enforcement of the occupation process it is proposed to inspect land use change through satellite imagery (SSRH-SP, 2017).

*G2. Environmental zoning***G2a. Does the PDPA consider areas already protected by other legislation (parks and other UCs)?**

Yes, since the APRM area overlaps with several other protected areas, such as Conservation Units, APPs, and indigenous lands, among others, the PDPA presents the compatibility between these areas and APRM area (SSRH-SP, 2017).

G2b. Is the municipal zoning in line with what is established by the APRM?

Although the municipality has obtained a certificate of zoning compatibility, there are some deviations in urban parameters, which are less restrictive than those of the APRM (SSRH-SP, 2017).

*G3. Monitoring***G3a. Does the PDPA propose environmental quality monitoring programs for the whole basin?**

The implementation of the Management Information System (SGI, Sistema Gerencial de Informações) is foreseen as an instrument of the Specific Law, which must contain relevant data to allow the assessment of the environmental quality of the basin and support decision-making. However, it has not yet been implemented (SSRH, 2017).

G4. Risks of accidents involving toxic products

G4a. Does the PDPA propose safety measures for the reservoir in cases of accidents, such as spills on the roads?

The PDPA indicates the need for an emergency and contingency plan for the transportation of dangerous goods on highways in the event of accidents and possible spills, therefore, there is a proposal to prepare this plan (SSRH-SP, 2017).

G4b. Does the PDPA mention high-risk industrial activities in the APRM?

There is no mention of this type of industrial activity in the PDPA, but it shows that, according to State Law No. 1,817/1978, only establishments that carry out assembly in areas of water supply that collaborate with the reduction of industrial effluents are allowed (SSRH-SP, 2017).

Immediate and long-term integration

H1. Strategic level of objectives and vision of the future

H1a. Does the PDPA include measures to mitigate existing conflicts over environmental resources (e.g. energy production vs water supply)?

The text of the PDPA does not mention the existing conflicts between the multiple uses of water (SSRH-SP, 2017).

H2. PDPA implementation

H2a. Does the PDPA have the resources needed for its implementation?

Throughout the text of the PDPA, the lack of financial resources for the implementation of the plan in the determined period was mentioned, highlighting urgent actions to be carried out (SSRH-SP, 2017).

H2b. Does the PDPA present different future scenarios taking into account the investments available?

The different scenarios proposed in the PDPA discuss the improvement of the efficiency of wastewater pumping stations (EEEs, *Estações Elevatórias de Esgoto*) and other actions to improve the sanitary infrastructure indicated by the phosphorus load, without addressing the development scenarios in other areas (SSRH-SP, 2017).

H3. Integration with other plans

H3a. Does the municipal Master Plan include the urban standards established in the PDPA?

The SBC Master Plan mentions the Specific Law and addresses the same classes of use and occupation, but they have different nomenclatures, which can make it difficult to understand (São Bernardo do Campo, 2011; SSRH-SP, 2017).

SOURCE: prepared by the author (2022).

From the analysis of Box 1, it was possible to identify strengths in the document's importance, as well as weaknesses in the context of APRM-Billings, that can be considered as areas for improvement in the next PDPA planning cycle. These include the failure to take into account industrial pollution (question A1i) and the efficiency of wastewater

treatment (question A1d); the failure to take into account environmental liabilities (such as the Alvarenga Dump) (question A1h); the lack of an information system for managing the plan (question G3a); the superficial approach to the multiple uses of water, provided for by the Law on the Protection of Water Sources itself, and the lack of detailed

rainfall studies of the APRM region and consequent lack of water security measures, consequently. Given the size limitations of this work, the following discussion will focus on the last two issues mentioned, which are considered by the authors the most strategic for the region, in addition to a discussion of governance in the context.

4.2.1. Strengths and potential of the PDPA

The PDPA is a planning instrument proposed for selected basins in the State of São Paulo. The PDPA-Billings operates in a metropolitan territory of great governance complexity, primarily due to the existence of a contiguous and integrated urban area, where there is a multiplicity of social actors and interests and which is governed by different municipalities and the state government, presenting significant challenges and regional planning gaps (Monteiro Neto *et al.*, 2020). In this context, the PDPA plays a key role in the integration between municipal master plans and the river basin plan (G2b, H3c), an integration that is necessary as the scale of the PBH-AT does not allow for the level of detail at the local scale that the PDPA can provide. In 2016, the Water Source Areas Law was updated to provide for the integration of the PDPA into the Basin Plan of the Water Resources Management Unit (UGRHI, *Unidade de Gerenciamento de Recursos Hídricos*). This, when implemented, has the potential to strengthen the link between plans by including the PDPA measures in the CBH-AT agenda (São Paulo, 1997). In addition, harmoniza-

tion between APRM zoning and municipal zoning has been defined in a legal standard, reinforcing the role of APRM planning and management as a link between environmental protection and land use strategies.

Municipal zoning regulations include the definition of urban parameters, which are the same as those defined in the APRM (C2a, C2b), a relevant environmental protection strategy because it allows land use and occupation control. In this sense, the PDPA helps to face the problem of integration between plans, explained by the concept of *tiering* in the scientific literature (Therivel & González, 2021; Coutinho *et al.*, 2019). This is true because its scope and objectives make it possible to connect land use strategies with water resources conservation strategies, a task that has not been successful regarding the link between the master plan and the basin plan (Peres & Silva, 2013). Being a plan with a smaller spatial scope than the Alto Tietê Basin Plan (PBH-AT), it has a higher level of detail, gathering a large amount of information at the local scale, which allows for a more in-depth analysis of the region's priorities and the corresponding allocation of resources to reduce the environmental degradation of the reservoir.

Potentially, the PDPA may also be able to fulfill some functions that would be expected of a Strategic Environmental Assessment⁵ in supporting environmental licensing decisions precisely because it provides regional information on socio-environmental quality and offers guidelines for action in the territory on essential issues for thinking about a sustainable development model for the region – with

⁵ Strategic Environmental Assessment, an Environmental Impact Assessment instrument, can be described as a tool that incorporates environmental and social issues into programs, plans, and projects at the planning stage, acting in a preventive manner and minimizing the occurrence of environmental impacts (Duarte, 2019).

territorial planning, basic sanitation, urbanization, and housing (Duarte *et al.*, 2022).

4.2.2. Multiple uses of water

In the section on the diagnosis of the water quality, which are related in this research to the criterion of socio-ecological system integrity, three sets of water quality indicators are presented, resulting from different studies in the basin, which come from:

(a) Water quality monitoring in the area of protection and recovery of water sources of the Billings and Guarapiranga Reservoir Basins, carried out by the Prime-Ecolabor Consortium in 2015;

(b) Phosphorus load estimates for 2015 using MQUAL, conducted for the PDPA; and

(c) Water quality monitoring carried out by the CETESB, of which two indices are presented: IAP and IET (SSRH, 2015; SSRH, 2017).

Considering the current uses in the basin, the indicators adopted for diagnosis can be considered as limited, given they do not include compounds that can impact the health of both aquatic organisms and humans who come into contact with the water or consume the fish, indices currently calculated by CETESB, such as bathing and the protection of aquatic life (Minte-Vera & Petrere, 2000; Menezes *et al.*, 2016; CETESB, 2020).

Within the criteria of livelihood sufficiency and opportunity, the questions developed included the approach taken by the PDPA-Billings for multiple uses (questions B1a, B1b, B1c, B1d, and B2a). This analysis reveals another important gap: the PDPA does not mention the fishing communities

that depend on the reservoir for their livelihood through fishing, nor does it make a diagnosis of tourism/leisure in the region, such as in *Prainha do Riacho Grande*, in São Bernardo do Campo. However, there is an action proposed for tourism, which includes the elaboration of the *Sustainable Tourism Development Plan*, within the *Environmental Recovery and Preservation Program*, in Action 5. Thus, the gap in fisheries issues may represent an exclusion of the population that benefits from the natural resources, such as subsistence fishermen and indigenous communities (Silva *et al.*, 2009).

Article 1 of the Law for the Protection of Water Source Areas states that the basins defined as APRMs have the priority use of public water supply for present and future generations and that multiple uses compatible with conservation must be ensured (São Paulo, 1997). In light of the above, it is possible to state that the use of flood control and the consequent dilution of wastewater currently observed in the APRMs is contrary to the legal guidelines and that the PDPA settlements may include measures capable of circumventing this issue. Furthermore, any section in the PDPA identifies the conflicts between water uses (Question H1a), as well as measures that can minimize them, such as the conflict between flood control in the city of São Paulo and urban supply. Although the PBH-AT cites the existing conflicts, as determined in the National Water Resources Policy (PNRH, *Política Nacional de Recursos Hídricos*), the PDPA could deepen the treatment of this issue (FABHAT, 2019; Risso *et al.*, 2018).

Despite not including the multiple uses issue, the effective implementation of PDPA-Billings measures to reduce the phosphorus load will ensure an overall improvement in the water quality of

the reservoir, which will also ensure the continuity of the multiple uses of water (Saad *et al.*, 2015). However, integrating multiple themes into planning can be more extensive and time-consuming, but it is an opportunity to find valuable connections between themes and advance interdisciplinary and intersectoral proposals. According to Gibson (2006a), the integration of key sustainability themes into planning should occur from the beginning of the process, avoiding negligence and maximizing multiple gains in terms of sustainability. In some ways, this broad integration will place greater demands on planning, but otherwise, greater risks will be taken (Gibson, 2006a).

Moreover, as it is a plan that is called a development plan, one would expect the PDPA to go into more detail on how the region could move forward in socio-economic development while ensuring the protection of water source. This gap becomes even more evident when analyzing the future scenarios that are presented in the PDPA-Billings, which focus exclusively on reducing the phosphorus loads, not presenting regional development scenarios that would not compromise the environmental quality of the basin, nor strategic objectives for these actions to be taken (Question H2b).

4.2.3. *Water security*

Another research highlight concerns the lack of in-depth studies on the rainfall regime of the APRM-Billings region and the impact of climate change on the region's water balance in the medium and long term (Questions A1g and D1c). As a result of this gap, the plan does not mention measures that could be taken to mitigate these impacts in the basin

– a point highlighted by two survey respondents (E1 and E2). Within the theme of water security, this is a topic of crucial importance to include in water resource plans today, especially given the context of water scarcity that São Paulo has faced in recent years (Jacobi *et al.*, 2015).

Water security is related to "sufficient quantity and quality to meet human needs, the practice of economic activities, and the conservation of aquatic ecosystems" (ANA, 2019, p. 13). Jacobi *et al.* (2015) look at the scenario of water insecurity faced by the RMSP and to the complexity of the current water system, noting that the current solutions are multiple water transfers from distant hydrographic basins to meet the demand of the RMSP, instead of promoting measures to restore rivers and reduce losses in the distribution network.

The PDPA points to the need to protect and restore degraded APPs (questions A1e and A2a), particularly the spring areas that are threatened by the intense occupation in the APRM. Another threat is the suppression of vegetation, which leads to the siltation of the springs and, consequently, to a reduction in water availability from the reservoir, a phenomenon highlighted by interviewee E2 (SSRH, 2017; ANA, 2020). In this way, the basin becomes more vulnerable to extreme events, which harms the water security context, in addition to the increasing concentration of pollutants that worsens water quality, making it impossible for Billings to expand its contribution to water supply (Consortio, 2017; ANA, 2020).

With the publication of the National Water Security Plan (PNSH, *Plano Nacional de Segurança Hídrica*), it is expected that the updates of the basin plans, as well as the PDPAs, will incorporate new diagnostic methodologies, as well as new actions

for the continuity of urban supply, and, if possible, its expansion (ANA, 2019). In the RMSP, SABESP, a sanitation company that operates in part of the area covered by the PDPA, published the *Resilient Strategies Plan*, which aims to incorporate climate variables in the face of changes in water management (SABESP, 2020), raising expectations that this material will influence future basin plans and PDPAs in the context of the study.

4.2.4. Governance

In a scenario of budgetary difficulties, referred to in several parts of the document, the PDPA-Billings seeks alternatives for the implementation of the planned actions to promote the protection of the basin and is considered in this research as an important instrument for the integration between sectoral planning. The document considers the territorial dynamics and emphasizes the importance of actions to regularize the settlements present in the riparian area, indicating the areas in which the interventions are essential according to the MQUAL calculation, which takes into account the type of land use and the associated load of phosphorus that can reach the reservoir and according to the compatibility of municipal zoning and APRM zoning (Question C2a). In addition, the PDPA also has structured general and sectoral guidelines, with housing and basic sanitation being given greater prominence, and there are guidelines for the responsible stakeholders that must be carried out in order to achieve a better scenario in terms of environmental quality of the reservoir.

The main problem with the PDPA is not necessarily its content, but rather its implementation. Although, as one of the interviewees (E5) pointed

out, it serves as a good guide to the areas in which intervention is needed, the evidence gathered in this research suggests that there is poor control over the implementation of what is provided for in the PDPA, particularly because, at the time of writing, the SGI, which is essential for monitoring the measures implemented, had not yet been established.

Two interviewees (E2 and E4) highlighted another important point to consider: the disarticulation of the subcommittee. This is reinforced by the analysis of the minutes of the meetings of the CBH-AT, which show that only one meeting was held during the period 2019-2021 period, just to set up the subcommittee. Furthermore, according to Article 4 of Decree No. 55,342/2010, which regulates the Billings Specific Law, the PDPA must be updated every four years. This has not been complied with, as the first version of the PDPA was published in 2010 and the second, which may still be the subject of a technical for approval by the CBH-AT, in 2017 (São Paulo, 2010b; CBH-AT, 2022).

It is therefore worth noting that even if the weaknesses identified in the sustainability assessment were better addressed technically in developing the plan, this new content would not necessarily mean that they would be incorporated into the basin management actions. In other words, good planning is not synonymous with good water management, as a plan may theoretically address several strategic issues from a sustainability perspective, but, in practice, the actions may not be implemented (Fracalanza *et al.*, 2013). Hence, for the PDPA to be more successful, we believe that the governance structure needs to be revised so that the integrative role of the plan can be realized and more stakeholders, such as fishermen, are involved in the process so that plurality is reflected in the plan.

4.2.5. Considerations on the application of the method adopted

Regarding the approach to sustainability assessment, Gibson (2005) states that it is not considered to be a precise tool when compared to other fields of science, as each context has its own uncertainties and specificities, and it is also subject to interpretation of a broad scope for its elaboration. In addition, sustainability assessment depends on a large amount of information available about the context to which it is applied, as well as on professionals qualified for interdisciplinary research, which may pose difficulties for its adoption.

In this research, the sustainability assessment approach adopted as the basis for the case study in this context was important for carrying out a comprehensive diagnosis of the content of the plan and allowed the objective of identifying weaknesses and strengths of the PDPA-Billings to be achieved. The question-and-answer approach, organized by topics, helped to organize the information collected during the research and allowed the same topic to be analyzed from different perspectives. Thus, we believe that the evaluation framework developed in this research can be used as a reference for the elaboration and evaluation of other water resources management plans, and we understand that sustainability assessment as applied in this research can also be considered as a method for evaluating public policies aimed at sustainability.

Among the limitations of the research, we highlight that the universe of socio-environmental themes was not exhausted in the elaboration of the results table (Box 1), questions and answers were included as evidence was found, and the effort was

limited by the duration of the research, which lasted two years. Therefore, the evaluation framework was developed based on a selection of themes that emerged from previous knowledge of the region, from the studies found in the bibliographic and documentary review, and from the interviews following Yin (2015) to organize the research trajectory as a case study. The research did not take into account all the existing plans and studies in the context of APRM-Billings, nor did it conduct interviews that represented all the stakeholders involved in the issues studied; some representatives were invited but did not respond with interest and availability to participate in this research. However, we understand that these limitations did not prevent the objective of presenting an assessment of the context based on sustainability assumptions and themes, and we believe that this work can stimulate important reflections on the role of sustainability planning, its content, and its implementation.

5. Conclusion

The PDPA, the central planning and management instrument of the APRM-Billings, contains guidelines, programs and goals aimed at improving the environmental quality of the basin, starting from a current scenario of severe degradation. The PDPA-Billings proved to be an essential link between water resource planning and municipal land use planning because it operates on a regional scale, enabling alignment of strategies among municipalities.

Based on the eight sustainability criteria proposed by Gibson (2006a), we believe this

assessment provides a foundation for reflecting on essential perspectives for sustainability; this includes evaluating the sufficiency of actions required for a transition from the current scenario to desired future scenarios, as well as examining the connections between social justice and environmental quality. Applying sustainability assessment to environmental plans is a valuable approach to aid in their construction and revision. It helps define the scope and identify strategic issues that need to be addressed.

The evaluation framework revealed the strengths of the PDPA-Billings and highlighted three weaknesses: shallow consideration of multiple water uses, non-consideration of water security, and difficulties in governance of planning and management in the APRM-Billings context. We acknowledge that progress in these matters would aid in achieving the goals outlined in the Law for the Protection of Water Source Areas, which specifies the plan's contents, thereby ensuring the right to a balanced environment and the continuity of water supply for current and future generations, as also mandated by legislation.

We found that the plan does not address water security issues in the face of past and future water scarcity scenarios in the RMSP, without considering the influence of climate change on the region's rainfall and hydrological regime. We recommend that a future revision of the PDPA should include the issue of water security and the impacts of climate change to increase socio-environmental resilience. Furthermore, it was observed that the plan prioritizes water quality improvement, which is crucial for expanding water abstraction for future supply and other purposes. However, it is important to

note that the plan may also facilitate discussions on strategic issues in the region in an integrated manner. While the PDPA is titled as a *development plan*, information on the social and economic development of the region could also be included in the document, particularly where it interfaces with water and land use and occupation issues, but also concerning industrial development and tourism in the basin.

The PDPA-Billings presents a series of relevant considerations about sectoral planning, especially about the relationship between land use and occupation and quality of water resources, playing an essential integrating role between these sectors. At the same time, its effective implementation remains a challenge, particularly regarding the governance structure for its implementation. To illustrate this situation, it is worth noting that more than ten years have passed since the approval of its first version, but the central instrument for monitoring the actions carried out, the information management system, has not yet been implemented. This makes management in the area difficult and hinders the protection of the basin itself.

To comply with the provisions of the Law for the Protection of Water Source Areas, which aims to preserve and recover water sources and promote participatory management, it is also essential that the Billings-Tamanduateí Subcommittee takes regular and permanent action to ensure the proper monitoring and updating of the PDPA, as well as the implementation of the other instruments provided for in the Billings Specific Law. This will contribute to enhance of the environmental quality of the water source area and the quality of life for the population of the region.

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